Impact of climate change on agricultural land use in the Austrian Upper Danube catchment - first results of ACRE-Danube

Auswirkungen des Klimawandels auf die landwirtschaftliche Landnutzung im österreichischen Einzugsgebiet der Oberen Donau – erste Ergebnisse von ACRE-Danube

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Zusammenfassung

Das agrarökonomisches Regionalmodell ACRE-Danube (Agro-eConomic pRoduction model at rEgional level) wurde als Entscheidungs-Unterstützungs-Werkzeug für die Politik entwickelt um Auswirkungen des Globalen Wandels auf die landwirtschaftliche Landnutzung im Einzugsgebiet der Oberen Donau abschätzen zu können. Hierzu wurden Szenarien zum Klimawandel simuliert, die auch die Reform der Gemeinsamen Agrarpolitik berücksichtigen. Diese Arbeit stellt erste Ergebnisse vor.
Schlagworte: Klimawandel, Landnutzung, Gemeinsame Agrarpolitik

Summary

ACRE-Danube is an Agro-eConomic pRoduction model at rEgional level and was developed as a decision tool for policy making with respect to questions of global change and policy scenarios for the Upper Danube basin. In order to estimate the impacts of climate change on the Austrian part of the Danube river basin, scenarios were simulated considering climate change as well as the CAP reform 2003. This paper introduces the first results.
Keywords: Climate change, Land use, Common Agricultural Policy

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1. Context and Motivation

1.1 Climate Change and Agricultural Production

Agricultural land use is influenced by the climatic, biological, physical, socio-economic, political and technological environment and its feedbacks between land use and its drivers (BUSCH, 2006).

Potential impacts of climate change on agricultural crop yields for the alpine region of Austria have been reported by ALEXANDROV et al., (2002). Model results indicate that crop yields may increase due to higher levels of CO_2 (Figure 1). However, drought risks may also increase; e.g. during the drought year 2003 average yield depression for Austria ranged from 12% (wheat) to 15% (grassland) (SOJA et al., 2005). Interannual variability of temperature and precipitation in summer are likely to increase substantially in future Europe (GIORGI et al., 2004). Both increased climate variability and extreme weather events could increase the risk of yield depressions, particularly for cereals (SOJA and SOJA 2003).

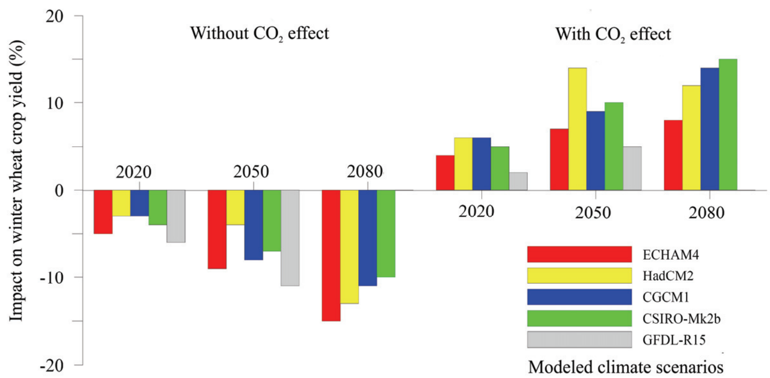

Fig. 1: Modeled crop yield changes of winter wheat on a site with good soil water properties in Lower Austria under different climate scenarios for the years 2020, 2050 and 2080 (modified from FORMAYER et al., 2001, p. 40). Source: ALEXANDROV et al., 2000.

Current impact studies on agricultural land use tend to focus either on the consequences of economic and policy conditions or on climate change. Only few studies explicitly consider both socioeconomic and climate change factors. Using the regional optimisation model ACRE-Danube, scenarios can be calculated which consider socio-economic conditions (Common Agricultural Policy (CAP), technological advance) as well as estimated impacts of climate change (elevated temperature and CO2-concentrations).

1.2 Investigation area: The Upper Danube Basin of Austria

The Upper Danube basin covers an area of 77,000 km² primarily in Germany and Austria. Approximately 55 % of the catchment area is agriculturally used. The Alps and their forelands enforce large gradients in climate, vegetation and water supply within a comparably small area (MAUSER, 2002). It therefore constitutes an ideal research area for the existing subproject, which aims to analyse socio-economic impacts of different policy measures and of climate change on agricultural land use and water demand of agricultural production as part of the integrative research project GLOWA-Danube[1] (Global Change in the Hydrological Cycle).

Due to local conditions (e.g. high annual precipitation, topography), grassland farming represents the major agricultural land use in the Alps and the southern alpine foreland. Dairy farming is the predominant practice in these regions, whereby average farm sizes tend to be larger than in the rest of the Danube catchment (WIRSIG et al., 2006). In the northern alpine foreland, cereals and fodder crops are cultivated to a minor extent (Table 1).

2. The Optimisation Model ACRE-DANUBE

ACRE-Danube is an **A**gro-e**C**onomic p**R**oduction model on r**E**gional-level for the Upper **Danube** catchment area. The model was developed within the project GLOWA-Danube by WINTER (2005), as a tool to

[1]The project GLOWA is funded by the German Federal Ministry of Education and Research (BMBF).

simulate the impacts on farming due to changes in climate and socio-economic conditions.

The complete model region of ACRE-Danube includes a total of 74 districts (NUTS[2]-level 3) out of which 16 districts are located in Austria.

Table 1: Agricultural landuse in the Upper Danube basin of Austria

Region	UAA	Arable land	Grassland
	ha	%	%
Reutte	25460	0	100
Zell am See	107544	0	100
St. Johann	72798	0	100
Kitzbühel	48903	0	100
Hallein	24575	0	100
Landeck	67989	1	99
Bludenz	52979	1	99
Bregenz	43686	1	99
Imst	50200	3	97
Schwaz	56838	3	97
Kufstein	40316	4	96
Innsbruck	65088	8	92
Salzburg	45713	8	92
Braunau	57737	48	52
Schärding	38440	53	47
Ried (Inn)	40291	60	40

Statistical data for urban and hinterland was aggregated.

Source: STATISTIK AUSTRIA, 1996.

ACRE-Danube is a comparative static partial-equilibrium model which maximises total gross margin at the regional level to find the optimal combination of production activities for each district (regional farm approach). The shortest simulation period is one year. ACRE-Danube has been calibrated for the reference year 1995, with regional statistical production data.

2.1 The Calibration Method

The calibration method is the Positive Mathematical Programming (PMP) published by HOWITT (1995). ACRE-Danube is based on the

[2] Nomenclature of Territorial Units for Statistics (NUTS)

extension of PMP published by RÖHM and DABBERT (2003). Whereas the standard approach estimates production functions for the same crop under different technologies separately from each other, the extended method introduces variant activities alongside the main activities to ensure a closer dependency between variant activities than between the main activities. This enhances the extended PMP approach to allow simulation of different production variants, (e.g. intensive winter wheat production and extensive winter wheat production) for example, alongside the main crop production activities.

2.2 Agricultural Production Activities

Agricultural production includes 24 food and non food crops, as well as 15 production processes for livestock, as listed in Table 2.

Table 2: Plant production and livestock modelled in ACRE-Danube

Plant production			
Winter wheat	Oats	Early potatoes	Legumes
Spring wheat	Triticale	Late potatoes	Clover
Winter barley	Cereal maize	Sugar beet	Special crops[1]
Spring barley	Silage maize	Sunflowers	Fallow land
Rye	Corn-Cobb-Mix	Winter rape	Grassland[2]
Livestock			
Dairy cows	Fattening heifers	Fattening pigs	Broilers
Suckling cows	Male calves	Piglets	Poultry
Fattening bulls	Female calves	Ewes	Ride horses
Breeding heifers	Breeding sow	Layers	

[1] including fruits, vegetables, hops; [2] including intensive and extensive grassland

Source: own representation.

The model consists of a process analytical approach. A simplified scheme of the product flow in ACRE-Danube is outlined in Figure 2. Cash crops or fodder crops for livestock production can be produced. The animals produce manure which is used for fertilisation in crop production. Both, prices for crops and animal products as well as *premiums* influence the total gross margin. Mineral fertiliser, feed concentrates and water are purchased. In the optimisation process

ACRE-Danube maximises the total gross margin for each district by optimising the acreage of crops and the number of animals with respect to the scenario constraints. Trade activities between the districts are not defined.

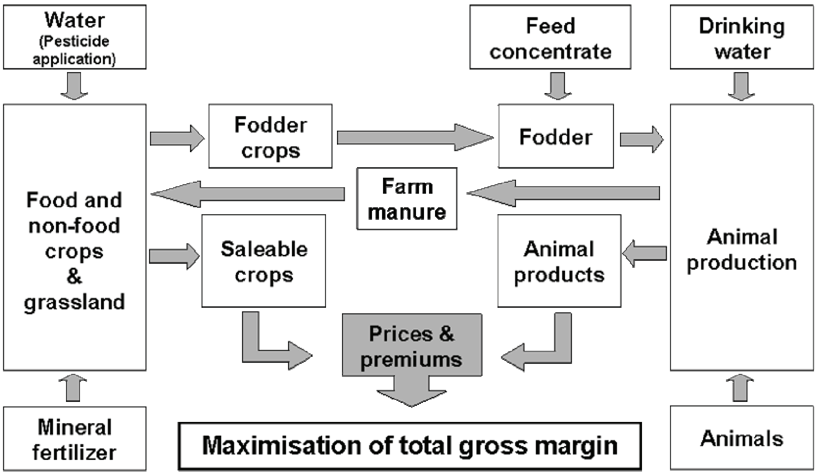

Figure 2: Product flow in ACRE-Danube.
Source: own representation.

Scenarios can be simulated by varying model parameters. Changes of production patterns can be calculated by varying agricultural input parameters; for example, by increasing input prices or reduction of arable land and grassland. Market situations can be represented by varying product prices or production quotas. To simulate policy instruments, CAP premiums (*1st pillar of CAP*), environmental programmes and payments to less favoured areas (*2nd pillar*) are implemented for the period from 1995 to 2013. Changes in climate are simulated by varying parameters for water supply and crop yields.

3. Scenario Assumptions

Policy conditions are included in the form of selected measures of the CAP reform of 2003. Climate change and technological advance factors are simulated as crop productivity factors for four scenarios of the IPCC (Intergovernmental Panel on Climate Change) scenario family.

3.1 Agricultural Policy Scenario

Agricultural policy conditions are considered up to the year 2013 and assumed to remain valid for the scenario year 2020. The CAP reform 2003 is modelled in ACRE-Danube by assuming reformed payments according to BMLFUW (2003) and AMA (2005). *Single Farm Payments (SFP)* were derived for the Austrian districts on the basis of the calculated average of direct payments received for crops and livestock, as well as the reference quantity of milk within the period from 2000 to 2002. Partial decoupling of premiums (100% suckler cow premium remains coupled, slaughter premium is not considered) and additional aids are included, as well as changes in set-aside rates (Table 3).

Table. 3: Direct payments and set-aside rates considered in ACRE-Danube

Crops	**Premiums according to Agenda 2000 in scenario year 2002**	**Premiums according to CAP reform in scenario year 2020**
	Euro/ha	Euro/ha
Suckler cow	230	230
Special premium bulls	210	-
Ewes	21	-
Cereals & Maize	332	SFP
Oilseeds	332	(45)+ SFP
Protein crops	382	(55,75)+ SFP
Set-aside	332 (10% of cash crop area)	SFP (10% of arable land)

Source: BMLFUW 2001, 2003. SFP: Single Farm Payments (81-273 Euro/ha).

Selected elements of *Cross Compliance* (e.g. grassland maintenance) are taken into account while *Modulation* is not considered. *Agri-environmental Payments* are implied for grassland (Table 4).

Table. 4: Agri-environmental payments for grassland

	McSharry[a)]	**Agenda 2000**[b)]	**2020**[c)]
	Euro/ha	Euro/ha	Euro/ha
Pasture for cutting	25	73	0
Alpine pasture	13	44	0
Rough pasture	13	44	0
Other	51	73	0

[a)] ÖPUL 95: 51 €/ha grassland: pasture for cutting x 0.5, extensive pasture x 0.25, intensive pasture and meadow of cutting x 1.0; [b)] ÖPUL2000: basic promotion as designated for ≥ 0.5 LSU/ha, [c)] assumption.

Source: BMLFUW, 2001, 2003.

Changes in product price were not taken into account. For reasons of model consistency, the implementation of the 2nd pillar of the CAP for Austria was conducted only for measures similar to those implemented for the German part of the Danube catchment (c.f. Winter, 2005).

3.2 Climate Change and Technological Advance

In order to simulate climate change and technological advance, crop yield data were modified. Basic yield data of ACRE-Danube were modified by yield change factors estimated by EWERT et al. (2005), who developed an internally consistent and plausible set of four crop productivity scenarios based on the IPCC SRES (Special Report on Emissions Scenarios) framework. The scenarios consider different effects of climate change and increasing CO_2, as well as technology development - in particular crop management and breeding. For simplicity, livestock productivity remains unchanged. For the scenario calculations in ACRE-Danube, the total crop productivity modification factors were used (Table 5).

Table 5. Factors of crop productivity relative to basis yield for different parameters and IPCC SRES scenarios in 2020 (Nakićenović et al. 2000).

Parameter	IPCC scenario			
	A1FI[a)]	A2[b)]	B1[c)]	B2[d)]
Climate	0.99	0.99	1.01	1.00
Co_2	1.04	1.04	1.03	1.04
Technology	1.37	1.37	1.30	1.20
Total	1.41	1.40	1.34	1.25

[a)] Global economic and fossil fuel intensive world, [b)] Regional economic world, [c)] Global environmental world, [d)] Regional environmental world.

Source: EWERT et al., 2005.

4. Results

Table 6 shows the development of acreages for selected crops in the years 2002 and 2020 for 4 IPCC SRES scenarios within 16 Austrian districts. Crops are ordered according to their share of acreages on arable land. Crops with shares below 3% scarcely change and are not shown (with the exception of oilseeds). The comparison between the scenario of the year 2002 (Agenda 2000 with no changes of crop productivity) and the IPCC scenarios in the year 2020 (CAP reform scenario and assumed crop productivity modifications) illustrates that the area of silage maize decreases by 3 to 4 % of arable land while clover increases by 2 to 3 % and set-aside by 7 %. The differences between the acreages in the IPCC scenarios are no higher than 1 % for silage maize and clover between scenario A1FI and the other scenarios. The increase of the obligatory set-aside area is mainly on account of other fodder cereals. For the majority of all other crops, the acreage does not change significantly in the scenarios, with the exception of oilseed cultivation which falls to almost zero.

Table 6. Development of crops and set-aside in the Austrian Upper Danube basin for the year 2002 and different IPCC SRES scenarios in 2020 based on EWERT et al., (2005) in percentage of total acreage of arable land.

	2002	2020			
		A1FI	A2	B1	B2
Clover	24	26	26	26	27
Silage maize	16	13	13	13	12
Winter wheat	15	14	14	13	13
Winter barley	10	7	7	7	7
Oat	7	4	4	4	4
Cereal maize	5	5	5	5	5
Spring barley	4	4	4	4	4
CCM	4	4	4	4	4
Triticale	3	3	3	3	2
Oilseeds	2	0	0	0	0
Set-aside	3	10	10	10	10

Source: own calculations.

The total gross margin is basically increasing, compared to Agenda 2000. For the most part, regions with a high share of grassland show an increase in TGM, while regions with a high share of arable land face only a slight or no increase (not shown).

5. Discussion and Conclusion

5.1 Discussion

The changes in crop productivity variation may be considered less significant, e.g. the difference between the crop productivity modification factor of scenario A1FI and B2 account for 16 %, while differences between the shares are only 2 to 3 %. However, taking price changes and follow up costs of climate change, such as insurance costs for extreme weather events, into account may result in a more significant land use change.

Under the assumption of stable prices, the CAP reform leads to an increase of TGM for the regional farms in the Upper Danube basin. This corresponds more or less with results of the farm optimisation model FAMOS (Schmid, 2004a). The observed tendency of increasing total gross margin for districts with high shares of grassland results mainly from the regional implementation of the Single Farm Payments as applied in the model (regional farm approach, c.f. chapter 2). A weak point in the current model is the poor representation of the second pillar of the CAP in Austria.

The extensification of arable crop production, by decreasing acreage of silage maize and increasing clover, may be explained by substitution as fodder crop due to increasing profitability of clover in comparison to silage maize. The decline of oilseed can also be explained as an effect of decoupling. However, since scenario assumptions did not consider the growing demand for energy crops, the cultivation of silage maize and oilseeds in particular are likely to be underestimated (c.f. HABERL et al., 2002). The increase in set-aside area is caused by the increase of obligatory set-aside area in the CAP reform to 10 % of arable land.

5.2 Conclusion

The principal implicating factors for the Austrian catchment – extensification of arable crop production, enlargement of grassland area and shift to extensive production – are predominantly a result of the CAP, as reported by other studies (SCHMID and SINABELL, 2004b, 2006). Potential impact of climate change (and technological advances) on agricultural land use for the Austrian Upper Danube basin seems small relative to the impact of agricultural policy changes. The results for the Upper Danube basin supports the conclusion that, at least in the short term, climate change may not be the major factor of global change having an impact on agricultural land use in Austria (c.f. FORMAYER et al., 2001).

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