Measuring climate-induced risks in crop production in Austria

H. Mitter, C. Heumesser and E. Schmid[1]

***Abstract* - Climate-induced production risks may increase in Austrian agriculture over the next decades. It calls for integration of disciplinary data and models as well as tools of risk analysis to measure and decompose the risks in crop production. Consequently, we employ an integrated modelling approach consisting of a statistical climate change model for Austria (ACLiReM) and the Environmental Policy Integrated Climate model (EPIC) to simulate climate change impacts on crop yields and environmental outcomes at 1km² pixel resolution in Austria. Several measures of risk are calculated to quantify and decompose crop production risks with respect to site characteristics and crop management measures. Results indicate that near future climate change will likely increase average crop yields and profitability but also ity. In addition, the cost-effectiveness of crop management measures to reduce climate-induced risks is mainly determined by site characteristics and opportunity costs.**

INTRODUCTION

Farmers are exposed to a variety of risks from different sources, e.g. (i) production risks due to sudden weather conditions or infestation pressure of pests and diseases, (ii) market risks related to variability of commodity prices, (iii) financial risks related to the ability to pay bills, (iv) legal and environmental risks including sudden changes in government regulations, and (v) human resource risks (Musser and Patrick, 2001). A farmer's optimal choice of risk management strategies should be based on several aspects such as (i) the correlations among these risks, (ii) their relative importance to the farm (e.g. the frequency and scale of risks may change as a consequence of long run changes in the farming environment), and (iii) information about the distribution of risk (OECD 2009). In a recent publication, the Organisation of Economic Cooperation and Development (OECD) suggests that information about production risks may typically be easier available than information on market or price risks and farmers usually have good records about their past production. Still, long term changes, such as climate change, may decrease trust in historical records (OECD, 2009).

For instance, Regional Climate Models (RCMs) project a larger warming trend in summer than in winter and decreasing annual precipitation sums for Central and Eastern Europe (cp. Alcamo et al., 2007). Also, a decline in precipitation rates in summer and an increase in winter is often projected (cp. Thaler et al., 2010). Hence, not only potential long term changes in climate conditions will affect production risks but also climate variability (Trnka et al., 2011). An increase in climate variability is likely to include extreme weather events like droughts or heat waves with adverse effects on crop yields (Rowell and Jones, 2006). Even though there is uncertainty about their spatial and temporal distribution, climate change and variability are expected to impact the level and variability of crop yields, to pose economic risks and affect the economic viability of e.g. rain-fed agricultural systems (cp. Kandulu et al., 2012). Even though farmers are used to adapt to changing environmental conditions, finding ways to deal with climate-induced variability of agricultural production remains important (OECD, 2009).

The aim of our analysis is twofold: Firstly, we assess the impacts of regional climate change scenarios on the level and variability of crop yields, profitability, and environmental outcomes at 1km² pixel resolution in Austria Climate change in agriculture and forestry: an integrated assessment of mitigation and adaptation measures in Austria. Secondly, we calculate several measures of risk to quantify and decompose crop production risks with respect to site characteristics and alternative crop management measures. We further assess the cost-effectiveness of alternative crop management measures to reduce climate-induced risks by accounting for site conditions and opportunity costs.

MODEL FRAMEWORK

The bio-physical process model EPIC (Williams, 1995) is applied to simulate annual dry matter crop yields and environmental outcomes such as soil organic carbon, nitrogen emission, and soil erosion for alternative crop management measures. These management measures include alternative crop rotations (consisting of 22 typical crops), tillage options (conventional, reduced, winter cover cropping), fertilization rates (high, moderate, low), and optional irrigation. The simulations are performed for three climate change scenarios generated by the statistical climate change model for Austria (ACLiReM, Austrian Climate Change Model using Linear Regression) for the period 2010-2040 (Strauss et al., 2013). The climate change scenarios consist of a rising trend in temperature (~0.05 °C per year), and alternative assumptions on precipitation patterns and distributions. For instance, scenario sc01 as-

[1] All from the Institute for Sustainable Economic Development, University of Natural Resources and Life Sciences, Vienna, Austria (hermine.mitter@boku.ac.at).

sumes unchanged annual precipitation sums compared to the period 1975-2005, scenario sc09 assumes a decrease in daily precipitation by 20% compared to sc01, and scenario sc13 assumes a shift in the seasonal precipitation distribution from the summer to the winter. The analysis is spatially explicit and performed for the Austrian cropland on a 1km² raster resolution. Each 1km² raster shares similar characteristics such as soil type, slope, and elevation and allow accounting for the natural heterogeneity in production and emission.

We calculate profits for each crop management alternative by using simulated crop yields and statistical commodity prices as well as computations of fixed and variable production costs. We then calculate the extent of climate-induced risks for both crop yields and profits. We employ five risk measures: mean, standard deviation (sd), coefficient of variation (cv), Value at Risk (VaR) and Conditional Value at Risk (CVaR). VaR and CVaR stem from finance theory and allow assessing the trade-off between expected returns and variability in returns. VaR allows the estimation of the maximum possible loss in a specific period at some confidence level. CVaR quantifies losses beyond the VaR concept and calculates the expected loss strictly exceeding VaR. For instance, CVaR allows calculating the average expected returns of the lowest 5% of possible outcomes (Rockafellar and Uryasev, 2002).

Results

Table 1 provides selected model results for winter wheat yield in Austria and alternative crop management measures. The results show that a decrease in annual precipitation sums (sc09) may lead to lower average winter wheat yield and higher yield variability – indicated by a higher coefficient of variation – on national average. For instance, irrigation can serve as cost-effective management option in order to reduce yield variability and increase yield level, particularly in the semi-arid Marchfeld region.

Table 1. Mean, standard deviation (stdev) and coefficient of variation (cv) for simulated winter wheat dry matter yields in tonnes per hectare and climate change scenarios sc01 and sc09.

scenarios		sc01			sc09		
mana		mean	stdev	cv	mean	stdev	cv
conventional	irrig	6.58	0.438	0.067	6.63	0.452	0.068
	high	5.53	0.554	0.100	4.59	0.767	0.167
	mod	5.13	0.533	0.104	4.33	0.722	0.167
	low	3.59	0.607	0.169	3.20	0.644	0.201
reduced	irrig	6.58	0.452	0.069	6.64	0.463	0.070
	high	5.52	0.559	0.101	4.59	0.770	0.168
	mod	5.12	0.535	0.104	4.33	0.723	0.167
	low	3.61	0.578	0.160	3.22	0.631	0.196
cover crops	irrig	6.60	0.469	0.071	6.63	0.476	0.072
	high	5.51	0.569	0.103	4.57	0.774	0.169
	mod	5.13	0.541	0.105	4.33	0.727	0.168
	low	3.60	0.557	0.155	3.20	0.618	0.193

Note: management measures (mana): tillage (conventional, reduced, cover crops), irrigation (irrig), and fertilization management (high, moderate (mod), low).

Discussion and Outlook

Climate change and climate variability may increase production risks for farmers in Austria. Our analysis reveals vulnerabilities in Austrian crop production as well as crop management measures that are cost-effective to reduce crop production risks. Alternative risk measures have been applied to quantify and decompose the risks in crop production with respect to site conditions and crop management measures.

Next, a spatially explicit portfolio optimization model will be developed to identify cost-effective crop management portfolios capturing the trade-offs between profit expectation and risk aversion as well as between profits and environmental impacts. The results shall inform the discussion on climate change adaptation requirements in Austrian agriculture.

Acknowledgement

This research has been supported by the research project Climate change in agriculture and forestry: an integrated assessment of mitigation and adaptation measures in Austria (CAFEE) funded by the Austrian Climate Research Programme as well as the Doctoral School of Sustainable Development.

References

Alcamo, J., Moreno, J.M., Nováky, B. et al. (2007). Europe. Climate change 2007: impacts, adaptation and vulnerability. In: Parry, M.L., Canziani, O.F. et al. (eds). *Contribution of working group II to the fourth assessment report of the IPCC,* pp. 541-580. Cambridge: Cambridge University Press.

Kandulu, J.M., Bryan, B.A., King, D., Connor, J.D. (2012). Mitigating economic risk from climate variability in rain-fed agriculture through enterprise mix diversification. *Ecological Economics* 79:105-112.

Musser, W.N. and Patrick, G.F. (2001). How much does risk really matter to farmers? In: Just, R.E., Pope, R.D. (eds). *A comprehensive assessment of the role of risk in US Agriculture*, Kluwer Academic Publisher.

OECD (2009). *Managing Risk in Agriculture. A Holistic Approach,* OECD Publishing.

Rockafellar, R.T., Uryasev, S. (2002). Conditional value-at-risk for general loss distributions. *Journal of Banking & Finance* 26:1443–1471.

Rowell, D.P., Jones, R.G. (2006). Causes and uncertainty of future summer drying over Europe. *Climate Dynamics* 27:281-299.

Thaler, S., Eitzinger, J., Rischbeck, P. et al. (2010). Vulnerability of crops to climate change in North-eastern Austria. *Bulgarian Journal of Meteorology and Hydrology*, 15(1):50-61.

Trnka, M., Olesen, J., Kersebaum, K. et al. (2011). Agroclimatic conditions in Europe under climate change. *Global Change Biology* 17:2298-2318.

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. *International Journal of Climatology* 33(2):430–443.

Williams, J.R. (1995). The EPIC Model. In: Singh, V.P. (ed) *Computer Models for Watershed Hydrology, Water Resources Publications.* Highlands Ranch, Colorado, pp. 909-1000.