Managing Vulnerabilities to Soil Erosion under Climate Change in Austria

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Abstract - **We assess the vulnerabilities of arable farm land to soil erosion as well as the effectiveness of soil conservation measures in Austria. Potential soil sediment losses are simulated with the RUSLE (Revised Universal Soil Loss Equation) methodology for five precipitation scenarios using the bio-physical process model EPIC (Environmental Policy Integrated Climate). The arable farm land has been assigned to five hazard classes describing its vulnerability to potential soil water erosion. The model results indicate an increase in soil sediment losses with higher precipitation sums. Reduced tillage and the cultivation of cover crops have been identified as effective soil conservation measures; however, the effectiveness varies spatially due to physical, agronomic and economic heterogeneities in crop production.**

INTRODUCTION

Soil erosion is a natural landscape-shaping process which can be accelerated by human activities. Besides adverse off-site effects, (e.g. import of suspended load into watercourses), erosion may cause harmful on-site damage to agricultural land and hence may impact the provision of a range of ecosystem services (Julien, 2010). Degradative processes like soil erosion impair agronomic productivity and environmental quality through their impact on soil quality, potential productivity and utility (Lal, 1999).

In Austria, approximately 25% of the total agricultural areas are regarded as vulnerable to soil water erosion (Strauss, 2006). Particularly the productive areas of the southeast and northeast plains and hills, the Alpine foreland as well as the Carinthian basin are considered to be most severely affected (Strauss and Klaghofer, 2006).

Driving factors for soil sediment losses are rainfall amount and intensity, soil characteristics, slope length and steepness, soil cover and management as well as implemented erosion control measures (Schwertmann et al., 1987). While soil and slope characteristics tend to be stable parameters and future precipitation patterns are uncertain, soil cover and crop management practices can be influenced by agricultural land users. They are frequently part of integrated assessments on climate change adaptation in agriculture. Therefore, we assess the impacts of different precipitation scenarios on potential soil sediment losses to depict the vulnerability of arable land to soil erosion in Austria. Furthermore, we assess the effectiveness of soil conservation measures under climate change. The analysis should help to developing robust soil conservation strategies spatially explicit for Austrian farmers.

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DATA AND METHOD

The bio-physical process model EPIC (Environmental Policy Integrated Climate) has been used to simulate potentials for soil sediment losses on arable farm land in Austria. In particular, we use the widely accepted RUSLE (Revised Universal Soil Loss Equation) methodology (Renard et al., 1997) in EPIC. We apply EPIC on 1 km² raster resolution interlinking information on weather, soil and topography as well as crop management to simulate – inter alia – important processes such as evapotranspiration, runoff, erosion, mineralization, nitrification, and respiration (Williams, 1995). The grid information contains data from the digital soil map of Austria (BFW), the digital elevation map (BEV), climate change data from a statistical climate change model (Strauss et al., 2012), and crop management data from the IACS data base as well as from expert knowledge.

Simulation analyses with conventional tillage and two soil conservation measures have been performed for the period 2010 to 2040 with five precipitation scenarios. The two soil conservation measures comprise reduced tillage and the cultivation of winter cover crops in distinct crop rotation systems.

- "conventional tillage": i.e. mouldboard plough, <15% crop residue on soil surface before planting.
- "reduced tillage": i.e. light disk or chisel plough, >15% crop residue on soil surface before planting.
- "winter cover crops": winter cover crops have been planted, if applicable in the crop rotations systems.

The climate change scenarios (sc) selected for the analysis show a rising trend in temperature and assume different precipitation sums:

- sc01: unchanged precipitation, compared to the reference period (1975 to 2005),
- sc05: daily precipitation increased by 20%,
- sc09: daily precipitation decreased by 20%,
- sc13: daily precipitation in the winter season (September to February) increased by 20%,
- sc17: daily precipitation in the summer season (March to August) increased by 20%.

For all simulation results, soil erosion vulnerability maps have been created with five vulnerability classes: (1) tolerable, (2) low, (3) moderate, (4) high, and (5) severe soil water erosion according to OECD (2001). Based on these maps, changes in extent of the defined vulnerability classes have been computed comparing the precipitation scenarios sc05, sc09, sc13 and sc17 with the reference scenario sc01.

The effectiveness of soil conservation measures for all five precipitation scenarios are assessed by a comparison to conventional tillage for each hazard class, separately.

RESULTS

The impact of different precipitation scenarios on the variation in areas vulnerable to soil erosion ("climate effect") is presented in Table 1. In general, decreasing precipitation sums (sc09) increase areas with tolerable and decrease areas with low, moderate, high and severe soil erosion potentials. In contrast, increasing precipitation sums (sc05) decrease areas with tolerable and increase areas with low, moderate, high and severe soil erosion potentials. Furthermore, higher precipitation sums during the summer season (sc17) have a more adverse effect on soil sediment losses than higher precipitation sums in the winter season (sc13). Results presented in Table 1 are relative values based on a comparison with sc01 of the respective tillage system. Hence, the data is only comparable within one tillage system.

Table 1. Changes in the extent of vulnerability to soil erosion by precipitation scenarios (sc) and five hazard classes in %; (Changes are relative with respect to sc01).

		soil erosion vulnerability classes				
tillage system	sc	1	2	3	4	5
conventional tillage	sc05	-24.5	8.8	20.6	9.1	96.2
	sc09	28.4	-27.7	-8.2	-43.0	-75.2
	sc13	-0.5	0.5	-4.5	-0.2	9.4
	sc17	-11.3	13.6	10.8	6.8	21.2
reduced tillage	sc05	-24.5	25.0	12.1	12.8	111.3
	sc09	24.9	-22.2	-14.0	-51.5	-77.0
	sc13	0.9	-1.0	-3.6	-0.1	1.9
	sc17	-12.0	17.0	9.4	11.0	32.5
winter cover crops	sc05	-20.5	29.5	9.8	30.7	152.6
	sc09	18.9	-11.5	-27.3	-66.0	-83.0
	sc13	0.8	0.0	-3.3	-1.0	-1.3
	sc17	-8.2	11.2	7.3	18.1	45.0

Table 2. Effectiveness of soil conservation measures by precipitation scenarios (sc) and five hazard classes in %; (Changes are relative to conventional tillage).

		soil erosion vulnerability classes				
measure	sc	1	2	3	4	5
reduced tillage	sc01	6.5	-7.3	-1.9	-5.7	-18.8
	sc05	6.5	6.6	-8.9	-2.5	-12.6
	sc09	3.6	-0.3	-8.2	-19.9	-24.8
	sc13	8.0	-8.7	-1.1	-5.7	-24.5
	sc17	5.6	-4.5	-3.2	-2.0	-11.3
winter cover crops	sc01	20.6	-23.0	-8.9	-25.1	-49.2
	sc05	27.0	-8.2	-17.0	-10.3	-34.6
	sc09	11.6	-5.8	-27.9	-55.4	-65.1
	sc13	22.1	-23.4	-7.7	-25.7	-54.2
	sc17	24.8	-24.6	-11.8	-17.2	-39.2

Table 2 shows that reduced tillage and winter cover crops are effective measures for reducing areas vulnerable to soil erosion. Maintaining a complete soil cover during the winter season conserves soils even better.

DISCUSSION

Reduced tillage and cultivating winter cover crops are widely recognized as effective measures to control soil sediment losses. Our model results indicate that these practices are also effective under changing climatic conditions and precipitation patterns. In all precipitation scenarios, the areas vulnerable to moderate, high and severe soil erosion could be decreased when applying soil conservation measures. Therefore, it is important to encourage farmers to retain and/or implement such measures.

In a next step, integrated analyses should enable us to detect cost-effective climate change adaptation measures and their trade-offs to other agri-environmental policy objectives such as nitrate leaching. The results can contribute to the debate on designing cost-effective agri-environmental policies.

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