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Flood prevention and nature conservation in the Weisseritz area (Eastern Erzgebirge, Saxony, Germany) Interdisciplinary evaluation of land use scenarios

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Abstract Within the framework of the project „Flood Prevention and Nature Conservation in the Weißeritz area" („HochNatur") measurements which integrate both flood prevention and nature conservation were designed for two sub-catchments selected in the Weißeritz catchment (Eastern Erzgebirge, Saxony, Germany) which was heavily affected by the floods in August 2002. Changes of land use such as extensification of grasslands, transformation of arable fields into grasslands, ecological transformation of forests, afforestation and establishment of small landscape structures like hedgerows were in the focus of the project.

For the sub-catchments a detailed survey of the present state with respect to landscape ecology and hydrology via systems analysis and modelling was performed. On this foundation different land use scenarios were developed and evaluated. Biotope types and landscape structure were analysed and evaluated using criteria from nature conservation on the one hand, and hydrology modelled by two tightly coupled models on the other hand. Results from this combined approach show that land use changes can substantially contribute both to flood prevention and nature conservation.

Key words: *landscape assessment, landscape metrics, hydrological modelling, runoff generation, mountainous catchment*

1 Introduction

Flood prevention and nature conservation are often considered not to be compatible. The Weißeritz catchment (Eastern Erzgebirge, Saxony, Germany) was heavily affected by floods in August 2002. In response to this event, the German Environmental Foundation (Deutsche Bundesstiftung Umwelt, DBU) funded the project "Flood Prevention and Nature Conservation in the Weißeritz area" ("HochNatur") which aimed to design measurements which integrate both flood prevention and nature conservation. Thus land use changes such as extensification of grasslands, transformation of arable fields into grasslands, ecological transformation of forests, afforestation and establishment of small landscape structures like hedgerows were in the focus of the project. In the following results on the evaluation of various land use scenarios considering both flood prevention and nature conservation will be presented, using two sub-catchments with contrasting land use and biotope patterns as an example.

2 Investigation area

The Weißeritz catchment in the Eastern Erzgebirge declines from about 800 m above sea level (m a.s.l.) in the mountain ranges down to 200 m a.s.l. in the northern foreland. The two subcatchments selected are the Weißbach (WB, 630 to 800 m a.s.l.) and Höckenbach (HB, 350 to 500 m a.s.l.). The Weißbach subcatchment is characterized, apart from forests (24% of the total area), by grassland (42% of the area), which is mainly extensively used (33% of the area). In contrast, the Höckenbach subcatchment is dominated by arable fields (69% of the area), whereas grasslands and forests occur on 6 and 13% only.

3 Methods

A detailed survey of the present state of the two subcatchment areas Höckenbach and Weißbach with respect to landscape ecology and hydrology via systems analysis and modelling was undertaken using a method transferable to other mountainous regions. On this foundation different land use scenarios were developed and evaluated both from the flood prevention and nature conservation perspective (Fig. 1). These scenarios considered land use changes such as extensification of grasslands, transformation of arable fields into grasslands, ecological transformation of forests, afforestation and conservation tillage, watercourse rehabilitation and the establishment of small landscape structures like hedgerows.

The main focus of the ecological analysis was high-resolution biotope mapping and the assessment of the present state and the developed scenarios. The assessment of the various biotope types was done with the help of three evaluation criteria, naturalness, substitutability and rareness and endangerment. However, the assessment of biotope types only does not yield any information about their spatial distribution and structural composition of the landscape. Therefore an assessment for the whole landscape through landscape metrics was necessary to analyse the structural and biotope type diversity at the landscape level. For this analysis the Shannon/Weaver diversity index, the mean patch size index as well as the interdispersion / juxtaposition index were calculated. In order to compare the different land use scenarios with each other and the current state a ranking system was used. Within a last step the results were weighted according to the percentage of the area with high conservation value.

For the analysis of the hydrological situation in the project area, three tightly coupled models were used. First the expert system WBS FLAB - area of equal runoff components identified areas with fast runoff components (surface runoff, saturation overland flow, fast interflow) on the basis of landscape characteristics such as soil type, land use and slope angle (MERTA et al. 2007 this volume, SCHULLA & JASPER 2006, MERTA et al. 2006a, MERTA et al. 2003, ZIMMERMANN et al. 2001, PESCHKE et al. 1999). The results were used to parameterise the afterwards following runoff-precipitation models WaSiM-ETH (SCHULLA 1997) and SWMM (UNITED STATES ENVIRONMENTAL PROTECTION AGENCY 2005), which were used to quantify the runoff of the respective sub-catchment.

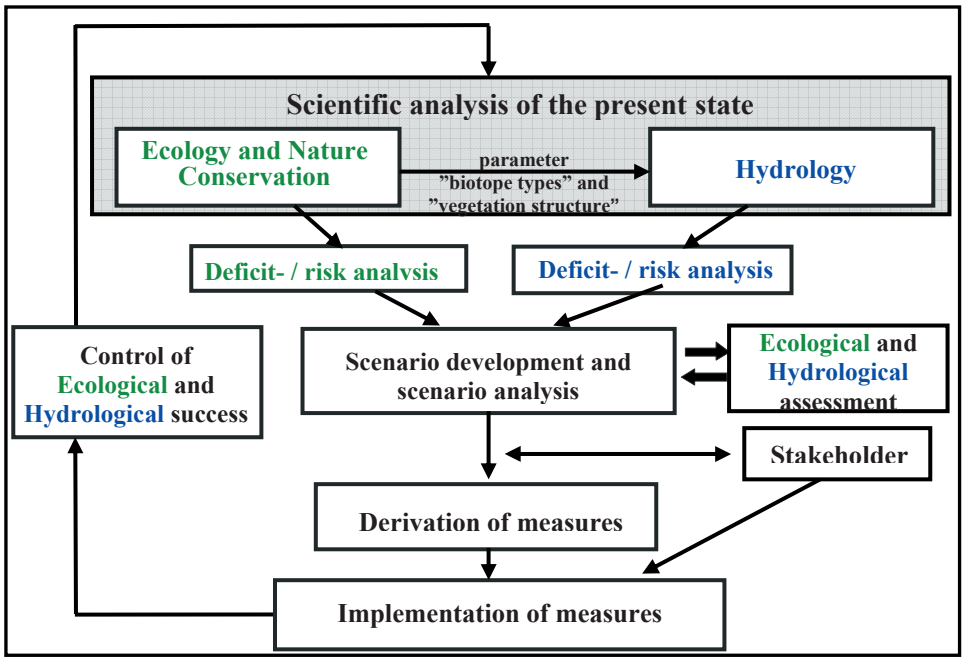

Figure 1: Main steps in the project HochNatur

4 Results

Apart from the present state, 9 respectively 8 scenarios were analysed for each subcatchment (Table 1). The scenario "extensification of grasslands" was not defined for the subcatchment Höckenbach due to the small percentage of grasslands in this area. For the scenarios "nature conservation measurements" and "flood prevention measurements" scenarios for land use changes were elaborated nearly exclusively with respect to the relevant object only. The scenario "combination of nature conservation and flood prevention measures" attempted to consider both aims as much as possible, on the basis of various guidelines (RICHERT et al. 2007). The assessment of the scenario "arable fields with conservation tillage" according to landscape metrics was not meaningful since the borderlines and spatial distribution of the fields did not change with respect to the present state.

Table 1: Compilation of the land use scenarios analysed in the project "HochNatur" ("Flood prevention and Nature Conservation in the Weißeritz area"), their abbreviations and the area percentages affected by land use changes in comparison to the present state in the subcatchments Höckenbach (HB) and Weißbach (WB). n. a. = scenario not analyzed

Szenario	Abbreviation	HB	WB
present landuse	pres	-	-
complete afforestation	c_aff	89,7	90,8
arable field into grassland	a-g	69,0	16,3
conservation tillage	c_till	69,0	21,0
ecological transformation of forests	tr_for	12,6	24,3
partial afforestation (areas with quick runoff components)	p_aff	25,9	24,9
extensification of grasslands	g_ext	n. a.	9,8
nature conservation measures	nat	83,7	53,8
flood prevention measures	flood	82,2	51,8
combination of nature conservation and flood prevention measures	comb	82,9	51,3

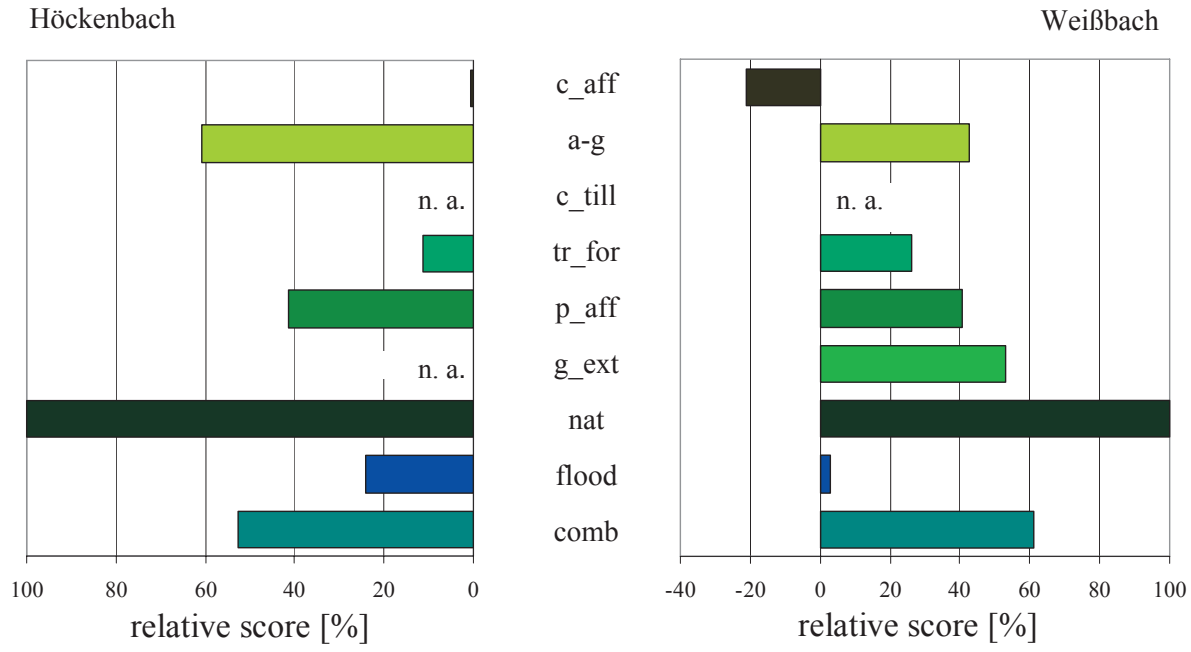

Fig. 2: Results from the evaluation of land use change according to nature protection criteria in relative scores with respect to the present state for the subcatchments Höckenbach and Weißbach. For abbreviations of scenarios refer to Table 1.

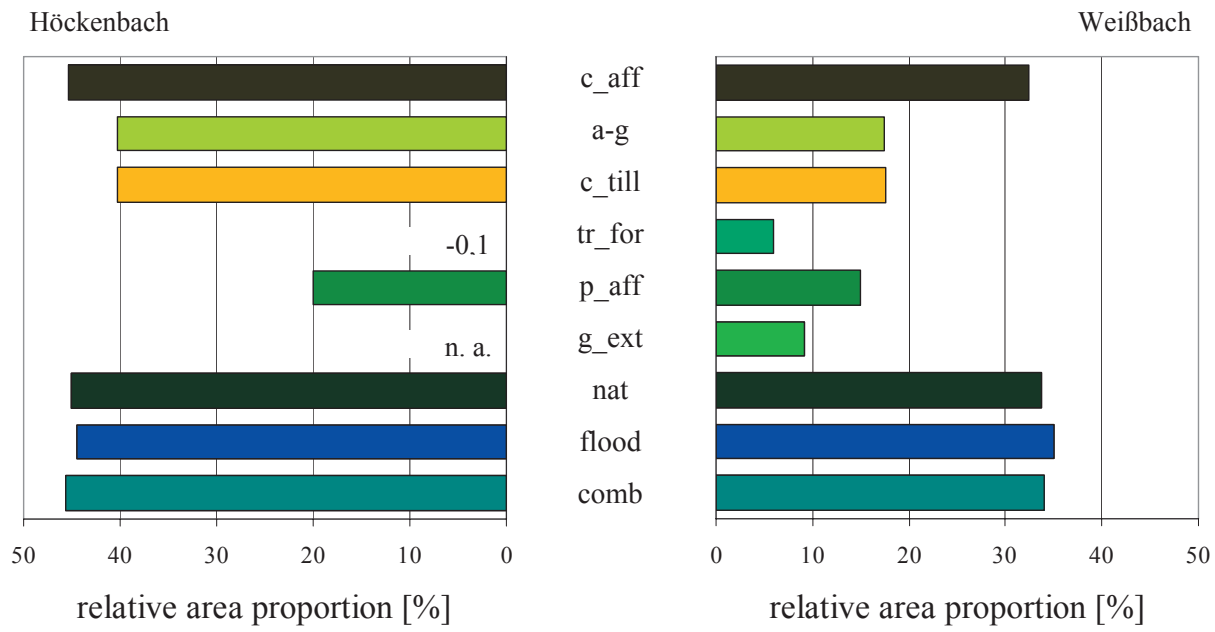

Fig. 3: Results from the hydrological assessment for the subcatchments Höckenbach and Weißbach. Numbers indicate the reduction of area proportions with fast surface and subsurface flow components in comparison to the present state. For abbreviations of scenarios see Table 1.

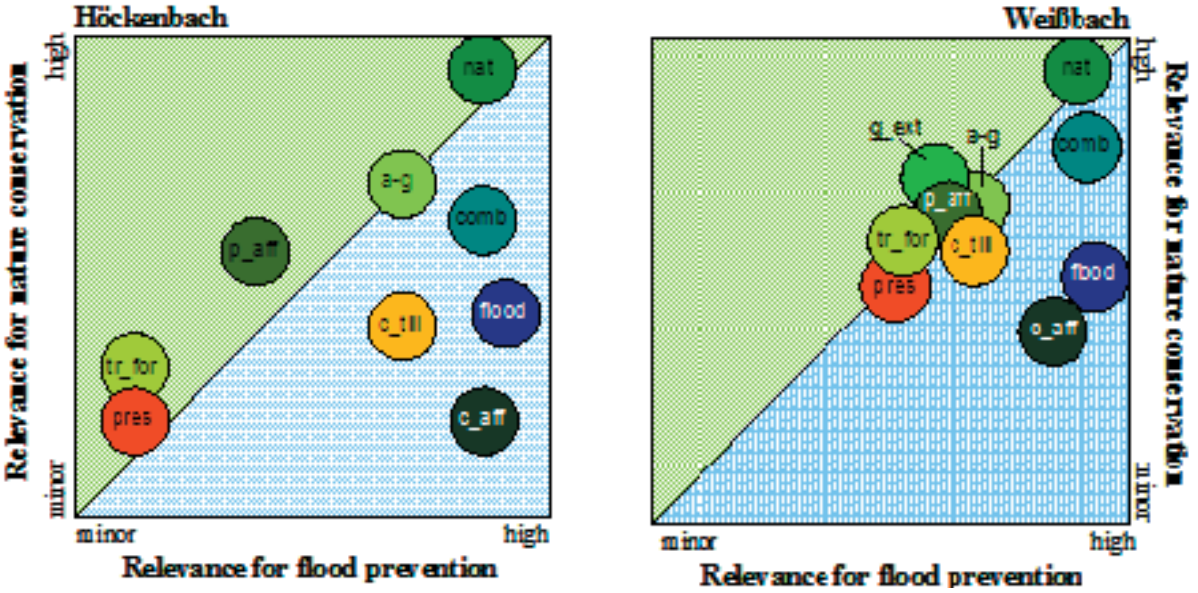

Fig. 4: Combined assessment of land use scenarios with respect to flood prevention and nature conservation (for abbreviations of scenarios refer to Table 1).

From the nature conservation point of view land use changes are promising especially for the Höckenbach subcatchment in comparison to the present state (Fig. 2 and Fig. 4). In contrast, due to the high scores of the present state in the Weißbach subcatchment most of the scenarios analysed did not yield in significant improvements in this area. For the two subcatchments, most of the scenarios resulted in higher scores compared to the present state, only for the "complete afforestation" scenario lower scores were determined in both subcatchments due to the loss in habitat diversity compared to the present state. Ecological transformation of forests did not yield in marked improvements due to the low area percentage of forests, especially in the Höckenbach subcatchment.

The scenarios "arable field into grassland", "combination of nature conservation and flood prevention measures" and "nature conservation measures" all resulted in high scores for both subcatchments.

The reduction of area proportions with fast surface and subsurface flow components was significantly correlated with the reduction of peak discharge in the river ($p < 0.05$). From the flood protection point of view especially the scenarios with large changes in land use (flood prevention measures, nature conservation measures, combination of nature conservation and flood prevention measures) resulted in marked improvements in comparison to the present state, with the effects in the Höckenbach subcatchment being more pronounced than in the Weißbach catchment (Fig. 3 and Fig. 4). A complete afforestation of the subcatchments will substantially improve flood prevention. However, the combination of flood prevention measures focused at the specific on-site problems will yield in even higher improvements (MERTA et al. 2006b). Moreover, these scenarios for flood prevention measures showed higher scores from the nature conservation point of view in both subcatchments also (Fig. 4). Similarly, the scenarios focused on nature conservation measures and on the combination of nature conservation and flood prevention measures markedly reduced the proportion of areas with fast surface and subsurface flow components in both subcatchments (Fig. 3). However, the scenarios "flood prevention measures", "nature conservation measures" and "combination of nature conservation and flood prevention measures" were associated with land use changes of large proportions of the area (50 to 85%) in both subcatchments. Conservation tillage, which does not change the proportion of arable fields in contrast to other scenarios, has a high relevance with respect to flood prevention. From the nature conservation point of view, this scenario slightly gains compared to the present state due to its soil protection effect.

Importantly, measures aimed at flood prevention synergistically interact with nature conservation (habitat and species diversity, connectivity), landscape conservation and aesthetics (tourism and recreation potential) and soil protection (erosion). Moreover, these measures contribute to a balanced regional hydrological budget, which can mitigate negative consequences of summers with low precipitation.

5 Conclusions

The integrative assessment of scenarios of land use changes aimed at both flood prevention and nature conservation in a mountainous area has shown that through a wide spectrum of measured on varying proportions of the area of individual subcatchments dramatic improvements in both objectives can be gained. Even scenarios with measures directed exclusively to nature protection yielded in a reduction in the extent of areas with fast surface and sub-surface flow and reduce flood peaks in rivers (MERTA et al. 2007). Similarly, land use management designed with respect to flood prevention had positive effects on nature protection. Highest effects were associated with land use changes on large area proportions. However, also single measures like the establishment of hedgerows may be positive both from the nature conservation and flood prevention perspective. They affect especially the local habitat, for example by reducing soil erosion.

The analysed effects of land use changes were the greatest in small to medium sized catchments and in the case of precipitation events with 5 to 50 years reoccurrence intervals. In large catchments, the temporal and spatial multiplicity of processes in the different parts overlap and therefore it depends on these interactions whether the discharge of the whole catchment is influenced or not. Several measures in some subcatchments affect the discharge of the whole catchment only slightly. Finally the flow processes in the river bed itself become more important.

The effect of land use changes heavily depends on the specific conditions of the landscape such as the presence of habitat and landscape elements with high relevance for nature conservation, and such as vegetation structure (density, height, root depth etc.) with relevance for flood prevention (see MERTA et al., this volume). Therefore results from the individual scenarios developed for the two subcatchments cannot be transferred to other catchments. On the other hand, the methods developed for the assessment both from the nature conservation and flood prevention perspective can be transferred to other regions as long as necessary data such as a digital landscape model, land use type and distribution and soil characteristics are available.

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