# Integrative model analysis of adaptation measures in the Marchfeld region

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***Abstract* - We assess the environmental and economic consequences of adaptation measures to drier climatic conditions in the Marchfeld region. Climate change scenarios have been developed to analyse the impacts of drier conditions on crop production as well as adaptation measures, for example irrigation, to mitigate possible negative effects of climate change.**
**We have developed a regional linear land use optimization model using bio-physical simulation data from the EPIC (Environmental Policy Integrated Climate) model. Results indicate that only sprinkler irrigation and standard fertilization appear in the optimal solutions. Both nitrogen loads and percolation water decrease slightly. Although drip irrigation would be a more efficient irrigation system it seems to be too costly.**

## INTRODUCTION

The agriculturally important region Marchfeld is part of the Vienna Basin located in the North-Eastern part of Austria. The approximately 1900 Marchfeld farmers produce mainly cereals and vegetables. The current regional climate is characterized as semi-arid (Thaler et al., 2008). Winters are relatively cold but with little snow cover. Summers can be hot and occasionally dry with annual precipitation sums of around 500 mm.

Climate change will affect agriculture in numerous ways (e.g. longer growing seasons, more $CO_2$ uptake by plants). Future climate scenarios show an increase in average annual temperatures for Austria. A statistical climate model developed by Strauss et al. (2010) predicts that average annual temperatures in Austria will increase by approximately 1.6 C° between 2008 and 2040. Similar results are also derived by a Regional Climate Model for Central Europe (Jacob et al., 2008).

It is generally assumed that annual precipitation rates will decrease in the Southern Europe but increase in Northern Europe. For Central Europe, it is often predicted that precipitation rates may decline in summer but increase in winter (Thaler et al., 2008; Jacob et al., 2008; Eitzinger et al., 2009). These predictions are much more uncertain than those for temperatures and will vary across regions (Eitzinger et al., 2009). Nevertheless, Thaler et al. (2008) predict that precipitation rates in Marchfeld will decrease in summer and increase in winter.

An increase in temperatures (which induces higher evaporation rates) together with a likely decline of rainfall in summer will likely produce more water stress in crop growth. For example, Strauss et al. (2011) find that higher average temperatures will decrease crop yields and thus profits in Marchfeld.

Therefore, it seems necessary to identify cost-efficient and environmentally sound adaptation measures, which could mitigate possible negative effects of climate change. A comprehensive list of adaptation measures can be found in the recently released first draft of the Austrian 'National Adaptation Strategy' (BMLFUW, 2010). We aim to contribute to this strategy by analysing the economic and environmental effects of adaptation measures in the Marchfeld region, particularly irrigation measures. Therefore, we investigate how the choice of management measures would change under drier climatic conditions (such as drought) and what consequences these changes could have on the environment and regional producer surplus.

## DATA AND METHOD

We conduct an integrative model analysis of adaptation measures in the Marchfeld region. Bio-physical simulation data from the EPIC (Environmental Policy Integrated Climate) model are integrated into a regional land use optimization model.

EPIC is a field-scale model and simulates major natural processes such as evapotranspiration, nitrification, mineralisation, erosion, etc. and provides outcomes on crop yields, percolation water, nitrogen leaching, top-soil organic carbon changes, etc. It operates on a daily time step and simulation outputs relate to edge of field. Climate data were taken from Strauss et al. (2010). It is assumed that precipitation rates will decrease by 20% in summer for the period 2031-2039. These climate data together with soil, topographical and crop management data are used in EPIC to simulate the bio-physical outcomes. The effect of increased $CO_2$ levels on plant growth is also considered. The period 1996-2005 serves as reference period. Crop budgets are calculated based on the standard gross margin catalogue (BMLFUW, 2008) as well as on variable costs of irrigation. Average crop prices for the years 2007-2010 have taken from Statistics Austria (2011).

In the linear regional land use optimization model, regional producer surplus (RPS) is maximized over all municipalities (r), homogeneous response units (h), which represent elevation, slope and soil classes, crop rotation systems (c) and management

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measures (m). RPS is the sum of the product of production choices (ProdChoice) and annual average gross margins (GrossMargin).

$$\max RPS = \sum_{r,h,c,m} \{ProdChoice_{r,h,c,m} * Gross\ Margin_{r,h,c,m}\}$$

The optimization problem is constrained to land endowments by municipality and homogeneous response units.

$$\sum_{c,m} \{ProdChoice_{r,h,c,m} * Land_{r,h,c,m}\} \leq Totalland_{r,h} \ \ \forall\, r,h$$

The linear optimization model has been solved by using the software package GAMS (General Algebraic Modelling System; www.gams.com).

The model allows choices among 19 different crop rotation systems and the following set of mutually exclusive management measures: (1) standard fertilization; (2) low fertilization (no commercial fertilizer); (3) reduced fertilization; (4) drip irrigation, and (5) sprinkler irrigation.

## Results

Table 1 shows that, with less water available for plants in a drier climate, farmers choose to use more irrigation measures. Only sprinkler irrigation and standard fertilization system appear in the optimal solutions.

**Table 1.** Changes in management measures.

| Management measures | 1996-2005 | 2031-2040 |
|---|---|---|
| Standard fertilization | 43.27% | 3.00% |
| Sprinkler irrigation | 56.73% | 97.14% |

The economic and environmental results for our model can be depicted in Table 2. Average crop yields increase by almost 10% while regional producer surplus decreases by 8%. Hence, the cost of irrigation is higher than the increase in revenue due to higher crop yields. Nevertheless, sprinkle irrigation still seems to be a cost-efficient measure to adapt to a drier climate.

Both nitrogen loads and percolation water decrease slightly. The decrease in percolation water outweighs nitrogen loads, which causes nitrogen concentration levels to increase in ground waters. However, these changes are only marginal and concentration levels are below the legal threshold level of 50mg/l.

**Table 2.** Economic and environmental effects.

| | 1996-2005 | 2031-2040 |
|---|---|---|
| RPS (€/ha) | 781.64 (342.30)[a] | 717.09 (303.44) |
| Average Crop Yield (t/ha) | 8.72 (1.66) | 9.58 (1.82) |
| PRKN (kg/ha) | 0.70 (0.66) | 0.58 (0.65) |
| PRK (mm) | 15.83 (7.67) | 15.40 (10.73) |
| NO3 (mg/l) | 19.60 (15.76) | 20.63 (15.19) |

[a]Standard deviations are given in parentheses.

## Discussion

Our first model results indicate that sprinkler irrigation measures could be a cost-efficient adaptation measure. More sprinkle irrigation also seems to have no significant effects on nitrogen concentration levels. Although drip irrigation would be a more efficient irrigation system it seems to be too costly.

We will extend our investigation to the effects of increased irrigation on percolation and groundwater levels. A decrease in groundwater levels could negatively affect the costs of extracting irrigation and drinking water in the Marchfeld region. Additionally, we will further improve the model by, for example, taking into account risk-averse behaviour of farmers and by calibrating the model to observed crop rotation system shares.

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