JAE Journal of Agricultural Economics

Journal of Agricultural Economics
doi: 10.1111/1477-9552.12065

Green Light for Green Agricultural Policies? An Analysis at Regional and Global Scales

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(Original submitted December 2012, revision received December 2013, accepted January 2014.)

Abstract

This paper analyses the effects of introducing biodiversity-targeted ecological focus area (EFA) requirements on all farms with arable land in the EU by quantifying their global, regional, economic and environmental impacts in a mutually consistent way. To capture these impacts, different spatial scales need to be considered – ranging from on-farm decisions regarding the EFA in the EU, to supply response around the world. In order to address this challenge, we combine the supply side of the CAPRI model, which offers high spatial, farm and policy resolution in the EU, with the GTAP model of global trade and land use. Both models are linked through a multi-product, restricted-revenue function for the EU crop sector. The results predict improved environmental status in the high-yielding regions of the EU. However, output price increases lead to intensification in the more marginal areas of the EU where little or no additional land is taken out of production. The decrease in arable land in the EU is partially compensated by an increase of crop land, as well as increased fertiliser applications, in other regions of the globe. Thus, the improvement of environmental status in the EU comes at the price of global intensification, as well as the loss of forest and grassland areas outside the EU. Overall, we find that every hectare of land that is taken out of production in the EU increases greenhouse gas emissions in the rest of the world by 20.8 tonnes CO_2 equivalent.

Keywords: *Biodiversity*; *computable general equilibrium*; *EU agricultural policy*; *regional intensification.*

JEL classifications: *C61, C68, F18, Q18, Q57.*

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1. Introduction

In its proposal of October 2011 to reform the Common Agricultural Policy (CAP) for 2014–2020, the EU Commission included a minimum farm-level share of so-called 'ecological focus area' (EFA) as one of several compulsory measures for receiving direct income support under the CAP (EU Commission, 2011). That support, known as Single Farm Premium, accounts for the bulk of CAP spending and amounts to about €40 billion per year, or on average about €300 per year for each hectare of agricultural land in the EU. Given the size of the subsidy, and assuming effective implementation, it is expected that farmers will have an incentive to meet the EFA requirement.[2] The EU proposal of 2011 suggests that 7% of the non-grassland area of a farm should consist of EFA, including fallow land, terraces, landscape features, buffer strips and afforested area.

The purpose of this paper is to estimate the global economic and environmental impacts of the EFA requirement, ignoring any other elements of the EU proposal. In so doing, we develop a new methodology for linking analytical tools operating at different spatial scales in a mutually consistent way.

Our analysis complements the lively discussion in Europe about the future of the CAP, which is expected to entail spending of about €50.5 billion annually for the period 2014–2020 (EU Parliament, 2013). A group of European agricultural economists (Hofreither *et al.*, 2009) has proposed complete elimination of income support to farmers and market interventions, instead targeting CAP payments to enhance the provision of ecosystem services. The declaration states 'the protection of biodiversity also warrants EU support because animals, ecosystems and biodiversity-threatening pollution cross borders' (Hofreither *et al.*, 2009). Indeed, since 2003, the EU regulation for support under the second Pillar of the CAP (EU Council, 2003) explicitly requires programmes supporting biodiversity-related EU legislation such as the so-called Birds and Habitats Directives as well as the maintenance of high nature value farming systems, in order to support the so-called '2010 objective of stopping biodiversity loss' (EU Commission, 2006). Member States thus need to develop EU co-financed agri-environmental measures into which farmers could opt in. It is now clear that the objective of halting biodiversity loss has not been met (EU Parliament, 2012), motivating the far more stringent proposal of compulsory EFA: 'One of the objectives of the new CAP is the enhancement of environmental performance through a mandatory 'greening' component of direct payments which will support agricultural practices beneficial for the climate and the environment applicable throughout the Union' (EU Commission, 2011).

[2]The proposal was somewhat ambiguous as to the size of the penalty in case of non-compliance. Whereas Article 33.1 stipulates 'In order to finance the payment referred to in this Chapter, Member States shall use 30% of the annual national ceiling set out in Annex II', the introduction states 'An important element is to enhance the overall environmental performance of the CAP through the greening of direct payments by means of certain agricultural practices beneficial for the climate and the environment that all farmers will have to follow, which go beyond cross compliance and are in turn the basis for Pillar II measures.' According to our general approach to evaluate the maximal impact of the proposal, we assume that farmers would lose all payments in the case of non-compliance.

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We take the proposed EFA requirement of 2011[3] to show the extent to which EU-wide legislation related to agri-environmental interactions influences global markets, thereby giving rise to global environmental spillover effects.

There is a tendency to concentrate solely on the regional or local externalities targeted by these programmes when assessing agri-environmental measures. However, with integrated global markets, reduced regional supplies from the EU will generally be accompanied by an increase in production as well as the intensification of farming in other parts of the world. These changes will affect the environment, including global externalities such as climate change or biodiversity loss. Such global interactions and related environmental leakage were vividly illustrated in the debate over land use changes induced by US and EU biofuel mandates (Fargione *et al*., 2008; Searchinger *et al*., 2008). To our knowledge, there has not yet been an analysis focusing only on the EFA requirement and putting it into a global land use context. The few existing analyses either seem to assess all measures simultaneously (van Zeijts *et al*., 2011), or neglect any international market effects (DG-AGRI, 2011).

This paper is organised as follows: In section 2 we present the methodology, including an overview of the two economic simulation models used – CAPRI (Common Agricultural Policy Regionalised Impact) (Britz and Witzke, 2012) and a version of the Global Trade Analysis Project (GTAP) model, which incorporates land use differentiated by agro-ecological zones (GTAP-AEZ: Lee *et al*., 2009). Furthermore, we discuss how the EFA programme of 2011 (EU Commission, 2011) is simulated and how crop supply response to changes in prices and the EFA obligation from CAPRI is integrated into the global GTAP model. The algebraic details can be found in an online Appendix S1. Section 3 presents our quantitative findings, starting with the global level and then discussing regional effects within the EU-27.

2. Methodology

2.1. Choice of quantitative tools

In order to quantify the global, regional, economic and environmental impacts linked to the proposed EFA requirement in a mutually consistent way, we combine economic and environmental analysis at different spatial scales – capturing both the regional heterogeneity within the EU as well as the worldwide variation in land use, yields and greenhouse gas (GHG) emissions. The EU proposal allows farmers to include any existing EFA in the 7% requirement, which renders analysis of this policy more complex, since it must factor in these pre-existing land use practices at the farm level.

In order to capture pre-existing land use practices with respect to land use, we require a high degree of spatial resolution and farm type detail within the EU, which is why we use the farm type module (Gocht and Britz, 2011) of the CAPRI system (Britz and Witzke, 2012). This depicts EU agricultural supply as coming from nearly

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[3]As indicated below, our analysis gives rather an upper limit of the impact of the 2011 Commission proposal. That proposal has been subsequently changed and flexibility opened up for Member States with regard to the implementation of the different measured proposed (EU Commission, 2013). As Member States have not yet decided how to use that flexibility, we take the stricter 2011 proposal as the basis for our analysis. Subsequent changes to the 2011 policy proposal are not considered.

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2000 individual deterministic, comparative-static programming models either for all farms in a NUTS-2 region (Bulgaria and Romania) or all farms belonging to a certain farm type inside a NUTS-2 region (EU-25). The nine farm types are further differentiated by specialisation (12 types) and economic size (3 classes); a residual (all other) farm type ensures consistency with regional totals. The models cover the impact of Pillar I measures on agriculture in detail, as well as a broad representation of important Pillar II measures. They also take into account the interaction between animal and crop production via the exchange of feed, fodder and nutrients comprised in manure at the regional level.

As we will see below, a key component of the analysis is the EU supply response for major arable crops, which has been econometrically estimated in the CAPRI model (Jansson and Heckelei, 2011). The most recent CAPRI market module incorporates agricultural land demands and the net supply of land to agriculture (Adenäuer and Britz, 2012). However, it does not yet distinguish different land use types – a necessary feature for quantifying carbon emissions induced by land use change, a key aspect of the paper.

In order to assess global land use changes in response to this EU policy, we utilise GTAP-AEZ, rather than the CAPRI global market module. GTAP-AEZ is a multi-regional and multi-product computable general equilibrium (CGE) model which covers all economic activities and sectors, and identifies land use changes by AEZ (Lee *et al.*, 2009). The GTAP-AEZ model covers 18 AEZs with six growing periods and three climatic zones. Land-using activities include crop land, pastures and forestry. GTAP-AEZ allows for shifting land use amongst these different activities (Lee *et al.*, 2005) and has been augmented by Hertel *et al.* (2010) with information on GHG emissions, computed from a carbon accounting model, to track the associated release of GHGs due to land use changes. Additionally, we supplement the GTAP model with information about spatially disaggregated, global fertiliser use taken from Potter *et al.* (2009). This is important since the EFA requirement is expected to have an effect both on area planted as well as incentives for intensification, in both the EU and the rest of the world. Increased nitrogen fertiliser applications lead to increased nitrate run-off as well as increased GHGs from agriculture. By pairing these two modelling systems, we try to exploit comparative advantages with respect to both global and regional data availability in this multi-scale analysis.

2.2. *Quantifying ecological focus areas at the regional scale*

In the following, we analyse the effect of the EFA obligation in comparison to a 2020 baseline[4] which reflects current legislation. None of the changes to the CAP in the EU Commission, 2011 proposal are part of this baseline.

The 2011 EU EFA proposal differs both from opt-in programmes such as the voluntary set-aside programmes in the EU or the Conservation Reserve Programme in the US, but also from the past, and now abandoned obligatory supply control

[4]For the current study, the 2020 baseline captures developments in exogenous variables, such as policy changes, population growth, GDP growth and agricultural market development, for the year 2020 relying on a combination of three information sources (for a detailed description, see Britz and Witzke, 2012): (i) a recent Aglink-COSIMO baseline from OECD/FAO, (ii) analysis of historical trends, and (iii) expert information, especially on the development of biofuel markets (Blanco Fonseca *et al.*, 2010).

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set-aside programmes of the EU. The latter difference arises from the fact that the EFA requirement, while being obligatory, takes existing practices of farmers into account, e.g. when their farms already comprise eligible areas such as idled land or when they farm ecologically. A critical factor in quantifying the EFA requirement is which existing arable areas in the 2020 baseline may be counted towards the 7% requirement. The more generous this definition is the more modest the impact of the policy. The EU proposal states in Article 32 that 'Farmers shall ensure that at least 7% of their eligible hectares . . . excluding areas under permanent grassland, is ecological focus area such as land left fallow, terraces, landscape features, buffer strips and afforested areas' (EU Commission, 2011). For practical reasons (mostly data availability), our quantitative implementation of this policy opts for the following specification: only areas shown in the 2020 baseline under fallow land or voluntary set-aside are counted towards this goal. This stringent definition results in estimated EU environmental benefits, as well as world price changes, which are likely to be at the outer bound of what will actually occur, since some farmers would be able to claim EFAs

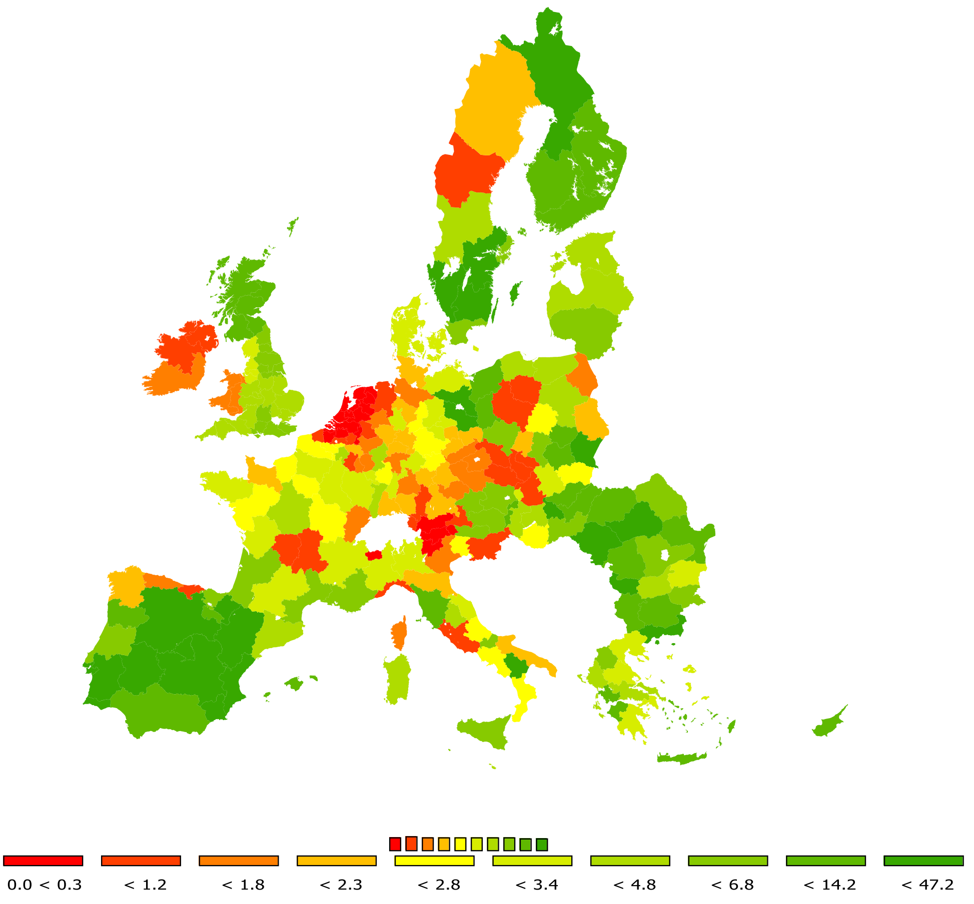

Figure 1. Percentage shares of idled land in total arable land in the baseline.
Note: Idled land: Fallow land or land in voluntary set-aside schemes; rectangles show the upper class limit.
Source: Authors' own calculations.

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currently not in our database. This would, in turn, lessen the stringency of the 7% EFA requirement. In addition, all farms under organic farming systems will automatically be assumed to comply with the EFA. Because we do not distinguish organic and other farming systems in our database, the analysis cannot consider the resulting dilution of the overall EFA requirements, which also leads us to overestimate the effect of the EFA obligation. Finally, the CAP agreement does not enforce the full 7% greening provisions, though it maintains this as a future goal (EU Commission, 2013).

Figure 1 shows the share of arable land in the EU which is under fallow or set-aside in the CAPRI baseline for 2020. It shows that in roughly 30% of the NUTS-2 regions, the EFA obligation is, on average, already fulfilled, suggesting that the EFA obligation will have little direct effect on production in these regions. Of course, individual farms in these regions may still be affected, and producers in these regions may respond to market price changes due to EFA impacts in other parts of the EU. Generally, parts of the Mediterranean basin, and some regions in the new Member States, especially in Romania, Bulgaria, Poland, as well as the Nordic countries show high shares of idled land. The results for Spain suggest very high shares of fallow land in the baseline. In contrast to these regions, the EFA obligation would require considerable adjustments in the more intensively managed regions of the EU, especially in those with high animal densities (with the possible exception of Denmark). As the EFA requirement is related to arable land only, it is quite modest in relation to total agricultural area in regions with large shares of permanent grass lands, such as Ireland and Scotland. In sum the estimates show that the EU would put an additional 3.7 million ha, or 4.52% of its total arable area, into the EFA under the provisions of the reform modelled here.

2.3. Integrating a maximum revenue function for EU crop supply in a global economic model

Both the CAPRI and GTAP models offer distinct and different responses of crop supplies to a reduction in available land area. In order to achieve a mutually consistent GE-PE analysis, we build on the response surface approach of Britz and Hertel (2012), which means treating EU crop production in GTAP as a production possibilities frontier represented by a normalised quadratic revenue function (Diewert and Wales, 1988). This approach to linking CAPRI and GTAP-AEZ is summarised in Figure 2 and is based on simulations with CAPRI where prices are systematically changed. From these simulations, the supply response at the EU level of CAPRI is summarised by uncompensated supply elasticities. Additionally, the effect of introducing the EFA obligation is calculated. Next, we determine the expansion effect from a CAPRI simulation where all crop prices are changed simultaneously. Finally, we calibrate the GTAP-AEZ model both against the supply elasticities and the expansion effect to match the compensated supply. In this application a shock of 4.52% is implemented to the total arable land in the EU which is the effective EFA that will be taken out of production as described above. Having solved the extended GTAP-AEZ model for a global equilibrium, the price changes are passed back to the CAPRI model in order to assess the production, income and environmental impacts of the EFA requirement at the regional level. More details on the methodology are provided in the online Appendix S1.

This approach has two advantages. Firstly, the revenue function, derived from CAPRI, summarises in one function how individual EU crop supplies, aggregated

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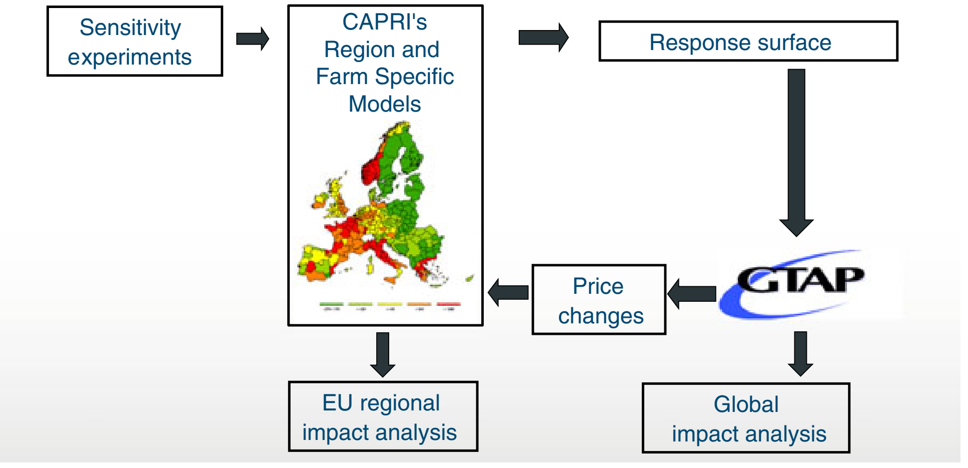

Figure 2. Overview of the GTAP-CAPRI framework.

from individual farm type and regional models to the EU total, react to changes in prices as well as to an expansion of EFA requirements. This gives us a direct estimate of the impact of the EFA requirement on EU optimal supplies of each crop type and is therefore of interest in its own right. A second advantage of this revenue function representation is that it can be incorporated directly into the GTAP-AEZ model with the EFA policy lever.

Table 1 presents the compensated own- and cross-price supply elasticities derived from CAPRI and the uncompensated elasticities derived from the modified GTAP-AEZ model.[5] As can be seen, we come quite close to matching the uncompensated elasticities between the two models, but are not able to match them perfectly due to the expansion effects which are not crop-specific in GTAP-AEZ. In the CAPRI model, this is estimated to be 0.36% for the aggregated crop sector. This means that if all crop prices rise by 1%, then aggregate crop supply will rise by 0.36%. In order to match the GTAP-AEZ representation of the EU with that of CAPRI, this expansion effect must also be appropriately adjusted. We do so by altering the land mobility parameters in GTAP-AEZ to match this expansion effect.

[5]Compared to Britz and Hertel (2012), the compensated own price elasticities of supply as reflected in the diagonal elements of the table are more responsive for oilseeds and coarse grains. For example, in this study a 1% change in oilseed prices, holding all other prices constant, leads to an expansion of oilseed supply by about 0.93%. In contrast, Britz and Hertel (2012) estimate the CAPRI compensated own-price elasticity of oilseeds to be somewhat smaller, at 0.69. The larger supply response in this study is mainly due to two methodological improvements in CAPRI. Firstly, CAPRI now includes price-dependent yields for major arable crops, in the range 0.25–0.3%, which increase the overall supply elasticity. And secondly, land supply is also more price-responsive in CAPRI, owing to potential substitution between arable and permanent grasslands. Additionally, changes stem from the fact that the analysis is now conducted at the level of individual farm types for the EU-25, whereas the analysis for Bulgaria and Romania is still at the NUTS-2 level because of missing data.

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Table 1
CAPRI compensated and GTAP-AEZ uncompensated price elasticities for the EU-27*

	Price					
	Rice	Wheat	Coarse grains	Oilseeds	Sugar	Other crops
Quantity						
Rice	0.125	−0.042	−0.054	−0.025	−0.011	0.008
	0.128	*0.004*	*−0.001*	*0.000*	*0.000*	*0.239*
Wheat	−0.002	0.736	−0.152	−0.101	−0.029	−0.451
	0.000	*0.758*	*−0.077*	*−0.055*	*−0.012*	*−0.134*
Coarse grains	−0.003	−0.140	0.813	−0.096	−0.025	−0.548
	0.000	*−0.055*	*0.834*	*−0.039*	*−0.007*	*−0.149*
Oilseeds	−0.003	−0.194	−0.202	0.925	−0.027	−0.498
	0.000	*−0.101*	*−0.103*	*0.929*	*−0.011*	*−0.167*
Sugar	−0.002	−0.099	−0.094	−0.049	0.407	−0.162
	0.000	*−0.007*	*−0.006*	*−0.003*	*0.421*	*0.011*
Other crops	0.000	−0.066	−0.088	−0.038	−0.007	0.200
	0.002	*−0.019*	*−0.029*	*−0.012*	*0.003*	*0.436*

Notes: *Uncompensated price elasticities in italics. Shaded regions show the own price elasticities.
Source: Authors' own calculations.

In GTAP-AEZ, a nested Constant Elasticity of Transformation (CET) structure of land supply is implemented. In the first nest, the land owner decides among three land cover types (forest, cropland and grassland) based on relative returns to land in these three uses. To match CAPRI's expansion effect, the CET parameter as described in Hertel *et al.* (2009) is reduced in absolute value from −0.20 to −0.058. In the second nest, the land owner decides among the allocation of land between various crops. Here, the CET parameter is also made less responsive for the EU, reducing it from −0.5 to −0.145. Both elasticities are smaller than in the original GTAP-AEZ model, suggesting that aggregate crop supply response in that model is considerably larger than in CAPRI – provided labour and capital are perfectly mobile across sectors. The latter assumption is typically altered in short-run (annual) simulations of that model.

2.4. Treatment of fertiliser use

An important response to the EFA is the potential for increased fertiliser use worldwide – due either to intensification on existing crop lands or to fertiliser use on new crop lands. Given the GHG emissions associated with nitrogen fertiliser applications, we seek to assess the magnitude of this effect. We do so by supplementing the database of GTAP-AEZ with fertiliser applications data from Potter *et al.* (2009). Specifically, we tie these applications to the use of purchased intermediate inputs in crop production. To capture the effects of increased fertiliser use within the EU, we capitalise on the CAPRI model's fertiliser module which calculates crop nutrient demand per crop as function of crop yield. Crop nutrient demands must be satisfied by either organic or mineral fertilisers, taking into account losses e.g. from volatilisation, runoff or leaching.

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3. Results

3.1. Price changes and comparison of quantity responses

When the revised GTAP-AEZ model is solved for a global equilibrium, global prices change in the wake of the EFA shock. Table 2 presents the EU price changes from the modified GTAP-AEZ model which are passed back to CAPRI together with the quantity changes of the combined modelling framework. The price effects are influenced by the own- and the cross-price elasticities of the EU shown in Table 1. Due to the EFA requirement in the EU, oilseed production experiences the largest decline of 3.1%, which boosts prices by 2.7%. The strong increase in the sugar price is also striking. Here the quantity produced is reduced by 0.3% while the price increases by 5.4%. On the one hand the strong price effect for sugar is due to the EU quota regime. In the simulation only sugar beyond the quota is reduced, such that the share of higher priced in-quota production in total supply increases. On the other hand these results are driven by the supply and demand elasticities in the EU as well as by the external trade structure. While the EU sugar market is highly protected, trade in oilseeds is not restricted by import tariffs. Thus, if the production of oilseeds is reduced in the EU, a price increase boosts production in other countries. They export more into the EU and thereby increase the supply and decrease the price in the EU. The EU sugar market, in contrast, is protected by high tariffs and only a few sugar exporters are allowed tariff concessions. For this reason, importers do not benefit from the average producer price increase of 5.4%, as they cannot profit from the EU quota regime. Additionally, partly due to WTO restrictions on subsidised exports, sugar is not an important export product of the EU, which removes another source of price responsiveness.

In our combined application of CAPRI and GTAP-AEZ, mutual compatibility depends on the agreement of supply effects between the two models. Table 3 shows quantity responses taking into account both the policy shock and the resulting price changes simulated within the GTAP-AEZ model (see also Figure 2). The first column in Table 3 gives the percentage quantity change if the compensated and expansion elasticities are used directly [i.e. absent the nonlinear revenue function summarised by equation (1) in the Appendix]. This is labelled the 'CAPRI point elasticities' approach, whereas columns 'GTAP-CAPRI' and 'CAPRI' report the simulation results from using GTAP-AEZ in the combined framework with CAPRI, and CAPRI, respectively. The CAPRI results are based on EFA requirements plus price changes, as taken from the GTAP-AEZ. This table highlights two important points. Firstly, a comparison of the first column with the remaining ones shows that the supply

Table 2

Percentage price and quantity changes due to an EFA requirement of 7% in the EU-27

	Price changes	Quantity changes
Rice	0.33	−0.35
Wheat	2.21	−2.35
Coarse grains	2.71	−1.86
Oilseeds	2.70	−3.12
Sugar	5.41	−0.26
Other crops	0.63	−0.15

Source: Authors' own calculations.

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Table 3
Supply effects (percentage changes) due to the 7% EFA requirement in the EU-27

	CAPRI point elasticities	GTAP-CAPRI	CAPRI
Rice	−0.64	−0.35	−0.30
Wheat	−2.73	−2.35	−2.09
Coarse grains	−2.45	−1.86	−1.88
Oilseeds	−2.79	−3.12	−2.24
Sugar	−0.53	−0.26	−0.33
Other crops	−0.64	−0.15	−0.09
Aggregated supply response		−0.73	−0.62

Source: Authors' own calculations.

responsiveness, both in GTAP-AEZ and in CAPRI, is lower compared to the point elasticities, i.e. in both systems, point elasticities diminish as prices rise and optimal supplies adjust. Secondly, the match between CAPRI and GTAP-AEZ, as seen by comparing columns 'GTAP-CAPRI' and 'CAPRI', is in most cases satisfactory.

A good match is virtually assured by the normalised quadratic functional form.[6] The divergence is largest for the category 'other crops' – probably due to compositional changes, as this category contains a wide range of crops which are differentially affected by the policy. The crops which are most important in our analysis are those which occupy a large share of the total EU land area and are important for international markets, namely cereals and oilseeds. We conclude that the crop quantity responses are close enough to justify a combined analysis focusing on land use issues. Further narrowing of these differences would require a large-scale reconciliation of the GTAP-AEZ and CAPRI databases, which is well beyond the scope of this paper.

3.2. Global trade impacts

In the global impact analysis we introduce a policy shock, according to the EU Commission proposal, along the lines described and implemented above. In a first experiment we implement the EFA requirements in the coupled CAPRI-GTAP-framework. To illustrate the importance of building in the spatial detail of CAPRI for the global analysis, we also run a second experiment. In this experiment we utilise the GTAP-AEZ model in stand-alone mode, without integrating the response surface. Here, it is simply assumed that the EU sets 3.7 million ha aside as EFA, or 4.52%, of arable crop area across all AEZs in the EU. By contrasting this 'neutral shock' with the more detailed shock based on CAPRI, we see the added value of including the spatially differentiated supply shocks.

[6]Heckelei (2002) shows that for a model with linear constraints and a quadratic objective function, net output quantities are a linear function of price as long as the set of binding constraints does not change. The structure of the CAPRI supply model is more complex (some nonlinear constraints and some non-quadratic terms in the objective function). But still, the linear relationship between prices and quantities should offer a rather good approximation, especially once the responses of the individual supply models are aggregated to EU level and to larger crop categories.

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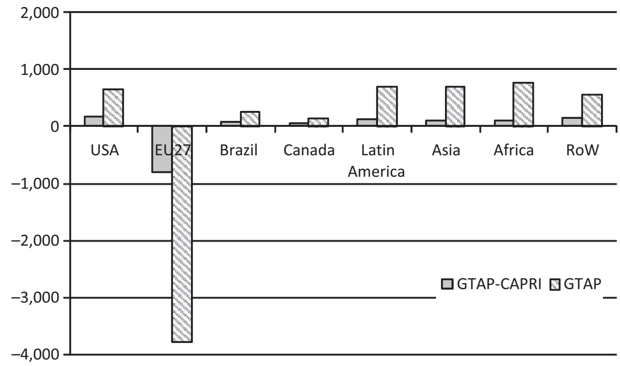

Figure 3. Changes in trade balance of crop products in US$ million.
Source: Authors' own calculations.

Implementation of the EU proposal reduces the supply of agricultural crops and boosts crop prices in the EU, thereby changing the overall crop trade balance (value of changes in exports minus change in imports) in the EU, as well as elsewhere around the world. The decline in EU net exports of crops is offset by an increase in net exports from the rest of the world, as shown in Figure 3.

In the CAPRI-GTAP framework (Experiment 1) the crops trade balance of the EU changes by US$ −807.1 million. A GTAP-only scenario (Experiment 2) results in a much larger trade balance change of US$ −3,785.3 million. By assuming that the area converted to EFA is equally as productive as the area remaining in production, this naive application of the GTAP-AEZ model greatly overstates the impact on the EU's crop trade.[7]

3.3. Land use changes

CAPRI estimates an increase in the EU-27 of ecological focus eligible area of 3.7 million ha. However, there is no change in total land used by agriculture. This is due to the fact that additional hectares cannot claim the Single Farm Payments[8] so there is no incentive to expand area. It is interesting to analyse in more detail, the effects on permanent grasslands which are also deemed important for biodiversity. Overall, as to be expected, changes in cropland are generally somewhat higher compared to permanent grassland. This is because permanent grassland is not subject to the environmental restriction and substitution possibilities are limited.

The percentage share of idled land in total arable land shown in Figure 1 gives a good indication of the impact on non-grasslands. Figure 4 reports the changes in grassland cover in the EU under the EFA proposal. Results indicate that in those regions where the share of idled land was small in the baseline, the EFA requirement leads, on average, to an expansion of arable lands in the EU (including EFA area) to

[7]Of course the performance of GTAP could be improved by targeting different rates of set-aside in different AEZs.

[8]This is an extreme interpretation of the scenario. If farmers could expand their eligible areas by also including, for example, landscape features such as groups of trees which were otherwise ineligible, less agricultural land would be needed to fulfill the 7% requirement.

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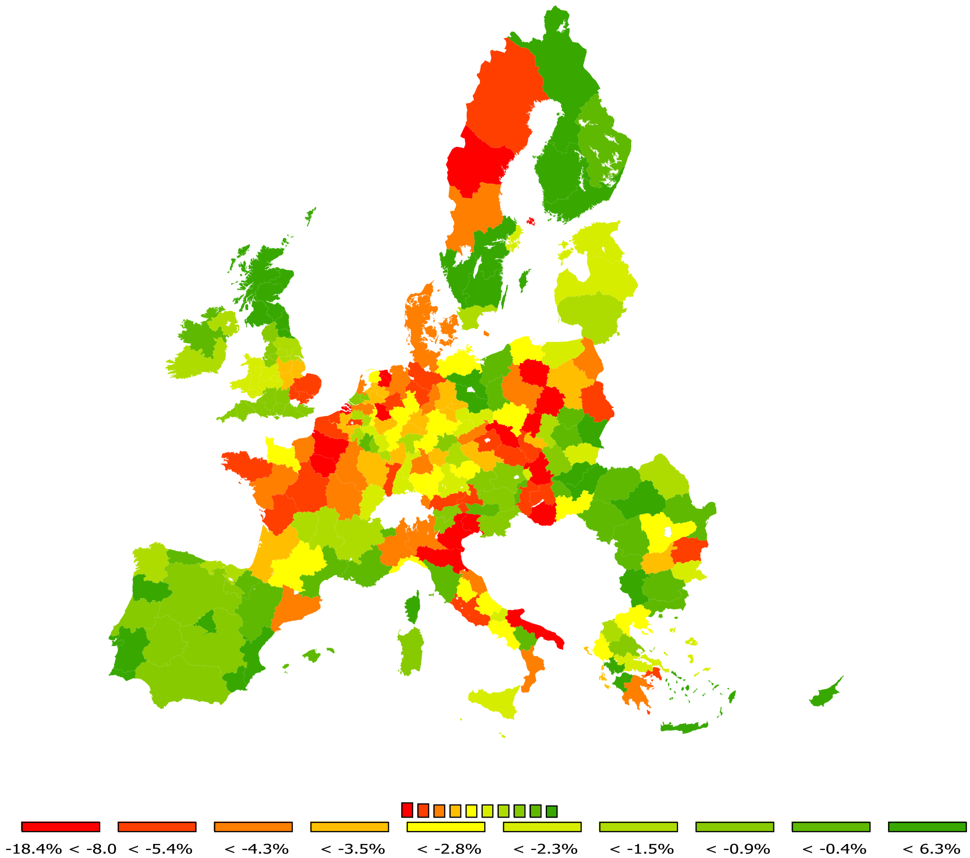

Figure 4. Change in grassland in % against the baseline.
Source: Authors' own calculations.

the detriment of grassland (grassland expands in only about 20% of the regions). The economic mechanism for this expansion may be explained by two interrelated effects. Firstly, with the reduction in cropped arable area, crop prices increase. And secondly, the direct impact of the EFA obligation is to idle additional land. This, in turn, reduces labour and machinery requirements. Farms are left with more excess labour and capital, the opportunity costs of which fall compared to the baseline situation. As long as the rents which must be paid for additional cropland do not exceed the increase in profits possible from using the available labour and capital, farmers have an incentive to increase arable area. This result hinges strongly on the quasi-fixed nature of labour and capital use in agriculture, captured indirectly in the CAPRI model by the parameters estimated by Jansson and Heckelei (2011). As a consequence, the impact on world crop supplies is far less than would be suggested by the large amount of land set-aside under this policy. Indeed, while 4.52% of arable land is set-aside under the EFA, aggregated crop output falls by just 0.7% under the GTAP-CAPRI simulation and 0.6% under the CAPRI simulation experiment (Table 3, final row). Gohin (2008) highlights the critical role of restricted labour and capital mobility in CAPRI. Indeed, when he assumes that labour and capital are perfectly mobile among

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all activities he observes a much larger supply response by EU farmers in the crop sector. In the case of the EFA, such a specification would result in a larger supply response to the restriction in land use.

Figure 5 maps the changes in cropland cover by AEZ for other regions in the world, as calculated with the integrated CAPRI-GTAP framework. The percentage changes represented in this map are generally very small, as expected, given small percentage changes in EU crop supplies and their modest share in world output. In a separate exercise (see Appendix S2 in the online supporting information), we have decomposed the sources of adjustment to the EFA in the rest of the world. We find that the final change in land use is only one-third as much as one would expect *a priori* due to the combination of yield response, consumer demand responses and factor market adjustments. Nonetheless, the remaining absolute change in area under crops is still significant in some regions (Figure 6). The largest percentage changes can be observed in the AEZs of Canada, Africa, Australia and South America, while the largest absolute expansion is in Africa with 155,000 ha. Canada with 67,000 ha is followed closely by Brazil where cropland expands by about 49,000 ha. This pattern of cropland change is consistent with the empirical findings of Villoria and Hertel (2011) who examine the international transmission of national price shocks to cropland decisions around the world. They find that the unique geography of international agricultural trade plays an important role in these crop area changes. In particular, countries with strong trade relations with the originating country tend to respond more to the price signal. In the case of the EFA requirements, we see this reflected in the strong responses of the EU's trading partners in Canada, Brazil, Africa and Australia. The links to Asia are much weaker.

A closer look at the changes in trade patterns and production quantities highlights the types of crops that are most affected by the EU-EFA policy. In Brazil, oilseed production increases while the production of all other crops changes only slightly. This is driven by the increase in exports to the EU, which rise by US$ 1,700,000. In Africa, some of the additional land is used for the production of 'other crops' which increase by 0.2%. After the implementation of the EU proposal, Africa increases exports of 'other crops' to the EU by US$ 5,184,000. In Canada, we observe a different picture.

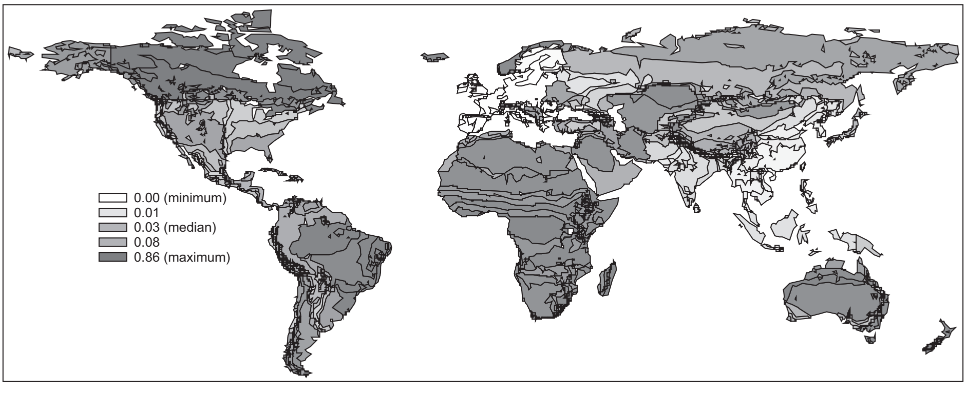

Figure 5. Percentage change in cropland cover, by AEZ in non-EU regions.*
Notes: *The changes of EU crop land cover are displayed at zero in this graph.
Source: Authors' own calculations.

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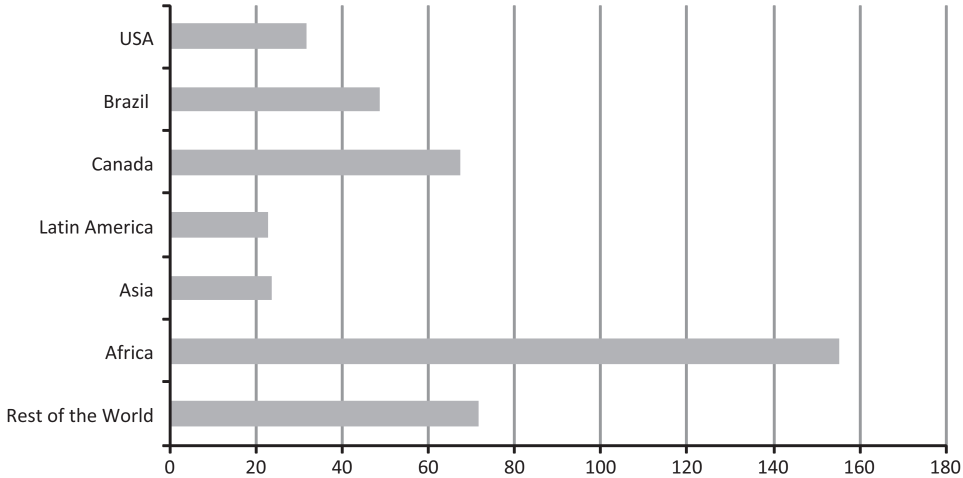

Figure 6. Changes of cropland cover by world region due to EU EFA requirement (in thousand ha).
Source: Authors' own calculations.

Here, oilseed production increases by 0.4% and wheat production by 0.6%, while the value of exports to the EU increases by US$ 146,000 for oilseeds and US$ 205,000 for wheat. Due to the increased world market prices of both crops, Canada increases its export value not only to the EU but also to other regions of the world. All of this cropland expansion can have important environmental implications – a topic to which we turn next.

3.4. Environmental indicators at EU level

At the EU level, major environmental indicators all show limited improvements. GHG emissions expressed in CO_2 equivalents are simulated to drop by about 1.8% (7 million metric tonnes, MMT). Crop nitrogen demanded falls by 3.4%. A reduction in mineral nitrogen fertiliser use decreases by 4.7%, which, together with a reduction in nitrogen in manure of about 0.9% means that surpluses decrease by 2.1%. The reduced manure output is a consequence of slightly reduced animal herds due to higher feed costs resulting from increased crop prices. Reduced organic and mineral nitrogen applications also reduce ammonia emissions by about 1.5%.

However, Figure 7 shows that the changes in nitrogen surpluses are far from uniformly distributed. In the high-yielding EU regions where higher set-aside percentages are needed to fulfil the EFA requirement (see also Figure 1), crop production and nitrogen use decreases, leading to reduced surpluses. Based on a detailed analysis for France drawing on the 1 × 1 km downscaling component of CAPRI (Paracchini and Britz, 2010) it appears that the programme does indeed improve the biodiversity status in more intensive farming regions. On the other hand, in the more marginal producing areas including the Mediterranean, Scandinavia and the new Member States, higher prices stimulate farm intensification and nitrogen surpluses increase. The changes are however relatively small, and mainly concentrated in areas with a low level of surplus.

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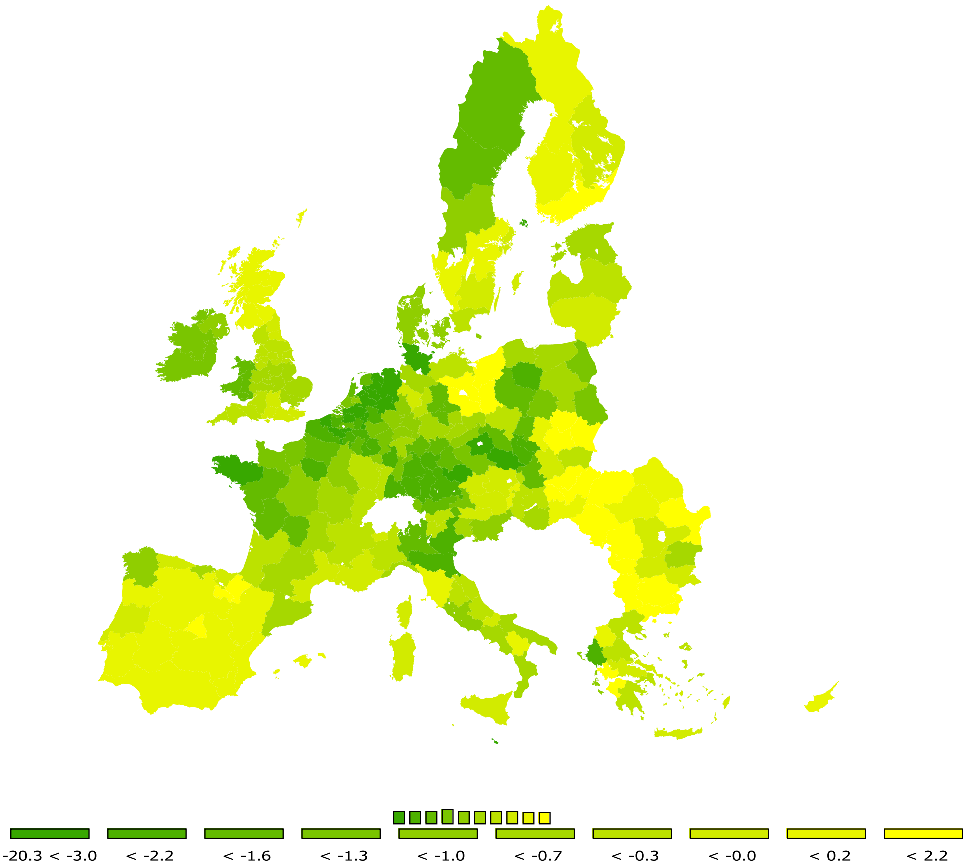

Figure 7. Change in nitrogen surplus in kg/ha.
Source: Authors' own calculations.

3.5. Environmental indicators at the global level

At the global level we observe an increase in fertiliser use due to land conversion and intensification of production (Table 4). Especially in Canada and Brazil, the application of all analysed fertilisers – nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) – increases. If we compare the percentage changes in fertiliser use to the changes in cropland cover in the analysed regions, it can be seen that in all countries or regions the percentage change in cropland cover is smaller than the percentage change in fertiliser use. This reflects an intensification of the production on the already cultivated cropland areas around the world, which may have both local and global environmental consequences. Here, we focus on the global GHG impacts, as the GTAP-AEZ model does not have sufficient detail to address issues of non-point source pollution and water quality.

As a consequence of global crop land conversion and increased fertiliser applications, GHGs rise in all non-EU countries by 77 MMT CO_2 equivalent. Thus, every additional hectare of land that is set-aside in the EU increases GHG emissions in the rest of the world by 20.8 tonnes CO_2 equivalent. Figure 8 reports the estimated

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Table 4
Percentage and absolute changes in fertiliser use at the global level

	USA	Brazil	Canada	Latin America	Asia	Africa	Rest of the World
Nitrogen (N)							
in %	0.17	0.24	0.28	0.17	0.08	0.25	0.25
in 1,000 t	15.64	4.44	4.24	6.85	28.89	9.00	7.44
Phosphorus (P_2O_5)							
in %	0.14	0.16	0.32	0.18	0.08	0.29	0.26
in 1,000 t	8.35	3.11	2.10	3.33	12.52	5.65	3.76
Potassium (K_2O)							
in %	0.12	0.16	0.17	0.18	0.09	0.22	0.27
in 1,000 t	8.88	3.84	0.70	2.70	8.84	1.57	3.55

Source: Authors' own calculations.

distribution of global GHG emissions in all non-EU regions. EFA requirements in the EU result in land use changes in other parts of the world. Particularly when cropland expands into forests, an increase in GHG emissions can be observed. Canada shows the highest GHG emissions from land cover change, and contributes 43% to the overall effect in the world. In contrast, Brazil, which also converts a relatively high amount of land, has a lower GHG emission rate. The reason for this is the origin of the converted land. While Canada converts mainly forest land into cropland, in Brazil the additional cropland is expected to come from grass and scrubland (e.g. the Cerrado).

4. Summary and Conclusions

Since 2003, the Common Agricultural Policy (CAP) of the EU has begun to focus on biodiversity protection and the maintenance of high nature value farming systems. EU Member States are required to implement agri-environmental measures in order

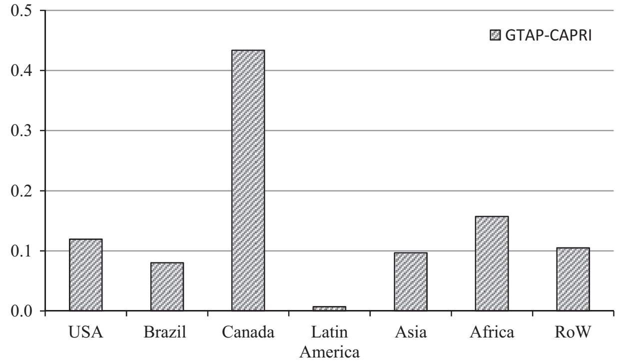

Figure 8. Share of contribution to the total change in global CO_2 equivalent emissions by non-EU regions (%)
Source: Authors' own calculations.

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to halt the loss of biodiversity. However, it appears that this objective has not been met. Thus, in 2011 the EU Commission proposed to 'green' the CAP and to devote 7% of arable farm land to an ecological focus. This paper analyses the global spillover effects of this particular policy measure which targets environmental public goods within the EU.

The proposed EFA requirement, while obligatory, takes into account existing practices of farmers, e.g. when they already set-aside land or manage their farm biologically. Accordingly, the share of additionally set-aside land is highest in high-yielding regions, which have to-date shown low participation rates for opt-in measures. Of course, our analysis cannot capture all the details of the proposed programme, such as exemptions for small farms or the effect of a possible update of the eligible areas. Therefore, our results should be seen as upper bound on the possible impacts of the EFA requirement.

The intra-EU regional analysis shows an improved environmental status in the high-yielding EU-regions due to the increase in idle land. However, prices increase across the EU, and create pressures for yield increases in the more marginal regions where little or no additional land is taken out of production. The global analysis adds the interaction between land use changes across world regions with croplands in the rest of the world expanding as a result of this policy. There are also modest increases in nitrogen, phosphorus and potassium fertiliser use in other regions of the world, contributing to higher GHG emissions.

Overall, we estimate that, for each additional hectare of land which the EU sets aside under the EFA proposal, land-based GHG emissions and emissions from fertiliser use in the rest of the world will rise by about 21 tonnes CO_2 equivalent. In summary, attempts to enhance biodiversity in Europe can have unintended consequences in the rest of the world and these consequences should be factored into the decision-making process when giving a green light for restrictions on cropland use in the EU.

The improved methodology for linking the GTAP-AEZ model and CAPRI allows for a model linkage which embodies a similar supply response to price changes and the introduction of the EFA proposal in both models. This allows a mutually consistent analysis of market and environmental impacts across regional, national and global scales. There are clearly many areas where the discussed linkage of GTAP and CAPRI could be improved and expanded, such as livestock activities, feed use or domestic support to agriculture, or to look deeper into input substitution relationships. Such improvements notwithstanding, this paper has shown how an appropriate meta-model approach can provide a workable alternative to the tendency to either build non-transparent, complex 'super-models' or to employ technically demanding 'hard linkages' between models. Given the increased demand for multi-scale and multi-domain impact assessments at global scale, we therefore conclude that more research is needed on how to properly summarise the behaviour of detailed, specialised analytical frameworks for use in more aggregate, global models.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Decomposition of global cropland conversion (in million ha).

Appendix S1. Implementation of the Crop Revenue Function into GTAP.

Appendix S2. Decomposition of Global Cropland Adjustment.

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