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02 May 2026

1 **How effective is greening policy in reducing GHG emissions from agriculture? Evidence from**  
2 **Italy**

3

4 **Abstract**

5 *Agriculture contributes significantly to greenhouse gas (GHG) emissions, accounting for more than*  
6 *10% of total CO<sub>2</sub> emissions in the EU-28 area. The Common Agricultural Policy (CAP) plays an*  
7 *important role in promoting environmentally and climate friendly practices and needs to respond to*  
8 *the new environmental challenges by better integrating its objectives with other EU policies.*

9 *In this respect, the recent CAP reform 2014-2020 made a further step, making a large part of direct*  
10 *payments conditional on new agricultural practices beneficial for the climate and the environment,*  
11 *i.e. “greening”.*

12 *In this study we estimate the potential environmental benefits from greening in terms of GHG*  
13 *emissions in four regions of Northern Italy, one of the major European agricultural areas in terms*  
14 *of emissions. The emissions were quantified and broken down into the three main GHGs (carbon*  
15 *dioxide, methane and nitrous oxide) per production process. This information was subsequently*  
16 *used in a Positive Mathematical Programming (PMP) farm-based model on more than 3,000 farms,*  
17 *to estimate the effects of greening on regional land use and its contribution in reducing the total*  
18 *emissions.*

19 *The new agri-environmental constraints produce a modest abatement of total emissions of*  
20 *greenhouse gases (-1.3%) in the analysed area. The model estimates a reduction in CO<sub>2</sub> emissions*  
21 *of about 2%, and a lower decrease in emissions of nitrous oxide (-1.4%) and methane (-0.5%). The*  
22 *process of “lightening” that affected the greening during the CAP negotiation has inevitably*  
23 *resulted in missing an opportunity to introduce a positive change of behavior into agriculture, in*  
24 *line with the expectations and needs of society for EU agriculture as a provider of public goods.*

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28 **Keywords:** CAP reform; Greening; GHG emissions; Environment; Positive mathematical  
29 programming (PMP); Farm behaviour

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32 **JEL Classification codes:** C61, Q15, Q18

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## 36 **1. Introduction**

37 In 2013, after three years of discussion and intensive negotiation, the Council of EU Agriculture  
38 Ministers formally adopted the Common Agriculture Policy (CAP) reform, setting out the rules for  
39 its implementation in the period 2014-2020. One of the main challenges of the CAP reform was to  
40 improve the environmental sustainability of the agricultural sector, in terms of resource efficiency,  
41 soil and water quality and threats to habitats and biodiversity (European Commission, 2015). The  
42 CAP plays an important role in maintaining sustainable agriculture across the EU and in promoting  
43 environmentally and climate friendly practices, and needs to respond to the new environmental  
44 challenges by better integrating its objectives with other EU policies. The EU biodiversity strategy  
45 to 2020 requires further integration of biodiversity in key sectors such as agriculture, and the  
46 Europe 2020 Strategy establishes the reduction of greenhouse gases as one of the EU's five headline  
47 targets (European Commission, 2010). The 2050 target for agriculture provides a reduction in  
48 greenhouse gases of between 42% and 49%, compared to the level of 1990, in other words a  
49 reduction of around 30% compared to emission levels of 2005 (European Commission, 2011;  
50 Westhoek et al., 2012).

51 Agriculture has an important role in greenhouse gas (GHG) emissions, contributing in 2013 11.7%  
52 of the total CO<sub>2</sub> emissions in EU-28, corresponding to 520 million tonnes of CO<sub>2</sub>e<sup>1</sup> (EEA, 2015).  
53 For Methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), agriculture is the main emitting sector in EU-28 (52%  
54 for CH<sub>4</sub> and 79.3% for N<sub>2</sub>O).

55 In the period 1990–2013, greenhouse gas emissions from the agricultural sector in the EU-28  
56 dropped by more than 20%. The main reasons were the shrinking stocks of farm animals – due to,  
57 for example, milk quotas and reductions in livestock numbers in central Europe – and a reduction in  
58 the use of nitrogen fertiliser (Galko and Jayet, 2011). Emissions have stabilised in recent years  
59 (Westhoek et al., 2012).

60 The six largest contributor countries to agricultural CO<sub>2</sub> emissions in EU are France (17.7%),  
61 Germany (13%), United Kingdom (10.4%), Spain (9.8%), Poland (8%) and Italy (7.5%). Italian  
62 GHG emissions from the agricultural sector were about 39 CO<sub>2</sub> million tons (Mt) in 2013. With  
63 regard to the incidence of the three main greenhouse gases (CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>) on total emissions,  
64 methane and nitrous oxide are responsible for about 80% of emissions, while carbon dioxide  
65 contributes to the remaining 20%. In particular, methane concentrates the largest share of emissions,  
66 49%, and nitrous oxide represents a share of 31%. At regional level, Lombardy is responsible for

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<sup>1</sup> Besides direct emissions from agriculture, there are also indirect emissions, such as those from fossil-fuels; we take these into account in agricultural operations (IPPC sector 1.A.4.c).

67 about 22% of total agricultural emissions in Italy, whereas Piedmont, Emilia-Romagna and Veneto  
68 are each singly responsible for about 11% (ISPRA, 2015). Overall, these four regions of Northern  
69 Italy, analysed in detail in this paper, account for almost 55% of the total national GHG emissions  
70 from agriculture.

71 In the light of the future requirements made of EU agriculture in terms of GHG reduction, it is  
72 worthwhile to evaluate the effectiveness of the new set of CAP greening instruments in terms of  
73 climate change. Few studies have evaluated the environmental implications of the new CAP  
74 greening on climate change. One preliminary assessment of the contribution in GHG emissions is  
75 provided by van Zeijts et al. (2011) and Westhoek et al. (2012), applying the CAPRI model  
76 (Helming and Terluin, 2011) at NUTS2<sup>2</sup> region for the EU-27. These studies find that greening  
77 measures would affect farmers' land allocation decisions and lead to a reduction of GHG of about  
78 2% compared to pre-2014, mainly due to a decrease of mineral fertiliser use and the maintenance  
79 and increase of organic matter in soils. These valuable results were based on the European  
80 Commission document prepared for institutional discussions on CAP reform (European  
81 Commission, 2010) and therefore very different from the current reform. More recently, Kirchner et  
82 al. (2016) and Pelikan et al. (2015) have evaluated the environmental impact of the current greening  
83 mechanisms for Austria and EU-27 respectively. In Austria, the PASMA model estimates that  
84 greening would have a negative impact, increasing GHG emissions between 3% and 6% depending  
85 on the scenario (Kirchner et al., 2015). For EU-27, the CAPRI model identifies a decrease of 1.8%  
86 of the GHG emissions (Pelikan et al., 2015). All these studies aimed to evaluate farm specific  
87 greening constraints, such as crop diversification and the ecological focus area, through regional  
88 partial equilibrium models, which, however, limit the application of farm-specific criteria included  
89 in the recent CAP reform (e.g. arable and forage land thresholds, criteria of exclusions).

90 So the aim of this study is to estimate the potential climate mitigation benefits of greening in a  
91 macro-region of Northern Italy, one of the major European agricultural areas in terms of emissions,  
92 using an approach able to assess all the farm-specific constraints established by the greening  
93 measures. We use the Farm Accountancy Data Network (FADN) as the main source of technical  
94 and economic information about the farms in the considered area. The estimation of the effects of  
95 greening on land use and its contribution to lowering the total GHG emissions is made using a  
96 Positive Mathematical Programming (PMP) farm-based model.

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<sup>2</sup> The Nomenclature of territorial units for statistics (NUTS) is a hierarchical system for dividing up the economic territory of the EU for the purpose of socio-economic analyses of the regions. Eurostat identifies three NUTS levels; the second level, NUTS2, corresponds to the basic regions for the applications of regional policies that are roughly equivalent to the administrative regions of each EU Member State.

## 98 **2. Greening of the CAP first pillar**

99 The European strategy to fight climate change gives a key role to the agricultural sector in reducing  
100 GHG emissions through less intensive agronomic practices and extending activities to renewable  
101 energies (European Commission, 2011a).

102 Despite its cultural and socio-economic value, agriculture is often thought to contribute to the  
103 deterioration of the environment. European consumers have become increasingly interested in  
104 sustainable food production (Fritz and Schiefer, 2008; Vermeir and Verbeke, 2006). Today, food  
105 quality includes the way in which the food has been produced (Singh et al., 2014) as well as  
106 organoleptic properties and health benefits.

107 In this respect, the CAP reform should not be considered as simply a “continuation” of the old  
108 policy in that it provides new policy tools and changes in policy objectives, principles and  
109 mechanisms. The early CAPs were based on a ‘productivist paradigm’ targeted at the modernisation  
110 of agriculture, fair incomes for farmers, price stability and availability of food at affordable prices  
111 (Erjavec et al., 2015; Garzon, 2006). The reformed CAP 1992-2013 was driven by objectives such  
112 as competitiveness, multifunctional and sustainable agriculture, realising a European model of  
113 agriculture and rural development. In the past, the issue of the CAP contribution to reducing  
114 environmental impact of agriculture was relegated to rural development programs. In 2005,  
115 environmental requirements were included into CAP direct payments (the First Pillar of the CAP<sup>3</sup>)  
116 through cross-compliance: all farmers receiving direct payments were subject to compulsory rules  
117 in the areas of environment, health and animal welfare. However, these rules were relatively mild  
118 and many of them were already either good practice recommendations or separate legal  
119 requirements regulating farm activities. The recent CAP reform 2014-2020 made a further step,  
120 making a large part of direct payments conditional on new environmental measures. For the first  
121 time, a share of direct payments, 30%, was explicitly linked to payment for agricultural practices  
122 beneficial for the climate and the environment for the production of public goods. This was called  
123 “greening”.

124 The main challenge during the reform process was how to design greening so as to reap  
125 environmental and climate change benefits and ensure the sustainable use of natural resources,  
126 without undermining either territorial balance throughout the EU or the long-term competitiveness  
127 of the agricultural sector (European Commission, 2010). During the negotiation process, following

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<sup>3</sup> The Second Pillar of the CAP is EU action to support rural development in the 28 EU Member States. The new Regulation (EU) no. 1303/2013 establishes the reference framework for the implementation of the rural development measures according to a principle of subsidiarity. This means that each EU Member can tailor rural development measures according to internal agricultural specificities and objectives (Matthews, 2013).

128 the initial CAP proposal of the European Commission in 2011, greening was one of the major areas  
129 of discussion between the Commission, the Parliament and the Council (Matthews, 2013). The  
130 reform faced unfavourable circumstances that resulted in a watering down of the environmental  
131 aspects. Moreover, it was subject to intense lobbying by interest groups and to severe ex-post  
132 critiques (Swinnen, 2015). During the negotiation process, key actors in EU agricultural politics  
133 used 'greening' vocabulary to justify specific policies, including the popular environmental element  
134 in all discourses, but it was not proportionately integrated into measures (Erjavec and Erjavec,  
135 2015). This was true for greening of the first pillar of the CAP, as well as the agri-environmental  
136 measures of the rural development policies that reduced the budget by 7.6% compared to the  
137 Commission proposal (European Commission, 2013).

138 In the final CAP agreement, the three greening requirements, significantly weaker than those in the  
139 initial Commission proposal, provided for: i) crop diversification; ii) maintenance of permanent  
140 grassland; iii) allocation of arable land to Ecological Focus Area (EFA) (Appendix).

141 Crop diversification and EFA requirements concern arable land. For crop diversification, farmers  
142 must cultivate at least 2 crops when their arable land exceeds 10 hectares and at least 3 crops when  
143 their arable land exceeds 30 hectares. The main crop may cover at most 75% of arable land, and the  
144 two main crops at most 95% of the arable area.

145 The ecological focus area must cover at least 5% of the arable area of the holding for farms with  
146 arable land above 15 hectares. The number of possible EFA increased during the negotiation phase,  
147 and the possibility to grow nitrogen-fixing crops in EFA was also introduced. This option, chosen  
148 by 27 Member States (including Italy), has been severely criticized by environmental organizations  
149 (Solazzo et al., 2015a). The concerns about EFA have been reported by environmental groups to the  
150 current Commissioner Phil Hogan, pointing out that EFAs were meant to protect and enhance  
151 landscape features on farms, but this worthy objective has unfortunately been watered down  
152 throughout the reform process (European Environmental Bureau, 2015).

153 Maintenance of permanent grassland establishes that Member States must designate  
154 environmentally sensitive permanent grasslands that cannot be ploughed or converted. In addition,  
155 Member States must maintain the ratio of permanent grassland to total agricultural area so that it  
156 does not fall by more than 5%.

157 Exemptions from the greening requirements are provided for units of the holding used for organic  
158 production and for farms specialized in the production of grasses or other herbaceous forage. Non-  
159 compliance (total or partial) with these measures will lead to green payment reductions and, from  
160 2017, administrative sanctions for the farms.

161 Despite the clear environmental implications of these measures, reiterated several times in the  
162 preparatory documents of the reform (European Commission, 2010), the long negotiation process  
163 considerably reduced the innovative capacity of the first proposal (European Commission, 2011)  
164 mitigating the initial force of the greening actions proposed by the Commission (Solazzo et al.,  
165 2015b). Greening can be considered a ‘victim’ of the compromise agreement, with a number of  
166 farmers exempted from the requirements, environmental requirements relaxed and ‘equivalent  
167 measures’ defined by member states allowed. Environmental NGOs such as BirdLife International  
168 consider that greening has been weakened, arguing that the reform was actually a step back and that  
169 ‘greening’ was in fact ‘greenwash’ (Erjavec et al. 2015). This raises the question of assessing the  
170 contribution of these measures to the effective improvement of environmental impact of agriculture.  
171

### 172 **3. Materials and Methods**

#### 173 ***3.1 FADN data and study area***

174 The information on the farm production and economic characteristics were extrapolated from the  
175 Farm Accountancy Data Network (FADN), held and managed at EU level by the Directorate  
176 General for Agriculture and Rural Development, of European Commission. FADN was established  
177 in 1965 through the Council Regulation 79/65 with the aim of providing EU with an instrument for  
178 evaluating the income of agricultural holdings and the effects of the CAP. Nowadays, FADN is the  
179 sole harmonized source of microeconomic information on EU Member States’ agriculture and is  
180 widely used for assessing the contribution of CAP mechanisms in determining the farmer’s  
181 allocative decisions and related economic, social and environmental impacts. FADN collects the  
182 data for a sample of more than 80,000 EU farms annually<sup>4</sup>.

183 A sample of more than 3,000 farms included in the Italian FADN and operating in Emilia-  
184 Romagna, Piedmont, Lombardy and Veneto regions was considered in the present analysis. As  
185 mentioned above these regions are highly representative of the GHG emissions in Italy,  
186 concentrating more than half of the Italian GHG emissions from agriculture. For each farm, the data  
187 on the production plan (i.e. hectares and yields per crop, animal heads and milk yields), data from  
188 farm accounting values, such as output and input prices, made it possible to define the framework  
189 within which farmers take decisions. Data refer to the year 2012. A specific weighting system,  
190 included in FADN for extending the sample to the whole population of EU farms, was applied to

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<sup>4</sup> FADN is the main source of microdata information about European agriculture allowing the agricultural policy monitoring within Member States. The survey covers only commercial farms but provides a disaggregated picture of European agriculture by region, farm type and farm size (Arfini and Donati, 2015). More specifically, the sampling methodology applied aims to provide representative data along three dimensions: region, economic size and type of farming (European Commission, 2010a).

191 make the outcomes more consistent with farm typologies and agricultural production systems of the  
192 area.

193 The four regions considered in the present analysis are at the core of the Po Valley, the most fertile  
194 and exploited agricultural area in Italy. In 2014, this area accounted for 36% of the crop production  
195 value in Italy (10,210 mln € out of 28,467 mln €) and for 64% of animal production value (10,491  
196 mln € out of 16,494 mln €) (Eurostat, 2016). Milk production, cereals and industrial crops, in  
197 particular processed tomato and potato, are the main agricultural activities in the area. In an  
198 agricultural area of 3.7 million hectares of utilized agricultural area (UAA) more than 1.1 million of  
199 dairy cows are bred (54% of the Italian dairy cow livestock). Furthermore, the four regions  
200 represent the main basin of processed tomato in EU, with more than 2.4 million tons produced in  
201 2014, corresponding to about 50% of the entire production in Italy and 24.5% at EU level  
202 (European Commission, 2015).

203

### 204 **3.2 GHG emissions from agriculture**

205 The main sources of GHG emissions from agriculture were estimated by implementing the ICAAI  
206 (Impronta Carbonica delle Aziende Agricole Italiane - Carbon Footprint of the Italian Farms), an  
207 approach developed by the Italian Council for Agricultural Research and Economics (formerly  
208 National Institute of Agricultural Economics) (Coderoni et al., 2013). This method is based on  
209 guidelines of the Intergovernmental Panel on Climate Change (IPPC, 2006) and enables the  
210 computation of the global warming compounds per agricultural activity.

211 The IPCC guidelines are a standard followed by different countries in determining the inventory of  
212 GHG emissions of different economic sectors. The procedure suggested by IPCC assumes that the  
213 emission factors are linearly correlated with the level of economic activity, so that an increase in the  
214 level of output determines a proportional increase in the level of GHG emissions. Each agricultural  
215 activity (crops and animal production) is a global warming contributor in terms of CO<sub>2</sub>, CH<sub>4</sub> and  
216 N<sub>2</sub>O emissions.

217 For CO<sub>2</sub> emissions, we considered those caused by the cropping operations and soil organic carbon  
218 (SOC). The estimation of fuel absorbed by each operation per crop (e.g. tillage, sowing, harvest)  
219 was retrieved from the Handbook of Italian Agriculture (Ribaudo, 2011), which presents the  
220 cropping systems according to geographical area. The SOC related to the specific land use was  
221 estimated as follows:

$$222 \quad SOC_j = SREF_j \cdot FLU_j \cdot FMG_j \cdot FI_j \cdot A_j \quad (1)$$

223 where the SOC (tC)<sup>5</sup> for each crop  $j$  ( $j=1,2,\dots,J$ ) is equal to the product of the reference carbon stock  
224 (tC ha<sup>-1</sup>),  $SREF_j$ , the stock change factor for land-use systems (dimensionless),  $FLU_j$ , the stock  
225 change factor for management regime (dimensionless),  $FMG_j$ , the stock change factor for input of  
226 organic matter (dimensionless),  $FI_j$ , and the land area occupied by a certain crop (ha),  $A_j$ . Each  
227 component of the Equation 1 is estimated from FADN data and IPCC guidelines (Coderoni et al.,  
228 2013; IPCC, 2006). The value of SOC is then converted in CO<sub>2</sub> using the stoichiometric factor of  
229 3.667 (European Commission, 2004).

230 N<sub>2</sub>O is generated by animal manure (storage and treatment), managed soil and the burning of  
231 stubble and crop residues, which however is banned in Italy. For animal manure, considering a  
232 production of 116 kg N head<sup>-1</sup>y<sup>-1</sup> for dairy cows, we adopted an IPCC emission factor (kg N<sub>2</sub>O -N/  
233 kg N) of 0.02 for solid storage and 0.001 for slurry; 5% of kg N was considered to be applied to the  
234 soil (ISPRA, 2011). Among direct emissions attributable to the soil management, we considered the  
235 emissions produced by synthetic fertilizers. The total quantity of N was converted into N<sub>2</sub>O-N using  
236 the default IPCC direct emission factor of 0.0125. The levels of N<sub>2</sub>O-N were converted into N<sub>2</sub>O  
237 using a factor of 1.571 according to IPCC guidelines. Indirect emissions due to the atmospheric  
238 deposition, leaching and runoff from managed soil were estimated accordingly.

239 Methane emissions are due essentially to the livestock enteric fermentation, manure management  
240 and rice cultivation. For enteric fermentation, we consider the standard IPCC coefficient, which is  
241 113 kg CH<sub>4</sub> head<sup>-1</sup> y<sup>-1</sup> for dairy cows. For manure management, the ICAAI approach uses the CH<sub>4</sub>  
242 burden provided by ISPRA (2011), for which the average value is 15.04 kgCH<sub>4</sub> head<sup>-1</sup> y<sup>-1</sup> for dairy  
243 cows. The CH<sub>4</sub> emission for rice is estimated by ICAAI using the ISPRA data that differentiates  
244 between dry-seeded and wet-seeded cropping, and corresponding to 249.6 kg CH<sub>4</sub> ha<sup>-1</sup> y<sup>-1</sup> and 336.7  
245 kg CH<sub>4</sub> ha<sup>-1</sup> y<sup>-1</sup>. Because the information about the rice sowing system is not present in FADN, we  
246 considered the average value of 293.15 kg CH<sub>4</sub> ha<sup>-1</sup> y<sup>-1</sup>.

247 Emissions of nitrous oxide and methane were converted into CO<sub>2</sub> equivalent (CO<sub>2</sub>e) using the  
248 coefficients of global warming potential (GWP) provided by IPCC<sup>6</sup> (Table 2).

249

250

251

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<sup>5</sup> tC: tonnes of carbon

<sup>6</sup> The GWP factors used in this study are consistent with the 100-year Global Warming Potentials provided by the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (IPCC, 2007:33).

252 Table 2: Estimated emissions for each hectare/head (GHG emissions expressed in tonnes of CO<sub>2</sub>  
 253 equivalents)

<b>Crop/activity</b>	<b>CO<sub>2</sub></b>	<b>N<sub>2</sub>O</b>	<b>CH<sub>4</sub></b>	<b>totCO<sub>2</sub>e</b>
durum wheat	0.46	1.2		1.66
soft wheat	0.44	1.11		1.55
barley	0.43	0.56		0.99
maize	1.57	1.95		3.52
rice	0.7	0.47	7.33	8.5
other cereals	0.49	0.83		1.33
processing tomato	1.19	0.93		2.11
potato	0.79	1.48		2.27
onion	0.86	1.3		2.15
other vegetables	0.82	1.39		2.21
grain legumes	0.58	0.46		1.04
herbaceous legum.	0.17	0.67		0.84
soya	0.53	0.62		1.15
oilseed	0.36	0.46		0.82
alfalfa	0.43	1.14		1.57
silage	0.84	0.93		1.77
other fodder crops	0.17	0.67		0.84
permanent pasture	0.29			0.29
permanent grassland	0.85	1.39		2.24
permanent crops	0.41	1.48		1.89
dairy cows	0.92	1.38	3.2	5.5

254 Source: own processing.

255

### 256 ***3.3 Greening assessment model***

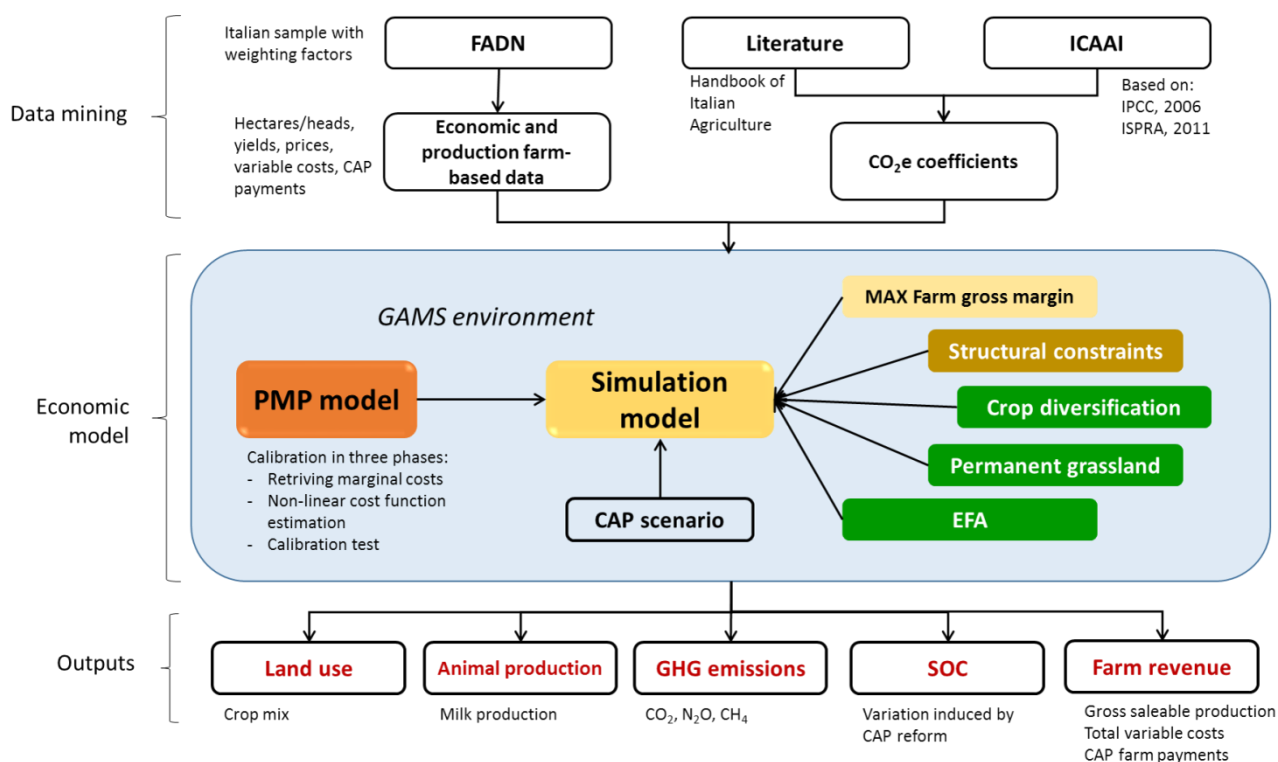
257 In order to estimate the impact of the three greening measures on the land use and the consequent  
 258 effect on GHG emissions, a farm-based PMP model was used (Solazzo et al., 2015b, 2014;  
 259 Heckeley et al., 2012; Paris and Howitt, 1998). The most useful methodology for the last ten years  
 260 for evaluating the effects of the CAP instruments on the dynamics of the agricultural activities and  
 261 farm economic variables, both for ex-post and ex-ante analysis, has been PMP. The European  
 262 Commission itself has developed a model for CAP assessment based on PMP (Louhichi et al.,  
 263 2015). The main reason this methodology is successful in agricultural policy analysis is its capacity  
 264 to use the information included in the agricultural statistical data at the highest level of detail. The  
 265 methodology can provide clear, understandable and, thus, useful results to policy makers  
 266 responding to a wide spectrum of policy analysis needs.

267 The PMP model used in this analysis follows the total variable cost estimation methodology of  
 268 Paris and Howitt (1998), where the calibration process (i.e. the information recovery about the  
 269 farmer's decision process) comprises three steps. Unlike the existing literature about the impact of

270 the greening on GHG emissions, our model is implemented at farm level using the policy analysis  
 271 approach proposed by Solazzo et al. (2015b, 2014)<sup>7</sup> (Figure 2).

272

273 Figure 2: Greening assessment design



274

275 Source: authors' own elaborations.

276 Once this information is estimated, we maximize farmers' gross margin (i.e. the difference between  
 277 total revenue and total variable costs) subject to a series of constraints represented by structural  
 278 constraints, such as the available farmland, and constraints of greening commitments.

279 The model implements the complex architecture of the three greening requirements, as described in  
 280 Appendix, with some simplifications due to the availability of information. With regard to the  
 281 maintenance of the permanent grassland area, farms in the model cannot reduce this surface by  
 282 more than 5% compared to the reference situation. The EFA constraint required the identification of  
 283 the nitrogen-fixing crops (soya, alfalfa and grain legumes and leguminous herbaceous) into FADN  
 284 database. Moreover, a weighting factor of 0.7 was applied to nitrogen-fixing crops as established by  
 285 the Commission Delegated Regulation (EU) 1001/2014, amending Annex X to Regulation (EU) No  
 286 1307/2013. In order to achieve the 5% threshold calculated on arable crop area, the model allows  
 287 farms to allocate land to nitrogen-fixing crops or, alternatively, to leave this area fallow.

<sup>7</sup> The PMP model was developed and implemented in General Algebraic Modeling System (GAMS) package, using the NLP solver Conopt3 (GAMS, 2016).

288 A specific constraint on GHG was developed for the calculation of the total impact of CO<sub>2</sub>  
289 emissions, using the emission estimates described in Section 3.2.

290 The greening effects are compared with the situation with the CAP in force prior the  
291 implementation of the new reform 2014-2020 were in force. We can define the reference scenario  
292 as the pre-2014 scenario. When relevant, the results for Commission greening proposal are  
293 provided.

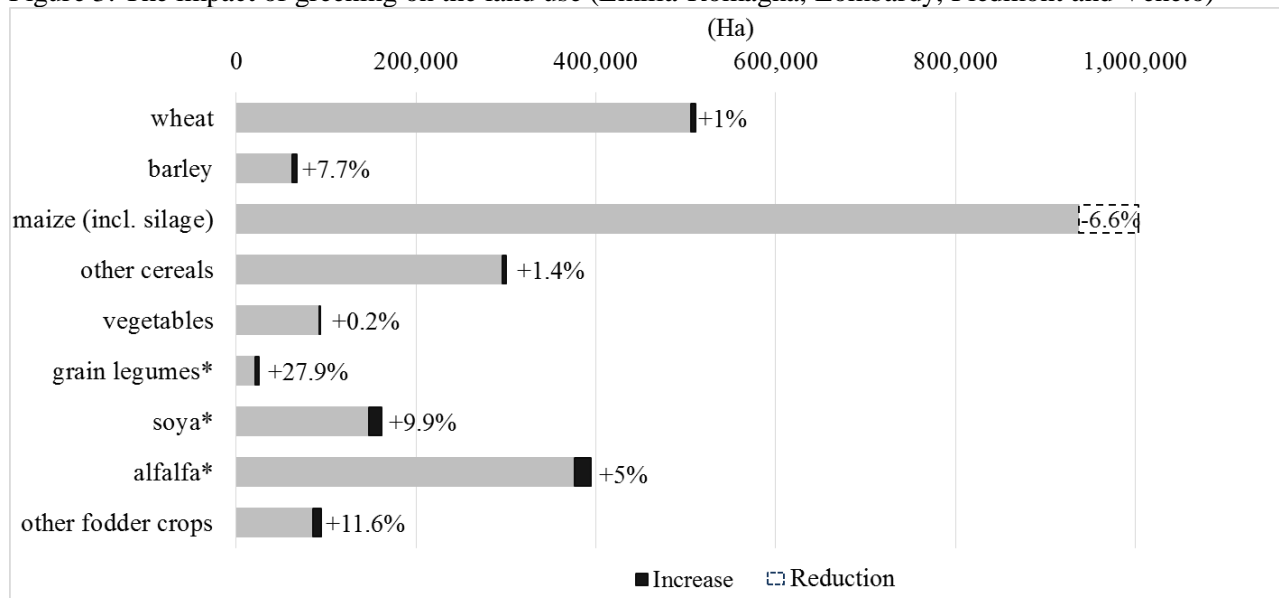
294

## 295 **4. Results**

### 296 *4.1 Effect on land use*

297 The changes in land use in the four regions considered are generally low, except for some cereal  
298 crops in certain highly specialized areas. Overall, the most significant impact is from the maize  
299 acreage. The contraction exceeds 6% for maize, with more than 66,000 hectares reallocated in order  
300 to meet the greening requirements (Figure 3). We observe an increase of area under nitrogen-fixing  
301 crops (NFC) crops driven by the qualification of these crops as EFA (applying the weighting factor  
302 of 0.7). Big farms highly specialized in cereal crops, in order to meet the diversification constraint,  
303 often reallocate to NFC part of the area exceeding the threshold of 75% (95% for the first two  
304 crops). In this way, they can comply with the EFA requirement while keeping the entire reallocated  
305 surface productive. Already diversified farms, subject to the EFA constraint, can choose to set aside  
306 5% of their arable area or move just over 7% to NFC, based on 0.7 weighting factor. Farms often  
307 opt to keep their area productive by introducing (or increasing) crops classified as EFA: legumes,  
308 alfalfa and soya. Among these crops, farm decisions are usually, and predictably, for the most  
309 widespread NFC crop in the reference area: alfalfa in Emilia-Romagna and Lombardy, soya in  
310 Veneto, and both crops in Piedmont.

311 Figure 3: The impact of greening on the land use (Emilia-Romagna, Lombardy, Piedmont and Veneto)



312  
313 \* Nitrogen-fixing crops

314 Source: authors' own elaborations.

315

316 The impact of greening is strongly differentiated at regional level according to the territorial  
317 specialization. The region most affected by new environmental constraints is Lombardy, due to the  
318 significant concentration of big farms highly specialized in maize production. Maize is the crop  
319 most affected by greening in Lombardy, with a reduction of the regional surface of over 10%, equal  
320 to more than 28,000 hectares. It should be noted that, although the maize surface is the only one to  
321 shrink, the impact of greening affects other cereal farms. These farms in many cases reduce their  
322 cereal surface in order to meet the diversification constraint, but this effect is hidden at regional  
323 level by large scale reallocation of maize acreage to other cereal crops.

324 In the other regions too, the impact of greening, although lower than Lombardy, is mainly related to  
325 the maize sector, with some differences due to the different regional production system. In  
326 Piedmont and Emilia-Romagna there is a drop in the area under wheat, due to the spread of farms  
327 specialized in this production and affected by the diversification constraint. In Emilia-Romagna,  
328 unlike other areas analyzed, alfalfa area is also reduced. This outcome is related to the “new”  
329 definition of leguminosae, according to the Commission guidance document, of July 2015. In this  
330 document the Commission clarified that species belonging to the botanical family of leguminosae  
331 (like clover and alfalfa) cultivated as monoculture should be classified as a crop and not under the  
332 category “grasses or other herbaceous forage”<sup>8</sup>. This implies that farms with more than 10 hectares  
333 and specialised in alfalfa production, frequent in Emilia-Romagna, are not excluded from greening

<sup>8</sup> Only when these species are sown in mixture with grasses or herbaceous forage, should be classified as “grasses or other herbaceous forage”.

334 constraints, having to reallocate up to 25% of the arable area to other crops<sup>9</sup>. Therefore, in this  
 335 region the reduction due to the diversification requirement more than offsets the increase (or  
 336 activation) of alfalfa in farms choosing it as a nitrogen-fixing crop to comply with the EFA  
 337 requirement.

338 The average cost of greening, calculated as lost income, for farms in the analysed macro-area, is of  
 339 6,5 €/ha. The reduction is slightly higher in Lombardy, due to the higher share of big size farms  
 340 specialized in maize. Limiting the analysis to farms affected by the greening requirements, the gross  
 341 margin is subject to a bigger reduction, reaching 20 €/ha, corresponding to -2%. Overall, the  
 342 greening payment compensates for income reduction caused by constraints.

343

344 Table 3: Impact of greening on main economic variables

Region	Gross Salable Production	Variable Costs	Gross Margin	Variation of the Gross Margin compared to pre-2014	
	(Euro/ha)			(Euro/ha)	%
Emilia-Romagna	3.632	2.088	1.543	-6,5	-0.4%
Lombardy	4.316	3.169	1.148	-8,8	-0.8%
Piedmont	2.151	1.261	890	-4,8	-0.5%
Veneto	4.304	2.327	1.977	-6,2	-0.3%
Macro-Area	3.536	2.162	1.374	-6,5	-0.5%

345 Source: authors' own elaborations.

346

#### 347 **4.2 Environmental impact**

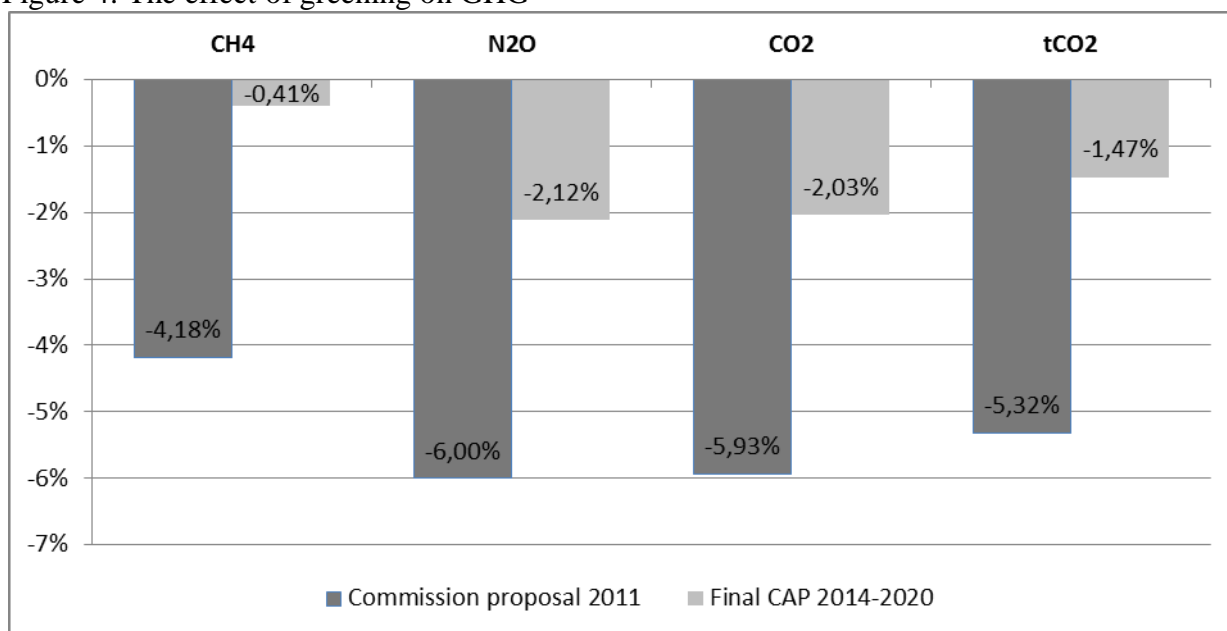
348 The model provides some useful information on the dynamics of GHG emissions produced by  
 349 agriculture resulting from greening. The transition to the new agri-environmental constraints,  
 350 provided in the CAP 2014-2020, results in a modest abatement of total emissions of greenhouse  
 351 gases. The reduction in the entire macro-region would be of 1.5% (Figure 4). This reduction is  
 352 significantly lower than would have been entailed by the Commission proposal. In the latter case  
 353 the reduction would have been greater than 5%. Indeed, the greening constraints provided in the  
 354 Commission proposal affected a much higher number of farms. The proposal provided the crop  
 355 diversification for farms over 3 hectares (rather than 10 hectares) and the EFA requirement, equal to  
 356 7% of the eligible area (excluding areas under permanent grassland), for all farms. Furthermore, the

<sup>9</sup> This interpretation will be implemented as from 2016. Only for the 2015 claim year, farmers, acting in good faith, who considered pure leguminous crop such as alfalfa as "grasses" further to letter (d) of Article 44(4) of the Regulation (EU) 1307/2013 in respect of fulfilling the crop diversification requirement, should not face negative consequences (DSCG/2014/39 FINAL- REV 1).

357 Commission proposal made it impossible to keep EFA in production, reallocating it to nitrogen-  
 358 fixing crops rather than leaving it unproductive.

359

360 Figure 4: The effect of greening on GHG



361

362 Source: authors' own elaborations.

363

364 Kirchner et al. (2016), with reference to the impact of the EFA requirement in Austria, also  
 365 highlight that it does not significantly affect GHG emissions or soil organic carbon sequestration at  
 366 national level.

367 Analysing the different components of the emissions, in the greening scenario, the model estimates  
 368 a reduction in CO<sub>2</sub> emissions of about 2% compared to the observed situation. Emissions from  
 369 nitrous oxide show a decrease by 2.1% and the reduction in the methane is about 0.4% compared to  
 370 the pre-2014 scenario. At territorial level, Lombardy is the region that most contributes to reduction  
 371 of CO<sub>2</sub>e emissions, being characterized by farms with intensive cultivation of maize and specialized  
 372 in dairy livestock. Almost 47% of the total emission reduction in the macro-area is due to the  
 373 downsizing of dairy cattle and maize-growing in this region. Piedmont and Veneto can contribute to  
 374 the downsizing of emissions by about 22% and Emilia-Romagna for the remaining 9%.

375 The simulation model shows the emissions of nitrous oxide, caused by the use of synthetic  
 376 fertilizers, fall due to the replacement of annual crops, with a high need in terms of nutrients, with  
 377 semi-permanent crops, such as alfalfa, less demanding in terms of fertilizer use.

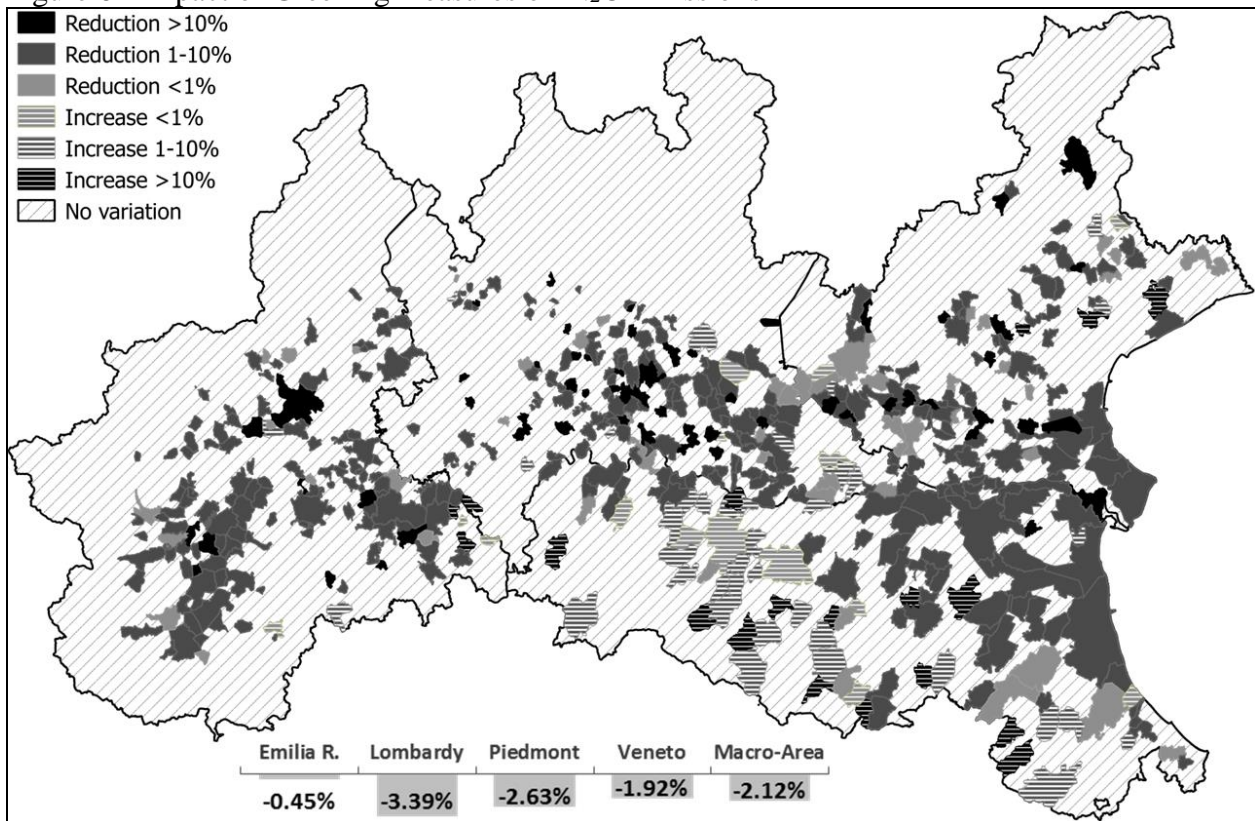
378 Lombardy shows the greatest reduction for nitrous oxide (-3.4%), while Emilia-Romagna, Piedmont  
 379 and Veneto reduce N<sub>2</sub>O emissions respectively by 0.5%, 2.6% and 1.9%. As stated above, very  
 380 limited changes (lower than 1%) are observed for methane in the four regions, compared to the pre-

381 2014 scenario. This is because greening does not make a big impact on the livestock sector, and  
382 because farms specialised in rice growing are exempted from both the diversification and EFA  
383 requirements.

384 Greening also influences the component relating to CO<sub>2</sub> emissions, due to the reduction in the  
385 cereals area, in particular wheat and maize. In Lombardy, the model estimates a reduction of CO<sub>2</sub>  
386 emissions of 3.2%, as a result of the contextual reduction in the maize area and increase in the NGC  
387 crop surface, mainly alfalfa. In both Veneto and in Piedmont there is reduction of CO<sub>2</sub> emissions of  
388 about 2%. The drop is smaller in Emilia-Romagna (-0.7%), a region characterized by more  
389 diversified farms with a greater spread of nitrogen-fixing crops.

390

391 Figure 6 - Impact of Greening measures on N<sub>2</sub>O Emissions



392

393 Source: authors' own elaborations.

394

395

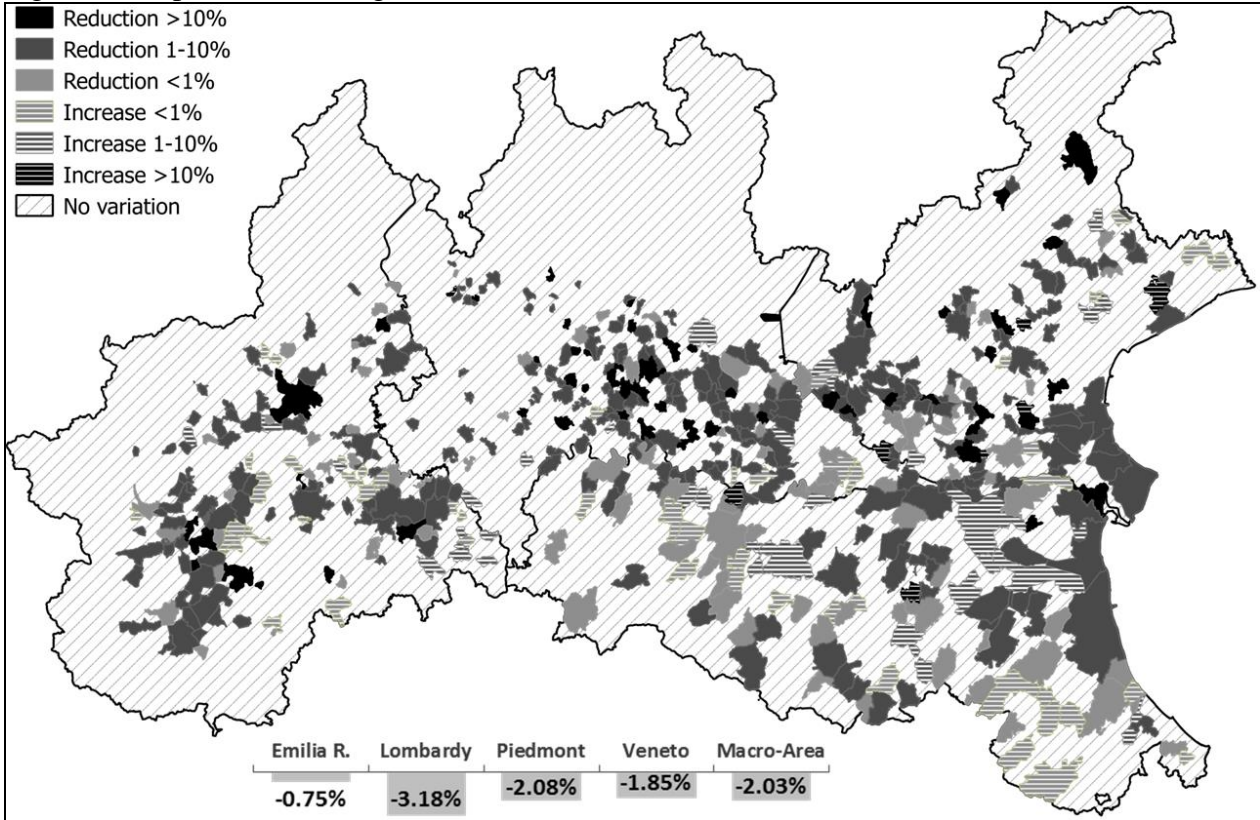
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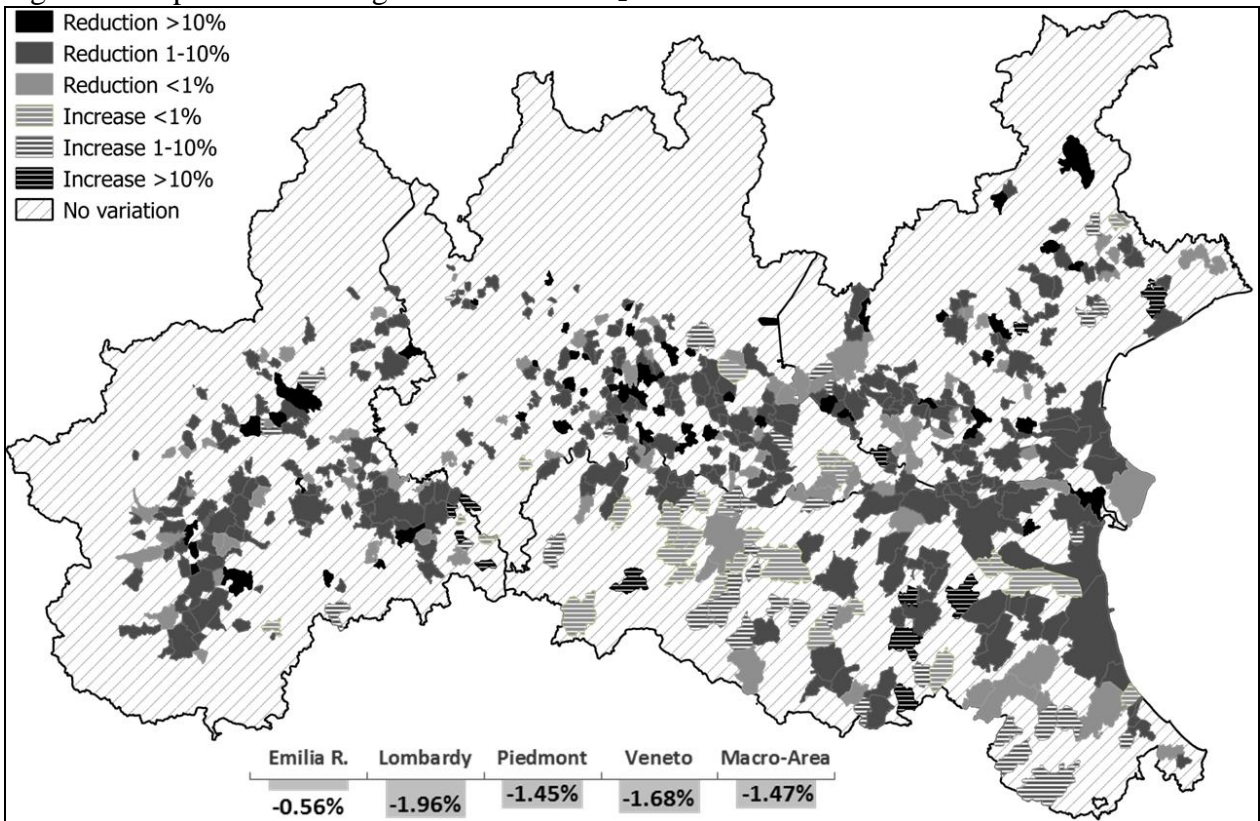
400 Figure 7 - Impact of Greening measures on CO<sub>2</sub> Emissions



401

402 Source: authors' own elaborations.

403 Figure 8 - Impact of Greening measures on tCO<sub>2</sub> Emissions



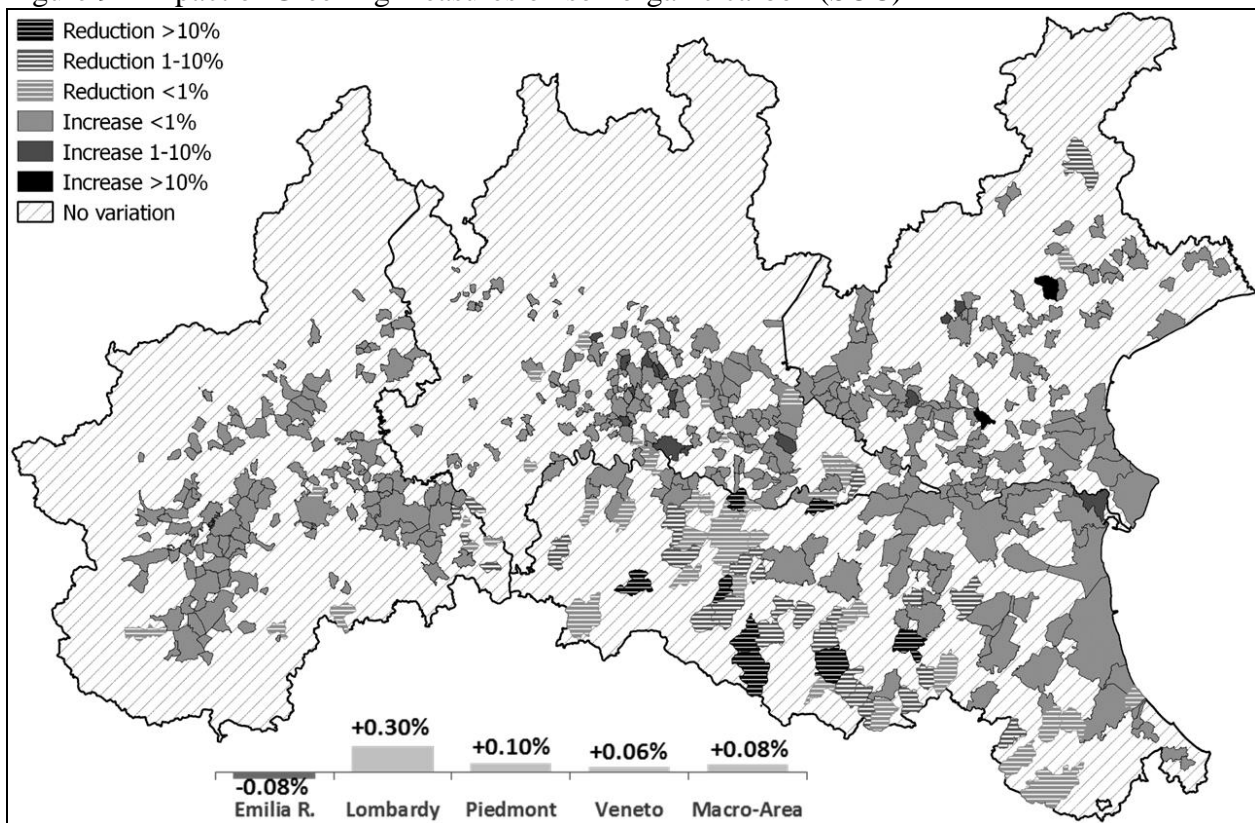
404

405 Source: authors' own elaborations.

406

407 In the long run, greening might affect positively the SOC for the four regions of the Po Valley.  
 408 Figure 9 shows that in plain areas the substitution of annual crops, such as maize, with alfalfa, the  
 409 NFC most frequently used to meet EFA requirements, leads to an increase in SOC level. Alfalfa  
 410 enables carbon sequestration in the soil significantly higher than annual crops. Alfalfa can indeed  
 411 remain on a same agricultural parcel for more than 5 years, without tillage. As mentioned above, in  
 412 Emilia-Romagna, the strong specialization in alfalfa for feeding dairy cows for the typical hard  
 413 cheese supply chains (i.e. Grana Padano and Parmigiano-Reggiano) means farms should reduce this  
 414 crop in order to fulfill the crop diversification commitment. The result is a net reduction of the SOC  
 415 in the region due to the substitution of alfalfa with annual crops.  
 416

417 Figure 9 - Impact of Greening measures on soil organic carbon (SOC)



418  
 419 Source: authors' own elaborations.  
 420

## 421 5. Discussion and conclusions

422 One of the main goals of the greening measures in the new CAP is to strengthen the production by  
 423 European agriculture of positive externalities, or limit the negative ones. The greening of the first  
 424 CAP pillar can determine conjoint effects on several environments compounds, such as  
 425 biodiversity, landscape, water consumption, climate. The aim of this paper was to assess the impact  
 426 of greening on the GHG emissions within one of the main agricultural area in Italy using a

427 quantitative approach based on PMP. The PMP model supplies interesting indications about to what  
428 extent the greening measures will affect the environmental impact of agriculture, in terms of GHG  
429 emissions abatement.

430 The main effect of greening on land use is the sharp reduction in maize and other cereal crops in  
431 some areas, and the increased spread of nitrogen-fixing crops, mainly alfalfa and soya. The dairy  
432 sector is affected only marginally by the new agri-environment measures, confirming the limited  
433 impact of greening on one of the highest GHG emitting types of production.

434 These changes result in a limited effect on overall GHG emissions; they are reduced by 1.5%. This  
435 reduction is significantly lower than would have been entailed by the Commission proposal (-  
436 5.3%). Lombardy accounts for over 40% of the total emissions of the analysed macro-region and  
437 contributes significantly to the emission reduction, because of stronger farm specialization in  
438 maize-growing and dairy livestock.

439 Some limits of the approach adopted in this study should be pointed out. First of all, the PMP model  
440 covers only a part, although a large part, of Italian agriculture. It does not take into account the less  
441 intensive agriculture characterizing the Southern Italy. Secondly, the total variable cost function is  
442 estimated using arbitrary support values, as the maximum entropy approach requires (Paris and  
443 Howitt, 1998). Thirdly, uncertainty in farm behaviour is not included in the PMP model. Future  
444 extensions of the model will consider constant absolute risk aversion (CARA) and decreasing  
445 absolute risk aversion (DARA) farm behaviour assumptions (Paris, 2015; Petsakos and Roasakis,  
446 2015).

447 The estimation of the GHG emissions per agricultural activity followed an approach relied on the  
448 IPCC criteria. However, due to a lack of information in FADN, the GHG coefficients adopted in the  
449 present study do not capture their variability among farms, since they are the same for all the farms  
450 belonging to the regional FADN samples.

451 Finally, this study does not consider the effects of greening on other important environmental  
452 indicators, such as biodiversity and water consumption. A comprehensive environmental  
453 assessment of the greening effect would be necessary to judge the degree of effectiveness of the  
454 new greening of the first CAP pillar. It would be therefore important to consider all the  
455 relationships between farmer decisions and farmland habitat, species and ecosystem services.  
456 Nevertheless, some studies suggest for instance that the greening diluted environmental  
457 prescriptions will have a negligible or neutral impact on biodiversity at regional or EU level (Pe'r et  
458 al., 2014; Waş et al, 2014; Kirchner et al., 2015; Cortignani and Dono, 2015; Westhoek et al.,  
459 2012). The environmental assessments of the new CAP greening, including the present analysis,  
460 agree that there is a weak link between policy objectives and policy action. The process of

461 "lightening" that affected greening during the entire CAP negotiation has inevitably resulted in  
462 missing the opportunity to introduce a significant positive change of behavior in agriculture through  
463 the reform.

464 As pointed out by the literature (Kirchner et al., 2016; Pelikan et al., 2015) and the findings of our  
465 analysis, the greening measures of the first pillar of the CAP are not so effective in GHG emission  
466 abatement. Other mitigation strategies for EU agriculture are therefore needed. In particular,  
467 integrated assessments including environmental and economic aspects are fundamental to avoid the  
468 risk that GHG mitigation policies incur high costs of implementation and disregard environmental  
469 objectives (Wu et al., 2015; Oliveira Silva et al., 2015). An integrated assessment needs to include  
470 the GHG mitigation policy effect within the food supply chain, including farm activities and the  
471 upstream and downstream phases (Coderoni et al., 2015). Including environmental and economic  
472 relationships along the food supply chain would make it possible to identify hot-spots and possible  
473 economic and technological solutions.

474 In view of the mid-term review of the multiannual financial framework (MFF) of EU (Matthews,  
475 2015; Anania and Pupo D'Andrea, 2015; Swinnen, 2015), the first pillar of the CAP needs to better  
476 justify its role as provider of public goods expected by society, carry out a wider assessment of its  
477 greening mechanisms with regard to biodiversity, climate change, water consumption and other  
478 ecosystem services.

479

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612

613

614 **Appendix - Greening measures in the CAP 2014-2020**

615

616

<b>MEASURES</b>	<b>CONSTRAINTS</b>
<b>1. Crop diversification (arable land)</b>	<b>10-30 ha: 2 crops &gt; 30 ha: 3 crops</b>
Limits for crops	2 crops: < 75% (main crop) 3 crops: < 75% (main crop) < 95% (2 main crops)
Exception	- if entirely cultivated with crops under water - if > 75% (eligible agricultural area) is grassland or used for production of grass or other herbaceous forage or cultivated with crops under water and the remaining arable area < 30 ha - if > 75% (arable land) for production of grass or other herbaceous forage, land laying fallow and the remaining arable area < 30 ha
<b>2. Permanent grassland</b>	<b>Maintenance of permanent grassland and permanent pasture</b>
Maximum conversion	- farmers shall not convert or plough permanent grassland situated in areas designated by Member States <sup>(*)</sup> - member States shall ensure that the ratio of areas of permanent grassland to the total agricultural area does not decrease by more than 5 % compared to a reference ratio <sup>(*)</sup>
<b>3. EFA (arable land)</b>	<b>5%</b>
Mandatory	> 15 ha (arable land)
Exception	- if > 75% (eligible agricultural area) is grassland or used for production of grass or other herbaceous forage or cultivated with crops under water and the remaining arable area < 30 ha - if > 75% (arable land) for production of grass or other herbaceous forage, land laying fallow or used for cultivation of leguminous crops and the remaining arable area < 30 ha
EFA	- land lying fallow - nitrogen-fixing crops ( <i>weighting factor 0.7</i> ) - terraces, landscape features, buffer strips, hectares of agro-forestry, strips of eligible hectares along forest edges, areas with short rotation coppice, areas with catch crops or green cover, afforested areas <sup>(*)</sup>
<b>Entitled IPSO FACTO to the greening component and equivalent practices</b>	- organic farms (units of a holding) - equivalent practices: covered by agri-environmental-climate commitments (Article 39(2) of Regulation (EC) No 1698/2005 or Article 28(2) of Regulation (EU) No 1305/2013) <sup>(*)</sup>

617 <sup>(\*)</sup> Option not or partially implemented into the evaluation model (described in the section 3.3).

618 Source: own elaboration based on Regulation (EU) n. 1307/2013 and Regulation (EU) n. 639/2014.

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