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Environmental effectiveness of GAEC cross-compliance Standard 3.1 'Ploughing in good soil moisture conditions' and economic evaluation of the competitiveness gap for farmers

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Abstract

Within the MO.NA.CO. Project the environmental effectiveness of GAEC cross-compliance Standard 3.1 'Ploughing in good soil moisture conditions' was evaluated, as well as the economic evaluation of the competitiveness gap for farmers which conform or do not conform to cross-compliance. The monitoring has been carried out at nine experimental farms with different pedoclimatic characteristics, where some indicators of soil structure degradation have been evaluated, such as bulk density, packing density and surface roughness of the seedbed, and the crop productive and qualitative parameters. In each monitoring farm two experimental plots have been set up: factual with soil tillage at proper water content (tilth), counterfactual with soil tillage at inadequate water content (no tilth). The monitoring did not exhibit univocal results for the different parameters, thus the effectiveness of the Standard 3.1 is 'contrasting' (class of merit B), and there was an evident practical problem to till the soil at optimum water content, even in controlled experimental condition. Bulk density was significantly lower in the factual treatment although in soils with very different textures (sandy-loam and clayey). Packing density (PD) showed a high susceptibility to compaction in soils with low PD and medium texture. The tortuosity index, indicating the roughness of the seedbed, was lower and generally significantly different in the factual treatment. Results showed that the ploughing done in excessive soil moisture conditions is more expensive due to the increased force of traction of the tractor, which causes an increase in slip of the tractor wheels, with a speed reduction and increase in the working times and fuel consumption. Moreover, the crop yield is also reduced considerably according to the cultivated species.

Introduction

The range of soil water content at which the most favourable workability conditions occur is called 'tilth', whereas the condition 'no tilth' is empirically attributed to higher or lower water contents of this range. In the scientific literature the tilth condition has been better defined by the optimum water content (θ_{OPT}), following the definition of 'Optimum water content for Tillage', *i.e.* the water content at which tillage produces the greatest proportion of small aggregates or, conversely, the smallest proportion of large aggregates and clods (Dexter e Bird, 2001). The value of the water content corresponding to the θ_{OPT} can be determined from the water retention curve, obtained by fitting the measured values with proper Pedotransfer functions (PTFs) such as the Van Genuchten equation (1980) and the Mualem (1976) restriction m = (1-1/n):

$$\theta = (\theta_{SAT} - \theta_{RES})[1 + (\alpha h)^n]^{-m} + \theta_{RES} \quad (1)$$

The Optimum Tillage Limit corresponds to the water content at the point of inflection of the van Genuchten equation ($\theta_{OPT} = \theta_{INFL}$), and can be derived from equation (1):

$$\theta_{INFL} = (\theta_{SAT} - \theta_{RES})\left[1 + \frac{1}{m}\right]^{-m} + \theta_{RES} \quad (2)$$

There is a range of water contents around the θ_{OPT} defined by the Upper Tillage Limit (θ_{UTL}), and the Lower Tillage Limit (θ_{LTL}). Their difference allows the estimation of the range of water content over which soil tillage can satisfactorily be done. The upper tillage limit θ_{UTL} is calculated by the equation proposed by Dexter e Bird (2001):

$$\theta_{UTL} = \theta_{INFL} + 0.4(\theta_{SAT} - \theta_{INFL}) \quad (3)$$

The Standards of Good Agricultural and Environmental Conditions (GAECs) are applied to any agricultural surface of the farm which benefits from the direct payments after the EC Regulation n. 73/2009. The Issue 3 of GAEC deals with soil structure protection through proper measures regulated in the Standard 3.1 'Appropriate machinery use'. The Standard prescribes that soil is tilled at a proper water content (tilth condition), and that the machinery use must avoid the degradation of soil structure. In the MO.NA.CO. Project the monitoring has evaluated some parameters to be used as indicators of soil structure, such as bulk density, packing density and soil roughness.

Materials and methods

The monitoring has been carried out at nine experimental farms with different pedoclimatic characteristics, two in plain areas in the North (Lombardy and Veneto), three in hilly areas in the Centre (Tuscany and Latium), three in plain areas in the South (Apulia and Basilicata), one in the plains of Sardinia:

1. Monitoring farm CREA-AAM, Research Unit for Agro-pastoral Systems in Mediterranean Environment, Podere 'Ortigara', Sanluri Stato (Medio Campidano);
2. Monitoring farm CREA-ABP, Research Centre for Agro-biology and Pedology, Fagna (Scarperia, FI);
3. Monitoring farm CREA-ABP, Research Centre for Agro-biology and Pedology, Farm Santa Elisabetta, Vicarello (Volterra, PI);
4. Monitoring farm CREA-CER, Research Centre for Cereal Crops, Località Manfredini, Foggia;
5. Monitoring farm Arcagna, CREA-FLC, Research Centre for Fodder Crop and Dairy Productions, Montanaso Lombardo (LO);
6. Monitoring farm CREA-RPS, Research Centre for the Soil-Plant System, Tormancina (Roma);
7. Monitoring farm CREA-SCA, Research Unit for Cropping Systems in Dry Environments, Podere 124, Foggia;
8. Monitoring farm CREA-SSC, Research Unit for the Study of Cropping Systems, Campo7, Metaponto (Matera);
9. Monitoring farm 'Vallevecchia' Veneto Agricoltura (Caorle, VE).

In each monitoring farm two plots with adequate dimensions and homogeneous soil type, topography, main physicochemical characteristics, and land use (previous crop management) have been set up:

Factual plot (F), soil tillage at proper water content (tilth);

Counterfactual plot (CF), soil tillage at inadequate water content (no tilth), that is at a water content higher than the Upper Tillage Limit (UTL).

The environmental priority parameter 'soil structure degradation' has been selected to evaluate the effectiveness of the Standard 3.1 through the following indicators:

- compaction, given by the measurement of soil bulk density (determined on soil cores with known volume, and used also for the determination of the water retention curve on undisturbed samples);
- susceptibility to compaction, evaluated through the packing density from soil bulk density and clay content;
- evaluation of the seedbed, that is the evaluation of soil cloddiness and surface roughness (roller chain method).

The last method, adopted in the MO.NA.CO. Project, allows the calculation of the Tortuosity index T (Bertuzzi *et al*., 1990) using a 'roller chain' (length 100 cm). Practically, the chain is stretched on the soil surface following the cloddiness, and measuring the actual length of the chain. The measurement is carried out on 10 sections perpendicular to the tillage direction, and 10 sections along the tillage direction

(Figure 1). The Tortuosity index T is expressed by the following equation:

$$T = \frac{100 \text{ cm (length of the chain)}}{\text{X cm (measured between the two ends of the chain stretched on the soil)}} \quad (4)$$

CREA-ABP has determined the surface roughness through a micromorphological analysis obtained from zenithal photos and further elaborations. The methodology is described in the technical paper by Bazzoffi et al. (2015) 'Metodologia di rilievo della rugosità superficiale del suolo con Pole Aerial Photography (PAP)'. If the cloddiness (tortuosity) is the same in the two treatments, the tilth or no tilth conditions have no influence at sowing time.

Soil water content

Undisturbed soil samples were collected in three/five replicates at 10-20 cm of depth; in the laboratory they were previously saturated with de-mineralized water on ceramic plates and were used for analyses of gravimetric water content at four different Tension values: a) 0, 10, 33, 85 kPa, with a Special Sampling Vacuum Plate n. 1725D22 (Soilmoisture Equipment Corp., Santa Barbara, CA, USA) and, b) 1500 kpa with WP4C Dewpoint PotentiaMeter (Decagon Devices Inc., Pullman, WA, USA), measuring water potential using the chilled-mirror dew point technique (Solone *et al*., 2012). Samples were weighted after draining to soil matrix potential of 0, 10, 33, 85 kpa. After applying the desired cell gas pressure, samples were allowed to equilibrate and weighted; when the equilibrium at the maximum pressure was reached, samples were re-weighed and the water contents were determined gravimetrically by drying the samples at 105°C for 24 h. Finally the gravimetric content was transformed into volumetric by multiplying it for the soil bulk density corresponding to that soil moisture content. Once the volumetric water content for each pressure was obtained, data were used for fitting with SWRC Fit http://seki.webmasters.gr.jp/swrc/ (Seki, 2007) to calculate the Van Genuchten parameters. With these parameters it is possible to calculate soil volumetric water content at any tension, including OTL and UTL (see equations 1, 2, 3).

Bulk density

Soil Bulk Density was measured by using a steel cylinder (20-30 cm of depth), with the undisturbed soil core method (Metodi Ufficiali di Analisi Fisica del Suolo, 1997). The soil cores were dried at 105°C and weighted. The soil dry bulk density, as ratio of the mass of dry soil to the total volume of soil expressed in grams per cubic centimetre, was determined.

Monitoring farms

CREA-AAM. The monitoring farm is located in a plain area at 50 m asl. Soils are alluvial, classified as Typic Fluvaquents (Soil Survey Staff, 2014) and Stagnic Fluvisol (WRB, 2014), are clay-loam (S=43%, Si=26%, C=31%), subalkaline (pH 8.0), with organic matter 1.7%. Mean annual rainfall and temperature are 450 mm and 18°C. The two monitoring plots, with a surface equal to 1500 m^2 (100 m x 15 m) and previously cultivated with durum wheat, have been cropped with a 2-year rotation durum wheat-Egyptian clover (sowing rate 200 and 40 kg ha^{-1} respectively). The wheat grain yield and the clover hay yield were determined.

CREA-ABP. The monitoring was carried out in Tuscany, at the Fagna and Vicarello farms. At Fagna (225 m asl), soil texture is clayey (S=6%, Si=50%, C=44%) with marked vertic characteristics, slightly alkaline (pH 8.3), organic matter 1.6%, slope 6-13% with marked erosion processes. Soils are classified as Typic Udorthents fine, vermiculitic, calcareous, mesic (Soil Survey Staff, 2014) and Calcaric Regosols (WRB, 2014). Mean annual temperature and rainfall are 12.6°C and 1178 mm. At Vicarello (200 m asl), the slope is low-moderate (6-20%), and soils are classified as Vertic Haploxerepts, fine, mixed, thermic (Soil Survey Staff, 2014) and Vertic Cambisols (WRB, 2014). Soil texture is silty-clay (S=20%, Si=38%, C=42%), slightly alkaline pH (7.6), organic matter 1.6%. Mean temperature and rainfall are 14.2°C and 833 mm. The sowing of common wheat was planned in both years 2011-12 and 2012-13, but in the second year the sowing was not possible due to the adverse climatic conditions. Sowing rate was 350 seeds/m^2, plot sizes were 4605 m^2 and 6874 m^2 at Fagna in the counterfactual and factual treatment respectively, 5259 m^2 and 4036 m^2 at Vicarello.

CREA-CER. The monitoring site is located in Foggia at the Manfredini farm. The soil is alluvial, flat, with vertic characteristics, classified as Chromic Calcixerert (Soil Survey Staff, 2014) and Chromi-Calcic Vertisol (WRB, 2014), with clay-loam texture (S=19%, Si=43%, C=38%), pH is very strong (8.8), organic matter 2.4%. Mean annual rainfall and temperature are 526.4 mm and 15.8°C. Two monitoring plots, with a surface of 5000 m^2 each (100 m x 50 m), and previously under durum wheat monoculture, with residue burning, have been tilled in tilth and no tilth conditions. Sowing rate was 350 seeds/m^2. The grain yield and the other biometric parameters have been determined.

CREA-FLC. The monitoring has been carried out for two years with common wheat at the Arcagna farm, on plots of 3500 m^2 each. The monitoring site is representative of the piedmont, alluvial and terraced Po Plain, with sandy-loam texture (S=64%, Si=2%, C=12%), moderately acid pH (5.2), organic matter 0.9%. The mean annual rainfall and temperature are 800 mm and 12.2°C. Sowing rate was 180 kg ha^{-1}, grain yield and the biometric parameters have been determined.

CREA-RPS. The monitoring site is located in Tormancina (Roma), in a hilly area (43 m asl) The soil is sloping (2-10%), classified as Typic Argixeroll (Soil Survey Staff, 2014) and Luvic Phaeozem (WRB, 2014), with loam-silty texture (S=30-36%, Si=44-49%, C=20-21%), neutral pH (6.8), organic matter 2.5-2.7%. Mean annual temperature and rainfall are 15.2°C and 800 mm. In 2012, after a durum wheat crop, two plots with a surface of 1680 m^2 (120 m x 14 m) were set up, tilled in tilth and no tilth conditions, and sown with durum wheat at a rate of 220 kg ha^{-1}. In 2013 common wheat was sown at a rate of 240 kg ha^{-1}. Field measurements were carried out to determine grain yield and the biometric parameters.

CREA-SCA. The monitoring site is located in Foggia at the experimental farm 'Podere 124'. The soil is plain and with clayey texture (S=20%, Si=31%, C=49%), moderately alkaline pH (8.3), organic matter 2.1%, alluvial and classified as Chromic Haploxerert fine, mesic (Soil Survey Staff, 2014) and Chromic Vertisol (WRB, 2014). The climate is accentuated thermo-Mediterranean with summer values above 40°C and rainfall concentrated in the autumn-winter period. In the first year, on a soil previously cultivated with tomato, two plots of 5.000 m^2 (100 m x 50 m) each were set up: the F plot with durum wheat (180 kg ha^{-1}), the CF with chickpea (137 kg ha^{-1}). In the second year durum wheat was sown in both plots. Grain yield and the biometric parameters were determined.

CREA-SSC. The monitoring site is located in Metaponto (Matera) at the experimental farm 'Campo 7' (10 m asl). The soil is plain, classified as Typic Epiaquert (Soil Survey Staff, 2014) and Stagnic Vertisol (WRB, 2014), weakly alkaline pH (7.8), 2.6% organic matter, clayey texture (S=19%, Si=39%, C=42%). Mean annual rainfall and temperature are 500 mm and 16°C. The two plots were sown at a rate of 220 kg ha^{-1}. The plot surface was 1270 m^2 (20 x 63.5 m), and samples to determine grain yield and the biometric parameters were taken.

Veneto Agricoltura. The experimental farm Vallevecchia is situated in Caorle (Venezia) on the Northern east-coast of Italy (0-1 m asl). Soils, classified as Fluvaquentic Eutrudept, fine-silty, carbonatic, mesic (Soil Survey Staff, 2014) and Gley-Fluvic Cambisol (WRB, 2014), have a silty texture (S=18%; Si=51%; C=31%), 2% organic matter content, sub-alkaline reaction (7.7). Mean annual rainfall and temperature are 970 mm and 13.7°C. The size of the two experimental plots for tilth and no tilth was respectively of 3206 e 2902 m^2. Grain yield, humidity and specific weight were determined.

Statistical analysis

One-way or two-way ANOVA was performed on all the data using the Statistica software (various versions, StatSoft Italia srl), while for the separation of means the Least Significant Difference test (LSD) at P<0.05 was applied.

Results and discussion

Soil water content

With reference to the soil water content at ploughing in the Factual (F) and Counterfactual (CF) plots, data are shown in Table 1. CREA-AAM. Soils in the CF treatment and in the three years were tilled above the UTL. The F treatment in 2012 and 2014 was tilled above the UTL, i.e. in no tilth conditions; in 2013 at a water content slightly below the OTL (0.38 *vs* 0.41 m^3 m^{-3}). CREA-ABP. At Fagna, soils in both the treatments have been tilled at water contents below the OTL. As a consequence, soils in the F treatment were tilled in a condition of 'dry tilth'. The CF treatment at Vicarello was tilled at a water content higher than the UTL (0.34 *vs* 0.30 m^3 m^{-3}), the F at a water content below the Optimum Tillage Limit (*i.e.*, in a dry tilth condition). CREA-CER and CREA-RPS. Soils of both treatments were tilled at water contents below the OTL. Again, soils in the F treatment were tilled in a condition of 'dry tilth'. CREA-SCA. Soils in the CF treatment were tilled at water contents above the UTL. Moreover, in 2012 the F plot was tilled in no tilth conditions, in 2011 at a value of 0.30 m^3 m^{-3} very close to the OTL. Veneto Agricoltura. Soils in the CF treatment in 2013 were tilled above the UTL. In the F treatment soil water content at ploughing was equal to the UTL.

Bulk density and packing density

Results for bulk density (BD) are reported in Table 2. Differences were statistically significant in the CREA-FLC plots with sandy-loam texture and CREA-SCA plots with clayey texture, with values lowering by 26.4% and 11.0% in the F plot respectively. Lower but not significantly different values were found in the CREA-AAM plots with clay-loam texture (-7.9%). BD values were not statistically different in the CREA-CER, CREA-RPS and Veneto Agricoltura plots. The values of the CREA-ABP plots (Fagna) are not statistically different, but are not comparable since soils were sampled in different periods. At Vicarello BD is significantly higher in the F plot (+6.4%). In addition, Packing density,

Table 1. Main soil characteristics, soil water reference volumetric contents and at ploughing.

Site	Plot/year	Bulk density (g cm^{-3})	Packing density (g cm^{-3})	Packing density class	FAO texture	Susceptibility to compaction	θ OTL (m^3 m^{-3})	θUTL (m^3 m^{-3})	θ at ploughing (m^3 m^{-3})
CREA-AAM	F 2012	1.24	1.52	Medium	Medium	Moderate	0.38	0.41	0.45
	CF 2012	1.31	1.59				0.41	0.44	0.48
	F 2013	1.28	1.56				0.41	0.46	0.38
	CF 2013	1.42	1.70				0.42	0.47	0.52
	F 2014	1.40	1.68				0.36	0.41	0.46
	CF 2014	1.30	1.58				0.39	0.44	0.48
CREA-ABP Fagna	F 2011-2012	1.16	1.56	Medium	Fine	Low	0.37	0.41	0.15
	CF 2011-2012	1.22	1.62				0.41	0.47	0.33
CREA-ABP Vicarello	F 2011-2012	1.61	1.99	High	Fine	Low	0.21	0.25	0.19
	CF 2011-2012	1.43	1.81				0.26	0.30	0.34
CREA-CER	F 2011	1.21	1.55	Medium	Fine	Low	0.46	0.49	0.29
	CF 2011	1.21	1.55				0.49	0.52	0.38
	F 2012	1.39	1.73				0.43	0.46	0.35
	CF 2012	1.37	1.71				0.44	0.47	0.43
CREA-FLC	F 2012	1.22	1.33	Medium	Medium	Moderate	0.25	0.29	0.19
	CF 2012	1.57	1.68				0.23	0.27	0.32
	F 2013	1.36	1.47				0.25	0.29	0.21
	CF 2013	1.70	1.81				0.23	0.27	0.31
CREA-RPS	F 2012	1.24	1.43	Low	Medium	High	0.40	0.44	0.36
	CF 2012	1.13	1.32				0.40	0.43	0.38
	F 2013	1.08	1.27				0.40	0.44	0.34
	CF 2013	0.98	1.17				0.40	0.43	0.36
CREA-SCA	F 2011	1.14	1.58	Medium	Fine	Low	0.32	0.34	0.30
	CF 2011	1.34	1.78				0.29	0.34	0.45
	F 2012	1.04	1.48				0.17	0.22	0.34
	CF 2012	1.07	1.51				0.22	0.26	0.36
CREA-SSC	CF 2011 (t0)	1.28	1.66	Medium	Fine	Low	0.56	0.63	-
	CF (2012) (t1)	1.32	1.70				0.51	0.57	-
Veneto Agricoltura	CF 2013-2014	1.32	1.59	Medium	Medium	Moderate	0.24	0.28	0.33
	F 2013-2014	1.30	1.57				0.22	0.26	0.26

F, factual; CF, counterfactual.

Packing density classes and susceptibility to compaction (Table 1) have been evaluated with the procedure proposed by Jones *et al.* (2003). The equation used is the following:

$$PD = BD + 0.009\ C \qquad (5)$$

where BD is the bulk density in g cm^{-3}, PD is the packing density in g cm^{-3}, C the clay content in %. Three classes of PD are recognized: low <1.40, medium 1.40-1.75 and high >1.75 g cm^{-3}. Matching the soil texture according to FAO and the PD values, the inherent susceptibility to compaction is derived (Table 1). Results showed that soils with medium PD and medium texture present a moderate susceptibility to compaction (AAM, FLC and Veneto Agricoltura); soils with low PD and medium texture present a high susceptibility to compaction (RPS).

Tortuosity index

Results for the tortuosity index are reported in Table 3. CREA-AAM: the index was statistically lower in the factual treatment (-5.5%), but no significant differences were found between the measurements along the tillage direction and perpendicularly to the tillage direction. CREA-ABP: ANOVA has shown a lower and statistically significant index in the F treatment, both at Fagna and Vicarello (-0.8 and -2.1% respectively). CREA-CER: the index was significantly lower in the F plot as average value (-3.5%). CREA-FLC: the index was significantly lower as mean value (-1.4%). CREA-RPS: the index was significantly lower in the F plot (-9.5%). CREA-SCA, CREA-SSC: the index was not statistically significant due to the previous heavy rainfall. Veneto Agricoltura: the index did not show significant differences between the two treatments (-0.1%).

Productive and qualitative results

CREA-AAM. Considering the 2-year rotation, data are reported for the two crops and the two years (Table 4). Wheat parameters have been significantly different in the F plot: +51% for the grain yield, +34.6% for the number of plants at emergence, -48% for the percent of weeds. For the clover the F treatment was strongly disadvantaged due to the low emergence (-54.6%), and the presence of weeds. CREA-ABP. Results in Table 5 have shown higher yields in the F treatment, both at Fagna (+33.7%) and Vicarello (+28.6%). CREA-CER. The results of the two years of monitoring are shown in Table 6. ANOVA has shown a significant effect of the season (year) for most parameters. As mean value the F plot has shown a higher grain yield (16.5%), protein content (2.2%) and grain gluten (1.9%). CREA-FLC. The effect of the year was significant for most parameters (Table 7). Significant and higher values in the F plot were found for the grain yield (+14.5%), the harvest index (+7.7%), the weight of 1000 seeds (+1.6%), and the number of plants at emergence (+19.3%). CREA-RPS. None of the parameters was statistically different except the percent of monocotyledonous weeds which was higher in the F treatment (Table 8). CREA-SCA. The chickpea yield (+49.7%) and the harvest index (+7.6%) were significantly higher in the F plot. No significant differences were found in wheat for most parameters (Table 9). CREA-SSC. ANOVA showed a significant effect of the year for most parameters (Table 10). Only the grain yield was statistically different in the F plot (+12.4%). Veneto Agricoltura. Data were not significantly different (Table 11), but grain yield and hectolitre weight were 9% and 6.4% higher in the F plot.

Economic evaluation of the competitiveness gap of the Standard 3.1 for farmers

To assess the competitiveness gap, data from the monitoring of farming operations were used. The time study of work was conducted adopting the recommendation of the Associazione Italiana di Genio Rurale (A.I.G.R.) III[a] R1 (Manfredi, 1971) that considers 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 effective work time (TE) and to turning accessory time (TAV), the sum of which corresponds to net work time (TN). The calculation of hourly cost of the machines and equipment, was calculated by using an analytical methodology (Biondi, 1999) and technical standards which this refers to (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, consist in 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

Table 2. Bulk density (BD) values in the factual (F) and counterfactual (CF) plots.

Sito	Plot/year	BD g cm^{-3}	Site	Plot/year	BD g cm^{-3}
CREA-AAM	F 2011	1.24	CREA-FLC	F 2012	1.22
	CF 2011	1.31		CF 2012	1.57
	F 2012	1.28		F 2013	1.36
	CF 2012	1.42		CF 2013	1.70
F = 1.26 ns	CF = 1.36 ns	-7.9 %	F = 1.29 a	CF = 1.64 b	-26.4 %
CREA-ABP Fagna	F 2011	1.16	CREA-RPS	F 2012	1.24
	CF 2012	-		CF 2012	1.13
	F 2012	1.22		F 2013	1.08
	CF 2013	1.22		CF 2013	0.98
F = 1.20 ns	CF = 1.22 ns	-1.3 %	F = 1.16 ns	CF = 1.05 ns	+ 9.5 %
CREA-ABP Vicarello	F 2011 (t0)	1.37	CREA-CER	F 2012	1.21
	CF 2011 (t0)	1.37		CF 2012	1.21
	F 2012	1.61		F 2012	1.39
	CF 2012	1.43		CF 2012	1.37
F = 1.49 b	CF = 1.40 a	+6.4 %	F = 1.30 ns	CF = 1.29 ns	+0.8 %
CREA-SCA	F 2011	1.14	Veneto Agricoltura	F 2013-2014	1.30
	CF 2011	1.34			
	F 2012	1.04		CF 2013-2014	1.32
	CF 2012	1.07			
F = 1.09 a	CF = 1.21 b	-11.0 %	F = 1.30	CF = 1.32	-1.5 %

ns, not significant.

A, Area 1, reported to the monitored provinces. Crops of durum wheat, common wheat and corn are considered. The data of cereals production costs were obtained by Centro Ricerche Produzioni Vegetali (CRPV, 2014) and the average prices of cereal in the last 12 months were obtained by Istituto di Servizi per il Mercato agricolo Alimentare (Table 12) (ISMEA, 2014). 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 in the table as lower limit and upper limit respectively. Due to the use of different machines and equipment in the ploughing operation, the data show a high standard deviation in the cost per hectare, amounting to € 126.78 in case of ploughing in conditions of excessive soil moisture (case A) and € 92.05 in case of ploughing in good soil moisture conditions (case B). For ease of calculation the number and cost of farming operations following the ploughing, in both cases, were considered identical for each crop. The production data were recorded by monitoring. The gross operative margin of the cultivations was calculated in optimal and suboptimal conditions for both cases. Since this Standard obliges to wait for good soil moisture conditions to perform the ploughing, may occur that waiting is extended in time, up to the point of preventing the normal crop cycle. Since working in a case A depends on unpredictable weather conditions and produces a change in the values of the competitiveness gap, it was assumed that it may occur from one to six times in six years (probability from 16.7% to 100%). It is assumed that the farmers who do not comply with the Standard, normally perform ploughing in case B and occasionally perform ploughing in case A, with different costs and revenues, resulting in a gross operative margin which, depending on the crop practiced, may be positive or negative. So the frequency of the ploughing in case A produces a change in the values of the competitiveness gap. The values obtained were discounted by the financial function NPV (Net Present Value). The difference between the cumulative discounted gross operative margin for the period in question, in cases A and B, allows to determine the cumulative values of competitiveness gap (€ ha^{-1}) for each scenario. By calculating the constant annuity the annual value of the competitiveness gap in € ha^{-1} $year^{-1}$ has been determined for the different conditions and crops considered (Table 13).

Conclusions

The monitoring did not exhibit univocal results for the different parameters, thus its effectiveness is 'contrasting' (class of merit B). In relation to the soil water contents at ploughing in the two treatments with the values given by the UTL and the OTL, there is an evident practical problem to till the soil at optimum water content since the difference between the two threshold values is 0.02-0.06 m^3 m^{-3}. Bulk density was significantly lower in the F treatment although in soils with different textures (sandy-loam and clayey). Packing density (PD) showed a high susceptibility in soils with low PD and medium texture. In relation to the tortuosity index, significant differences were found as average values. Yield and qualitative parameters of the crops in many cases have shown a prevailing positive effect of the season in favour of the tilth tillage. The analysis of the monitoring results showed that the ploughing done in excessive soil moisture conditions appears to be more expensive due to the increased force of traction of the tractor, which causes an increase in slip of the tractor wheels, with speed reduction and the consequent increase in the working times and fuel consumption. Moreover, crop yield is also reduced considerably according to the cultivated species. In some cases, the ploughing executed in excessive soil moisture conditions determines the conditions that lead to negative gross operating margin. The economic loss can be avoided by farmers who, adhering to the Standard, do not perform the crop cycle.

Table 3. Values of the tortuosity index in the counterfactual (CF) and factual (F) treatment.

Plot		CREA-AAM	
	Along tillage	Perpendicular	Mean
CF	1.218	1.249	1.233 b
F	1.159	1.179	1.169 a
F-CF (%)	-5.1	-5.9	-5.5
Plot		CREA-ABP Fagna	
	Along tillage	Perpendicular	Mean
CF	1.016 b	1.019	1.017 b
F	1.010 a	1.008	1.009 a
F-CF (%)	-0.6	-1.1	-0.8
Plot		CREA-ABP Vicarello	
	Lungo lavorazione	Perpendicolare lavorazione	Media
CF	1.041 b	1.028	1.034 b
F	1.015 a	1.013	1.013 a
F-CF (%)	-2.6	-1.5	-2.1
Plot		CREA-CER	
	Along tillage	Perpendicular	Mean
CF	1.124 b	1.081	1.102 b
F	1.061 a	1.068	1.065 a
F-CF (%)	-5,9	-1,2	-3,5
Plot		CREA-FLC	
	Along tillage	Perpendicular	Mean
CF	1.081 a	1.093 b	1.087 b
F	1.055 c	1.090 ab	1.072 a
F-CF (%)	-2.5	-0.3	-1.4
Plot		CREA-RPS	
	Along tillage	Perpendicular	Mean
CF	1.151 b	1.188 b	1.169 b
F	1.059 a	1.077 a	1.068 a
F-CF (%)	-8.6	-10.4	-9.5
Plot		CREA-SCA	
	Along tillage	Perpendicular	Mean
CF	1.091	1.072	1.081
F	1.082	1.085	1.084
F-CF (%)	-0.8	+1.2	+0.3
Plot		CREA-SSC	
	Along tillage	Perpendicular	Mean
CF	1.045	1.061	1.053
F	1.051	1.052	1.052
F-CF (%)	+0.6	-0.9	-0.1
Plot		Veneto Agricoltura	
	Along tillage	Perpendicular	Mean
CF	1.071	1.097	1.084
F	1.074	1.092	1.083
Mean	1.072 a	1.094 b	
F-CF (%)	0.3	-0.5	-0.1

Table 4. Yields, emergences and weeds in the monitoring plots of CREA-AAM.

Year	Crop	Plot	Grain yield d.w. (t/ha)	Plants at emergence (n/m^2)	Total weeds (%) (%)
2012	Wheat	6.06	367	50	
2012	Wheat	CF	2.97	240	74
		P value	0.011	0.046	0.018
		F-CF%	51.0	34.6	-48
Year	**Crop**	**Plot**	**Hay yield d.w. (t/ha)**	**Plants at emergence (n/m^2)**	**Total weeds (%) (%)**
2013	Clover	F	0.00	262	98
2013	Clover	CF	0.54	405	90
		P value	0.002	0.009	0.051
		F-CF%		-54.6	8.2

F, factual; CF, counterfactual.

Table 5. Plot size, yield and hectolitre weight of grain in the monitoring plots of CRA-ABP.

Monitoring site	Plot	Size (m^2)	Yield ($t\ ha^{-1}$)	Weight ($kg\ hL^{-1}$)
Fagna	No tilth (CF)	4605	4.343	81.19
	Tilth (F)	6874	6.546	82.08
	F-CF %		33.7	1.1
Vicarello	No tilth (CF)	5259	1.274	74.88
	Tilth (F)	4036	1.784	78.54
	F-CF %		28.6	4.7

F, factual; CF, counterfactual.

Table 6. Yield and qualitative parameters in the monitoring plots of CREA-CER.

Year	Crop	Plot	Grain yield (t/ha)	1000 seeds weight (g)	Hectolitre weight (kg)	Proteins (% d.w.)	Glutene (% d.w.)	Plants at emergence (n/m^2)	HI	Plant height (cm)	Fertile plants (n/m^2)	Flour proteins (% d.w.)
2012	Wheat	CF	2.75	44.2	85.7	13.4	10.1	243	37.4	65	251	
2012	Wheat	F	2.51	43.9	85.3	13.5	10.1	206	41.5	67	211	
2013	Wheat	CF	3.22	54.7	84.1	12.2	8.6	285	41.9	71	300	10.8
2013	Wheat	F	4.65	50.3	84.3	12.7	9.0	337	41.8	75	351	11.3
Media		CF	2.99 b	49.5 a	84.9	12.8	9.4	264	39.6	68 b	276	10.8
Media		F	3.58 a	47.1 b	84.8	13.1	9.5	272	41.7	71 a	281	11.3
Year		P value	0.000	0.000	0.000	0.001	0.000	0.002	ns	0.000	0.002	
Plot		P value	0.002	0.004	ns	ns	ns	ns	ns	0.045	ns	ns
Year x Plot		P value	0.001	0.010	ns	ns	ns	0.047	ns	ns	ns	
2012		F-CF (%)	-9.6	-0.8	-0.4	0.7	-0.7	-18.0	10.0	2.5	-18.9	
2013		F-CF (%)	30.7	-8.9	0.3	3.7	4.8	15.5	-0.2	5.3	14.6	4.0
Mean		F-CF (%)	16.5	-5.1	-0.1	2.2	1.9	2.8	4.9	4.2	2.0	

CF, counterfactual; F, factual; ns, not significant.

Table 7. Yield and qualitative parameters in the monitoring plots of CREA-FLC.

Year	rop	Plot	Grain yield d.w. (t/ha)	Straw yield d.w. (t/ha)	HI	1000 seeds weight (g)	Hectolitre weight (kg)	Plants at emergence (n/m^2)	Weeds (%) monocotyledons	dicotyledons
2012	Wheat	CF	7.37	5.60	0.57	38.8	73.9	306	1.0	2.3
2012	Wheat	F	8.75	5.00	0.64	39.3	75.6	384	1.0	1.0
2013	Wheat	CF	3.02	4.75	0.39	35.0	52.0	264	1.0	5.3
2013	Wheat	F	3.41	5.00	0.41	35.7	52.1	321	0.7	3.7
Mean		CF	5.20 a	5.00	0.48 a	36.9 a	63.0	285 a	1.0	3.8
Mean		F	6.08 b	5.18	0.52 b	37.5 b	63.9	353 b	0.8	2.3
Year		P value	0.000	0.253	0.000	0.000	0.000	0.020	0.347	0.075
Plot		P value	0.003	0.621	0.021	0.048	0.155	0.006	0.347	0.310
Year x Plot		P value	0.042	0.253	0.123	0.747	0.219	0.584	0.347	0.907
							F-CF %			
2012		F-CF (%)	15.8	-12.0	10.7	1.3	2.2	20.3	0.0	-130.0
2013		F-CF (%)	11.4	5.0	4.1	2.0	0.2	17.8	-42.9	-43.2
Mean		F-CF (%)	14.5	3.5	7.7	1.6	1.4	19.3	-25.0	-65.2

CF, counterfactual; F, factual.

Table 8. Yield and qualitative parameters in the monitoring plots of CREA-RPS.

Plot	Plants at emergence (n/m²)	Stems (n/m²)	Grain yield f.w. (t/ha)	Straw and bran yield (t/ha)	Grain yield at at 13% g (t/ha)	HI	Hectolitre weight (kg)	1000 seeds weight at 13% (g)	Proteins (%)	Weeds mono (%)	Weeds dico (%)	Total weeds (%)	Braun-Blanquet class
CF	201	267	3.50	6.12	3.56	0.36	76.9	52.94	10.71	0.1a	11.5	11.6	2
F	231	304	2.83	6.16	2.90	0.31	71.0	50.71	11.93	2.2b	12.7	14.8	2
F-CF %	13.0	12.2	-23.7	0.6	-22.8	-16.1	-8.3	-4.4	10.2	95.5	9.4	21.6	-

CF, counterfactual; F, factual.

Table 9. Yield and qualitative parameters in the monitoring plots of CREA-SCA.

Year	Crop	Plot	Grain yield at 14% humidity (t/ha)	HI	1000 seeds weight (g)	Year	Crop	Plot	Grain yield at 13% humidity (t/ha)	HI	Hectolitre weight (kg)	1000 seeds weight (g)	Proteins (%)
2012	Chickpea	F	2.21	0.68	308.75	2013	Wheat	F	5.74	0.26	81.83	37.80	15.80
2012	Chickpea	CF	1.11	0.63	297.53	2013	Wheat	CF	5.51	0.27	83.40	41.43	14.77
			***	*	ns				ns	ns	*	***	ns
		F-CF %	49.7	7.6	3.6			F-CF %	4.0	-4.1	-1.9	-9.6	6.5

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

Table 10. Yield and qualitative parameters in the monitoring plots of CREA-SSC.

Year	Crop	Plot	Grain yield at 13 % humidity (t/ha)	Residues weight f.w. (t/ha)	HI	Height (cm)	Tillering coefficient	Stems (n)	Ears (n)	Hectolitre weight (kg)	1000 seeds semi weight (g)	Proteins (%)
2012	Wheat	CF	7.19	8.31	0.45	90.6	2.5	34.3	29.7	81.3	43.8	11.2
2012	Wheat	F	7.09	8.14	0.45	92.2	2.1	37.7	33.3	81.8	47.2	11.7
2013	Wheat	CF	3.93	7.54	0.39	70.0	2.5	31.7	29.3	79.9	37.6	9.2
2013	Wheat	F	5.60	5.97	0.41	73.3	2.2	33.0	34.7	78.8	40.1	9.9
Mean		CF	5.56 a	7.92 b	0.42	80.3	2.5	33.0	29.5	80.6	40.7	10.2
Mean		F	6.35 b	7.06 a	0.43	82.8	2.2	35.3	34.0	80.3	43.7	10.8
Year		P value	0.000	0.001	0.008	0.000	0.850	0.256	0.873	0.000	0.002	0.006
Plot		P value	0.004	0.019	0.346	0.464	0.325	0.459	0.174	0.469	0.072	0.289
Year x Plot		P value	0.002	0.046	0.306	0.804	0.795	0.747	0.789	0.055	0.773	0.795
2012		F-CF (%)	-1.4	-2.1	0.0	1.7	-19.0	8.8	10.8	0.6	7.2	4.3
2013		F-CF (%)	29.8	-26.3	4.9	4.5	-13.6	4.0	15.6	-1.4	6.2	7.1
Mean		F-CF (%)	12.4	-12.2	2.3	3.0	-13.6	6.5	13.2	-0.4	6.9	5.6

CF, counterfactual; F, factual.

Table 11. Yield and qualitative parameters in the monitoring plots of Veneto Agricoltura.

Year	Crop	Plot	Grain yield d.w. (t/ha)	Grain yield at 15.5% humidity (t/ha)	Hectolitre weight (kg)	Plants at emergence (n/m²)
2013	Corn	CF	5.67	6.53	60.9	6.73
2013	Corn	F	6.24	7.17	65.1	6.77
	Plot	P value	ns	ns	ns	ns
F-CF %						
		F-CF (%)	9.0	8.9	6.4	0.5

Table 12. Average prices (ISMEA, 2014).

Average prices	(€ t⁻¹)
Durum wheat grain	261.25
Common wheat grain	209.77
Corn grain	188.88

Table 13. Annual values of the competitiveness gap (€ ha^{-1} $year^{-1}$).

Scenarios	Durum wheat			Common wheat			Corn		
	Lower limit	Average	Upper limit	Lower limit	Average	Upper limit	Lower limit	Average	Upper limit
Once every 6 years (16.7% probability)	-44.14	-10.12	23.89	-12.26	21.76	55.78	-42.01	-5.00	32.01
Once every 5 years (20% probability)	-52.97	-12.15	28.67	-14.71	26.11	66.93	-50.41	-6.00	38.41
Once every 4 years (25% probability)	-66.21	-15.19	35.84	-18.38	32.64	83.67	-63.01	-7.50	48.01
Once every 3 years (33% probability)	-88.28	-20.25	47.79	-24.51	43.52	111.56	-84.01	-10.00	64.02
Once every 2 years (50% probability)	-132.42	-30.37	71.68	-36.77	65.28	167.34	-126.02	-15.00	96.03
Once a year (100% probability)	-264.85	-60.74	143.36	-73.54	130.57	334.67	-252.04	-29.99	192.05

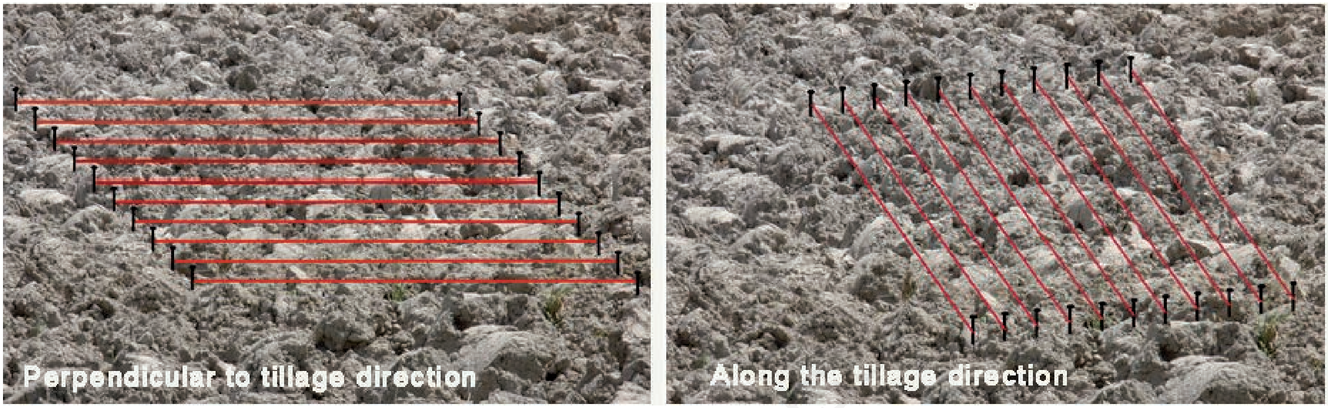

Figure 1. Measurements of the tortuosity index with the roller chain method.

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