

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

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Abstract

This study analyzes the effects of introducing a biodiversity-targeted program for ecological focus area on all farms with arable land in the EU by quantifying its global and regional, economic and environmental impacts in a mutually consistent way. This is challenging due to the differing spatial scales of the problem – ranging from on-farm decisions regarding set-aside 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 crops sector.

The results predict improved environmental status in the high yielding regions of the EU. However, price increases trigger intensification in the more marginal areas of Europe where little or no additional land is taken out of production. We find that the loss of 3.7 Mio ha of arable land in the EU is partially compensated by an increase of 0.4 Mio ha in other regions of the globe, as well as increased fertilizer applications. Thus the improvement of environmental status in the EU comes at the price of global intensification, as well as the loss of forest and grass land areas outside the EU. Overall, we find that every hectare of land that is set-aside in the EU increases these emissions in the rest of the world by 20.8 tonnes CO₂eq.

1. Introduction

In its recent proposal for a reformed Common Agricultural Policy (CAP), the EU Commission included a minimum farm-level share of ‘ecological focus area’ as one of several compulsory measures for receiving direct income support under the CAP. That support, the so-called Single Farm Premium, accounts for the bulk of CAP spending and amounts to about 40 Bio € on an annual basis, or on average about 300 € per year for each hectare of agricultural land in the EU. Given the size of the subsidy, and assuming a suitable control strategy, it is expected that farmers will have an incentive to meet the set-aside requirement. The current EU-proposal suggests to set-aside 7% of arable hectares as ecological focus areas. Eligible areas include: field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips and afforested area.

The purpose of this paper is to estimate the global economic and environmental impacts of this massive set-aside program. In so doing, we develop an elegant new methodology for linking analytical tools operating on different spatial scales in a mutually consistent way.

Our analysis complements the lively discussion in Europe about the future of the CAP which is estimated to cost about 50 Bio. € annually (Farmer et al., 2008). A group of European agricultural economists (Hofreither et al., 2009) recently proposed complete elimination of income support to farmers and market interventions, instead targeting the CAP towards 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 CAP includes a strategic focus on biodiversity conservation and the maintenance of high nature value farming systems. EU Member States are required to develop EU co-financed, opt-in agri-environmental measures in order to support the 2010 objective of stopping bio-diversity loss. It is now clear that this

objective will not be met (EU Commission, 2010), leading to the far more stringent proposal of a compulsory ecological focus area program. The EU Commission describes this as follows: “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).”

We take the EU Commission proposal as a test case for our investigation of the extent to which EU-wide agri-environmental programs impact global markets, potentially giving rise to global environmental spill-over effects. There is a strong temptation when assessing agri-environmental measures to concentrate solely on the externalities targeted by these programs. 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. And these changes will also affect the environment, including global externalities such as climate change or bio-diversity loss. This was vividly illustrated in the recent debate over induced land use changes from US and EU bio-fuel mandates (Searchinger et al., 2008 and Fargione et al., 2008).

The paper is organized as follows: In section two we present the methodology, including an overview of the two economic simulation models used - CAPRI (Common Agricultural Policy Regionalised Impact) (Britz and Witzke, 2008) and a version of the Global Trade Analysis Project Model, which incorporates land use differentiated by Agro Ecological Zones (GTAP-AEZ: Lee et al., 2009). Furthermore, we discuss how the ecological focus area program is simulated and how the crop supply response to changes in prices and set-aside obligations from CAPRI is integrated into the global GTAP model. Section three presents our quantitative findings, starting with the global level and then discussing

regional effects within the EU27. The paper concludes with a summary and discussion of implications for future research.

2. Methodology

2.1 Choice of quantitative tools

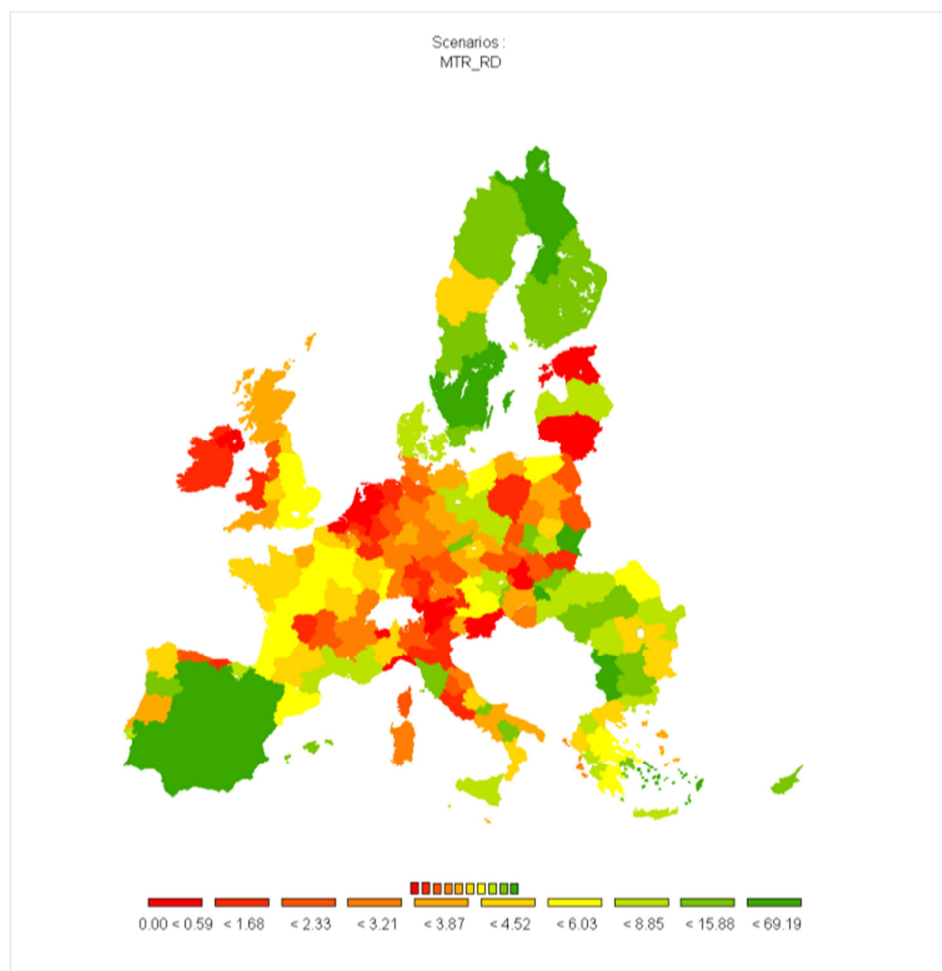
We aim to quantify the global and regional, economic and environmental impacts linked to the proposed European ecological focus area program on farm land in a mutually consistent way. In order to accomplish this goal, we combine economic and environmental analysis at different spatial scales – capturing both the regional heterogeneity within the EU as well as the worldwide variation in land use, yields and carbon fluxes. The current proposal allows farmers to include any existing ecological focus areas in the 7% set-aside requirement which make implementation of this policy more complex, since it must factor in these pre-existing actions at the farm level. This necessitates a high degree of spatial resolution within the EU, which is why we use the farm type module (Gocht and Britz, 2011) of the CAPRI system, a partial equilibrium model (PE) of the agricultural sector (Britz and Witzke, 2010). That module depicts EU agricultural supply by almost 2000 individual programming models, covering in detail the impact of Pillar I measures on agriculture, as well as a broad representation of important Pillar II measures. It takes the interaction between animal and crop production via the exchange of feed, fodder and nutrients at the regional level into account. As we will see below, a key factor in the analysis is the EU supply response for major arable crops, which has been econometrically estimated in the CAPRI model (Jansson and Heckeles, 2010). We refrain from using the global market module of CAPRI as we are especially interested in global land-use transitions, a feature not yet covered by that module.

In order to assess global land-use changes, in response to this EU policy, we utilize a multi-regional and multi-product computable general equilibrium (GE) model which covers all economic activities and sectors, and which identifies land use changes by Agro-Ecological Zones (Lee et al., 2009). GTAP-AEZ has been augmented to track the associated release of Green House Gases (GHGs) due to land use changes (Hertel et al., 2010a). Additionally, we supplement the GTAP model with information about spatially disaggregated, global fertilizer use, thereby permitting us to examine global changes in nitrogen, phosphorus and potassium use due to the EU biodiversity program. This approach relies on data by Potter et al. (2010) which is implemented in the GTAP-AEZ model for the first time in this paper.

2.2 Quantifying EU farm type specific set-aside areas at the regional scale

A critical factor in quantifying the set-aside policy is which arable areas currently not under production may be counted towards the 7% requirement. The more generous this definition, 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 (namely data availability), our quantitative implementation of this policy opts for the following specification: only areas currently under fallow land or set-aside are counted towards this goal. This stringent definition results in estimated EU environmental benefits, as well as world price changes, which are the likely at the outer bound of what will actually occur, since some farmers will be able to claim ecological focus-areas currently not in our data base. Equally, all farms under biological farming systems would automatically be assumed to comply – a feature which is not accounted for in our analysis.

Figure 1: Percentage share of idled land in total arable land in the baseline



Source: Own Calculations.

Figure 1 shows the share of arable land in the EU which is presently set-aside in the CAPRI baseline. It shows that, in about 30% of the regions, the set-aside obligation is, on average, already fulfilled suggesting that the new program will have little effect on their production. (Of course individual farms in these regions may still be affected, since this map just reports an average.) Generally, parts of the Mediterranean areas, and some regions in the new Member States, especially in Romania, Bulgaria, Poland, and Scandinavia show high shares of idling land prior to implementation of this policy. And Spanish statistics show very high shares of fallow land. In contrast to these regions, the

program 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). However, the reader is reminded that the set-aside requirement is expressed per unit of arable land. The set-aside requirement is hence quite modest in relation to total agricultural area in agricultural regions such as Ireland and Scotland with large shares of permanent grass lands.

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

Both the CAPRI and GTAP models predict endogenous changes in crop supplies. In order to achieve a mutually consistent, GE-PE analysis, we build on the response surface approach by Britz and Hertel (2011) treating EU crop production as a production possibilities frontier in GTAP represented by a normalized quadratic function (Diewert and Wales 1988), where the normalization is with respect to the Nth commodity price. It reflects maximum normalized revenues from five different crop types at the vector of normalized prices \tilde{p} , for a given level of composite input, X , and for given set-aside requirement S :

$$\max_{\tilde{p}} R(\tilde{p}, S, X) = \alpha + \sum_i \beta_i \tilde{p}_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \tilde{p}_i \tilde{p}_j + \sum_i \eta_s \tilde{p}_i S + \sum_i \eta_x \tilde{p}_i X \quad (1)$$

Based on the envelope theorem, we derive the optimal output quantities Q for the crop types i :

$$Q_i \equiv \frac{\partial R}{\partial p_i} = \beta_i + \sum_j \gamma_{ij} \tilde{p}_j + \eta_{is} S + \eta_{ix} X \quad (2)$$

The inclusion of S is a novel contribution of our study. By including this as a separate argument in the aggregate revenue function, we capture the unique effect of these ecological

requirements on aggregate crop sector revenue. This approach has several advantages. Firstly, the revenue function (1), derived from CAPRI, summarizes in one compact function the manner in which individual EU crop supplies in CAPRI, aggregated from individual farm type and regional models, to the EU aggregate, react to changes in prices as well as to an expansion of set-aside requirements (Figure 2). Indeed, this gives us a direct estimate of the impact of the set-aside requirement on EU optimal supplies of each crop type. A second advantage of this revenue function representation is that it can be incorporated directly into the GTAP model, with the set-aside shock being applied via a shock to S (a higher value corresponds to a more stringent set-aside requirement).

By taking the partial derivative of the optimal supplies in (2) with respect to prices, we arrive at the *compensated* Hessian H which is constant and dictated by the parameter matrix γ for this quadratic revenue function. In contrast to the earlier paper by Britz and Hertel (2011), which stopped after matching these compensated supply effects, this paper also seeks to calibrate the model to the *uncompensated* supply elasticities. This entails adjustment of the expansion effect in the GTAP model, which is determined by the elasticity of aggregate input supply to the sector in response to changes in crop revenue. The following formula details the relationship between the uncompensated and compensated elasticities of crop supply given in (3):

$$\varepsilon_{ij}^u = \varepsilon_{ij}^c + \frac{\partial Q_i}{\partial X} \frac{\partial X}{\partial R} \frac{\partial R}{\partial P_j} \frac{P_j}{Q_i} = \varepsilon_{ij}^c + \left(\frac{\partial Q_i}{\partial X} \frac{X}{Q_i} \right) \left(\frac{\partial X}{\partial R} \frac{R}{X} \right) \left(\frac{\partial R}{\partial P_j} \frac{P_j}{R} \right) = \varepsilon_{ij}^c + \Omega \theta_j \quad (3)$$

Where the final equality uses the assumption of linear homogeneity of the revenue function in the aggregate input, X ; the parameter, Ω , is the elasticity of aggregate input supply with respect to crop sector revenue, and θ_j is the share of total revenue from sales of crop j .

Assuming that total resources in the crops sector are fixed, $\Omega = 0$, the supply response for a single crop to a price increase is driven by the transformation possibilities between different crops and captured in the revenue function (1). Thus, for example, area currently in oilseed production could be converted to wheat if wheat price increases. This aspect of supply response is captured by the *compensated* supply elasticity of crop i with respect to a change in the price of crop j : ε_{ij}^c and shown in equation (2). However, higher returns to wheat contribute to higher overall revenue in the crop sector. Indeed, for a one percent change in the wheat price, the percentage change in aggregate revenue is approximated by the share of wheat in total revenue, θ_w . This rise in aggregate crop revenue induces additional resources to move into crop production, as reflected in the factor supply elasticity, Ω , ultimately expanding the crops production possibilities frontier, and impacting individual crop supply by the term $\eta_{ix}X$ in (2). The combined result of the transformation effect and the expansion effect is captured by the uncompensated supply elasticity, ε_{ij}^u . Matching this elasticity between the CAPRI and GTAP models entails adjusting the factor supply elasticity in GTAP which has been done for this paper. Specifically, we compute the expansion elasticity implied by CAPRI by changing all crop prices simultaneously, thereupon imposing this on the GTAP-AEZ model by altering the factor mobility parameters in the latter model.

This approach to multi-scale model linkage is summarized in Figure 2 and is based on sensitivity experiments with the CAPRI model. These allow calculation of the uncompensated elasticities relating to changes in crop prices and introduction of set-aside. Next, we determine the expansion effect by changing all crop prices simultaneously. Finally, we calibrate the GTAP model to permit matching compensated supply effects as well as matching the simulated elasticities and the expansion effect. The last step is conducted as follows: Let p^* denote the normalized prices – where the crop with the largest revenue share is the numeraire.

The indexes k and l refer to the remaining (non-numeraire) $n-1$ crops. Our approach relies on estimation of a positive-definite, symmetric Hessian matrix (H) which parameterizes the revenue function:

$$H_{kl} = \frac{\partial Q_k}{\partial p_l^*} = \varepsilon_{kl}^c \frac{Q_k}{p_l^*} \quad (4)$$

While the compensated elasticities satisfy the homogeneity condition. This is accomplished via a constrained optimization problem which minimizes the sum of squared differences between the uncompensated point elasticities as derived from CAPRI and the term defined in (1), while using as constraints the following: (a) the definitional relation in equation (4), (b) the symmetry and homogeneity conditions embedded in the compensated elasticities, (c) a LL' Cholesky decomposition of H to ensure curvature positive-definite Hessian, and (d) the level equations (2)..

The compensated own and cross price elasticities of CAPRI are then passed to the modified GTAP model and the values are integrated into the Hessian matrix of the EU-wide crop revenue function. Additionally, an extra column in the Hessian matrix of the GTAP model reflects the impact on supply response of a given level of set-aside requirement. Having solved the extended GTAP 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 program at the regional level.

Table 1: CAPRI-compensated and GTAP-uncompensated price elasticities¹⁾ for the EU27

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

¹⁾ in italics

Source: Own Calculations.

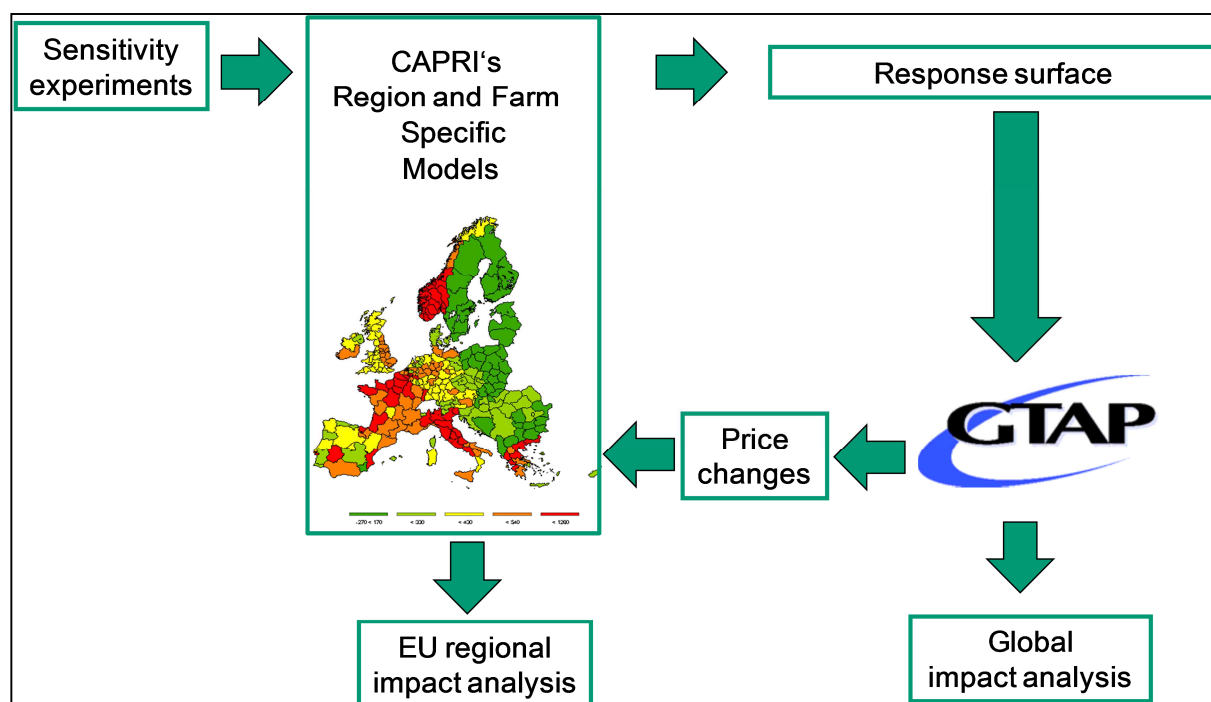
Table 1 presents compensated own- and cross-price supply elasticities derived from CAPRI and the uncompensated elasticities derived from the modified GTAP model after the CAPRI elasticities are included.¹ Having established the input-constant supply elasticities, it remains

¹ Compared to Britz and Hertel (2011) the compensated own price elasticities of supply as reflected in the diagonal elements of the table are relatively more responsive for oilseeds and coarse grains. For example in this study a 1% change in oilseed prices, holding all other prices

to establish the expansion effect associated with aggregate agricultural supply response in the EU. In the CAPRI model, this is estimated to be 0.358 for the aggregated crops sector. This means that if all crops prices rise by 1%, then aggregate crop supply will rise by 0.358%. 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. 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 grazing land), based on relative returns to land in these three uses. To match CAPRI's expansion effect, the CET parameter 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 described in Hertel et al. (2009).

constant, leads to an expansion of oilseed supply by about 0.93%. In contrast, Britz and Hertel (2011) 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 of 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 grass lands. Additionally, changes stem from the fact that the analysis is now conducted at the level of individual farm types for EU 25.

Figure 2: Overview of the framework



2.4 Comparison of quantity responses

The response surface discussed above provides a first order approximation of quantity changes to changes in prices and the introduction of compulsory ecological focus area. In a combined application, mutual compatibility will largely depend on the extent of agreement in the point elasticities between the two models (CAPRI and GTAP). Table 2 shows quantity responses taking into account the set-aside shock and the price change simulated with the GTAP model (compare also Figure 2). The first column gives the percentage quantity change if the compensated and expansion elasticities are used directly (i.e. absent the non-linear model), whereas columns 2 and 3 report the simulation results from using the GTAP and CAPRI models, respectively. The table highlights two important points. Firstly, a comparison of the first column with the remaining ones shows that the supply responsiveness both in GTAP and in CAPRI is lower compared to the point elasticities, i.e. in both systems, point elasticities diminish as non-marginal shocks are implemented. Secondly,

the match between CAPRI and GTAP as seen by comparing columns two and three is satisfactory in most cases. A good fit is virtually assured by the normalized quadratic functional form, provided basis in the CAPRI model does not change, since it has mostly a quadratic objective function, subjected to mostly linear constraints (Heckelei, 2002). The proportionate divergence is largest for other crops – likely due to compositional changes. The crops which will be most important in our analysis are those which occupy large share of the EU land base and are important for international markets, namely cereals and oilseeds. We conclude that the quantity responses are close enough to justify a combined analysis as mutually consistent. Further narrowing of these differences will require a large scale reconciliation of the GTAP and CAPRI data bases, which is well beyond the scope of a single study.

Table 2: Percentage quantity change as derived from CAPRI's point elasticities and simulated by GTAP and CAPRI in response to a change in a required share of 7% land in ecological focus area (EU Commission proposal) and the resulting price change as simulated by GTAP

	Estimated based on		
	CAPRI point elasticities	GTAP-CAPRI	CAPRI
Rice	-0.64	-0.35	-0.30
Wheat	-2.73	-2.35	-2.09
Cgrains	-2.45	-1.86	-1.88
Oilseeds	-2.79	-3.12	-2.24
Sugar	-0.53	-0.26	-0.33
OthCrop	-0.64	-0.15	-0.09

Source: Own Calculation.

3. Results

3.1 Global Trade Impacts

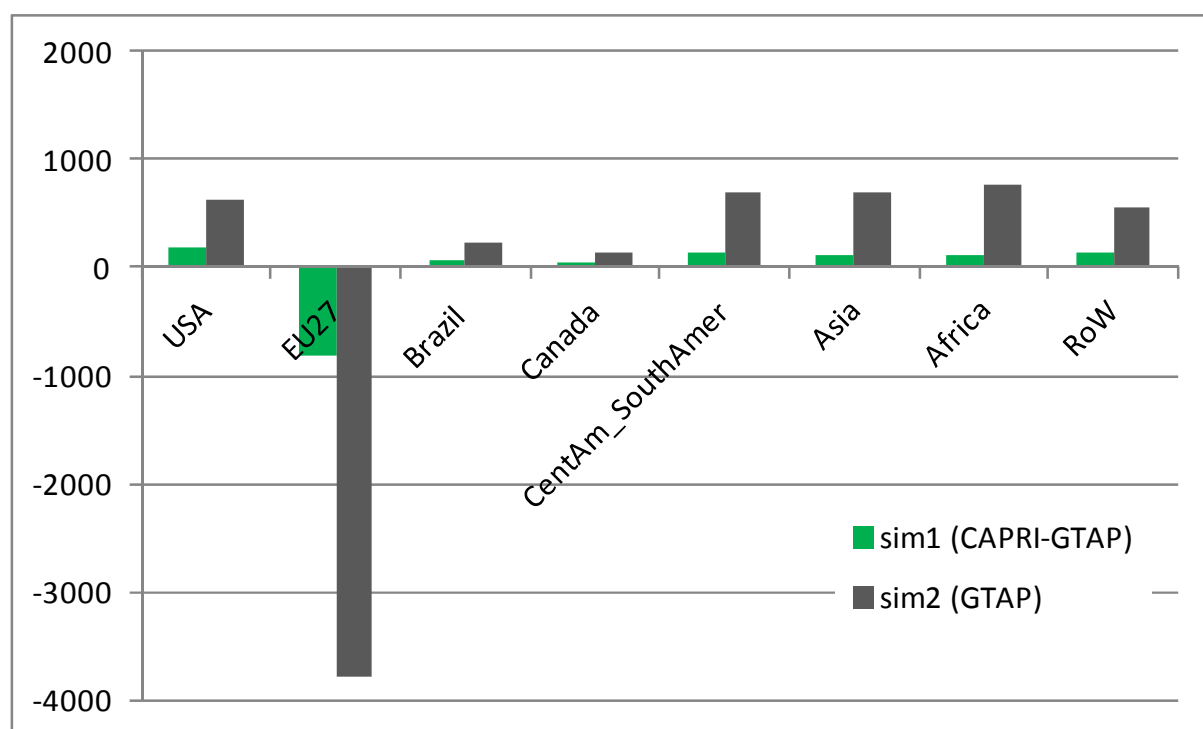
Scenarios: We introduce a policy shock, according to the EU Commission-proposal, along the lines described and implemented above. In a first experiment we implement the ecological focus requirements in the coupled CAPRI-GTAP-framework. To illustrate the importance of building in the spatial detail of CAPRI for the global analysis, we also run a second experiment. In this experiment we utilize the GTAP-AEZ model in stand-alone mode, without integrating the response surface. Here, it is simply assumed that the EU sets-aside 3.7 Mio. ha 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.

Global Trade Impacts: Implementation of the set-aside policies reduces the supply of agricultural crops and boosts crop prices in the EU, thereby changing the overall crops trade balance (value of exports minus imports) in the region, 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 may be seen from Figure 3.

In the CAPRI-GTAP-framework (simulation 1) the crops trade balance of the EU changes by -807.1 Mio. US\$. A GTAP-only scenario (simulation 2) would result in a much larger trade balance change of -3785.3 Mio. US\$. By assuming that the area set-aside is equally as productive as the area remaining in production, this naïve application of the GTAP model greatly overstates the impact on EU’s crop trade.²

² Of course the performance of GTAP-AEZ could be improved by targeting different rates of set-aside in different Agro-ecological Zones.

Figure 3: Changes in trade balance of crop products in Mio. US\$



Source: Own Calculation.

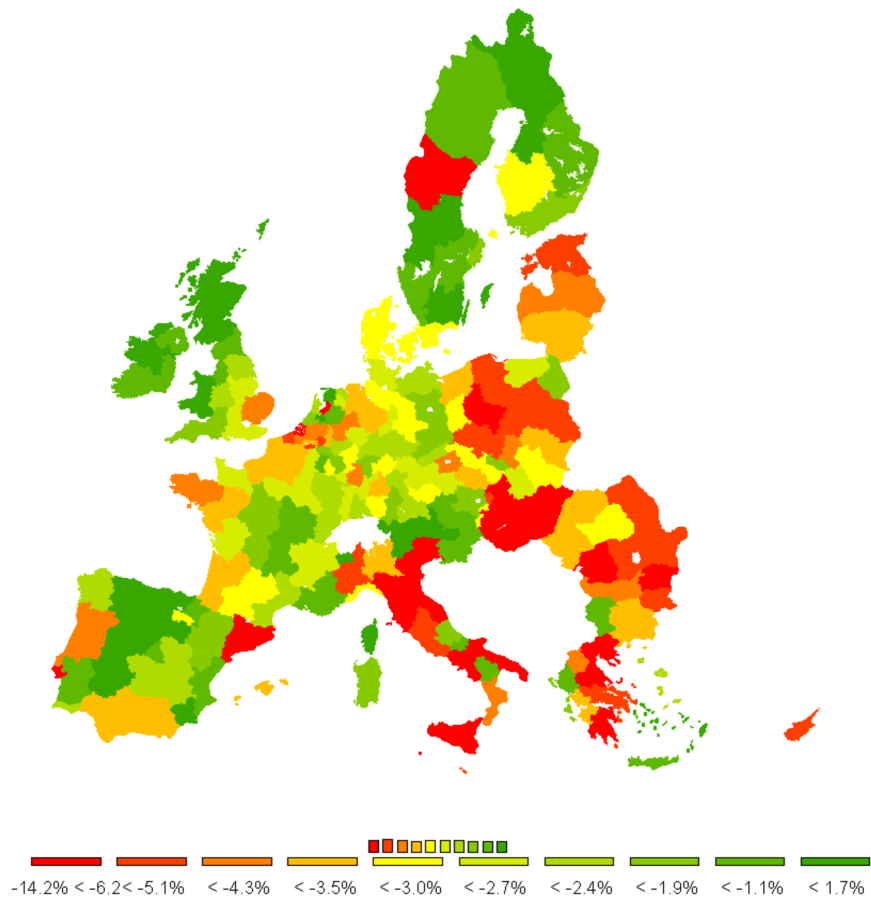
3.2 Land use changes

CAPRI estimates an increase in EU-27 set-aside areas of 3.7 Mio ha. However, there is no change in total land used by agriculture. That is due to the fact that additional hectares cannot claim the Single Farm Payments³ so that there is no incentive to expand area.

The changes in arable land are generally somewhat higher compared to permanent grass lands. That is due to the fact that permanent grass lands are not subject to the environmental restriction and that substitution possibilities are limited.

³ That is an extreme interpretation of the scenario. If farmers could expand their eligible areas by also including e.g. landscape features such as group of tree which were so far no eligible, less agricultural land would be needed to fulfill the 7% requirement.

Figure 4: Change in grass lands in % against the reference

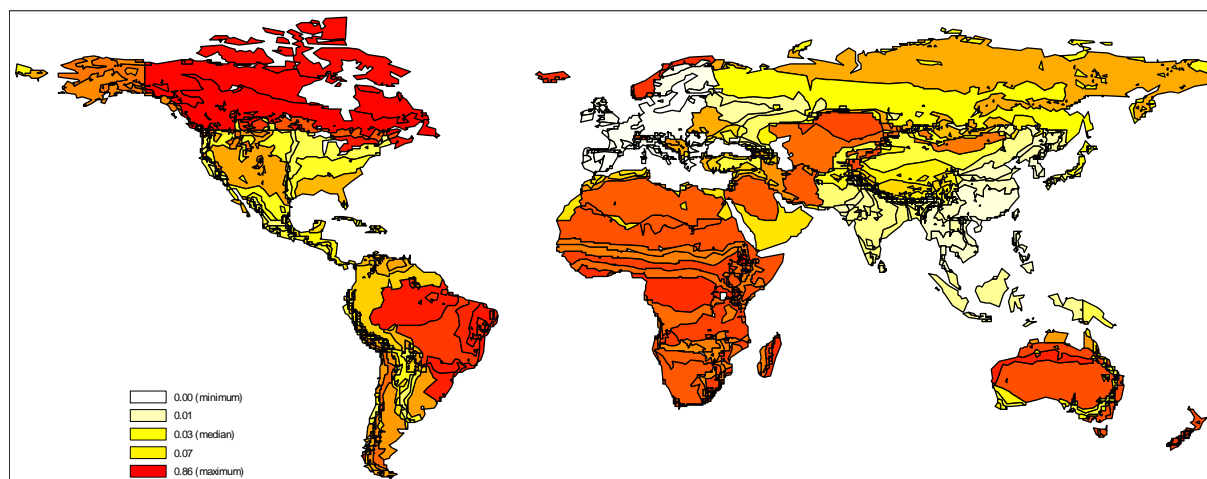


Source: Own Calculation.

Figure 4 reports the changes in grassland cover in the EU under the set-aside policy. Results indicate that in those regions where the share of idling land was small in the baseline, the program leads to an expansion of arable lands (including set-aside area) to the detriment of grass-lands (grasslands expand in 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 increases. And secondly, the immediate impact of the increased set-aside obligation is to idle additional land and

decrease cropped area. This, in turn, reduces labor and machinery requirements. Farms are left with excess labor and capital, the opportunity cost of which fall in the near term - as compared to the reference situation. As long as the cropland rents paid for additional land do not exceed the increase in short-run profits possible from using the available labor and capital, farmers will have an incentive to increase arable lands, and they do so in these important agricultural regions. This result hinges importantly on the quasi-fixed nature of labor and capital use in agriculture, as estimated for the CAPRI model by Jansson and Heckelei (2011).

Figure 5: Percentage change in cropland cover, by AEZ



Source: Own Calculation.

At the global level, percentage changes of crop land cover by AEZ and absolute changes can be identified. 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, but the areas involved are quite large, leading to some significant absolute changes in area under crops (Table 3). 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 thousand ha and

Canada with 67 thousand ha. Canada is followed closely by Brazil where cropland expands by about 49 thousand ha.

Table 3: changes in crop land cover by region

	USA	Brazil	Canada	Latin America	Asia	Africa	Rest of the World
Thousand hectares	31.81	48.67	67.25	22.94	23.76	155.46	71.49
Percentage change	0.02	0.09	0.16	0.00	0.00	0.00	0.00

Source: Own Calculation.

Where do these changes come from? Villoria and Hertel (2011) study 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 EU set-aside policy, we see this reflected in the strong responses in the EU's trading partners in Canada, Brazil, Africa and Australia. The links to Asia are much weaker.

A closer look at the trade patterns and production quantity changes reveal the crops that are produced on these additional land areas. In Brazil mainly oilseed production increases while the production of all other crops changes only slightly. This is also mirrored by the increase in exports to the EU. Here, Brazil increases oilseed exports by 1700 thousand US\$. 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 will export "other crops" with a value of 5184 thousand US\$ to the EU. In Canada, we observe a different picture. Here, oilseed production increases by 0.4% and wheat production by

0.6%. But the value of exports to the EU increase only by 146 thousand US\$ for oilseeds and 205 thousand US\$ 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.

At the first glance it seems peculiar that the decrease of 3.7 Mio. ha cropland in the EU results only in an absolute increase of 0.4 Mio. ha in the rest of the world. However, the ensuing price increases reduce demand, especially feed demand. They also lead to intensification of agricultural production around the world. Both of these factors serve to diminish the required increase in total area in non-EU regions. Of course, the intensification of crop production in the rest of the world may also have important environmental impacts, and we turn next to this assessment.

3.3 Environmental indicators at the global level

At the global level we observe an increase in fertilizer use due to land conversion and intensification of production (Table 4). Especially in Canada and Brazil, the application of all analysed fertilizers: nitrogen (N), potassium (K₂O) and phosphorus (P₂O₅) increase in percentage terms. If we compare the percentage changes of fertilizer use to the changes in crop land 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 fertilizer use. This reflects an intensification of the production on the already cultivated crop land areas around the world.

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

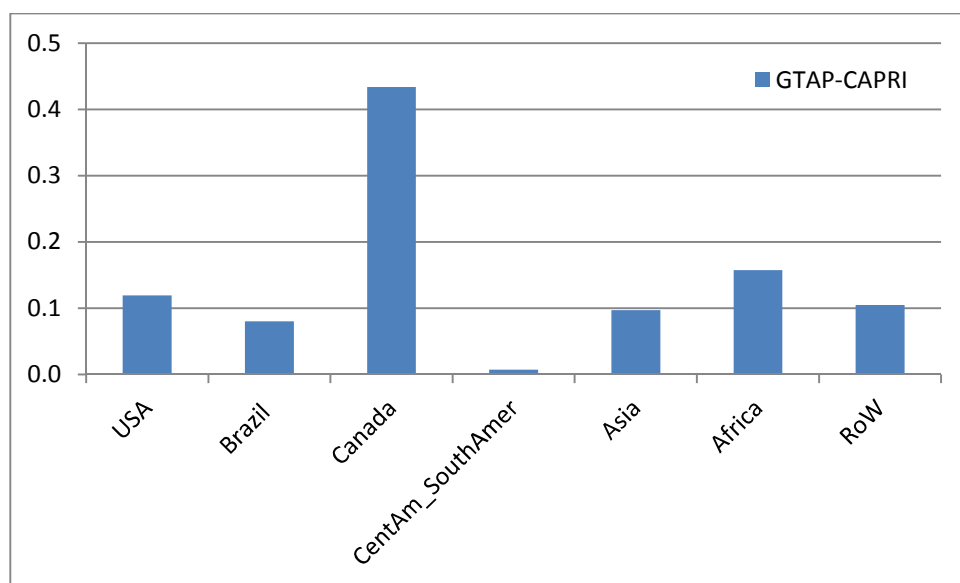
	Latin						
	USA	Brazil	Canada	America	Asia	Africa	RoW
N							
in %	0.17	0.24	0.28	0.17	0.08	0.25	0.25
in 1000 t	15.64	4.44	4.24	6.85	28.89	9.00	7.44
P2O5							
in %	0.14	0.16	0.32	0.18	0.08	0.29	0.26
in 1000 t	8.35	3.11	2.10	3.33	12.52	5.65	3.76
K2O							
in %	0.12	0.16	0.17	0.18	0.09	0.22	0.27
in 1000 t	8.88	3.84	0.70	2.70	8.84	1.57	3.55

Source: Own Calculation.

As a consequence of global crop land conversion and increased fertilizer applications, Green House Gas emissions rise in all non EU countries by 77 million metric tonnes CO₂eq. Thus, every hectare of land that is set-aside in the EU increases the Green House Gas emission in the rest of the world by 20.8 metric tonnes CO₂ equivalent. Figure 6 reports the estimated distribution of Global GHGs emissions in all non-EU-regions. The corresponding land use conversion factors are taken from Hertel et al. (2010b) who used a carbon accounting model that estimates the emissions from land use conversion. The results of this model are combined with the GTAP model by transferring regional emission factors of the carbon accounting model into the GTAP model. Set-aside policies in the EU result in land use changes in other parts of the world. Especially 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 with 43 % to the total effect. In contrast Brazil that also converts a relatively high amount of land has a lower GHG emission rate. The reason for this observation is the origin of the converted land. While Canada converts mainly forest land into cropland, in Brazil the additional crop land is expected to come from pasture land (e.g., the Cerrado). Finally, recall that the CAPRI model suggests no new land conversion in the EU.

Figure 6: Share of contribution to the change in global CO₂eq emissions by non-EU Region



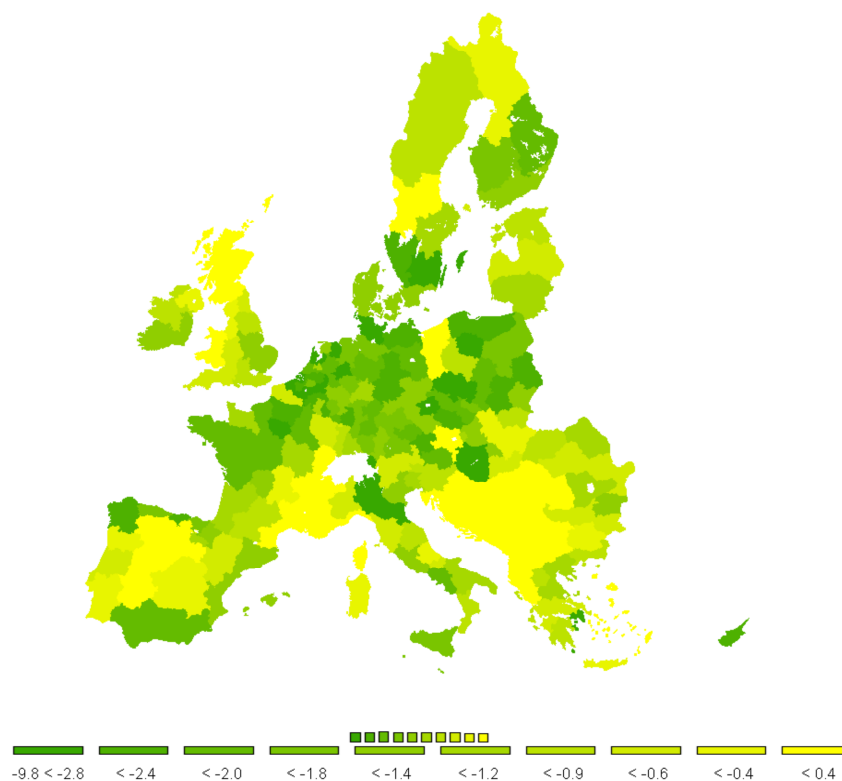
Source: Own Calculation.

3.4 Environmental indicators at EU level

At the EU level, major environmental indicators all show smaller improvements. Emissions of gases relevant for climate change expressed in CO₂ equivalents are simulated to drop by about 1.8%. Crop nitrogen demanded falls by 3.4%, allowing a reduction in mineral nitrogen fertilizer use by -4.7%, which, together with a reduction in nitrogen in manure of about -0.9% let 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 use reduced also ammonia emissions by about -1.5%.

The map below (Figure 7) reveals however that the changes in nitrogen surpluses are far from uniformly distributed. In the high yielding regions where a larger set-aside percentage are needed (see also Figure 1), crop production and nitrogen use decreases, leading to reduced surpluses. Based on a detailed analysis for France drawing on the 1x1 km downscaling component of CAPRI (Paracchini and Britz, 2010) it appears the program 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 let surpluses increase. The changes are however relatively small, and mainly concentrated in areas with a low level of surplus.

Figure 7: Change in nitrogen surplus in kg/ha



Source: Own Calculation.

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 to support the so-called 2010 objective of stopping biodiversity loss. By all accounts, this objective has not been met. Thus, EU Commission suggested in its recent proposal for the CAP post

2013 to set-aside 7% of all arable farm land for ecological focus areas. Taking the EU Commission-proposal as an example, this paper analyses global spill-over effects of domestic programs targeting environmental public goods.

We build on the methodology of Britz and Hertel (2011) who contribute to the recent discussion about induced land use change by analysing regional and global environmental consequences of EU biofuel mandates, combining the GTAP and CAPRI models. We take that methodology as a starting point to compare regional and global environmental effects of a proposed set-aside program for the EU targeting biodiversity. The proposed set-aside policy differs both from opt-in programs such as the voluntary set-aside programs in the EU or the Conservation Reserve Program (CRP) in the US, but also from the past and now abandoned obligatory supply control set-aside programs of the EU. The latter difference is that the EU program while being obligatory takes existing commitments of farmers e.g. when already idling land or managing their farm biologically into account. Accordingly, the share of additionally idled land is highest in high yielding regions, which have to date shown far low participation rates for the opt-in measures. Since the program disproportionately affects the most productive regions, the percentage reduction in EU production exceeds the percentage EU area changes.

Our analysis cannot capture all the details of the proposed program, such as exemptions for small farms or the effect of a possible update of the eligible areas. It rather gives an upper limit about the possible impact.

The improved methodology for linking the GTAP-AEZ model and CAPRI allows for an elegant model linkage while showing a sufficiently similar supply response to price changes and the introduction of the set-aside program in both models. This allows a

mutually consistent analysis of market and environmental impacts across regional, national and global scales.

The regional analysis shows an improved environmental status in the high yielding regions of the EU due to the increase in idling land. However, price increases trigger across Europe, 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 regions: the loss of 3.7 Mio ha of arable land in the EU is compensated by an increase of 0.4 Mio ha in other regions of the globe. In the EU direct CO₂ emissions drop by 1.8% while indirect emissions in non-EU countries increase by 76.8 MMT CO₂. There are also modest increases in nitrogen, phosphorus and potassium fertilizer use in other regions of the world. When the EU set-aside one hectare of land this results in an increase in climate change relevant gas emissions of 20.8 mt CO₂ eq in the rest of the world. In summary, attempts to enhance biodiversity in Europe can have unintended consequences in the rest of the world, and these should be factored into the decision making process.

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