Impacts of climate and policy change on Austrian protein crop supply balances

Auswirkungen von Klimawandel und Politikänderungen auf die österreichischen Versorgungsbilanzen von Eiweißpflanzen

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Summary

We assess climate change impacts on crop yields and investigate potential effects of the recent CAP reform on the competitiveness of protein crop production in Austria. The bio-physical process model EPIC is applied to simulate mean annual crop yields and environmental outcomes for three climate change scenarios until 2040. Marginal opportunity costs of expanding protein crop production are computed by the economic bottom-up land use optimization model BiomAT. The implications of expanding domestic protein crop production are quantified by using national supply balances. Our analysis shows that climate change and an aligned policy reform could increase domestic protein crop production and reduce nitrogen fertilizer inputs. The impact of policy change is likely to exceed that of near future climate change.
Keywords: protein crop production, climate change, CAP reform

Zusammenfassung

Wir untersuchen die Auswirkungen des Klimawandels auf Pflanzenerträge und analysieren mögliche Einflüsse der Reform der Gemeinsamen Agrarpolitik (GAP) auf die Wettbewerbsfähigkeit der österreichischen Eiweißpflanzenproduktion. Pflanzenerträge und Umweltwirkungen werden mit dem bio-physikalischen Prozessmodell EPIC für drei Klimawandelszenarien bis 2040 simuliert. Die Grenzopportunitätskosten einer Expansion der inländischen Eiweißpflanzenproduktion werden mit dem ökonomischen Landnutzungsoptimierungsmodell BiomAT berechnet. Die Auswirkungen werden mittels nationaler Ver-

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sorgungsbilanzen quantifiziert. Unter den getroffenen Annahmen zeigt unsere Analyse, dass der erwartete Klimawandel und die GAP-Reform die österreichische Eiweißpflanzenproduktion erhöhen und den Einsatz von mineralischem Stickstoff senken könnten. Der Einfluss der GAP-Reform auf die Pflanzenproduktion könnte jenen des Klimawandels übersteigen.
Schlagworte: Eiweißpflanzenproduktion, Klimawandel, GAP-Reform

1. Introduction

Several recent studies suggest that agricultural systems need to adjust in order to reduce food scarcities (e.g. MISSELHORN et al., 2012; MATTHEWS et al., 2013). Most authors agree that the technical potential is sufficient to feed the projected world population in 2050. However, economic and institutional constraints may limit agricultural outputs available for human consumption (KONING et al., 2009). Another concern is climate change which will likely impact level and variability of crop yields and may increase regional disparities of food supplies.

We investigate climate change and policy impacts on food supplies by focusing on protein crop production in Europe using Austria as a case study region. Several authors discuss reasons for the decline of protein crop production in Europe and propose measures to address the import imbalances (e.g. MURPHY-BOKERN and WATSON, 2012; STODDARD, 2013). These reports may have contributed to the decision made by the ministers of agriculture in spring 2013. They agreed on arrangements in the recently reformed CAP that are intended to enhance environmental and climate change performance of European agriculture and, at the same time, could halt the decline of domestic protein crop production. The compulsory 'greening' component of direct payments allows for protein crop production on land that would otherwise have to be set aside. Accordingly, recipients of direct payments are expected to cultivate protein crops more frequently in the next years.

This article analyzes two questions: (i) what is the likely impact of the recent policy change on protein crop production and land use, and (ii) how will climate change affect the competitiveness of protein crop production relative to other crops? We aim at enhancing the understanding if a policy change that stimulates protein crop production in Europe could be effective in the long run. The effects on the Austrian supply balance are quantified in order to show trade-offs with respect to other crops.

The article is structured as follows. Section 2 describes the data and methods used for the analysis. In section 3, the results are illustrated and discussed and section 4 concludes the article.

2. Data and methods

2.1 Data sets

We use four major data sets in our analysis:

- Daily weather data with a spatial resolution of 1 km are derived from a statistical climate change model for Austria (ACLiReM, Austrian Climate Change Model using Linear Regression) for three physically consistent climate change scenarios and the period 2010-2040. The climate change scenarios project a rising trend in temperature (+1.5 °C until 2040) and assume different mean annual precipitation sums. Climate change scenario sc01 assumes similar precipitation sums compared to those observed in 1975-2007, scenario sc05 assumes an increase and scenario sc09 a decrease in precipitation sums by 20% in 2040 compared to sc01 (see STRAUSS et al., 2012 and 2013 for a discussion on the rationale for these assumptions).
- Soil parameters and other topographic site characteristics are available on a 1 km grid. Historical land use data at municipality level are used to account for observed region specific crop rotations.
- Historical data on agricultural commodity prices and variable production costs of major crops are used to compute average annual crop gross margins. Commodity prices are considered with a mean value of the period 2010-2012 (STATISTICS AUSTRIA, 2013). Production costs are derived from the standard gross margin catalogue (BMLFUW, 2008) and further data sources (e.g. STÜRMER et al., 2013).
- Agricultural crop supply balances are provided by the Austrian Statistical Office and cover the period until 2011/12 (STATISTICS AUSTRIA, 2012). They are used to quantify the impacts of expected changes in crop yields on self-sufficiency rates.

2.2 Modeling framework

The bio-physical process model EPIC (Environmental Policy Integrated Climate; WILLIAMS, 1995) is applied to simulate mean annual dry matter crop yields and environmental outcomes for 1 km cropland grid cells in the period 1975-2005 and for three climate change scenarios in the period 2010-2040. The simulations cover up to eight distinct crop rotations per grid cell, three fertilization levels (high, moderate, and low) and irrigation which is combined with high fertilization intensity. Alternative crop rotations are derived from observed acreages of more than 2,000 municipalities and are specified per cropland grid cell using the model CropRota (SCHÖNHART et al., 2011). We consider the production of protein crops (i.e. soybean, faba bean and field pea) on land that was previously set aside and on cropland with similar bio-physical characteristics as the current production area in alternative crop rotations. This enables us to account for the potential supply or protein crops. The EPIC outputs of annual dry matter crop yields and applied inputs (i.e. nitrogen, phosphorus and irrigation water) are used in the bottom-up economic land use optimization model for Austria (BiomAT). BiomAT uses linear programming to maximize total crop gross margins subject to spatial resource endowments and agronomic restrictions (ASAMER et al., 2011; STÜRMER et al., 2013). We develop 20 protein crop price scenarios to investigate the marginal opportunity costs of potential policy effects on protein crop production.
Data and model interfaces are depicted in Figure 1.

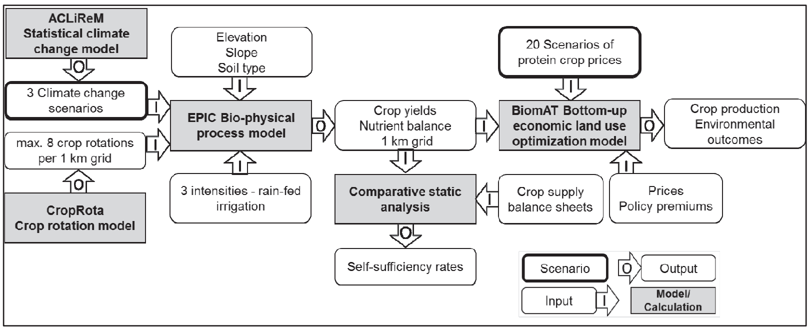

Fig. 1: Data and modeling framework
Source: own illustration

2.3 Comparative static analysis

We apply a comparative static analysis to quantify potential changes of climate conditions and the CAP reform on domestic self-sufficiency rates (SSR). SSR is defined as the ratio of domestic crop production and domestic use including animal feed, human consumption, industrial uses, seeds, and losses. Average values of the crop supply balance sheets of the period 2008-2010 serve as a reference (STATISTICS AUSTRIA, 2012). Domestic use and storage as well as costs and prices are held constant. Factors such as demand shifts or progress in breeding do not enter the analysis. A comparative static analysis is useful for comparing different scenarios. Its main limitation is that dynamic market feedbacks cannot be considered and the results depend on the consistency of the investigated scenarios.

3. Results and discussion

3.1 Changes in self-sufficiency rates

Average levels of SSR are reported in Table 1 for major crops in the period 2008-2010 as well as for climate and policy change in the period 2010-2040. The data reveal that the average SSR was about 58% for soybean and exceeded 85% for cereals and pulses in the period 2008-2010. Winter wheat and durum wheat even reached SSR above 100%. The results of the comparative static analysis reveal that the SSR of most crops are similar in climate change scenario sc01, higher in sc05, and lower in sc09, showing a likely spectrum of climate change impacts. We expect that the SSR of protein crops almost doubles in the climate change scenarios assuming that their production is allowed on previous fallow land of about 75,000 ha (about 6% of Austrian cropland). This assumption conforms to the CAP post-2013 regulation. However, soybean products (e.g. defatted soybean meal used for livestock feed) is not considered in this analysis due to lack of supply balance data.

3.2 Land use change and marginal opportunity costs

We present the marginal opportunity costs of an expansion of protein crop production on Austrian cropland for the three climate change scenarios in Figure 2. The results show that, under similar climate conditions than in the past (sc01), an expansion of current protein crop production by around 28% leads to an increase of marginal opportunity costs by around 50%. With increasing marginal opportunity costs (i.e. larger shares of cropland are cultivated with protein crops), total agricultural production decreases due to a decline in oil crop, maize, and root crop production. Only the output of cereals would slightly increase. The slope of climate change scenario sc09 in the marginal opportunity costs indicates that drier conditions raise average production costs compared to climate change scenarios sc01 and sc05.

Tab. 1: Levels of self-sufficiency rates (SSR) and trade balances (bal) for the period 2008-2010 and changes in SSR in percentage points due to climate change (CC) and policy change (PC) using the mean and the median of simulated crop yields for the period 2010-2040 for the three climate change scenarios sc01, sc05, and sc09

	SSR	bal		mean			median		
	2008-2010			sc01	sc05	sc09	sc01	sc05	sc09
	%	1,000 t		%	%	%	%	%	%
winter wheat	107	95.6	CC	1	10	-18	2	10	-20
winter rye	85	-35.5		1	6	-9	-2	6	-11
barley	94	-64.0		0	3	-6	-1	0	-7
oats	95	-5.2		-1	-3	-2	-1	-3	0
maize	89	-272.0		-1	1	-8	0	3	-7
triticale	99	-3.1		2	3	-3	2	3	-3
soybean	58	-51.6		2	3	-1	3	4	-2
pulses	95	n.a.		0	4	-10	0	4	-11
protein crops			CC	2	4	-5	2	4	-4
cereals				1	5	-12	1	6	-10
protein crops			PC	97	103	81	97	103	80

Source: own calculations

Potential regional patterns of protein crop production are depicted in Figure 3 for climate change scenario sc01 with marginal opportunity costs of (a) 19 €/t and (b) 812 €/t. At low marginal opportunity costs (a), the production areas concentrate on a few small regions in the provinces of Upper and Lower Austria, Burgenland and Carinthia. Their regional distribution is similar to the current production areas though their spatial extent is smaller.

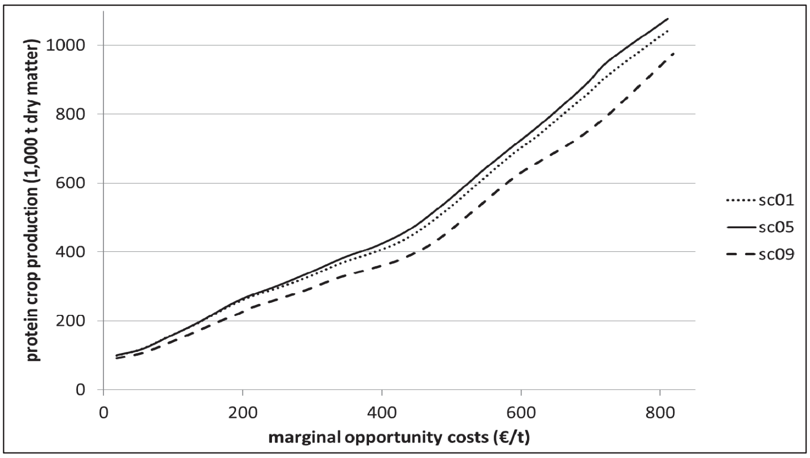

Fig. 2: Marginal opportunity costs of protein crop production on cropland for the three climate change scenarios sc01, sc05, and sc09
Source: own calculations

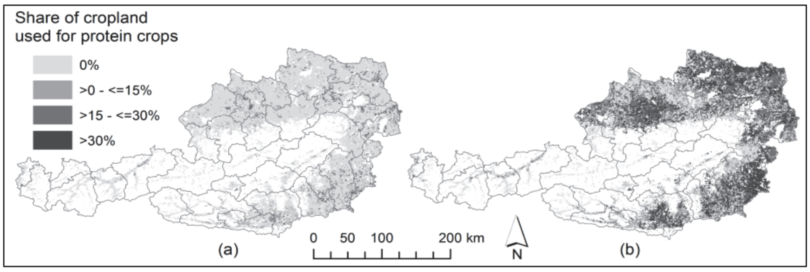

Fig. 3: Share of cropland used for cultivating protein crops, i.e. soybean, faba bean, and field pea, per cropland grid cell for climate change scenario sc01 with marginal opportunity costs of (a) 19 €/t and (b) 812 €/t; no cropland in white areas
Source: own calculations

At high marginal opportunity costs (b), the share of cropland used for cultivating protein crops increases to 15% or more in Eastern parts of Austria. Such a land use change is realistic as protein crops (i.e. soybean, faba bean and field pea) were planted on a much larger acreage in the 1990ies compared to today's levels (111,000 ha in 1992 compared to 55,000 ha in 2013).

3.3 Effects of additional protein crop production on input demand

A higher share of protein crops in the crop rotations would lead to a reduction in total nitrogen application on cropland as shown in Figure 4. The decline is similar for climate change scenarios sc01 and sc05 but lower for climate change scenario sc09 when the total protein crop production level exceeds 600,000 t. The lower effect of climate change scenario sc09 is mainly due to the growing importance of irrigation in combination with high fertilization rates leading to increasing crop production. The input of nitrogen fertilizer could be reduced between 15% (in climate change scenario sc01) and 21% (in sc05) by a ten-fold increase in total protein crop production.

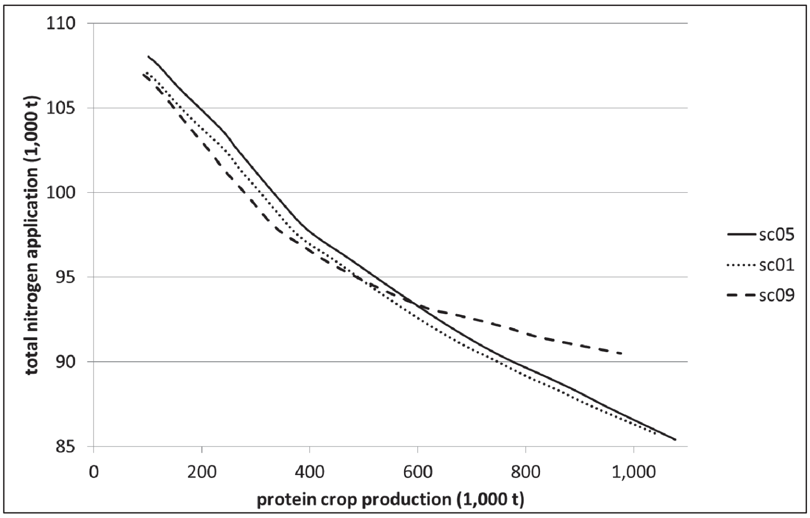

Fig. 4: Total nitrogen application on cropland by increasing levels of protein crop production for the three climate change scenarios sc01, sc05, and sc09
Source: own calculations

4. Conclusions and outlook

Changes in climate and agricultural policies are likely to impact agricultural commodity supplies in the near future. We show simulation results of crop production responses of three climate change scenarios in Austria. Our investigation focuses on protein crops – an important aspect of the recent CAP reform. Assuming constant domestic use and storage, we find that changes in domestic production could contribute to a substantial reduction of protein crop imports in the next decades. The analysis indicates that the impacts of policy changes on SSR of protein crops are likely to exceed those of near future climate change. However, climate induced production risks (e.g. from sudden weather conditions) exacerbate the projection of level and variability of crop yields. This stresses the importance of further investigations on domestic crop yield and supply volatilities as well as the roles of storage and trade.

A rising share of protein crops on Austrian cropland will likely increase the marginal opportunity costs of production and decrease the input of nitrogen fertilizer as well as subsequent emissions of greenhouse gases. However, the expansion of protein crops might provoke the discussion on the competition for land arising from a changing and increasing demand for food, feed, and bio-energy and induced environmental risks. The primary objective of the greening component of the reformed CAP is to indirectly improve biodiversity. This aspect is not addressed in our analysis yet. Future research efforts should therefore cover the whole set of objectives of the CAP reform.

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