Comparison of lysimeter measurements and simulated nitrogen percolation from different vegetable management practices in Upper Austria

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Abstract

Computer models are increasingly used to predict environmental impacts of alternative agricultural systems on soil and water resources. In this study, monthly data from lysimeter measurements over four years are used to statistically test the performance of the bio-physical process model EPIC (Environmental Policy Integrated Climate). Field experiments were carried out in the Eferdinger Becken (Upper Austria). Nitrogen concentrations in seepage water from seven field lysimeters at two representative farms in Seebach and Wörth were analysed to evaluate different management practices. EPIC is calibrated to base-run data from Wörth and then the calibrated model is applied to data from different management alternatives, and to the site in Seebach. Simulations over 50 years are used to predict long-term effects of management measures. The performance testing indicates that EPIC can be used to analyse short and long-run environmental impacts of management measures in agricultural land uses.

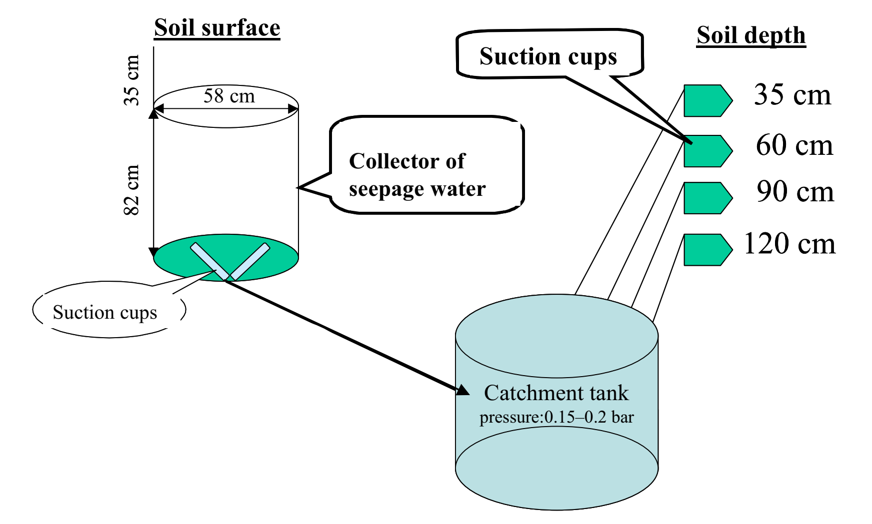

Figure 1: **System of the suction cups and collectors of seepage water (with changes from LIEBHARD et al., 2003)**

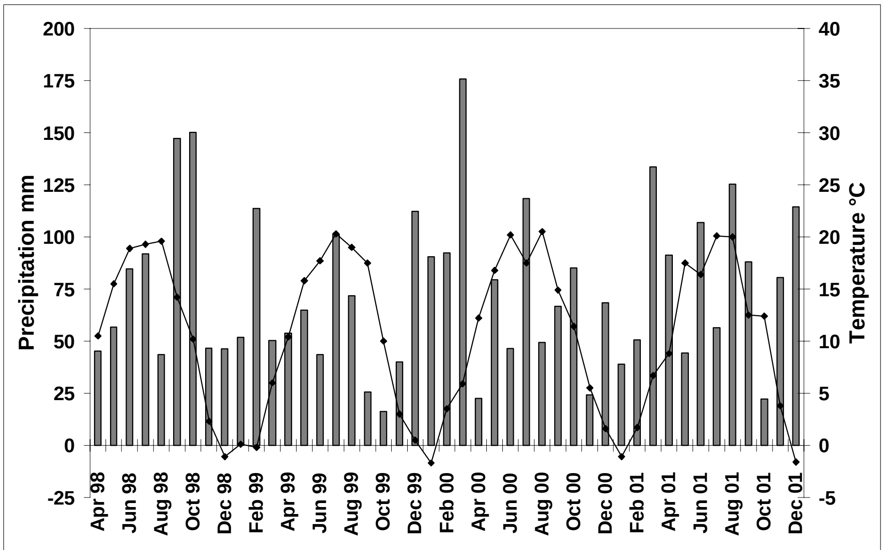

Figure 2: **Precipitation (bars) and temperature (line) over the period of measurements**

Introduction

Intensive production systems with major shares of vegetables in the crop rotations often lead to high nitrate emissions. In the Southern Eferdinger basin the vegetable sector is of economic importance and produces a variety of field vegetables for the fresh market as well as for the processing industry. Because nitrate concentrations in the groundwater are exceeding the threshold of 45 mg NO_3 per litre at different monitoring sites, management measures to reduce nitrate leaching need to be implemented (LIEBHARD et al., 2003). A sanitation program with environmentally friendly management measures has been implemented to mitigate nitrate emissions in ground water. Field experiments were carried out on two farms to evaluate alternative management measures. Hence, seepage water was collected in field lysimeters to analyse nitrate concentrations. Computer models are increasingly used to evaluate long-term effects of alternative management measures. Model calibration to specific sites is necessary to test its performance and reliability of predictions. Consequently, lysimeter

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Table 1. **Crop rotations and nitrogen fertilization rates (N in kg ha^{-1} in brackets) for the four alternatives at the site in Wörth (with changes from LIEBHARD et al., 2003)**

Year	Crop order	Variation 1	Variation 2	Variation 3	Variation 4
1998	1st crop 2nd crop Cover crop	Potatoes (140) Chinese cabbage (91) -	Potatoes (100) Chinese cabbage (82) -	Potatoes (100) Chinese cabbage (82) Green rye / Winter vetch	Potatoes (140) Chinese cabbage (91) Green rye / Winter vetch
1999	1st crop Cover crop	Celery (154) -	Celery (38) -	Celery (57) Green rye	Celery (112) Green rye
2000	1st crop Cover crop	Cauliflower (255) Phacelia	Cauliflower (148) Phacelia	Cauliflower (194) Green rye / Phacelia	Cauliflower (241) Green rye / Phacelia
2001	1st crop 2nd crop 3rd crop Cover crop	Green salad (91) Green salad (97) Green salad (98) Winter wheat	Green salad (84) Green salad (60) Green salad (51) Winter wheat	Green salad (90) Green salad (49) Green salad (49) Winter wheat	Green salad (96) Green salad (98) Green salad (87) Winter wheat

measurements are compared with simulation results from the bio-physical process model EPIC (Environmental Policy Integrated Climate).

The article is structured such that field sites, experiment design, measurement methods, and the bio-physical process model EPIC are described next. Measurements on nitrate leaching and model predictions are presented and discussed in the last section of this article.

Material and methods

Sampling Sites

Two representative farms in Seebach and Wörth were chosen for the installation of seven field lysimeters (three in Seebach and four in Wörth). Lysimeters had a diameter of 58 cm and height of 82 cm. Collection of seepage water took place at a depth of 117 cm as shown in *figure 1*. Additionally, suction cups were installed in different soil depths. The fields in Seebach had a size of 13 m x 50 m, the four fields in Wörth 5.4 m x 145 m. Monthly data from April 1998 to December 2001 are used for calibrating EPIC and for testing its performance. The sites are characterised by average long-term annual precipitation of 795 mm, soil textures of loamy sand to sandy loam in Seebach and loamy sand in Wörth, and high soil water storage capacity. *Figure 2* shows precipitation and temperature from the observed time period. Data were obtained from the meteorological station in Aschach/D, which is close to the sampling sites. In Seebach, one field was cultivated with green salad (variation 1), whereas on two other fields crop rotations included green rye (variation 2) and phacelia mixed with high mallow (variation 3) as cover crops. Fertilization rates followed the N_{min} target values system (KNS). The nitrogen fertilization rates were reduced by 30% from the KNS-targets on two alternative fields (variation 2 and 4) in Wörth (LIEBHARD et al., 2003). Data on crop rotations and fertilization management for the sites in Wörth are summarized in *table 1*.

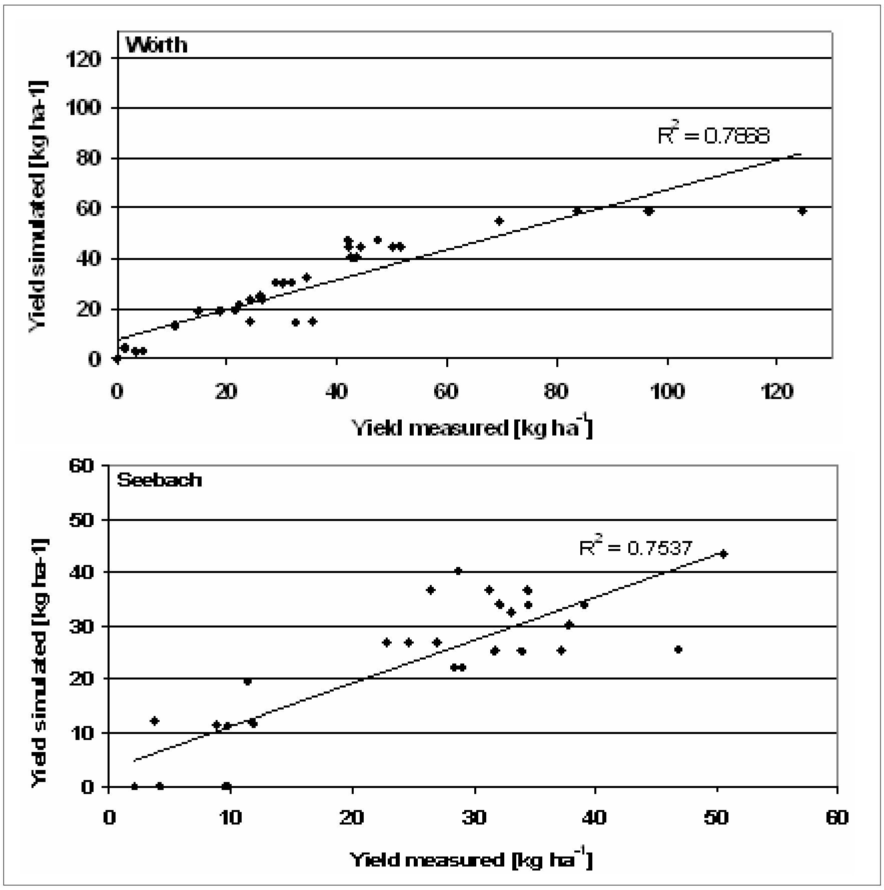

Figure 3. **Simulated and measured fresh weight crop yields for Wörth (top) and Seebach (down) in kg ha^{-1} y^{-1}**

The model

The bio-physical process model EPIC (Environmental Policy Integrated Climate) allows simulation of many processes important in agricultural land use management. It was developed by a

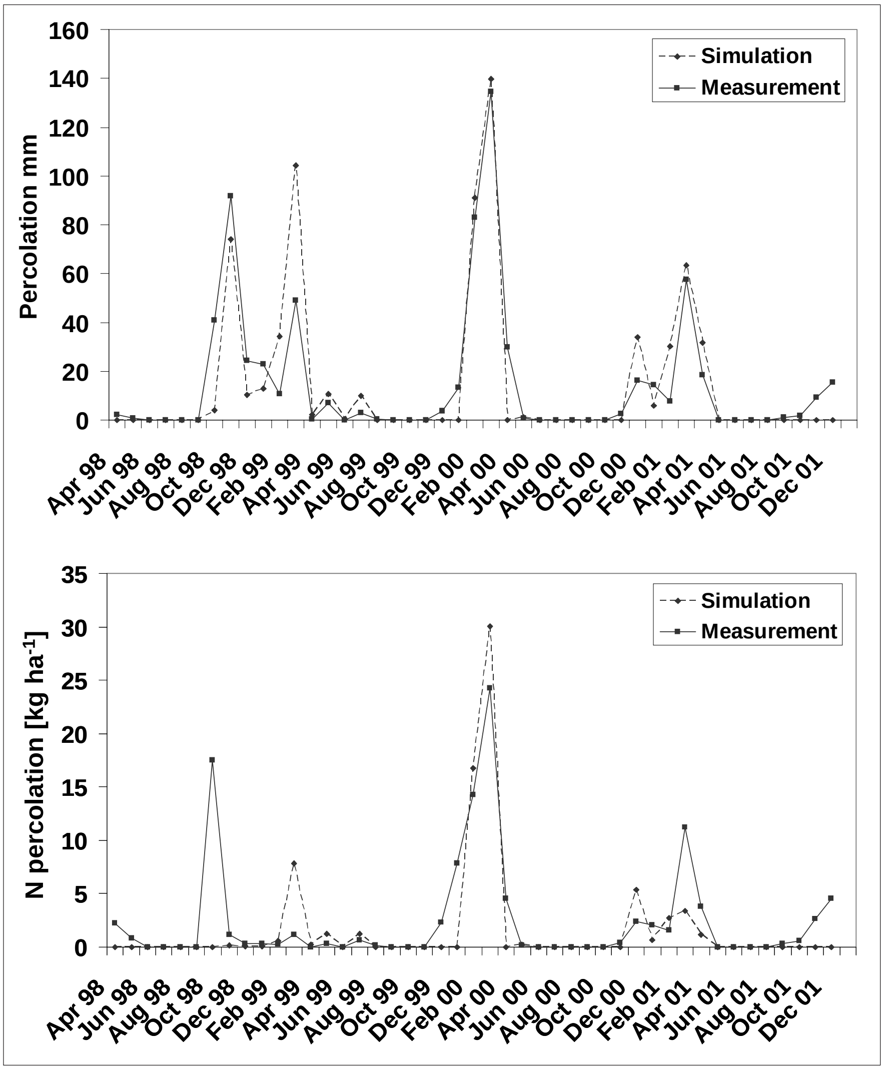

Figure 4. **Predictions and measurements of water percolation (in mm) and N leaching (in kg ha^{-1}) in Wörth (variation 1) at 1.2 m soil depth**

USDA modelling team in the early 80s to asses the status of U.S. soil and water resources (WILLIAMS et al., 1984). Since then it has been continuously expanded and refined (WILLIAMS 1995; IZAURRALDE et al., 2006). The major components in EPIC include weather simulation, hydrology, erosion-sedimentation, nutrient and carbon cycling, pesticide fate, plant growth and competition, soil temperature and moisture, tillage and plant environment control. EPIC operates on a daily time step and is capable of simulating hundreds of years if necessary. The model offers options for simulating several processes with different algorithm - five potential evapotranspiration equations, six erosion/sediment yield equations, two peak runoff rate equations, etc., which allow reasonable model applications in very distinct natural areas. In this study, EPIC is calibrated to base-run data from variation 1 in Wörth and then the calibrated model is applied to the different management alternatives and to the sites in Seebach.

Results and discussion

The management measures, which aiming at reducing nitrate leaching into groundwater, could decrease nitrogen emissions between 10 kg ha^{-1} y^{-1} and 80 kg ha^{-1} y^{-1}. The fertilization rates based on the KNS-system did not significantly reduce quantity and quality of vegetables yields. However, the reduction in fertilization rates by 30 % (variation 2 and 4, Wörth) has resulted in yield losses for some vegetables. Intercropping shows positive effects on soil conditions (DIETRICH et al., 2002).

EPIC simulations and measurements of crop yields showed good agreement, where the coefficient of determination (R^2) are 0.79 in Wörth and 0.75 in Seebach (*Figure 3*).

The predictions demonstrate that mean values and variability of percolation water and nitrogen leaching can be reasonably reproduced by the model (*figure 4*). Peaks of nitrogen leaching in December 1998 could not be reproduced by the model, whereas higher values were obtained by the model in the following spring (peak in April 1999). In general, percolation water shows better correlation between simulated and measured values than nitrogen leaching, which is evident by the coefficient of determination (R^2) and index of agreement (d)[1] calculated following LIU et al. (2006) and presented in *Table 2*. The index of agreement ranges between 0 and 1, and a value of 1 implies perfect agreement. The best agreement shows variation 1 at the site in Wörth, which was used for model calibration. Model results from Wörth perform better agreements than results from Seebach. Especially

[1]
$$d = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}\left[\left|S_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right]^2}$$

where S are simulated values and O are observed values.

Table 2. **Coefficient of determination (R^2) and index of agreement (d) between predicted and measured percolation water and nitrogen leaching**

	Wörth								Seebach					
	Variation 1		Variation 2		Variation 3		Variation 4		Variation 1		Variation 2		Variation 3	
	R²	d	R²	d	R²	d	R²	d	R²	d	R²	d	R²	d
percolation	0.81	0.95	0.25	0.70	0.40	0.79	0.18	0.66	0.20	0.51	0.29	0.25	0.63	0.60
N leaching	0.57	0.86	0.05	0.49	0.05	0.48	0.05	0.45	0.24	0.50	0.03	0.33	0.47	0.72

nitrogen leaching from Seebach shows poor performance due to overestimation of the model (data not shown), which will be further investigated.

This study shows that EPIC can be used to analyse environmental impacts of management practices. Further analysis will focus on simulations to evaluate long-term effects of alternative crop management measures.

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