EU-wide Economic and Environmental impacts of CAP greening with high spatial and farm-type detail

Alexander Gocht[1], Pavel Ciaian[2], Maria Bielza[2], Jean-Michel Terres[2], Norbert Röder[3], Mihaly Himics[2], Guna Salputra[2]

[1] Institute of Farm Economics, Johann Heinrich von Thünen Institute
[2] Joint Research Centre, European Commission
[3] Institute of Rural Studies, Johann Heinrich von Thünen Institute

Contribution presented at the XV EAAE Congress, "Towards Sustainable Agri-food Systems: Balancing Between Markets and Society"

August 29th – September 1st, 2017

Parma, Italy

EU-wide Economic and Environmental impacts of CAP greening with high spatial and farm-type detail[1]

Alexander Gocht[1], Pavel Ciaian[2], Maria Bielza[2], Jean-Michel Terres[2], Norbert Röder[3], Mihaly Himics[2], Guna Salputra[2]

[1] Institute of Farm Economics, Johann Heinrich von Thünen Institute
[2] Joint Research Centre at the European Commission
[3] Institute of Rural Studies, Johann Heinrich von Thünen Institute

Abstract

This paper analyses the economic and environmental impacts of CAP greening. The simulated results reveal that the economic and environmental impacts of CAP greening are rather small. The CAP greening leads to a small increase in prices and a small decrease in production. Farm income slightly increases because the price effects offset the production decline. The environmental effects are positive on a per hectare basis, but the increase in UAA can reverse the sign for total impacts. GHG and ammonia emissions decrease in the EU, while the total N surplus, soil erosion and biodiversity-friendly farming practices slightly increase.

Keywords: CAP greening, economic and environmental impacts, CAPRI, farm model, EU.

1. Introduction

The reform of the Common Agricultural Policy (CAP) in 2013 changed both the implementation and the level of the direct farm support. The main 'innovation' of the 2013 reform was the introduction of the so-called CAP greening as conditional requirement to farmers receiving direct payments. The policy aim of CAP greening "is the enhancement of the environmental performance" of farming sector (EU 2013).

Given that the primary objective of CAP greening is to motivate farmers to produce more environmental public goods, the key policy question in this context is to what extent the greening measures actually contribute to improving the environmental output linked to agricultural production. A second important policy question is how strong are the market impacts of CAP greening in terms of affecting land use, production, prices and farm income. Answering these questions provides evidence of whether the CAP greening achieves its objectives of stimulating production of public goods and allows the assessment of effects on agricultural commodity markets.

[1] The modeling and analytical framework of CAP greening on which this paper is based was developed as part of the project "*Farm level Modelling of CAP 'Greening'*" and the FP7 project "*The Common Agricultural Policy Regionalised Impact - The Rural Development Dimension (CAPRI-RD)*" financed by the European Commission (Röder, Gocht and Laggner, 2016; Gocht *et al*., 2016a,b; CAPRI-RD, 2013). The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

There is a growing body of agroeconomic literature analysing the impact of the CAP greening on the EU agricultural sector starting from the assessment of the initial proposals of CAP greening as put forward by the European Commission in 2010 and 2011 (e.g. van Zeijts et a., 2011) up to the final adopted greening measures in 2013 (e.g. Czekaj, Majewski and Was 2014). The regional scope of the studies spans from small regions with specific conditions (e.g. Brown and Jones 2013) to studies with a national coverage (e.g. Czekaj, Majewski and Was 2014) to studies on an European scale (e.g. van Zeijts et a., 2011). While some studies focus on a specific farm type (e.g. beef and sheep farms in Vosough-Ahmadi et al. 2015) others cover a wider range of farm type (e.g. Solazzo and Pierangeli 2016).

Furthermore, the papers differ whether they consider the entire CAP greening package (e.g. Solazzo and Pierangeli 2016) or focus on selected measures (e.g. Mahy et al. 2015). While the above mentioned studies focus on aspects such as land use and profitability, other authors as e.g. Matthews (2013) highlight the institutional and political economy aspects of CAP greening. The agro-economic body of literature is mirrored by agro-ecological studies focussing on various indicators to evaluate the environmental impacts of CAP greening (e.g. Leip et al. 2015).

The most frequently used methodology to study the CAP greening impact is based on Mathematical Programming (e.g. van Zeijts et a., 2011). The key advantage of Mathematical Programming models is the possibility to express explicitly farm technology in terms of the interlinkage between production activities and the physical input use. This is a an important requirement for modelling CAP greening as it allows the simulation of specific farm management decisions linked to the greening requirements and allows calculating the induced environmental impacts.

The main objective of this paper is to analyse the potential economic and environmental impacts of CAP greening. The analysis is based on simulations with the Common Agricultural Regionalised Impact Analysis model (CAPRI) model (Gocht and Britz, 2011; Britz and Witzke 2014). The main advantage of CAPRI is that it models farm types across the EU capturing farm heterogeneity in terms of the specialisation and size. Capturing farm heterogeneity is a necessary prerequisite, given that the implementation of the greening measures strongly depends on farm characteristics. The advantage of CAPRI compared to other models used for CAP greening impact simulations is its geographical coverage that allows simulating policy impacts across all EU farming systems and regions. Furthermore, CAPRI simulates the market interaction of farm types as well as it calculates key environmental indicators which allow us to capture the CAP greening impacts both on the agricultural commodity markets and on the environment. To our knowledge this is the first paper providing a comprehensive analysis of EU-wide economic and environment impacts of greening measures adopted by the 2013 CAP reform.

2. The CAPRI model

CAPRI is a global, spatial, partial equilibrium model specifically designed to analyse CAP measures and trade policies for agricultural products. CAPRI consists of two modules, a highly detailed and disaggregated supply module for Europe and a global market module. The modules are linked by sequential calibration such that production, demand, trade and prices can be simulated simultaneously and interactively from global to regional and farm-type scale (Britz and Witzke, 2014).

CAPRI's strengths are that it simulates policy impacts for the EU at sub-Member States (NUTS 2 and farm-type) level, whilst at the same time being able to model consistently global world agricultural trade. This interaction between EU and global markets allows global price feedback of the simulated CAP policies to be captured. It also comprises a consistent welfare and environmental analysis, including a detailed analysis of agricultural policies. CAPRI has been used in numerous assessments of agricultural and trade policies and environmental effects, such as the impacts of the introduction of direct payments schemes, sugar quota reform, trade liberalization or biofuel policies and climate change (the most recent being Burrell et al., 2014; Delincé et al., 2014).

The farm-type module aims to capture heterogeneity in farming practices within a region to reduce the aggregation bias of the CAPRI regional responses to policies and market signals. Its application is very suitable for the analysis of policy instruments that depend on farm characteristics, as is the case for CAP greening (Gocht and Britz, 2011; Gocht et al., 2013).

Each farm type in CAPRI is represented by a non-linear programming model that captures all activities belonging to all farms of that type in a specific NUTS 2 region. Each model optimises aggregated farm income under restrictions relating to land balances — including a land-supply curve (see below for details), nutrient balances and nutrient requirements of animals and policy restrictions (Gocht and Britz, 2011; Gocht et al., 2013).

The farm-type module considers, for each NUTS 2 region, the most important farm types in addition to a residual farm type, together representing the total regional agricultural production as well as the input and primary factor use. The main data sources used for development of the farm-type module are the Farm Structure Survey (FSS) for 2007 and the Farm Accountancy Data Network (FADN) for the 2007-2009 period.[2] The farm types are defined according to Gocht et al. (2013). Overall, there are 2 450 farm types in CAPRI: 2 200 are characterized by a specific production specialisation and size class, while the remaining are the residual regional farm types (Gocht et al., 2013).

3. The 2013 CAP reform

The 2013 CAP reform introduces explicit measures to remunerate the provision of public goods by farmers, the so-called greening payment. The aim of CAP greening is to impose a stronger linkage of the decoupled direct payments to 'agricultural practices beneficial to the climate and environment' through three CAP greening measures: crop diversification, maintenance of permanent grassland and ecological focus area (EFA). The CAP greening payments account for 30 % of the total direct payment funds. However, not respecting these requirements may lead to a reduction of up to 1.25 times the greening payments (EU, 2013).

Under the crop diversification measure, farms cultivating between 10 and 30 hectares of arable land need to grow at least two different arable crops. Farms with a larger arable area must cultivate at least three arable crops. The main crop should not exceed 75 % of arable land, and the two main crops should not exceed 95 % of the arable area (in this case three are required). Under the maintenance of permanent grassland, farms cannot convert grassland or plough environmentally sensitive permanent grassland. This measure requires that the ratio of grassland to total agricultural area does not decrease by more than 5 % compared to the reference ratio in 2015. The EFA requires farms with more than 15 hectares of arable land to allocate at least 5 % of the farm's arable land to an EFA.

[2] Croatia is not included in the farm-type module as there are no available FSS and FADN data.

4. Scenarios

We simulate a reference and a greening scenarios. The *reference assumes* the introduction of the 2013 CAP reform (i.e. new direct payments) without CAP greening. It defines the baseline development of the agricultural sectors and thus serves as a comparison point for the counterfactual comparison of the greening scenario. For the current paper, the reference captures developments in exogenous variables, such as policy changes, population growth, GDP growth and agricultural market development, for the year 2025 (for more details see e.g. Britz and Witzke, 2014). Regarding the policies, the reference scenario assumes the introduction of new direct payments as adopted by the 2013 CAP reform, but without CAP greening.

The *Greening scenario* considered in this paper models the CAP greening, while keeping the direct payments and other policies as defined in the reference. Adding greening requirements on the top of the reference allows to identify the impact of CAP greening.[3]

5. Modelling CAP greening

The modelling of crop diversification measure in CAPRI employs a methodology developed by Britz et al. (2012). It is based on the Shannon index using single farm records from the FADN and the CAPRI's farm type module. This measure targets crop allocations at the farm level and thus is subject to a strong aggregation bias if regional or country data are used. Regional- or country-level models seriously underestimate the impacts of this measure. CAPRI reduces the aggregation problem through modelling farm types at NUTS 2 level. However, modelling the crop diversity measure solely based on the farm-type module in CAPRI still underestimates the effect (Britz et al. 2012, 2013).

In order to address the aggregation bias, we combine single FADN farm records for 2008 with the farm types in CAPRI. The single FADN records and farm types in CAPRI are linked through the Shannon diversity index.[4] The Shannon index approach has the advantage of measuring crop diversity by transforming the crop structure of a given farm to one single indicator. After having derived Shannon index for single farm observations in FADN, it can be easily transferred to the farm types in CAPRI, which are also developed based on FADN data. A second advantage is that it captures the effects of both key elements of the crop diversity measure, i.e. the number of crops and the (in)equality of crop shares on the land. The main disadvantage of this approach is that the Shannon index does not link specific crops between the individual FADN level and the CAPRI farm-type level, as a result of which the information on which crops are most affected by the measure is lost.

We set the area of permanent grassland to be maintained in the greening scenario at a weighted average of the 2008 base year area and the 2025 reference scenario area. We assume that it would more or less reflect the amount of permanent grasslands around 2015. Neglecting some peculiarities, 2015 is the reference year established in the CAP regulation to determine the reference ratio of grassland to total agricultural area.

[3] In line with most studies on CAP greening, we assume full compliance of the greening measures without allowing farmers (farm types) to trade-off between income reduction with full compliance versus direct payment reduction as a consequence of a partial or full non-compliance.

[4] The index is defined as follows: $H = \sum(i,N)\, p_i \log(p_i)$, where H is the value of Shannon index, i is the index for crops, N is the number of crops and p is the share of a given crop on total arable land.

The EFA considered in the greening scenario (within the 5 % of the eligible area) includes fallow land, voluntary set-aside, N-fixing crops and cover crops, with their corresponding weights as defined in the CAP regulations (EU, 2014a, 2014b). Cover crops are allowed for crops with no winter cover. We consider variation of areas eligible for EFA between MS as implemented in 2015 given that under the EU regulation MS are given flexibility to select which land elements qualify for EFA (EU, 2013; European Commission 2016). As data for landscape elements eligible for EFA are not available we do not consider them when modelling an EFA in CAPRI.

6. Modelling the environmental impacts of CAP greening

CAPRI calculates several agri-environmental indicators at regional (NUTS 2) level, specifically nutrient balances and GHG and ammonia emissions. The calculation of further indicators (mainly soil erosion and biodiversity-friendly farming practices (BFP)) is possible, requiring additional information on local environmental conditions. These indicators are calculated at high spatial resolution, for so called homogeneous spatial mapping units (HSMU) defined with homogeneous characteristics regarding e.g. soil, climate, altitude (Leip et al., 2015).

CAPRI production outputs, such as crop area and livestock densities at a geographical resolution of NUTS 2 region are distributed on the spatial units using a combination of statistical and geographical information system (GIS) techniques (e.g. Lamboni et al., 2015). As a last step, the nitrogen (N) budget is calculated for each crop-spatial unit combination or simulation entity (Leip et al., 2011), making sure that crop needs plus over-fertilisation equals the total input by mineral and organic fertilisers, biological N fixation, atmospheric deposition or any other source of N. The database obtained is used to calculate a large array of agri-environmental indicators. For analysis, the indicators calculated at HSMU level can be aggregated for NUTS 2 regions or specific geographic areas, e.g. nitrate vulnerable zones.

The environmental impact assessment of greening measures is based on the following indicators (i) Greenhouse gas (GHG) emissions, (ii) Nutrient (NPK) budgets/nutrient surplus, (iii) Ammonia (NH_3) emissions, (iv) Soil erosion by water and (v) Biodiversity-friendly farming practices (BFP) index.

7. Economic impacts of CAP greening

7.1. Land-use effects

In general, the EU level impacts of CAP greening on aggregate land use categories (grassland, arable land and UAA) are relatively small, ranging from – 0.5 % to 3.7 %. To comply with the grassland measure (i.e. maintain reference area) farmers need to compensate for the decreasing historical trend in grassland areas, e.g. by converting arable to grassland. The EFA restriction, on the other hand, forces farmers to expand the eligible land use activities, partially by bringing additional land to agriculture. The above two impacts are indeed reflected in the simulation results as the main land allocative effect in absolute terms of the greening scenario leading to an expansion of permanent grassland and fallow land at the expense of arable land. The additional area needed to comply with the grassland and EFA measures comes to a large extent from the conversion of arable area but partially also from increasing UAA. The combination of greening requirements induces an increase in grassland by 2.7 % in EU-28, while arable area declines by 0.3 % relative to the reference. Fallow land increases by 23.3 % in EU-28, however, from a relatively low initial level (representing only 4.3 % of the UAA in the reference). Note that the EFA effect on fallow land is likely overestimated in our simulations as we do not take into account all landscape elements eligible for EFA.

Different farm types are affected heterogeneously by CAP greening depending on the initial land use patterns. Farms specialising in cereal and field crops (e.g *cereals, oilseed and protein crops*, *general field and mixed cropping*) adjust their grassland areas more than other farm types in the EU-28. With respect to impacts on arable land, farms specialising in *cattle-dairying -rearing and fattening*, *sheep, goats and other grazing livestock* and *mixed livestock holdings* are the most affected. Concerning the impacts on fallow land the picture is rather heterogeneous. Overall, two thirds of farm types increase and one third of farm types decrease fallow land due to CAP greening. Concerning the changes in UAA, the largest increase (between 0.7 % and 0.9 %) is observed in farms specialising in *cereals, oilseed and protein crops*, *dairying*, *sheep, goats and other grazing livestock*.

Not only farm specialization but also farm size has an impact on the results. With regard to the impacts on grassland and fallow land, larger farms (> 100 ESU) are more affected by CAP greening (in relative terms) than smaller ones. On the other hand, smaller farms tend to be more affected with respect to the changes in arable land. Interestingly, the greening impacts on UAA seem to have little correlation with the farm size classes. Smaller and larger farms tend to be affected equally by CAP greening.

The above discussed aggregate results can be broken down to more detailed cropping area impacts.. The greening restrictions force farms to increase fodder area in the EU-28 by 0.5 % and pulses by 4.2 %, while cereal and oilseed areas decrease by 1.7 % and 1 %, respectively. Land allocated to other arable crops changes only by 0.4 %, and the area of vegetables and permanent crops is not affected.

7.2. Production effects

The production effects of CAP greening compared to the reference are very limited for the EU-28, varying between – 1 % and 0.2 %. The exception is pulses, which, similar to area, reports a more sizable production increase of 3.5 %. As expected, the production of cereals, oilseeds, other field crops, fodder and pulses show a larger change relative to other production activities as these activities are in particular targeted by crop diversification, the EFA and the maintenance of permanent grassland requirements, respectively. The lower cereal production and the resulting higher cereal prices (see below), imply also higher feed costs, resulting in a small decrease in livestock production ranging from 0.1 % for milk to 0.2 % for meat.

At farm-type level the production effects are larger but for most products the changes are still relatively low, varying by ± 4 % relative to the reference in the EU-28. Again, larger effects (more than 4 %) are observed for pulses, which is a minor production activity in the reference in many farm types (e.g. *cattle- dairying -rearing and fattening*, *vineyards* and *olives*).

The Greening causes sizable relative changes in a certain production activity nearly always exclusively only in farm types, in which the respective activity is of minor relevance e.g. arable crops in *cattle- dairying -rearing and fattening* or *mixed livestock holdings*). Despite the fact that the relative changes might be sizeable, their contribution to the aggregate change in production quantity at the EU level is generally negligible.

7.3. Price and income effects

CAP greening measures tend to reduce the supply of primary agricultural products by taking land out of production and by reducing farm productivity (due to land-reallocation). At the same time, assuming inelastic demand for most agricultural commodities, output prices increase. The magnitude of the price effects is similar to the changes in production but with an opposite sign: small production responses induce rather small price adjustments. At the

EU aggregate level agricultural commodity prices only change between – 0.4 % and 1.6 % in the greenig scenario, relative to the reference.

The income changes caused by CAP greening are driven primarily by production effects and price changes.[5] As the price effect outweighs the production effect in most cases the farm income is increasing by 0.9 % in the EU-28. Within the greening measures EFA leads to the largest increase in income as it alters production and price levels the most.

The aggregate income results directly translate to a small increase in income for all farm types in the EU-28. Farms specialising in permanent crops and vegetables are less affected by CAP greening. Their increase in income is insignificant because prices and production in which they specialise are hardly altered by CAP greening. In contrast, field cropping farm groups (*cereals, oilseed and protein crops*, *general field cropping*), mixed farms and livestock farms (*dairy farms*, *sheep, goats and other grazing livestock*) obtain a more sizable increase in income at the EU-28 level, but still below 3 %. With respect to farm size, middle-sized and large farms obtain a slightly larger income increase than small farms. These results could be due to the differences in specialization between large farms and small farms. Large farms tend to be specialised in capital intensive crop production such as cereal and oilseeds, whereas small farms tend to be specialised in labour intensive products such as fruits, vegetables and livestock (Kancs and Ciaian 2010). Given that prices of former products are affected (increase) more by CAP greening than prices of latter products, larger farms obtain higher income increase compared to smaller ones.

8. Environmental impacts of CAP greening

As seen in the previous sections, the greening measures globally (EU-28) result in smaller areas of cereals, oilseeds and fodder arable crops than the scenario (– 2.26 million ha). These areas shift mainly to grassland (1.55 million ha) and fallow land (0.8 million ha). Compared to the reference there is a small decrease in the number of animals for all animal types. All this is expected to have a positive effect on tvarious environmental indicators on the EU-28 level. The increase in fallow areas (+ 1.81 million ha) is stronger than the increase in total UAA (1.12 million ha). Therefore the cultivated area is declining. Whether the increased UAA will lead to a negative total effect on emissions, biodiversity and erosion will largely depend on how the fallows are managed. Additionally, there is a significant increase in the winter-cover catch crop, which will reduce soil erosion and reduce N losses.

The slight increase in yields for arable crops, including fodder crops (between 0.5 % and 0.75 % for main cereals), is associated with a small increase in fertilisation per cultivated hectares.[6] Nevertheless, the total production of arable crops decreases, driven by the area decrease. This leads to higher imports of cereals (682 580 t), and oilseeds (273 700 t) This means that the positive environmental impact of greening measures in the EU may cause negative secondary effect (leakage effect) outside the EU.

---

[5] Note that in greening scenarios we assume the same direct payments as in the reference scenario meaning that they do not impact farm income.

[6] Note that yields increase because the positive price effect of CAP greening increases land profitability which triggers an endogenous and upward adjustments of fertilizers' use and hence of arable crop yields (i.e. higher prices incentivise farmers to increase fertilizers' use which leads to higher yields) as well as because farmers move to higher yielding arable crops (e.g. cereals, oilseeds) as a response to the introduction of CAP greening (e.g. less productive land is left fallow to comply with for EFA).

8.1. Greenhouse gas emissions

The greening measures reduce the aggregate GHG emissions for the whole EU-28 sector by 0.20 %. This is mainly due to the EFA measure, inducing a decrease of 0.38 %. The grassland measure has the opposite effect, a relative increase by 0.25 %, due to the relative higher ruminant numbers induced by this measure. As emissions from changes in soil carbon due to land use changes (conversion of grassland to arable land or the use of organic soils) are not considered, the larger area of grasslands and fallow land might likely lead to a more significant reduction in the GHG emissions related to the agricultural sector than calculated. The reduction of the GHG emission is mostly (80 %) due to the reduction in animal numbers, and only 20 % is caused by changes in land based activities.

8.2. Nitrogen surplus

In general, the greening measures do not have a relevant impact on nutrient balances. In the greening scenario the total N surplus for the EU-28 increases compared to reference situation by 0.23 %. This effect can be explained by the declining N-efficiency and therefore increasing N-surplus on the cultivated areas (+0.42 kg / ha). As the relative increase in the N-surplus per cultivated ha (+ 0.63%) exceeds the decrease in the cultivated area (- 0.4%), the overall nitrogen surplus is increasing. The grassland measure results in a slightly higher surplus (0.34 %), which is partially offset by the decrease in the surplus caused by the EFA measure (– 0.05 %). Total N inputs and exports also decrease due to the decrease in cultivated area, but inputs increase per hectare of cultivated area. All these figures are too small to be relevant.

Even though biological N fixation could be expected to increase due to the expansion of the area of N-fixing crops, this is not the case in the CAPRI simulation results. The reason behind this is that the higher biological N fixation from increased area of pulses is more than offset by the decrease in the area of 'other fodder crops'. N-fixing crops include pulses (peas, beans, lupins), but also clover and alfalfa/lucerne. The CAPRI greening simulation only takes into account pulses as EFA N-fixing crops, but not N-fixing crops in grasslands nor those under 'other fodder crops'. The CAPRI category 'other fodder crops' includes different crops and mixes, but it is mainly composed of alfalfa / lucerne. However, 'other fodder crops' are responsible for 66 % of the total biological N fixation in the EU-28 in the reference, while grasslands account for 29 % of total biological N fixation and pulses only for 5 %. The non-inclusion of small grain legumes under EFA N-fixing crops results in an overestimation of the pulses area and its production in the greening scenarios at the expense of underestimated 'other fodder crops' area and total biological N-fixation.

8.3. Ammonia emissions

Total NH_3 emissions are slightly lower in the greening scenario than in the reference in the EU-28 (– 0.33 %), mainly due to the impacts of EFA measures: substitution of field crops by fallow land, increase in N-fixing crops and lower number of animals. In fact, the EFA measure implies a decrease of 0.31 %, while the grassland measure results in a 0.1 % increase in NH_3 emissions. The crop diversification measure has hardly any effect on the NH_3 emissions.

Despite the overall marginal effect of the greening measures on ammonia emissions, the emissions decrease per ha can reach 4 % in some regions with high cattle density. This decrease is mainly due to the EFA measure, the increase in fallow land resulting in a decrease in crops (cereals and oilseeds) and fodder areas, with the subsequent decrease in ammonia from mineral fertilizer. In some of these regions the decrease in cereals and fodder areas leads to a decrease in animals, mainly pigs, with the corresponding decrease in ammonia from manure.

8.4. Soil erosion

While pasture and grassland strongly protect the soil from erosion, fallow land only does so if it has some green cover. Otherwise, if fallow land is left ploughed, disced or tilled, erosion can be higher than for most crops. Given that no information on the cover of fallow land is available (except where the standards on good agricultural and ecological conditions (GAEC) require certain practices[7]) we assume that it is ploughed every year in most countries. For this reason, we likely overestimated the erosion calculated on fallow land.

Consequently, the greening scenario results show that potential soil erosion in the EU-28 is slightly increasing by + 1.2 %. This is due to both the increase in total UAA, and the increase in the average erosion per hectare (+0.56%). The increase in the erosion per hectare is due to the additional fallow land area (+ 0.8 million ha), which offsets the beneficial effect of the increase in cover crops and in fodder areas. As expected, the grassland measure implies a small decrease in per hectare soil erosion (– 0.4 %) due to the increase in grassland relative to the reference situation, but the increase in UAA in this scenario offsets the per hectare decrease. The crop diversification measure has no impact on soil erosion.

8.5. Biodiversity-friendly farming practices (BFP)

Significant changes in the BFP indicator cannot be expected in the light of the land-use, production and environmental effects discussed in the previous sections. Particularly so because (1) the Shannon index did not increase significantly due to the limited land use impacts; (2) the N use did not change significantly; and (3) grassland shares only slightly increase at the aggregated level.

The BFP indicator shows a very small increase in the greening scenario of 0.06 points in the 1 to 10 scale (+ 0.6 %) in the EU-28. This positive impact is mainly caused by the EFA requirements. However, the effect might be underestimated as the BFP does not catch the pronounced positive effect fallow has on the biodiversity in intensively managed agricultural areas (e.g. Pywell et al., 2015, Tscharntke, 2011).

Changes at regional level are also rather small, lower than 0.5 index points. The highest increases are observed mainly in central and north-western Europe (Austria, Germany, northern Italy and France). In central Spain where the index decreases, the greening scenario leads to more cereals and less fallow. This is corroborated by the increase in total nitrogen fertilisation observed in those regions. The opposite effect takes place for example in Denmark, where the total nitrogen fertilisation of arable crops declines. The positive effect of fallow land and N-fixing crops is caused by EFA, while the grassland measure shows a negative impact of slightly higher livestock density in some regions. The crop diversification measure shows mixed effect, with a small positive impact in a few regions due to the higher crop richness and crop diversity, together with lower fertilisation as a consequence of higher fallow land in those regions.

[7] Green cover in fallow land and set-aside has been taken into account for the calculation of soil erosion only in those countries where GAEC requires it. The GAEC database managed by the JRC has been used for this purpose.

9. Conclusions

This is the first paper analysing both economic and environmental impacts of CAP greening as introduced by the 2013 CAP reform. We employ the CAPRI partial equilibrium model to simulate the quantitative impacts. The advantage of CAPRI compared to other modelling approaches is its EU-wide coverage, its ability to take into account the heterogeneity in farm production systems and to model environmental effects and market (price) feedback of the simulated policy scenario.

The economic and ecological impacts of CAP greening are rather limited, although some farm types or MS may face higher changes. The simulated changes for aggregated land-use categories (grassland, arable land and UAA) vary between – 0.5 % and 3.7 % relative to the reference level, while the land-use changes for the main crop activities (e.g. cereals, oilseeds) range between – 1.7 % and 4.2 % in the EU-28. The exception is fallow land, which is more significantly affected by the CAP greening (23 %). The simulation also reveals that CAP greening leads to a slight increase in the utilised agricultural area (around 0.6 % in the EU-28), meaning that farmers partially alleviate the impact of greening requirements by bringing new land into cultivation or by accounting it as EFA.

Similar to area changes, the production effects of CAP greening are very limited, varying between – 1 % and 0.2 % in the EU-28. The exception is the cultivation of pulses, with a production increase of 3.5 %. Production across different farm types is heterogeneously affected by CAP greening, depending on the current land-use structure. Simulation results show that CAP greening will lead to a small increase in prices in parallel with the decrease in production.

Farm income slightly increases (0.9 %.) in the EU-28 as the price effects offset the production decline observed across several sectors. As expected, there is a more sizable increase in incomes at EU-28 level for farms specialising in arable field cropping and in mixed farms and livestock farms, but the income increase is still below 3 %.

Similarly to economic effects, the environmental impacts of CAP greening are limited. In general, the positive effect due to the decline in the cultivated areas is counteracted by the effects of the market feedback intensification of the remaining cultivated area and the increasing UAA. Effects at EU level are generally positive on a per hectare basis, but the increase in UAA can reverse the sign of total impacts of CAP greening. The crop diversification measure is inducing the smallest effects. The grassland measure has positive effects on soil erosion but its effects on other indicators are mixed, as it sometimes implies an increase in animal numbers or is balanced by a decrease in fodder crops. The EFA measure has a positive impact on most indicators; only for soil erosion its effect is heterogeneous.

GHG emissions decrease on average by – 0.2 % in the EU-28. The total N surplus increases marginally by + 0.2 %. This increase, however, is driven by the increase in UAA, as the per ha surplus decreases by 0.4 %. Ammonia emissions benefit from all three measures, resulting in a 0.3 % decrease.

Changes in soil erosion are limited in the EU-28, but their assessment is sensitive to the assumed soil management practices on fallow land. As these practices are not known at the required geographical resolution and scale, the impacts on soil erosion are difficult to simulate. If a high share of the fallow land is annually ploughed this could offset the beneficial effect of increased grassland on soil preservation. The greening measures have limited effect on BFP. While the crop diversity and grassland measures show almost no impact on the index, the EFA measure shows a small positive impact (+ 0.05) due to the lower N input from fallow land and N-fixing crops.

Based on the simulated impacts, we can conclude that the introduction of the greening measures in the CAP does not lead to significant increase in environmental benefits, in general. Complying with the greening requirements does not put a significant additional economic burden on farmers, at the aggregate level. But the devil is, as always, in the details. The regional allocation of environmental and economic impacts is uneven. The simulation results were able to identify regions with a more significant environmental and/or economic impacts, and farm types that are more exposed to greening impacts. Further analysis at a more disaggregated geographical or farm structure level (e.g. farm models) should not be neglected.

Despite the comprehensiveness of the analyses, the findings of this paper have to be considered with some caution on account of the model's assumptions. First, the model does not model individual farms but only farm types. Second, the modelled greening scenario does not take into account all landscape elements eligible for EFA. Third, alfalfa and clover have not been taken into account as an EFA N-fixing crop. Fourth, the reference area for the grassland measure is based on the reference and on base year areas, which may depart from the reference area as established in the CAP regulations. Fifth, the criteria for exemption from CAP greening are not fully accounted for in the CAP greening scenarios (e.g. small farms exemptions). Sixth, the lack of information on farm practices results either in over- or underestimation of some environmental impacts. A careful analysis of each of these limitations to the current model is needed to test the robustness of these results and to provide a complete picture of the EU-wide impact of the CAP greening simulated in this paper. Despite these limitations, the paper shows the potential implications of CAP greening, and in particular it indicates its key economic and environmental effects in the EU.

10. References

Bartolini, F., G. Brunori and O. Gava (2014). "Assessing the ex-ante impact of the CAP post 2013 reform on land market. A case study in Tuscany region." In: G. Marotta and C. Nazzaro (eds), *CAP 2014-2020: Scenarios for European Agri-Food and Rural Systems*, Proceedings of the 51st SIDEA Conference, Benevento (Italy), 8-20 September 2014, pp. 81-88.

Britz, W. and T. Hertel (2011). 'Impacts of EU biofuels directives on global markets and EU environmental quality: an integrated PE, global CGE analysis', *Agriculture, Ecosystems & Environment*, Vol. 142, Nos 1-2, pp. 102-109.

Britz, W., M. Himics, A. Gocht, J. Helming, B. Allen, J.M. Terres, M.L. Paracchini (2012). "Impact assessment of scenario – CAP reform proposal 2011." Deliverable D6.3 of the FP7 project "Common Agricultural Policy Regionalised Impact – The Rural Development Dimension (CAPRI-RD)".

Britz, W., P. Ciaian and J.M. Terres (2013). "CAPRI baseline and greening scenario - CAPRI-RD." Presentation of the CAPRI-RD results at the DG AGRI Seminar, 27 June 2013, Brussels: European Commission.

Britz, W. and Witzke, P. (2014), *CAPRI model documentation 2014: Version 2* (http://www.capri-model.org/docs/capri_documentation.pdf).

Brown, M., Jones J. (2013). 'The predicted impacts of the proposed greening measures of the 2014 CAP reform on farming businesses in north Cornwall', paper presented at the 87th Annual Conference of the Agricultural Economics Society, University of Warwick.

CAPRI-RD (2013). 'Common Agricultural Policy Regionalised Impact – The Rural Development Dimension (CAPRI-RD)'. FP7 project, European Commission (http://www.ilr.uni-bonn.de/agpo/rsrch/capri-rd/caprird_e.htm).

Czekaj, S., Majewski, E. and Was, A. (2014), 'The impact of the "greening" of the common agricultural policy on the financial situation of Polish farms', *Problems of Agricultural Economics*, No 4, pp. 105-121.

Cortignani, R. Severini, S. and Dono, G. (2017), 'Complying with greening practices in the new CAP direct payments: An application on Italian specialized arable farms ', *Land Use Policy* 61, 265–275.

EU (2013), Regulation No 1307/2013 of the European Parliament and the Council establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009, *Official Journal of the European Union* L 347/608.

European Commission (2016), *Direct payments: Basic Payment Scheme*, European Commission, Directorate-General for Agriculture and Rural Development, Brussels.

European Commission (2016). “Review of greening after one year.” Commission Staff Working Document SWD(2016) 218, European Commission.

Gocht, A. and Britz, W. (2011), ‘EU-wide farm type supply models in CAPRI — How to consistently disaggregate sector models into farm type models’, *Journal of Policy Modeling*, Vol. 33, No 1, pp. 146-167.

Gocht, A., Britz, W., Ciaian, P. and Gomez y Paloma, S. (2013). ‘Farm type effects of an EU-wide direct payment harmonisation’, *Journal of Agricultural Economics*, Vol. 64, No 1, pp. 1-32.

Gocht, A., P. Ciaian, M. Bielza, J.M. Terres, N. Röder, M. Himics, G. Salputra (2016a). "Economic and environmental impacts of CAP greening: CAPRI simulation results." *JRC Technical Reports* (JRC102519), Joint Research Centre, European Commission.

Gocht, A., P. Ciaian, M. Bielza, J.M. Terres, N. Röder, M. Himics, G. Salputra (2016b). "EU-wide Economic and EnvironmentalImpacts of CAP Greening with HighSpatial and Farm-type Detail." *Journal of Agricultural Economics* Forthcoming.

Heckelei, T., R. Mittelhammer and T. Jansson (2008). ‘A Bayesian alternative to generalized cross entropy solutions for underdetermined econometric models’, *Food and Resource Economics* — discussion paper 56973 (2), University of Bonn.

Himics, M., Ciaian, P., Van Doorslaer, B. and Salputra G., (2013), ‘Management guidelines for the CAPRI baseline’, deliverable D4.8, FP7 project ‘Common agricultural policy regional impact — the rural development dimension (CAPRI-RD)’ (http://www.ilr.uni-bonn.de/agpo/rsrch/capri-rd/docs/d4.8.pdf).

Kancs, D. and Ciaian, P. (2010). ‘Factor content of bilateral trade: the role of firm heterogeneity and transaction costs,’ *Agricultural Economics* Vol. 41, No 13-4, pp. 305-317.

Lamboni, M., Koeble, R. and Leip, A. (2015). ‘Multi-scale land-use disaggregation modelling: concept and application to EU countries’, *Environmental Modelling & Software*, Vol. 82: 183-217.

Leip, A., Bielza, M., Bulgheroni, C., Ciaian, P., Lamboni, M., Koeble, R., Paracchini, M.-L., Terres, J.-M., Weiss, F. and Witzke, H.-P. (2015), ‘Spatially explicit evaluation of the agri-environmental impact of CAP’, paper presented at the IAAE Congress, Milan, Italy, 9-14 August 2015.

Leip, A., Busto, M. and Winiwarter, W. (2011), ‘Developing spatially stratified N_2O emission factors for Europe’, *Environmental Pollution*, Vol. 159, No 11, pp. 3223-3232, doi:10.1016/j.envpol.2010.11.024.

Louhichi, K., Ciaian, P., Espinosa, M., Colen, L., Perni, A. and Gomez y Paloma, S. (2015), ‘The impact of crop diversification measure: EU-wide evidence based on IFM-CAP model’, paper presented at the IAAE Congress, Milan, Italy, 9-14 August 2015.

Mili, S., L. Júdez, R. de Andrés (2015). "Effects of New CAP Reform and Trends in Sustainable Olive Growing Systems in Southern Spain." Paper presented at the EAAE 2015 Congress, 8-14 August, 2015 Milan, Italy.

Matthews, A. (2013). "Greening agricultural payments in the EU’s Common Agricultural Policy." *Bio-based and Applied Economics* 2(1): 1-27, 2013.

Mahy, L., Dupeux, B., Van Huylenbroeck, G. and Buysse J. (2015), ‘Simulating farm level response to crop diversification policy’, *Land Use Policy* 45, 36–42.

Pywell, R., Heard, M., Woodcock, B., Hinsley, S., Ridding, L., Nowakowski, M. & Bullock, J. (2015). 'Wildlife-friendly farming increases crop yield: evidence for ecological intensification.' Proceedingsofthe Royal Society B: Biological Sciences, 282(1816).

Röder, N., Gocht, A. and Laggner, B. (2016). 'Farm level modelling of CAP Greening.' Final deliverable of the JRC project '*Farm level modelling of CAP Greening*.' Braunschweig: Institute of Farm Economics - Johann Heinrich von Thünen Institute and JRC - European Commission.

Shrestha, S., Ciaian, P., Himics, M. and Van Doorslaer, B. (2013), ‘Impacts of climate change on EU agriculture.’ *Review of Agricultural and Applied Economics*, Vol. 16, No 2, pp. 24-39.

Solazzo, R., and Pierangeli, F. (2016) 'How does greening affect farm behaviour? Trade-off between commitments and sanctions in the Northern Italy’, *Agricultural Systems* 149: 88–98.

Tscharntke, T.; Batary, P.; Dormann, C.F. (2011), 'Set-aside management: How do succession, sowing patterns and landscape context affect biodiversity?' *Agriculture, Ecosystems and Environment* 143, 37-44.

van Zeijts, H., K. Overmars, W. van der Bilt, N. Schulp, J. Notenboom, H. Westhoek, J. Helming, I. Terluin and S. Janssen (2011). “Greening the Common Agricultural Policy: Impacts on Farmland Biodiversity on an EU Scale.” Policy Studies, The Hague: PBL Netherlands Environmental Assessment Agency.

Vosough-Ahmadi B., S. Shrestha, S.G. Thomson, A.P. Barnes And A.W. Stott (2015). "Impacts of greening measures and flat rate regional payments of the Common Agricultural Policy on Scottish beef and sheep farms." *Journal of Agricultural Science*, 153: 676-688.

Table 1: The impact of CAP greening on land-use change for grassland and fallow land in EU-28 (1 000 hectares and % change to reference)

	Reference	GREEN
	1 000 hectares	*% to reference*
Grassland	58 485	2.7
Fallow land	7 767	23.3
Arable land	122 652	– 0.3
Utilised agricultural area	181 136	0.6

Table 2: The impact of CAP greening on land-use change for selected production sectors in EU-28 (1 000 hectares and % change to reference)

	Reference	GREEN
	1 000 ha	*% to Reference*
Cereals	57 137	– 1.7
Oilseeds	13 468	– 1.0
Pulses	1 264	4.2
Other arable crops	6 098	0.4
Vegetables and permanent crops	14 055	0.0
Fodder activities	82 612	0.5