Agricultural Decision Support System for Soil and Water Conservation Measures

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Résumé

In this study a decisions support system (DSS) was developed to compare soil erosion control measures based on their monetary and ecological effects within a 126 ha large agricultural watershed in Lower Austria. The DSS consists of a soil erosion and a phosphorus transport model to cover the ecological effects, of an economical model for the monetary assessment, and of a value benefit analyses for evaluation and ranking of the compared scenarios.
The results showed that under the existing agricultural and economical framework in Austria conservation tillage systems and cover crops during the winter season are favourable soil protection systems. All other compared treatments did not fulfil the required economical and ecological targets. The developed DSS has a great potential to be used by public administration and policy for decision making in sustainable land use planning.

Introduction

Soil erosion and associated nutrient translocation cause damages on the field but also off-site. Erosion and deposition change the soil structure and soil's physical and chemical composition on the field and may lead to less favourable growing conditions for plants. Sedimentation outside the agricultural unit causes costs for dredging road ditches or flood detention basins for example. Furthermore nutrient inputs into surface water bodies affect their water quality and may lead to eutrophication.
Several simulation models are available to assess the amount of soil erosion and sediment yield in agricultural used areas. These models allow the calculation/evaluation of ecological and environmental impacts of erosion processes but are not able to cover also socio-economic and economic aspects. For comprehensive planning of sustainable land use of agricultural watersheds the consideration of ecological as well economical factors is imperative.
Objective of this study was to develop and apply a decision support system for sustainable agricultural land use planning with respect to following goals:
1) to conserve and improve soil quality, soil fertility and local water balance, 2) to minimize soil and nutrient translocation into surface water bodies and downstream fields, and 3) to optimize benefits for the farmers as well as for the society.

Material and Methods

The investigation area is a 126 ha large agricultural used watershed in the north-eastern part of Austria. Long-term average precipitation is 667 mm, average air temperature 9.8 °C. Soil texture ranges from silt loam to silty clay loam with slopes between 12-18%.
The fields of the watershed are managed by 33 farms. Main crops during the investigation period of 2000-2002 were small grains, corn, canola, sugar beets and sunflower.
The developed decision support system consists of three components (Fig.1): 1) a soil erosion and a phosphorus model cover the ecological effects, 2) an economical model is applied for

the monetary assessment, and 3) a value benefit analyses is used for the evaluation and ranking of the compared scenarios.

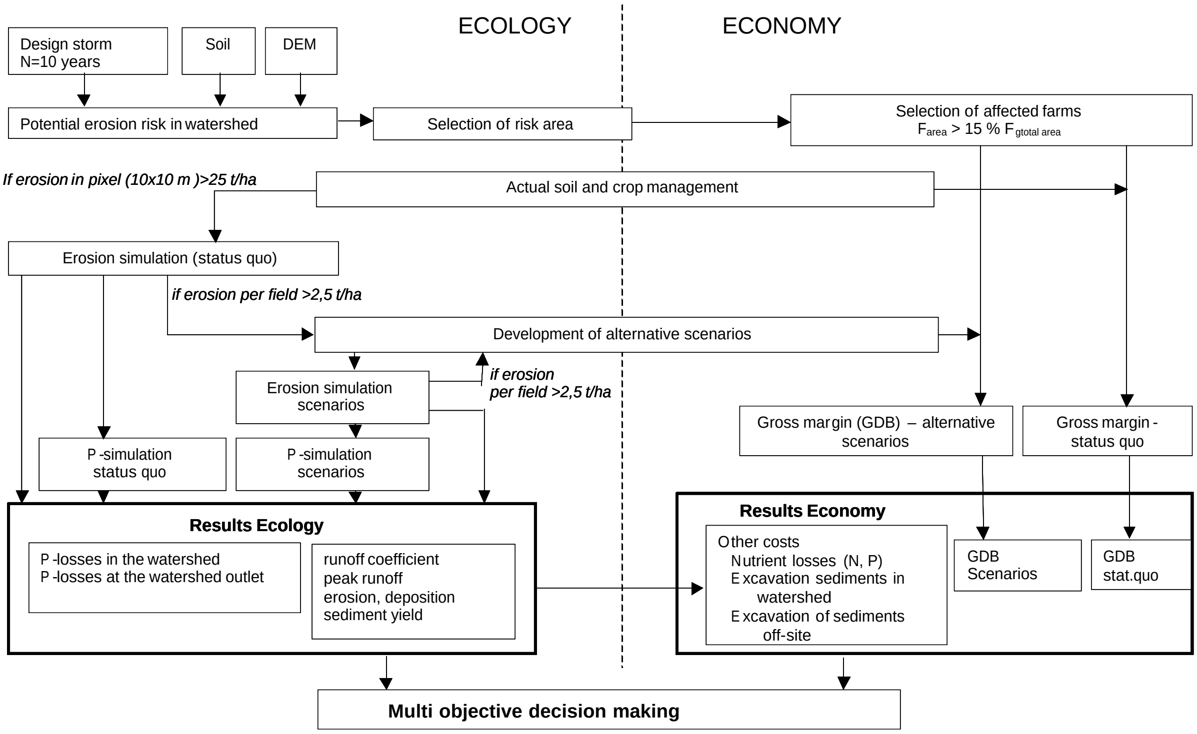


Fig.1 Scheme of the Decision Support System

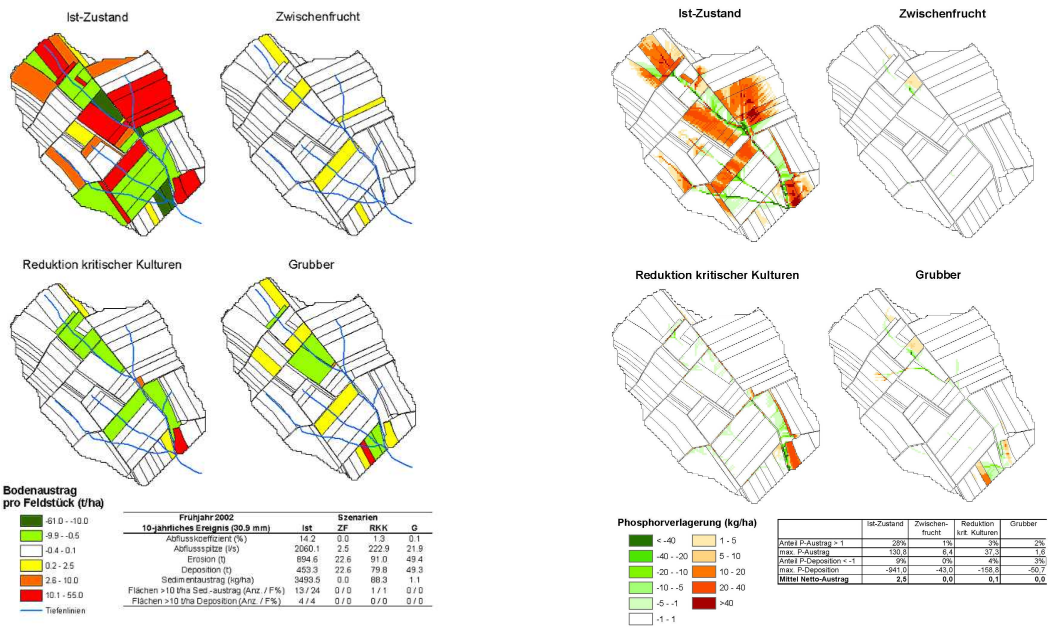
Soil erosion was assessed using the LISEM (Limburg Soil Erosion) model (de Roo et al., 1994). It is one of the first examples of a physically based model that is completely incorporated in a raster Geographical Information System. LISEM is a single event model which enables the assessment of environmental impacts of single erosive storm events. A typical rainstorm with a 10-years occurrence probability was simulated for three stages in the growing season (spring, summer, fall). For a period of 60 min such a design storm delivers 31 mm in this area. The different stages were chosen to represent different initial soil conditions (from bare soil to full soil cover).
Model calibration and validation were performed with measured data for a subwatershed of 18 ha. For the application in the 126 ha large watershed model input parameters were extrapolated using geostatistics and multiple regressions and/or taken from the literature.
The developed phosphorus model is based on an empirically derived P-enrichment factor which accounts for the soil phosphorus contents attached to different aggregate sizes, their susceptibility to erosion and on the spatial distributed net soil losses (Staudinger, 2005).
Based on a risk area assessment in the watershed, fields exceeding the threshold value were identified. The profit margins of the corresponding farms were calculated for the current cultivation (Ist-Zustand) and subsidy structure as well as for soil protection scenarios which were:

1) growing of cover crops during the winter season (ZF),
2) replacement of mouldboard ploughing by conservation tillage considering a yield reduction of 2% (G-2%)
3) replacement of mouldboard ploughing by conservation tillage considering a yield reduction of 5% (G-2%), and
4) replacement of erosion enhancing crops like maize with protective ones (RKK).

For decision making a value benefit analysis was developed. The three main goals listed above were divided into seven sub-goals (four ecological and three economical), each characterized by at least one indicator. These sub-goals included: reduction of average soil loss in the watershed, minimization of sediment yield at the watershed outlet, reduction of surface runoff and damping of surface hydrograph, reduction of nutrient losses (N and P), optimization of gross margin of farms, cost of nutrient losses and costs of excavation of deposited sediments. Ecological indicators were expressed in degrees of goal achievement (0-1) and economical indicators in monetary units. Corresponding objective functions were developed using threshold values found in literature, laws and directives, or at a relative scale with respect to the worst case scenario.
The results of the economical and ecological assessment were visualized in a diagram. A target area indicating minimum ecological and the economical requirements of the compared scenarios was defined. Investigated scenarios lying within the target area fulfilled the objectives and could then be ranked.

Results

For the period of 2000-2002 surface runoff, soil loss, deposition, sediment yield, phosphorus losses as well as gross margin of the farms were calculated. Soil erosion and phosphorus transport results are shown in Fig. 2.



Frühjahr 2002	Szenarien			
10-jährliches Ereignis (30.9 mm)	Ist	ZF	RKK	G
Abflusskoeffizient (%)	14.2	0.0	1.3	0.1
Abflussspitze (l/s)	2060.1	2.5	222.9	21.9
Erosion (t)	894.6	22.6	91.0	49.4
Deposition (t)	453.3	22.6	79.8	49.3
Sedimentaustrag (kg/ha)	3493.5	0.0	88.3	1.1
Flächen >10 t/ha Sed.-austrag (Anz. / F%)	13 / 24	0 / 0	1 / 1	0 / 0
Flächen >10 t/ha Deposition (Anz. / F%)	4 / 4	0 / 0	0 / 0	0 / 0

	Ist-Zustand	Zwischen-frucht	Reduktion krit. Kulturen	Grubber
Anteil P-Austrag > 1	28%	1%	3%	2%
max. P-Austrag	130,8	6,4	37,3	1,6
Anteil P-Deposition < -1	9%	0%	4%	3%
max. P-Deposition	-941,0	-43,0	-158,8	-50,7
Mittel Netto-Austrag	**2,5**	**0,0**	**0,1**	**0,0**

Fig.2 Sediment yield (in t ha^{-1}) for each field (left) and spatial distribution of phosphorus loss (in kg ha^{-1}, right) for investigated scenarios (Spring 2002)

It can be observed that soil conservation scenarios reduced soil loss from 895 tons under status quo (Ist-Zustand) to 91, 49 and 23 tons under RKK, G and ZF, respectively. Therefore, total sediment yield could be diminished from 3.49 t ha^{-1} (Ist-Zustand) to zero (ZF). Corresponding P-losses were 2.5 kg ha^{-1} under Ist-Zustand, whereas no phosphorus left the watershed under ZF and G. Based on these results criteria were defined and ecological indicators were calculated (Table 1). For economic evaluation gross margin difference (in €) for the whole watershed between status quo and investigated scenarios, costs of nutrient losses and excavation costs were used and summed up (Table 1). Fig.2 shows that only G-5%

and ZF are lying within the target area in the upper right zone which indicates that only these two scenarios fulfil the required ecological and economical targets.

Table 1 Compilation of ecological and economical decision support criteria

		Average erosion 2002				
Ecology		**Ist**	**RKK**	**ZF**	**G-5%**	**G-2%**
Indicators						
Average soil loss in watershed (t ha^{-1})		10,0	3,3	3,3	0,3	0,3
Areas with soil erosion > 10 t ha^{-1}		32,5	11,3	11,9	0,4	0,4
Deposition (in % of erosion)		46,4	76,4	86,4	99,9	99,9
Reduction of surface runoff (%)		4,7	62,4	71,0	99,7	99,7
Reduction of peak runoff rate (%)		4,8	61,7	71,2	99,5	99,5
P-concentration in runoff at watershed outlet (mg l^{-1})		1,3	0,7	0,3	0,0	0,0
criteria score	weight					
Average soil loss in watershed (t ha^{-1})	0,125	0,28	0,75	0,80	1,00	1,00
Areas with soil erosion > 10 t ha^{-1}	0,125	0,35	0,77	0,76	0,99	0,99
Deposition (in % of erosion)	0,25	0,46	0,76	0,86	1,00	1,00
Reduction of surface runoff (%)	0,125	0,05	0,62	0,71	1,00	1,00
Reduction of peak runoff rate (%)	0,125	0,05	0,62	0,71	0,99	0,99
P-concentration in runoff at watershed outlet (mg l^{-1})	0,25	0,40	0,72	0,89	1,00	1,00
weighted utility score	1,00	**0,31**	**0,72**	**0,81**	**1,00**	**1,00**
Economy		**Ist**	**RKK**	**ZF**	**G-5%**	**G-2%**
Difference gross margin (€)		0	-12746	-3347	-10451	-865
Diff. average P-losses (€) per year		0	40	40	58	58
Diff. average N-losses (€) per year		0	84	84	122	122
Difference excavation costs (€)		0	1207	1286	1550	1550
SALDO		**0**	**-11.415**	**-1.936**	**-8.720**	**865**

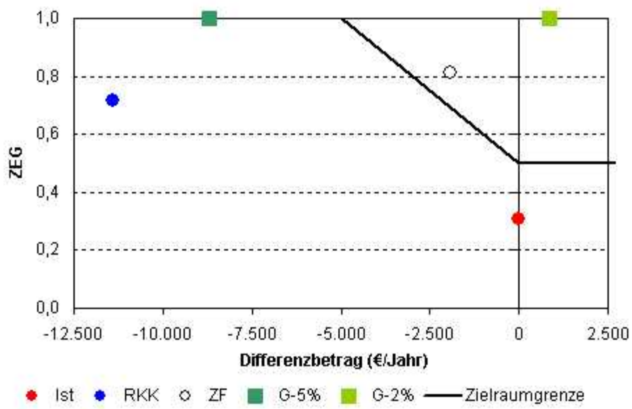


Fig.2 Evaluation diagram including difference gross margin (in € per year) and total criteria score (ZEG) of compared scenarios

Conclusions

The results showed that under the existing agricultural and economical framework in Austria conservation tillage systems and cover crops during the winter season are favourable soil protection systems. All other treatments did not fulfil the required economical or ecological targets. The developed decision support system has a great potential to be used by public administration and policy for decision making in sustainable land use planning.

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