European Commission

JRC TECHNICAL REPORTS

Economic and environmental impacts of CAP greening

CAPRI simulation results

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2016

EUR 28037 EN

Joint Research Centre

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JRC Science Hub

https://ec.europa.eu/jrc

JRC102519

EUR 28037 EN

PDF ISBN 978-92-79-60682-3 ISSN 1831-9424 doi:10.2788/452051

Luxembourg: Publications Office of the European Union, 2016

How to cite: Gocht, A., Ciaian, P., Bielza, M., Terres, J. M., Röder, N., Himics, M., Salputra, G., *Economic and environmental impacts of CAP greening: CAPRI simulation results*, EUR 28037 EN, Joint Research Centre, European Commission, 2016, doi:10.2788/452051.

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List of abbreviations

BFP	biodiversity-friendly farming practices
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Impact Modelling System
CDP	coupled direct payments
EU	European Union
EU-15	Belgium, Luxemburg, Denmark, Germany, Austria, Netherlands, France, Portugal, Spain, Greece, Italy, Ireland, Finland, Sweden, United Kingdom,
EU-13	Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovenia, Slovakia, Cyprus, Malta, Croatia, Bulgaria, Romania
Eurostat	Statistical Office of the European Union
FADN	Farm Accountancy Data Network
FSS	Farm Structure Survey
GAEC	good agricultural and environmental condition
GHG	greenhouse gases
GIS	geographical information system
GNB	gross nutrient balance
GNS	gross nutrient surplus
GWPA	global warming potential of agriculture
HSMU	homogeneous spatial mapping units
LFA	less favoured areas
MS	Member States
N	nitrogen
NH_3	ammonia emissions
HNV	high nature value
NUTS 2	regions belonging to the second level of the Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Cooperation and Development
RDP	rural development programme
SE	simulation entity
SO	standard output
SMR	statutory management requirements
UAA	utilised agricultural area

Economic and environmental impacts of CAP greening: CAPRI simulation results (1)

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Abstract

In this report we analyse the economic and environmental impacts of CAP greening introduced by the 2013 CAP reform. We use the CAPRI farm-type layer, an extension of CAPRI by farm group module capturing farm heterogeneity across the EU. Its main advantage in the context of our analysis is that it allows the current implementation of the CAP greening measures to be depicted in high detail, while also capturing the environmental effects and the market feedback of the simulated policy changes. The simulated results reveal that the economic impacts (land use, production, price and income changes) of CAP greening are rather small, although some farm types, sectors (fallow land and pulses) or Member States may be affected more significantly. Simulation results show that the CAP greening will lead to a simultaneous small increase in prices and a small decrease in production. The latter impact is due to the greening obligations that require farms to take out of production a small share of land and to the slight reduction in farm productivity driven by the land reallocation effects of greening measures. Farm income slightly increases because the price effects offset the production decline. The results indicate that EFA and grassland measures tend to induce slightly higher economic effects relative to the crop diversification measure, nevertheless some variation across crops and economic indicators is observed. Similarly to economic effects, the environmental impacts of CAP greening are small, although some regions may see greater effects than others. In general, effects at EU level are positive on a per hectare basis, but the increase in UAA can reverse the sign for total impacts. Overall, simulated GHG and ammonia emissions decrease in the EU, while the total N surplus, soil erosion and biodiversity-friendly farming practices indicator slightly increase due to the CAP greening. The crop diversification measure tends to have the lowest environmental impacts, while the grassland measure has mixed (both positive and negative) effects on the reported environmental indicators. The EFA measures have positive impacts on most environmental indicators, except for soil erosion.

Key words: CAP reform, CAP greening, crop diversification, maintenance of permanent grassland, ecological focus area, EU, economic and environmental impacts, CAPRI, farm types.

1. Introduction

In 2013 the common agricultural policy (CAP) underwent substantial reform, changing both the implementation and the level of direct payments (EU 2013; European Commission 2013b; European Commission 2016). With the aim of strengthening the

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(1) The modelling and analytical framework of CAP greening on which this report 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; 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.

environmental performance of farming sector, the reform introduced 'agricultural practices beneficial for the climate and the environment' (so-called CAP greening). CAP greening includes three measures: crop diversification, maintenance of permanent grassland and ecological focus area (EFA). The greening measure is a mandatory component of direct payments: all farmers that receive direct payment (i.e. the Basic Payment Scheme) must also comply with the greening measures.

The main objective of this report is to analyse the potential economic and environmental impacts of CAP greening. The analysis is based on simulations with the Common Agricultural Policy Regionalised Impact (CAPRI) model (Gocht and Britz, 2011; Britz and Witzke, 2014). The main advantage of CAPRI is that it models farm types in the EU, which allows the capturing of farm heterogeneity in terms of the specialisation and size of farming systems across EU regions. Capturing farm heterogeneity is a necessary prerequisite to be able to model CAP greening impacts, given that the implementation of the greening measures strongly depends on farm characteristics. The advantage of CAPRI compared to other farm type models (e.g. the AROPAj system, Baranger et al., 2008; Farmis, Offermann et al., 2005) is its EU-wide geographical coverage that allows for the simulation of policy impacts across all EU regions. Furthermore, CAPRI simulates the market interaction of farm types and calculates key environmental indicators that allow to model the impacts of CAP greening both on the agricultural commodity markets and on the environment.

There is a growing number of studies analysing the impact of CAP greening on the agricultural sector. Most studies, however, have only limited coverage of the greening measures and they usually focus only on specific agricultural sectors and selected Member States (MS)/regions, model a specific greening measure and/or provide selected impacts. Often the studies investigate the reform proposal and not its actual implementation. For example, studies have analysed the impact of CAP greening in selected EU regions (e.g. Solazzo et al. 2014, Vanni and Cardillo 2013 and Cimino et al. 2015 for Italian farms; Brown and Jones 2013 for north Cornwall in the United Kingdom; Mahy et al. 2014 for Flanders in Belgium; Czekaj, Majewski and Was 2014 for Polish farms), the EU-wide economic effects of selected greening measures (e.g. Louhichi et al. 2015 for crop diversification measures) and the environmental impacts of CAP greening for selected indicators (e.g. Leip et al., 2015). To our knowledge there are no studies providing a comprehensive analysis of the EU-wide economic and environment impacts of CAP greening.

The report is organised as follows. The next section provides a brief overview of the CAPRI model, which is followed by the section explaining the 2013 CAP reform and CAP greening. The fourth section presents the scenarios simulated in the report. The fifth section details the modelling of CAP greening, while sixth section describes the modelling of environmental impacts. The seventh section presents the simulated scenario results, while the last section concludes the report.

2. The CAPRI model

CAPRI is a global, spatial, partial equilibrium model specifically designed to analyse CAP measures and trade policies for agricultural products (Britz and Witzke, 2014). CAPRI consists of two modules, the highly detailed and disaggregated supply module for Europe and the global market module, which 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.

The supply module consists of non-linear programming models for the EU-28, the western Balkans, Norway and Turkey, which depict farming decisions in detail at the NUTS 2 level or at the level of farm types. The mathematical programming approach offers a high degree of flexibility in capturing important interactions between production activities and with the environment, as well as in modelling CAP and national policy measures. The programming models comprise low- and high-intensity variants for most crop and livestock activities, while a non-linear cost function captures the effects of capital and labour on farm behaviour.

The market module is a static, deterministic, partial, spatial model with global coverage, depicting about 60 commodities (primary and secondary agricultural products) and breaking the world down into 60 countries or country blocks, grouped into 40 trade blocks. The Armington approach, assuming that the products are differentiated by origin, allows the simulation of bilateral trade flows and of related bilateral and multilateral trade instruments, including tariff-rate quotas.

CAPRI's strengths are that it simulates results for the EU at sub-MS (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 GHG emissions from the agricultural sector, the impacts of direct payments schemes, the quota milk abolition, sugar quota reform, climate change, biofuel policies or bilateral trade policies (e.g. Blanco-Fonseca et al., 2010; Burrell et al., 2014; Leip et al., 2010; Britz and Hertel, 2011; Kempen et al., 2011; Gocht et al., 2013; Shrestha et al., 2013; Delincé et al., 2014).

2.1. Farm types in CAPRI

The introduction of farm-specific direct payment schemes as part of the CAP (e.g. the Single Payment Scheme) motivated the development of a farm-type module for CAPRI, which disaggregates the NUTS 2 regions of the EU into farm-type models. The farm-type module mainly 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 hence 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. The same economic optimisation principles are used as for the NUTS 2 models: 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, if applicable, to quotas and to set-aside obligations. Decision variables are crop acreages and total land use, herd sizes, fertiliser application rates and the feed mix. Direct payments available under the CAP are captured in detail. The allocation response rests largely on non-linear objective function terms, which are either econometrically estimated or derived from exogenously given supply elasticities (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]). Each single farm type is characterised by its specialisation and 'economic size class'. The module considers 39 farm types based on 13 production specialisations and three farm size classes (Table 1). The three economic farm size classes are defined as less than 16

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

'economic size units' (ESUs), between 16 and 100 ESUs and greater than 100 ESUs, where each ESU is equivalent to a gross margin of EUR 1 200. To reduce the model size and computational complexity, and to keep the database and model results at a manageable size, the only farm types that are explicitly modelled are those that are important according to two equally weighted criteria: livestock units (LUs) and utilised agricultural area (UAA). The rest of the farms are represented by an aggregated (residual) farm type. Overall, there are 2 450 farm types in CAPRI: 2 200 are explicitly distinguished by production specialisation and size class, while the remaining farm types (250) are aggregated into a residual farm type.

The farm-type layer (i.e. the simulation models for the 2 450 farm types) is fully integrated with the overall CAPRI structure. Farm types are made fully consistent with regional statistics regarding production quantities, activity levels and input use. The top-down consistency of the farm-type layer ensures a harmonised data set across regional scales and farm types. The top-down data consistency integrates the farm-type models into the overall system, ensuring also their interoperability with the global partial equilibrium market model.

Table 1: Farm types in CAPRI

Farm types by production specialisation	Farm types by economic size class
Specialist cereals, oilseed and protein crops	< 16 ESU ≥ 16 ≤ 100 ESU > 100 ESU
General field cropping and mixed cropping	
Specialist horticulture	
Specialist vineyards	
Specialist fruit and citrus fruit	
Specialist olives	
Various permanent crops combined	
Specialist dairying	
Specialist cattle and dairying rearing, fattening	
Sheep, goats and other grazing livestock	
Specialist granivores	
Mixed livestock holdings	
Mixed crops-livestock	

Source: Gocht and Britz (2011) and Gocht et al. (2013)

3. The 2013 CAP reform

The CAP has undergone several major reforms since 1992, characterised by a move away from price support towards direct payments to farmers (Pillar I) and to payments for environmental services and regional development (Pillar II). In this paper we will focus on the implementation of Pillar I. In particular, the 1992 reform introduced coupled area and animal payments. These coupled payments replaced the previous price intervention mechanism. The 2003 CAP reform has progressively decoupled these payments from production and introduced decoupled payments, represented by the Single Payment Scheme (SPS) and the Single Area Payment System (SAPS). The decoupled payments are now by far the largest component of the CAP budget. The 2013 CAP reform maintained the decoupled payments as major policy instrument in the current 2014-2020 financial period, but linked them more closely with the provision of public goods and externalities (i.e. to CAP greening) (EU, 2013).

The CAP reform was negotiated at the time when EU and global economy faced a severe economic and financial crisis. These economic pressures affected the financial resources allocated to CAP. The overall CAP budget (including the direct payment budget) was reduced because of the fiscal austerity pursued within the EU. Another important element of the 2013 CAP reform that alters the availability of funds for direct payments is the possibility for MS to transfer funds between direct payments (Pillar I) and rural development programs (RDP) (Pillar II). MS may transfer up to 15 % of the respective annual ceiling between the Pillars. MS with an average direct payments per hectare below 90 % of the EU average are allowed to transfer up to 25 % of the RDP funds to direct payments (EU, 2013; European Parliament, 2015).

An additional element of the 2013 CAP reform that changes the allocation of direct payments between MS is the external convergence of direct payments. The aim of the external convergence is to rebalance the CAP support among MS. The external convergence partially harmonises the payments among MS; they are adjusted either upwards or downwards to bring them closer to the average EU level. More specifically, the national budgets of MS where the average payment (in EUR per hectare) is below 90 % of the EU average are gradually increased (by one third of the difference between their current rate and 90 % of the EU average). This convergence is financed proportionally by MS that have payment levels above the average EU level (EU, 2013).

The MS may provide special support for certain groups of farms and farming practices under the reformed CAP. With respect to farm specific payments the MS can choose among the following instruments: payments for young farmers, the small farmer scheme, payment for areas with natural constraints, and size dependent reallocation of payments. The payments for young farmers complement the decoupled payments and are mandatory. These payments are financed by up to 2 % of the direct payment funds. The small farmer scheme is a voluntary payment aiming to reduce administrative burdens and facilitate small farmers' access to direct payments. The payment for areas with natural constraints aims to support farmers performing their activities in naturally disadvantaged areas. MS may grant an additional payment of up to 5 % of the direct payment funds to farms located in areas with natural constraints. In order to generate a more equitable distribution of direct payments, the reform introduced a mandatory reallocation of funds from larger to smaller farms (EU, 2013; European Commission, 2015, 2016).

The 2013 CAP reform extended the availability of coupled direct payments (CDP). However, there are imposed strict budgetary ceilings for funds that can be allocated to coupled payments. In general, CDP cannot account for more than 8 % of the direct payment funds. They can be increased to 13 % limit in MS where the pre-reform coupled support was higher than 5 %. If the share in the pre-reform period exceeded 10 %, the MS may allocate more than 13 % of its national ceiling to coupled support provided that the European Commission gives its explicit authorisation. Furthermore, the share of direct payments allocated to CDP may be increased by an additional 2 % for the support granted to protein crops (EU, 2013; European Parliament, 2015, 2016).

3.1. CAP greening

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 EFA. The CAP greening takes up 30 % of the total direct payment funds. The greening conditions are similar to cross compliance, but are more demanding than the cross-compliance requirements. Not respecting these requirements may lead to a reduction of up to 1.25 times the Greening payments ([3])(EU, 2013; European Commission, 2015, 2016). ([4])

([3]) 30% of the national ceiling for Pillar I is devoted to the Greening. The Greening payment must be paid as

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 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 larger than 15 hectares to allocate at least 5 % of the farm's eligible area (excluding areas under grassland) to an EFA, with the possibility of increasing this percentage to 7 % subject to an evaluation review in 2017. The following area types that qualify as an ecological focus area: land left fallow, terraces, landscape features, buffer strips, agro-forestry, strips, areas with short rotation, afforested areas, catch crops and N-fixing crops (EU, 2013, 2014).

4. Scenarios

We simulate four greening scenarios alongside the reference scenario.

1. The reference scenario assumes the introduction of the 2013 CAP reform (i.e. new direct payments) without CAP greening. This scenario represents the counterfactual scenario for CAP greening scenarios.
2. The crop diversification scenario (CropDiv) assumes new direct payments as in the reference scenario and the implementation of the crop diversification measure.
3. The ecological focus area scenario (EFA) assumes new direct payments as in the reference scenario and the implementation of an EFA measure.
4. The maintenance of grassland scenario (GRAS) assumes new direct payments as in the reference scenario and the implementation of the maintenance of grassland measure.
5. The CAP greening scenario (GREEN) assumes new direct payments as in the reference scenario combined with all three greening measures.

4.1. Reference scenario

The reference scenario defines the baseline development of the agricultural sectors and thus serves as a comparison point for the counterfactual comparison of the greening scenarios. For the current report, the reference scenario captures developments in exogenous variables, such as policy changes, population growth, GDP growth and agricultural market development, for the year 2025. It relies on a combination of three information sources: (i) most importantly, the DG Agriculture and Rural Development baseline based on Aglink-Cosimo; (ii) analysis of historical trends; and (iii) expert information (for a detailed description, see Blanco Fonseca et al., 2010; Nii-Naate, 2011; Himics, et al., 2013; Britz and Witzke, 2014).

Expert information is introduced in the reference scenario first because the regional resolution of Aglink-Cosimo is limited to the EU-15 and EU-13 aggregates, and second to add detail beyond Aglink-Cosimo. The reference scenario integrates simulation results

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flat rate decoupled payment.

([4]) In order to avoid penalising those farms that already address environmental and sustainability issues, the 'greening equivalency' system is applied whereby the application of environmentally beneficial practices already in place is considered to replace the greening requirements.

from the Primes energy model for the biofuel sector (Capros et al., 2010). The three sources of information used for the reference scenario construction may be inconsistent in some aspects or violate basic technical constraints, such as crop area and/or young animal balances. Consequently, a Bayesian estimator treats all three information sources as a priori information and introduces the minimal necessary deviations to respect consistency requirements. The latter constitute the data information and encompass definitional and consistency relations, as well as plausible ranges for certain variables from a technological viewpoint.

Regarding the policies, the reference scenario assumes the introduction of new direct payments as adopted by the 2013 CAP reform, but without CAP greening. Among others, it includes the new decoupled payments, coupled support, the young farmer scheme, natural constraint payments, redistributive payments, the transfer of funds between pillars (between direct payments and RDPs), the external convergence of direct payments and overall CAP budgetary changes (EU budget cut). Adding greening requirements on the top of the reference scenario allows the impact of CAP greening to be identified (either for individual greening measures or for overall CAP greening depending on the greening scenario, see below).

4.2. CAP greening scenarios

The greening scenarios model the greening measure while keeping the direct payments and other policies unchanged (i.e. new direct payments) as defined in the reference scenario. ([5]) We simulate each greening measure separately to identify the contribution of each measure to the total effects, along with a scenario that combines all three measures. As explained above, the greening scenarios are defined as follows: (i) the crop diversification scenario (CropDiv), which assumes new direct payments and the implementation of the crop diversification measure; (ii) the ecological focus area scenario (EFA), which assumes new direct payments and the implementation of an EFA; (iii) the maintenance of grassland scenario (GRAS), which assumes new direct payments and the implementation the maintenance of grassland measure; and (iv) the CAP greening scenario (GREEN), which assumes new direct payments combined with all three greening measures.

5. Modelling CAP greening

Following Britz et al. (2012), the implementation of crop diversity measures in CAPRI is done through the Shannon index using the single farm records from the FADN. 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 would thus seriously underestimate the impacts of this measure. The reason is that the measure imposes restrictions on land allocation at farm level and its impact is farm specific. For example, highly specialised large farms may overshoot the upper threshold for crop shares and/or may also be required to introduce new crops if they have fewer than required. If however one aggregates the areas over farms in a given region, the crop diversity increases and will likely be in compliance with the requirements. As explained above, CAPRI reduces the aggregation problem through modelling farm types at NUTS 2 level. However, farm types in CAPRI represent aggregated farm groups over a large number of individual farms and thus significantly reduce farm heterogeneity across EU. Basing the analysis of the crop diversity measure solely on the farm-type module in CAPRI would still significantly bias the effects downward (Britz et al., 2012, 2013).

([5]) We assume farmers' (farm types) full compliance with the greening measures without allowing them to trade-off between income reduction with full compliance versus direct payment reduction as a consequence of a partial or full non-compliance. This assumption is in line with the EU CAP regulation which establishes the greening requirements as an obligation for farms receiving direct payments (EU, 2013).

In order to address the aggregation bias, single FADN farm records for 2008 were used. One of the main data sources used to develop farm types in CAPRI is FADN data, and there is a straightforward way to link the single FADN observations with farm aggregates in CAPRI. The single FADN records and farm types in CAPRI are linked through the Shannon diversity index (6). 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 for single farm observations in FADN, it can be easily transferred to the farm types in CAPRI. (7) 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.

The permanent grassland area to be maintained was set in the greening scenario at a weighted average of the 2008 base year area and the 2025 reference scenario area, assuming that it would more or less reflect the amount of permanent grasslands around 2012. This approach applies to all farm types with declining grassland trends in the reference scenario.

The EFA area 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. 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

A number of agri-environmental impacts are modelled in CAPRI at regional (NUTS 2) level, specifically nutrient balances and GHG and ammonia emissions. The calculation of other indicators (mainly soil erosion and biodiversity-friendly farming practices (BFP)) is also possible, but requires additional information on the local environmental conditions. This is why they are calculated at high spatial resolution level, on homogeneous spatial mapping units (HSMU) defined with homogeneous characteristics regarding soil, climate, altitude zone, etc. (Leip et al., 2015).

CAPRI production outputs, such as crop area and livestock densities, are simulated at farm-type level and then distributed on the spatial units (USU) using a combination of statistical and geographical information system (GIS) techniques (Kempen et al., 2005; Lamboni et al., 2015; Heckelei et al., 2008). As a last step, the nitrogen (N) budget is calculated for each crop-spatial unit combination or simulation entity (SE) (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 to NUTS 2 region level or to specific geographical boundaries, for example the nitrate vulnerable zone.

The following agri-environmental indicators have been used for the environmental assessment of greening measures.

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(6) 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 index increases with the number of crops and decreases in inequality of area distribution among crops.

(7) For more details on modelling the crop diversification measure in CAPRI see Appendix.

- Greenhouse gas (GHG) emissions. GHG emitted by agriculture are calculated in CAPRI according to IPCC (2006) methodologies and categories. The emissions estimated correspond to the main emission sources from agriculture: (i) CH_4 emissions from enteric fermentation from cattle; (ii) CH_4 and N_2O emissions from manure storage and management; (iii) N_2O emissions from agricultural soils. N flows in agriculture are calculated according to the Miterra model (Velthof et al., 2009). Emissions of CH_4 and N_2O are converted to total GHG emissions, expressed in CO_2 equivalent, using the global warming potentials of IPCC (2007). Emissions from agricultural used soils e.g. release of CO_2 due to the conversion of arable land to grassland or the agricultural use of organic soils are not considered in this study, as according to IPCC these emissions are not recorded in the source group agriculture but land use, land use change and forestry.
- Nutrient (NPK) budgets/nutrient surplus. The gross nutrient balance (GNB) lists nutrient (N, P or K) inputs into agricultural soils and nutrient outputs removed from the soil. The main result from the GNB is the gross nutrient surplus (GNS), which is calculated as the difference between total nutrient inputs and outputs (as defined by the OECD/Eurostat *Gross nitrogen balances handbook*). The surplus includes all losses to the environment from animal housing and manure management systems, grazing and soils ([8]).
  A persistent N surplus indicates potential environmental problems, such as ammonia emission (see below), N_2O (a potent GHG gas, see above) emissions or nitrate leaching (resulting in pollution of drinking water and eutrophication of surface waters). A persistent deficit indicates the risk of decline in soil fertility and reduced crop yields.
- Ammonia (NH_3) emissions. The agriculture sector is responsible for over 90 % of NH_3 emissions across the EEA-32 ([9]). NH_3 contributes to acid deposition and eutrophication, and contributes to the formation of particulate aerosols with adverse impacts on human health. Ammonia emissions are calculated from N balances. They increase with animal population, crop area and crop fertilisation intensity. They also depend on animal feed, animal housing and manure storage type.
- Soil erosion by water. Risk of soil erosion by water is calculated following the revised universal soil loss equation (RUSLE — Renard et al., 1997). The indicator predicts the potential average annual rate of erosion on a unit of land based on biophysical factors (rainfall pattern, soil type, slope length) and crop system and management practices. Of these factors, only the crop-management factors change with CAPRI output: crop areas and farming practices (currently only catch crop).
- BFP. The concept of biodiversity-friendly farming practices (BFP) refers to the causality between farming activity and its potential impact on biodiversity. It is closely linked to the concept of high nature value (HNV) farmland, but rather than identifying those areas where agriculture supports biodiversity, it scores (in a qualitative way) the degree to which any farming practices can support biodiversity, from a lower to a higher degree. BFP is a 0 to 10 index (10 being best practices for biodiversity) (Paracchini and Britz, 2010).

([8]) Currently, N soil stock changes cannot be quantified in CAPRI.
([9]) The EEA-32 country grouping includes countries from the EU-27 (Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom), the EFTA-4 (Iceland, Liechtenstein, Switzerland and Norway) and Turkey.

7. CAP greening impacts: simulation results

In this section we present the simulation results of CAP greening as introduced by the 2013 CAP reform. As explained above, we present the results of three scenarios that consider the three greening measures individually (CropDiv, EFA, GRAS) and a scenario that simulates the impact of all three measures combined (GREEN). The first three scenarios allow us to evaluate the importance of individual greening measures in affecting agricultural sectors, whereas the last scenario delivers the total effects of CAP greening. The greening simulation results are presented as changes compared to the reference scenario simulations in relative terms (mostly for economic impacts) or absolute values (mostly for environmental impacts).

7.1. Economic impacts of CAP greening

This section analyses the economic impacts of CAP greening. We report the simulation results for land use, production, prices and income.

7.1.1. Land-use effects

The allocation of land to different activities is steered in CAPRI by the profit-maximising behaviour of the farmer. If, compared to a reference scenario situation, a land-based activity is in breach of the greening requirements, the land allocated to this activity will decrease in favour of most profitable alternative activity. To further understand land-use impacts, it is important to note that CAPRI features an upward-sloping land-supply curve. This allows for land leaving and entering the agricultural sector and transformation between arable land and grassland in response to relative price or policy changes (Jansson et al., 2008). For example, changes in direct payments (e.g. due to the CAP reform) or output prices will lead to changes in marginal returns from agriculture. If marginal returns reduce, a part of the land ceases to be economically viable. The amount of land in agriculture will decrease. The reduction in the amount of land in agriculture ultimately depends on the slope of the land-supply curve and changes in marginal returns (Britz et al., 2012).

Table 2 and Table 3 show the impact of the greening scenarios on grassland, fallow land, arable land and UAA across EU aggregates and MS. Overall at EU level the impact of CAP greening on land aggregates (grassland, arable land and UAA) is relatively small, varying between – 0.5 % and 3.7 % in the GREEN scenario relative to the reference scenario. As expected, the main land allocative effect in absolute terms of the greening scenarios is an expansion of permanent grasslands and fallow land at the expense of arable area. The additional area needed to maintain the share of permanent grassland and fallow land (compared to the reference scenario) comes to a large extent from (cultivated) arable area and partially also from additional land brought into cultivation. The combined requirements of the three measures induce farms to increase grassland land in EU-28 by 2.7 %, while arable area declines by 0.3 % relative to the reference scenario. The fallow land increases by 23.3 % in EU-28, however, from a relatively low level in the reference scenario (fallow land accounts for 4.3 % of the UAA in the reference scenario). The impact of CAP greening in EU-15 and EU-13 largely follows the changes at EU-28 level. Generally speaking the area of fallow land is more responsive to the scenarios in the EU-15, while the increase of grassland and UAA is stronger in the EU-13.

As expected, the main measure causing a greater grassland area in the GREEN scenario is the maintenance of grassland (GRAS) measure. The crop diversification and EFA measures have a minimal impact on grassland as they target arable area rather than grassland. The impact of these two measures on grassland is only indirect. Farmers switch between grassland and arable land to fulfil the greater diversity and EFA requirements, as well as adjusting grassland, reflecting the changes in relative land returns. The arable area decrease in the GREEN scenario in the EU-28 is driven by the grassland measure, which more than offsets the impact of other two greening measures

(CropDiv, EFA). As expected, fallow land changes in the GREEN scenario are primarily driven by EFA, followed by grassland and crop diversification measures. Farms increase fallow land to respond to the EFA requirements to allocate land for ecological purposes. Note that the EFA effect on fallow land is likely overestimated as we do not take into account all land elements eligible for EFA (Table 2 and Table 3).

Enforcing higher shares of permanent grass and EFA, combined with the higher diversity requirements of CAP greening, reduces production and increases prices (see below), leading to a slight increase in profitability and returns to land from agricultural land use. Consequently, based on the land-supply curve implemented in CAPRI, it leads to a very slight increase in the utilised agricultural area relative to the reference scenario, but the effect is very small: 0.62 % in the EU-28, 0.46 % in the EU-15 and 0.97 % in the EU-13. The total agricultural area increase in the GREEN scenario appears to be mainly driven by the EFA and grassland measures, followed by the crop diversification measure (Table 3). However, the differences are very small. The increase in UAA due to CAP greening indicates that farmers partially alleviate the impact of greening requirements by bringing new land into cultivation or using it as EFA area.

The simulation results reveal that the land-use impacts of the greening scenarios vary slightly more between MS, reflecting the production structure and the relevance of the greening measures. As expected, the largest variation for the GREEN scenario is observed for fallow land, where the changes vary between – 6 % and 320 %. The fallow land depicts higher changes particularly in those MS where its reference scenario value is small (e.g. Belgium, France, Ireland, United Kingdom). The large heterogeneity of fallow land effects across MS is caused by the variation in the availability of other land elements eligible for EFA (N-fixing crops and cover crops). Also, grassland change is slightly more sizable across MS. The largest increase in grassland area in the GREEN scenario is found in Bulgaria, Cyprus, Denmark, Hungary, Finland, France, Malta, Lithuania, Poland, Slovakia and Sweden, increasing between 4 % and 8.6 %. For the rest of the MS, the grassland change varies between 0.67 % and 3.51 %. The change in arable area and UAA relative to the reference scenario is rather small in the GREEN scenario across MS, varying between – 1.85 % and 0.54 % and between 0 % and 1.63 %, respectively (Table 2 and Table 3).

Table 2: Land-use change for grassland and fallow land across EU aggregates and MS (1 000 hectares and % change to reference scenario)

	Grassland					Fallow land				
	Reference	EFA	CropDiv	GRAS	GREEN	Reference	EFA	CropDiv	GRAS	GREEN
	1 000 hectares	*% to reference*				*1 000 hectares*	*% to reference*			
EU-28	58 484.5	− 0.2	0.1	2.9	2.7	7 767.3	26.7	3.1	− 4.0	23.3
EU-15	44 025.5	− 0.3	0.0	2.6	2.3	5 569.5	27.5	3.6	− 5.7	24.0
EU-13	14 459.0	0.3	0.5	3.7	3.7	2 197.8	24.8	2.0	0.2	21.6
EU-15										
Belgium	547.5	− 0.2	0.0	3.0	2.9	7.8	337.2	28.2	− 15.4	320.5
Denmark	189.0	− 0.6	0.0	8.6	8.6	55.0	138.0	19.5	− 12.7	135.1
Germany	4 304.5	− 0.4	− 0.1	4.1	3.5	288.4	106.4	21.2	− 20.8	104.0
Austria	1 571.8	− 0.7	0.0	1.3	1.0	118.8	21.9	1.7	− 6.1	12.2
Netherlands	844.0	0.0	0.0	2.4	2.4					
France	8 758.5	− 0.5	0.0	4.8	4.2	339.8	182.6	35.0	− 28.6	176.3
Portugal	1 110.1	0.0	0.0	0.7	0.7	500.6	− 0.1	− 0.3	− 0.5	− 1.0
Spain	6 736.5	− 0.2	0.2	1.7	1.7	2 812.8	− 0.9	− 2.5	− 3.3	− 6.2
Greece	1 630.6	0.0	0.0	3.1	3.1	352.0	− 0.4	0.7	− 1.8	− 1.2
Italy	3 835.1	− 0.6	0.0	3.2	2.9	370.9	59.3	1.3	− 1.5	53.5
Ireland	3 481.5	0.0	0.0	0.7	0.7	8.2	184.1	35.4	− 37.8	174.4
Finland	43.3	0.0	0.0	4.2	4.2	343.5	2.3	− 0.1	− 0.1	2.1
Sweden	398.6	− 0.7	− 0.3	6.3	6.1	187.0	13.1	19.2	− 3.6	21.6
United Kingdom	10 574.5	− 0.4	0.0	1.3	0.9	184.6	119.4	17.4	− 13.5	127.1
EU-13										
Czech R.	1 062.0	− 0.1	0.2	0.7	0.7	79.2	80.4	0.1	− 0.1	76.8
Estonia	276.8	0.4	0.4	0.8	0.8	59.9	0.0	0.8	0.3	− 0.3
Hungary	868.2	− 0.4	0.2	7.1	7.2	162.9	63.2	0.9	− 1.0	57.3
Lithuania	855.6	0.0	0.1	4.8	4.8	70.1	3.7	1.0	− 2.6	0.1
Latvia	644.4	− 0.4	0.1	2.5	2.5	68.2	40.6	0.0	0.0	38.0
Poland	3 214.5	0.3	0.4	4.2	4.3	383.9	41.4	0.8	− 0.2	40.1
Slovenia	290.8	0.0	0.0	2.9	2.9	0.1	0.0	0.0	0.0	0.0
Slovakia	657.1	− 0.1	0.1	4.4	4.4	37.2	105.4	0.3	− 1.6	93.8
Cyprus	4.4	0.3	0.3	6.9	6.9	19.8	0.0	− 1.0	0.0	− 1.0
Malta	1.0	0.0	0.0	5.4	5.4	1.3	0.0	0.0	0.0	0.0
Croatia	376.1	0.4	0.1	1.4	1.4					
Bulgaria	1 562.9	0.0	0.2	6.7	6.6	169.4	45.2	1.1	− 1.5	30.5
Romania	4 645.1	0.8	0.9	2.6	2.6	1 145.8	6.5	3.2	1.0	4.7

Table 3: Land-use change for arable area and utilised agricultural area across EU aggregates and MS (1 000 hectares and % change to reference scenario)

	Utilised agricultural area					Arable land				
	Reference	EFA	CropDiv	GRAS	GREEN	Reference	EFA	CropDiv	GRAS	GREEN
	1 000 hectares	*% to reference*				*1 000 hectares*	*% to reference*			
EU-28	181 136.2	0.4	0.2	0.4	0.62	122 651.7	0.7	0.3	− 0.7	− 0.3
EU-15	125 088.1	0.3	0.1	0.2	0.46	81 062.7	0.6	0.1	− 1.1	− 0.5
EU-13	56 048.1	0.8	0.6	0.8	0.97	41 589.1	0.9	0.7	− 0.1	0.0
EU-15										
Belgium	1 466.2	0.3	0.0	0.3	0.65	918.7	0.7	0.1	− 1.3	− 0.7
Denmark	2 761.7	0.4	0.1	0.1	0.47	2 572.7	0.4	0.1	− 0.5	− 0.1
Germany	17 219.7	0.6	0.1	0.4	0.76	12 915.2	0.9	0.2	− 0.9	− 0.2
Austria	3 049.8	0.1	0.0	0.2	0.45	1 478.0	1.0	0.1	− 1.0	− 0.1
Netherlands	1 848.7	0.1	0.0	0.2	0.27	1 004.7	0.3	0.0	− 1.7	− 1.5
France	28 079.2	0.5	0.1	0.3	0.70	19 320.7	1.0	0.2	− 1.8	− 0.9
Portugal	3 462.3	0.0	0.0	0.0	0.03	2 352.2	0.0	0.0	− 0.3	− 0.3
Spain	22 886.5	0.0	0.0	0.0	0.08	16 149.9	0.1	− 0.1	− 0.7	− 0.6
Greece	4 851.9	0.0	0.0	0.7	0.74	3 221.3	0.1	0.0	− 0.6	− 0.5
Italy	13 996.6	0.1	0.0	0.1	0.18	10 161.6	0.4	0.0	− 1.0	− 0.8
Ireland	4 142.6	0.1	0.0	0.2	0.27	661.1	0.7	0.1	− 2.4	− 1.9
Finland	2 233.6	0.2	0.0	0.1	0.25	2 190.4	0.2	0.0	0.0	0.2
Sweden	2 852.5	0.4	0.5	0.3	0.98	2 453.9	0.5	0.6	− 0.7	0.1
United Kingdom	16 236.8	0.2	0.0	0.4	0.55	5 662.3	1.2	0.0	− 1.2	− 0.2
EU-13										
Czech R.	4 013.6	0.2	0.1	0.1	0.29	2 951.6	0.3	0.1	− 0.1	0.1
Estonia	935.3	0.6	0.5	0.5	0.62	658.5	0.7	0.6	0.4	0.5
Hungary	5 714.0	0.8	0.5	0.8	1.02	4 845.7	1.0	0.6	− 0.4	− 0.1
Lithuania	2 901.5	0.8	0.6	0.8	0.90	2 045.9	1.1	0.9	− 0.9	− 0.7
Latvia	1 961.2	0.9	0.8	0.8	1.01	1 316.8	1.6	1.1	0.0	0.3
Poland	16 592.4	0.8	0.6	0.9	1.06	13 377.9	0.9	0.6	0.1	0.3
Slovenia	482.8	0.0	0.0	1.5	1.59	192.0	0.1	0.1	− 0.8	− 0.4
Slovakia	2 111.3	0.1	0.1	0.1	0.15	1 454.2	0.2	0.1	− 1.8	− 1.8
Cyprus	165.6	0.3	0.0	0.3	0.19	161.2	0.3	0.0	0.2	0.0
Malta	11.6	0.0	0.0	0.2	0.27	10.6	0.1	0.0	− 0.3	− 0.2
Croatia	1 521.0	0.0	0.0	0.0	0.00	1 144.8	− 0.1	0.0	− 0.5	− 0.5
Bulgaria	5 361.7	1.1	0.7	1.5	1.63	3 798.7	1.6	1.0	− 0.7	− 0.4
Romania	14 276.3	1.0	1.0	1.0	1.03	9 631.1	1.1	1.0	0.2	0.3

Table 4 reports the impact of the greening scenarios on grassland, fallow land, arable land and UAA by farm type. The results largely follow those reported for the EU aggregate. Different farm types are affected heterogeneously by CAP greening depending on the land type. Farms specialising in cereal and field crops (*cereals, oilseed and protein crops*, *general field and mixed cropping*), *mixed crops-livestock*, *vineyards*, *fruit and citrus fruit*, *olives*, *permanent crops mixed* and *horticulture* adjust their grassland more sizably to CAP greening requirements. The main explanation for this result is that many of these farms have little grassland area and hence they tend to be more significantly affected by the grassland measure in relative terms. The second reason for these effects could be the availability of more possibilities for the substitution of grassland with the cultivation of other crops in the reference scenario, given that their main specialisation is not grassland-based production (e.g. livestock production), while when introducing the grassland measure they may need to revert the converted area. The grassland area of farms specialising in livestock activities (e.g. *dairying*, *cattle-dairying -rearing and fattening*, *sheep, goats and other grazing livestock*) is less affected in relative terms by CAP greening. Following the above intuition, these results could be due to the large size of grassland areas on farms, causing the relative CAP greening effect to be small, as well as the production specialisation in grassland-dependent livestock activities giving these farm types less possibilities for the substitution of grassland with the cultivation of other crops in the reference scenario, and thus when CAP greening is introduced they are less affected.

For arable area, farms specialising in *cattle-dairying -rearing and fattening*, *sheep, goats and other grazing livestock* and *mixed livestock holdings* are more affected than other farm specialisations. These effects are driven primarily by the grassland measure. Because these farms tend to have a larger proportion of grassland relative to arable land, they need to convert a greater share of arable land to grassland relative to other farm types in order to comply with the grassland measure requirements.

For 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. As expected, the EFA measure tends to increase fallow land across farm types, whereas the grassland measure has the opposite effect as farms tend to convert fallow land to grassland to comply with the requirements. The crop diversification measure has a mixed impact on fallow land. The overall CAP greening effect on fallow land depends on which measure dominates. For farms specialising in permanent crops (e.g. *vineyards*, *fruit and citrus fruit*, *olives*, *permanent crops mixed*, *horticulture*) fallow land declines in the GREEN scenario relative to the reference scenario. The decrease is driven by both crop diversification and the grassland measure, which more than offset the effects of the EFA measure. For most other farm types fallow land increases where the EFA measure dominates and is reinforced by the crop diversification measure.

For farm size classes, large farms (> 100 ESU) are more strongly affected by CAP greening than smaller farms with regard to grassland and fallow land, while they are less affected with regard to arable land (Table 4).

For the total agricultural area, the largest increase in area (between 0.7 % and 0.9 %) in the GREEN scenario is observed in farms specialising in *cereals, oilseed and protein crops*, *dairying*, *sheep, goats and other grazing livestock*. For the size classes, all farms tend to be affected equally across the three size classes reported in Table 4. The total agricultural area increase in the GREEN scenario across all farm types appears to be caused slightly more by the EFA and grassland measures than by the crop diversification measure (Table 4).

The total amount of land-use change caused by CAP greening in the EU-28 for the land categories reported in Table 4 comes predominantly from the following three groups of farms: (i) cereal, oilseed and field cropping farms (*cereals, oilseed and protein crops*, *general field and mixed cropping*); (ii) livestock farms (*dairying*, *cattle- dairying -rearing and fattening*, *sheep, goats and other grazing livestock*); and (iii) mixed farms (*mixed cropping*, *mixed crops-livestock*). These three farm groups account for more than 80 % of the total land-use change for grassland, fallow land and UAA in the EU-28; for arable land they account for 64 %. The other farm groups, which include mainly granivores and vegetable and permanent crop farms, account for the remaining share of land-use change (less than 20 % and 36 %, respectively). For farm size classes, the land-use change contribution to the total land-use change caused by CAP greening tends to be more equally distributed among the three size classes, although medium-sized and large farms appear to contribute slightly more to the total CAP greening land-use effects than small farms.

Overall, these land-use results are in line with expectations, as CAP greening mainly targets arable land and grassland, mainly impacting arable and livestock farms, whereas granivores and vegetable and permanent crop farms have a small share of these land categories and thus contribute less to the total greening impact. The same holds true for farm size classes: given that many small farms are exempted from greening (particularly from crop diversification and EFA) they are expected to be less impacted by CAP greening than medium-sized and large farms. However, we must acknowledge that we were not able to fully capture small-farms' exemptions from CAP greening as farm size classes in CAPRI are aggregated farm groups without modelling fully the size heterogeneity of the EU farm population. In addition in many countries a significant share of the small farms is not included in the FADN sample. We account for the small-farm size effect only for the crop diversification measure, where for the modelling of this measure we combine CAPRI farm groups with individual farm data from FADN. Overall, these considerations imply that the impact of CAP greening on small farms simulated in this paper might be overestimated.

Table 4: Land-use change for grassland, arable area, fallow land and UAA by farm type in the EU-28 (1 000 hectares, % change to reference scenario and % contribution to the total land-use change)

	Reference	EFA	CropDiv	GRAS	GREEN	
	1 000 hectares	*% to reference*			*% to reference*	*% contribution to the total land-use change*[*]
Grassland						
Cereals, oilseed and protein crops	3 307	− 0.3	0.2	8.8	8.8	18.8
General field and mixed cropping	2 937	− 0.1	0.3	6.0	6.0	11.4
Dairying	9 380	− 0.3	0.1	2.4	1.9	11.8
Cattle- dairying -rearing and fattening	10 539	− 0.4	0.0	1.5	1.1	7.3
Sheep, goats and other grazing livestock	16 901	− 0.1	0.2	1.4	1.2	12.6
Granivores	339	− 0.1	0.0	4.0	3.9	0.9
Mixed livestock holdings	2 519	− 0.2	0.1	3.1	3.0	4.9
Mixed crops-livestock	5 220	− 0.2	0.0	4.8	4.6	15.5
Vineyards	125	− 0.1	0.2	7.4	7.3	0.6
Fruit and citrus fruit	71	0.4	0.5	6.5	6.5	0.3
Olives	111	− 0.1	0.0	10.8	10.7	0.8
Permanent crops mixed	60	− 0.1	0.1	8.8	8.8	0.3
Horticulture	6	0.1	− 0.7	7.7	7.3	0.0
< = 16 ESU	18 698	− 0.1	0.2	2.2	2.1	24.9
> 16 and < = 100 ESU	22 810	− 0.2	0.1	2.6	2.3	33.8
> 100 ESU	10 009	− 0.5	0.0	4.4	4.1	26.5
Residual	6 592	0.0	0.1	3.5	3.5	14.7
Arable area						
Cereals, oilseed and protein crops	37 164	0.8	0.4	− 0.2	0.2	− 15.3
General field and mixed cropping	22 204	0.5	0.2	− 0.5	− 0.2	9.3
Dairying	9 841	1.3	0.4	− 1.2	− 0.4	9.9
Cattle- dairying -rearing and fattening	4 623	1.5	0.2	− 2.5	− 1.2	12.7
Sheep, goats and other grazing livestock	3 476	2.9	0.6	− 2.9	− 1.4	11.3
Granivores	1 945	0.6	0.2	− 0.4	0.0	− 0.1
Mixed livestock holdings	4 446	0.5	0.1	− 1.3	− 1.1	11.5
Mixed crops-livestock	16 237	0.6	0.2	− 1.0	− 0.6	24.7
Vineyards	1 605	0.0	− 0.1	− 0.5	− 0.6	2.2
Fruit and citrus fruit	1 387	0.1	0.1	− 0.1	− 0.1	0.2
Olives	3 383	0.0	− 0.1	− 0.2	− 0.2	1.6
Permanent crops mixed	961	0.1	0.0	− 0.3	− 0.2	0.5
Horticulture	115	0.1	0.1	− 0.5	− 0.4	0.1
< = 16 ESU	28 216	0.7	0.3	− 0.7	− 0.4	26.0
> 16 and < = 100 ESU	39 407	0.8	0.3	− 0.8	− 0.3	32.6
> 100 ESU	39 763	0.8	0.3	− 0.6	− 0.1	9.9
Residual	14 121	0.3	0.2	− 1.1	− 0.9	31.5
Fallow land						
Cereals, oilseed and protein crops	2 340	20.5	4.0	− 3.4	19.3	25.0
General field and mixed cropping	1 245	21.4	3.1	− 3.0	19.8	13.6
Dairying	216	152.5	17.3	− 10.0	144.0	17.2
Cattle- dairying -rearing and fattening	245	87.9	4.3	− 8.6	79.1	10.7
Sheep, goats and other grazing livestock	769	32.7	1.2	− 3.4	22.0	9.3
Granivores	80	52.2	12.1	− 6.5	52.3	2.3
Mixed livestock holdings	318	28.6	1.4	− 4.5	23.6	4.1
Mixed crops-livestock	723	41.9	5.2	− 8.1	38.3	15.3
Vineyards	152	0.1	− 1.7	− 1.4	− 3.1	− 0.3
Fruit and citrus fruit	127	0.9	− 0.6	− 0.7	− 0.8	− 0.1
Olives	181	0.1	− 4.0	− 1.3	− 5.0	− 0.5

Permanent crops mixed	70	0.7	– 2.3	– 1.3	– 3.1	– 0.1
Horticulture	13	1.6	– 0.8	– 2.3	– 2.3	0.0
< = 16 ESU	2 508	14.0	1.0	– 1.6	10.3	14.3
> 16 and < = 100 ESU	2 588	28.4	3.6	– 4.5	25.3	36.2
> 100 ESU	1 382	64.9	8.0	– 8.1	60.4	46.1
Residual	1 289	7.3	1.2	– 3.2	4.7	3.4
UAA						
Cereals, oilseed and protein crops	40 471	0.7	0.4	0.6	0.9	31.5
General field and mixed cropping	25 141	0.4	0.2	0.3	0.5	12.2
Dairying	19 220	0.5	0.3	0.6	0.7	12.5
Cattle- dairying -rearing and fattening	15 162	0.2	0.1	0.3	0.4	5.3
Sheep, goats and other grazing livestock	20 378	0.4	0.3	0.7	0.7	13.2
Granivores	2 283	0.5	0.2	0.2	0.6	1.2
Mixed livestock holdings	6 965	0.3	0.1	0.3	0.4	2.5
Mixed crops-livestock	21 456	0.4	0.2	0.4	0.6	12.0
Vineyards	1 730	0.0	0.0	0.0	0.0	0.0
Fruit and citrus fruit	1 458	0.2	0.1	0.2	0.2	0.3
Olives	3 495	0.0	– 0.1	0.1	0.2	0.5
Permanent crops mixed	1 021	0.1	0.0	0.3	0.3	0.3
Horticulture	121	0.1	0.0	0.0	0.0	0.0
< = 16 ESU	46 914	0.4	0.3	0.5	0.6	24.5
> 16 and < = 100 ESU	62 216	0.4	0.2	0.4	0.6	34.3
> 100 ESU	49 772	0.6	0.2	0.4	0.7	32.8
Residual	20 713	0.2	0.1	0.4	0.5	8.5

Note: *This column reports the relative (percentage) contribution of a particular farm type to the total land-use change in EU-28 caused by CAP greening (GEEN).

More detailed sectoral impacts of CAP greening on land use reported in Table 5 confirm the above results. The fodder area (driven by grassland) and land cultivated with pulses expand at the expense of cereal and oilseed area. The additional area needed to keep permanent grassland (fodder) and to comply with EFA come to a large extent from cereals and partially from oilseeds. The combined requirements of the three measures (GREEN scenario) induce 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, relative to the reference scenario. Land allocated to other arable crops and vegetables and permanent crops changes by 0.4 % and 0 %, respectively. The land-use effects for the EU-15 and the EU-13 show the same signs and similar magnitudes as for the EU-28. In the EU-15 the area of cereals and oilseeds is slightly more affected than in the EU-28; for other crops the land-use impacts are smaller. In the EU-13 the land-use effects are stronger for pulses, fodder area and other arable crops, while the oilseed area is little changed (– 0.1 %) relative to the reference scenario.

The main measure causing land-relocation effects between crop sectors reported in Table 5 in the GREEN scenario is EFA. The grassland and crop diversification measures have a small impact on sectoral land-relocation effects. The exception is the area of minor crops such as other arable crops and in particular pulses, which are more significantly affected by crop diversification as farmers use them for diversification purposes to shift away from major crops such as cereals and oilseeds and combined with their low area in the reference scenario causes a more substantial change in the CropDiv scenario relative to the reference scenario.

Note that, although the patterns of CAP greening impacts on land relocation between different crops are largely in line with expectations, the magnitudes of the changes are rather small. For most of the crop sectors reported in Table 5, the land-area change relative to the reference scenario varies between – 2 % and 2.3 % across the greening scenarios and EU aggregates. The exception is pulses, for which the area change expands up to 6.6 % in the EFA scenario in the EU-13.

Table 5: Land-use change for selected production sectors for EU aggregates (1 000 hectares and % change to reference scenario)

	Reference	EFA	CropDiv	GRAS	GREEN
	1 000 ha	*% to Reference*			
EU-28					
Cereals	57 137	− 0.9	0.2	− 0.3	− 1.7
Oilseeds	13 468	− 0.5	0.3	− 0.1	− 1.0
Pulses	1 264	1.9	3.4	− 0.4	4.2
Other arable crops	6 098	0.1	0.8	− 0.1	0.4
Vegetables and permanent crops	14 055	0.0	0.0	0.0	0.0
Fodder activities	82 612	− 0.9	0.0	1.6	0.5
EU-15					
Cereals	34 416	− 1.2	− 0.2	− 0.4	− 2.0
Oilseeds	7 419	− 1.2	− 0.1	− 0.4	− 1.7
Pulses	889	− 0.1	4.4	− 0.5	3.4
Other arable crops	3 974	− 0.5	1.1	− 0.2	0.2
Vegetables and permanent crops	11 773	0.0	0.0	0.0	0.0
Fodder activities	61 936	− 1.1	− 0.2	1.3	0.1
EU-13					
Cereals	22 721	− 0.5	0.7	− 0.1	− 1.3
Oilseeds	6 049	0.2	0.8	0.3	− 0.1
Pulses	375	6.6	1.0	0.0	6.0
Other arable crops	2 124	1.1	0.3	0.0	0.8
Vegetables and permanent crops	2 282	0.0	0.0	0.0	0.0
Fodder activities	20 676	− 0.2	0.4	2.3	1.6

7.1.2. Production effects

Table 6 shows the impact of the greening scenarios on the production of selected agricultural products across EU aggregates. The production effects of CAP greening (GREEN scenario) as compared to the reference scenario 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), which causes feed cost rise, is more than offset by increased fodder production (and hence lower fodder prices) on farms yielding a small decrease in livestock production ranging from 0.1 % for milk to 0.2 % for meat (Table 6). For the EU-15 the production effects appear to be slightly stronger than those in the EU-28 for cereals, oilseeds and other arable field crops and slightly weaker for fodder, while for the EU-13 the reverse effects are observed.

The production effects are mainly driven by the EFA followed by the grassland measure, though their magnitudes are rather small. These results are expected, given that the EFA and grassland measures impose stronger restrictions on land allocation as they require land to be left out of production and the shifting of land from arable crop production to grassland, respectively. These land effects are reflected in lower land availability for arable crop cultivation (particularly for cereals and oilseeds), causing lower production levels of arable crops. Or, conversely, the grassland measure stimulates the allocation of land to grassland, which causes higher fodder production. The production of pulses is positively affected because this crop is eligible to be an EFA. The crop diversification measure leads to small production effects (with the exception of pulses) as it only requires farms to relocate land use between arable crop activities in line with greater crop diversity obligations without obliging farms to withdraw land from production or convert it to other non-arable crop cultivation (Table 6).

Table 6: Change in production for selected sectors across EU aggregates (1 000 tonne and % change to reference scenario)

	Reference	EFA	CropDiv	GRAS	GREEN
	1 000 tonne		*% to Reference*		
EU-28					
Cereals	326 693.3	− 0.50	0.00	− 0.20	− 1.00
Oilseeds	36 850.8	− 0.40	0.10	− 0.10	− 0.70
Other arable field crops	175 616.9	− 0.70	0.20	− 0.10	− 0.90
Pulses	2 362.1	1.90	2.80	− 0.50	3.50
Vegetables and permanent crops	139 997.1	0.00	0.00	0.00	0.00
Fodder	2 362 921	− 0.50	0.00	0.90	0.20
Meat	47 607.8	− 0.20	0.00	0.00	− 0.20
Milk	162 711.9	− 0.10	0.00	0.00	− 0.10
Other animal products	198 532.2	− 0.10	0.00	0.00	− 0.10
EU-15					
Cereals	*224 647.4*	*− 0.70*	*− 0.20*	*− 0.30*	*− 1.30*
Oilseeds	22 817.1	− 0.90	− 0.20	− 0.30	− 1.40
Other arable field crops	137 823.6	− 0.80	0.20	− 0.20	− 1.00
Pulses	1 771.5	0.40	3.30	− 0.60	2.80
Vegetables and permanent crops	119 361.1	0.00	0.00	0.00	0.00
Fodder	1 933 538	− 0.60	− 0.10	0.80	0.10
Meat	39 464.9	− 0.20	0.00	0.00	− 0.20
Milk	139 745.9	− 0.10	0.00	0.00	− 0.10
Other animal products	163 965.7	− 0.10	0.00	0.00	− 0.10
EU-13					
Cereals	102 045.9	− 0.10	0.50	0.00	− 0.50
Oilseeds	14 033.7	0.40	0.70	0.30	0.40
Other arable field crops	37 793.3	− 0.10	0.30	0.10	− 0.30
Pulses	590.5	6.30	1.00	0.00	5.60
Vegetables and permanent crops	20 636	0.00	0.00	0.00	0.00
Fodder	429 383.2	− 0.10	0.40	1.30	0.80
Meat	8 142.9	− 0.10	0.10	0.00	− 0.10
Milk	22 965.9	0.00	0.00	0.00	0.00
Other animal products	34 566.5	0.00	0.10	0.10	0.00

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 scenario. Again, larger effects (more than 4 %) are observed for pulses, which is a minor production activity in the reference scenario in many farm types (e.g. c*attle- dairying -rearing and fattening*, *vineyards* and *olives*) (Table 7).

Although certain farm types report sizable changes in production in the GREEN scenario relative to the reference scenario (e.g. *cattle- dairying -rearing and fattening* and *mixed livestock holdings*) for cereals, oilseeds and pulses, their contribution to the aggregate change in production at EU level is relatively small. For example, the three farm types — i.e. those specialising in *cereals, oilseed and protein crops*, *general field and mixed cropping* and *mixed crops-livestock* — account for more than 55 % of the total change in cereal, oilseed and pulse production caused by CAP greening in the EU-28. The same holds true for medium-sized and large farms (farms larger than 16 ESU), which account for more than 70 % of the total change in production in these three sectors caused by CAP greening. The remaining change in production (less than 45 % and 30 %, respectively) for cereals, oilseeds and pulses is distributed across the remaining farm specialisations or farm-size classes.

As expected, the greatest share of the change in fodder production and meat production caused by CAP greening (more than 70 %) comes from farms specialising in animal production (e.g. *dairying*, *granivores*) or mixed livestock farms (e.g. *mixed livestock* *holdings*, *mixed crops-livestock*). The other farm types account for less than 30 % of the total change in production (Table 7).

Table 7: Change in production for selected sectors across EU-28 aggregated farm types (1 000 tonne, % change to reference scenario and % contribution to the total production change)

	Reference	EFA	CropDiv	GRAS	GREEN	
	1 000 tonne	*% to reference*			*% to reference*	*% contribution to the total production change[*]*
Cereals						
Cereals, oilseed and protein crops	136 405	− 0.20	− 0.10	0.10	− 0.50	21.00
General field and mixed cropping	63 847	− 0.40	0.10	− 0.10	− 0.60	11.06
Dairying	14 177	− 2.30	0.40	− 0.90	− 4.20	17.64
Cattle- dairying -rearing and fattening	6 263	− 2.40	0.30	− 2.10	− 4.40	8.28
Sheep, goats and other grazing livestock	2 706	− 1.70	1.80	− 1.80	− 2.40	1.92
Granivores	8 898	− 0.60	− 0.30	0.00	− 0.90	2.35
Mixed livestock holdings	10 216	− 1.30	0.00	− 1.00	− 2.50	7.61
Mixed crops-livestock	51 269	− 0.90	− 0.10	− 0.40	− 1.60	24.71
Vineyards	1 303	0.40	− 0.70	− 0.50	− 0.70	0.26
Fruit and citrus fruit	424	1.00	1.10	0.20	1.30	− 0.16
Olives	438	1.40	7.40	− 0.40	8.50	− 1.11
Permanent crops mixed	308	1.40	0.80	− 0.50	1.80	− 0.17
Horticulture	96	0.40	− 0.30	− 0.40	− 0.30	0.01
< = 16 ESU	57 509	0.20	0.10	− 0.30	− 0.30	5.05
> 16 and < = 100 ESU	102 381	− 0.50	− 0.10	− 0.20	− 1.00	31.60
> 100 ESU	136 458	− 1.00	0.00	− 0.10	− 1.40	56.76
Residual	26 838	0.00	0.10	− 0.60	− 0.80	6.60
Oilseeds						
Cereals, oilseed and protein crops	21 023	− 0.30	0.20	0.10	− 0.50	39.32
General field and mixed cropping	5 420	− 0.60	0.00	0.00	− 0.70	13.60
Dairying	711	− 0.80	1.20	− 0.60	− 2.00	5.17
Cattle- dairying -rearing and fattening	320	− 2.50	0.40	− 2.00	− 4.30	5.06
Sheep, goats and other grazing livestock	170	0.30	3.70	− 1.10	1.00	− 0.63
Granivores	454	− 0.70	0.30	− 0.10	− 0.90	1.48
Mixed livestock holdings	443	− 0.40	0.40	− 0.30	− 1.30	2.18
Mixed crops-livestock	5 233	− 0.80	0.10	− 0.20	− 1.20	22.58
Vineyards	140	0.00	1.10	− 1.40	− 0.40	0.22
Fruit and citrus fruit	9	0.50	5.10	− 0.20	4.00	− 0.11
Olives	134	0.70	− 7.90	0.30	− 6.60	3.25
Permanent crops mixed	9	0.70	− 4.20	0.00	− 3.10	0.11
Horticulture	1	− 0.80	7.90	− 0.80	6.30	− 0.04
< = 16 ESU	3 159	0.80	1.40	0.40	1.30	− 15.63
> 16 and < = 100 ESU	11 186	− 0.30	0.20	0.00	− 0.60	25.91
> 100 ESU	19 723	− 0.70	− 0.10	− 0.10	− 1.10	81.93
Residual	2 423	0.10	0.10	− 1.00	− 0.90	7.80
Pulses						
Cereals, oilseed and protein crops	1 115	0.90	3.10	− 0.20	3.20	43.62
General field and mixed cropping	501	2.30	1.60	− 0.50	2.70	16.40
Dairying	69	4.50	3.20	− 1.60	5.20	4.25
Cattle- dairying -rearing and fattening	22	9.00	5.70	− 2.30	11.10	3.04
Sheep, goats and other grazing livestock	33	− 1.10	2.30	− 2.00	− 0.90	− 0.36
Granivores	42	4.40	1.80	− 0.30	5.50	2.79
Mixed livestock holdings	51	5.60	1.40	− 1.40	5.50	3.40
Mixed crops-livestock	320	3.20	1.80	− 0.80	3.40	13.12
Vineyards	15	− 0.50	18.00	− 0.60	16.50	3.04
Fruit and citrus fruit	7	1.30	3.00	0.10	3.70	0.24
Olives	17	− 0.50	22.80	− 0.70	21.50	4.37
Permanent crops mixed	9	− 0.50	5.80	− 0.30	4.80	0.49

Horticulture	2	– 0.40	4.80	– 0.50	4.20	0.12
< = 16 ESU	489	2.00	3.60	– 0.80	4.20	24.79
> 16 and < = 100 ESU	840	1.80	3.80	– 0.30	4.60	46.66
> 100 ESU	873	1.90	1.20	– 0.40	2.20	23.21
Residual	160	1.50	2.80	– 0.90	2.80	5.47
Fodder						
Cereals, oilseed and protein crops	127 190	– 0.70	– 0.10	1.60	0.40	8.48
General field and mixed cropping	105 385	– 0.90	0.00	1.20	0.00	– 0.52
Dairying	850 203	– 0.40	0.00	0.60	0.10	15.08
Cattle- dairying -rearing and fattening	438 803	– 0.70	– 0.10	0.50	– 0.20	– 18.60
Sheep, goats and other grazing livestock	239 953	– 0.60	0.10	0.80	0.00	0.94
Granivores	11 643	– 1.30	– 0.30	1.10	– 0.60	– 1.29
Mixed livestock holdings	117 810	– 0.50	0.00	1.20	0.70	13.92
Mixed crops-livestock	288 808	– 0.50	– 0.10	1.60	0.90	45.11
Vineyards	2 387	0.00	0.30	0.80	1.10	0.47
Fruit and citrus fruit	814	0.60	0.80	2.30	2.50	0.37
Olives	1 255	0.50	1.40	2.10	4.00	0.90
Permanent crops mixed	785	0.30	0.40	1.80	2.40	0.34
Horticulture	140	– 0.10	– 0.30	1.40	1.00	0.03
< = 16 ESU	411 683	– 0.30	0.10	0.90	0.40	32.69
> 16 and < = 100 ESU	1 011 806	– 0.60	– 0.10	0.80	0.10	10.10
> 100 ESU	761 688	– 0.70	– 0.10	0.90	0.20	22.44
Residual	168 890	– 0.10	0.00	1.50	1.10	34.77
Meat						
Cereals, oilseed and protein crops	1 075	– 0.20	0.00	0.10	– 0.20	1.92
General field and mixed cropping	2 285	– 0.20	0.00	0.00	– 0.20	4.79
Dairying	3 192	– 0.30	0.00	0.10	– 0.30	8.33
Cattle- dairying -rearing and fattening	2 940	– 0.30	0.00	0.10	– 0.30	8.91
Sheep, goats and other grazing livestock	1 215	– 0.40	0.00	0.20	– 0.30	3.45
Granivores	18 279	– 0.10	0.00	0.00	– 0.20	27.20
Mixed livestock holdings	4 325	– 0.30	0.00	0.00	– 0.40	14.66
Mixed crops-livestock	7 705	– 0.20	0.00	0.00	– 0.30	20.69
Vineyards	20	– 0.10	0.10	– 0.10	– 0.10	0.00
Fruit and citrus fruit	37	0.00	0.00	0.10	0.00	0.00
Olives	46	– 0.10	0.00	0.10	0.00	0.00
Permanent crops mixed	24	– 0.10	0.00	0.10	0.10	– 0.10
Horticulture	4	– 0.20	0.00	– 0.30	– 0.30	0.00
< = 16 ESU	4 896	– 0.10	0.00	0.10	– 0.10	6.23
> 16 and < = 100 ESU	12 578	– 0.20	0.00	0.00	– 0.30	32.76
> 100 ESU	23 671	– 0.20	0.00	0.00	– 0.20	51.05
Residual	6 220	– 0.10	0.00	0.00	– 0.20	10.15

Note: *This column reports the relative (percentage) contribution of a particular farm type to the total sectors' production change in EU-28 caused by CAP greening (GEEN).

7.1.3. Price and income effects

Price changes caused by CAP greening are reported in Table 8 for selected key sectors in the EU-28. Overall, the prices tend to increase as CAP greening takes a small share of land out of production and reduces productivity due to the induced land-reallocation effects. The magnitude of the price effects largely follows the changes in production but with an opposite sign. Because the production response is relatively small, it results in rather small price adjustments. In the EU-28 the price changes vary between ± 1 % in scenarios simulating individual greening measures (CropDiv, EFA, GRAS) and between – 0.39 % and 1.5 % in the scenario modelling all three measures (GREEN).

As expected, the EFA scenario leads to the largest price increase as it takes a share of land out of production, but the price increase is still less than 1 %. The crop diversification scenario has a mixed impact on prices as this greening measure induces the reallocation of land between crops, and thus causes a mixed adjustment of production across sectors. The grassland scenario aims to preserve grassland area, which favours animal production at the expense of arable crop production. These production adjustments cause an increase in arable crop prices and the reduction of animal prices in the GRAS scenario.

The overall impact of CAP greening on prices (GREEN scenario) appears to be dominated by EFA, which accounts for more than 60 % of the total price changes. The exceptions are pulses, which experience a price decline driven by the greater diversification requirements of CAP greening (CropDiv). The most affected are cereal and oilseed prices, which experience the largest changes as these sectors are some of the main targets of CAP greening.

Table 8: Price change in the EU-28 (EUR/tonne and % change to reference scenario)

	Reference	EFA	CropDiv	GRAS	GREEN
	EUR/tonne		*% to reference*		
Cereals	160	0.96	0.07	0.14	1.55
Oilseeds	353	0.92	– 0.14	0.09	1.46
Pulses	253	0.43	– 1.01	0.05	– 0.39
Other arable field crops	225	0.21	– 0.05	0.04	0.29
Vegetables and permanent crops	730	0.10	– 0.02	0.05	0.17
Meat	2 091	0.40	0.04	– 0.07	0.45
Milk	402	0.40	0.03	– 0.05	0.47
Other animal	444	0.37	0.03	– 0.04	0.45

Farm-income changes for MS and EU aggregates are presented in Table 9. The income changes are driven primarily by production effects and price changes. These tend to move in an opposite direction, however the prices have a tendency to increase slightly more than production declines, causing an improvement in farm income. Since most agricultural products have inelastic demands, farmers typically see their incomes rise when there is a decline in production. In the EU-28 farm income increases by 0.9 %, implying that the price effects more than offset the change in production. In the EU-15 farm income also increases by 0.9 %, whereas in the EU-13 it is slightly higher at 1 %. At MS level the income increase varies between 0.1 % and 3.9 %. The largest relative income change occurs in Denmark (3.9 %), Malta (2.8 %), Lithuania (1.7 %), Germany (1.7 %), Hungary (1.6 %), Slovakia (1.6 %) and France (1.5 %). In the other MS the income increases by less than 1.5 %. Following the production and price effects the EFA leads to the largest increase in income as it alters production and price levels the most. However, its income effect is still small, less than 1 % in most MS. Crop diversification and grassland measures cause income changes between ± 0.4 % in the majority of MS.

Table 9: Income change across EU aggregates and MS (million EUR and % change to reference scenario)

	Reference	EFA	CropDiv	GRAS	GREEN
	million EUR		*% to Reference*		
EU-28	173 846	0.60	0.00	0.00	0.90
EU-15	148 699	0.60	0.00	0.10	0.90
EU-13	25 147	0.50	– 0.20	0.00	1.00
EU-15					
Belgium	2 366	0.90	0.00	0.20	1.30
Denmark	1 516	2.90	0.40	0.20	3.90
Germany	18 608	1.20	0.10	0.10	1.70
Austria	3 755	1.00	0.10	0.10	1.00
Netherlands	8 228	0.10	0.00	0.00	0.20
France	26 750	1.10	0.10	0.10	1.50
Portugal	3 332	0.50	0.00	0.10	0.70
Spain	35 000	0.30	0.00	0.00	0.50
Greece	6 086	0.30	0.00	– 0.30	0.10
Italy	27 593	0.40	0.00	0.00	0.50
Ireland	3 370	0.70	0.00	0.00	0.90
Finland	2 020	0.50	0.00	0.00	0.60
Sweden	24	0.83	0.59	– 0.23	1.08
United Kingdom	10 052	0.30	– 0.10	0.20	0.70
EU-13					
Czech Republic	1 272	0.70	– 0.30	0.00	1.40
Estonia	359	0.90	– 0.10	0.10	1.20
Hungary	2 383	0.80	– 0.20	0.30	1.60
Lithuania	1 082	1.00	– 0.10	0.40	1.70
Latvia	443	0.10	– 0.30	0.30	1.30
Poland	8 657	0.60	– 0.10	0.00	0.90
Slovenia	490	0.30	0.00	0.20	0.70
Slovakia	646	1.10	– 0.20	0.00	1.60
Croatia	1 660	– 0.10	– 0.10	0.00	0.20
Cyprus	231	0.10	0.30	0.10	0.50
Malta	4	1.80	– 0.90	– 0.30	2.80
Bulgaria	1 478	0.30	– 0.40	– 0.10	1.00
Romania	6 443	0.30	– 0.30	– 0.20	0.70

The income effects for farm types are analysed in Table 10 for the EU-28, the EU-15 and the EU-13. Following the aggregate income results, CAP greening leads to a small increase in income for all farm types in the EU-28. Farms specialising in permanent crops and vegetables are little affected by CAP greening. They experience an insignificant increase in income because prices and production in which they specialise are little 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 incomes at the EU-28 level, but still below 3 %. For farm size classes, middle-sized and large farms obtain a slightly larger income increase than small farms. These results could be due to the differences in specialization of 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 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, large farms obtain higher income increase compared to small farms.

Income changes for farm types in the EU-15 and the EU-13 follow the patterns observed for the EU-28. The exception is farm types specialising in *sheep, goats and other grazing livestock*, which experience a minor reduction in income (– 0.2 %) in the EU-13.

The total value of the income change caused by CAP greening in the EU-28 comes predominantly from the following four farm types: *cereals, oilseed and protein crops*, *general field and mixed cropping*, *dairying* and *mixed crops-livestock*. These four farm types account for more than 70 % of the total income change caused by CAP greening in the EU-28, the EU-15 and the EU-13. The other farm types account for less than 30 % of the total income change. For farm size classes, the contribution to the total income change comes mainly from large farms, followed by medium-sized farms (Table 10). These results can be explained by the combination of production and price changes reported in Table 7 and Table 8. As reported in Table 7, farms specialising in *cereals, oilseed and protein crops*, *general field and mixed cropping* and *mixed crops-livestock* account for a moderate magnitude of the relative change in the crop production for cereals and oilseeds relative to other farm types, whereas Table 8 shows that the prices of these crops increase the most compared to animal or other crop products. These two effects make these four types of farm account for the largest share of income change. The same holds true for medium-sized and large farms, which tend to specialise in cereal and oilseed production to a larger extent than small farms (Table 7) and thus also report a greater income change caused by CAP greening (Table 10).

Table 10: Income change across EU aggregated farm types (million EUR, % change to reference scenario and % contribution to the total income change)

	Reference	EFA	CropDiv	GRAS	GREEN	
	million EUR	*% to reference*			*% to reference*	*% contribution to the total income change**
EU-28						
Cereals, oilseed and protein crops	16 474	1.80	0.10	0.30	2.90	30.97
General field and mixed cropping	30 085	0.50	0.00	0.10	0.80	15.11
Dairying	28 212	0.70	0.10	0.00	0.90	15.47
Cattle- dairying -rearing and fattening	5 786	1.30	0.00	– 0.20	1.50	5.55
Sheep, goats and other grazing livestock	6 861	1.00	– 0.10	– 0.30	0.80	3.66
Granivores	– 2 505	0.90	0.20	0.10	0.60	1.03
Mixed livestock holdings	3 100	1.00	– 0.20	– 0.20	1.40	2.72
Mixed crops-livestock	10 423	1.30	0.00	0.20	2.00	13.65
Vineyards	6 985	0.50	0.00	0.20	0.80	3.51
Fruit and citrus fruit	6 180	0.00	0.00	0.00	0.00	0.07
Olives	11 224	0.20	0.00	0.00	0.20	1.73
Permanent crops mixed	3 081	0.20	0.00	0.00	0.20	0.49
Horticulture	1 730	0.10	– 0.10	0.00	0.00	– 0.01
< = 16 ESU	30 764	0.50	– 0.10	– 0.10	0.70	13.12
> 16 and < = 100 ESU	50 345	0.80	0.10	0.00	1.10	36.16
> 100 ESU	46 526	1.00	0.00	0.20	1.50	44.68
Residual farms	44 552	0.10	0.00	0.00	0.20	6.04
EU-15						
Cereals, oilseed and protein crops	12 793	1.90	0.10	0.40	2.90	28.17
General field and mixed cropping	24 119	0.50	0.00	0.10	0.80	14.15
Dairying	25 955	0.70	0.10	0.00	0.90	17.44
Cattle- dairying -rearing and fattening	5 345	1.40	0.00	– 0.20	1.60	6.38
Sheep, goats and other grazing livestock	6 673	1.10	0.00	– 0.20	0.90	4.75
Granivores	– 3 210	0.70	0.10	0.00	0.50	1.21
Mixed livestock holdings	1 693	1.60	0.10	0.00	1.90	2.47
Mixed crops-livestock	7 133	1.60	0.20	0.40	2.40	13.21
Vineyards	6 957	0.50	0.00	0.20	0.80	4.13
Fruit and citrus fruit	5 565	0.00	0.00	0.00	0.00	0.08
Olives	11 224	0.20	0.00	0.00	0.20	2.05
Permanent crops mixed	3 081	0.20	0.00	0.00	0.20	0.58
Horticulture	1 730	0.10	– 0.10	0.00	0.00	– 0.01
< = 16 ESU	20 391	0.60	0.00	0.00	0.60	9.40
> 16 and < = 100 ESU	46 723	0.80	0.10	0.00	1.10	38.72
> 100 ESU	41 944	1.00	0.10	0.20	1.50	46.49
Residual farms	39 642	0.10	0.00	0.00	0.20	5.38
EU-13						
Cereals, oilseed and protein crops	2 072	2.00	– 0.20	0.30	3.50	41.01
General field and mixed cropping	2 715	0.60	– 0.20	0.10	1.10	17.13
Dairying	2 124	0.20	0.00	0.10	0.50	6.12
Cattle- dairying -rearing and fattening	440	0.40	– 0.20	– 0.10	0.50	1.29
Sheep, goats and other grazing livestock	287	0.00	– 0.30	– 0.40	– 0.20	– 0.39
Granivores	699	0.10	0.20	0.10	0.00	0.06
Mixed livestock holdings	1 085	0.40	– 0.30	– 0.10	0.70	4.55
Mixed crops-livestock	2 608	0.70	– 0.30	0.00	1.30	18.93
Vineyards	0	0.00	0.00	0.00	0.00	0.00
Fruit and citrus fruit	435	0.00	0.10	0.00	0.00	0.00
Olives	0	0.00	0.00	0.00	0.00	0.00
Permanent crops mixed	0	0.00	0.00	0.00	0.00	0.00
Horticulture	0	0.00	0.00	0.00	0.00	0.00
< = 16 ESU	5 770	0.40	– 0.30	– 0.10	0.90	27.64

> 16 and < = 100 ESU	3 108	0.80	– 0.10	0.10	1.30	22.92
> 100 ESU	3 585	1.10	0.00	0.30	1.90	38.09
Residual farms	3 103	0.40	0.00	0.20	0.60	11.29

Note: *This column reports the relative (percentage) contribution of a particular farm type to the total income change in EU-28, EU-15 and EU-13 caused by CAP greening (GEEN).

7.2. Environmental impacts of CAP greening

This section analyses the environmental impacts of CAP greening. We report the simulation results for GHG emissions, N surplus, ammonia emissions, soil erosion, and BFP.

7.2.1. Expected environmental impacts from activity levels

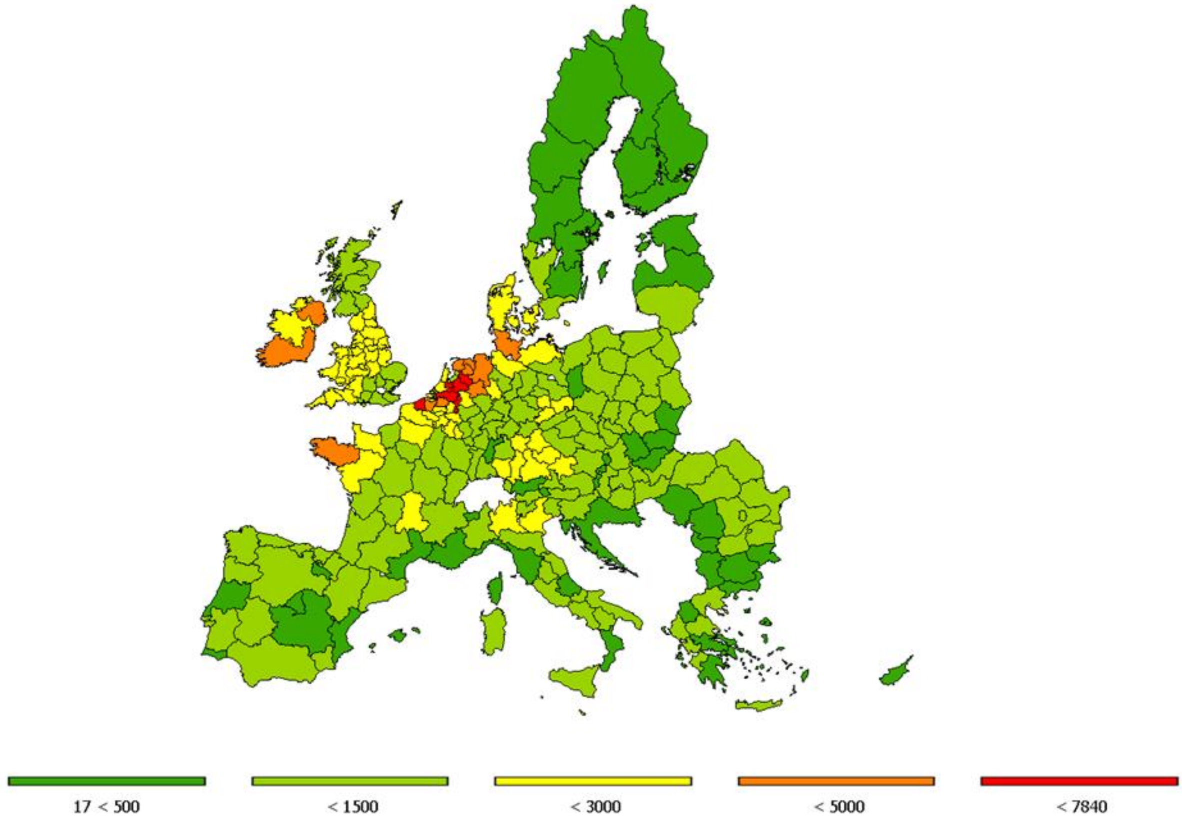
As seen in the previous sections, the greening measures globally (EU-28) result in lower areas of cereals, oilseeds and fodder crops than the reference scenario (– 2.26 million ha). These areas shift mainly to grassland (+ 1.55 million ha) and fallow land (+ 0.8 million ha). Compared to the reference scenario there is a small decrease in the number of animals for all animal types. All this is expected to have a positive effect on the reduction of GHG emissions, N budget and other environmental indicators on a hectare basis. The small increase in total UAA (+ 1.12 million ha) may have a negative effect on total (aggregate) values. Additionally, there is a significant increase in the winter-cover catch crop, which should have a positive effect on soil erosion.

The slight increase in yields for arable crops, including fodder crops (between + 0.5 % and + 0.75 % for main cereals), is due to a small increase in fertilisation (manure and mineral) per crop ha. However, 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), mainly from Europe (non-EU), Asia and North America (cereals) and from South America (soya). This means that the positive environmental impact of greening measures in the EU may have a secondary effect (leakage effect) on non-EU countries.

7.2.2. Greenhouse gas emissions

GHG emissions per total area, measured by the global warming potential of agriculture (GWPA) in kg of CO_2 equivalent, are shown for the reference scenario in Figure 1. It can be observed that the highest emissions per hectare are concentrated in zones with high livestock density (e.g. Belgium, Denmark, Ireland, the Netherlands), mainly due to methane emissions from cattle.

Figure 1: GHG emissions in reference scenario (kg CO_2 equivalent/total ha)

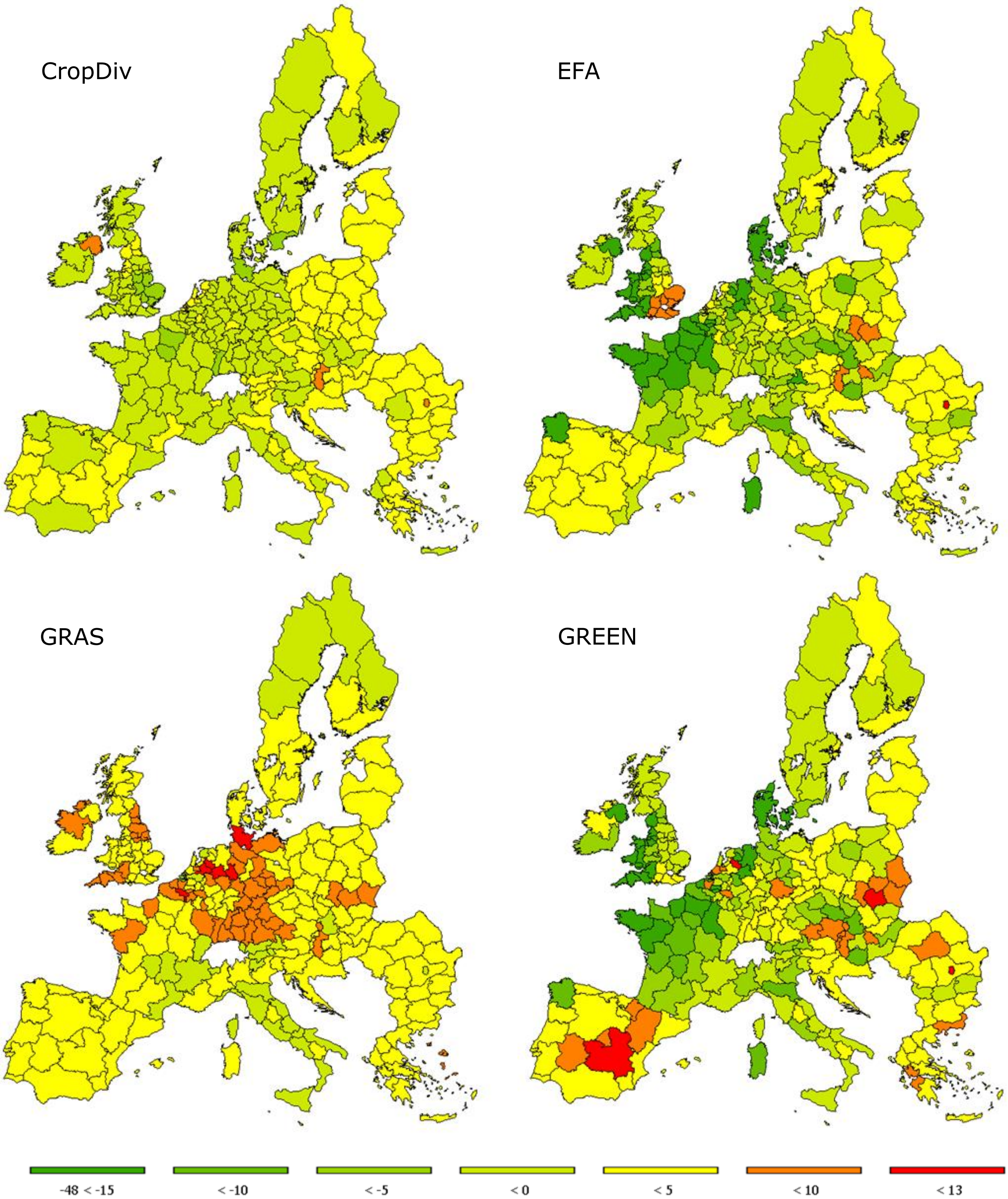


The greening measures result in a decrease in aggregate GHG emissions for the whole EU-28 sector (– 0.20 %). This is mainly due to the EFA measures, because under the EFA scenario the decrease is 0.38 %, while the GRAS scenario results in the opposite effect of a relative increase by 0.25 %, due to the relative increase in animal numbers in this scenario. The CropDiv scenario does not have an effect on GHG emissions. 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 might likely lead to a more significant reduction in the GHG emissions related to agricultural sector.

The GWPA decrease is mostly (80 %) due to the reduction in animal numbers, and only 20 % of it is a consequence of the changes in land based activities. For these, there is a large decrease from fodder crops and a smaller one from cereals, but most of it (84 %) is compensated by the GHG increase from grasslands (N_2O from manure and mineral fertilisation).

There are, however, differences between regions, as can be observed in Figure 2, which shows the absolute changes per total hectare produced by the greening measures in the four simulated scenarios. In the GREEN scenario, some regions face an increase in GWPA of up to 2.45 % (in particular Spain, Poland and Romania). This is due to the increase in N_2O from crops (mainly cereals), while in the Belgian and Dutch regions the increase (up to +0.29 %, however high in absolute value) is mainly due to the increase in methane from more cattle.

Figure 2: GHG emissions change from reference scenario (kg CO_2 eq/total ha)



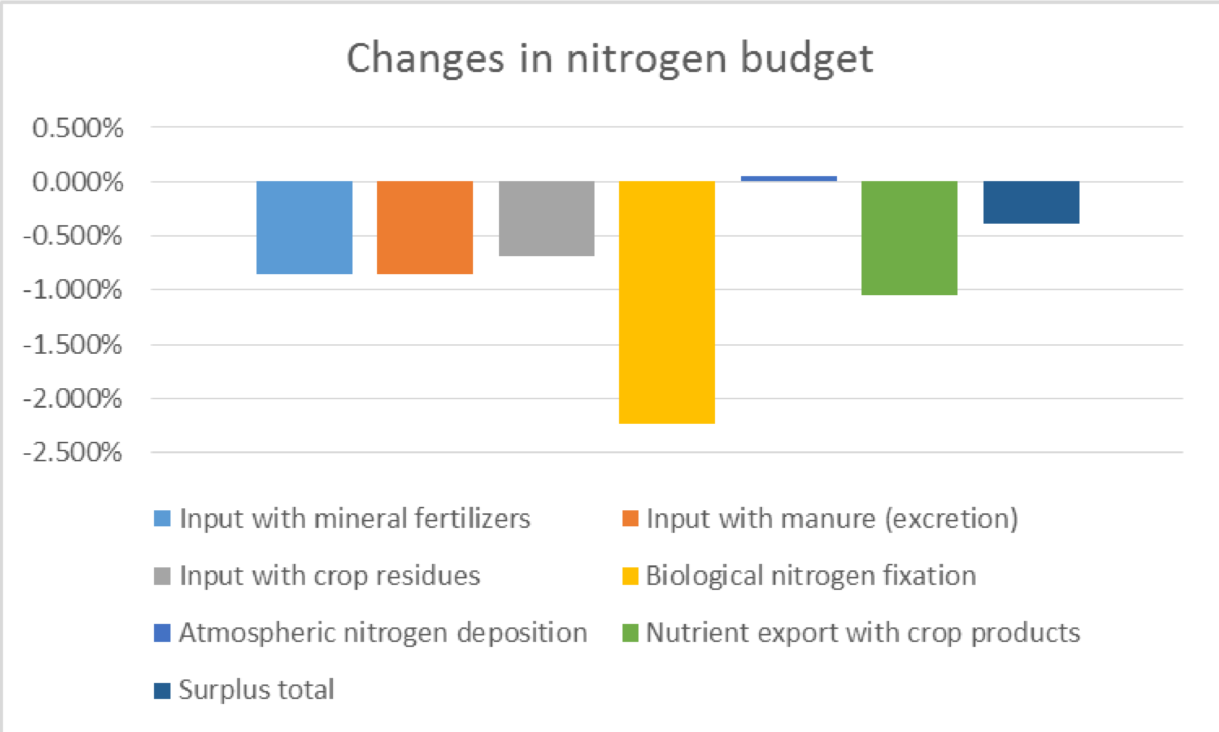
7.2.3. Nitrogen surplus

In general, greening measures do not have significant impacts on nutrient balances. Due to the increase in UAA in the GREEN scenario compared to reference scenario, greening measures result in a very small increase in total N surplus for the whole of the EU-28 (+ 27 030 t, + 0.23 %). The GRAS scenario would result in a slightly higher surplus (+ 0.34 %), which is partially offset by the decrease that would be produced under the EFA scenario (– 0.05 %) (Table 11). The increase is associated with a higher UAA, as the N surplus per ha decreases slightly (– 0.25 kg/ha, – 0.39 %), as well as the total and the per hectare N inputs with mineral fertilisers, with manure (excretion) and with crop residues (see Figure 3). All these figures are too low to be significant.

Table 11: Gross N surplus in the EU-28 (absolute value and % change to reference scenario)

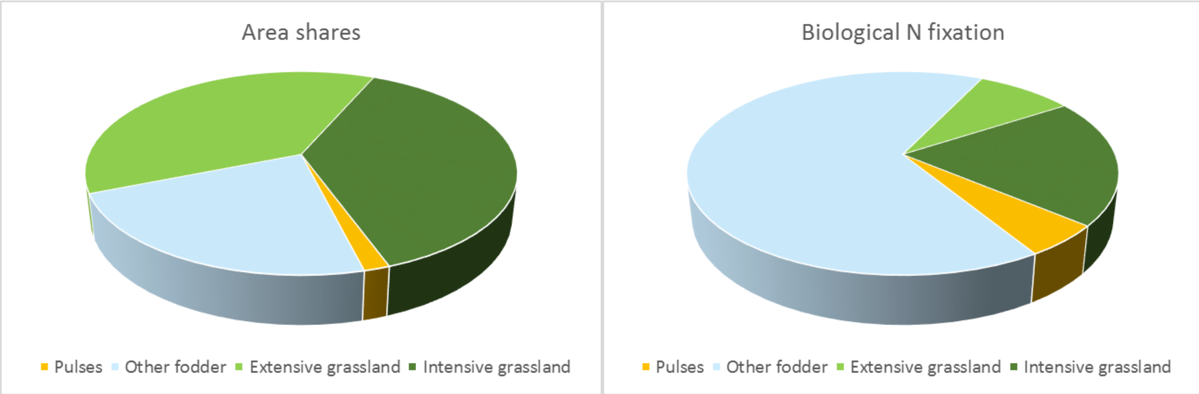
		CropDiv	EFA	GRAS	GREEN
Total	1 000 t N	+ 8.8	– 6.2	+ 40.1	+ 27.0
	%	+ 0.08 %	– 0.05 %	+ 0.34 %	+ 0.23 %
Per UAA ha	Kg N/ha	– 0.10	– 0.30	– 0.06	– 0.25
	%	– 0.16 %	– 0.47 %	– 0.09 %	– 0.39 %

Figure 3: Changes in N budget for GREEN scenario in the EU-28 (% change of kg N/UAA ha to reference scenario)



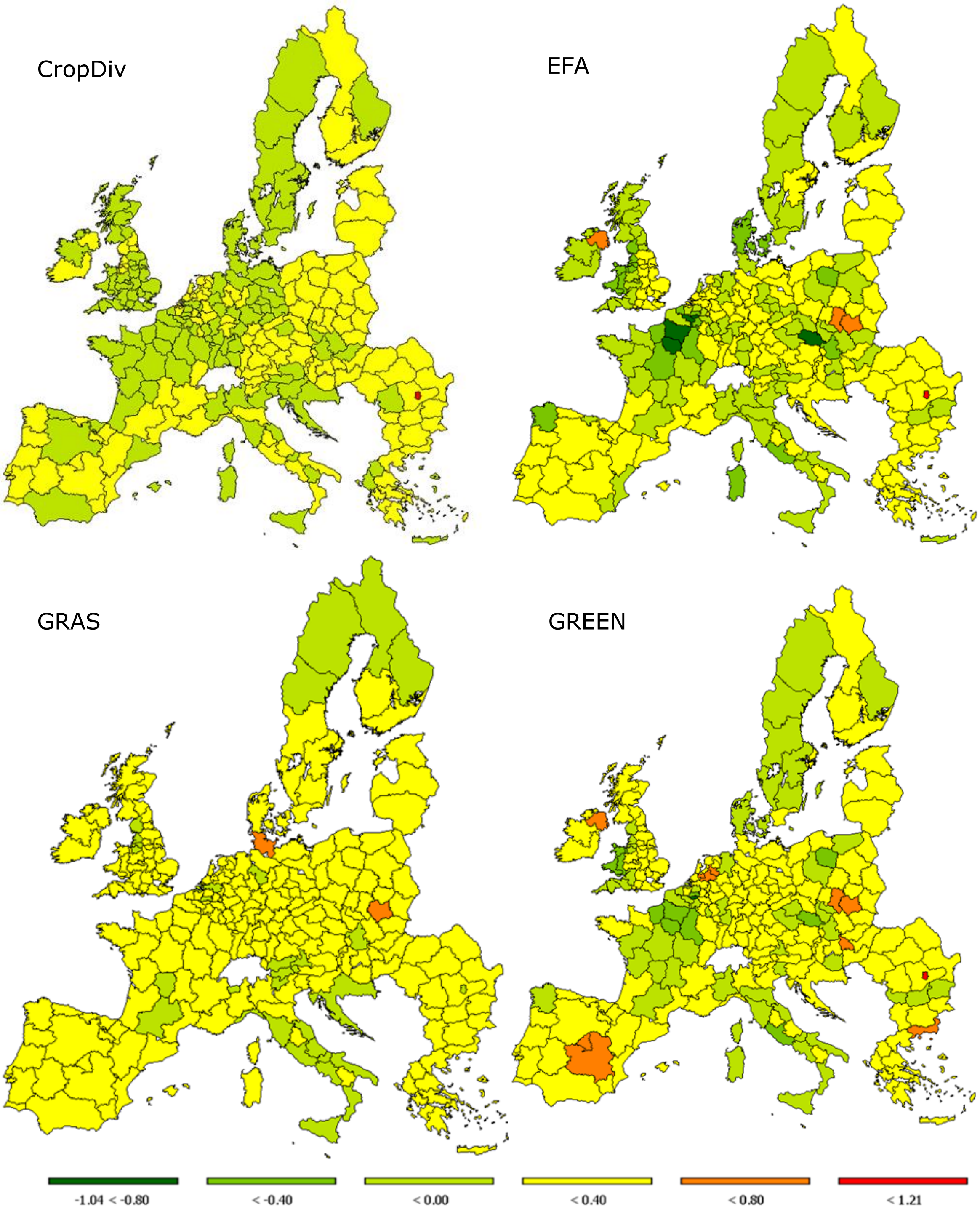
Even though biological N fixation could be expected to increase due to additional area of N-fixing crops, this is not the case in the CAPRI simulation results. The reason behind this is that the higher biological N fixation from increased pulses area is offset by the decrease in 'other fodder crops' area. In fact, 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. In fact, this category is responsible for 66 % of the total biological N fixation in the EU-28 in the reference scenario, while grasslands account for 29 % of total biological N fixation and pulses only for 5 % (see Figure 4). The non-inclusion of alfalfa under EFA N-fixing crops probably results in an overestimation of the pulses area and production in the greening scenarios.

Figure 4: Biological N-fixation shares and area shares for N-fixing crops in the reference scenario in the EU-28



Regional differences are shown in Figure 5. It must be noted that they are expressed per total area, not agricultural area, therefore they also reflect the impacts of the increase in the UAA area. The very limited impacts of the crop diversification measure (top left panel) can be observed, and some higher impacts in the EFA scenario with the increase of fallow land, N-fixing crops and cover or catch crops (top right panel), especially in regions in northern France, Belgium and the Czech Republic. In Northern Ireland, the increase in set-aside is accompanied by a shift from extensive to intensive grassland, which may explain the increase in the N surplus. In the southern Polish regions, where arable crops have a much higher weight in total UAA, there is an increase of more than 1.5 % in UAA, mainly cereals area. The GREEN scenario shows limited and mixed effects from the combination of the three greening measures.

Figure 5: N surplus regional change from the reference scenario (kg N per total ha)



7.2.4. Ammonia emissions

Total NH_3 emissions are slightly lower in the GREEN scenario than in the reference scenario in the EU-28 (– 0.33 %, – 8 290 t), mainly due to the impacts of EFA measures: substitution of field crops by fallow land, increase in N-fixing crops and a lower number of animals. In fact, the EFA scenario shows a decrease of 0.31 % while the GRAS scenario shows a 0.1 % increase. There is almost no change in the CropDiv scenario.

The overall effect of the greening measures on ammonia emissions looks positive, as ammonia reductions are more important in regions with higher ammonia emissions per hectare (or with high livestock density), as can be observed from Figure 6 and Figure 7.

Figure 6: NH_3 emissions levels in reference scenario (kg N/total ha)

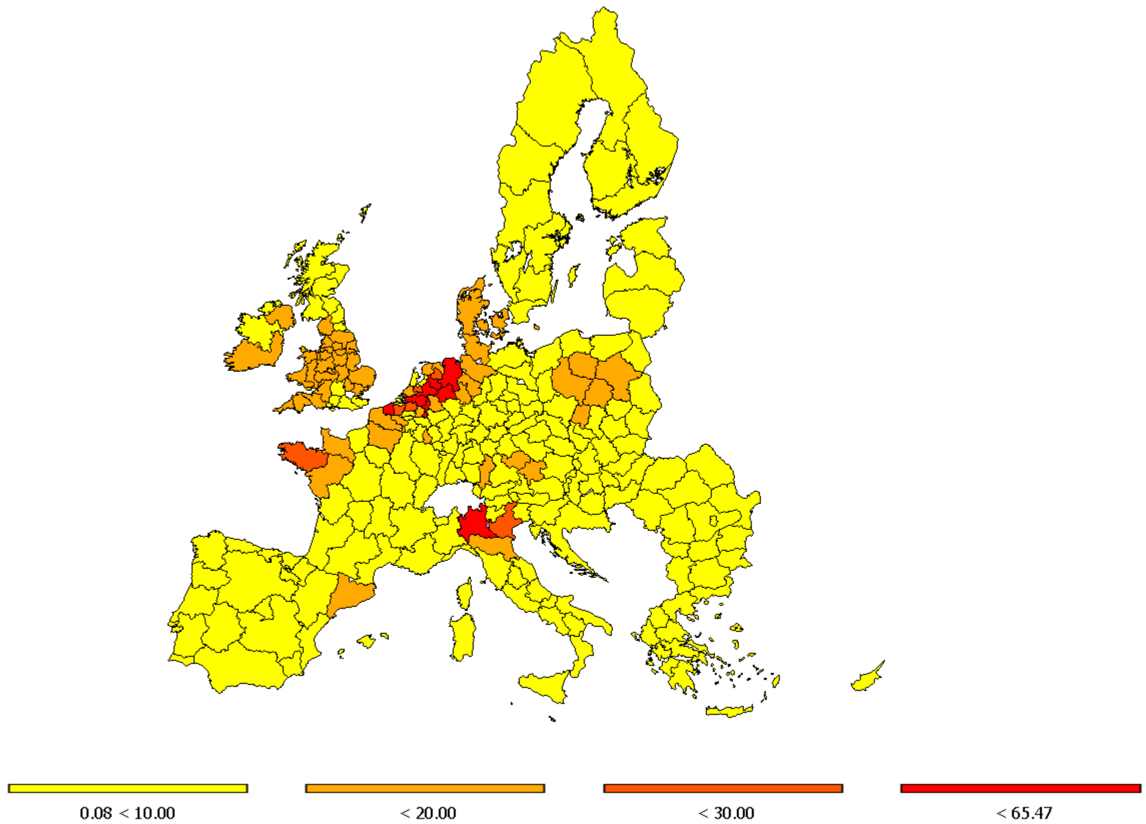
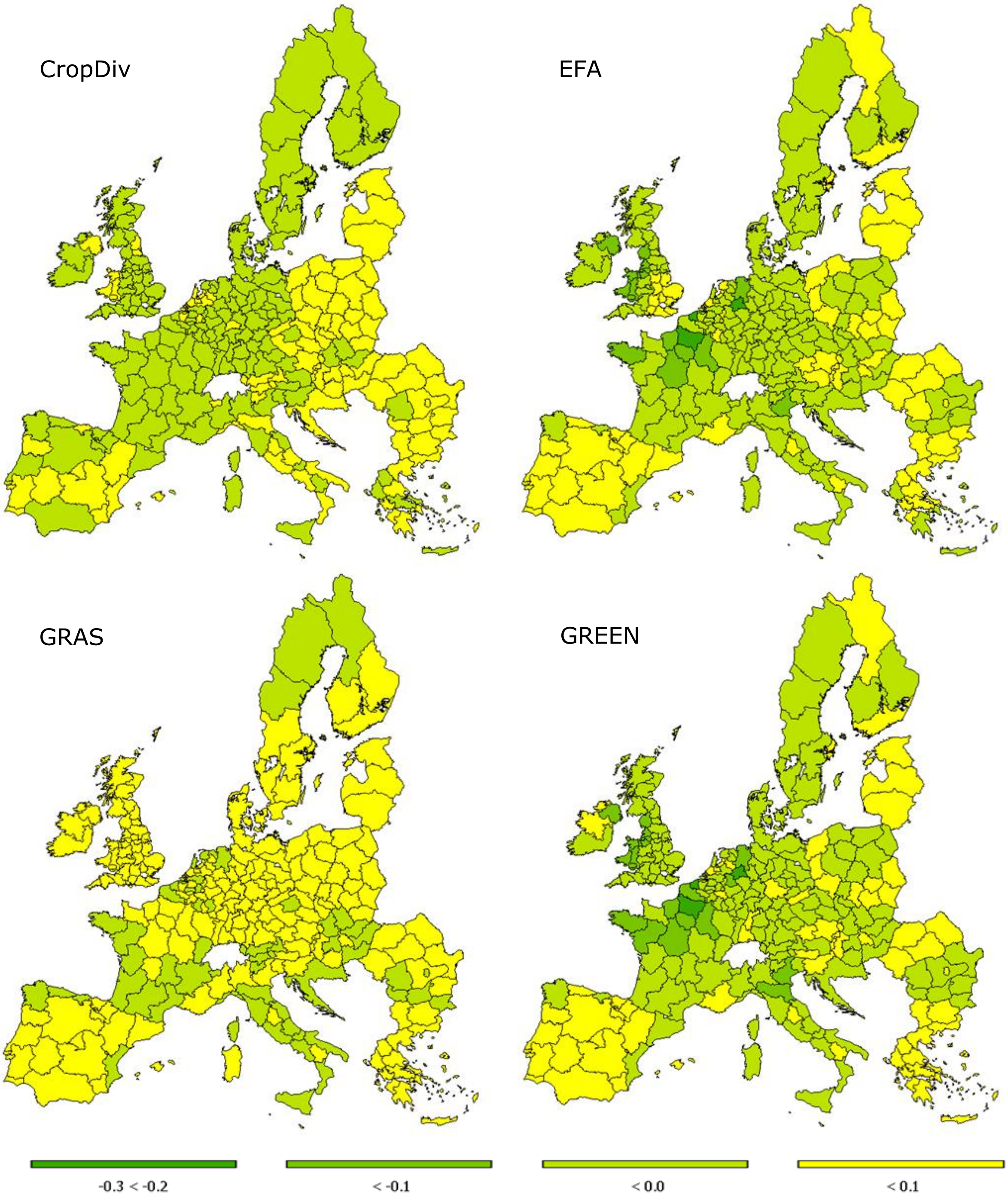


Figure 7: NH_3 emissions change from reference scenario (kg N/total ha)



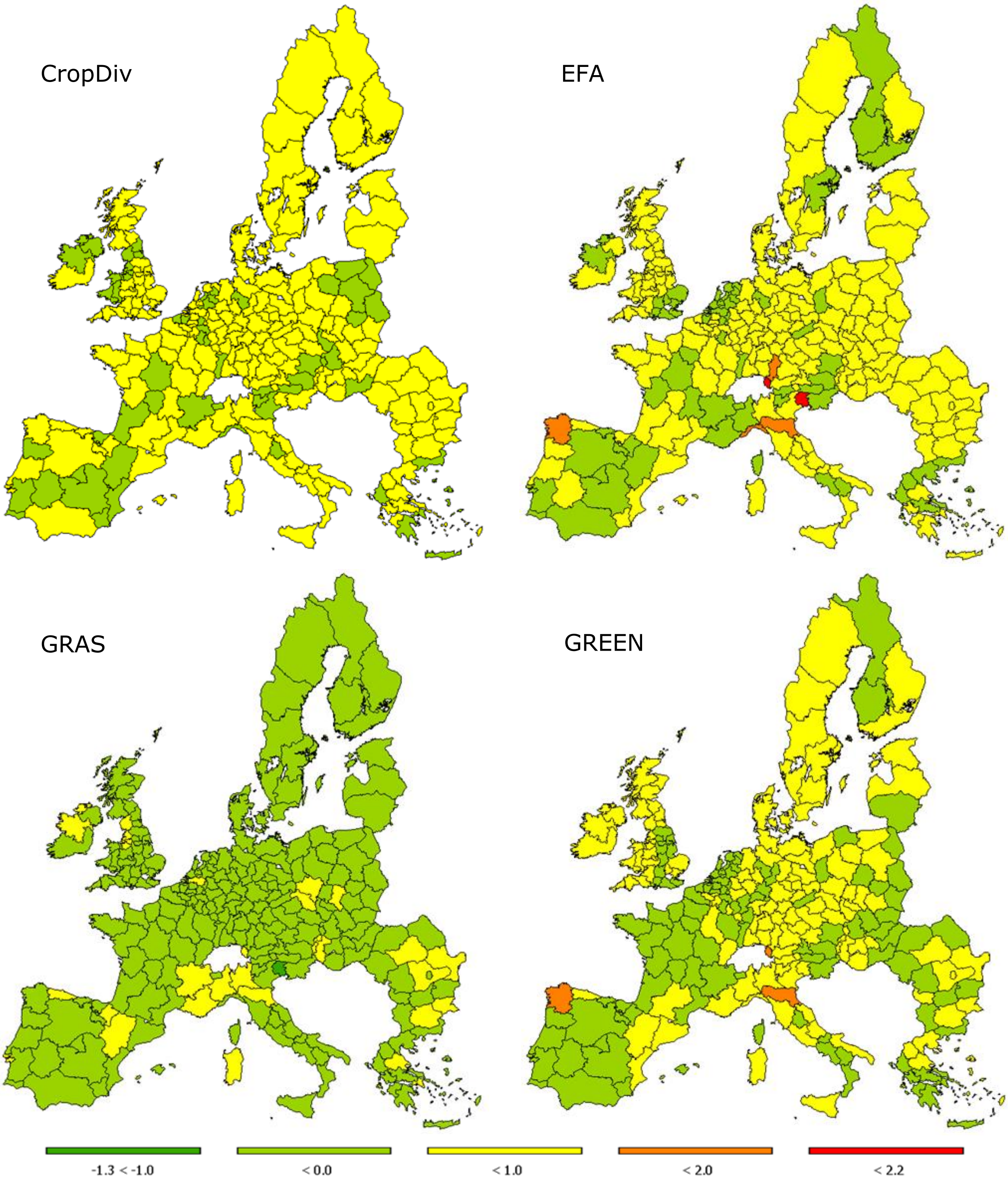
7.2.5. Soil erosion

While pasture and grassland strongly protect the soil from erosion, set-aside and fallow land only do so when they have some green cover. Otherwise, if they are left ploughed, disced or tilled, the soil erosion can be higher than for most crops. Given that it was not possible to know the cover of fallow land (except where GAEC requires certain practices ([10])) it has been assumed that it is ploughed every year for most countries. For this reason, soil erosion calculated by CAPRI in fallow and set-aside areas is probably overestimated in this assessment.

Consequently, the greening scenario results show that soil erosion per hectare in the EU-28 experiences a minor increase of + 0.56 % (+ 0.03 t/ha and year), mainly in those regions with a higher increase in fallow land and set-aside (Figure 8, bottom right panel). This effect is due to the total increase in set-aside and fallow land area (+ 0.8 million ha), which offsets the beneficial effect of the increase in cover crops and in fodder areas (pastures and grasslands area increase by 1.5 million ha but alfalfa and other fodder areas with low soil-erosion factors decrease by 0.9 million ha). As expected, the GRAS scenario (Figure 8, bottom left panel) presents a small decrease in average soil erosion (– 0.4 %, – 0.02 t/ha and year) due to the increase in grassland relative to the reference scenario. The crop diversification measure has no impact on soil erosion. As a matter of fact, none of these differences are significant.

([10]) 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.

Figure 8: Soil erosion change from reference scenario (t/UAA ha year)



7.2.6. Biodiversity-friendly farming practices (BFP)

The BFP index aims at showing the likelihood of farming systems to support biodiversity. It takes value between 0 (bad for biodiversity) and 10 (best for biodiversity) and its calculation is based on:

- crop richness and crop diversity indexes;
- N input index;
- the share of arable land, grassland, permanent crops and olive groves in UAA.

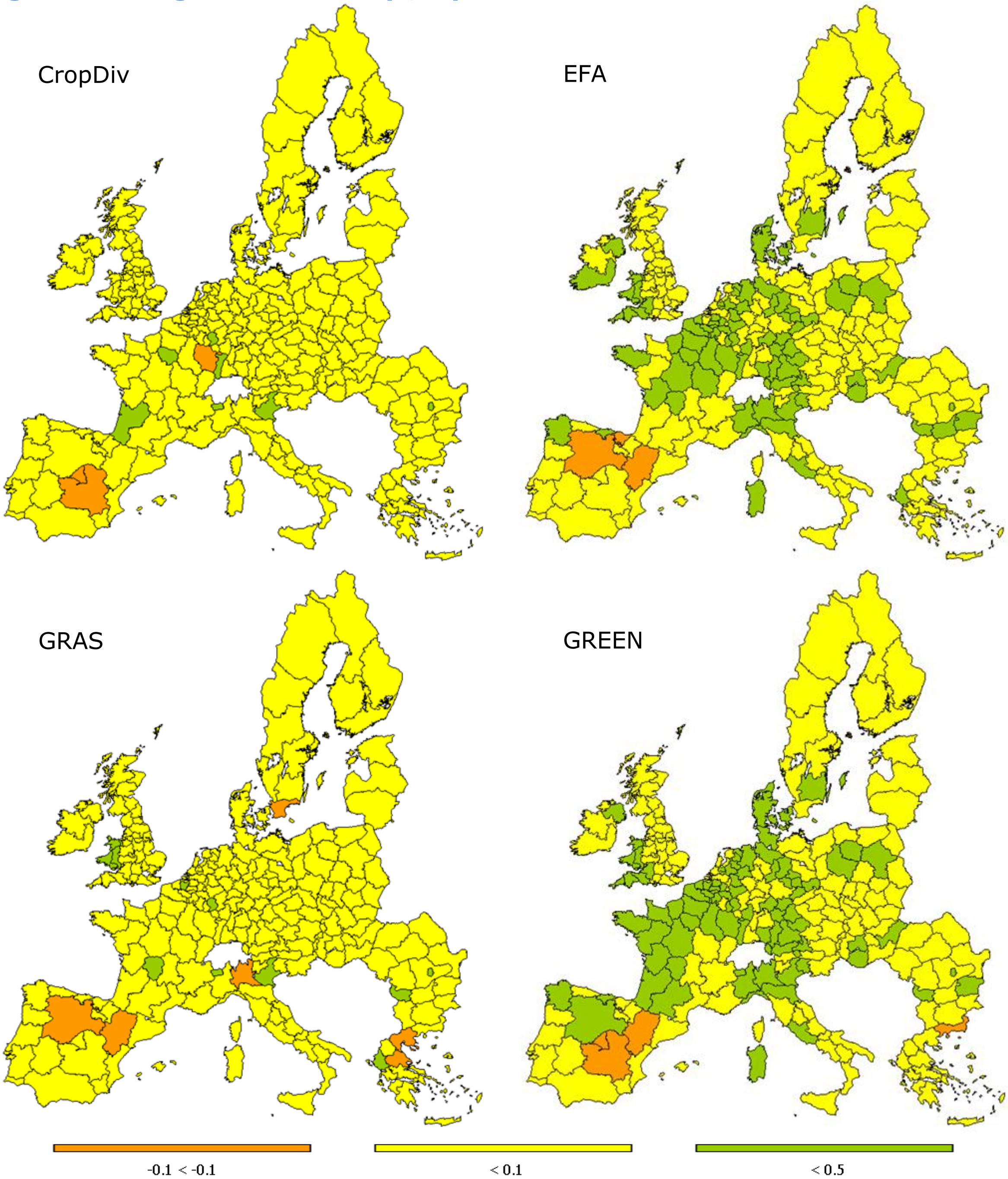
The BFP indicator shows a very small increase in the GREEN scenario of only 0.06 points in the 1 to 10 scale (+ 0.6 %) in the EU-28. This positive impact is mainly led by the EFA scenario. The changes across all four greening scenarios, however, are negligible, given than they do not reach even 0.1 index points (1 %).

Table 12: BFP indicator in the EU-28 (index, absolute change to reference scenario)

	Reference	CropDiv	EFA	GRAS	GREEN
	Index 1-10	*Absolute change to reference*			
EU-28	5.25	+0.01	+0.05	-0.01	+0.06

Changes at NUTS 2 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, see Figure 9, bottom right panel). In central Spain where the index decreases, the GREEN scenario shows more cereals and less fallow area. This is corroborated by the increase in total nitrogen fertilisation observed in those regions. The opposite happens for example in Denmark, where the total nitrogen fertilisation of arable crops declines. The positive effect of fallow land and N-fixing crops can be observed in the EFA scenario (Figure 9, top right panel), while the GRAS scenario shows the consequences of slightly higher livestock density in some regions. The CropDiv scenario 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 (Figure 9, top left panel).

Figure 9: Change in BFP index (0,10) from reference scenario.



8. Conclusions

The 2013 CAP reform introduced a substantial change to the implementation of direct payments. With the aim of strengthening the environmental performance of the farming sector, the reform made direct payments conditional on the adoption of 'agricultural practices beneficial for the climate and the environment' (so called CAP greening). The CAP greening measures include crop diversification, maintenance of permanent grassland and EFA.

This report aims to provide a quantitative analysis of the economic and environmental impacts of CAP greening, covering all EU regions. We employ the CAPRI partial equilibrium model to simulate the quantitative impacts. The advantage of CAPRI compared to other modelling approaches available in the literature is its geographic coverage and its ability to take into account the heterogeneity in farm production systems. More precisely, CAPRI is able to simulate the impacts of CAP greening at farm-type level across the whole EU, including environmental effects and market (price) feedback.

The simulated results reveal that the economic impacts of CAP greening are rather limited, although some farm types or MS may face substantial changes. The simulated changes for aggregated land-use categories (grassland, arable land and UAA) are 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 %) as it increases from a low level in the reference scenario. The simulation exercise 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 area. Overall it is not straightforward to identify which greening measure is the main driver of the land-use impacts, as the impacts are strongly crop and land-type specific. However, it appears that EFA and grassland measures tend to induce slightly higher land-relocation effects relative to the crop diversification measure for several crops and land categories. In line with expectations, the total land-use change caused by CAP greening in the EU-28 comes predominantly from the three farm types (i) cereal, oilseeds and field cropping farms, (i) livestock farms and (iii) mixed farms, while other farm types account for a minor share of total land-use change.

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, which is expected to be more affected, with a sizable simulated production increase (3.5 %). This significant impact is due to the fact that pulses are directly targeted by the EFA measure and can also be used as alternative crops for fulfilling the increased diversification obligations. The production effects are driven by the EFA followed by the grassland measure, though both have relatively low magnitudes, reflecting the limited combined effects. With the exception of pulses, the crop diversification measure has relatively little impact on production. Production across different farm types is heterogeneously affected by CAP greening, depending on the current land-use structure. However, farms specialising in cereals, oilseeds, field crops and mixed cropping account for the main bulk of the aggregate changes in production for arable crops (cereals, oilseeds and pulses) caused by CAP greening in the EU-28. For animal products and fodder, the greatest share of the change in production caused by CAP greening comes from farms specialising in animal production or from mixed livestock farms. Other farm types account for a minor share of the total change in production. In term of farm size, medium-sized and large farms tend to account for the major share of the total changes in production caused by CAP greening.

Simulation results show that CAP greening will lead to a small increase in prices in parallel with the decrease in production. There are two main reasons for the decrease in production: (i) greening obligations require farms to take a small amount of land out of production; and (ii) farm productivity slightly reduces due to the land reallocation effects induced by the adoption of the three greening measures. The price impact varies between – 0.39 % and + 1.5 % for the main agricultural products in the EU-28, with arable crop products being the most affected, while animal products being little impacted by CAP greening.

Farm income slightly increases due to CAP greening because the price effects offset the production decline observed across several sectors. At EU-28 level farm income increases by 0.9 %. At MS level the income increase varies between 0.1 % and 3.9 %. Of the three greening measures, EFA leads to the largest increase in income as it alters production and price levels the most. However, its income effect is still relatively small (less than 1 %) in most MS. Crop diversification and grassland measures cause only small income changes, in the range of ± 0.4 % in the majority of MS. As expected, there is a more sizable increase in incomes at EU-28 level for farms specialising in arable field cropping (*cereals, oilseed and protein crops*, *general field cropping*) and in mixed farms and livestock farms (*dairy farms*, *sheep, goats and other grazing livestock*), but the income increase is still below 3 %. These farm types also account for the major share (more than 70 %) of the total income change caused by CAP greening in the EU-28.

Similarly to economic effects, the environmental impacts of CAP greening are limited. In general, effects at EU level are 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 the one inducing the lowest effects or no impact at all. 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, but regional changes vary between – 1.7 % and + 2.4 % relative to the reference level. The total N surplus presents instead a small, non-significant increase of + 0.2 %. This increase, however, is due to the increase in UAA, as the per ha surplus decreases by 0.4 %. Regional differences on a per hectare basis are between – 3.3 % and + 3.4 %, with the exception of one region with very low levels of N surplus. Ammonia emissions benefit from all three measures, resulting in a 0.3 % decrease, with regional changes between – 2 % and + 1.9 %. Nevertheless, the emissions decrease per ha can reach 4 % in some regions with high cattle density. The EFA measure is the main driver for the changes in ammonia emissions, mainly due to the decrease in emissions on arable land. On the other hand, the grassland measure does not contribute to ammonia reduction.

Soil erosion changes are limited in the EU-28, but they are sensitive to 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 with precision. Nevertheless, a higher area of annually ploughed fallow land could offset the beneficial effect of increased grassland on the soil. As expected, the grassland scenario is the most advantageous for soil erosion. The greening measures have limited effects on BFP, with an increase of only 0.06 points in the 1 to 10 scale. While the crop diversity and grassland maintenance scenarios show almost no impact on the index, the EFA scenario shows a small positive impact (+ 0.05) due to the lower N input from fallow land and N-fixing crops.

Despite the comprehensiveness of the analyses, the findings of this report have to be considered with some caution on account of the model's assumptions. First of all, the model does not model individual farms but only farm types, which does not allow the full complexity of the CAP greening measures (particularly for crop diversification measure and EFA) to be taken into consideration. It may also lead to aggregation bias. Therefore, the simulated results probably tend to be underestimated for several indicators (e.g. land use, production effects, income), while for specific activities the impacts could be either underestimated or overestimated. A second potential caveat of the analysis is that the modelled greening scenario does not take into account all landscape elements eligible for EFA, as a result of which the overall impacts of this measure are likely overestimated. Third, certain crops are defined in the model as an aggregation of a set of individual crops (e.g. fodder crops), which may also lead to a slight overestimation of the simulated impacts. In particular, with alfalfa being included under fodder crops it has not been taken into account as a N-fixing crop, so the impact of the EFA measure on the area of other N-fixing crops (pulses) is overestimated. Fourth, not all the specificities regarding the 'greening' implementation are considered in the model. In particular, not considering those farming practices that yield an equivalent or higher beneficial effect for the climate and the environment in comparison to the three 'greening' obligations likely leads to overestimated effects. Fifth, the reference area for the grassland measure is based on the reference scenario and on base year areas, which may depart from the reference area as established in the 2013 CAP reform. This potential mismatch in reference areas may also cause a bias in the simulated results in either direction. Sixth, the criteria for exemption from CAP greening are not fully accounted for in the CAP greening scenarios. This refers in particular to exemptions for small farms from crop diversification and EFA obligations, which may lead to overestimated impacts for these farm types. Seventh, 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 report. Despite these limitations, the report shows the potential implications of CAP greening, and in particular it indicates its key economic and environmental effects in the EU.

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10. Appendix: Modelling crop diversification measure

Following Britz et al. (2012), the modelling of crop diversification measure in CAPRI is done through the Shannon index using the single farm records from the FADN and farm type module in CAPRI. The process to combine the single FADN farm records with CAPRI farms types is done in two steps.

In the first step, a land optimization model is run for each FADN farm unit to simulate the land allocation effect of the crop diversification measure. The objective function of the optimization model represents the minimization of the square difference between the actual arable crop area and the simulated area subject to crop diversity constraints and land endowment constraint. Then, the Shannon index is calculated for both actual land use data and the simulated results. To ensure consistency, the Shannon index is calculated for the CAPRI farm types as defined in Table 1. The difference between the actual and the simulated values of the Shannon index represents the land allocation adjustments that farms need to undertake to fulfil the crop diversity requirements (Britz et al., 2012, 2013).

In the second step, the difference between the actual and the simulated Shannon index obtained in the first step is introduced as a land use constraint for farm types in CAPRI. For each farm type in CAPRI, crop diversity measure is introduced as an adjustment of arable crop area represented through conditioning land allocation to be in line with the crop diversity as indicated by the simulated Shannon index relative to the reference scenario level Shannon index (Britz et al., 2012, 2013).

LB-NA-28037-EN-N

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doi:10.2788/452051
ISBN 978-92-79-60682-3