Integrative assessment of crop management portfolios in adapting to climate change in the Marchfeld region

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***Abstract* – In this study we develop climate change scenarios for the period 2008-2040 in Austria based on weather observations from 1975-2007. The scenarios are used in the biophysical process model EPIC (Environmental Policy Integrated Climate) together with other site specific data from the Marchfeld region to simulate among others crop yields, topsoil organic carbon contents and nitrate leaching. The aim is to define portfolios by investigating profit distributions of crop management options under climate change in the Marchfeld region.**

We estimate an average temperature increase of 1.5 °C in the next 30 years. Major results of the portfolio optimization show that minimum tillage is always the optimal option (with respect to risk aversion parameters) for all crops considered, while different management alternatives concerning irrigation, straw management and fertilizer application rates are crop specific.

Introduction

Climate change has major biophysical and economic impacts on agricultural production. Assessing optimal portfolios of crop management options is one instrument to develop adaptation strategies in agricultural production to climate change. We introduce a dataset of climate change scenarios for 2008 to 2040 in Austria based on linear regression models. Furthermore, we present a case study analysis of optimal crop management portfolios in the Marchfeld region under climate change and different levels of risk aversion. Havlik et al. (2008) investigated agricultural portfolios under *price uncertainty* and different levels of risk aversion. In our analysis, *uncertainties in future climate scenarios* are considered as the main risk for the farmer.

The data used in this study are weather observations from 1975 to 2006 from a representative weather station in the region. These data are used in linear regression models to estimate climate scenarios for the period 2008-2040 which are then integrated in the biophysical process model EPIC (Environmental Policy Integrated Climate, see Williams, 1995). We use simulated crop yields together with data on variable costs (BMLFUW, 2008) and commodity price distributions (gained by bootstrapping of annual prices from 1995-2008) to calculate profit distributions. The profit distributions are input for the portfolio model (Fuss et al., 2008), which maximizes profits subject to risk aversion constraints. Changes in topsoil organic carbon contents and nitrate leaching are investigated as consequences and are not yet part of our portfolio optimization.

Data and Method

The Marchfeld region corresponds to one of the 60 climate clusters in Austria (Fig. 1) that are characterized by mean annual temperatures (T) and precipitation sums (P) from 1961-1990 (Auer, 2002). In a forthcoming analysis, all 60 climate clusters will be considered. Each cluster is associated with a weather station of which we have built time series of daily weather observations from 1975-2007. Based on the method of Strauss et al. (2009), we have developed stochastic climate scenarios for Austria and the period 2008-2040. We have identified one average temperature trend for all of Austria, which we have then applied to every cluster station. Residuals from maximum and minimum temperature have been reallocated randomly together with the observed values of the other weather parameters. The reallocations have been repeated 30 times to produce stochastic climate change scenarios.

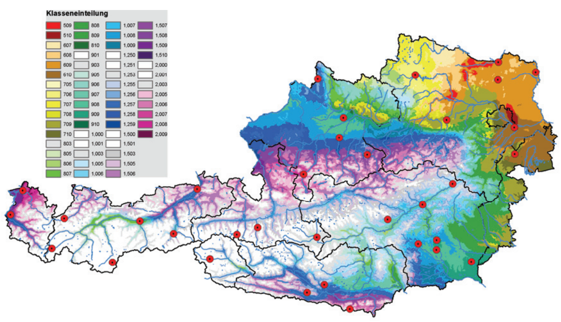

Figure 1. Climate clusters in Austria and representative weather stations.
Note: The cluster number for Marchfeld is 509 (P between 400 and 500 mm; T between 8.5 and 9.5°C).

Our results on residuals, which do not change significantly with time, are in contradiction with results from IPCC (2007), which claims that residuals of precipitation are generally increasing. Furthermore, IPCC (2007) finds that interannual temperature variability is likely to increase in summer periods in

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most areas, however, with the magnitude of change being uncertain.

Our climate change scenarios have been integrated into the EPIC model together with other site specific data to assess biophysical impacts of crop management options in the Marchfeld region. The simulated crop yields are used to calculate profit distributions for alternative production systems (BMLFUW, 2008) including conventional, reduced and minimum tillage with/without irrigation, with/without straw removal, and with different fertilizer application rates.

We maximize profits of crop management options and analyse how crop management portfolios for corn, winter wheat (wwht), sunflower (sunf) and spring barley (sbar) change under alternative levels of risk aversion described by the standard deviation of the portfolio.

RESULTS AND DISCUSSION

Climate change is characterized by an increase of mean temperatures of about 1.5 °C in Austria in the next 30 years. We simulate an average decrease in dry matter crop yields for corn and spring barley by 0.5 t/ha, for winter wheat by 0.25 t/ha, and for sunflower by 0.18 t/ha in the next 30 years and under conventional tillage. On average, crop yield variabilities measured in standard deviations are decreasing for winter wheat by 0.1 t/ha, increasing for corn by 0.12 t/ha, and remaining unchanged for sunflower and spring barley. Both topsoil organic carbon contents (SOC) and nitrate leaching (NL) are decreasing over time (SOC from 59 t/ha to 55 t/ha and NL from 11 kg/ha to 7.5 kg/ha). The highest profit standard deviations (Table 1) are calculated for managements with corn followed by sunf, wwht, and sbar.

Table 1. Crop management portfolios described by standard deviation (SD in €/ha), management option with portfolio composition (in %), and expected profit (EP in €/ha).

	SD in €/ha	management option	EP in €/ha
corn	375	MIN3 100%	195
	355	MIN3 13.6% and MNS3 86.4%	155
wwht	207	MNS1 100%	317
	178	MIS3 86.4% and MNS3 13.6%,	146
sunf	215	MNN1 100%	93
	179	MIS3 84.0% and MNS3 26%	-98
sbar	129	MNS3 100%	171
	114	MIN3 89.5% and MNN3 10.5%	-44

The four-digit coding of management options in table 1 is: 'M' for minimum tillage, 'N/I' for no irrigation/irrigation, 'N/S' for without straw removal or with straw removal, and '1/2/3' for fertilizer application rates of 100/120/80%.

Model results show that minimum tillage is most profitable for all crops, while crop management alternatives such as irrigation, straw management and fertilizer application rates change with different levels of risk aversion (Table 1). A higher constraint on standard deviation (higher risk accepted by the farmer) leads to lower diversification of crop managements, but higher expected profits.

However, most of the profit distributions are skewed to the left. Our current research therefore focuses on the adoption of other risk measures like the (Conditional) Value at Risk (C)VaR, which takes also the tails of a distribution into account, while standard deviations consider only the spread. VaR is the β^{th} percentile of the distribution, CVaR the expected value of random values exceeding that threshold (Rockafellar and Uryasev, 2000).

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