The riverine landscape Kamp (Austria): an integrative case study for qualitative modeling of sustainable development

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Abstract

This paper presents basic features for modeling some important aspects of sustainable development of the riverine landscape Kamp. We used the QR ontology to collect and organize expert knowledge on ecological effects of water abstraction on fish and the integration of stakeholder interests for successful and sustainable implementation of (ecological) river engineering measures. Following a standardized QR-modeling framework, a concept map served as the basis for the structural model of the Kamp system. Based on this, two causal models are presented expressing system behaviors. Based on the most relevant entities, interacting static and process model fragments are presented. Conclusions and remarks on ongoing work are given.

Introduction

Sustainability and the NaturNet-Redime project

Sustainable development means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs. It is an overarching objective of the European Union set out in the Treaty governing all the Union's policies and activities[1]. One main important target of the renewed EU-Strategy for Sustainable Development (EU-SSD) is the involvement of citizens in the sustainability decision-making process (enhancing the participation in decision-making, promoting education and public awareness of sustainable development, informing citizens about their impact on the environment and their options for making more sustainable choices). The NaturNet-Redime project (www.naturnet.org) is charged with development of new education and decision support models for active behavior in sustainable development based on innovative web services and qualitative reasoning. Different case studies (Cioaca et al., 2006; Salles & Rios Caldas, 2006; Uzunov et al., 2006) (and also Cioaca et al., Salles et al., Nakova et al., and Noble et al., submitted to this QR workshop) are representing sustainability issues using QR and provide model fragments stored in and freely available at an online model fragment library[2]. To support integration of these case studies into a curriculum for learning about sustainability (Nuttle et al., 2006), a new software program (Garp3; see footnote 2) and a standardized QR modeling approach were developed (Bredeweg et al., 2007). Within the NaturNet-Redime-project the presented case study serves as a basis for the development of learning material for the QR-portal focusing on ecosystem, social, economic and cultural/political processes and integrated management related to catchment planning and river restoration in Austria. Main issues treated within the models are stakeholder integration as a crucial basis for a sustainable development of the whole river basin and the ecological restoration of river sites affected by water abstraction with regard to the EU-Water Framework Directive.

The EU water framework directive

In 2000, the European Union launched new water legislation, the Water Framework Directive (WFD, 2000). Within this framework, a program of measures is developed aimed at rehabilitation of degraded aquatic ecosystems across Europe. One of the key objectives of the WFD is to achieve "good ecological status" of running waters by 2015. Four organism groups (fish, macrozoobenthos, algae, macrophytes) are used as indicators to describe the ecological status.

The Kamp valley case study

Catastrophic floods and inundations in August 2002, a nearly 2000-year event, set new conditions for life and economy in the in the Kamp valley (Austria) facing flood control management, landscape architecture and land use planning with essential and future challenges. The high-water event represents a chance to develop the riverine landscape together with the local population as well as with the concerned scientific disciplines considering social, economic and ecological claims with regard to the EU-WFD. Within the whole valley there is a long tradition in water power use for grain and saw mills. Some power plants abstract water from the river for hydropower production and cause significant problems to fish by creation of residual flow stretches. The first river

[1] http://ec.europa.eu/environment/eussd/, accessed 14 February 2007.

[2] http://hcs.science.uva.nl/QRM/

engineering measures besides local bank protection were carried out around 1900. This paper presents preliminary steps in developing a QR model of the Kamp system following the structured methodology (Bredeweg et al., 2007).

Main model goals

Based on this description of the main issues facing the Kamp riverine landscape, we identified the main model goals to represent basic processes for a sustainable development of riverine landscapes:

- To develop a better understanding and representation of entities and processes involved into the very complex task of sustainable development and management of riverine landscapes in industrialized countries.
- To develop a QR-approach representing river restoration with regard to fish and the EU-WFD.

System Structure

To describe the most important concepts of sustainable development of the Kamp landscape, a concept map was developed (Zitek, 2006). This concept map includes the basic concepts of sustainable development like human society (with its sub-concepts of legislation, infrastructure, culture), institutions, nature and economy. From this, we describe the system structure, including the main entities and their structural relationships (Fig. 1). This sets the system boundaries for the modeling approach, representing interactions between energy production, flood protection and the river. Entities involved are human, infrastructure, hydropower production, economy, flood protection, vegetation, land, river, animal, river features, legislation and institution.

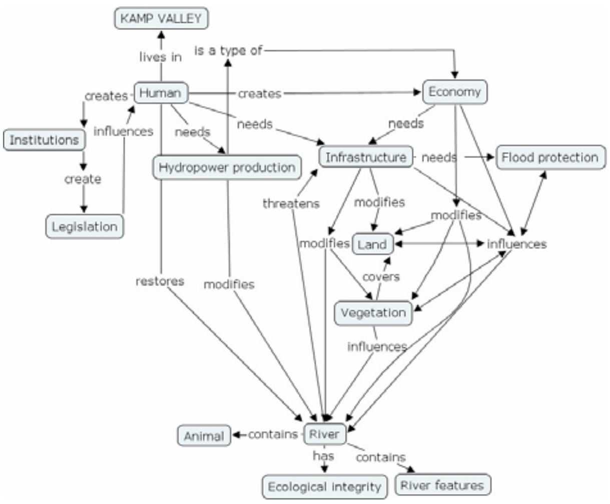

Figure 1: System structure of the Kamp valley (without restoration activity).

Two sub-systems were selected for the modeling process:

- development and implementation of measures with regard to information and participation processes with the acceptance of a measure as an indicator for sustainability (Model A)
- restoration of river sites impacted by water abstraction and channelization with regard to the EU-WFD (Model B).

Model A: Acceptance of a measure

Entities overview. The most relevant entities for the model A are “environment” (local environment, social environment), “human” (stakeholder, local population, politician, planner), “management action” (information, participation, development of measures, implementation of measures), “economic unit” (money) and “indicator” (acceptance of a measure).

Configurations overview. An initial list of entities and their configurations is presented below. If new entities are to be included, new configurations may be required.

- Human *lives* in Environment
- Planner *sets* Management action
- Economic unit *influences* Management action
- Information *informs* local population and stakeholders
- Participation *integrates* stakeholders
- Management action *influences* indicator

Agents. Agents are used to model processes that affect the system of interest, but are external to it. A catastrophic event sets the pre-requisition for the development of measures and is treated as an agent, or external influence.

Assumptions. Assumptions represent something about the system of interest, which makes them conceptually different from both entities and agents. E.g. the WFD defines the role that ecological targets have within planning activities; environmental sustainability due to measures should be reached following the approach of minimizing economic loss. It is assumed that the participation process creates multipliers that have a high influence on the acceptance of a measure within the local social environment. But additionally, official information is still important to increase the integration of the local environment to reach a high acceptance of the measures.

Model B: River restoration focusing on channelization and water abstraction

Entities overview. The most relevant entities for the model B are “water body” (river, residual flow stretch), “river feature” (water, habitat, substrate, shoreline vegetation), “driver” (hydropower production, flood protection), “technology” (hydropower plant), “human pressure” (water abstraction, channelization), “indicator” (fish, ecological integrity), “management action” (restoration), “economic unit” (money).

Configurations overview. An initial list of entities and their configurations is presented below. If new entities are to be included, new configurations may be required.

- Water body *contains* river features
- Human pressure *modifies* river features
- River features *influence* indicators
- Management action *modifies* human pressure
- Management action *influences* economic unit

Assumptions. The WFD directive is influences the whole modeling approach (5-level scheme, economic commensurability of measures, indicators, etc.). Furthermore it is assumed, that flood protection of a riverine landscape is often achieved by river channelization together with the construction of levees. But only channelization is treated as a direct impact on habitat heterogeneity within the models neglecting the importance of lateral connectivity for fish that is lost due to levees. It is further assumed that the WFD status reflects the degree of the impact. Temperature changes due to the impoundment upstream are not integrated into models yet. Also the effect of the interruption of longitudinal connectivity is not integrated.

Causal Models

Human occupation of the Kamp valley has substantially altered the riverine landscape and the river features reducing the ecological integrity of the river. Hydropower production and channelization for flood protection cause the most important pressures to the riverine system. Sustainable restoration activities integrating all stakeholder interests are an important task, especially with regard to the EU-WFD (Harrison et al., 2001). To illustrate these typical situations in the Kamp valley, two causal models are presented: one for model A and one for model B.

Causal model A: Acceptance of a measure

Fig. 2 shows the causal model for the acceptance of a measure. The success and sustainability of a measure largely depend on high agreement of the local population (integration of the local environment) and other stakeholders to the proposed measures. Acceptance of a measure is mainly influenced by information, participation, integration of stakeholder interests and of the local environment (including typical habits of the local population, landscape history, etc.). Catastrophic events, increasing the motivation of the local population influencing political interest for development and implementation of measures is treated as an important external influence (agent).

According to the causal model some of the relations might read as follows:

- Fear from catastrophic events increases the motivation of local population for actions (P+) which increases the pressure on politicians (P+) which positively influences the political interest for actions (I+); this propagates positively the money available (P+) and the development of measures (P+) as a pre-condition for the following steps.
- The integration of scientific know-how positively influences the success of the measures (P+).
- Participation and Information processes increase the integration of stakeholder interests and the integration of the local environment (I+).
- Both affect the acceptance of the measure (P+).
- If the acceptance of the measure is low, resistance against measures is high (P-).
- If resistance against measures is high, pressure on politicians is high (P+) which increases the pressure on planners (P+) which activates the information and participation process (P+).

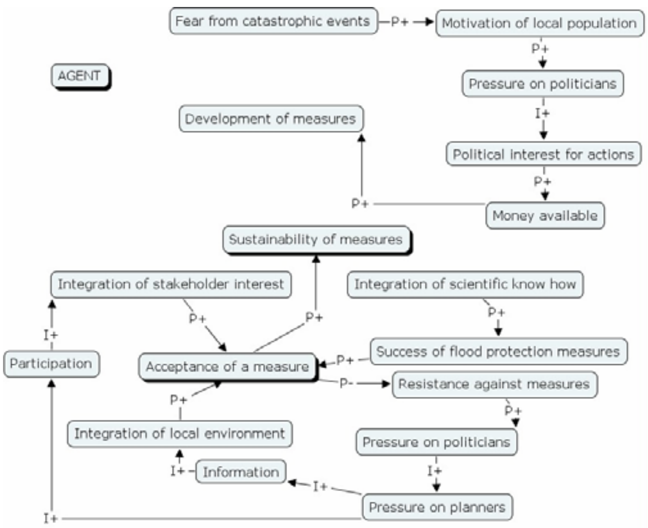

Figure 2: Causal model "acceptance of a measure" with "catastrophic event" as agent.

Causal model B: River restoration with regard to water abstraction and channelization

Water abstraction and river channelization are generally known as two of the main pressures to Austrian rivers (BMLFUW, 2005) and restoring river sections impacted by reduced flow and a changed flow regime is known to be a challenging task (Scruton et al., 1998; Erskine et al., 1999). Fig. 3 shows the causal model for two different possibilities of river restoration activities to restore the ecological integrity of impacted rivers in compliance with the WFD. According to the two pressure types, two restoration activities (Restoration I and II) might reduce the pressures, positively influencing related river features and indicators.

In this causal model some relations can be described as follows:

- The Water abstraction rate positively influences the amount of abstracted water (I+).
- The higher the amount of abstracted water, the lower is the amount of water in the river (P-), lowering the depth and flow velocity (P+), but increasing temperature (P-); these factors are known to be relevant factors influencing fish biomass, density and species diversity (P+), representing indicators for the ecological integrity (P+).
- River channelization reduces habitat heterogeneity (P-); habitat heterogeneity is positively proportional to fish reproduction, biomass, density and species diversity (P+), which are all indicators for the ecological integrity of a river (P+). Channelization is often accompanied with a reduction of shoreline vegetation (P-) which increases the temperature of a river section (P-).
- Restoration opportunities (I and II) can be seen as single or combined processes. Restoration I reduces (I-) river channelization and increases (I+) the amount of shoreline vegetation.. Restoration II reduces (I-) the water abstraction rate and positively influences the naturalness of the discharge regime (I+) which decreases substrate clogging that is negatively linked to fish reproduction (P-).

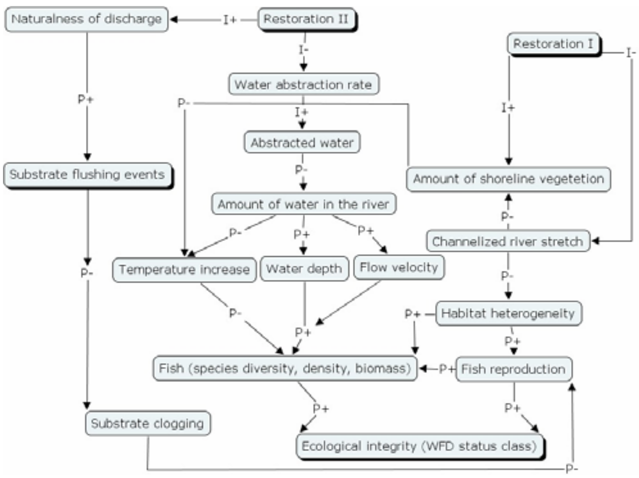

Figure 3: Causal model “river restoration with regard to the WFD”.

Detailed system structure and behavior

QR models generally comprise a hierarchical library of model fragments.. In this section, the basic model fragments for the River Kamp case study are defined. The model fragments are classified as static fragment, process fragment and agent fragment. These implement the ideas presented in the causal models. Some examples for both models are given:

Model A: Static model fragments

The purpose of static model fragments is to define structural relations between entities as well as to indicate propagation of changes from one quantity to another by using proportionalities (Bredeweg et al. 2006).

Sustainability of measures.

- Conditions:
  - Entities: Indicator, Human
  - Configurations: influences
- Consequence
  - Quantities: Acceptance of a measure, Resistance against a measure, Sustainability of measures
  - Causal dependencies: Acceptance of a measure propagates negatively to resistance to a measure (P-) and positively to sustainability of a measure (P+).

Model A: Process model fragments

Process model fragments describe how values of quantities cause changes to occur in other quantities via direct influences (I+ and I-).

Participation process.

- Conditions:
  - Entities: Planner, local population, stakeholders, management action, indicator
  - Configuration: sets, participates, influences
- Consequence
  - Quantities: Participation, Integration of stakeholder interests, Acceptance of a measure
  - Causal dependencies: Participation process has a positive influence (I+) on Integration of stakeholder interests.

Model A: Agent model fragments

Agent model fragments are a special kind of process model fragment (containing direct influences I+, I-), that model how external influences cause changes in a system. They generally relate to processes that humans can potentially exert some control over, as opposed to natural processes, that humans generally cannot or do not directly control.

Pressure on politicians/political interest.

- Conditions:
  - Entities: Local population, politician
  - Configuration: influences
- Consequence
  - Quantities: Pressure on politicians, Political interest
  - Causal dependencies: Pressure on politicians has a positive influence (I+) on political interest for actions.

Model B: Static model fragments

River feature and fish.

- Conditions:

- o Entities: Water body, River feature, Indicator
  - o Configurations: contains, influences
- Consequence
  - o Quantities: Amount of water, Impact on water depth, Temperature increase, Impact on flow velocity, Species diversity, Size of fish, Loss of sensitive species, Biomass.
  - o Causal dependencies: Impact on water depth and flow velocity negatively propagate to species diversity, size of fish, and biomass (P-) and positively to loss of sensitive species (P+).

Model B: Process model fragments

Process model fragments describe how values of quantities cause changes to occur in other quantities via direct influences (I+ and I-).

Water abstraction.

- Conditions:
  - o Entities: Water body, River feature, Human pressure
  - o Configuration: contains, influences
- Consequence
  - o Quantities: Water abstraction rate, Water abstracted, Water in the river,
  - o Causal dependencies: The water abstraction rate positively influences the amount of abstracted water (I+) which negatively influences the amount of water in the river (I-).

Model B: Agent model fragments

No agent model fragments are currently used within model B.

Discussion

Guided by the standardized QR modeling framework (Bredeweg et al., 2007) we were able to develop the presented models in QR language capturing important problems related to a sustainable development of riverine landscapes related to the EU-WFD. During the model implementation phase, the two models presented and scenarios will be further developed and specified. Model fragments will collaboratively developed within the collaborative model-building workbench together with the case study from UK (Noble, 2006). The collaborative model-building workbench allows for the exchange of sketches of ideas and the re-use of model fragments produced by other case studies available at the repository at the QRM portal by simply copying and pasting (see Liem et al., also presented in this workshop). At the end both presented models will represent basic aspects of a sustainable development of riverine landscapes with validity throughout Europe. To evaluate the efficacy and efficiency of the models, an interactive workshop with various stakeholders of the valley (fishermen, local water authorities and river engineers, energy producers and planners) will be organized.

Public participation is seen as perhaps the most pressing and problematic issue in ensuring the prompt and adequate implementation of the Water Framework Directive (WFD) and the achievement of integrated river basin management planning (Harrison et al., 2001). Therefore and in order to manage water resources in a more sustainable manner, new planning methodologies/ processes for river basin management need to be developed especially to achieve participation and integration in a decision-making or planning process (Hedelin, 2007). Integration of interests at various dimensions has to be achieved, including the consideration of multiple issues and stakeholders, the key disciplines within and between the natural and human sciences, multiple scales of system representation and behaviour and cascading effects both spatially and temporally. The trend to more integrative or holistic assessment and management of our resources requires the corresponding development of our science (Jakeman & Letcher, 2003). Participatory approaches to natural resource use planning and management have significant implications for managers, planners and researchers (Walker et al., 2001). Especially communication is suggested to be crucial to achieve integrated environmental management, integrated modelling, integrated assessment, or integrated knowledge (Parker et al., 2002).

Model-generated information might help in the process of stakeholder integration (Olsson & Berg, 2005). The causal models and graphic presentations as produced by Garp3 may effectively summarise a large quantity of information and will help to understand and communicate processes and relationships relevant for sustainable river restoration besides statistical relationships currently dominating in aquatic science.

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