ECONOMIC ASSESSMENT OF NATURAL FLOOD DETENTION MEASURES – SCIENTIFIC APPROACHES TO IDENTIFY FLOOD RELATED LAND USE EXTERNALITIES

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ABSTRACT

Spatial measures for water detention like river redevelopment, decrease of sealing or extensification of land use are often ignored in the planning of flood protection measures. Main problem is the estimation of reliability and technical effectiveness of spatial measures and the quantification of the economic benefit, for example in cost comparison or cost-benefit analysis. Another aspect is the missing influence of local authorities to force the implementation on a large scale. The described economic assessment shows, that increased run-off due to intensive land use must be interpreted as an externality of land use. Upstream land users fully export their run-off to downstream riparian land users. Damages in downstream sections of the river system are therefore not only the results of natural hazards, but also partially of economic market inefficiencies. For a small scale river basin in Southern Germany the cause effect chain of land use and flood damage was assessed, and the economic dependencies evaluated. The conclusion shows, that water related objectives must be integrated into other sectoral policies to counteract market failures and foster sustainable flood protection.

Keywords: flood detention, externalities of land use, river renaturalisation, economic assessment

ARE FLOOD DAMAGES MARKET FAILURES?

Rivers cover our landscape like a net and provide the link between our environment and landscape. Rivers also connect different human groups and their activities from the head to the tailwaters of the catchment. Almost every quantitative or qualitative human impact to the river system is transported by the flow and may affect downstream stakeholders. Most environmental economic problems or externalities in rivers basins are caused by the upstream to downstream conflicts discussed above, and they represent a special form, called a unidirectional externality (Bernauer 2002). Bernauer (2002) lists water use, irrigation, agriculture (adding sediments and chemicals) and hydroelectric power production (creating additional peak flows and hindering navigation) as common upstream to downstream problems. Other types of common costs can also be considered as water related externalities.

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They include for example the maintenance required for trained rivulets (small stream channels) in agricultural catchments following land clearance projects and the resulting responsibility of governments or city councils to conserve the existing river structures. Other types of land uses and their effects on the quantitative and qualitative availability and appearance of water would include:

- effects of land use, such as surface sealing in cities or intensive farming, on the peak and duration of floods
- river training and artificial channel structures, which increase the flow rate, reduce the detention capacity of the natural flood plain and increase the flood damages in settled areas.

These types of externalities can be negative and are worth analyzing from an economical viewpoint for different reasons because:

- The environmental costs of human actions are not integrated into the economic equation of the producer, but assigned over time to other people.
- Externalities may have intertemporal effects. The negative effects can be delayed and occur as economic costs to future generations.
- Minor externalities of different individual polluters or causers can accumulate over time and on a catchment scale.

We know that human action in the catchment and along the river system affects flood development and consequently the peak, volume and duration of a flood. Maniak (1993, p. 10) states "Beim Ausbau oberirdischer Gewässer wurden vielfach die natürlichen Rückhalteräume in der Talaue verkleinert, um die Landwirtschaft gegen Sommerhochwasser und die Siedlungsgebiete gegen noch größere Hochwasser zu schützen. Dies führt zu Abflussverschärfungen mit größeren Hochwasserspitzen in den unterliegenden Gebieten." [As the river systems were developed the natural detention storage was often reduced in the flood plain. Measures were required in order to protect agriculture from summer floods and the settlement areas against increased floods. There has been an increase in flood water levels and peaks in the lower catchment areas.].

Especially in small scale catchments these quantitative relations between land use and water in the literature have been proven (Bormann, Diekkrüger & Hauschild 1999, Koehler 2005). But linkages between land use, river training and flood development can be shown for larger catchments as well (Lammersen, Engel, van de Langemheen & Buitveld 2002, de Roo, Odijk, Schmuck, Koster & Lucier 2001). Dyck (1995, p. 433) describes the enormous losses in flood capacity along the Elbe in Germany over the past 800 years and refers to the inadequate or token attempts to construct flood detention works to compensate these losses within the past 100 years. He states "Infolge Flußregelung und Deichbau haben sich die Retentiosflächen vieler Flüsse verringert. Dies konnte auch durch Rückhaltebecken und HW-Schutzräume in Talsperren meist nicht kompensiert werden. [In-stream works and levee construction have reduced the flood capacities of many river systems. It was not possible to balance this by detention reservoirs or flood storage in dams.]" (Dyck 1995, p. 433).

The hydrological cycle as a physical process links detention in the catchment and in the river valley to flood development and resulting flood damages. The economic hypothesis would be: the extent of flood damages is influenced by land use in the upstream areas. Therefore, flood damages are a function of hydrological parameters, e.g. surface characteristics, catchment and river structure, and land use and other anthropogenic impacts. The main questions, that follow are whether

- externalities, for example flood damages, can be directly linked to land use and human induced changes to hydrology and river morphology, and so quantified using hydrological models,
- externalities can be assigned to identified causers or polluters, or at least alternatively equirement to specified user groups,
- natural effects of flood development can be split from anthropogenic ones
- the costs of the internalisation process do not exceed the benefit.

In a heavily modified environment and intensively used landscape these questions could also be reversed:

- What is the benefit of natural river structures e.g. regarding detention and reduction of flood damages?
- Is it possible to include river renaturalisation in flood mitigation studies and compare the effects from an economic point of view with classical technical measures?
- Is river renaturalisation an effective and efficient mean of flood protection from an environmental and economic stand point?

Umweltbundesamt (2007, p. 5) points out: "Die Umweltpolitik muss sich heute mehr als in früheren Zeiten dem ökonomischen Kalkül stellen. Die ökonomische Bewertung von Umweltschäden ermöglicht es, den ökonomischen Nutzen umweltpolitischer Maßnahmen zu schätzen, denn Umweltpolitik heute vermeidet Umweltschäden morgen. [Environmental politics must have a greater rational now than in previous times the economic calculus. The economic assessment of environmental damages allows the benefit resulting from environmental political measures to be estimated, because environmental politics today avoids environmental damages tomorrow.] " This must also be applied to land use management, river renaturalisation and flood mitigation.

The hypothesis addressed in this project is that internalisation of the economic costs of human actions in a catchment provides significant assistance towards preventing environmental degradation and that flood damages can be prevented. It is postulated that the external effects of human actions on other parties using a river system must be managed, The objective of this project was to investigate the impacts and reactions between humans and nature in a river catchment. The Umweltbundesamt (2007, p. 53) describes a standardized approach for the analysis and evaluation of externalities. The authors propose a methodology in seven steps:

1. definition of objectives
2. specification of the subject of analysis and the boundries of the system
3. description of impacts
4. description of cause-effect relations
5. allocation of economic benefit and cost categories
6. economic interpretation of resulting changes in benefits
7. interpretation and comparison of damages with internalized costs

The focus of this study was on relation between environmental system and human activities in the catchment. It concentrated on the items 1-4 from the list above. This is necessary to provide scientific basis for economic instruments like cost benefit analysis.

The project aimed to identify parameters environmental economic instruments can be based on, so they can successfully internalise and allocate these interactions in the case of flood development and flood damages. The proposed model structure and approach should help to apply scientific methods as a basis for environmental economics as an instrument of river basin management and flood mitigation.

CASE STUDY

The idea to identify and quantify unidirectional externalities in river basins makes it necessary to solve interdisciplinary problems. The study connects hydrology and environmental sciences, with engineering methods and economic analysis. This project is based on the hydrologic behavior of the catchment. Water related processes in the landscape, such as evapotranspiration, infiltration and surface run-off and the genesis and development of floods, are first quantified. A broad variety of computer models is available to describe and simulate different sub processes of the hydrology of a catchment. They can be used to calculate the volume and peak of design floods as well as for flood forecasting and the control of detention structures, like lakes and reservoirs. In a lot of cases they have shown that the development and extent of flood waves can be simulated accurately (Plate 2002).

When combined with a hydrodynamic model the extent, depth and velocity of floods in settlements and a relation between land use and flood affected areas in a catchment can be established. A comparison of the situation in the catchment before human land use with the status quo, can then be used to split off the human induced effects from the natural run-off. Hence it should be possible to connect human impact and the resulting changes of the natural system, to the economic consequences for flood affected citizens. These analytical linkages would establish flood-damage functions for defined design floods under these scenarios and quantify externalities.

Changes in land use and landscape structures happened in central Europe over the last 2000 years. Only the status quo of climate, land use and run-off can be evaluated using statistical and topographic data sets of the last 50 to 200 years. For small river basins no detailed recordings about discharge and precipitation pattern are available. The analysis of historic maps and recordings, but also paleontologic studies give us a very detailed idea, how our landscape looked like. This allows to make assumptions about land distribution, agricultural techniques, typical vegetation and natural river structures. These data can be input for different types of computer models.

The concept of combining different types of models, was tested on the Herzogbach catchment. The models, described later on in detail, were developed to simulate different situations of land use in the test catchment. Responsible human impacts in the catchment like land use and river training were identified for the study site. As a main approach different scenarios of land uses and river structures were used to detect the effect of land use practices and other influences on the hydrological cycle. The focus in the upstream part and middle section of the catchment was on the changes in agriculture, which influenced the hydrological characteristics. Downstream the development of urban settlements was investigated to estimate the flood damages and mitigation costs. The scenarios simulated compared the status quo (Scenario A) to a number of different alternatives, including a pristine catchment (Scenario B) or river without any human influences (Scenario C), as it existed before humans started to act in the region.

The models adopted for this project interacted by exchanging data with each other. The hydrological model calculated the main run-off data in the river at specified nodes depending on land use scenarios, river bed structure and precipitation. The hydraulic model used the run-off at the nodes to calculate the flood situation in settled areas. Outputs were the exact size of the flood plain, flow velocity and flow depth for all points of the flood plain. Empirical formulas for costs and damages were used with floods of different recurrence intervals to establish average costs per year.

The Herzogbach catchment is located in southern Bavaria (Germany). The main river reach has a length of about 20 km and a catchment size of 72.1 km2 (53.9 km2 above Osterhofen). It flows from west to east through a hilly landscape. The Herzogbach and all its tributaries originate in the southern hilly landscape. The areas in the upper reaches have a rural structure with about 80% agriculture and 5% forestry. Settlements are mainly located in the flat depressions along the rivulets. The lower reach passes through the city of Osterhofen, where in the past major floods have caused severe damages. The Herzogbach ends in the floodplain of the Danube and has its outlet into the Danube near the city of Vilshofen at the Danube.

Land use in the catchment followed the geomorphology except on the flood plains. The top of the tertiary hilly landscape in the south of the catchment is still mainly used for forestry. Rough winds, different climatic conditions, because of the altitude, and thinner loess levels in this region, make farming only possible in the small valleys between the hills. The open plains of the Gäuboden provide better conditions for farming, because of the fertile soils and larger field units.

The changes in agricultural production during the last century led to a focus on agriculture which replaced previous livestock farming in this area (Herbert & Maidl 2005, p. 295 et sqq.). Meadows and pastures were converted to fields (Figure 3.6). Field names and local names still refer to the old functions of areas and land strips. Especially in the flood plains of rivers and rivulets old names like “Speckwiese” (bacon meadow), “Doblwiesn” (ravine meadow) or “Puttinger Bach Wiesn” (Putting rivulet meadow) have remained and indicate the former use of these wett areas or wetlands (Maidl 2004, p. 113). This opened space for settlement development on the former meadows in the flood plain. Other important landscape structure were lost during this development, such as bushes, hedges, boundary ridges and wetlands.

Changes did not only take place in the landscape, but also the characteristics of settlements and cities were changed. The city Osterhofen shows these developments very clearly. In former times the settlements occupied the edges of the river valleys to avoid flood damages on the one hand side and reserve the open spaces for agriculture. Because of the fertility of the loess soils, the settlement development was forced towards the valleys and the flood plains. The loss of livestock farming and the availability of former meadows in the river valleys as well as the intensification of agriculture on the flat fertile plains have been the main drivers for this development.

Because of the long history of land clearance and agricultural development, there is insufficient statistical hydrological data available for the analysis of small catchments. The lack of statistical data can be compensated using hydrological models. The computer model used for this study is a conceptional deterministic river basin model to simulate precipitation-run-off processes in small and medium size catchments. “Deterministische konzeptionelle Flussgebietsmodell für den Abfluß setzen sich nach dem Baukastenprinzip aus Verfahren zur

Simulation verschiedener Teilprozesse zusammen." [Deterministic conceptual river basin models for discharge simulation are modular systems to simulate different processes.] (Maniak 1993, p. 361). The applied model consists of three elements:

- a regionalisation approach to calculate losses from evapotranspiration, and infiltration
- and derive a flood wave as a hydrograph for each subbasin,
- a flood routing approach to estimate the superposition of flood waves from subbasins
- and simulate the detention of the river reach and flood plain,
- a reservoir routing approach to check the efficiency of detention measures.

In Bavaria the SMS - HydroAS-2D software package (Nujic n.d.) is a standard system used for 2D hydrodynamic flood routing. It is based on the SMS - Surface Water Modelling System developed by the Environmental Modeling Research Laboratory at Brigham Young University. It includes a pre- and a postprocessor for two- and three-dimensional finite element and finite difference models. HydroAS-2D is a 2D stream-flow and water level calculation package. It is based on the Finite Volume Method. For the whole catchment five models for the villages of Bachling, Neusling, Buchhofen, Wis selsing and Osterhofen were prepared. Three of them were selected for the study: Bachling, Buchhofen and Osterhofen. The three selected villages represent different sections of the river system (Bachling headwater, Buchhofen middle section, Osterhofen lower reach) and different structures and settlement sizes.

Total flood damages of an object or a village over a certain period depend not only on affected buildings and discharge, but also on the probability of discharge. "The total damages caused by periods of recurrent flooding (flood return periods) are utilized to determine the probability-damage relationship [..] At the same time, this curve presents the flood damages incurred for different intervals of recurrent flooding (flood return periods). The expected annual flood damage can be determined from the above probability-damage curve. [..] the expected annual flood damage is the damage divided by its return period, or the damage multiplied by its exceedance probability." (Lekuthai & Vongvisessomjai 2001, p. 357)

For the calculation of potential flood damages over a certain period two functions were derived (Schmidtke 1981):

- The distribution function of the flood peaks as a result of the hydrological model or statistical analysis of stream gauging.
- The flood damage function as a result of hydrodynamically simulated discharges and damage analysis.

A comparison interval of 100 years was selected in this thesis. This represents the standard design level for flood protection works. It is also the technical design period and depreciation period for technical structures like dams and levees (Worreschk 2000, Länderarbeitsgemeinschaft Wasser - LAWA 1998).

The analysis showed that land use and river morphology influence both peak and shape. Therefore three measures can be identified to quantify the externality on a catchment scale:

- The flood damages of scenario A (status quo) minus those of scenario C (natural situation of catchment and river)

- The costs for flood protectin works for scenario A minus those of scenario C
- The costs for detention reservoirs for scenario A minus those of scenario C

Bachling is a typical small village in the steeper upper part of the catchment (Tertiary Hilly Landscape). 72% of the catchment consists of fields, mainly used for root crops and vegetables without intermediate crops (result of inspections in summer and early autumn 2004 and 2005). 15% of the catchment is covered by forest, 12% by grassland and less than 1% is sealed and impervious area. The rivulet is straight and with a deep river bed between 1 and 1.4 m below the natural surface. Within the village, the river bed lies between 1.2 and 1.4 m below the level of the streets or the courts. The peak flow of 1.5 m^3/s for a 100 year flood event is mainly influenced by land use in the status quo scenario (Scenario A). The catchment with natural land cover results in a simulated peak flow of 1.2 m^3/s, while a natural river structure only causes an additional decrease of 0.1 m^3/s to 1.1 m^3/s. The insertion of intermediate crops (Scenario D) causes an decrease of only 0.1 m^3/s to 1.4 m^3/s in comparison to Scenario A.

In contrast to the results at other model nodes these minor reductions can be explained by the steepness of slopes and the river bed. On the other hand the changes in river structure and land use have a significant impact on the shape of the flood wave. Land use increased the volume of the 100 year flood wave by 0.005 mio m^3 to 0.019 mio m^3 (Scenario A). The use of intermediate crops decreases the volume by 0.002 mio m^3 to 0.019 mio m^3 (Scenario D). In addition a flattened wave would result from a renaturalisation (Scenario C) and decrease the volume necessary for flood detention. A potential detention pond has a maximum available volume of 6,600 m^3. Damages in the village start with a discharge of 0.6 m^3/s. For scenario A a volume of 3,900 m^3 would be necessary to mitigate a flood wave of 1.5 m^3/s to 0.6 m^3/s. For scenario B the same reduction could be achieved already with a storage capacity of 2,000 m^3. In scenario C a volume of 1,800 m^3 would be necessary. Assuming average building costs for detention volume of 30 Euro/m^3 this will increase building costs from 54,000 Euro for scenario C to 60,000 Euro for scenario B and 117,000 Euro for scenario A. Splitting up these costs per hectar of farmland means in this catchment 580 Euro/ha for scenario B for 86 ha of farmland in this subcatchment causing this extra runoff. For scenario A the extra costs of detention in contrast to scenario C are 730 Euro/ha. The difference of buildings costs of 6,000 Euro between scenario B and C would represent the extra costs to compensate the effects of river training. For a channel lenght of 1.1 km in this particular subcatchment this means extra costs of 5.45 Euro/m of channel.

A reservoir is located just upstream of Osterhofen. It provides a total detention volume of 56,000 m^3. It provides protection against a 20 year flood event for the village Wisselsing just 3 kilometers upstream of Osterhofen, but not for Osterhofen. It decreases the peak of a 10 year flood event in Osterhofe to by 8 m^3/s to 10 m^3/s. Using an optimized control strategy the detention volume would result in a maximum peak of about 5 m^3/s in scenario C with relevant impacts on the flood protection level of Osterhofen.

In Osterhofen mainly the wide flood plain in the lower system (section 3) contributes to the majority of damages in scenario A. Flooding result from an overtopping of the embankment and an inundation of the wide open flood plain. Therefore, also minor reductions of the flood peaks in scenarios B and C could contribute to a reduction of affected buildings and damages, because overtopping can be avoided (Fig. 1). In contrast to this backwater effects in the middle section and the natural restriction of the valley result in a very constant extent of the flood plain in these areas and, therefore, a minor reduction of damages in scenarios B and C.

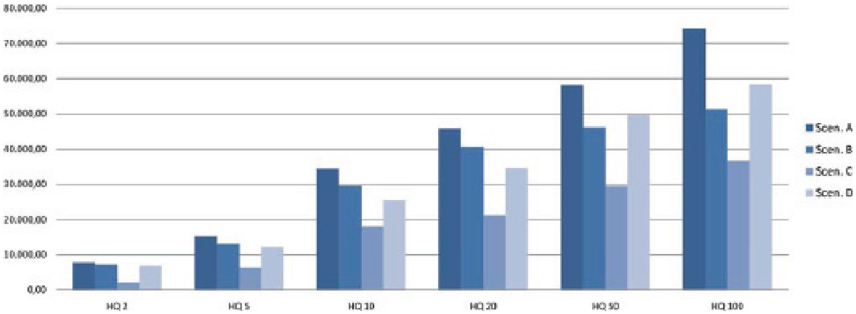

Fig. 1 Flood affected base area of buildings in Osterhofen in m² depending on the type of flood event (recurrence interval) and scenario

It is not always possible to quantify the externality with all three suggested measures: in the Herzogbach catchment no location for larger detention works are available, therefore, it is impossible to quantify the extent and costs of these structures. In larger cities also major supra regional infrastructure can also be affected. In such a case it will be difficult to calculate the total damages resulting from indirect and intangible damages. At rivulets and smaller rivers no significant flood protection systems are available and especially here land use and river training seem to have a higher relevance for flood development. The study showed that especially smaller events are influenced by land use and river training and small events contribute to the majority of damages. "Neben den sehr seltenen Katastrophen-HW sind jedoch die häufiger auftretenden HW geringerer Größe von Interesse, da sie meist den Hauptbeitrag zur Schadenssumme für längere Zeitabschnitte liefern. [Besides the rare disaster floods more common floods of smaller extent are of interest, because they provide the main contribution to the total damage over a longer period.]" (Dyck 1995, p. 430). The study proves that land use and river training contribute to flood damages in small catchments or equally that an internalisation strategy would aid to increase the level of flood protection, reduce the effects from land use or redraw negative developments.

For the whole catchment only three settlements out of over 30 known hotspots in the Herzogbach basin have been evaluated. Remaining hotspots show similar damage potential and floodplain characteristics like the villages of Bachling and Buchhofen. This means that only in the catchment of the Herzogbach a significant part of all flood damages can be called externalities. Damages in the city of Osterhofen make the majority of damages in an individual settlement. But villages like Buchhofen contribute to the total damages on a catchment scale.

CONCLUSION

The evaluation of small landscape structures on a catchment scale is generally problematic because of missing parameters in catchment models and the necessary large amount of work to collect the required detailed data. Different types of hydrologic models could be used to better represent the different processes (DVWK 1999). But this is also bound to more detailed data and modeling efforts. Under today's conditions data gathering and model building on a catchment scale would exceed the work load for practical studies and a broader application of the suggested methodology. At the moment hydrological river basin models are not capable to deal with the problems of detailed rural structures like trenches, drains and field structures on a larger scale. There exists too little experience and statistical data to quantify the effects of these structures and assume their effect on parameters used in catchment modeling. It can be assumed, that natural structures like depressions and boundary ridges would have an additional detaining effect, whereas technical elements, like drains and trenches will increase and accelerate runoff.

The results of the hydrologic model prove three effects of human interventions:

- Reduced land cover increases surface run-off and, therefore, flood peaks and total flood volumes
- Natural river structures increase the flow time of flood waves from several branches
- and can reduce the probability of superpositioning of flood waves
- Natural flood plains store large amounts of water. In combination with decoupled flood waves this can reduce flood peaks

In general the suggested methodology can be used very well to evaluate natural detention in the catchment from an economic and technical point of view. Because classical planning often ignores "non-technical" measures of flood mitigation the approach to couple hydrologic and hydraulic modeling, economic analysis and a scenario analysis, should become the basis for future planning. Other models like erosion and diffuse pollution, sediment transport or morphology models could be integrated as well to estimate the effects of human impacts in these areas.

The results of the case study show that high probability low loss events have a high relevance for flood damages in small catchments, because technical flood protection is not available. These high probability events are influenced by non technical measures of flood detention in the catchment and floodplain. If land use and other human impacts increase floods, classical methodologies for flood mitigation underestimate the effect of non-technical measures for example the renaturalisation of trained sections of river systems. Focusing on technical measures, renaturalisation and natural detention are ignored in a technical analysis. Economic analysis, for example cost benefit analysis, also does not value the benefit of these measures. Natural detention is interpreted as costs, which means it is on the wrong side of the equation. If we apply the polluter pays principle and have to interpret missing natural detention as an emission, then it represents a benefit in the analysis. Also the state subsidies for flood mitigation project must be calculated using the compensation effect for upstream externalities and social welfare, for example resulting from increased production. This results in different forms of inefficiencies. In most studies of flood mitigation concepts, natural measures are ignored. As a consequence technical measures are favored and subsidised. The externalities caused by artificial river structures or missing natural detention are ignored and compensated through technical measures subsidised by the state and financed by the downstream riparian community. This contradicts the polluter pays principle. In addition other forms of state subsidised projects such as land clearance and reallocation, agriculture in general as well as urban development can still increase externalities.

The results of this study can not be directly transferred to other catchments or be upscaled to bigger river systems. Each catchment has its characteristics and the human impacts on the Herzogbach basin are more severe than in other basins. One big issue is the effect of river training and diking to protect land use in the flood plain of bigger rivers that is widely discussed. While environmentalists say, that the loss of natural detention causes higher flood waves, some engineers mention the low effect that these restricted uncontrolled detention volumes have on the enormous volumes of floods. In bigger river systems effects of river training, levees and the superposition of flood waves due to technical intervention maybe relevant.

In general the following counter measures could be applied to reduce the hydrological impacts of land use:

- Application of sustainable farming techniques such as direct cropping or intermediate crops (e.g. Auerswald 2002),
- renaturalisation of run-off relevant landscape structures like ditches for example into grassed waterways (e.g. Fiener & Auerswald 2003),
- methods for local rain water detention and infiltration in urban storm water management (e.g. Sieker & Klein 1998),
- renaturation of river sections and redevelopment of the natural flood plain (e.g. Umweltbundesamt 2001).

Of course these suggested instruments can only achieve a significant result if they are applied on a large scale, representative of the catchment. The effectiveness depends very much on the local climatic and hydrologic conditions and the size and structure of the catchment, like mentioned above. The broad application of these instruments on a national level also requires a review of actual policies and an evaluation of impacts on other sectors, including an economic impact assessment and cost-benefit-analysis. Especially the impacts of actions over different scales still must be developed. While the shown effects of land use and river development on flood behavior can be stated for general in smaller catchments, their dependencies in bigger catchments or international river basins is not always clear.

In general new methodologies for project assessment are necessary. To avoid future externalities, resulting from hydro-engineering projects, rural and urban development as well as other forms of land use, the effects of these measures need to be quantified in technical and economic terms. Environmental and technical models are needed to simulate different scenarios and make predictions about the impacts. Cost-benefit and cost-comparison studies must be extended and externalities be taken into account. This means that environmental, physical and economic methods and knowledge must be combined to establish new combined and integrated management and evaluation instruments to deal with often mentioned water crisis and to protect the water resource. In general can be stated that there is a need for further studies in the field of “hydroeconomics”. Physical aspects of water related externalities are not well described in literature. The economic understanding of the resource water is very little. Most hydrological processes and use types known to be of economic relevance are technically well understood, but have rarely been monitored and highlighted from an economic point of view. The protection of our water resources is not only an environmental, but also an economic task. Hydro-economics as a combination of environmental and engineering knowledge with economics could provide the right instruments to increase the environmental and economic efficiency of our activities.

LITERATUR

Auerswald, K. (2002), Landnutzung und Hochwasser, in 'Rundgespräche der Kommission für Ökologie', 24, Verlag Dr. Friedrich Pfeil, München.

Bernauer, T. (2002), 'Explaining success and failure in international river management', Aquatic Sciences 64, 1–19.

Bormann, H., Diekkr¨uger, B. & Hauschild, M. (1999), 'Impacts of landscape management on the hydrological behaviour of small agricultural catchments', Phys. Chem. Earth (B) 24(4), 291 – 296.

de Roo, A., Odijk, M., Schmuck, G., Koster, E. & Lucier, A. (2001), 'Assessing the effects of land use changes on floods in the meuse and oder catchment', Phys. Chem. Earth (B) 26(7-8), 593–599.

DVWK (1999), Einflüsse land- und forstwirtschaftlicher Maßnahmen auf den Hochwasserabfluß - Wissensstand, Skalenprobleme, Modellansätze, Materialien 7/1999, DVWK.

Dyck, S. (1995), Grundlagen der Hydrologie, 3 edn, Verlag für Bauwesen.

Fiener, P. & Auerswald, K. (2003), 'Concept and effects of multi-purpose grassed waterway', Soil Use and Management 19, 65–72.

Herbert, H. & Maidl, S. (2005), Der Strukturwandel in der Landwirtschaft dargestellt an den Dörfern der Gemeinde Buchhofen, in 'Deggendorfer Geschichtsblätter', number 27, pp. 227–314.

Koehler, G. (2005), Vorbeugender Hochwasserschutz durch Maßnahmen in der Fläche, in 'Wasserwirtschaft in der Fläche', DWA Landesverband Bayern.

Lammersen, R., Engel, H., van de Langemheen, W. & Buitveld, H. (2002), 'Impact of river training and retention measures on flood peaks along the rhine', Journal of Hydrology 267, 115 – 124.

Länderarbeitsgemeinschaft Wasser - LAWA (1998), Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinie), Technical report, Länderarbeitsgemeinschaft Wasser.

Maidl, S. (2004), Flurnamen der Ortschaften Buchhofen, Manndorf, Nindorf und Ottmaring, in 'Deggendorfer Geschichtsblätter', Vol. 25, pp. 87–126.

Maniak, U. (1993), Hydrologie und Wasserwirtschaft, 3 edn, Springer Verlag.

Nujic, M. (n.d.), HYDRO AS-2D Benutzerhandbuch.

Plate, E. J. (2002), 'Flood risk and flood management'.

Schmidtke, R. (1981), Monetäre Bewertung wasserwirtschaftlicher Maßnahmen – Systematik der volkswirtschaftlichen Nutzenermittlung: Ergebnisse eines interdisziplinären Forschungsvorhabens., Technical report, Bayerisches Landesamt für Wasserwirtschaft.

Sieker, H. & Klein, M. (1998), 'Best management practices for stormwater runoff with alternative methods in a large urban catchment in berlin, germany', Water, Science & Technology 38, 91–97.

Umweltbundesamt (2001), Quantifizierung des Einflusses der Landoberfläche und der Ausbaumaßnahmen am Gewässer auf die Hochwasserbedingungen im Rheingebiet, Technical report, Umweltbundesamt.

Umweltbundesamt (2007), Ökonomische Bewertung von Umweltschäden – Methodenkonvention zur Schätzung externer Umweltkosten, Technical report, Umweltbundesamt.

Worreschk, B. (2000), Wirksamkeit von Hochwasservorsorge- und Hochwasserschutzmaßnahmen, Technical report, Länderarbeitsgemeinschaft Wasser.