How does climate change adaptation impact GHG emissions – The case of Austrian agriculture

M. Kirchner, M. Schönhart, H. Mitter and E. Schmid[1]

***Abstract* - We analyse how adaptation measures to climate change scenarios (2025-2040) affect GHG emissions. A spatially explicit integrated modelling framework (IMF) is applied to model climate change impacts and adaptation in Austrian agriculture. GHG emissions are calculated according to the National Inventory Report. On national average, we find that agricultural adaptation leads to intensification such that total GHG emissions from the agricultural sector increase between 0% and 3%. However, the regional differences are considerable and show that agricultural intensification and extensification are mainly driven by the sign and magnitude of local climate change impacts.**

INTRODUCTION

Much research focus in agricultural ecosystem management has been put on either adaptation or mitigation measures. However, only few empirical analyses focus on both issues simultaneously despite a need to consider the interaction between adaptation and mitigation: First, agriculture is significantly affected by climate change impacts (Bindi and Olesen, 2011). Second, agriculture contributes about 10% to the total GHG emissions in Austria (Anderl et al., 2013). Third, measures of adaptation and mitigation can have conflicting or synergetic effects which are often diffuse and volatile due to the stochastic nature of ecosystem processes and the heterogeneity of site conditions (Falloon and Betts, 2010). It is therefore not clear *ex ante* if adaptation and mitigation measures are complementary, conflicting or independent of each other.

Therefore, we quantitatively analyse how agricultural adaptation to different climate change scenarios until 2040 affects GHG emissions of the agricultural sector in Austria.

METHODOLOGY

We apply a spatially explicit integrated modelling framework (IMF) which sequentially links the Austrian Climate model based on Linear Regression Methods *ACLiReM* (Strauss et al., 2013), the agronomic crop rotation model *CropRota* (Schönhart et al., 2011), the biophysical process model *EPIC* (Williams, 1995), and the spatially explicit bottom-up agricultural and forestry sector model $PASMA_{[grid]}$, which is based upon *PASMA* (Schmid et al., 2007). The IMF allows us to quantify climate change impacts on yields and environmental outcomes considering the natural and economic heterogeneity of agricultural production in Austria.

Four climate change scenarios are used for the analysis. They all share a temperature increase of 1.5 °C from 2008 to 2040 but differ with respect to precipitation patterns, i.e.:

- *High*: +20% annual precipitation sums
- *Similar*: assuming similar distributions of precipitation sums compared to the past
- *Shift*: 20% decrease in summer precipitation sums and respective increase in winter
- *Low*: -20% annual precipitation sums

We consider the period 2025-2040 and keep prices, costs, and agricultural policies constant in order to quantify pure climate change impacts and adaptation.

GHG emissions are calculated using the IMF model output. We have developed a GHG module that resembles the accounting methods of the Austrian National Inventory Report (AIR) for GHG emissions of the agricultural sector (Anderl et al., 2013). The $PASMA_{[grid]}$ production activities relevant for GHG emissions (e.g. fertilizer use, legume area, livestock production) are used in the GHG module to calculate total GHG emissions for each scenario. Total GHG emissions from agriculture comprise of (1) enteric fermentation (ca. 43%), (2) manure management (ca. 16%), (3) soil emissions (ca. 41%), and (4) field burning (less than 1%). Almost all necessary GHG activities can be represented by $PASMA_{[grid]}$ except the distribution and usage of different manure management systems which are therefore kept constant. Field burning is illegal in Austria.

The GHG module has been successfully validated for the reference year 2008 using both AIR production activity data (difference of -0.2% to the official total GHG emissions from the agricultural sector) as well as $PASMA_{[grid]}$ production activities (difference of -5.5%). Discrepancies between $PASMA_{[grid]}$ activities and AIR occur due to different activity levels and livestock categories. The difference with regard to GHG emissions remains reasonably small.

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[1] Mathias Kirchner, Martin Schönhart, Hermine Mitter and Erwin Schmid are from the University of Natural Resources and Life Sciences, Vienna, Institute for Sustainable Economic Development, Vienna, Austria (mathias.kirchner@boku.ac.at).

M. Kirchner and H. Mitter are doctoral candidates at the Doctoral School Sustainable Development (dokNE).

RESULTS

Table 1 provides major IMF results on agricultural adaptation to the climate change scenarios. *EPIC* simulations show an overall increase in yields. This leads to an increasing marginal added-value of fertilizer use in *PASMA*$_{[grid]}$ and hence more fertilizer use at national level but with ample regional differences.

In addition, we also observe an increase in more intensive soil management measures as well as decreases in the application of winter cover crops in *Similar*, *Shift* and *Low*. The decline of winter cover crops in these scenarios could be related to an increased competition for water resources between cash and winter cover crops in some areas. Finally, changes in livestock production or crop choices remain negligibly small among the scenarios.

Table 1. Changes in management measures in %.

Management measures		Climate change scenarios High	Similar	Shift	Low
Fertilizer intensity[a]	High intensity	64	36	35	8
	Moderate intensity	2	9	6	4
	Low intensity	-24	-21	-19	-11
Soil measure[b]	Standard tillage	11	15	13	20
	Reduced tillage	-8	1	3	11
	Winter cover crops	3	-14	-15	-32

[a]Refers to fertilizer intensity on both crop and grassland.
[b]Refers to cropland only.

Changes in fertilizer intensity as well as soil management measures affect important environmental indicators (see Table 2). As expected, due to intensification of land use more nitrogen is applied to agricultural soils (from +1% in *Low* to +8% in *High*), which correlates with small increases in total GHG emissions (from +0% in *Low* to +3% in *High*). In addition, we also observe changes in topsoil organic carbon stocks (SOC) in agricultural soils. SOC is very sensitive to the climate change scenarios as it is highly influenced by changes in temperatures, rainfall, soil management measures, soil erosion processes, and carbon residues from crops.

Table 2. Changes in environmental outcomes in %.

Environmental indicators	Climate change scenarios High	Similar	Shift	Low
Nitrogen applied to soils	8	6	5	1
Total GHG emissions	3	2	1	0
Topsoil organic carbon stock	-3	1	1	4

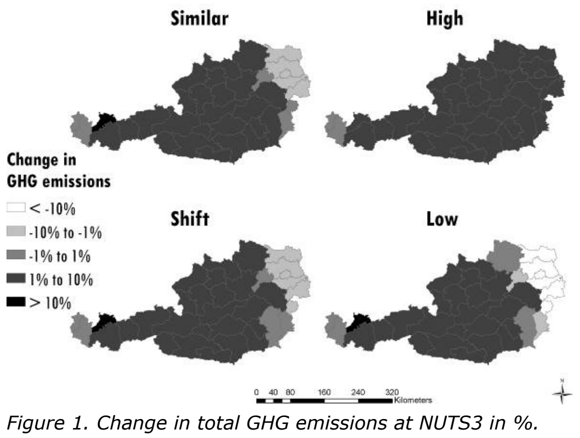

Figure 1. Change in total GHG emissions at NUTS3 in %.

Notably, our spatially explicit IMF reveals considerable regional differences. Particularly in the eastern semi-arid crop production regions, agricultural adaptation leads to lower fertilizer inputs and thereby also lower GHG emissions (Figure 1).

CONCLUSION AND OUTLOOK

Our analysis shows that adaptation measures in agriculture can have considerable impacts on GHG emissions. These impacts differ by climate change scenario and the heterogeneity of agricultural production in Austria. At national level, climate change could lead to slightly higher GHG emissions from the agricultural sector until 2040. Further, the higher the GHG emissions in the scenarios the lower is the SOC in agricultural soils. Although not accounted for in the AIR, changes in SOC in agricultural soils can substantially affect GHG emissions. This strongly indicates that adaptation and mitigation measures are interdependent.

Future analyses will focus on agri-environmental measures to incentivize farmers to adopt mitigation measures (e.g. low fertilization and winter cover crops). This allows us to (i) trace the effects of mitigation measures; and (ii) reveal measures and regions with low marginal abatement costs.

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REFERENCES

Anderl, M., et al. (2013). *Austria's National Inventory Report 2013*. Report No. 0416. Vienna: Environment Agency Austria.

Bindi, M. and Olesen, J.E. (2011). The responses of agriculture in Europe to climate change. *Reg. Environ. Change* 11, 151–158

Falloon, P. and Betts, R. (2010). Climate impacts on European agriculture and water management in the context of adaptation and mitigation—The importance of an integrated approach. *Sci. Total Environ.* 408, 5667–5687.

Schmid, E., Sinabell, F. and Hofreither, M.F. (2007). Phasing out of environmentally harmful subsidies: Consequences of the 2003 CAP reform. *Ecol. Econ.* 60, 596–604.

Schönhart, M., Schmid, E. and Schneider, U.A. (2011). CropRota – A crop rotation model to support integrated land use assessments. *Eur. J. Agron.* 34, 263–277.

Strauss, F., Formayer, H. and Schmid, E. (2013). High resolution climate data for Austria in the period 2008-2040 from a statistical climate change model. *Int. J. Climatol.* 33, 430–443.

Williams, J. (1995). The EPIC Model. In: Singh, V.P. (Ed.). *Computer Models of Watershed Hydrology*, pp. 909–1000. Colorado: Water Resources Publications.