Environmental effectiveness of GAEC cross-compliance Standard 1.1a (temporary ditches) and 1.2g (permanent grass cover of set-aside) in reducing soil erosion and economic evaluation of the competitiveness gap for farmers

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Abstract

This paper shows the results of the monitoring carried out in three hilly farms of the MO.NA.CO. project in order to verify the effectiveness of the Standard 1.1 $_{\text{(commitment a)}}$ (temporary ditches) and Standard 1.2 $_{\text{(commitment g)}}$ (Vegetation cover throughout the year in set-aside land) in the reduction in soil erosion, contained in Rule 1: 'minimum land management that meets specific conditions' of the decree Mipaaf 2009 and following modifications, until the recent decree No. 180 of January 23, 2015. In addition, the assessment of the competitiveness gap was done. That is the evaluation of the additional costs borne by the beneficiary of the single payment determined from agronomic commitments.

Monitoring has also compared the erosion actually observed in the field with that predicted by RUSLE model (Revised Universal Soil Loss Equation) in the two situations: with and without the presence of temporary ditches, *i.e.* assuming Factual (compliance rules) and in that Counterfactual (infringement). This comparison was made in view of the fact that the RUSLE model was chosen by the 'European Evaluation Network for Rural Development (EEN, 2013) as a forecasting tool for the quantification of' Common Indicator 'soil erosion by water'.

The results of soil erosion survey carried out by using a new UAV-GIS methodology on two monitoring farms in two years of observations have shown that temporary ditches were effective in decreasing erosion, on average, by 42.5%, from 36. 59 t ha^{-1} to 21.05 t ha^{-1} during the monitoring period. It was also evaluated the effectiveness of grass strips (at variance with the commitment of temporary ditches). The results showed a strong, highly significant, reduction in erosion by about 35% times respect soil erosion observed in bare soil and also a significant reduction in the volume of runoff water.

With regard to Standard 1.2 $_{\text{(commitment g)}}$ the statistical analysis shows a strong and highly significant decrease in the erosion due to the vegetation cover of the soil compared to bare soil.

The economic competitiveness gap of Standard 1.1$_{\text{(commitment a)}}$ stood at € 4.07±1.42 € ha^{-1} year^{-1}, while CO_2 emissions due to execution of temporary ditches was 2.58 kg ha^{-1}year^{-1}.

As for the Standard 1.2 $_{\text{(commitment g)}}$ the average differential competitiveness gap amounted to 50.22±13.7 € ha^{-1} year^{-1} and an output of CO_2 equal to 31.52 kg ha^{-1} year.

Introduction

The GAEC Cross-compliance Standard 1.1$_{\text{(commitment a)}}$ (Reg. (EC) No. 1782/2003) (hereafter abbreviated to Standard 1.1a) applies to arable crops and requires the beneficiary of the single payment to the 'Realization of temporary ditches' in the land slopes affected by soil erosion. In the absence of specific rules dictated by the Italian Regions, the Standard provides for the realization of temporary ditches with a distance between them of no more than 80 metres, or the realization of grass strips of a width of not less than 5 metres, at a distance between them of no more than 60 metres.

Monitoring of the effect of temporary ditches on soil erosion is necessary for two purposes:

- To allow the evaluation of the environmental effectiveness of actions applied by farmers through this cross-compliance Standard.
- To calibrate and validate the soil erosion prediction models that are commonly adopted in the scenario analysis of needs, that constitute the premise to the formulation of RDPs, and also utilised in the mid-term and ex-post RDP evaluations.

In the programming period of CAP 2007-2013 the 'independent evaluators' (Reg. (EC) No. 1698/2005) of some Italian RDPs estimated quantitatively the beneficial effect of agri-environment measures in the reduction in soil erosion by using the RUSLE model (Renard *et al.*, 1997).

The same RUSLE model was chosen by the 'European Evaluation Network for Rural Development (ENRD, 2013)' as a forecasting tool to quantify, at the regional scale, the Common Indicator 'Soil erosion by water'. This indicator is defined as the mean rate of soil loss by water erosion (t ha^{-1} year^{-1}) and was adopted in order to respond the Common Evaluation Question for Focus area 4C (preventing erosion and improving soil management): 'To what extent have RDP interventions supported the prevention of soil erosion and improvement of soil management?'. Regulation (EU) No. 808/2014, which codifies the application of Regulation (EU) No. 1305/2013, entails that for each focus area included in the RDP, the related question must be answered in the enhanced annual implementation reports (AIRs) that will be due in 2017 and 2019, and in the ex-post evaluation report.

Calibration and validation of the RUSLE model is therefore crucial for a proper evaluation of RDPs. Calibration requires the assignment of values to the model coefficients that are specific to the site in question. Validation is to compare observed values of soil erosion with the predicted values by RUSLE model.

Through the present work we also intended to provide Regions with a methodology to adapt RUSLE model to various local contexts.

Materials and methods

Description of monitoring sites

Monitoring of the Standard 1.1a was conducted in four experimental farms (Figure 1):

1. CREA-ABP farm, Agrobiology and Pedology Research Centre, Fagna (Scarperia, FI).
2. CREA-ABP farm, Agrobiology and Pedology Research Centre, Santa Elisabetta (Volterra, PI).
3. CREA-RPS farm, Research Centre for the Soil-Plant System, Tor Mancina (Rome).
4. CREA-SCA farm, Research Unit for Cropping Systems in Dry Environments, ME Venezian Scarascia, Rutigliano (BA).

Monitoring site: Santa Elisabetta farm

General characters

The Santa Elisabetta farm is located in Vicarello, Volterra (Pisa) (Figure 2). The geographic coordinates WGS84 of farm centroid are: N 43° 27' 48.26"; E 10° 51' 54.71". The average altitude is 153.2 m asl. The soils evolved from marine Pliocene clays. They are classified as Vertic Xerorthent and Vertic Xerochept (Soil Survey Staff, 2014). Dominant clay minerals are: kaolinite, illite, chlorite.

Monitoring Materials and methods

In the farm the monitored parameters were:

- For the Standard 1.1a: erosion and runoffs in conditions of implementation of the Standard (Factual) and in conditions of non-implementation (counterfactual); with land sown with wheat.
- For the Standard 1.2g: erosion and runoff in conditions of a) set-aside with management of vegetation cover by shredding once a year (Factual); b) permanent vegetation cover not shredded once a year (counterfactual); c) land sown with wheat.
- The competitiveness gap due to the commitments of this Standard, and CO_2 emissions related to fuel consumption for the realization of temporary ditches.

The evaluation of the effectiveness of temporary ditches and permanent grass cover in reducing soil erosion and runoff volumes was performed during two years of monitoring by using a system of runoff plots (Figure 3) that is present in the farm since the late 60 (Figure 3). The runoff plots, 75 m long on the steepest slope and 15 m wide, with a slope of 25%, are equipped with electronic recording hydrological units (tipping pots) (Bazzoffi, 1993a, 1993b) that acquire extreme detail data (one record for each tipping of the pot).

To evaluate the effectiveness of the Standard 1.2g we used the data collected in a previous study conducted in 1999-2002 on the same experimental plots.

Only the values of erosion and runoff collected in the autumn-winter period were used for elaboration (until before the doffing of wheat), since this is the period of maximum occurrence of erosive rains and minimum protection of soil by vegetation cover (seed bed condition).

Three kinds of evaluation were performed:

Standard 1.1$_a$ (temporary ditches)

Two theses have been compared with four replicas for a total of 8 plots (Figure 3), as follows: 1) Factual thesis (with a single ditch located at a distance of 36 m from the top edge of the plots, soil chiselling instead of ordinary mouldboard ploughing); 2) Counterfactual thesis (no temporary ditch applied, no chiselling, ordinary mouldboard ploughing of soil). The plots with the Factual thesis are shown in Figure 2 with the numbers 1, 3, 6, 8; while the Counterfactual thesis plots are shown with the numbers 2, 5, 7, 10.

Standard 1.1$_a$ grass strips (in derogation from the realization of temporary ditches)

Five thesis have been compared with two replicas for a total of 10 plots, as follows: 1) one 3-metre-wide grass strip; (36 m of bare soil left from the uphill edge of the plot and 36 m from the foothill edge of the plot); 2) two 3-metre-wide grass strips; (23 m from the upper edge, 23 m between the first and the second strip and 23 m between the second strip and the downhill edge of the plot); 3) one 5-metre-wide grass strip; (35 m of bare soil from both the uphill and downhill edge of the plot); 4), two 5-metre-wide grass strips 5 (21.5 metres from the top edge, 21.5 m between the first and second strip and 21.5 m between the second strip and the downhill edge of the plot); 5) bare soil kept in seedbed condition (mouldboard ploughing followed by disking and chemical weeding).

Standard 1.2$_g$ (natural or sowed vegetation cover along the year)

Three theses have been compared with two replicas for a total of 6 plots: 1) Factual thesis (aside from production with management of vegetation cover by shredding once a year, 2) thesis Counterfactual 1 (aside from production, covered by natural Mediterranean vegetation, with no management of vegetation cover), 3) Thesis counterfactual 2

Figure 1. Location of monitoring sites.

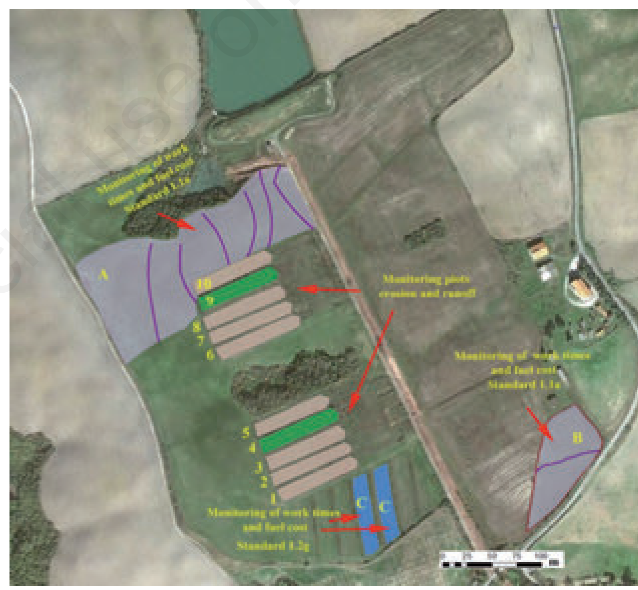

Figure 2. Santa Elisabetta farm (CREA-ABP) and location of monitoring plots.

Figure 3. Plots for measuring runoff and erosion in the Santa Elisabetta farm.

(bare soil kept in seedbed condition by mouldboard ploughing followed by disking and chemical weeding).

Factual-thesis plots are shown in Figure 2 with the numbers 5 and 19 (the trial has been conducted during years different from those in which the effectiveness of temporary ditches, with the presence of wheat, has been tested). The Counterfactual plots are shown in Figure 2 with the numbers 4 and 9.

Competitiveness gap

The measurement of the working times and fuel consumption for Standard 1.1a was carried out in the areas marked by the letters A and B in Figure 2. For Standard 1.2g, the measurements were carried out on two plots marked with the letter C in Figure 2, where shredding of vegetation cover was practiced once a year.

Monitoring site: Fagna farm

General characters

The farm (Figure 4) is located at Fagna (Scarperia, province of Florence), the WGS84 coordinates of the farm centroid company are: N 43° 58' 53.35"; E 11° 20' 57.27". The average altitude is 247.6 m asl. The soils evolved on the Pleistocene (Villafranchiano) lacustrine clay and silt deposits; floods and in the (Holocene) sand and gravel alluvial deposits. The soils are moderately deep, with clay to clay loam texture, with strong vertic characters, very calcareous, from weakly to strongly alkaline, rather poorly drained. They are classified as fine Typic Udorthents (Soil Survey Staff, 2014). The dominant clay minerals are: illite, kaolinite and halloysite. Soil bulk density at UAV survey time resulted 1.222 t m^{-3}.

Monitoring Materials and Methods

In the farm the monitored parameters were:

- For the Standard 1.1a: erosion in conditions of implementation of the Standard (Factual) and in conditions of non-implementation (counterfactual); with land sown with wheat.
- For the Standard 1.2g: erosion in conditions of set-aside with management of vegetation cover by shredding once a year (Factual).
- The competitiveness gap due to the commitments of this Standard, and CO_2 emissions related to fuel consumption for the realization of temporary ditches.

The evaluation of the effectiveness of temporary ditches and permanent grass cover in reducing soil erosion was performed through the UAV-GIS methodology as described in the paper titled *Measurement of rill erosion through a new UAV-GIS methodology* (Bazzoffi, 2015a). In Figures 5 and 6 a monitoring plot is shown.

Three kinds of evaluation were performed, as per the following paragraphs.

Standard 1.1_a (temporary ditches)

Two theses have been compared as follows: 1) Factual thesis (with ditches, soil chiselling instead of ordinary mouldboard ploughing); 2) Counterfactual thesis (no temporary ditch applied, no chiselling, ordinary mouldboard ploughing of soil). The plots with the Factual thesis are shown in Figure 4 with the numbers 1, 2, 4; while the Counterfactual thesis is named 'counterfactual plot 3' in the same Figure.

Standard 1.2_g (natural or sowed vegetation cover along the year of set-aside)

Two theses have been compared: 1) Factual thesis (aside from production with management of vegetation cover by shredding once a year); 2) Counterfactual thesis (aside from production, covered by natural, with no management of vegetation cover).

Factual-thesis plots are shown in Figure 4 with the number 5. The Counterfactual plot is shown in Figure 4 with the number 6.

Figure 4. Fagna farm (CREA-ABP) and location of monitoring sites.

Figure 5. Tor Mancina CREA-RPS farm and location of monitoring sites of Standard 1.1_a.

Competitiveness gap

The measurement of the working times and fuel consumption for Standard 1.1a was carried out in the plots with numbers 1 and 4 in Figure 4. For Standard 1.2g, the measurements regarding the shredding of vegetation were carried out on plot with number 5 in Figure 4.

Monitoring site: Tor Mancina farm

General characters

Monitoring was made at Tor Mancina (Monterotondo, province of Rome). The WGS84 coordinates of farm centroid are: N 42° 05' 43.09''; E 12° 38' 04.83", the average altitude is 43 m asl (Figure 5). Soils derive from pedogenized stratified volcanic tuff with lapilli, cinerites and Pleistocene leucitic scorias. The soil classification in the plot area is Typic Argixeroll (Soil Survey Staff, 2014). Soil bulk density at UAV survey time resulted 1,247 t m^{-3}.

Monitoring Materials and Methods

In the farm the monitored parameters were:

- For the Standard 1.1a: erosion in conditions of implementation of the Standard (Factual) and in conditions of non-implementation (counterfactual); with land sown with wheat (Figures 6 and 7).
- The competitiveness gap due to the commitments of this Standard, and CO_2 emissions related to fuel consumption for the realization of temporary ditches.

The evaluation of the effectiveness of temporary ditches and permanent grass cover in reducing soil erosion was performed, as for Fagna farm, through the UAV-GIS methodology (Bazzoffi, 2015a).

Two kinds of evaluation were performed, as per the following paragraphs.

Standard 1.1a (temporary ditches)

Basin comparisons

Two theses have been compared, during two crop years (2012-2013 e 2013-201 for a total of 4 monitored basins, as follows: 1) Factual thesis (with ditches, soil chiselling instead of ordinary mouldboard ploughing); 2) Counterfactual thesis (no temporary ditch applied, no chiselling, ordinary mouldboard ploughing of soil). Basins with the Factual thesis are shown in Figure 7 with 'Factual 13' and 'Factual 14'; while the Counterfactual basins are shown as 'Counterfactual 13' and 'Counterfactual 14'. Figures 8 and 9 show the development of rills on basins during the crop year 2012-2013.

Plot comparisons

During the same two crop years, at the same survey times as for basins, two runoff plots (marked in Figure 7 with 'Factual' and 'Counterfactual') were monitored to determine soil erosion.

Competitiveness gap

The measurement of the working times and fuel consumption for Standard 1.1a was carried out in the basin marked 'Factual 13' in Figure 5.

Monitoring site: M.E. Venezian Scarascia farm

General characters

Monitoring plots were located and made in Rutigliano (BA). The WGS84 coordinates of farm centroid are : N 40°59' 37.01"; E 17° 2' 7.66", the average altitude is 125 m asl (Figure 8).

Soils are classified as Rhodoxeralf Lithic Ruptic (Soil Survey Staff, 2014) and developed from the 'Tufi delle Murge' calcareous complex of Pleistocene origin.

In the farm the only monitored parameter was as follows.

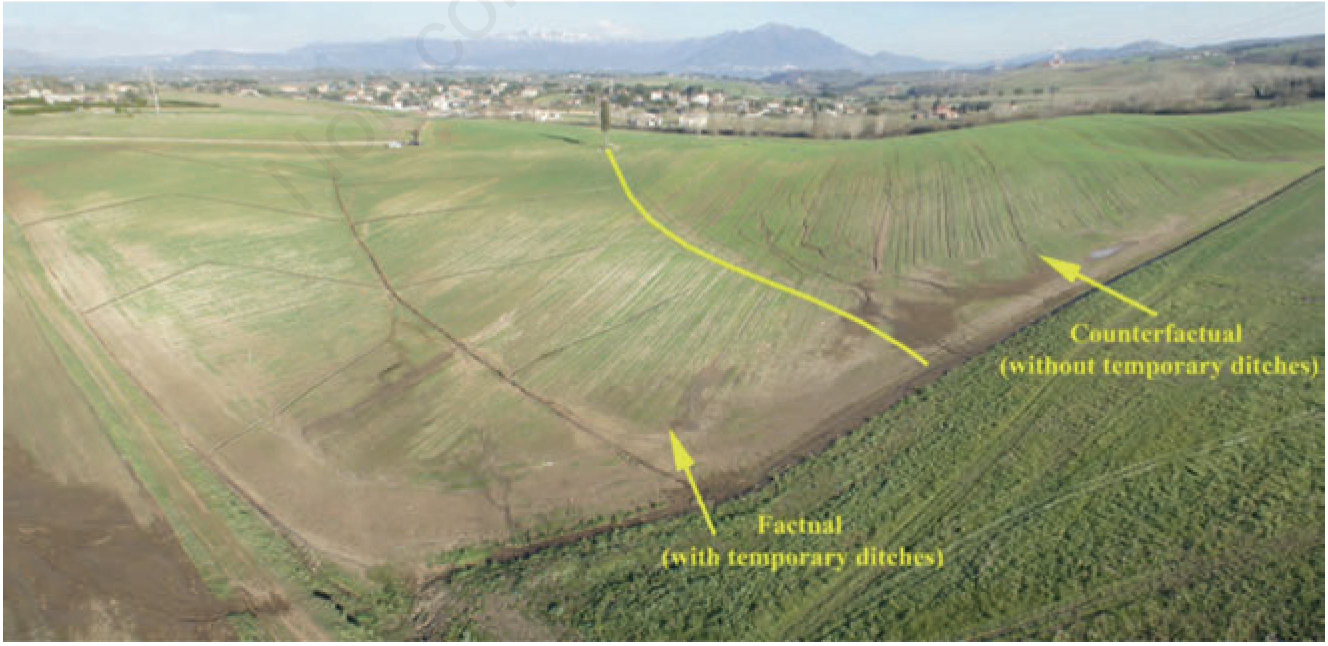

Figure 6. Soil erosion monitoring basins in Tor Mancina. Note the strong development of rills in the area where temporary ditches were not made (Counterfactual).

Competitiveness gap

The measurement of the working times and fuel consumption for Standard 1.1a was carried out in the plot coloured in green in Figure 8.

Results of monitoring

Results of direct monitoring of erosion and runoff on runoff plot - Santa Elisabetta farm

Standard 1.1a (temporary ditches)

The statistical analysis of data (Table 1) shows a strong and highly

Figure 7. Tor Mancina Farm. Detail of the basin were temporary ditches were not made (Counterfactual) which shows the development of severe rill erosion.

Figura 8. M.E. Venezian Scarascia farm (CREA-SCA) and location of monitoring sites.

Table 1. Evaluation of the effectiveness of temporary ditches on runoff plots located at Santa Elisabetta farm. Statistical comparison.

Thesis	Erosion Standard 1.1a t ha^{-1} year^{-1} mean	Std. Err	Duncan (mean separation)*	No. of events
Factual (with temporary ditches)	1.12	0.07	B	88
Counterfactual (without temporary ditches)	5.23	1.25	A	88
Thesis	**Runoff Standard 1.1a m^3 ha^{-1} year^{-1} mean**	**Std. Err**	**Duncan (mean separation)***	**No. of events**
Factual (with temporary ditches)	70.95	26.41	A	88
Counterfactual (without temporary ditches)	132.18	30.90	A	88
Total active rainfall mm 405.08				

*P≤0.05.

Table 2. Evaluation of the effectiveness of grass strips on runoff plots located at Santa Elisabetta farm. Statistical comparison.

Thesis	Erosion Standard 1.1a (grass strips) t ha^{-1} year^{-1} mean	Std. Err	Duncan (mean separation)*	No. of events
Factual: 2 strips, 3 m wide each	0.84	1.322	B	46
Factual: 1 strip, 5 m wide	1.22	1.325	B	46
Factual: 1 strip, 3 m wide	1.77	1.316	B	46
Factual: 2 strips, 5 m wide each	1.94	1.312	B	46
Counterfactual: bare soil	8.16	1.098	A	46
Thesis	**Erosion Standard 1.1a (grass strips) m^3 ha^{-1} year^{-1} mean**	**Std. Err**	**Duncan (mean separation)***	**No. of events**
Factual: 2 strips, 3 m wide each	101.28	27.60	BC	46
Factual: 1 strip, 3 m wide	102.66	27.60	BC	46
Factual: 1 strip, 5 m wide	108.51	23.04	BC	66
Counterfactual: bare soil	166.25	27.60	AB	46
Factual: 2 strips, 5 m wide each	219.06	27.60	A	46
Total active rainfall mm 133.8				

P≤0,05.

significant decrease in soil erosion due to temporary ditches.

The Factual thesis (with temporary ditches) shows to be significantly effective in limiting erosion. In fact, it determined a decrease in soil loss of approximately 84.4% compared to soil without temporary ditch.

As regards runoff, the presence of the ditch has resulted in a general decrease in the volumes of the scouring water of about 46.3% (with statistical significance of 86.4%).

Standard 1.1a grass strips (in derogation from the realization of temporary ditches)

Statistical analysis (Table 2) shows a strong, highly significant, decrease in erosion due to grass strips, which passes from 8.16 t ha^{-1} year^{-1} in the case of bare soil to 0.84 t ha^{-1} year^{-1} for thesis with two 3-m-wide grass strips. Also the other thesis with grass strips have resulted in a significant reduction in erosion, which on average dropped to 1.44 t ha^{-1} year^{-1}. That amounts to a reduction of about 5.7 times that observed erosion on bare soil.

As for runoff there is a general decrease in the volume of scouring water determined by grass strips, passing, on average, from 166.25 m^3 ha^{-1} year^{-1} for bare soil to 108.51 m^3 ha^{-1} year^{-1} for thesis with only one 5-m-wide strip.

The thesis with one grass strip of 5 metres, so similar to the provisions in derogation from the temporary ditches, shows to be effective in limiting erosion. In fact, it lowered soil erosion of about 35% compared to bare soil.

In Figure 9 the runoff plots at Saint Elizabeth with the different treatments of grass strips are shown.

Figure 9. A group of plots at Santa Elisabetta farm for measuring runoff and soil erosion under different grass strips treatments.

Figure 10. Visual demonstration of the effectiveness of temporary ditches in interrupting the development of rill downditch and consequently in reducing soil erosion. On the left, seen from drone. On the right, ground picture of the zone of hydraulic connectivity between rill and ditch (Fagna farm).

Table 3. Soil erosion as detected by UAV-GIS methodology on the monitoring sites. Rainfall, RUSLE factors and estimated soil erosion by RUSLE model.

Location	Treatment	Monitoring site	Observation start time	Observation end time	Period (months)	Slope (%)	Plot area (ha)	t ha^{-1} period^{-1}	Period rainfall (mm)	RUSLE factors* R	K	C	P	RUSLE_GIS on DEM 20 metres (t ha^{-1} period^{-1})
Fagna	Factual	Plot 4	01 Oct. 12	07 Jan. 13	3.3	13.2	0.75	18.2	427.0	9911.35	0.040	1.00	1.00	n.a.
Fagna	Factual	Plot 1	25 Dec. 13	26 Jan. 14	1.1	14.4	1.18	29.1	69.4	1550.14	0.040	1.00	1.00	66.39
Fagna	Counterfactual	Plot 2	25 Dec. 13	26 Jan. 14	1.1	14.8	0.87	22.3	69.4	1550.14	0.040	1.00	1.00	n.a.
Fagna	Factual	Crocioni basin all	08 Oct. 11	03 May 12	6.9	16.5	1.05	33.0	427.0	9911.35	0.040	1.00	1.00	54.97
Fagna	Counterfactual	Crocioni sub-basin 1	08 Oct. 11	03 May 12	6.9	20.3	0.09	17.5	427.0	9911.35	0.040	1.00	1.00	n.a.
Fagna	Counterfactual	Crocioni sub-basin 2	08 Oct. 11	03 May 12	6.9	20.3	0.18	37.3	427.0	9911.35	0.040	1.00	1.00	55.40
Tor Mancina	Counterfactual	Basin 13	16 Nov. 12	27 Feb. 13	3.4	15.4	1.58	87.6	372.8	6580.82	0.054	1.00	1.00	79.38
Tor Mancina	Factual	Basin 13	16Nnov. 12	28 Feb. 13	3.5	13.8	1.72	43.9	372.8	6580.82	0.054	1.00	1.00	57.22
Tor Mancina	Factual	Basin 14	19 Sep. 14	23 Nov. 14	2.2	13.2	2.50	2.8	210.9	9486.20	0.054	1.00	1.00	3.12
Tor Mancina	Counterfactual	Basin 14	19 Sep. 14	23 Nov. 14	2.2	13.8	2.45	12.4	210.9	9486.20	0.054	1.00	1.00	13.9
Tor Mancina	Factual	Plot	16 Nov. 12	27 Feb. 13	3.4	12.4	0.13	6.4	372.8	6580.82	0.054	1.00	1.00	n.a.
Tor Mancina	Counterfactual	Plot	16 Nov. 12	28 Feb. 13	3.5	13.5	0.11	34.0	372.8	6580.82	0.054	1.00	1.00	n.a.
Tor Mancina	Factual	Plot	19 Sep. 14	23 Nov. 14	2.2	12.4	0.18	14.0	210.9	9486.20	0.054	1.00	1.00	n.a.
Tor Mancina	Counterfactual	Plot	19 Sep. 14	23 Nov. 14	2.2	13.5	0.12	45.0	210.9	9486.20	0.054	1.00	1.00	n.a.

*LS calculated according to Nearing (1997) by cell by cell through GIS; n.a., not applicable because plot is too small (no resample was possible into 20 m cells).

Results of measurement of soil erosion at Fagna and Tor Mancina farms

Standard 1.1a (temporary ditches)

Table 3 shows the synoptic view of soil erosion (t ha^{-1} $period^{-1}$) measured on monitoring sites by using the UAV-GIS methodology (Bazzoffi, 2015). Period means the time that has elapsed between the date of execution temporary ditches (immediately after sowing of wheat) and the date of the survey with drone. Table 3 also shows the characteristics of monitoring sites, the amount of rainfall during the observation period, the RUSLE factors applied through GIS. The last column on the right shows the RUSLE estimates by using resampled DEMs with cell size of 20 metres (the original cell size of DEM is 4.7 cm).

As for the farm M. E. Venezian Scarascia, during the monitoring period there were no rainfall events that generated runoff. For this reason on the plot surface there was no evidence of rill formation detectable with the UAV methodology. Therefore, erosion amounted to 0 t ha^{-1} $period^{-1}$.

Table 4 shows the mean values of soil erosion measured through the UAV-GIS methodology on sites respectively with (factual) and without (counterfactual) temporary ditches. The same table shows the confidence limits and mean separation through the Duncan's test.

Visual evidence of the effectiveness or ineffectiveness of temporary ditches

Figure 10 shows, in a visual way, the effectiveness of the temporary ditches to intercept runoff and to decrease the formation of rills downditch. On the contrary, Figure 11 shows the disastrous effect of concentration of runoff and the ineffectiveness of temporary ditches where they are not able to fulfil their function of channelling all the volume of runoff water due to undersizing.

Figure 11. Zenithal picture from drone that illustrates the zones of breakage of the temporary ditches because of their undersize. Arrows of different colours identify different rills and indicate points where runoff has not been effectively intercepted by ditches, causing a 'domino effect' of concentration of erosion downstream (Tor Mancina farm).

Table 4. Mean values of soil erosion as detected through the UAV-GIS methodology (Standard 1.1_a). Statistics and mean separation by Duncan's test (P≤0.005).

Thesis	N	Erosion (t ha^{-1} $period^{-1}$) Mean	Std. Dev.	Conf. ±95.00%	Duncan's test (mean separation)
Counterfactual (without temporary ditches)	7	36.59	25.28	23.38	A
Factual (with temporary ditches)	7	21.05	14.92	13.79	A

Table 5. Evaluation of the effectiveness of vegetation cover on runoff plots located at Santa Elisabetta farm. Statistical comparison.

Thesis	Soil erosion Standard 1.2_g t ha^{-1} $year^{-1}$ mean	Std. Err.	Duncan (mean separation)	No. of events with runoff
Factual (Set-aside shredded)	0.55	0.27	B	153
Counterfactual 1 (Set-aside not shredded)	0.0003	0.0092	B	153
Counterfactual 2 (bare soil)	5.33	1.32	A	153
Thesis	**Runoff Standard 1.2_g m^3 ha^{-1} $year^{-1}$ mean**	**Std. Err.**	**Duncan (mean separation)**	**No. of events with runoff**
Factual (Set-aside shredded)	3.51997	2.12	B	153
Counterfactual 1 (Set-aside not shredded)	1.39502	1.35	B	153
Counterfactual 2 (bare soil)	89.65	27.34	A	153

Standard 1.2g (natural or sowed vegetation cover along the year on set-aside)

Plot monitoring (Santa Elisabetta farm)

With regard to Standard 1.2 $_{\text{(commitment g)}}$ the statistical analysis of data (Table 5) shows a strong and highly significant decrease in erosion due to the vegetation cover of the soil compared to bare soil (counterfactual 2).

In the Factual thesis (aside from production with management of vegetation cover by shredding once a year) the decrease in soil erosion was of 89.7% (0.55 t ha^{-1} year^{-1}). In the counterfactual 1 thesis (set aside, not managed, covered by Mediterranean stain) erosion approached zero (0.0003 t ha^{-1} year^{-1}) compared to bare soil. The Factual thesis (set aside with shredding once a year) shows to be significantly effective in reducing runoff of 96.1% compared to bare soil, passing from 89.65 m^3 ha^{-1} year^{-1} to 3.51 m^3 ha^{-1} year^{-1}. Runoff volumes on factual thesis (3.52 m^3 ha^{-1} year^{-1}) are slightly higher than on the Counterfactual thesis (set aside with Mediterranean stain) which showed an average runoff of 1.40 m^3 ha^{-1} year^{-1}.

Figure 12. Visual evidence of complete lack of rills on plots where the Standard 1.2g was applied. Only walkways and traces of soil tillage prior to set-aside (that cannot be attributed to erosion) are distinguishable.

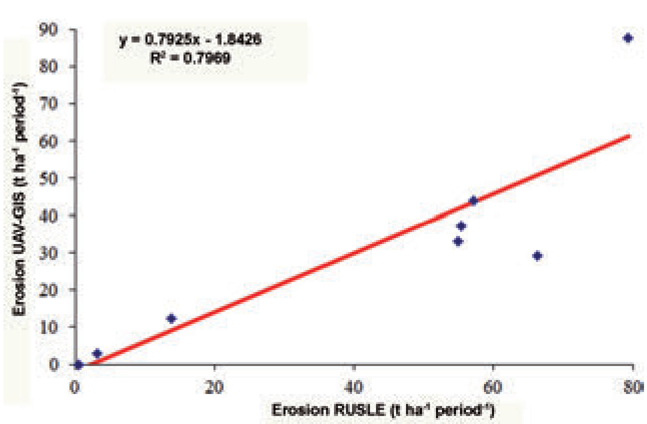

Figure 13. Regression between RUSLE-predicted erosion and measured values with the UAV-GIS methodology.

Table 6. Soil erosion as detected by UAV-GIS methodology on set-aside plots at Fagna farm. Characteristics of monitoring sites, rainfall, RUSLE factors and estimated soil erosion by RUSLE model.

Location	Treatment	Monitoring site	Observation start time	Observation end time	Period months	Slope %	Plot area ha	Soil bulk density (t m^3)	T ha^{-1} periodo^{-1}	Period rainfall (mm)	RUSLE factors* R period	K	C	P	RUSLE_GIS on 20 m DEM t ha^{-1} period^{-1}
Fagna	Factual (set aside with shredding)	Plot 5	25 Dec 13	26 Jan 14	1.1	17.4	1.78	1.22	0.0	69.4	1550.14	0.040	0.02	1.00	0.54
Fagna	Counterfactual (set aside without shredding)	Plot 6	25 Dec 13	26 Jan 14	1.1	16.7	1.97	1.22	0.0	69.4	1550.14	0.040	0.02	1.00	0.54

*LS calculated according to Nearing (1997) by cell by cell through GIS.

UAV-GIS survey results (Fagna farm)

With regard to Standard 1.2g both theses Factual (aside from production with management of vegetation cover by shredding once a year) and Counterfactual (aside from production without shredding) did not evidence any formation of rills detectable through aerial drone pictures, therefore soil erosion was equal to 0 t ha^{-1} (Figure 12).

The estimated soil erosion by RUSLE model was, in both theses, a value of 0.54 t ha^{-1} $period^{-1}$, that is a value close to zero (Table 6).

Validation of RUSLE model

From results of soil erosion acquired through the application of the methodology UAV-GIS and application of the RUSLE model in GIS (Tables 3 and 6) it was possible to validate the predictive RUSLE model.

Mean separation via the Duncan's test (Table 7) shows that there is no significant difference between the observed the predicted values with the RUSLE model. The Levene's test, reported in the same Table 7, shows that the variances are homogeneous. Figure 13 shows the linear regression between predicted values of erosion and the observed ones. Table 8 shows the regression summary. Despite the few observations at our disposal the performance of the RUSLE model resulted quite satisfactory.

Competitiveness gap for Standard 1.1a (temporary ditches)

In addition to the environmental effectiveness of the Standard 1.1a the economic competitiveness gap for farmers was evaluated. The competitiveness gap is composed by the additional costs induced by the Italian and Community cross compliance rules. The analysis made it possible to determine the energy consumptions generated by the application of the Standard, in order to assess CO_2 emissions resulting from the adoption of this commitment by the recipient of direct payments.

Two hypotheses were considered:

a) Application of the Standard by the beneficiary according to a restrictive approach. That is, in the hypothesis that farmer would try to reduce the costs, by adopting the maximum distance of 80 metres allowed by decree for the Standard in 1.1a under the: 'Existing provisions in the absence of the intervention of the autonomous regions and provinces.'

b) Application of the Standard according to what happens in reality. That means by considering the mean distances between ditches observed from a territorial survey of satellite images.

Typically the farmer realizes a number of temporary ditches significantly higher than that imposed, as a minimum, by the Standard 1.1a. In fact, the distance of 80 metres is the maximum limit specified by the Standard 1.1a, but nothing prohibits farmers to adopt a smaller distance between ditches.

Competitiveness gap for the Standard 1.1a assuming the adoption of the maximum distance of 80 metres allowed by the cross compliance decree

To evaluate competitiveness gap the cost of agricultural machining was calculated using data from field surveys carried out by the working units of the MO.NA.CO. project during the course of different farming operations.

For each type of operation, by using the project database, the average cost has been calculated (Table 9). In addition, the values obtained by subtracting and adding to the mean value the Standard deviation (indicated in Table 12 as upper and lower machining cost limits) were calculated. The monitoring of the competitiveness gap for these Standards was carried out on plots planted with wheat. For calculating the economic balance for this crop, a simplification was adopted: input costs and revenues from the sale of the grain were disregarded. That was possible because they did not affect the competitiveness gap, as they were identical in the two conditions (factual and counterfactual).

To determine the competitiveness gap for the average machining costs, the difference between costs in adoption of cross compliance rules and not in adoption was calculated.

The competitiveness gap amounted to 2.34±0.38 € ha^{-1} $year^{-1}$, which corresponds to 0.01872±0.003€ m^{-1} $year^{-1}$. Therefore, the adhesion to the commitment provided by this Standard requires an increase in costs which represents a modest economic loss to the farmer. The emission of CO_2 for the execution of temporary ditches resulted equal to 1.365±0.46 kg ha^{-1}.

We also measured (P. Bazzoffi, pers. comm.) the total length of ditches (m) and areas (m^2) for 25 random plots of the Italian territory belonging to farmers not involved in the MO.NA.CO. project. Therefore, absolutely free from constraints in choosing the way of application of the Standard 1.1a. For these areas the survey of the total length of ditches and areas has been done on satellite imagery in Google Earth Pro (year 2013). From the analysis, it appears that on average the com-

Table 7. Duncan's test for mean separation (observed erosion and RUSLE-predicted erosion) and Levene's test for homogeneity of variances.

Duncan's Test: Homogeneous groups, alpha = 0.5000 Error: SM between groups P=901.89, df = 16.

	Erosion mean (t ha^{-1} $period^{-1}$)	1
Observed erosion	27.34	****
RUSLE erosion	36.83	****

Levene's test of variance homogeneity F.D. for all F: 1, 16

	SM Effect	SM Error	F	P
Erosion	272.81	191.72	1.42	0.250

Table 8. Summary of regression between RUSLE-predicted erosion and measured values with the UAV-GIS methodology.

Regression R^2= 0.797 F(1,7)=2 7.467 P<0.0120; established St. Err.: 13.58.

	Beta	Std. Err.of Beta	B	Std. Err. of B	t(7)	P
Intercept			-1.843	7.178	-0.257	0.805
RUSLE erosion	0.893	0.170	0.793	0.152	5.240	0.001**

Table 9. Competitiveness gap for the cultivation of wheat determined by the average values of machining. Upper and lower limits obtained by adding and subtracting the Standard deviation to the mean value of the individual machining costs. Values are calculated on the basis of 125 m ha-1 of ditches.

Machining works	Lower limit of working cost (€ ha^{-1} y^{-1}) In adoption of cross compliance rules	Lower limit of working cost (€ ha^{-1} y^{-1}) Not in adoption of cross compliance rules	Mean value of working cost (€ ha^{-1} y^{-1}) In adoption of cross compliance rules	Mean value of working cost (€ ha^{-1} y^{-1}) Not in adoption of cross compliance rules	Upper limit of working cost (€ ha^{-1} y^{-1}) In adoption of cross compliance rules	Upper limit of working cost (€ ha^{-1} y^{-1}) Not in adoption of cross compliance rules
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
Rolling	16.02	16.02	19.32	19.32	22.62	22.62
Temporary ditches	1.95	-	2.34	-	2.72	-
Weeding	4.87	4.87	6.78	6.78	8.68	8.68
Harvesting	93.98	93.98	126.64	126.64	159.29	159.29
Total cost of agricultural machining	312.81	310.86	461.18	458.84	609.54	606.82
Competitiveness gap (€ ha-1 y^{-1})	1.95		2.34		2.72	
Competitiveness gap (€ m-1 y^{-1})	0.0156		0.01872		0.02176	

Table 10. Cost of mowing by using different machinery.

Equipment used for mowing	Lower limit of working cost (€ ha^{-1} y^{-1})	Mean value of working cost (€ ha^{-1} y^{-1})	Upper limit of working cost (€ ha^{-1} y^{-1})
Swing blade mower	27.27	33.40	39.52
Rotary shredder	45.83	67.05	88.27
Mean	36.55	50.22	63.89

petitiveness gap stood at 4.07 € ha^{-1} ±1.42 (Conf. ±95%). CO_2 emissions resulted kg ha^{-1} 2.575±0.88 (Conf. ±95%). The density of ditches amounted to m ha^{-1} 217.16±73.83 (Conf. ±95%), that is 1.736 times more dense than in application of the minimal hypothesis in the decree (that is, with an average distance between the grooves of 80 m).

These values are realistic and usable for the application of the two indicators at regional scale.

Competitiveness gap for the Standard 1.2g (natural or sowed vegetation cover along the year on set-aside)

Even for the Standard 1.2g the competitiveness gap was calculated related to the maintenance of vegetation cover, natural or sown, throughout the year.

For each type of agricultural machining, by using the MO.NA.CO. survey database, the average cost has been calculated (Table 10). In addition, the values obtained by subtracting and adding to the mean value the Standard deviation (indicated in Table 10 as upper and lower machining cost limits) were calculated. The competitiveness gap amounted on average to 50.22 € ha^{-1} year^{-1} (Table 10), with costs varying between 27.27 and 39.52 € ha^{-1} year^{-1} in the case of use of the swing blade mower, while it is equal to 67.05 € ha^{-1} year^{-1}, with prices varying between 45.83 and 88.27 € ha^{-1} year^{-1}, where it was used a rotary cutter.

The average value of the competitiveness gap for the Standard 1.2g, therefore, amounted to 50.22±13.7 € ha^{-1} year^{-1}. Mowing with the equipment described above causes the emission of 31.52 kg ha^{-1} of CO_2.

In the event of having to sow the vegetation cover, the competitiveness gap affects only the year of sown with an average cost of 196.62 € ha^{-1} year^{-1}. The emission of CO_2 for this Standard (mowing plus sowing) is equal to 48.77 kg ha^{-1}.

Discussion and conclusions

Results of soil erosion achieved through the UAV-GIS methodology on two monitoring farms and in two years of observations have shown that temporary ditches were both effective in decreasing erosion, on average, by 47.7% (passing from 36.59 t ha^{-1} to 21.05 t ha^{-1} during the monitoring period. This result can be considered very satisfactory by considering that the monitoring period was characterized by abundant and quite intense rainfall that occurred in a few months, in the autumn-winter period. Therefore temporary ditches were tested for their capacity to reduce erosion under severe conditions, having had to cope with considerable runoff volumes.

Data from runoff plots in the Santa Elisabetta farm showed a statistically significant reduction in erosion, equal to 84.4%, determined by the Factual thesis in the implementation of the Standard 1.1a, compared to the Counterfactual thesis (without ditches).

As regards to runoff, the presence of temporary ditches has resulted in a general decrease in the volumes of scouring water equal to about

46.3%. These results confirm what has been found in a previous trial conducted in Guiglia (Modena) on small basins planted with corn (Chisci and Boschi, 1988), where ditches significantly decreased soil erosion by 94%, from 14.4 t ha^{-1} $year^{-1}$ to 0.8 t ha^{-1} $year^{-1}$. Overall, the reduction in the erosion in application of the Standard 1.1a observed in the present monitoring and in the previous research at Guiglia results in the range between 48% and 94%.

Results also showed a strong, highly significant, reduction in the erosion due to the grass strips, which decreased from 8.16 t ha^{-1} $year^{-1}$ in the case of bare soil to 0.84 t ha^{-1} $year^{-1}$ on theses with two 3-metre-wide grass strips. As for runoff there is a general decrease in the volume of scouring water determined by grass strips, passing on average from 166.25 m^3 ha^{-1} $year^{-1}$ for bare soil to 108.51 m^3 ha^{-1} $year^{-1}$ for plots with one 5-metre-wide grass strip.

With regard to Standard 1.2g, the statistical analysis of shows a strong and highly significant decrease in soil erosion due to natural vegetation cover of soil (both managed once a year by shredding or not shredded) compared to bare soil. In the Factual thesis (set aside managed by shredding) soil erosion decrease was 89.7% (0.55 t ha^{-1} $year^{-1}$) compared to bare soil. In plots with not managed set-aside covered by Mediterranean stain soil erosion was virtually annulled (0.0003 t ha^{-1} $year^{-1}$) compared to bare soil.

For the same Standard 1.2g, the factual thesis (once a year shredded set-aside) shows to be significantly effective in reducing runoff volumes of 96.1% compared to bare soil, passing from 89.65 m^3 ha^{-1} $year^{-1}$ to 3.51 m^3 ha^{-1} $year^{-1}$. However, in comparison with the Counterfactual thesis (set-aside covered by Mediterranean stain) that showed an average runoff of 1.40 m^3 ha^{-1} $year^{-1}$ the Factual thesis (once a year shredded set-aside) determined a slightly higher runoff (3.52 m^3 ha^{-1} $year^{-1}$). From the results of soil erosion acquired through the application of the methodology UAV-GIS and application of the RUSLE model in GIS (Tables 7 and 10) it was possible to validate the predictive RUSLE model. Despite the few observations at disposition the performance of the RUSLE model resulted quite satisfactory.

With regard to the economic competitiveness gap the Standard 1.1a shows an average cost of 2.34±0.38 € ha^{-1} $year^{-1}$ for ditched spaced 80 m and 4.07±1.42 € ha^{-1} $year^{-1}$ for ditches as realised by farmers in the reality as detected from a territorial analysis. CO_2 emissions were 1365 kg ha^{-1} $year^{-1}$ for 80-m spaced ditches and 2.58 kg ha^{-1} as determined in the territorial analysis. As for the Standard 1.2g the average competitiveness gap amounted to 50.22±13.7 € ha^{-1} $year^{-1}$, whereas CO_2 emission resulted in the range 31.52-48.77 kg ha^{-1} $year^{-1}$.

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