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

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Abstract

Agriculture contributes significantly to greenhouse gas (GHG) emissions, accounting for more than 10% of total CO_2 emissions in the EU-28 area. The Common Agricultural Policy (CAP) plays an important role in promoting environmentally and climate friendly practices and needs to respond to the new environmental challenges by better integrating its objectives with other EU policies.

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

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

The new agri-environmental constraints produce a modest abatement of total emissions of greenhouse gases (-1.3%) in the analysed area. The model estimates a reduction in CO_2 emissions of about 2%, and a lower decrease in emissions of nitrous oxide (-1.4%) and methane (-0.5%). The process of "lightening" that affected the greening during the CAP negotiation has inevitably resulted in missing an opportunity to introduce a positive change of behavior into agriculture, in line with the expectations and needs of society for EU agriculture as a provider of public goods.

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

JEL Classification codes: C61, Q15, Q18

1. Introduction

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

Agriculture has an important role in greenhouse gas (GHG) emissions, contributing in 2013 11.7% of the total CO_2 emissions in EU-28, corresponding to 520 million tonnes of CO_2e[1] (EEA, 2015). For Methane (CH_4) and nitrous oxide (N_2O), agriculture is the main emitting sector in EU-28 (52% for CH_4 and 79.3% for N_2O).

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

The six largest contributor countries to agricultural CO_2 emissions in EU are France (17.7%), Germany (13%), United Kingdom (10.4%), Spain (9.8%), Poland (8%) and Italy (7.5%). Italian GHG emissions from the agricultural sector were about 39 CO_2 million tons (Mt) in 2013. With regard to the incidence of the three main greenhouse gases (CO_2, N_2O and CH_4) on total emissions, methane and nitrous oxide are responsible for about 80% of emissions, while carbon dioxide contributes to the remaining 20%. In particular, methane concentrates the largest share of emissions, 49%, and nitrous oxide represents a share of 31%. At regional level, Lombardy is responsible for

[1] 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).

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

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

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

[2] 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.

2. Greening of the CAP first pillar

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

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

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

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

[3] 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).

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

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

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

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

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

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

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

3. Materials and Methods

3.1 FADN data and study area

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

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

[4] 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).

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

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

3.2 GHG emissions from agriculture

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

The IPCC guidelines are a standard followed by different countries in determining the inventory of GHG emissions of different economic sectors. The procedure suggested by IPCC assumes that the emission factors are linearly correlated with the level of economic activity, so that an increase in the level of output determines a proportional increase in the level of GHG emissions. Each agricultural activity (crops and animal production) is a global warming contributor in terms of CO_2, CH_4 and N_2O emissions.

For CO_2 emissions, we considered those caused by the cropping operations and soil organic carbon (SOC). The estimation of fuel absorbed by each operation per crop (e.g. tillage, sowing, harvest) was retrieved from the Handbook of Italian Agriculture (Ribaudo, 2011), which presents the cropping systems according to geographical area. The SOC related to the specific land use was estimated as follows:

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

where the SOC (tC)[5] for each crop j ($j=1,2,...,J$) is equal to the product of the reference carbon stock (tC ha^{-1}), $SREF_j$, the stock change factor for land-use systems (dimensionless), FLU_j, the stock change factor for management regime (dimensionless), FMG_j, the stock change factor for input of organic matter (dimensionless), FI_j, and the land area occupied by a certain crop (ha), A_j. Each component of the Equation 1 is estimated from FADN data and IPPC guidelines (Coderoni et al., 2013; IPPC, 2006). The value of SOC is then converted in CO_2 using the stoichiometric factor of 3.667 (European Commission, 2004).

N_2O is generated by animal manure (storage and treatment), managed soil and the burning of stubble and crop residues, which however is banned in Italy. For animal manure, considering a production of 116 kg N head^{-1}y^{-1} for dairy cows, we adopted an IPCC emission factor (kg N_2O -N/ kg N) of 0.02 for solid storage and 0.001 for slurry; 5% of kg N was considered to be applied to the soil (ISPRA, 2011). Among direct emissions attributable to the soil management, we considered the emissions produced by synthetic fertilizers. The total quantity of N was converted into N_2O-N using the default IPCC direct emission factor of 0.0125. The levels of N_2O-N were converted into N_2O using a factor of 1.571 according to IPCC guidelines. Indirect emissions due to the atmospheric deposition, leaching and runoff from managed soil were estimated accordingly.

Methane emissions are due essentially to the livestock enteric fermentation, manure management and rice cultivation. For enteric fermentation, we consider the standard IPCC coefficient, which is 113 kg CH_4 head^{-1} y^{-1} for dairy cows. For manure management, the ICAAI approach uses the CH_4 burden provided by ISPRA (2011), for which the average value is 15.04 kgCH_4 head^{-1} y^{-1} for dairy cows. The CH_4 emission for rice is estimated by ICAAI using the ISPRA data that differentiates between dry-seeded and wet-seeded cropping, and corresponding to 249.6 kg CH_4 ha^{-1} y^{-1} and 336.7 kg CH_4 ha^{-1} y^{-1}. Because the information about the rice sowing system is not present in FADN, we considered the average value of 293.15 kg CH_4 ha^{-1} y^{-1}.

Emissions of nitrous oxide and methane were converted into CO_2 equivalent (CO_2e) using the coefficients of global warming potential (GWP) provided by IPCC[6] (Table 2).

[5] tC: tonnes of carbon

[6] 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 (IPPC, 2007:33).

Table 2: Estimated emissions for each hectare/head (GHG emissions expressed in tonnes of CO_2 equivalents)

Crop/activity	CO_2	N_2O	CH_4	totCO_2e
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

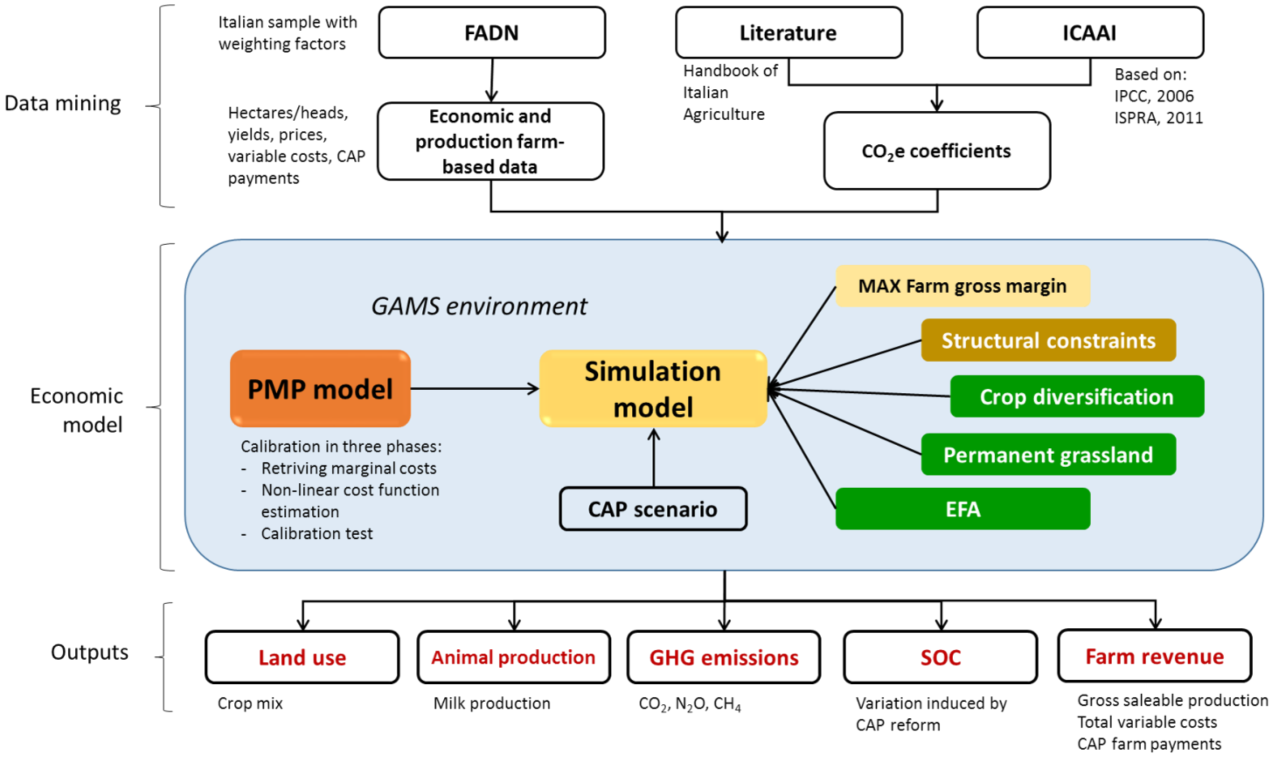
Source: own processing.

3.3 Greening assessment model

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

The PMP model used in this analysis follows the total variable cost estimation methodology of Paris and Howitt (1998), where the calibration process (i.e. the information recovery about the farmer's decision process) comprises three steps. Unlike the existing literature about the impact of the greening on GHG emissions, our model is implemented at farm level using the policy analysis approach proposed by Solazzo et al. (2015b, 2014)[7] (Figure 2).

Figure 2: Greening assessment design



Source: authors' own elaborations.

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

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

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

A specific constraint on GHG was developed for the calculation of the total impact of CO_2 emissions, using the emission estimates described in Section 3.2.

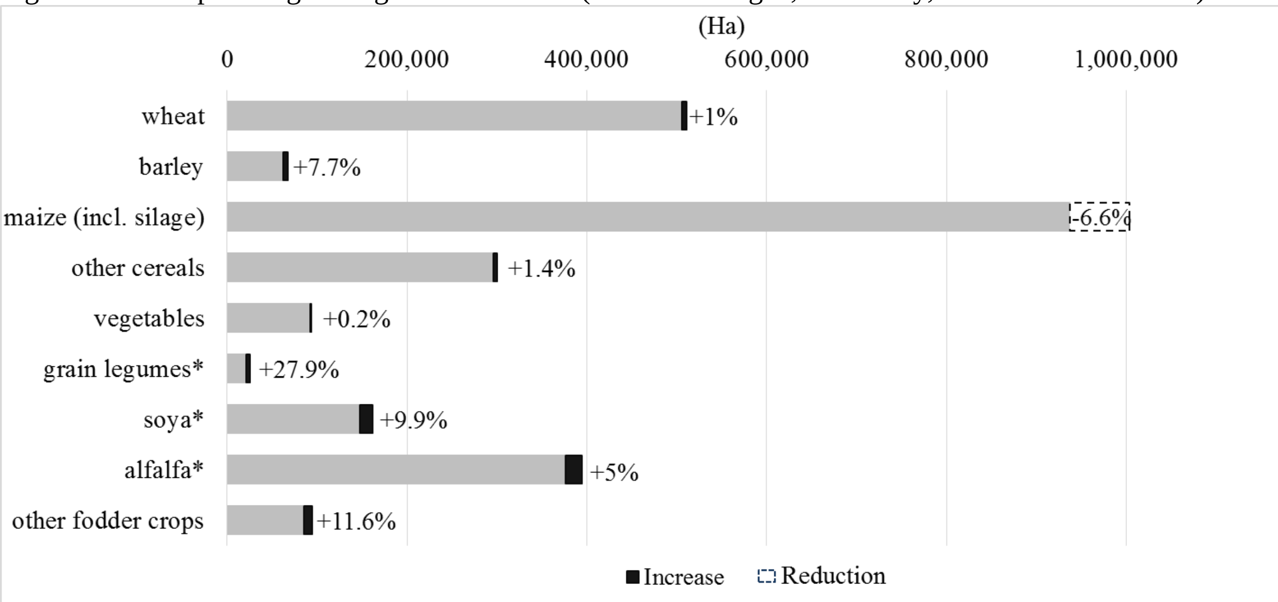
The greening effects are compared with the situation with the CAP in force prior the implmentatation of the new reform 2014-2020 were in force. We can define the reference scenario as the pre-2014 scenario. When relevant, the results for Commission greening proposal are provided.

4. Results

4.1 Effect on land use

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

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



* Nitrogen-fixing crops

Source: authors’ own elaborations.

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

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

[8] Only when these species are sown in mixture with grasses or herbaceous forage, should be classified as “grasses or other herbaceous forage”.

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

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

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%

Source: authors' own elaborations.

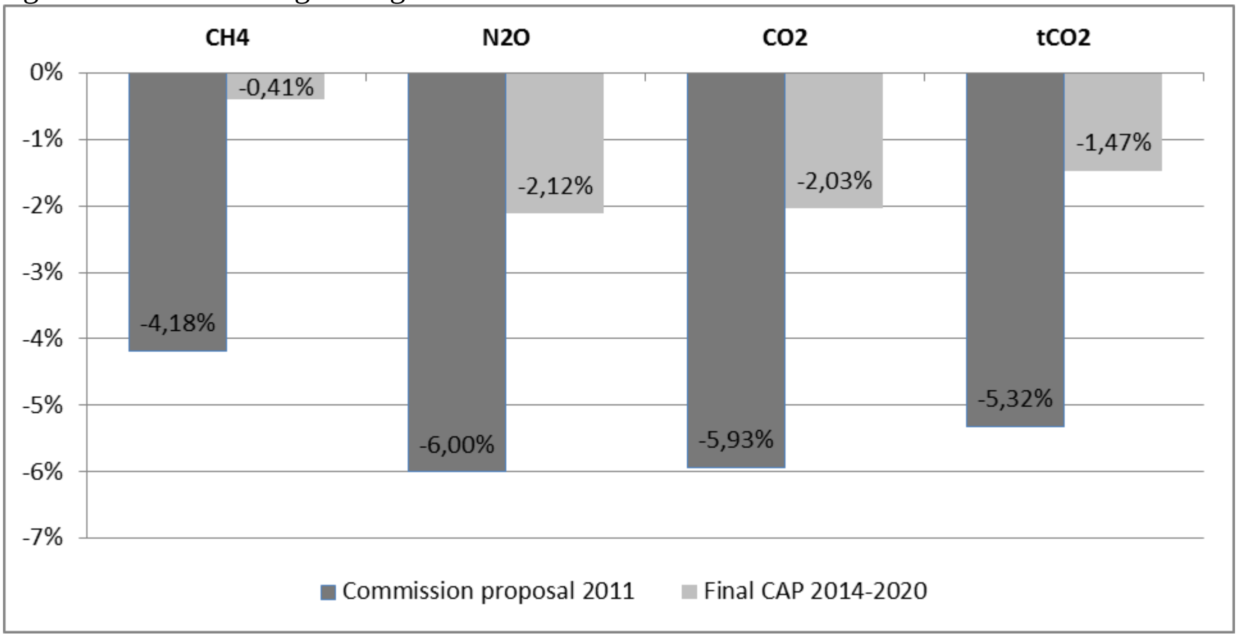
4.2 Environmental impact

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

[9] 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).

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

Figure 4: The effect of greening on GHG



Source: authors' own elaborations.

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

Analysing the different components of the emissions, in the greening scenario, the model estimates a reduction in CO_2 emissions of about 2% compared to the observed situation. Emissions from nitrous oxide show a decrease by 2.1% and the reduction in the methane is about 0.4% compared to the pre-2014 scenario. At territorial level, Lombardy is the region that most contributes to reduction of CO_2e emissions, being characterized by farms with intensive cultivation of maize and specialized in dairy livestock. Almost 47% of the total emission reduction in the macro-area is due to the downsizing of dairy cattle and maize-growing in this region. Piedmont and Veneto can contribute to the downsizing of emissions by about 22% and Emilia-Romagna for the remaining 9%.

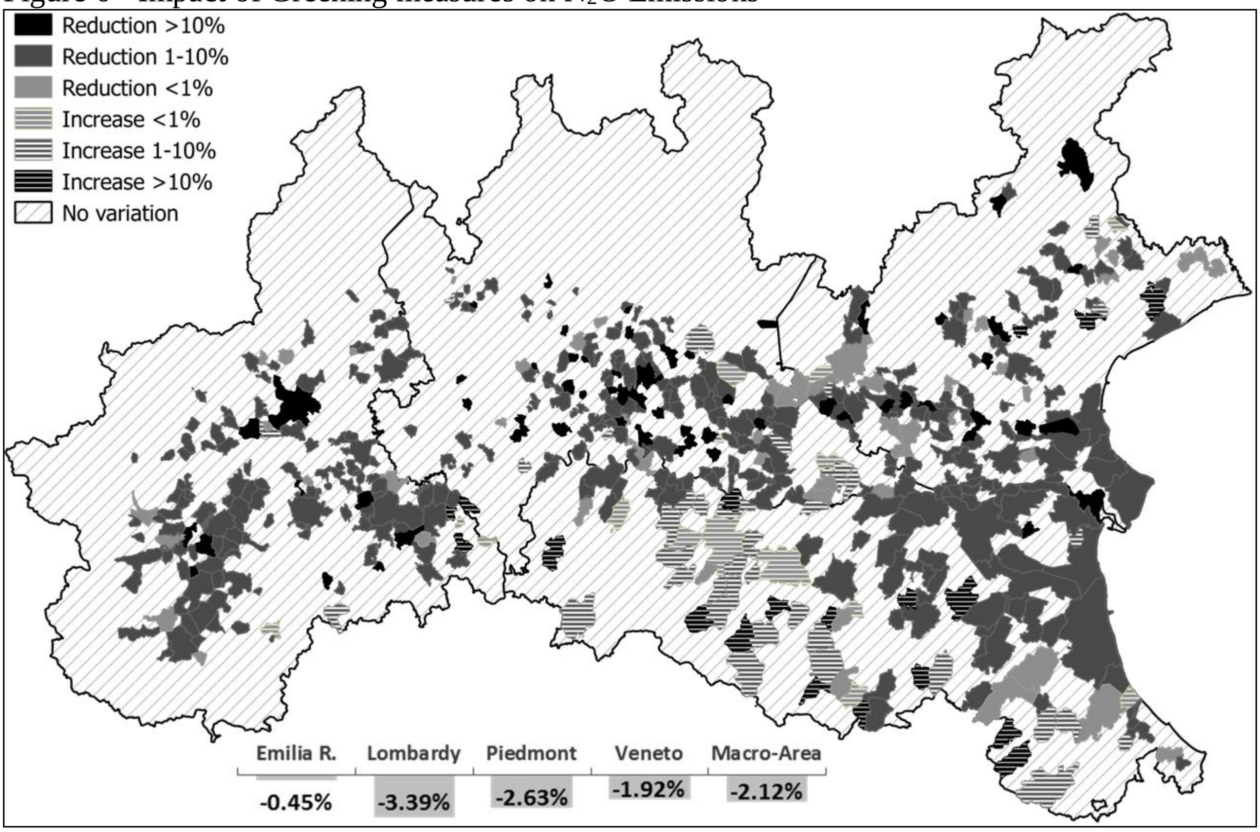
The simulation model shows the emissions of nitrous oxide, caused by the use of synthetic fertilizers, fall due to the replacement of annual crops, with a high need in terms of nutrients, with semi-permanent crops, such as alfalfa, less demanding in terms of fertilizer use.

Lombardy shows the greatest reduction for nitrous oxide (-3.4%), while Emilia-Romagna, Piedmont and Veneto reduce N_2O emissions respectively by 0.5%, 2.6% and 1.9%. As stated above, very limited changes (lower than 1%) are observed for methane in the four regions, compared to the pre-

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

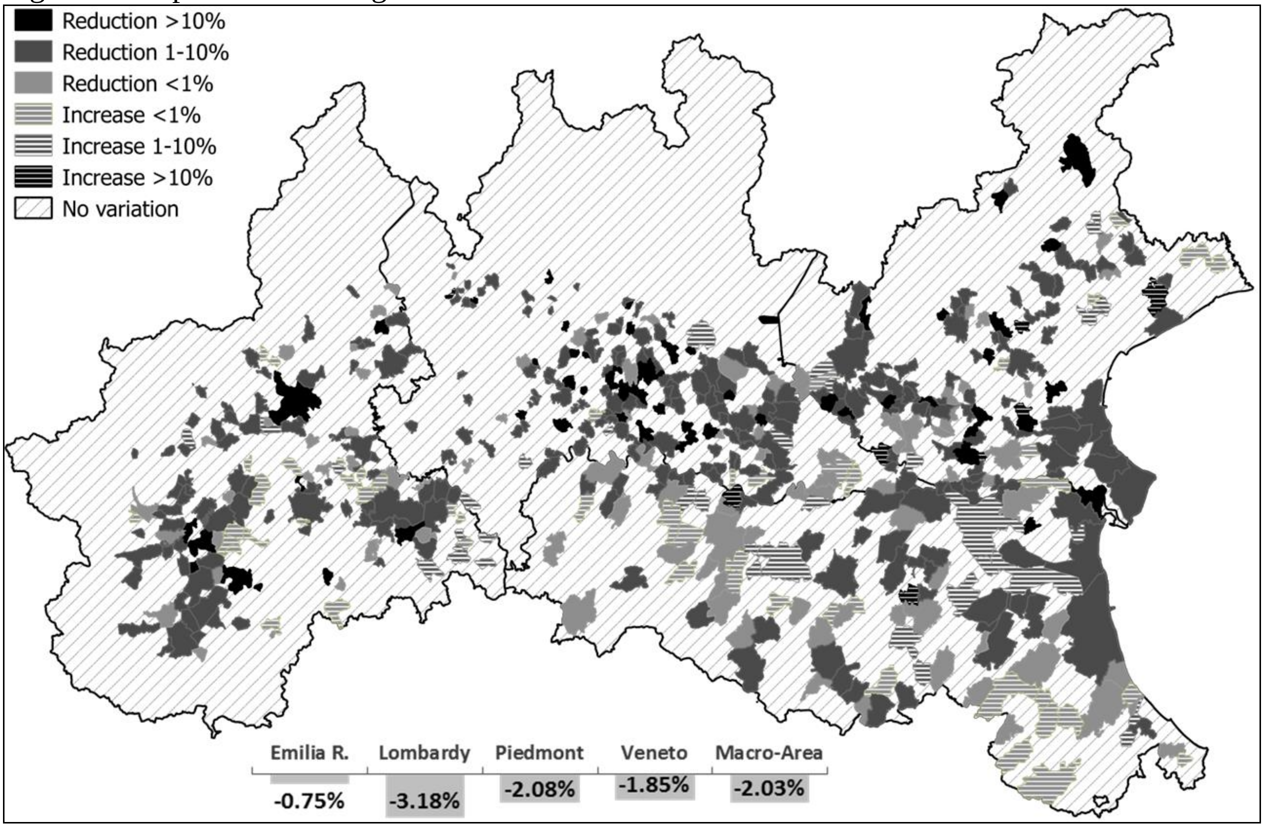
Greening also influences the component relating to CO_2 emissions, due to the reduction in the cereals area, in particular wheat and maize. In Lombardy, the model estimates a reduction of CO_2 emissions of 3.2%, as a result of the contextual reduction in the maize area and increase in the NGC crop surface, mainly alfalfa. In both Veneto and in Piedmont there is reduction of CO_2 emissions of about 2%. The drop is smaller in Emilia-Romagna (-0.7%), a region characterized by more diversified farms with a greater spread of nitrogen-fixing crops.

Figure 6 - Impact of Greening measures on N_2O Emissions



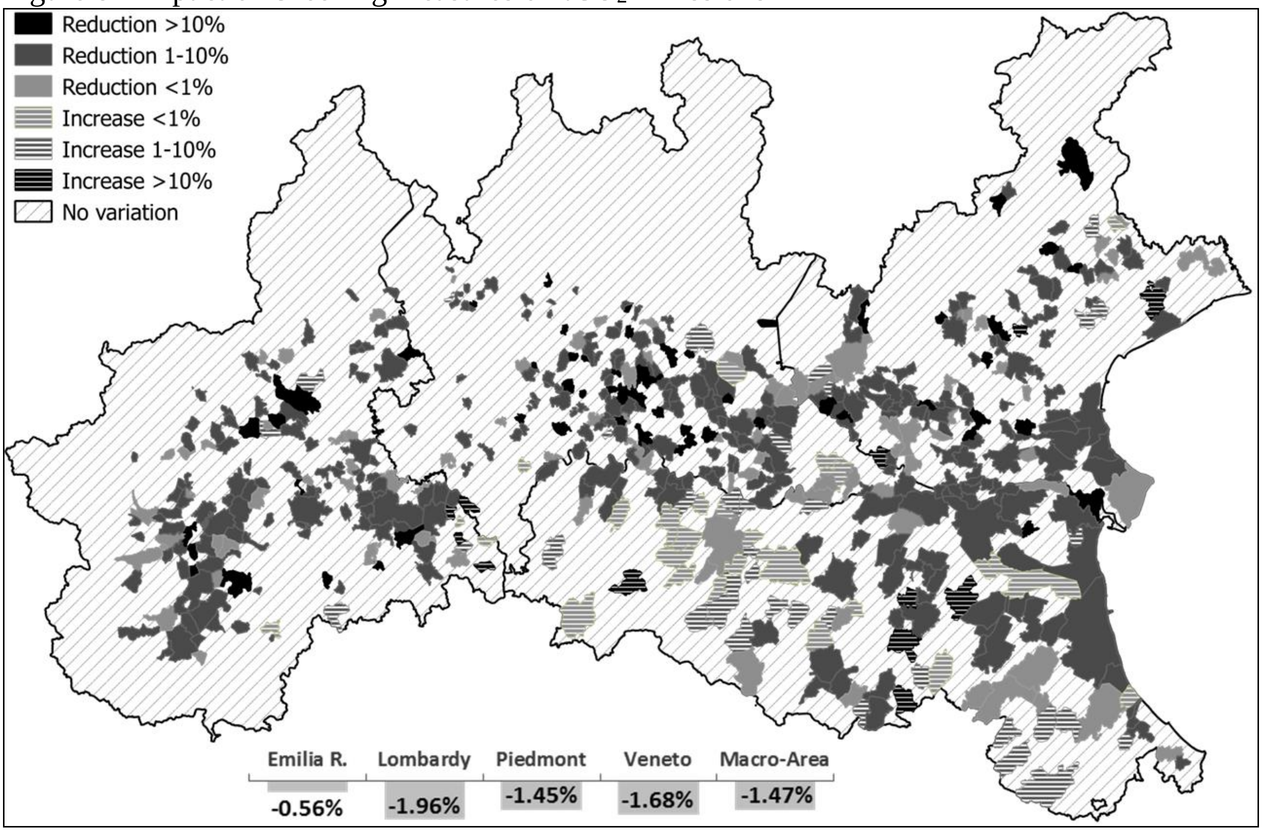
Source: authors' own elaborations.

Figure 7 - Impact of Greening measures on CO_2 Emissions



Source: authors' own elaborations.

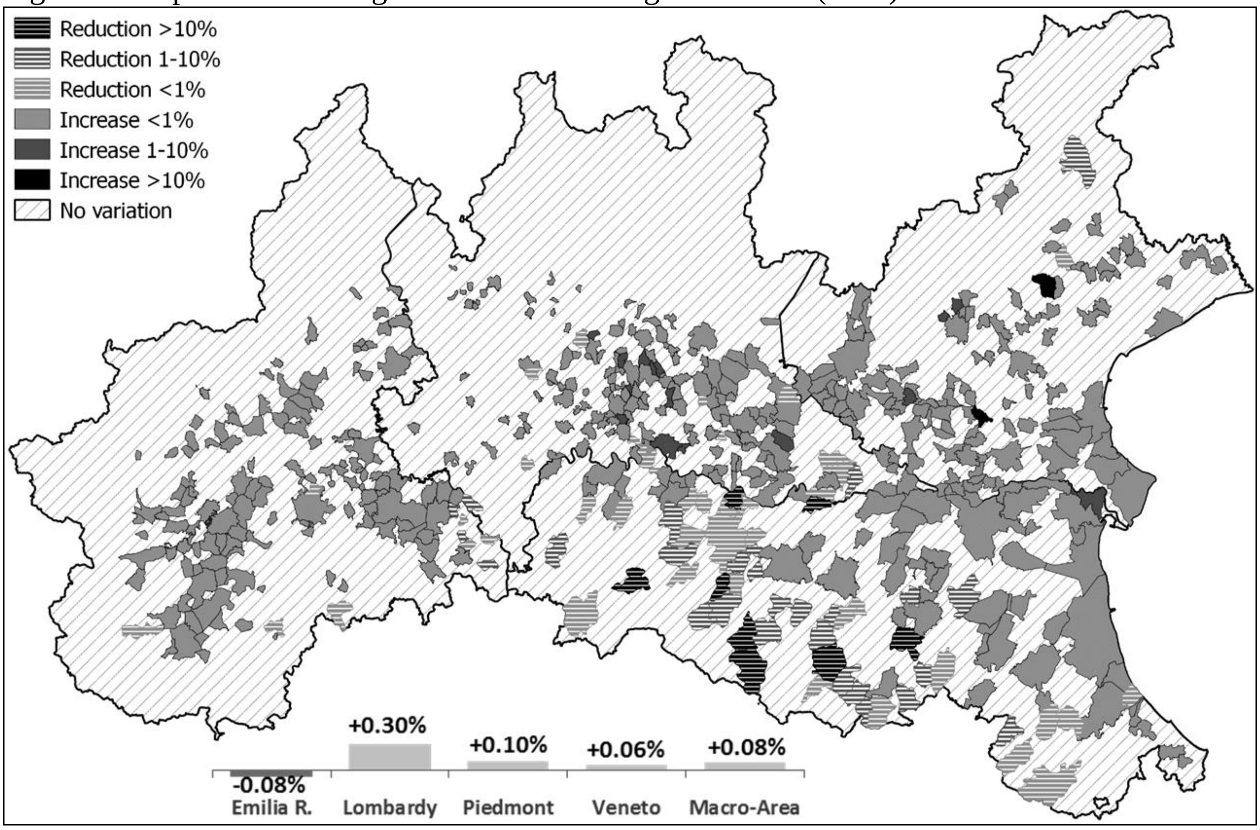
Figure 8 - Impact of Greening measures on tCO_2 Emissions



Source: authors' own elaborations.

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

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



Source: authors' own elaborations.

5. Discussion and conclusions

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

quantitative approach based on PMP. The PMP model supplies interesting indications about to what extent the greening measures will affect the environmental impact of agriculture, in terms of GHG emissions abatement.
The main effect of greening on land use is the sharp reduction in maize and other cereal crops in some areas, and the increased spread of nitrogen-fixing crops, mainly alfalfa and soya. The dairy sector is affected only marginally by the new agri-environment measures, confirming the limited impact of greening on one of the highest GHG emitting types of production.
These changes result in a limited effect on overall GHG emissions; they are reduced by 1.5%. This reduction is significantly lower than would have been entailed by the Commission proposal (-5.3%). Lombardy accounts for over 40% of the total emissions of the analysed macro-region and contributes significantly to the emission reduction, because of stronger farm specialization in maize-growing and dairy livestock.
Some limits of the approch adopted in this study should be pointed out. First of all, the PMP model covers only a part, although a large part, of Italian agriculture. It does not take into account the less intensive agriculture characterizing the Southern Italy. Secondly, the total variable cost function is estimated using arbitrary support values, as the maximum entropy approach requires (Paris and Howitt, 1998). Thirdly, uncertainty in farm behaviour is not included in the PMP model. Future extensions of the model will consider constant absolute risk adversion (CARA) and decreasing absolute risk adversion (DARA) farm behaviour assumptions (Paris, 2015; Petsakos and Roasakis, 2015).
The estimation of the GHG emissions per agricultural activity followed an approach relied on the IPCC criteria. However, due to a lack of information in FADN, the GHG coefficients adopted in the present study do not capture their variability among farms, since they are the same for all the farms belonging to the regional FADN samples.
Finally, this study does not consider the effects of greening on other important environmental indicators, such as biodiversity and water consumption. A comprehensive environmental assessment of the greening effect would be necessary to judge the degree of effectiveness of the new greening of the first CAP pillar. It would be therefore important to consider all the relationships between farmer decisions and farmland habitat, species and ecosystem services.
Nevertheless, some studies suggest for instance that the greening diluted environmental prescriptions will have a negligible or neutral impact on biodiversity at regional or EU level (Pe'r et al., 2014; Wąs et al, 2014; Kirchner et al., 2015; Cortignani and Dono, 2015; Westhoek et al., 2012). The environmental assessments of the new CAP greening, including the present analysis, agree that there is a weak link between policy objectives and policy action. The process of

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

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

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

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Appendix - Greening measures in the CAP 2014-2020

MEASURES	CONSTRAINTS
1. Crop diversification (arable land)	**10-30 ha: 2 crops** **> 30 ha: 3 crops**
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
2. Permanent grassland	**Maintenance of permanent grassland and permanent pasture**
Maximum conversion	- farmers shall not convert or plough permanent grassland situated in areas designated by Member States(*) - 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(*)
3. EFA (arable land)	**5%**
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 *(weighting factor 0.7)* - 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(*)
Entitled IPSO FACTO to the greening component and equivalent practices	- 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)(*)

(*) Option not or partially implemented into the evaluation model (described in the section 3.3).

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