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Abstract

This deliverable (D6.2.5) documents the models developed by the University of Natural Resources and Life Sciences, Vienna (BOKU) for Task 6.2. The models are implemented in the different learning spaces of the prototype DynaLearn software. D6.2.5 covers basic topics and models that address the seven core themes identified in the DyanLearn curriculum for Environmental Science. The 31 presented models cover the following topics: Natural processes forming riverine landscapes and habitats, Populations, The river continuum concept (RCC), Education, Tourism and recreation, Flood protection, Integrated plans for management of catchment areas, Food webs and energy flow, Hydropower generation, Indicator species, Organic water pollution, Climate change effects on river catchments, International agreements and treaties on environmental issues and cooperation for sustainability.

Internal Review

- **Wouter Beek and Bert Bredeweg (UvA), Informatics Institute, Faculty of Science, University of Amsterdam, Netherlands.**
- **David Mioduser (TAU), Department of Education in Math, Science and Technology, Tel Aviv University, Israel.**

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Document History

Version	Modification(s)	Date	Author(s)
01	First draft based on model documentations	2010-07-23	Andreas Zitek Michaela Poppe Annemarie Jung Maria Zacharias Michael Stelzhammer
02	Second and final draft for internal review	2010-07-26	Andreas Zitek Michaela Poppe Annemarie Jung Maria Zacharias Michael Stelzhammer
03	Final document including TAU review	2010-08-20	Andreas Zitek, David Mioduser
04	Final document including UvA review	2010-08-25	Andreas Zitek, Wouter Beek

Contents

1. Introduction

The DynaLearn project is aiming at developing a software learning environment that integrates three well established, but as yet independent, technologies to create an individualised and engaging cognitive tool for acquiring conceptual knowledge in environmental science. The software integrates a diagrammatic approach to constructing qualitative conceptual models, ontology mapping and semantic technology to ground model building terms and compare models, and virtual character technology to provide individualised feedback and enhance motivation of learners. In addition to the software development the project is also developing a curriculum in environmental science based around the learning by modelling approach which is the cornerstone concept for the DynaLearn pedagogical approach.

Development of the learning by modelling curriculum requires the creation of a resource base of models that cover important concepts identified in the themes and topics relevant to environment science education. The relevant themes and topics were identified in project deliverable D6.1 (Salles et al. 2009). In addition to providing a resource base for an environmental science curriculum the simple topics and models (and modelling activity) presented here serve three purposes:

- **explore and test the capabilities of the new modelling software and the learning spaces (LSs),**
- **provide a resource of models to help develop and test the semantic and virtual character technologies,**
- **provide a resource on which lesson plans and evaluation activities can be developed.**

The purpose of the first phase of modelling (Task 6.2) is to deliver a set of basic topics and models. These basic topics and models explore important concepts in environmental science in the form of simple models that utilise the different opportunities available in the new learning spaces of the prototype DynaLearn workbench. These learning spaces are designed to handle different levels of complexity and focus on different types of modelling. The six learning spaces in the software are:

LS1 – simple concept maps

LS2 – simple causal models with emphasis on model structure, definition of entities, quantities and configurations and the sign of the relationships (positive or negative) between quantities.

LS3 – simple causal models with state graphs focussing on the qualitative states and values of quantities that are important to the concept (including correspondences between values for different quantities).

LS4 – causal differentiation models where the emphasis is differentiating between direct influence relationships and proportionality relationships denoting aspects of causality within the system.

LS5 – conditional knowledge models where the emphasis is on representing consequences that may only occur under certain conditions.

LS6 – generic and re-useable models that utilise the full qualitative modelling approach within Garp3, includes the compositional modelling approach and the use of hierarchy and inheritance of properties.

Models were developed in different learning spaces considered to be appropriate to convey key concepts in each topic in the curriculum with a focus on LS 2 – LS5 (Section 2). LS6 models will be produced during the second phase of the project, when more detailed models are being produced.

2. Topics and models addressed in this deliverable

2.1. Links to DynaLearn Curricula (D6.1)

The DynaLearn deliverable D6.1 identified and described a series of topics in Environmental Science that cover the seven main themes identified in the project description of work. Table 2.1 summarises the themes and topics allocated to BOKU for development in work package six (WP 6). Within these topics 31 models were developed in different learning spaces in the prototype DynaLearn software.

Table 2.1 Summary of themes and topics assigned to BOKU in from the D6.1 curricula in Environmental Sciences and the simple topics and models covered in BOKU D6.2.5.

Theme	Topic	Sub-topic / model title	LS 01	LS 02	LS 03	LS 04	LS 05	LS 06
ESR	Natural processes forming riverine landscapes and habitats	Sediment transport		✓				
		Sediment transport in river widenings				✓		
		Precipitation and flooding					✓	
LW	Populations	Habitat quality affects populations		✓				
		General population model				✓		
	The river continuum concept (RCC)	RCC: from midwater stream towards headwater stream		✓				
		RCC: from headeadwater towards midwater stream		✓				
		RCC large floodplain river		✓				
		Forest removal and benthic invertebrates					✓	
HP	Education	Quality of environmental education		✓				
		Build up of new knowledge		✓				
		General principles of env.education		✓				
		Sustainable development and env. education		✓				
		Class size and learning					✓	
	Tourism and recreation	Recreation at restored river sites		✓				
		Recreation and management of restored river sites				✓		
LWU	Flood protection	Deforestation and its effect on flooding				✓		
		Land sealing and its effect on flooding				✓		
		Flood protection					✓	
	Integrated plans for management of catchment areas	DPSIR scheme					✓	
		Adaptive management cycle				✓		
ERC	Food webs and energy flow	Concept energy flow	✓					
		Energy flow		✓				
		Predator and prey				✓		
	Hydropower generation	Water abstraction		✓				
PO	Indicator species	Indicator species			✓			
	Organic water pollution	Estrogens and progestogens		✓				
GC	Climate change effects on river catchments	Services of natural floodplain forest		✓				
		Natural floodplain versus maize production		✓				
		EC directives coflicts: WFD versus Biomass action plan				✓		
	Int. agreements and treaties on environmental issues and cooperation for sustainability	Dynamic restoration versus conservation				✓		

2.2. Educational context of modelling content and goals

Whilst the purpose of WP 6 was to develop a repository of models for use in testing the DynaLearn software, the requirement to use at least some of the models in the evaluation activities in the project means that the local educational context of the topics and models also had to be considered.

In general, the successful application of DynLearn in classrooms faces two major challenges:

- To rethink the way in which the subject matter of environmental science is administered in education, and restructure this such that the features emerging from the DynaLearn software will actually make a difference and enhance learning significantly.
- Blend in with ongoing classroom learning activities such that undesired disturbances minimised as much as possible, while the positive impact and learning enhancements caused by the DynaLearn innovation are maximised.

These two challenges necessitated a comprehensive review of the existing background information on the different topics, and a restructuring of the content delivered to students, as for each LS different perspectives on the learning material had to be chosen. Only a complete review of existing scientific literature, reports and other learning and teaching material available for the different topics yielded the basic information needed to produce useful models representing the current state of knowledge and integrating well with an up-to-date educational context. Information best suited to be represented in different LSs was then selected and implemented in models using always the latest available prototype of the DynaLearn software.

Furthermore the background information collected serves as context material for using the DynaLearn approach in classrooms creating the situative framework for the modelling activity, showing the relevance of the topic and gaining the interest of students to create motivation for self-directed learning.

As the main interest at BOKU is the understanding and teaching of processes being active within riverine landscapes, the focus of the models is on processes within river catchments.

Finally, the background information collected and newly structured serves as an important input for the second phase of the project, where more detailed models have to be developed.

2.3. Model presentation and documentation

The models presented here are grouped by topic. Within each section the background knowledge relevant for the topic is presented. For each topic a small suite of models is presented. In many cases the general model contents and ingredients are shared between the different models (model ingredients for all models are generally summarised in a single table). For each model the rationale assumption and goals (from a content point of view and from modelling perspective) are briefly summarised and the model structure is presented. For each model an example scenario and simulation or the range of possible scenarios/simulations are described. For each specific scenario the causes and conditions for the resulting behaviour are given in terms of exogenous controls, (in)equalities and ambiguity. Table 2.1 shows how models are presented along the selected topics in the following section.

3. Natural processes forming riverine landscapes and habitats

3.1. Topic and model metadata

Topic	Water and sediment transport in rivers as basic features shaping riverine landscapes		
Author	Andreas Zitek Michael Stelzhammer Michaela Poppe	Version(s)	Draft 14/07/10 DynaLearn 0.6.8(CM) (LS2 & LS4) DynaLearn 0.6.11(CM) (LS5)
Models	Sediment transport_LS2 Sediment budget_river widening_LS4 Precipitation and flooding LS5		
Target users	Secondary school students and bachelor students; Master students		

3.2. Topic rationale

3.2.1. Background

Important note: *This section is mainly compiled from Tüysüz (no year indicated)[1] and FISRWG (10/1998)[2].*

The hydrologic cycle describes the continuum of the transfer of water from precipitation to surface water and ground water, to storage and runoff, and to the eventual return to the atmosphere by transpiration and evaporation (Figure 3.1). Precipitation returns water to the earth's surface, and a part of it, the so called runoff forms river channels, which represent the routes by which the runoff flows to its base level. Factors that affect runoff processes include climate, geology, topography, soil characteristics, and vegetation.

"Water, by evaporating from the ocean, from other water surfaces and from land surface or by transpiring through vegetation, condenses into clouds that are displaced by wind. Clouds release the water vapour a precipitation: rain, snowfall and hail" (Gutknecht et al. 2008).

"The exchange of water between earth and atmosphere is the hydrologic cycle… The water that falls on the earth is disposed of in three ways. It evaporates into the air, sinks into the ground, or it runs off the surface of the ground…The excess of precipitation over evaporation and transpiration provides flow of rivers and springs, recharges groundwater storage, and is supply from which humans draw to meet their needs… Water that is not infiltrated flows downhill over the ground surface…The channel that carries runoff is that aspect of the river most obvious to the observer…The channel is carved by the flowing water but it takes the form dictated by the sediment carried" (Leopold 1994; Leopold 1997).

Precipitation can do one of three things once it reaches the earth. It can return to the atmosphere, move into the soil and/or run off the earth's surface into a stream, lake, wetland, or other water body. All three

[1] Fluvial systems (compiled from different inter sources (http://www.eies.itu.edu.tr/dersnotlari/notlar/y%C3%BCksek_lisans/jeomorfoloji_okan/Fluvial%20systems.pdf)

[2] Stream Corridor Restoration: Principles, Processes, and Practices (http://www.nrcs.usda.gov/technical/stream_restoration/)

pathways play a role in determining how water moves into, across, and down the stream corridor. E. g. more than two-thirds of the precipitation falling over the United States evaporates to the atmosphere rather than being discharged as streamflow to the oceans. This “short-circuiting” of the hydrologic cycle occurs because of interception followed by evaporation and transpiration.

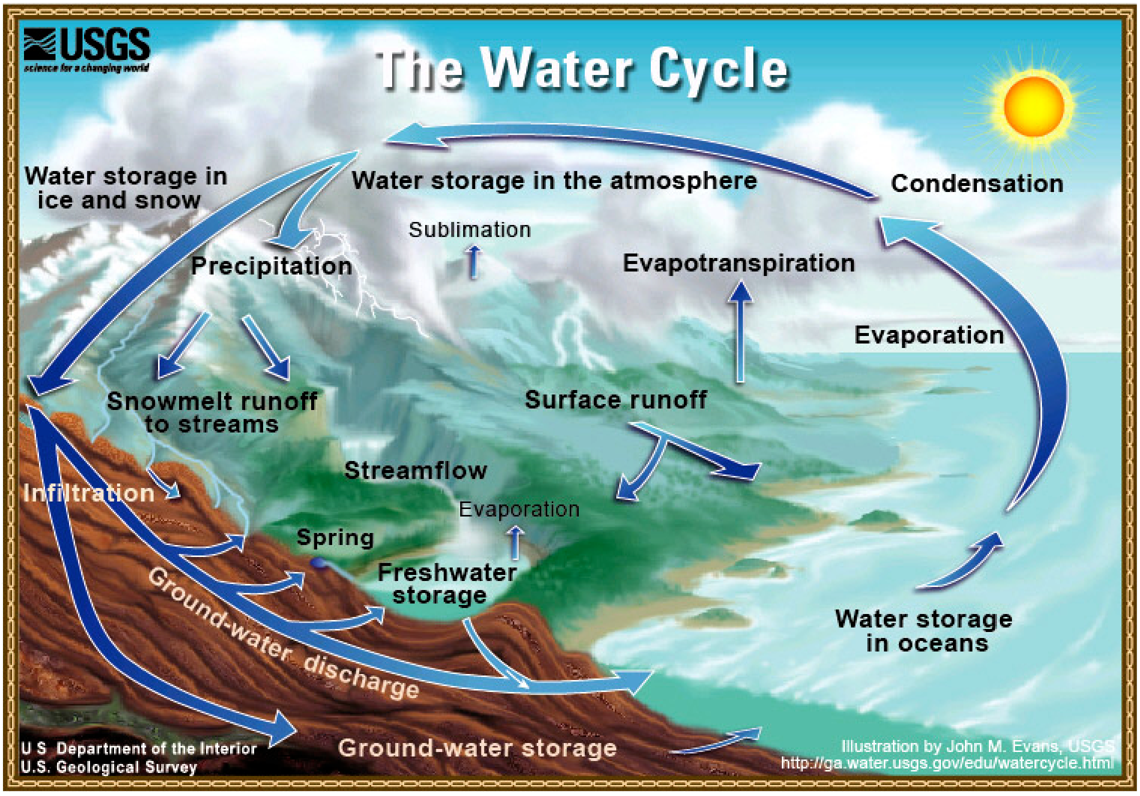


Figure 3.1: The hydrologic cycle. The transfer of water from precipitation to surface water and ground water, to storage and runoff, and eventually back to the atmosphere is an ongoing cycle (source: http://ga.water.usgs.gov/edu/watercycleprint.html).

A portion of precipitation never reaches the ground because it is intercepted by vegetation and other natural and constructed surfaces. The amount of water intercepted in this manner is determined by the amount of interception storage available on the above-ground surfaces. In vegetated areas, storage is a function of plant type and the form and density of leaves, branches, and stems (Fig. 3.2). Interception is usually insignificant in areas with little or no vegetation. Bare soil or rock has some small impermeable depressions that function as interception storage sites, but typically most of the precipitation either infiltrates the soil or moves downslope as surface runoff. In areas of frozen soil, interception storage sites are typically filled with frozen water. Consequently, additional rainfall is rapidly transformed into surface runoff. Interception can be significant in large urban areas. Although urban drainage systems are designed to quickly move storm water off impervious surfaces, the urban landscape is rich with storage sites. These include flat rooftops, parking lots, potholes, cracks, and other rough surfaces that can intercept and hold water for eventual evaporation.

Transpiration is the diffusion of water vapor from plant leaves to the atmosphere. Unlike intercepted water, which originates from precipitation, transpired water originates from water taken in by roots. Transpiration from vegetation and evaporation from interception sites and open water surfaces, such as ponds and lakes, are not the only sources of water returned to the atmosphere. Soil moisture also is subject to evaporation. Because it is virtually impossible to separate water loss due to transpiration from water loss due to evaporation, the two processes are commonly combined and labeled evapotranspiration. Evapotranspiration can dominate the water balance and can control soil moisture content, ground water recharge, and streamflow (Fig. 3.2).

Precipitation that is not intercepted and evaporated or transpirated or flows as surface runoff into rivers infiltrates into the soil and in the groundwater. When the water moves horizontally (along the hill slope) through the soil/litter zone and contributes to the river discharge it is called subsurface runoff (or "throughflow"). When the rate of rainfall or snowmelt exceeds infiltration capacity, excess water collects on the soil surface and travels downslope as surface runoff. If the water moves through the soil into an aquifer, it contributes to the groundwater storage; during times without precipitation groundwater provides the baseflow of rivers.

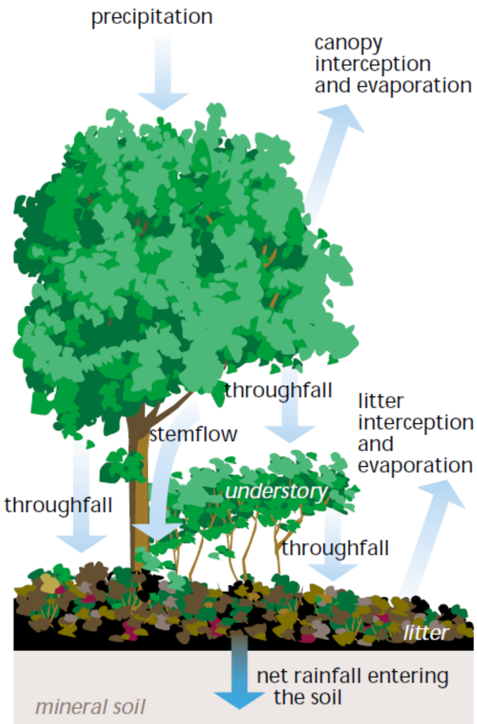


Figure 3.2: Typical pathways for forest rainfall. A portion of precipitation never reaches the ground because it is intercepted by vegetation and other surfaces (FISRWG 10/1998).

Although most hydrologic processes are described in terms of rainfall events (or storm events), snowmelt is also an important source of water, especially for rivers that originate in high mountain areas and for continental regions that experience seasonal cycles of snowfall and snowmelt. The type of precipitation that will occur is generally a factor of humidity and air temperature. Topographic relief and geographic location relative to large water bodies also affect the frequency and type of precipitation. Rainstorms occur more frequently along coastal and lowlatitude areas with moderate temperatures and low relief. Snowfalls occur more frequently at high elevations and in mid-latitude areas with colder seasonal temperatures.

Surface (and subsurface) water runoff in river catchments are parts of the hydrological cycle being active at global and local (catchment) scales and are the main part of precipitation that appears in surface streams. It is therefore water that plays the principle role in fashioning and modifying the fluvial landscape (Schumm 1977). But also groundwater and/or snow or glacial melt contribute to the river flow.

The following equation represents a common way of describing the water balance in a river catchment based on the conceptual model of the hydrological cycle

$$R\ (+S) = P - ET - \Delta S1 - \Delta S2$$

with R=surface runoff, S=subsurface runoff (water that infiltrates into the soil and moves below the surface contributing to the river discharge), P=precipitation, ET=evapotranspiration, ΔS1 = surface storage (surface interception at plants and land structures) and ΔS2 = subsurface storage (groundwater, soil moisture) (Gutknecht et al. 2008).

Energy and riverine landscapes

Fluvial landforms are produced by the power of water during different kinds of processes. To initiate such kind of processes, energy must be generated, and the subsequent work performed will in turn result in the dissipation of energy. The study of river energy is therefore critical as far as the study of fluvial geomorphology is concerned.

The potential energy rivers possess actually originates from the sun which evaporates water from the sea enabling its deposition at higher levels as precipitation over land.

A still body of water at any point above the sea level has a certain amount of stored energy as a result of its position. This is potential energy available to do work in the river channel. The kinetic energy of a river is caused by its movement and is derived from the potential energy. The amount of potential energy a river possesses depends on

- the amount of water present,
- and the vertical distance of water above base level.

The greater the amount of water and the higher the vertical distance, the more energy the river possesses.

Kinetic energy is generated by the flow of the river, which is actually using up the supply of potential energy. The amount of energy is determined by the

- volume of flowing water
- its mean velocity

in other words its discharge, and as discharge is derived by multiplying the volume and flow velocity of the flow; an increase in any of these will result in an increase in the amount of kinetic energy.

The energy a river possesses is used up when the river

- erodes its channel
- transports sediment load
- experiences frictional drag (along the channel bed and banks and between threads of water flowing at different speeds)

Discharge and energy

Rivers display considerable variations in energy from place to place and from time to time. This is mainly the result of variations in discharges. As described earlier, the energy a river possesses is determined by its discharge

$Q=A*V$

Where Q=discharge (m^3/s), A=cross sectional area of the river (in m^2) and V=the mean velocity (m/s).

The volume of water is important since an increase in the amount of water will mean a higher discharge and a more efficient river. This explains why floods can cause so much destruction to human property. The flow velocity is an additional important factor as a function of discharge. Factors influencing velocity are shown in Manning`s equation

$V= R^{2/3} * S^{1/2} / n$

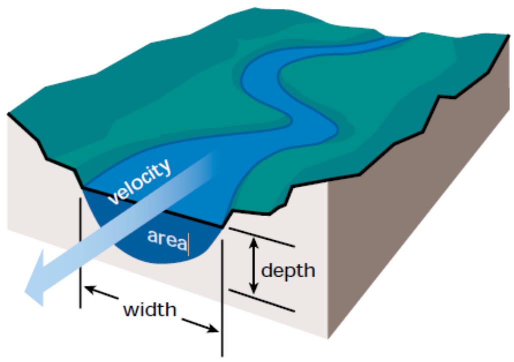


Figure 3.3: Cross section of a river to illustrate the parameters width, depth and the cross sectional area (FISRWG 10/1998).

Where V=velocity, R=hydraulic radius, S=channel slope and n= coefficient of roughness – the Manning 'n'. Tools to calculate velocity and discharge under varying conditions are available online[3].

[3] http://www.lmnoeng.com/manning.htm

Since stream flow is caused by the force of gravity, a change in the channel`s slope will affect the amount of energy the stream possesses. Channel roughness is another factor influencing velocity, described by the Manning`s coefficient of bed roughness (the higher the value the rougher the channel). Generally, from upstream to downstream, the channel bed roughness decreases as a result of river bed and banks made up by clay, sand instead of boulders. You can find the n values for the Manning equation in Chow (Chow 2009) and at the web[4]. Guidance for selecting the Manning`s n for natural rivers can be also found online[5].

With reference to Manning`s equation since S normally decreases in the downstream direction, V should logically also be lower with decreasing distance from source. However an increase in R and a decrease in n will compensate for the decrease in S. As a result the average stream velocity of rivers tends to increase or at least to remain constant, from upstream to downstream direction despite a decrease in slope (Fig. 3.4).

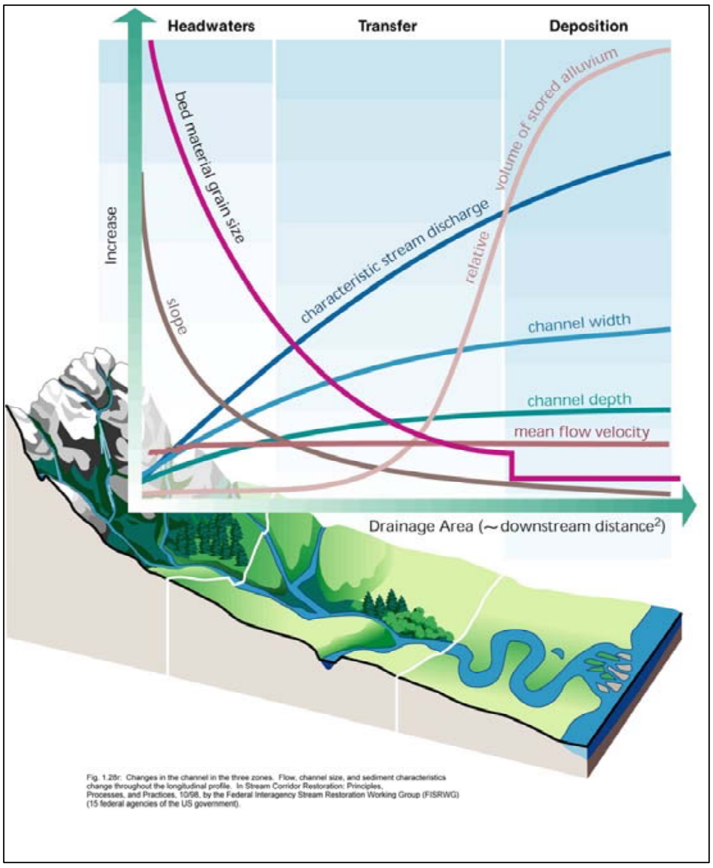


Figure 3.4: Channel changes along the longitudinal course of a river within three zones; flow, channel size and sediment characteristics change throughout the longitudinal profile (FISRWG 10/1998).

The hydraulic radius is the ratio between the area of the cross section of a river channel and the length of its wetted perimeter.

R=A/WP

Where R= hydraulic radius, A=cross sectional area, WP=wetted perimeter (the total length of the bed and bank sides in contact with the water channel). Fig. 3.5 shows two channels with the same cross sectional area but with different shapes and radii.

Stream A

- has a larger hydraulic radius because of a smaller wetter perimeter—i.e. a smaller amount of water is in contact with the bed and banks of the channel due to a more balanced width depth ratio
- this creates less friction which in turn reduces energy loss and allows greater velocity
- stream A is therefore said to be the more efficient of the two rivers

[4] http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm
[5] http://www.fhwa.dot.gov/bridge/wsp2339.pdf

Stream B

- **has a smaller hydraulic radius because of a larger wetted perimeter—i.e. a larger amount of water is in contact with the bed and banks of the channel due to a very large width-depth ratio**
- **this results in greater friction, more energy loss and reduced velocity**
- **stream B is therefore less efficient than stream A**

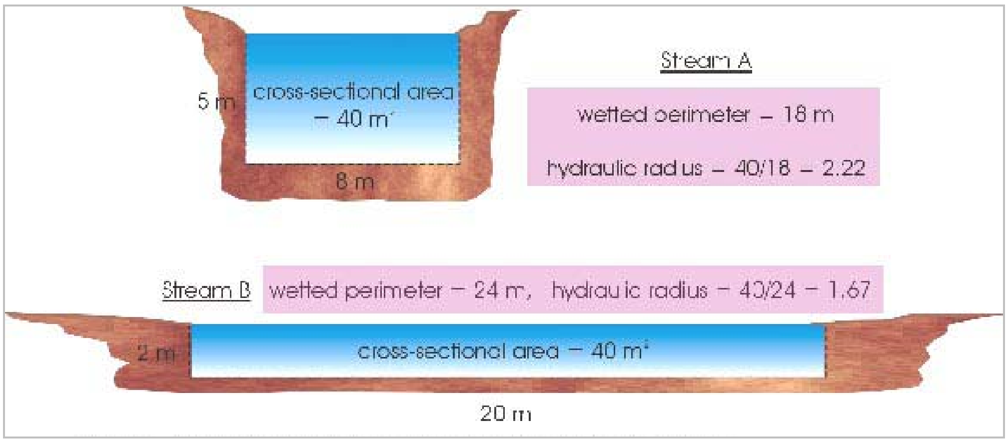


Figure 3.5: The wetted perimeter, hydraulic radius and efficiency of rivers (Tüysüz, year not indicated).

In fact, a semi circle is the ideal shape for the cross profile of a river channel creating the least friction on stream velocity.

Application: **To reduce the risk of floods urban drainage systems are often designed to get rid of storm run-off as fast a possible. Therefore these channels are usually straight, smooth and semi-circular in shape with very high R and low n values.**

Factors shaping riverine landscapes

Water and sediment regimes can be seen as major processes being active in natural river catchments (Calow und Petts 1992). The hydrologic regime and sediment regime therefore represent the basic processes (together with wood regime) shaping riverine landscapes and habitats, and finally the biodiversity along the longitudinal and lateral course of a river. At a landscape level these processes are influenced by vegetation, physiography (including geomorphology), and climate (Fig. 3.6) and the shape of a channel is a function of the flow, the quantity and character of sediment in motion, and the character and/or composition of the material (including vegetation) that make up the bed and banks of the channel (Leopold 1994). For the management of river ecosystems it is crucial to understand theses key variables and their linkages for example in relation to changes in land use, but also global change issues.

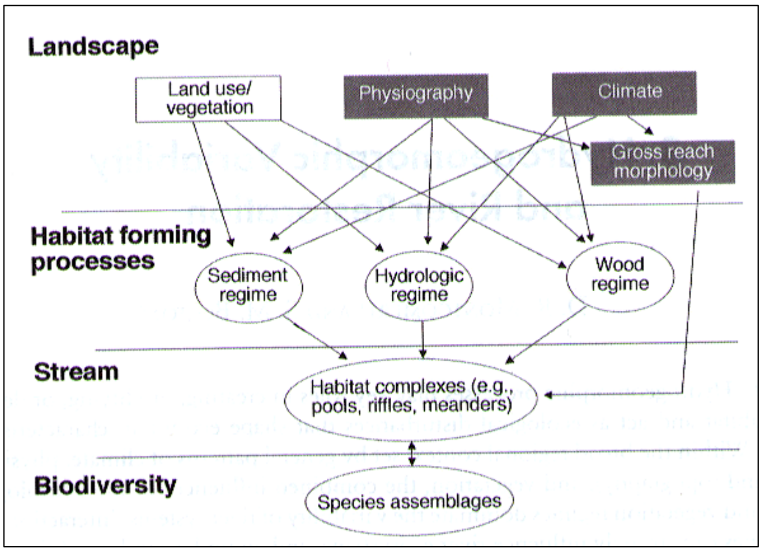


Figure 3.6: Simplified schematic diagram of linkages between controls on watershed processes. The shaded boxes indicate those controls that are not directly affected by land use (Montgomery und Bolton 2003).

Geomorphic processes

Three primary geomorphic processes are involved with flowing water, as follows:

- Erosion, the detachment of soil particles.
- Sediment transport, the movement of eroded soil particles in flowing water.
- Sediment deposition, settling of eroded soil particles to the bottom of a water body or left behind as water leaves. Sediment deposition can be transitory, as in a stream channel from one storm to another, or more or less permanent, as in a larger reservoir.

Sediment Transport Terminology

Sediment transport terminology can sometimes be confusing. Because of this confusion, it is important to define some of the more frequently used terms.

- Sediment load, the quantity of sediment that is carried past any cross-section of a stream in a specified period of time, usually a day or a year.
- Sediment discharge, the mass or volume of sediment passing a stream cross section in a unit of time. Typical units for sediment load are tons, while sediment discharge units are tons per day.
- Bed-material load, part of the total sediment discharge that is composed of sediment particles that are the same size as streambed sediment.
- Wash load, part of the total sediment load that is comprised of particle sizes finer than those found in the streambed.
- Bed load, portion of the total sediment load that moves on or near the streambed by saltation, rolling, or sliding in the bed layer.
- Suspended bed material load, portion of the bed material load that is transported in suspension in the water column. The suspended bed material load and the bed load comprise the total bed material load.
- Suspended sediment discharge (or suspended load), portion of the total sediment load that is transported in suspension by turbulent fluctuations within the body of flowing water.
- Measured load, portion of the total sediment load that is obtained by the sampler in the sampling zone.
- Unmeasured load, portion of the total sediment load that passes beneath the sampler, both in suspension and on the bed. With typical suspended sediment samplers this is the lower 0.3 to 0.4 feet of the vertical.

The total sediment load is correctly defined by the combination of the following terms:

Total Sediment Load = Bed Material Load + Wash Load or Bed Load + Suspended Load or Measured Load + Unmeasured Load

Sediment transport rates can be computed using various equations or models.

Discharge Regime

Discharge is the term used to describe the volume of water moving down the channel per unit time. The basic unit of measurement used in Europe to describe discharge is cubic meter per second (m^3/s). Discharge is calculated as:

Q = A*V

where Q = Discharge (m^3/s), A = Area through which the water is flowing in m^2, V = Average velocity in the downstream direction in m per second.

As discussed earlier, streamflow is one of the variables that determine the size and shape of the channel. There are three types of characteristic discharges:

- **Channel-forming (or dominant) discharge: If the streamflow were held constant at the channel-forming discharge, it would result in channel morphology close to the existing channel. However, there is no method for directly calculating channel-forming discharge. An estimate of channel-forming discharge for a particular stream reach can, with some qualifications, be related to depth, width, and shape of channel. Although channel-forming discharges are strictly applicable only to channels in equilibrium, the concept can be used to select appropriate channel geometry for restoring a disturbed reach.**
- **Effective discharge: The effective discharge is the calculated measure of channel-forming discharge. Computation of effective discharge requires long-term water and sediment measurements, either for the stream in question or for one very similar. Since this type of data is not often available for stream restoration sites, modeled or computed data are sometimes substituted. Effective discharge can be computed for either stable or evolving channels.**
- **Bankfull discharge: This discharge occurs when water begins to leave the channel and spread onto the floodplain. Bankfull discharge is equivalent to channel-forming (conceptual) and effective (calculated) discharge (Fig. 3.7).**

Figure 3.7: Bankfull discharge. This is the flow at which water begins to leave the channel and move onto the floodplain (FISRWG 10/1998).

Channel formation

Channels are formed, maintained, and altered by the water and sediment they carry. The channel size is determined by four basic factors:

- **Sediment discharge (Qs)**
- **Sediment particle size (D50)**
- **Streamflow (Qw)**
- **Stream slope (S)**

Lane (1955) showed this relationship quantitatively as Qs*D50 $\propto$ Qw*S. This equation can be envisioned as a balance with sediment load on one weighting pan and streamflow on the other (Fig. 3.8). The hook holding the sediment pan can slide along the horizontal arm according to sediment size. The hook holding the streamflow side slides according to stream slope.

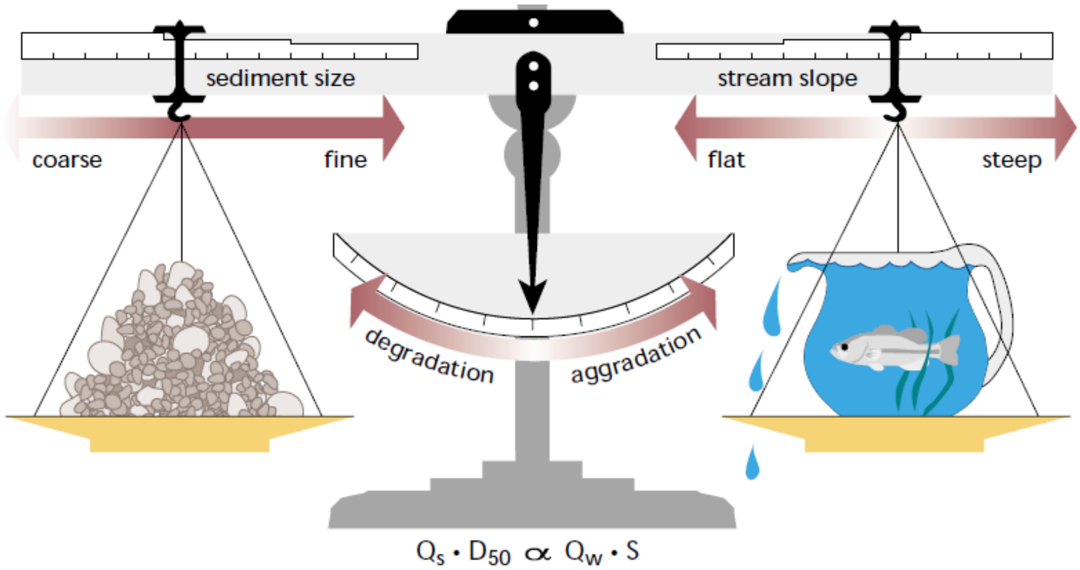


Figure 3.8: Factors affecting channel equilibrium; at equilibrium, slope and flow balance the size and quantity of sediment (FISRWG 10/1998).

Channel equilibrium occurs when all four variables are in balance. If a change occurs, the balance will temporarily be tipped and equilibrium lost. If one variable changes, one or more of the other variables must increase or decrease proportionally if equilibrium is to be maintained.

For example, if slope is increased and streamflow remains the same, either the sediment load or the size of the particles must also increase. Likewise, if flow is increased (e.g., by an interbasin transfer) and the slope stays the same, sediment load or sediment particle size has to increase to maintain channel equilibrium. A stream seeking a new equilibrium tends to erode more sediment that has larger particle size.

Alluvial streams that are free to adjust to changes in these four variables generally do so and reestablish new equilibrium conditions. Non-alluvial streams such as bedrock or artificial, concrete channels are unable to follow Lane's relationship because of their inability to adjust the sediment size and quantity variables. The stream balance equation is useful for making qualitative predictions concerning channel impacts due to changes in runoff or sediment loads from the watershed. Quantitative predictions, however, require the use of more complex equations. Sediment transport equations, for example, are used to compare sediment load and energy in the stream. If excess energy is left over after the load is moved, channel adjustment occurs as the stream picks up more load by eroding its banks or scouring its bed. No matter how much complexity is built into these and other equations of this type, however, they all relate back to the basic balance relationships described by Lane.

Changes in the amount and nature of sediment load downstream

The amount of sediment load increases downstream because of

- contribution by tributaries, and

- continued feeding in of weathered material from the valley sides.

The size of the individual sediment particles tends to become more rounded and of finer calibre in a downstream direction due to (1) attrition, and due to (2) gentler valleyside slopes only being able to deliver material of finer calibre to the river channel.

Deposition of sediment takes place when the river becomes incompetent either because

- there is a sudden input which in effect overloads the river, or because
- there is a loss of energy

When the river no longer has the competence or capacity to carry its entire load, deposition will occur. So starting with the largest particles, material begins to get deposited. Deposition occurs where

- a river broadens out and therefore has a larger wetted perimeter which, assuming the volume of water remains constant, results in increased friction and a reduction of velocity,
- a river enters the sea or a lake and therefore velocity is lessened (due to a sharp change in gradient)
- discharge is reduced following a period of low precipitation or when excessive
- percolation takes place (as is common in deserts),
- the river is shallower on the outside of a meander (i.e. the convex bank), or
- the load is suddenly increased, e.g. by debris from a landslide

River Self Regulation

Rivers are open systems—systems that receive inputs of matter and energy from its environment and produces outputs that return to the environment. They

- are sustained by inputs of
    - water (from precipitation, slope run-off and springs), and
    - sediments (from slope weathering and channel erosion),
- experience outputs of
    - water (into lakes or seas) and
    - sediments (by channel deposition and the formation of deltas)

Such systems have the capability to achieve a steady state/dynamic equilibrium where the inputs and outputs are balanced. This also can be related to the concept of entropy as an important factor of landscape evolution (Leopold und Langbein 1962).

There is therefore no tendency for progressive long-term change to occur. However, if any of these is disturbed (e.g. when sediment input increases or discharge decreases), the state of equilibrium will be upset and the river will have to try to re-establish equilibrium by self-regulation.

For example

- when there is an increased sediment input (such as from the valley slopes after mass movement, Fig. 3.9)
    - the river will try to re-establish equilibrium by changing its channel slope
    - for instance, since a greater energy is needed to transport this increased sediment load, it will deposit part of the load (Figure 3) this will result in an increase in the river slope

and velocity downstream from the site of the deposition, which will in turn lead to an increase in the river energy for the transport of the extra load

- when there is an increase in the water input (e.g. due to climatic changes)
    - o the river will erode its banks so that the development of a very wide and shallow channel will increase the wetted perimeter
    - o this will in turn cause a decrease in the hydraulic radius and velocity of the river leading to the formation of an inefficient river
    - o in this way, the increase in stream energy from the increased discharge will be offset

It is through these self-regulation mechanisms that rivers are able to achieve a state of equilibrium and this is reflected in the way the rivers' long profile adjusts to changes in discharge, sediment and channel characteristics in the downstream direction.

When the total energy of the river is just sufficient to transport its water content and its load of sediment, the river is said to be in equilibrium.

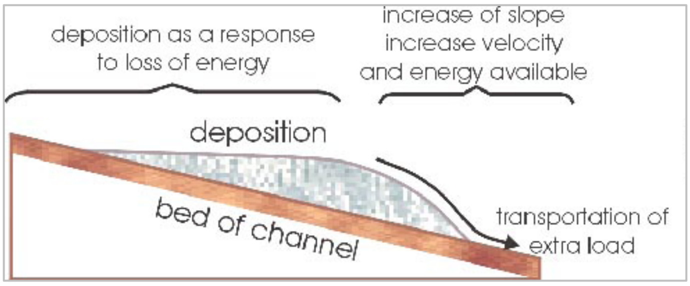


Figure 3.9: River self-adjustion to an increased sediment load (Tüysüz, year not indicated).

Different morphological river types

Depending on the described natural conditions, e.g. slope, discharge, valley width and form, sediment supply, rivers develop certain forms of appearance of the water transporting channel(s) itself and also of their floodplains. These forms are classified in Functional Process Zones (FPZ), e.g. gorge zone, anabranching zone, braided zone or meandering zone (Thorp et al. 2008) (Fig. 3.10). Gorges (=straight channel) are deep, narrow valley sections of a river dominated by steep bed slopes, in which the valley sides are nearly vertical and the river channel occupies the entire valley floor. The three other 'end-member' fluvial styles, already mentioned in the text above, are:

- Braided River systems
- Meandering River systems
- Anastomosed River systems

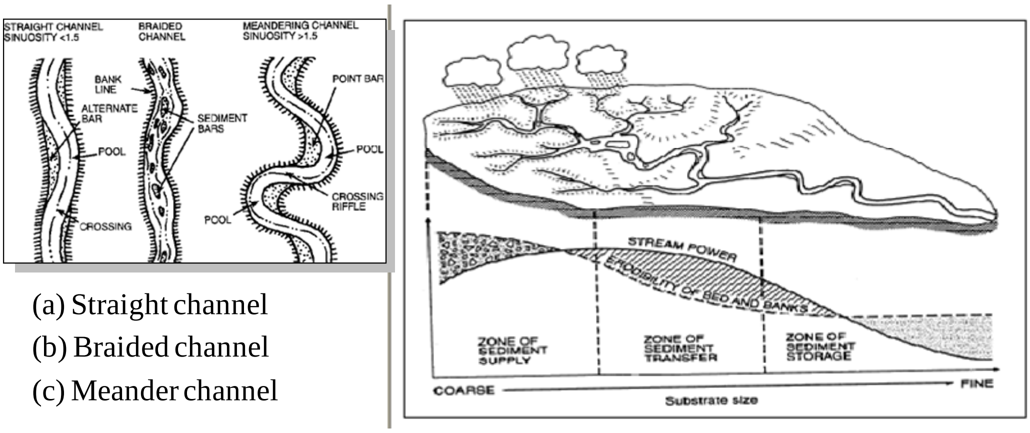
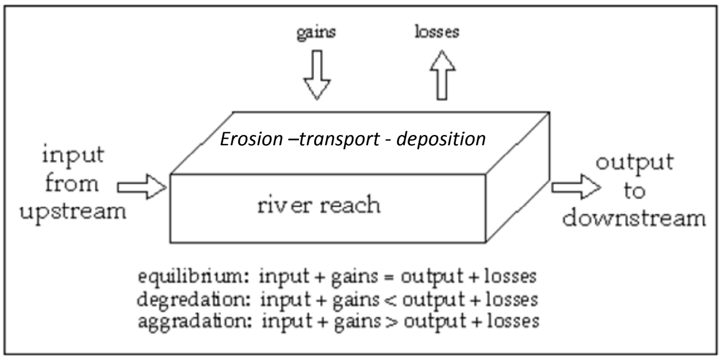


Figure 3.10: Broad functional zone types within a river system. After Schumm (1988) (Parsons et al. 2002).

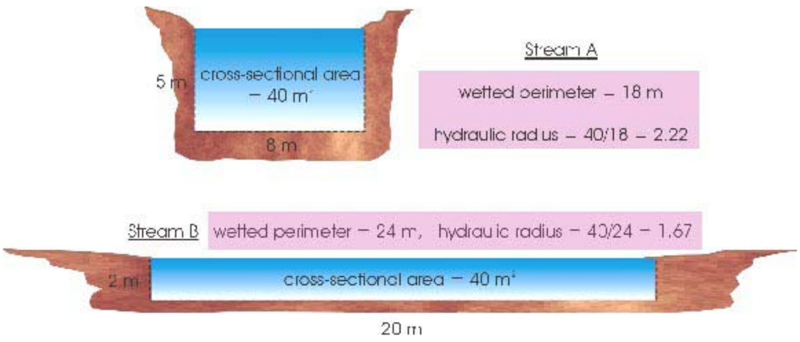
3.2.2. Key themes

1) **Sediment regime**

   a. **Sediment budget of a river reach based on sediment input and output and the effect of imbalance on erosion and aggradation (Figure below from: Brady et al. 1998).**



   b. **The causal effect of changed river channel shape (river bed widening) on sediment transport, following the idea of increased friction due to increased contact area of the water with the river bed with a subsequent decrease of sediment transport capacity of a river due to lowered flow velocities (Figure below from: Tüysüz, year not indicated).**



Stream A

- **has a larger hydraulic radius because of a smaller wetter perimeter—i.e. a smaller amount of water is in contact with the bed and banks of the channel due to a more balanced width depth ratio**
- **this creates less friction which in turn reduces energy loss and allows greater velocity**
- **stream A is therefore said to be the more efficient of the two rivers**

Stream B

- **has a smaller hydraulic radius because of a larger wetted perimeter—i.e. a larger amount of water is in contact with the bed and banks of the channel due to a very large width-depth ratio**
- **this results in greater friction, more energy loss and reduced velocity**
- **stream B is therefore less efficient than stream A**

2) **Which factors influence river discharge and flooding during a precipitation event?**

This model follows the general formula R (+S)=P – ET – ΔS1 – ΔS2 with R=surface runoff, S=subsurface runoff (water that infiltrates into the soil and moves below the surface; contributes to the river discharge), P=precipitation, ET=evapotranspiration, ΔS1 = surface storage (surface interception at plants and land structures) and ΔS2 = subsurface storage (groundwater, soil moisture) to show the effect of different factors on surface runoff and river discharge following a precipitation event including the principle of “bankfull” river discharge and natural flooding.

3.3. Sediment transport_LS2.hgp

3.3.1. Concepts and goals

Content

- To show the effect of sediment input and output on the sediment balance in a river reach and therefore the development of the height of the river bottom.
- To show the effect of imbalances in the sediment budget on the height of the river bottom.

Modelling

- To introduce the principle of inequality statements.
- To stimulate the discussion on the factors that might in/decrease the sediment input, and which abiotic and biotic effects might be related.

The entities and quantities as well as quantity spaces are summarised in Table 3.1.

Table 3.1: Entities, quantities and quantity spaces (QSs) used in the model Sediment transport_LS2.hgp.

Entity	*Quantity*	*QS*	*Remarks*
River reach	Sediment input rate	zp	zero, plus
	Sediment output rate	zp	zero, plus
	Amount of sediment in river reach	zlah	zero, low, average, high
	Height of river bottom	zlah	zero, low, average, high

3.3.2. Model expression

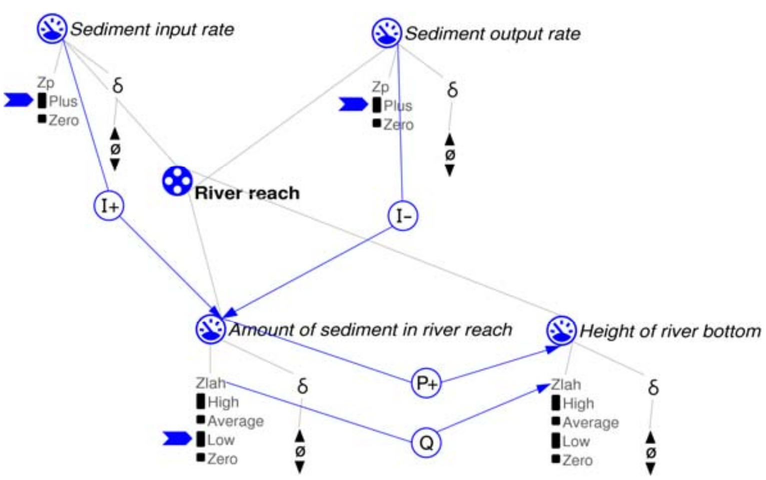


Figure 3.11: Model expression for Sediment transport_LS2.hgp.

3.3.3. Scenarios and simulations

Without a specific inequality statement the simulation shows all potential behaviours of the system with four different end states. Putting an inequality statement between the two rates limits the behaviour of the simulation path in one direction.

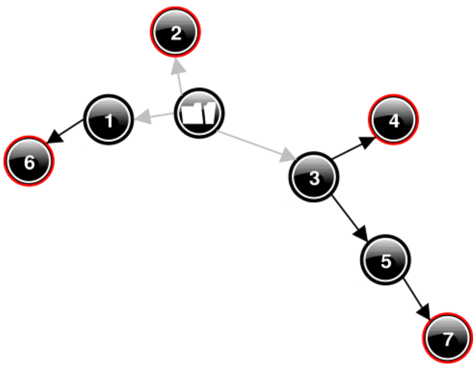


Figure 3.12: Behaviour path of the model Sediment transport_LS2.hgp.

Table 3.2: Scenario information – causes and conditions.

Type	Details
Exogenous control	Sediment input and sediment output rates
(In)equality	To be set
Ambiguity	None

3.4. Sediment budget_river widening_LS4.hgp

3.4.1. Concepts and goals

Content

- **To show the causal chain related to effect of river bed widening on sediment transport capacity of a river.**
- **To stimulate discussion which other factors influence the stream power and sediment transport capacity.**
- **To stimulate the discussion of the effects of river channelization on abiotic and biotic components of a river.**
- **To discuss the idea of river bed degradation.**
- **To discuss the idea of an equilibrium state of a river with regard to sediment transport.**
- **To discuss options of sediment management in rivers to maintain an equilibrium, as all changes in the sediment budget lead to subsequent changes of the abiotic conditions and therefore also to effects on the biological components of a river.**

Modelling

- **To introduce quantity spaces, the idea to use calculations to trigger a rate of change, the use of I`s and P´s to describe rates and state variables.**

Assumptions

- **The discharge as second parameter contributing to the sediment transport capacity is not modelled and assumed to be constant.**
- **Sediment delivery is constant and set to average**

The entities and quantities used in this model, together with their quantity spaces are summarised in Table 3.3.

Table 3.3: Entities, quantities and quantity spaces (QSs) used in the model Sediment budget_river widening_LS4.hgp.

Entity	*Quantity*	*QS*	*Remarks*
Riverbed widening	Widening rate	zp	zero, plus
River reach	Contact area with river bed	zlahm	zero, low, average, high, maximum
	Friction	zlahm	zero, low, average, high, maximum
	Flow velocity	zlahm	zero, low, average, high, maximum
	Transport capacity	zlahm	zero, low, average, high, maximum
	Amount of sediment in	zlahm	zero, low, average, high, maximum
	Amount of sediment out	zlahm	zero, low, average, high, maximum
		zlahm	zero, low average, high, maximum
	River bed development rate	mzp	minus, zero, plus (Aggradation=plus and degradation=minus)
	Height of river bed	zlahm	zero, low average, high, maximum

3.4.2. Model expression

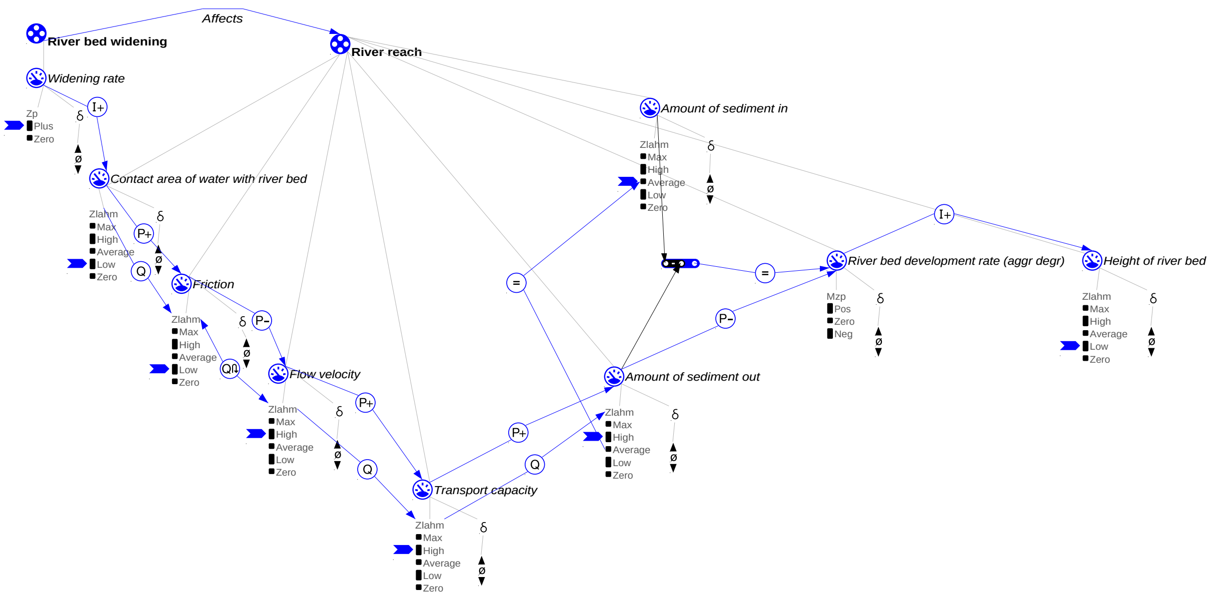


Figure 3.13: Model expression for Sediment budget_river widening_LS4.hgp.

3.4.3. Scenarios and simulations

The simulation shows how river bed widening (expressed as a widening rate) increases the contact area of the water with the river bed, which increases friction and decreases the flow velocity and sediment transport capacity at a given river reach. Due to the reduced transport capacity of the river, the sediment output decreases leading to a positive river bed development rate, which finally increases the height of the river bed.

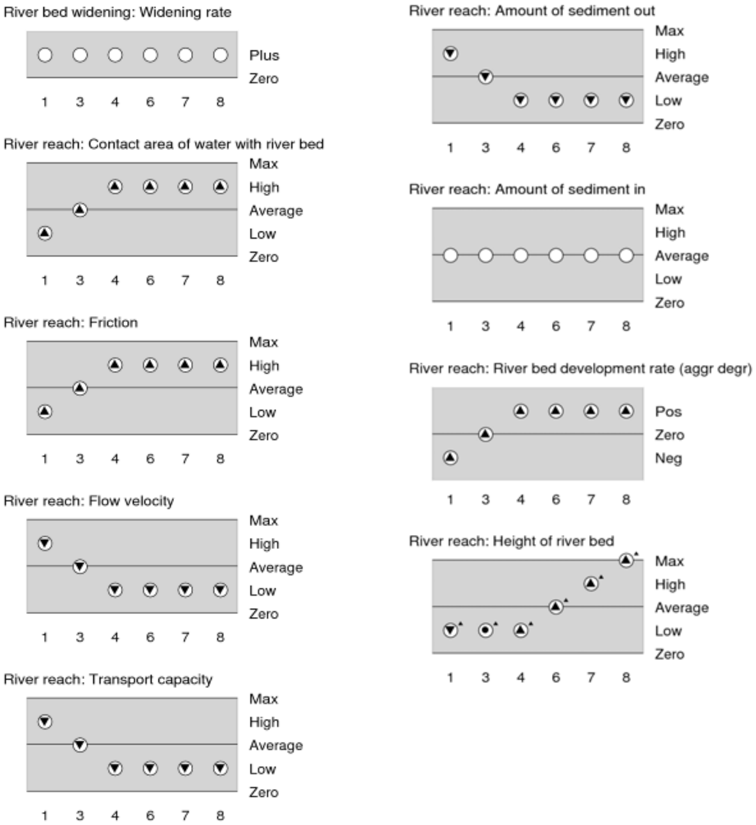


Figure 3.26: Value history for the full simulation of Sediment budget_river widening_LS4.hgp.

Table 3.4: Scenario information – causes and conditions for simulating Sediment budget_river widening_LS4.hgp.

Type	Details
Exogenous control	River widening rate
(In)equality	None
Ambiguity	Yes, there is a second simulation path (1-2-5-4-6-7-8)

3.5. Precipitation and flooding_LS5.hgp

3.5.1. Concepts and goals

Content

- **To stimulate the discussion which sources of water contribute to river flow during floods.**
- **To show the effect of storage, interception and evapotranspiration capacity of a catchment on the occurrence of flooding related to the amount of precipitated water.**
- **To show how flooding is related to the maximum or bankfull discharge of a river bed.**

Modelling

- **To introduce conditional statements.**
- **To discuss the phenomenon of non-linear events.**

Assumptions

- **The base flow of the river stems form groundwater discharge, which is not explicitly modelled.**

The entities, quantities and quantity spaces used in this model are summarised in Table 3.5.

Table 3.5: Entities, quantities and quantity spaces (QSs) used in the model Precipitation and flooding_LS5.hgp

Entity	*Quantity*	*QS*	*Remarks*
Rain	Precipitation rate	zp	zero, plus
Catchment	Amount of precipitated water	zlah	zero, low, average, high
	Storage interception and evapotranspiration capacity	zlah	zero, low average, high
	Surface and subsurface runoff rate	mzp	minus, zero, plus
	Water delivery rate from surface and subsurface runoff	zp	zero, plus
Water in river	Amount of water in river	Zlahmo	zero, low, average, high, maximum, overflow
Floodplain	Flooding rate	zp	zero, plus
	Amount of flooded area	zlah	zero, low average, high

3.5.2. Model expression

Expression

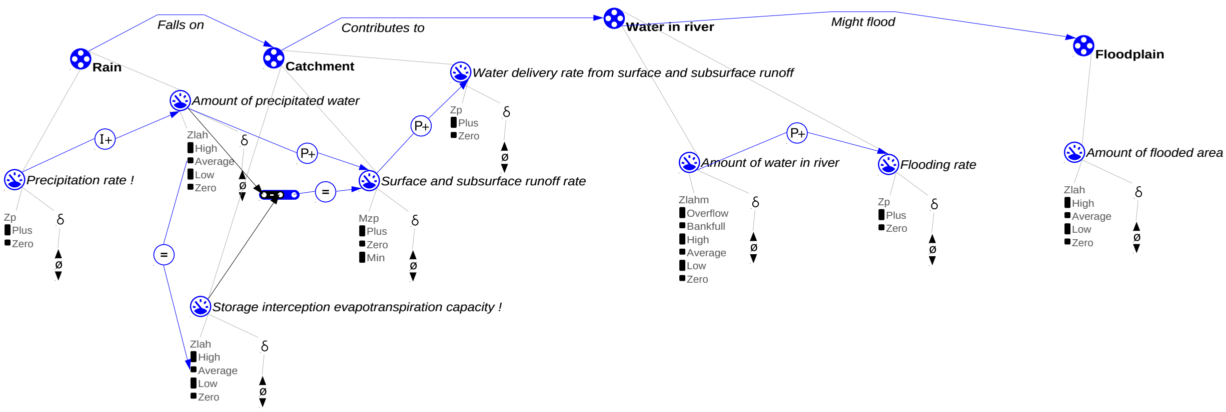


Figure 3.14: Model expression for Precipitation and flooding_LS5.hgp.

Initial values

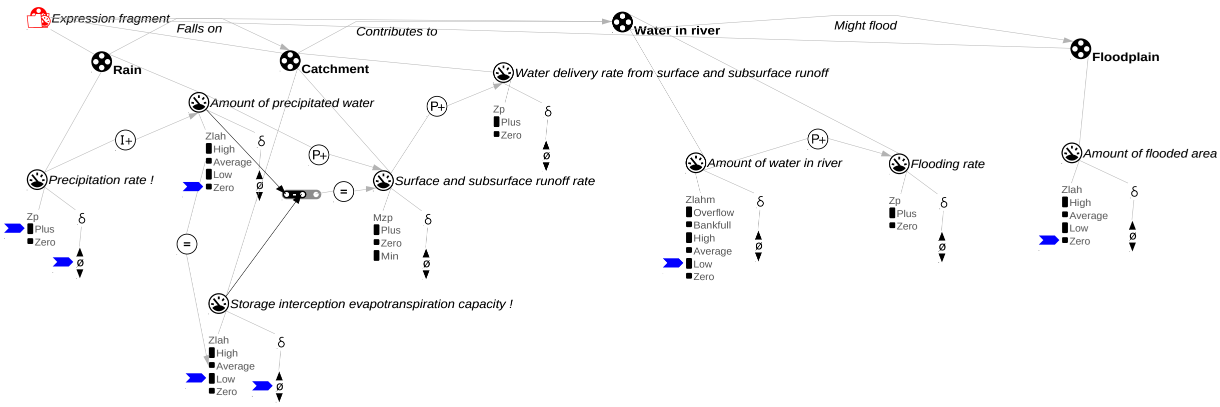


Figure 3.15: Initial values of Precipitation and flooding_LS5.hgp.

As the model is implemented in LS 5 there are two conditional statements implemented:

Amount of water in river bed is higher than bankfull and flooding rate is set to plus
Amount of precipitated water exceeds storage capacity why water delivery rate from surface and subsurface runoff ist set to plus

These statements trigger the delivery of water by surface and subsurface runoff when the storage capacity of the catchment is exceeded by setting the water delivery rate from surface and subsurface runoff to the river to plus. Secondly, when the bankfull stage of the river is reached, the flooding rate is set to plus.

Amount of precipitated water exceeds storage capacity why water delivery rate from surface and subsurface runoff is set to plus

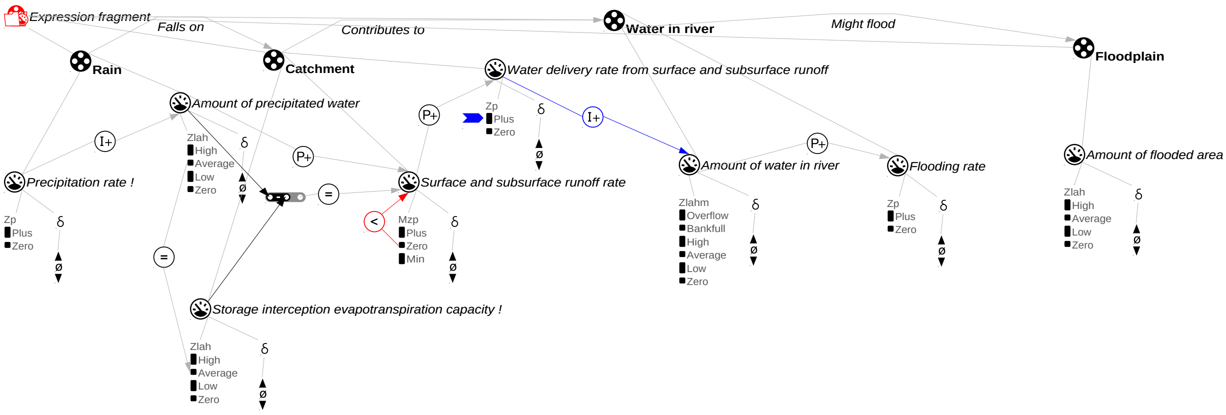


Figure 3.16: Conditional statement of Precipitation and flooding_LS5.hgp.

Amount of water in river bed is higher than bankfull and flooding rate is set to plus

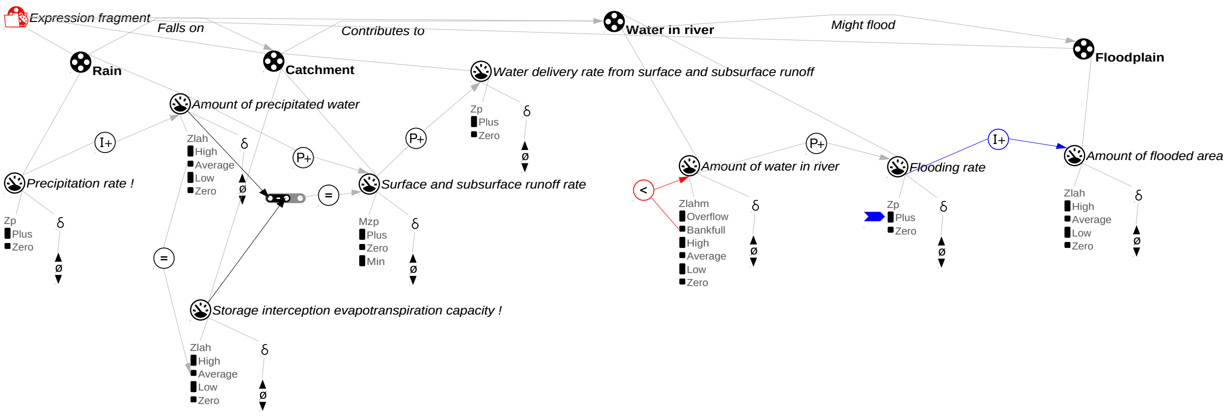


Figure 3.17: Conditional statement of Precipitation and flooding_LS5.hgp.

3.5.3. Scenarios and simulations

The simulation, that should to be run with the simulation preferences shown below shows that the water delivery to the river via surface and subsurface flow starts when the storage, interception and evapotranspiration capacity of the catchment is exceeded.
The water in the river then starts to increase, and at bankfull discharge flooding occurs (flooding rate is set to plus). As the precipitation is still ongoing and the water in the river is still increasing, the amount of flooded area increases as long as it is high and still increasing.

The model structure allows for changes in the storage capacity of the catchment, which allows exploring the question, which factors contribute to the storage capacity of a catchment.

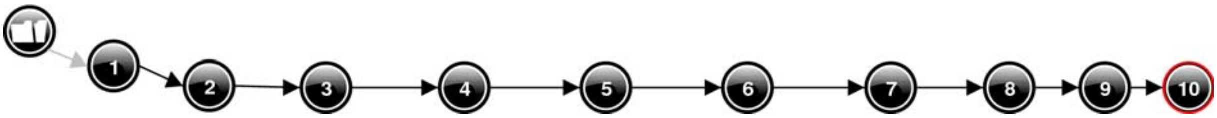


Figure 3.18: Behaviour path of Precipitation and flooding_LS5.hgp.

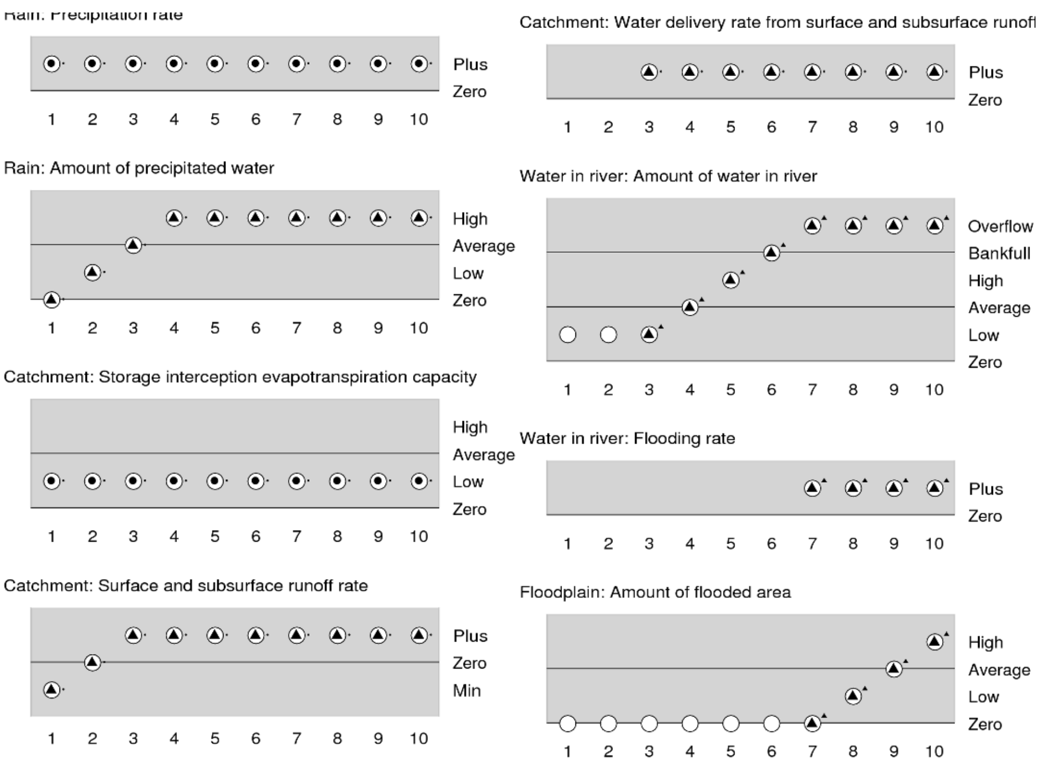


Figure 3.19: Value history for the full simulation of Precipitation and flooding_LS5.hgp.

Table 3.6: Scenario information – causes and conditions for simulating Precipitation and flooding_LS5.hgp.

Type	Details
Exogenous control	Precipitation rate
(In)equality	None
Ambiguity	Yes, see simulation preferences (coming from epsilon ordering)

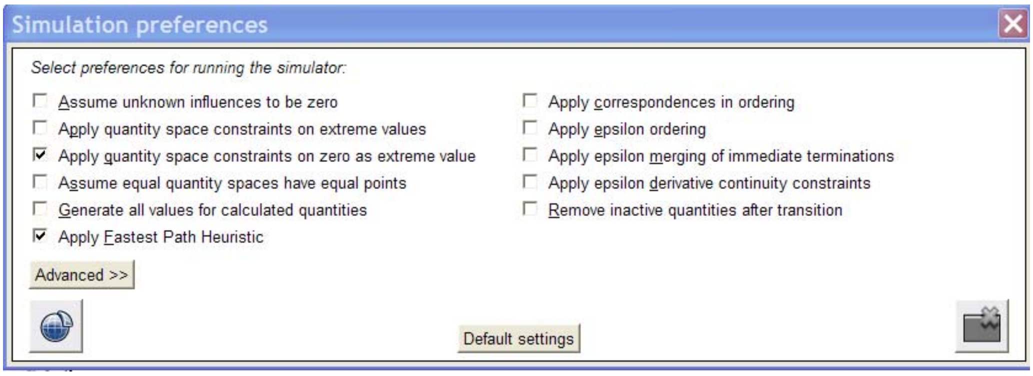


Figure 3.20: Simulation preferences for simulating Precipitation and flooding_LS5.hgp.

3.6. Conclusion of the topic

3.6.1. Planned improvements

The planned enhancement for these models in the next period will deal with a more detailed description of the development of different river types in relation to different abiotic factors, especially water and sediment transport. These models then describe the circumstances under which a specific river type or "functional" process zone develops and serve as a basis for a better management of rivers and the development of adequate river restoration measures given the limitations and already changed processes in human dominated riverine landscapes..

3.6.2. Links to other models

This model links to

- **flood protection,**
- **management models, providing basic knowledge for the understanding and management of river ecosystems,**
- **the hydrological cycle,**
- **river continuum concept,**
- **energy production and consumption.**

4. Populations

4.1. Topic and model metadata

Topic	**Populations**		
Author(s)	**Andreas Zitek**	**Version(s)**	**Final draft 03/07/10** **DynaLearn 0.6.8(CM)**
Model files	**BOKU_LW_Population_LS 2.hgp** **BOKU_LW_population_LS 4.hgp**		
Target users	**Secondary school students, bachelor students**		

4.2. Topic rationale

4.2.1. Background

Populations constitute the basic organisational level for environmental studies. Understanding organisms' vital processes (natality and mortality), their movements (immigration and emigration), environmental factors that regulate their growth processes, their reproductive strategies (r and K) and density dependency are important aspects to be explored in a curriculum for environmental science.

"A population is a group of individuals that belong to a single species and live in some defined area. Ecologists strive to understand the causes of variation in the sizes of populations and to predict trends in these numbers over time and from place to place. A population increases in size by births and the immigration of individuals into the population from outside. Deaths and emigration decrease population size. These inputs and outputs can be set up as an equation where the subscript t indicates a discrete point in time. The population at time t+1 is N_{t+1} and its size given by $N_{t+1} = N_t$ + births – deaths + immigration – emigration. The births, deaths, immigration and emigration in this equation are those that occurred during the time interval between t and t+1" **(Case, 2000). Figure 4.1 summarizes these flows.**

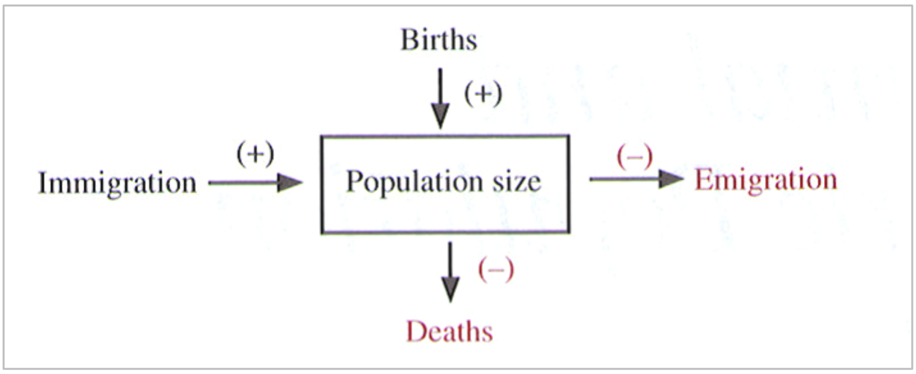


Fig. 4.1: General factors increasing (+) and decreasing (-) population size (Akcakaya et al., 1999).

4.2.2. Key themes

Key themes to be represented in the models are the effect of birth, death, immigration and emigration on the size of a population. Furthermore, the effects of habitat changes on different factors relevant for fish populations (habitat quality, carrying capacity, births, and deaths) are explored.

4.3. BOKU_LW_Population_LS 2.hgp

4.3.1. Concepts and goals

Content

- **To develop the understanding of basic population processes and their effects on population size**
- **To understand the concept of carrying capacity as another factor influencing populations**

Modelling

- **The use of positive and negative causal relations.**

Assumptions

- **Births, deaths, immigration and emigration are seen only influenced by habitat quality, with e.g. no feedback from population size to births and deaths. It is assumed that habitat quality reduces deaths and increases births and has also an effect on immigration because of its increased attraction for fish. It is also assumed that habitat quality has a negative effect on emigration as fish tend to stay in the restored sections.**
- **If one wants to model the effect of a restored river section on down and upstream situated sites, a positive effect of habitat quality on emigration to neighboured habitats can be assumed.**

Table 4.1: Entities, quantities and quantity spaces (QS) used in the model BOKU_LW_Population_LS 2.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Human	Habitat change rate		Describes the increase of habitat quality by restoration efforts, and the decrease of quality due to habitat destructive human activities
River	Habitat quality		
	Carrying capacity		Carrying capacity refers to the number of individuals who can be supported in a given area within natural resource limits.
Fish population	Population size		
	Births		
	Deaths		
	Immigration		
	Emigration		

4.3.2. Model expression

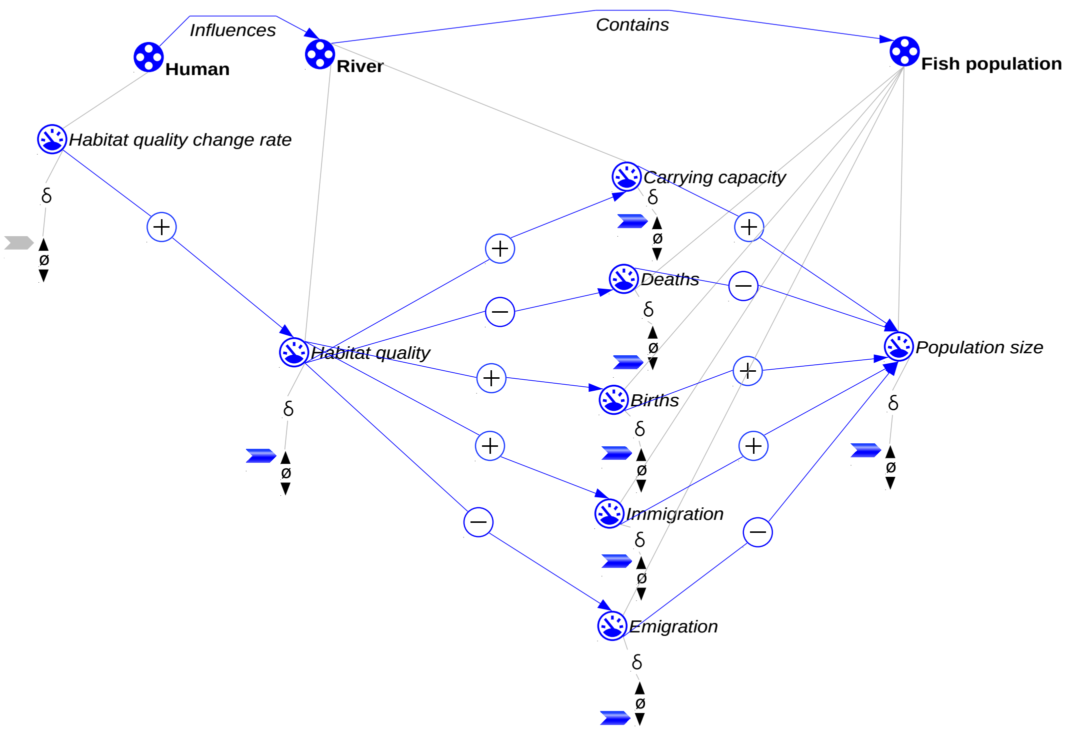


Figure 4.2: Model expression for BOKU_LW_Population_LS 2.hgp.

4.3.3. Scenarios and simulations

A positive habitat quality change rate, representing habitat restoration, increases the habitat quality which positively influences carrying capacity, births and immigration, and negatively influences deaths and emigration.

4.4. BOKU_LW_population_LS 4.hgp

4.4.1. Concepts and goals

The idea behind this generic population model is to show the combined influence of birth (B), death (D), immigration (I) and emigration (E) on populations. Thereby B+I represents the inflow to the population and D+E represents the outflow of the population. Depending on which factor is bigger a given population can increase or must decrease. Due to the structure of this model, other factors contributing to the in- and outflow of a population (like stocking, fishing) can be easily included. Habitat limitation and the concept of carrying capacity are not represented in this model.

Content

- To understand the combined effects of birth (B), death (D), immigration (I) and emigration (E) on populations.
- To learn to judge, under which conditions the relationship between in- and outflow might change.
- The model should stimulate the discussion about which additional factors, like carrying capacity, food availability and density, also might influence the size of a given population. These discussions form the basis for the development of more advanced models.

Modelling

- To introduce inequality statements, the use of I`s and P´s to describe rates and state variables.

Assumptions

- No other factors like carrying capacity or competition influence the population development process.

Table 4.2: Entities, quantities and quantity spaces (QS) used in the model BOKU_LW_Population_LS 4.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Population	Birth rate	zp	zero, plus
	Death rate	zp	
	Immigration	zp	
	Emigration	zp	
	Inflow	zp	
	Outflow	zp	
	Population size	zsmh	zero, small, medium, high
	Biomass	zlah	zero, low, average, high

4.4.2. Model expression

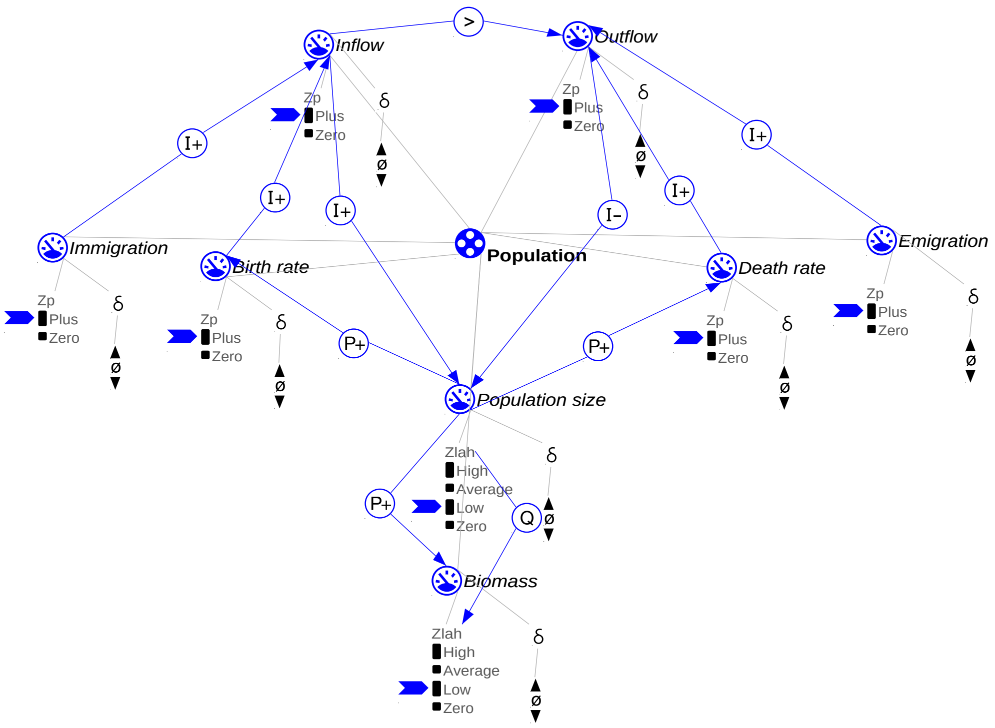


Figure 4.3: Model expression for BOKU_LW_Population_LS 4.hgp.

4.4.3. Scenarios and simulations

Immigration, emigration, birth and death are active, acting positively on the in- and outflow of a given population. When inflow is bigger than outflow, the population can grow from a small population size to a large one.

By simply making the outflow bigger than the inflow, it can be shown how a large population decreases, with the possibility to include factors like overfishing.

Table 4.3: Scenario information – causes and conditions

Type	Details
Exogenous control	Immigration, birth, emigration, death
(In)equality	inflow > outflow, inflow=outflow, inflow < outflow
Ambiguity	none

4.5. Conclusion of the topic

4.5.1. Planned improvements

- **To include the effects of other factors on population size like carrying capacity, nutrition, competition on population size.**
- **To show, how the restoration of connectivity and habitat in riverine systems affect fish populations due the re-establishment of lost functions of rivers.**

4.5.2. Link to other models

This model links especially to management models, providing basic knowledge for the understanding and management of river ecosystems.

5. The River Continuum Concept

5.1. Topic and model metadata

Topic	Education		
Author(s)	Andreas Zitek	Version(s)	Final draft 25/07/10 DynaLearn 0.6.11(CM)
Model files	BOKU_river continuum towards headwater stream_LS2.hgp BOKU_river continuum from headwater towards midwater stream_LS2.hgp BOKU_large floodplain river_LS2.hgp BOKU_RCC_LS5.hgp		
Target users	Secondary school students, bachelor students		

5.2. Topic rationale

5.2.1. Background

"The River Continuum Concept (RCC) is an attempt to generalize and explain longitudinal changes in stream ecosystems (Fig. 5.1) (Vannote et al. 1980).
This conceptual model not only helps to identify connections between the watershed, floodplain, and stream systems, but it also describes how biological communities develop and change from the headwaters to the mouth. The River Continuum Concept can place a site or reach in context within a larger watershed or landscape and thus help practitioners define and focus restoration goals.

The River Continuum Concept hypothesizes that many first- to third-order headwater streams are shaded by the riparian forest canopy. This shading, in turn, limits the growth of algae, periphyton, and other aquatic plants. Since energy cannot be created through photosynthesis (autotrophic production), the aquatic biota in these small streams is dependent on allochthonous materials (i.e., materials coming from outside the channel such as leaves and twigs). Biological communities are uniquely adapted to use externally derived organic inputs. Consequently, these headwater streams are considered heterotrophic (i.e., dependent on the energy produced in the surrounding watershed). Temperature regimes are also relatively stable due to the influence of ground water recharge, which tends to reduce biological diversity to those species with relatively narrow thermal niches.

Predictable changes occur as one proceeds downstream to fourth-, fifth-, and sixth-order streams. The channel widens, which increases the amount of incident sunlight and average temperatures. Levels of primary production increase in response to increases in light, which shifts many streams to a dependence on autochthonous materials (i.e., materials coming from inside the channel), or internal autotrophic production (Minshall 1978). In addition, smaller, preprocessed organic particles are received from upstream sections, which serves to balance autotrophy and heterotrophy within the stream. Species richness of the invertebrate community increases as a variety of new habitat and food resources appear. Invertebrate functional groups, such as the grazers and collectors, increase in abundance as they adapt to using both autochthonous and allochthonous food resources. Midsized streams also decrease in thermal stability as temperature fluctuations increase, which further tends to increase biotic diversity by increasing the number of thermal niches.

Larger streams and rivers of seventh to twelfth order tend to increase in physical stability, but undergo significant changes in structure and biological function. Larger streams develop increased reliance on primary productivity by phytoplankton, but continue to receive heavy inputs of dissolved and ultra-fine organic particles from upstream. Invertebrate populations are dominated by fine-particle collectors, including zooplankton. Large streams frequently carry increased loads of clays and fine silts, which increase turbidity, decrease light penetration, and thus increase the significance of heterotrophic processes. The influence of storm events and thermal fluctuations decrease in frequency and magnitude, which increases the overall physical stability of the stream. This stability increases the strength of biological interactions, such as competition and predation, which tends to eliminate less competitive taxa and thereby reduce species richness.

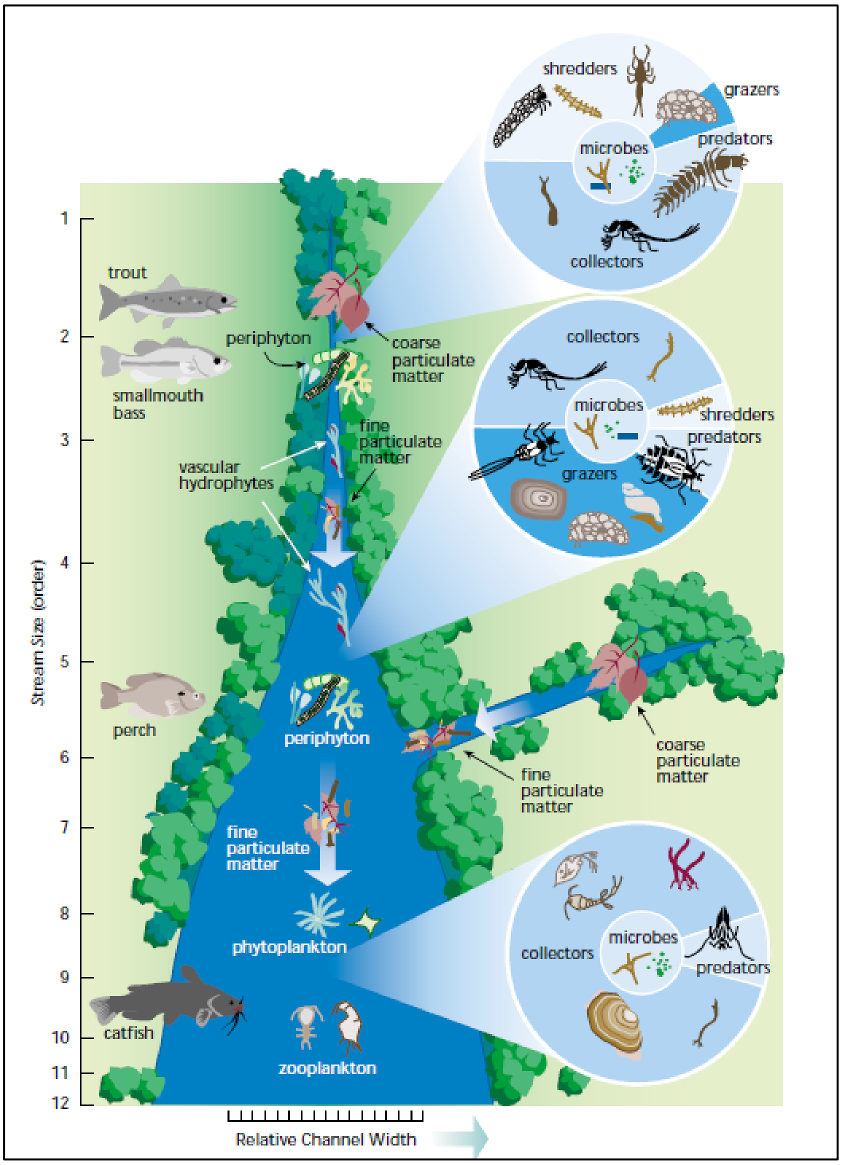


Figure 5.1: The River Continuum Concept. The concept proposes a relationship between stream size and the progressive shift in structural and functional attributes (FISRWG 10/1998).

The fact that the River Continuum Concept applies only to perennial streams is a limitation. Another limitation is that disturbances and their impacts on the river continuum are not addressed by the model. Disturbances can disrupt the connections between the watershed and its streams and the river continuum as well. The River Continuum Concept has not received universal acceptance due to these and other reasons (Statzner und Higler 1985; Junk et al. 1989). Nevertheless, it has served as a useful conceptual model and stimulated much research since it was first introduced in 1980" (FISRWG 10/1998).

5.2.2. Key themes

- **The change in composition of invertebrates (shredders, collectors, grazers and predators), as a response to different abiotic characteristics along a river course.**
- **To represent the contribution of a floodplain at a large river to the available matter in river ecosystems, a feature originally not considered by the RCC.**

- **To assess the effects of clearcutting of forests and subsequent development of younger suiccessional states on the availablity of allochthonous matter and the density of shredders in a headwater stream.**

5.3. BOKU_river continuum towards headwater stream_LS2.hgp

5.3.1. Concepts and goals

Content

- **To show how the benthic community changes when one moves from a midstream section to a headwater stream, where the contribution of allochthonous material (vegetation debris) and amount of shaded water surface increase, and autochthonous production of algae decreases.**
- **In general this model supports to explore the effects of the removal of shoreline vegetation on the benthic community, and is able to include rivers above the forest growth zone, which are not included in the original version of the RCC.**
- **The model should help students, to develop an understanding of which environmental factors shape the benthic community along a river course, and that these factors not necessarily must follow the longitudinal axis of a river.**
- **This forces a process-based understanding of biological communities in rivers, overcoming partially the limitations of the original RCC.**

Modelling

- **To introduce the issue of ambiguity in simulations.**

Assumptions

The model shows the perspective of moving from downstream to an upstream section of the stream.

Table 5.1: Entities and quantities of all models of LS 2.

Entity	*Quantities*	*QS*	*Remarks*
Water in river section	Amount of CPOM		
	Amount of FPOM from physical destruction		
	Amount of FPOM from shredding activity		
	Amount of FPOM from upstream activity		
	Turbidity		
	Amount of dissolved organic matter		
	Local FPOM		
Riparian vegetation	Amount of vegetation debris		
	Amount of energy input from riparian vegetation		
Biotic lotic community	Amount of shredders		
	Amount of collectors		
	Amount of predators		
	Amount of grazers		
Periphyton and hydrophytes	Amount of available microproducers		
Light as energy source	Amount of light as energy source		
Canopy cover	Amount of shaded water surface area		
Floodplain	Amount of energy input from floodplain		
	Amount of lateral exchange between floodplain and river		
	Amount of soil and vascular plant material		

5.3.2. Model expression

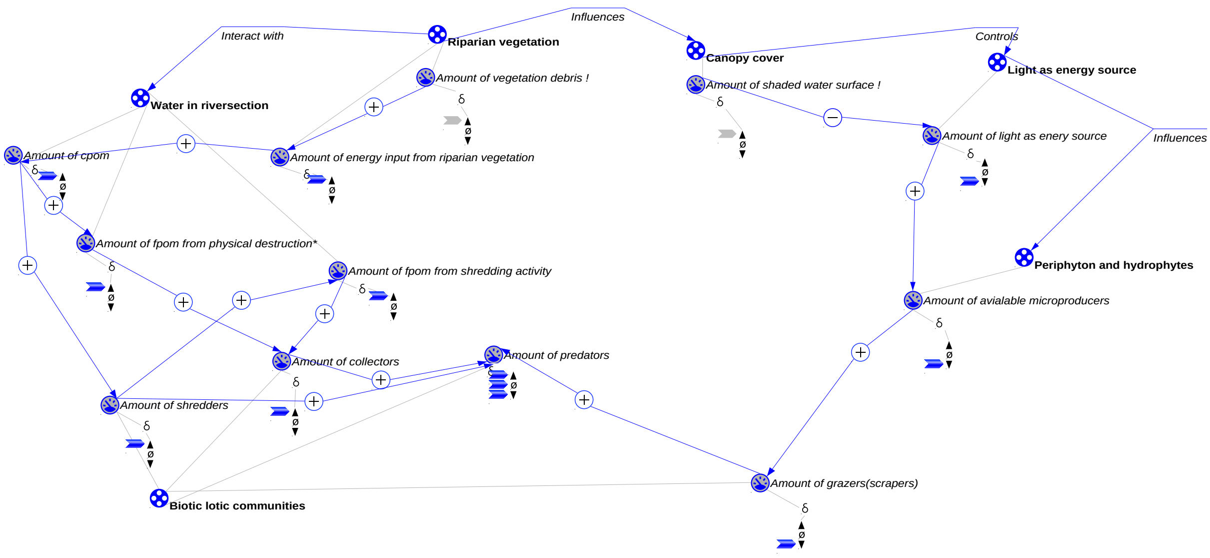


Figure 5.2: Model expression for BOKU_river continuum towards headwater stream_LS2.hgp.

5.3.3. Scenarios and simulations

The simulation shows, that especially shredders increase due to the increasing amount of available allochthonous CPOM, and that CPOM is contributing to FPOM via physical destruction and shredding activity, supporting the collector species. As the amount of collectors, shredders and grazers determines the amount of predators, ambiguity in the amount of predators occurs. Collectors depend on local production of FPOM from shredding and physical destruction and might be increasing when moving from downstream to upstream. The generic representation of the RCC assumes that collectors and predators remain relatively stable in their proportion of the total benthic community, and the main shift is from grazers to shredders when moving from downstream in upstream direction.

Table 5.2: Scenario information – causes and conditions for BOKU_river continuum towards headwater stream_LS2.hgp.

Type	Details
Exogenous control	Amount of vegetation debris and amount of shaded water surface area increase when you mode from a midstream section of river to a headwater stream.
(In)equality	none
Ambiguity	Yes, amount of predators

5.4. BOKU_river continuum from headwater towards midwater stream_LS2.hgp

5.4.1. Concepts and goals

Content

- **To show how the benthic community changes when one moves from a headwater stream section to a midstream section, where the contribution of allochthonous material (vegetation debris) and amount of shaded water surface decrease and autochthonous production of algae increases and FPOM is delivered from upstream shredding and physical destruction activity.**
- **The model should force the understanding of which factors determine the production in different river types with regard to abiotic factors.**
- **The model should help students to develop an understanding, which environmental factors shape the benthic community along a river course, and that these factors must not necessarily follow the longitudinal axis of a river.**
- **This forces a process-based understanding of biological communities in rivers, overcoming partially the limitations of the original RCC.**

Modelling

- **To intorduce the isse of ambiguity in simulations.**

Assumptions

The model shows the perspective of moving from upstream to an downstream section of the stream. Amount of FPOM from grazing is not represented as an important source of FPOM.

For the list of entities and quantities see Table 5.1.

5.4.2. Model expression

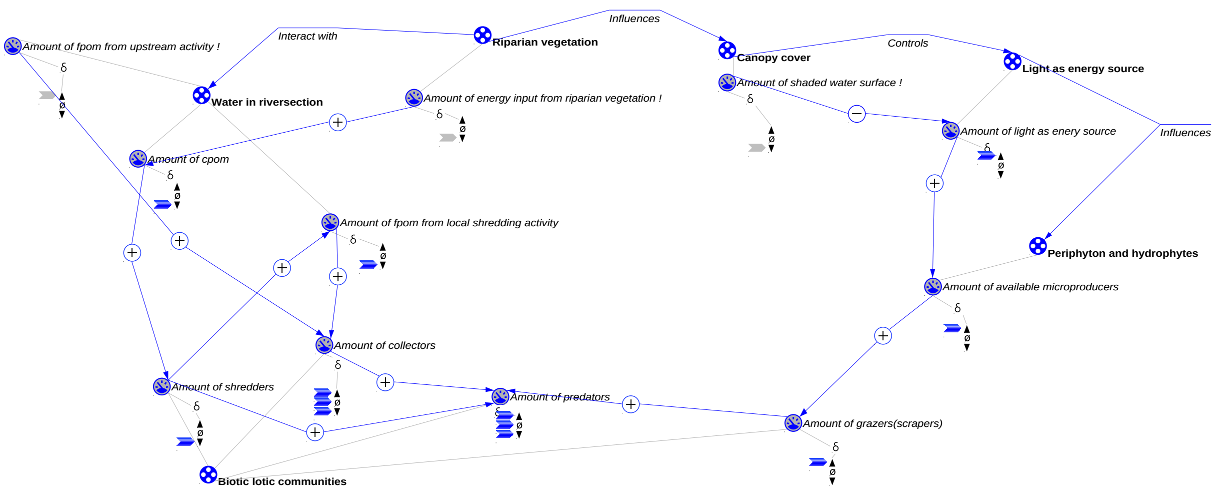


Figure 5.3: Model expression for BOKU_river continuum from headwater towards midwater stream_LS2.hgp.

5.4.3. Scenarios and simulations

The simulation shows, that especially shredders decrease due to the decreasing amount of available allochthonous CPOM from shoreline vegetation (=amount of energy input from shoreline vegetation), whereas the amount of grazers increases due to the development of algae that are supported by an increase of light due to the decrease of shaded surface area.

FPOM is mainly delivered from upstream shredding and physical destruction activity, because shredders decrease which also causes a decrease in FPOM from local shredding activity. Given the ambiguity between the increase of FPOM from upstream and decrease of FPOM from local shredding, collectors might increase, decrease, or remain stable. This ambiguity fosters the discussion, what might be the effect on a benthic community when the delivery of FPOM from upstream river sections decreases as a result of clear cutting of headwater shorelines.

As the amount of grazers increases and the amount of shredders decreases, the simulation also produces ambiguity with regard to the proportion of predators. But the generic representation of the RCC assumes that collectors and predators remain relatively stable in their proportion of the total benthic community, and the main shift is from shredders to grazers when moving from upstream in downstream direction.

Table 5.3: Scenario information – causes and conditions for BOKU_river continuum from headwater towards midwater stream_LS2.hgp.

Type	Details
Exogenous control	Amount of vegetation debris and amount of shaded water surface area decrease when you move from a headwater stream to a midstream section.
(In)equality	none
Ambiguity	Yes

5.5. BOKU_large floodplain river_LS2.hgp

5.5.1. Concepts and goals

Content

- **To show how the benthic community changes when one moves from a midstream section to a large lowland stream section, where FPOM is delivered from floodplain and upstream shredding and physical destruction activity and supports the development of collectors, which dominate in this river region. The contribution of allochthonous material (vegetation debris) stems from interaction with floodplains and might significantly contribute to the amount of shredders locally – a fact that has not been considered by the original RCC concept; the amount of turbidity limits the autochthonous production of algae, and therefore the development of grazers.**
- **The model should force the understanding of which factors determine the development of the composition of the benthic feeding groups in different river types with regard to abiotic factors, especially the importance of exchange processes between rivers and their floodplains.**
- **This forces a process-based understanding of biological communities in rivers, overcoming partially the limitations of the original RCC.**

Modelling

- **To introduce the issue of ambiguity in simulations.**

Assumptions

The model shows the influence of the natural exchange processes of organic matter between a large lowland river and its floodplain, a process originally not covered by the RCC.

For the list of entities and quantities see Table 5.1.

5.5.2. Model expression

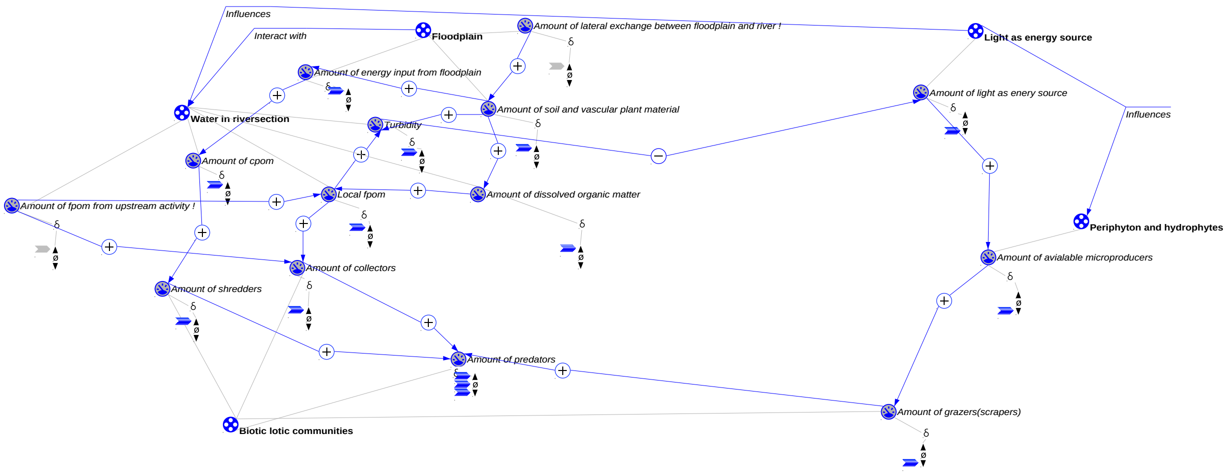


Figure 5.4: Model expression for BOKU_large floodplain river_LS2.hgp.

5.5.3. Scenarios and simulations

The simulation shows, that especially grazers decrease due to the decreasing amount of available algae from autochthonous production if one moves from a midstream section to a lowland floodplain river, which is caused by a decrease of the available light caused by an increase in turbidity. The dominant source of organic matter is FPOM from upstream shredding and physical destruction and floodplain exchange, why collectors are dominating in this river type. But due to the exchange with the floodplain during high discharges, CPOM is delivered to the river increasing locally (and probably only temporally) the amount of shredders.

As the amount of grazers decreases, and the amount of shredders and collectors increases, and all of them have an influence on the amount of predators, the amount of predators shows an ambiguous behaviour. The generic representation of the RCC assumes that collectors strongly increase and predators remain relatively stable in proportion to the total benthic community, and the change in the benthic community is characterized by a loss of grazers when moving from a midstream section to a lowland river section. The original RCC does not consider the contribution of lateral exchange processes on the availability of CPOM and therefore the potential increase of shredders if one moves from a midstream section to a lowland floodplain river, a fact that is explicitly considered in this model.

Table 5.4: Scenario information – causes and conditions for BOKU_large floodplain river_LS2.hgp.

Type	Details
Exogenous control	Amount of FPOM from upstream activity and the amount of exchange between floodplains and their associated river sections section increase
(In)equality	none
Ambiguity	Yes

5.6. BOKU_RCC_LS5.hgp

5.6.1. Concepts and goals

Forested head water streams depend largely on terrestrial vegetation as a primary energy source, and aquatic macroninvertebrates especially shredders are major consumers why their ecological roles are indicative of energy resources available (Stout et al. 1993).

Shredders have relatively low assimilation efficiencies, so they tend to process large amounts of leave material. Shredders do not specialize on litter of a given plant source but on appropriately conditioned litter, regardless of species. This conditioning time can differ from weeks (fast processing) to months (slow processing) depending on plant species and stream temperature (Cummins et al. 1989). Quantity and quality of leaves available to shredders in streams depend on the relative stage of forest succession. Especially clear cutting forests may reduce the volume of leaf litter reaching associated streams and result in reduction of leaf shredding insects. But rapid re-growth may provide sufficient leaf material, especially of fast processing leave material of high quality to allow shredders` recovery in a reasonably short time. The growth and survival of shredders appears to be linked to leaf quality. In general leaves from many early successional forest trees are processed rapidly. Mature forests tree leaves are slowly processed. So shredder production in disturbed forests exceeds that of mature natural forests streams, but this will eventually decline as plant community succession proceeds in the catchment (Stout et al. 1993).

Content

- **The model shows how human use, in this case forestry and removal of forested areas in headwater stream catchments influence the availability and the quality as well as the quantity of leaves, which furthermore influences the amount and the production of shredders in the headwater catchment areas.**
- **Removal of the forest begins in a natural stage of vegetation in which the amount of slow processing leaves dominates. The amount and production of shredders is low. The succession area without forest gets higher and the amount of slow processing trees shrinks. The condition in this model is that, when the succession areas without forest are high, the influence of the succession rate really starts. At the beginning the amount of younger states is low as well as the amount of fast processing leaves. As the succession rate progresses, both amounts begin to grow, thus the amount and production of shredders gets higher. During the growth of areas with younger succession states and the ageing of these successional stages, succession proceeds, and the vegetation begins to age again and will slowly achieve its initial stage.**
- **The model should force the understanding, of how changes in the riparian vegetation might change the abundance of specific benthic feeding groups.**

- **The model should also force thinking about the principle, that an increase in natural abundance is not always good, as it might represent a significant deviation from a river type specific reference condition with lower natural abundance, indicating ecosystem stress.**

Modelling

- **To introduce the concept of conditional knowledge.**

Assumptions

It is assumed, that the forest is gradually removed and the succession of younger succession states inversely corresponds to the removal of forest and the creation of succession areas without trees. Succession from young succession states into forest occurs when the amount of younger succession state plants is high.

Table 5.5: Entities, quantities and quantity spaces used in BOKU_RCC_LS5.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Catchment	Forest removal rate	mzp	minus, zero, plus
	Natural forest	lah	low, average, high
	Succession area without forest	lah	low, average, high
	Amount of slow processing leaves	lah	low, average, high
	Amount of fast processing leaves	lah	low, average, high
	Amount of younger succession state plants	lah	low, average, high
	Amount of shredders	nsi	natural, slightly increased, strongly increased
	Succession into forest transformation rate	zp	zero, plus

5.6.2. Model expression

The model consists of one expression and one conditional statement.

<u>Expression</u>

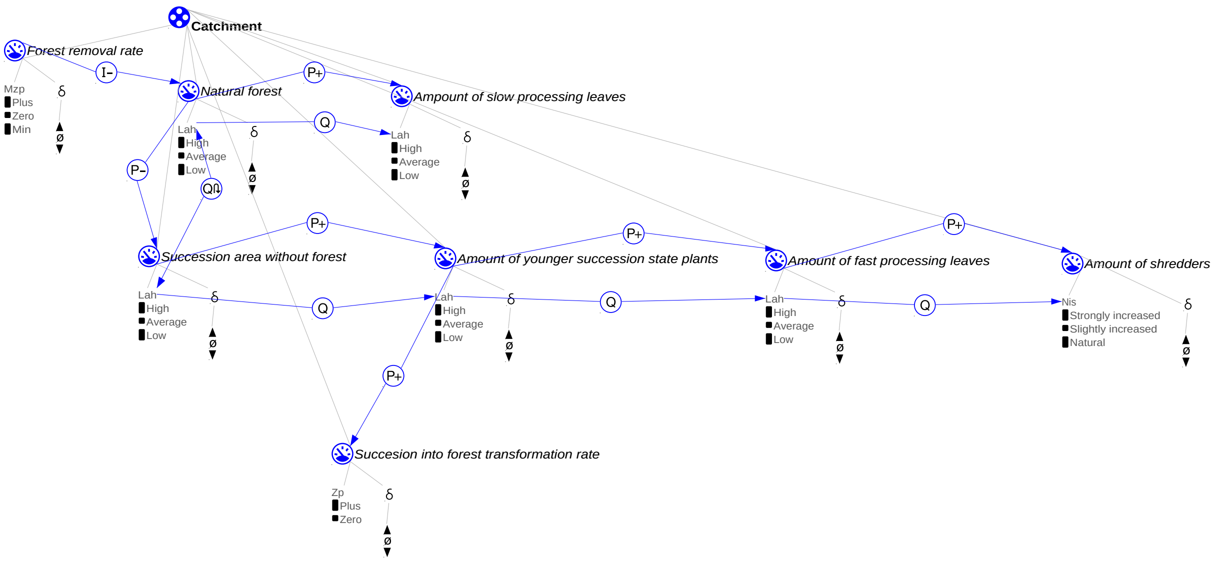


Figure 5.5: Model expression for BOKU_RCC_LS5.hgp.

Initial values

At the beginning of the simulation the amount of natural forest is high, and therefore the amount of slow processing leaves is high keeping the amount of shredders at its natural level.

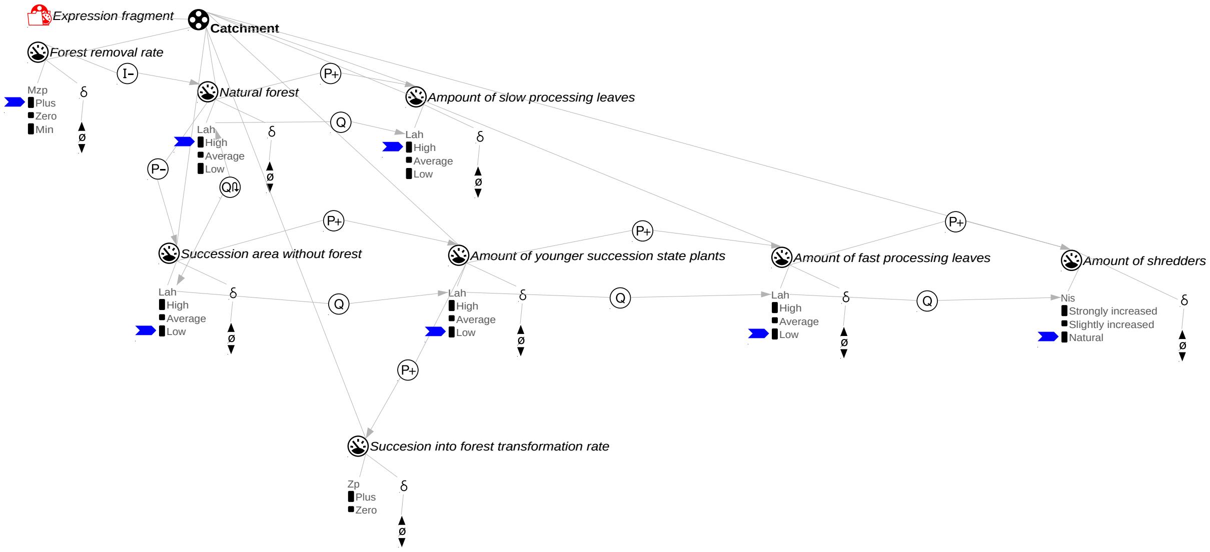


Figure 5.6: Initial values in BOKU_RCC_LS5.hgp.

Condition

The conditional expression says, that the succession of younger succession states into forest occurs, when the amount of younger succession state plants is high.

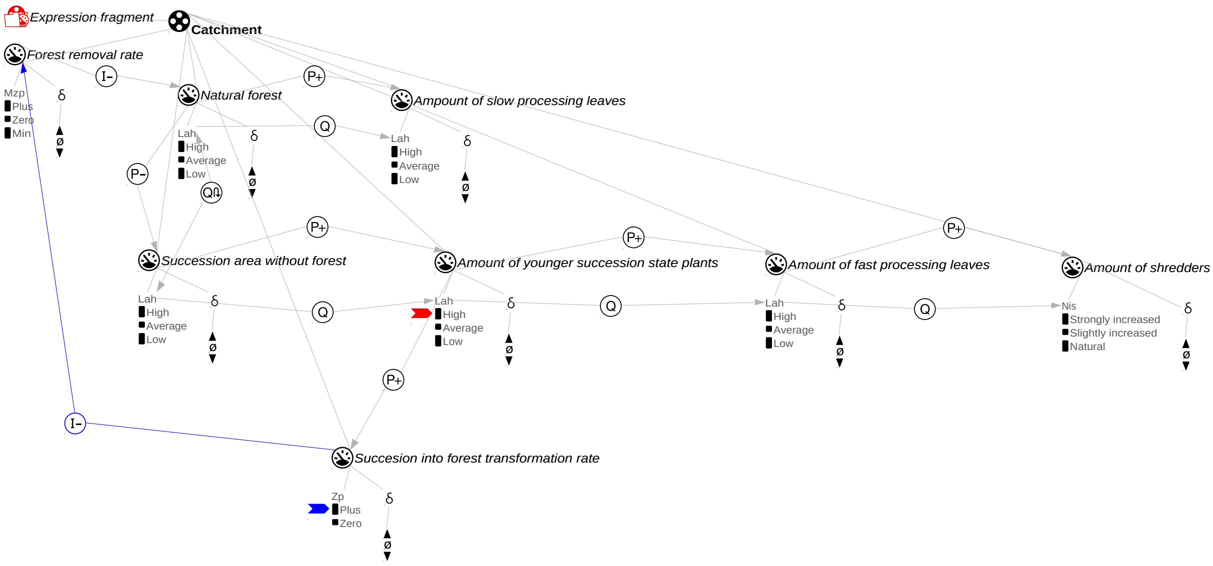


Figure 5.7: Conditional expression for BOKU_RCC_LS5.hgp.

5.6.3. Scenarios and simulations

The simulation yields seven states and one end state. The forest removal rate decreases the amount of forest until it reaches a low state; as a result the amount of slow processing leaves also decreases. At the same time the succession area without trees and the amount of young succession state plants increases, and as a result the amount of fast processing leaves increases, leading to an increase of the amount of shredders.

When the succession into forest starts (i.e. when the amount of younger succession state plants reaches *high*), the amount of forest again increases, and the amount of fast processing leaves decreases, so that the amount of slow processing leaves increases again, and the amount of shredders reaches their river type specific abundance.

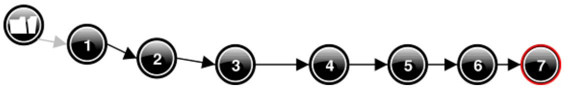


Figure 5.8: Behaviour path of BOKU_RCC_LS5.hgp.

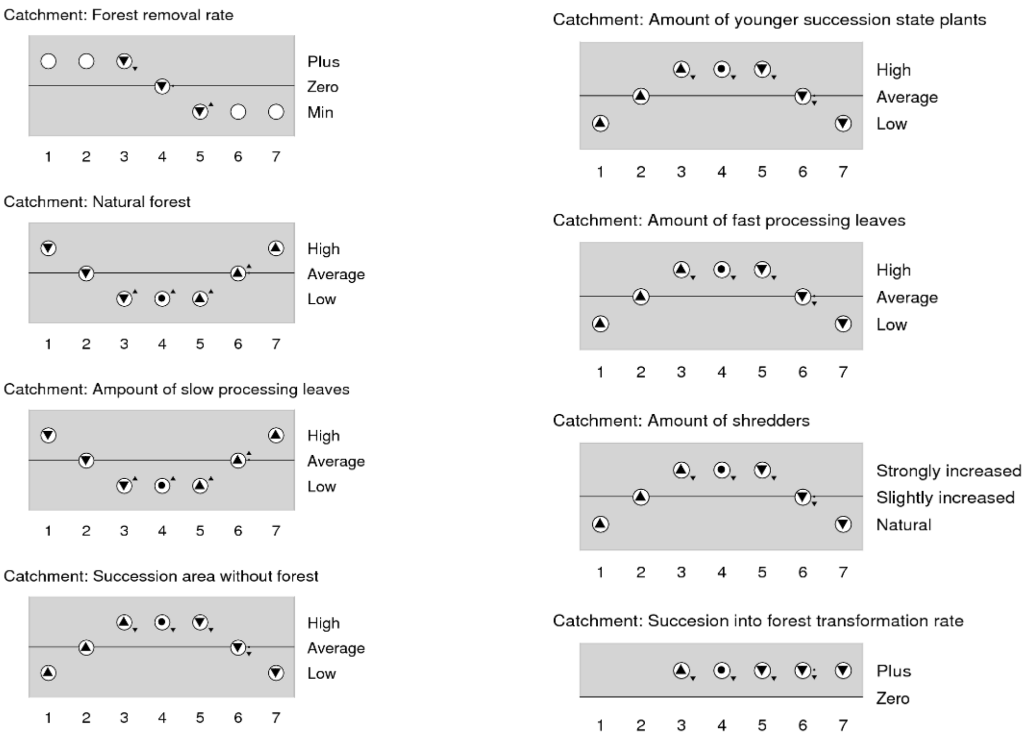


Figure 5.9: Value history of all variables included in the simulation.

Table 5.6: Scenario information – causes and conditions.

Type	Details
Exogenous control	Forest removal rate is set to *plus*
(In)equality	none
Ambiguity	none

5.7. Conclusion of the topic

5.7.1. Planned improvements

- **To better represent the factors shaping the macrozoobenthos community along a river course, including other natural (e.g. temperature) and anthropogenic (e.g. increase in fine sediments) factors.**
- **To include the effects of river tributaries on benthic community composition.**

- **To include the shaping of fish communities along a rivercourse depending on different natural factors.**
- **To include potential climate change effects on benthic and fish communities along a river course.**

5.7.2. Links to other models

This model links especially to models describing populations, food webs, management, natural processes, land and water use and climate change.

6. Education

6.1. Topic and model metadata

Topic	Education		
Author(s)	Andreas Zitek	Version(s)	Final draft 25/07/10 DynaLearn 0.6.11(CM)
Model files	Education_LS2_quality of env education.hgp Education_LS2_Factors influencing build up of new knowledge.hgp Education_LS2_general principles env education.hgp Education_LS2_sustainable development.hgp Education_LS5_class size.hgp		
Target users	Secondary school students, bachelor students, teachers		

6.2. Topic rationale

6.2.1. Background

"Education in its broadest sense is any act or experience that has a formative effect on the mind, character or physical ability of an individual. In its technical sense education is the process by which society deliberately transmits its accumulated knowledge, skills and values from one generation to another. The right to education has been established as a basic human right: since 1952. Article 2 of the first Protocol to the European Convention on Human Rights obliges all signatory parties to guarantee the right to education. At world level, the United Nations' International Covenant on Economic, Social and Cultural Rights of 1966 guarantees this right under its Article 13. In developing countries, the number and seriousness of the problems faced regarding education are naturally greater. People in more remote or agrarian areas are sometimes unaware of the importance of education".[6]

But *"education is a fundamental human right and essential for the exercise of all other human rights. It promotes individual freedom and empowerment and yields important development benefits. Yet millions of children and adults remain deprived of educational opportunities, many as a result of poverty. Education is a powerful tool by which economically and socially marginalized adults and children can lift themselves out of poverty and participate fully as citizens"*.[7]

"Education is the process by which an individual is encouraged and enabled to develop his or her potential; it may also serve the purpose of equipping the individual with what is necessary to be a productive member of society. Through teaching and learning, the individual acquires and develops knowledge and skills. There is an important distinction between education, which relates to a transactive process between a teacher and student, and learning, which is a process that happens internally for a student".[8]

The process of successful education is a complex process, and is known to be shaped even during early years of education. Finn et al. (2005) found that the class size in early school years significantly influences the success at higher levels of education. Four main findings are described: First, small classes are

[6] en.wikipedia.org/wiki/Education
[7] http://www.unesco.org/en/right-to-education/
[8] http://en.wikipedia.org/wiki/Outline_of_education

associated with significantly higher academic performance in every school subject in every grade during the experiment (K–3) and in every subsequent grade studied (4–8). Second, many of the academic benefits of small classes are greater for students at risk, i.e, minority students, students attending inner-city schools, or students from low-income homes. Third, students in small classes were more engaged in learning than were students in larger classes which provides a partial explanation of the process by which small classes are academically beneficial. But at least three or four years of small classes are needed to affect graduation rates, and three or four years have been found necessary to sustain long-term achievement gains that are academically beneficial.

Environmental education

Due to the strong increase of human pressures on the environment the conservation and restoration of man`s natural environment and the development of sustainable strategies, on both a local and a global level, form central contemporary scientific, social and political issues. The high contemporary need of an adequate environmental science education for a sustainable development has consequently been globally recognized (UN-Decade of Education for a Sustainable Development). On a European level the Eurydice network systematically captures the organisation of education across the European member states, also focusing on the ways in which environmental sciences are currently taught and identifying how to make environmental science education more efficient and interesting (EURYDICE 2006). Unfortunately the content and pedagogy associated with such curricula are increasingly failing to engage young people with the further study of science, so the quality of environmental education has to be increased to reach its targets (Osborne and Dillon 2008).

The understanding of environmental issues by students might be limited or biased due to several reasons (Rickinson 2001):

(1) Student`s understanding of environmental issues is more limited than their factual knowledge.

A common point made by several research reports is that while students may have factual knowledge about environmental phenomena, this is often not reflected by sound understanding of such phenomena.

(2) Students display considerable confusion about the science of environmental issues, often characterised by persistent misconceptions

From a number of studies in this area, there is a recurring finding that young people's ideas about many environmental issues are characterised by considerable confusion, and scientifically inaccurate conceptions. There appear to be two particular areas of confusion in young people's thinking: confusion in distinguishing between phenomena and confusion about processes.

Three ways in which classroom discussions may lead children to build new knowledge based on revision of their personal conceptions and beliefs include:

(1) `collaborative learning' which `fosters meaning negotiation and sharing to advance the children's conceptual understanding';
(2) `discourse reasoning' which promotes the `anchorage of new data to children's new knowledge' and
(3) `argumentative dynamics' by which the children make `explicit the presuppositions underlying their conceptions' and thereby enhancing their metaconceptual awareness and triggering conceptual change.

(3) Students' confusions appear to relate to the way they structure their knowledge.

There are some studies that seek to understand students' various understandings and misunderstandings by exploring in more detail the structure of their thinking. The evidence from such work suggests that students' thinking about environmental phenomena:

- **encompasses `robust [often inaccurate] models' and metaphors**
- **is `rich in content but poor in structure'**
- **comprises `funnelled' ideas**

(4) Students' difficulties with understanding environmental issues appear to relate to various external influences, such as school, media and the issues themselves.

(5) Young people's environmental understanding appears to be affected by several factors like age, gender, geographical location.

It seems that students (especially in Western urbanized areas?) tend to perceive `nature' as a natural/non-human entity, associated with recreation, danger and being under threat and that students' perceptions of `nature' appear to be shaped by several influences like the socio-economic setting, gender, experiences of nature age and cognitive development and media.

So environmental education has to overcome these issues in order to achieve its aim of *"developing a world population that is aware of and concerned about the total environment and its associated problems, and which has the knowledge, attitudes, motivations, commitments and skills to work individually and collectively toward solutions of current problems and the prevention of new ones".*"[9]

Definition of environmental education:

According to the International Union for the Conservation of Nature (IUCN), environmental education (EE) is: *"... the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings. EE also entails practice in decision-making and self-formulation of a code of behaviour about issues concerning environmental quality".*

Environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help to solve these problems, and motivated to work toward their solution (Stapp et al. 1969). Stapp et al. (1969) defined the major objectives of environmental education to help individuals acquire:

- **A clear understanding that man is an inseparable part of a system, consisting of man, culture, and the biophysical environment, and that man has the ability to alter the relationships of this system.**
- **A broad understanding of the biophysical environment, both natural and man-made, and its role in contemporary society.**
- **A fundamental understanding of the biophysical problems confronting man, and how these problems can be solved, and the responsibility of citizens and government to work together toward their solution.**
- **Attitudes of concern for the quality of the biophysical environment which will motivate citizens to participate in biophysical problem-solving.**

[9] UNESCO Conference in Tbilisi, Georgia, USSR in 1977, downloaded from http://nnrec.org/profdev/plt/handouts/Definition&Objectives.pdf

At the UNESCO Conference in Tbilisi, Georgia, USSR in 1977 the objectives of Environmental Education were summarized as follows:

- Awareness – to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.
- Knowledge – to help social groups and individuals gain a variety of experiences in and acquire a basic understanding of the environment and its associated problems.
- Attitudes – to help social groups and individuals acquire a set of values and feelings of concern for the environment and motivation for actively participating in environmental improvement and protection.
- Skills – to help social groups and individuals acquire the skills for identifying and solving environmental problems.
- Participation – to help provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems.

General factors influencing successful education

Finally, there are several factors that influence successful teaching and learning and therefore education of students (Tileston 2005).

- Creation of an environment that facilitates learning, by increasing the motivation of students to learn (by an optimal scaffolding of their learning process).
- Variation in teaching strategies that address different learning styles (auditory, visual, kinesthetic).
- Strategies that help students make connections from prior learning and experiences to new learning across disciplines.
- Teaching for long term memory as primary goal.
- Constructing knowledge through higher level reasoning skills (induction, deduction, classification, error analysis, abstracting and pattern building, critical thinking, creative thinking, problem solving).
    - This also links to the use of modelling activities (Fig. 6.1) and the use of already proven patterns of systems understanding (e.g. system archetypes).
- Collaborative learning.
- Strategies to bridge the gap between all learners regardless of race, socioeconomic status, sex or creed.
- Evaluation of learning activities through a variety of authentic assessments as we need to know that students can construct meaning from learning.
- In-depth understanding that leads to real world practices – learning has to be perceived as useful, practical and real.
- Seamless integration of technology for high quality instruction.

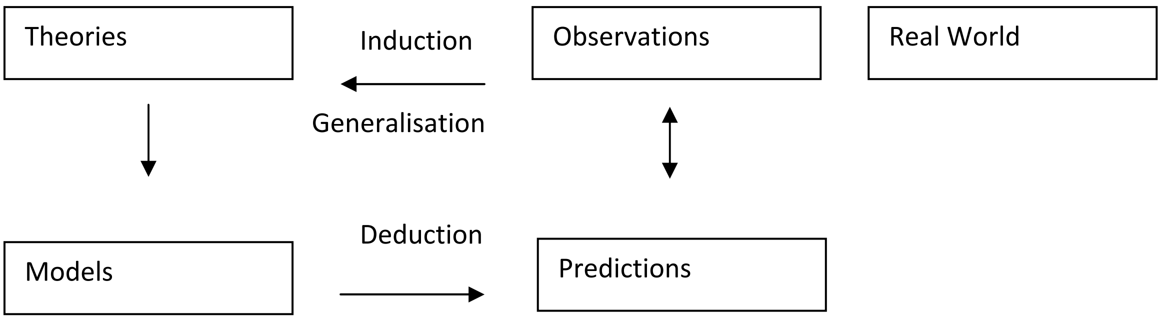


Figure 6.1: Induction-deduction process for learning by building models.

6.2.2. Key themes

Content

- **To show how an increase in quality of environmental education influences the structure of students` knowledge and hence leads to less confusion about phenomena and processes.**
- **To show how successful environmental education leads to an increase in informed decisions and therefore to more sustainability and how sustainable development influences the quality of education.**
- **To show which factors influence the build-up of new knowledge.**
- **To show which principles of environmental education have to be fulfilled to increase the probability of a sustainable future.**
- **To show, how society and policy might influence the success of education; as an example the effect of class sizes during early school years (from 6-9 years) on later academic performance, learning engagement and on performance of students at risk is modelled.**

Modelling

- **To develop simple causal simulations.**

6.3. Education_LS2_quality of env education.hgp

6.3.1. Concepts and goals

This model is constructed to show the effects of changes in the quality of environmental education on the capabilities of students to understand environmental phenomena.

Table 6.1: Entities and quantities of Education_LS2_quality of env education.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Education	Quality of environmental education		
Individuals	Structure of knowledge		
	Confusion in distinguishing between phenomena		
	Confusion about environmental processes		
	Sound understanding of environmental phenomena		

6.3.2. Model expression

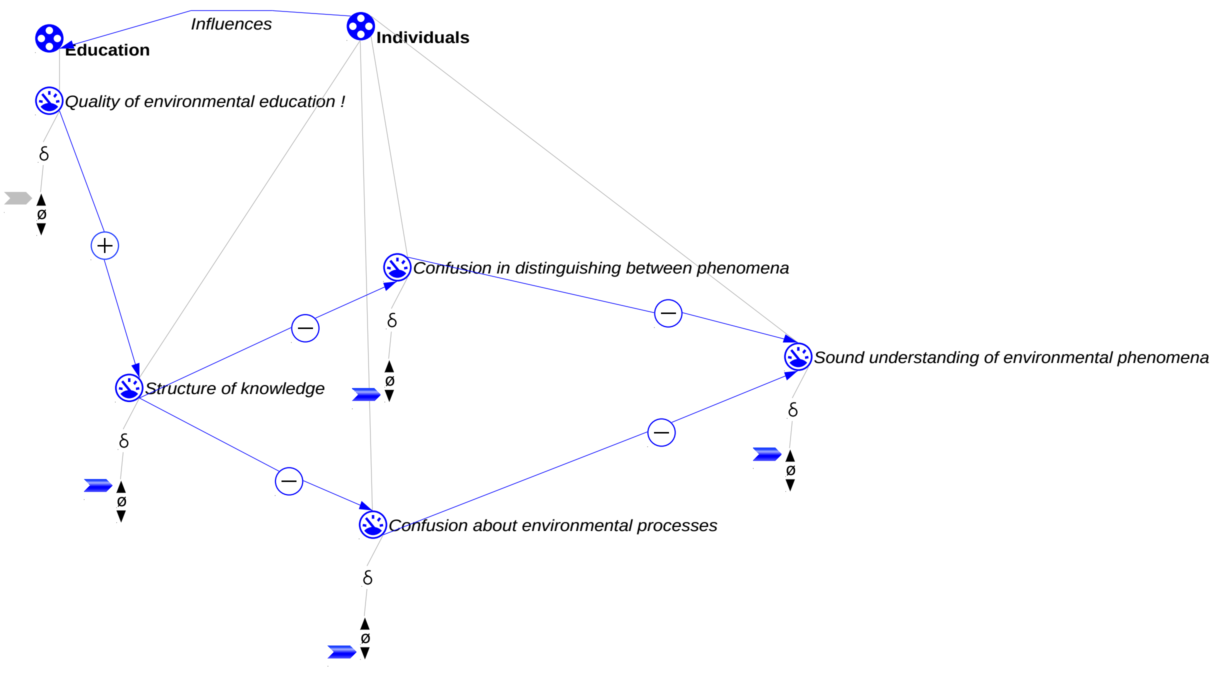


Figure 6.2: Model expression of Education_LS2_quality of env education.hgp.

6.3.3. Scenarios and simulations

The simulation shows how an increase in the quality increases the structure of knowledge, decreases the confusion and contributes to a sound understanding of environmental phenomena.

Table 6.2: Scenario information – causes and conditions of Education_LS2_quality of env education.hgp.

Type	Details
Exogenous control	Quality of environmental education *increases*
(In)equality	none
Ambiguity	none

6.4. Education_LS2_sustainable development.hgp

6.4.1. Concepts and goals

This model shows the effects of changes in the quality of environmental education on social development.

Table 6.3: Entities and quantities of Education_LS2_sustainable development.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Education	Quality of environmental education		
Individuals	Fundamental knowledge of basic environmental concepts and processes		
	Amount of informed decisions		
Society	Sustainable development		

6.4.2. Model expression

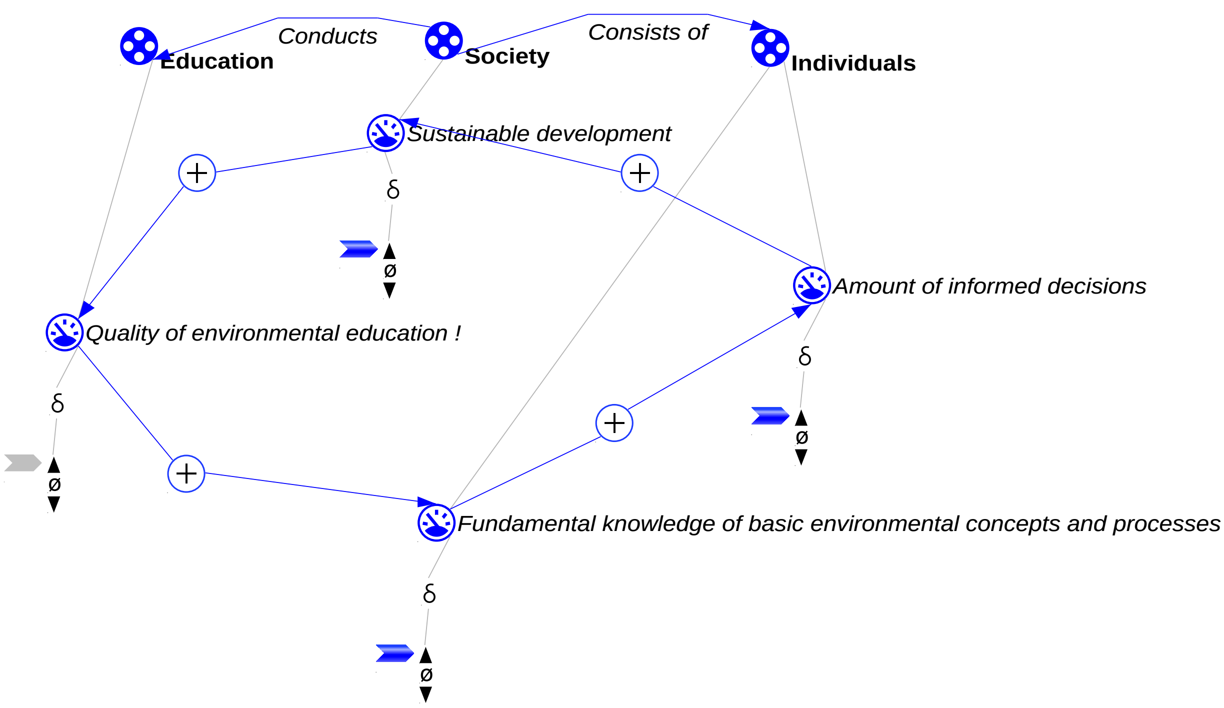


Figure 6.3: Model expression of Education_LS2_sustainable development.hgp.

6.4.3. Scenarios and simulations

The simulation shows how an increase in the quality of environmental education increases the fundamental knowledge of basic environmental concepts, which increases the amount of informed decisions which positively contribute to a sustainable development. There is a feedback to environmental education, as a sustainable development will lead to further increases in the quality of environmental education.

Table:6.4: Scenario information – causes and conditions of Education_LS2_sustainable development.hgp.

Type	Details
Exogenous control	Quality of environmental education *increases*
(In)equality	none
Ambiguity	none

6.5. Education_LS2_general principles env education.hgp

6.5.1. Concepts and goals

This model shows the elements that have to be considered for successful environmental education as a basis for sustainable development.

Table 6.5: Entities and quantities of Education_LS2_general principles env education.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Education	Quality of environmental education		
World population	Awareness and sensitivity to the environment and related problems		
	Knowledge and basic understanding of the environment		
	Skills for working towards the solution of environmental problems		
	Positive attitudes and strong feelings of concern for the environment		
	Develop an understanding for the need of active participation in solving environmental problems		
	Sustainable development		

6.5.2. Model expression

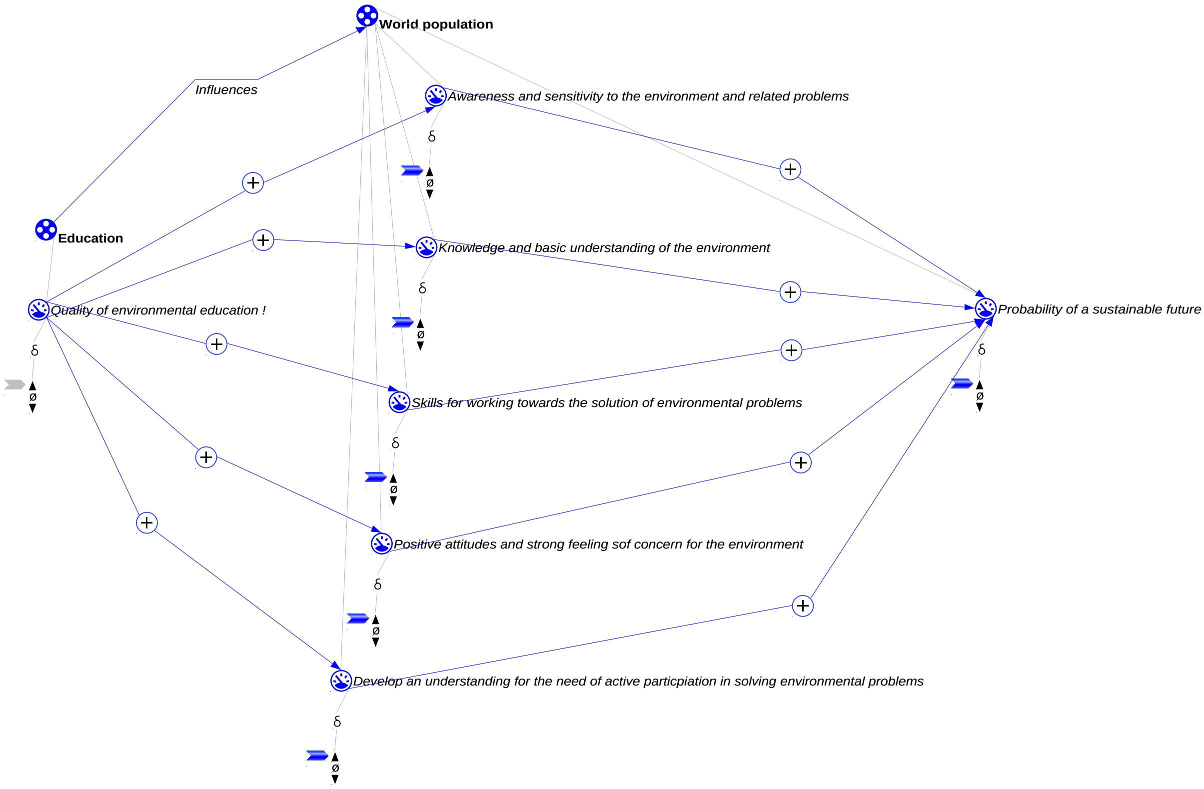


Figure 6.4: Model expression of Education_LS2_general principles env education.hgp.

6.5.3. Scenarios and simulations

The simulation shows, which elements of environmental education are considered when the quality of environmental education increases. The increase in these factors contributes to the probability of a sustainable future.

Table 6.6: Scenario information – causes and conditions of Education_LS2_general principles env education.hgp.

Type	Details
Exogenous control	Quality of environmental education *increases*
(In)equality	none
Ambiguity	none

6.6. Education_LS2_Factors influencing build up of new knowledge.hgp

6.6.1. Concepts and goals

This model shows which factors might contribute to the build-up of new knowledge based on the revision of personal conceptions and beliefs.

Table 6.7: Entities and quantities of Education_LS2_Factors influencing build up of new knowledge.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Learning activities	Collaborative learning		
	Discourse reasoning promoting anchoring of new knowledge to the existing one		
	Making underlying assumptions explicit		
Students	Build up of new knowledge based on revision of their personal conceptions and beliefs		

6.6.2. Model expression

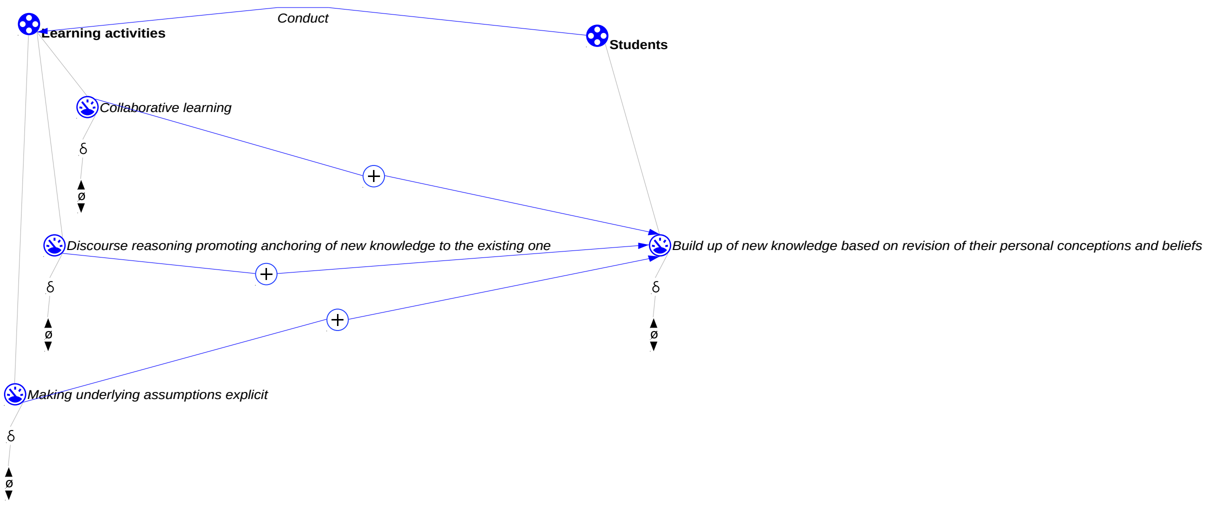


Figure 6.5: Model expression of Education_LS2_Factors influencing build up of new knowledge.hgp.

6.6.3. Scenarios and simulations

The simulation shows that new knowledge based on the revision of personal conceptions and beliefs is build up, when these three factors are considered.

Table 6.8: Scenario information – causes and conditions of Education_LS2_Factors influencing build up of new knowledge.hgp.

Type	Details
Exogenous control	All three factors might be triggered by the inclusion of a quality increase in environmental education, which then would be set to *increase*
(In)equality	none
Ambiguity	none

6.7. Education_LS5_class size.hgp

6.7.1. Concepts and goals

Content

- **To show how social and policy decisions, e.g. for smaller class sizes in early school years, have an effect on the later performance of students.**
- **To trigger a discussion about which factors might additionally contribute to a better motivation and performance of students.**
- **To trigger students to think about their own experiences of students in school classes.**

Modelling

- **To introduce the idea of conditional knowledge.**

Assumptions

An underlying assumption to this model is, that the years spent in small classes during early school career (from 6-9 years) lasts about 3-4 years, as it is thought that the positive effects und students performance may only occur in these situations.

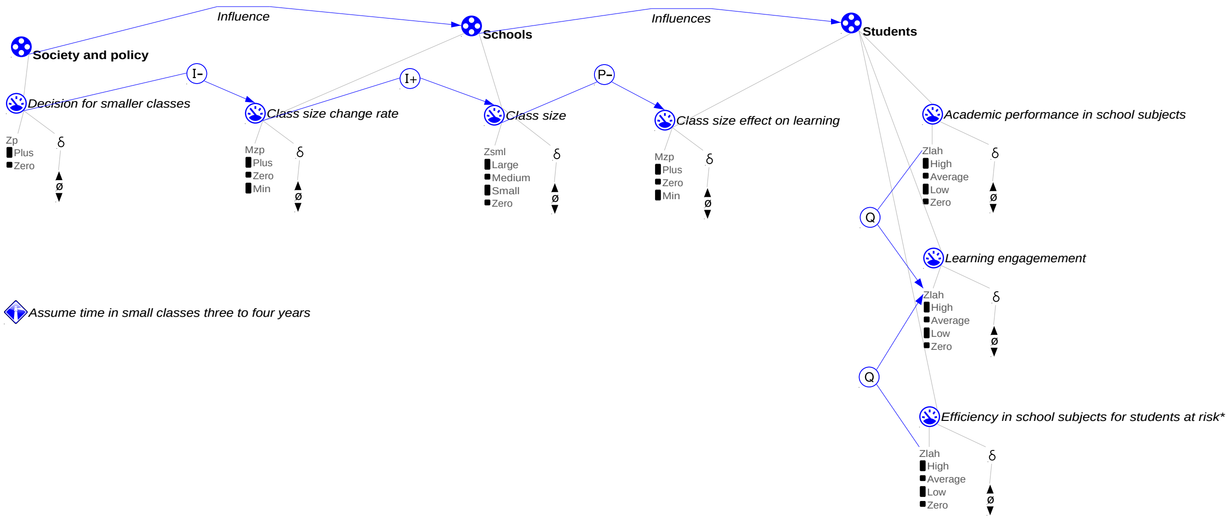
Table 6.9: Entities, quantities and quantity spaces of Education_LS5_class size.hgp

Entity	*Quantities*	*QS*	*Remarks*
Society	Decision for smaller classes	zp	Zero, plus
Schools	Class size change rate	mzp	Minus, zero, plus
	Class size	zlmh	Zero, small, medium, high (small is considered as the adequate class size)
Students	Class size effect on learning	mzp	Minus, zero, plus
	Academic performance in school subjects	zlah	Zero, low, average, high
	Efficiency in school subjects for students at risk	zlah	Zero, low, average, high
	Learning engagemement	zlah	Zero, low, average, high

6.7.2. Model expression

Expression

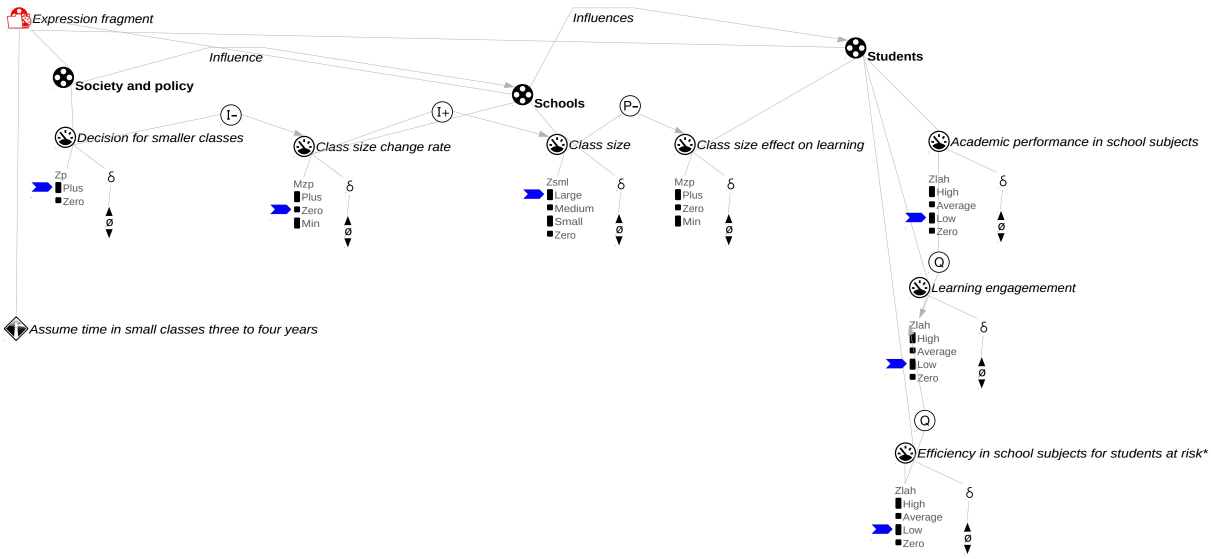
The model shows, how change in class sizes triggered by political and social decision has an effect on the academic performance in school subjects, learning engagement and efficiency in school subjects for students at risk.



Firgure 6.6: Model expression of Education_LS5_class size.hgp.

Initial values

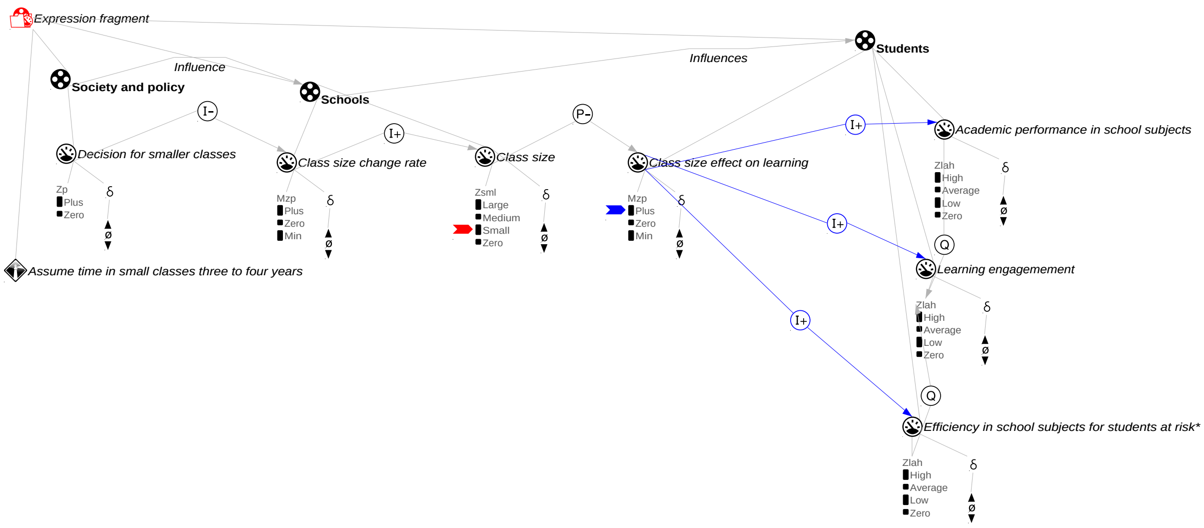
At the beginning of the simulation the class sizes are high, and the expected performance of students later in their career is low. But Society and policy have decided to decrease class sizes to improve this situation.



Firgure 6.7: Initial values of Education_LS5_class size.hgp.

Conditional expression

The conditional expression says, that a positive effect of class size on learning can only be expected and started at small class sizes.



Firgure 6.8: The conditional expression of Education_LS5_class size.hgp.

6.7.3. Scenarios and simulations

The simulation has six states and one end state.

Table 6.10: Scenario information – causes and conditions of Education_LS5_class size.hgp.

Type	Details
Exogenous control	**Decision for smaller class sizes set to *plus***
(In)equality	**none**
Ambiguity	**none**

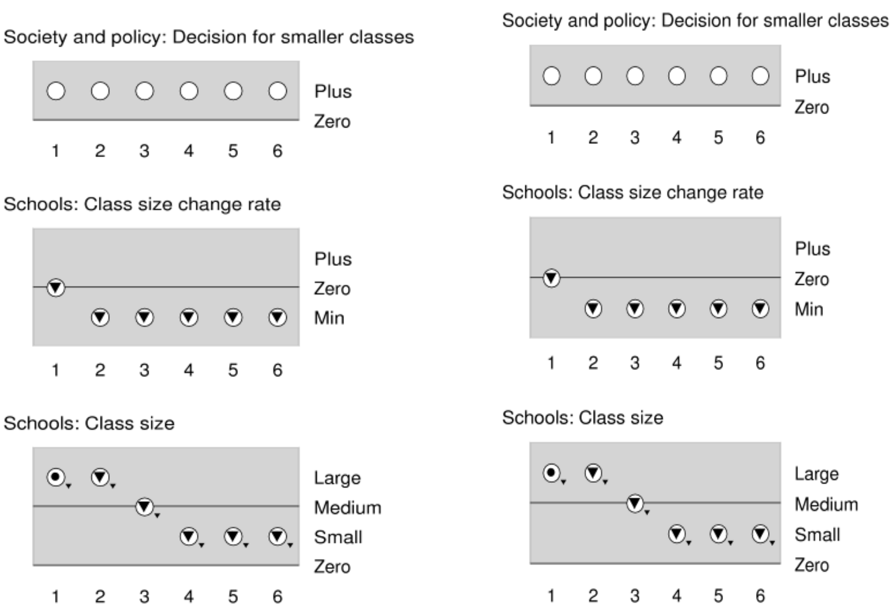


Figure 6.9: Value history of all variables included in the simulation.

6.8. Conclusion of the topic

6.8.1. Planned improvements

- **To better represent the effect of education on the possibilities of individuals for their self-determination and fulfilment of their physical and mental needs.**
- **To better represent the effect of education on physical and mental health and human well-being.**
- **To include education into practical problem solving strategies for natural resource management.**
- **To include other internal (like motivation, socio-cultural background) and external factors that might influence education.**

6.8.2. Links to other models

This model links especially to models describing the management of natural resources, energy production and consumption, overfishing, pollution and human population in general.

7. Tourism and recreation

7.1. Topic and model metadata

Topic	Effects of recreational and touristic activities on the environment, with an example of a riverine landscape		
Author(s)	Michaela Poppe Andreas Zitek Sybille Chiari Michael Stelzhammer	Version(s)	Final draft 03/07/10 DynaLearn 0.6.8(CM)
Model files	BOKU_recreation UL 2.hgp BOKU_recreation_LS4_regulation.hgp		
Target users	Secondary school students, bachelor students		

7.2. Topic rationale

7.2.1. Background

In the past Austrian rivers faced a series of human impacts leading to a loss of both ecological and social functionality. The lack of usable riverine sites led to the situation that recreational use is likely to concentrate in ecologically sensitive or restored areas, resulting in management conflicts.

The aim of this project was to combine both social and ecological aspects within an integrated management approach. The focus of this thesis was set on spatial and structural prerequisites enabling multifunctionality in riverscapes as well as on recreational use patterns and preferences. Based on these two main aspects, i.e. ecological and social values, an interdisciplinary study design was developed. A multi-method approach was applied, including qualitative face-to-face interviews with recreationists and experts, a quantitative survey using a semi-standardised questionnaire, peak-day observations and mapping indicator species for riverside habitats (Common Sand-piper, Little Ringed Plover, see Fig. 7.1). The investigations were carried out along three alpine gravel bed rivers: River Enns in Styria, River Drau in Carinthia and River Lech in Tyrol. The results showed that access to the riverscape and to the water combined with the availability of shallow areas are crucial prerequisites for recreational use along rivers. Besides, users seemed to be rather tolerant regarding the presence of other users.

Figure 7.1: Little ringed plover, *Charadrius dubius curonicus* (S. Chiari).

Nevertheless, the majority of users disliked the idea of use restrictions and showed a rather low sensitivity concerning ecological disturbance, which points out the challenge of acceptable management measures. Furthermore the spatial analysis clarified users' preference for heterogeneous, ecologically intact river stretches, leading to a frequent overlap between recreational use and the habitats of the indicator species. Along river stretches with a high availability of gravel banks recreational use proved to be rather disperse. Where the spatial extension of rivers was more restricted, a concentration of use

could be observed, leading to a more competitive situation between recreation and ecology. In conclusion, there seems to be a consensus on the recreational value of rivers, but there is no code of practice to deal with this aspect satisfying both ecological and social needs. An integrative river management approach seeking for long-term solutions should therefore aim to raise the capacity of rivers to fulfil several functions by giving back space and structural diversity to the rivers (Chiari, 2010).

7.2.2. Key themes

Channelized rivers show poor ecological status according to the EU-Water Framework Directive (WFD) (BMLFUW 2005). They can hardly provide any ecosystem services. They are neither attractive for recreational use for humans nor for breeding activities for birds. To improve the ecological integrity restoration actions are needed. The enlargement of the river channel enhances the development of gravel banks and islands (sediment area index - Chiari 2010). The availability of shallow water areas is a crucial pre-requistite for recreational use. Gravel breeding birds need sediment areas to reproduce. The increase of recreational use affects the population of gravel breeding birds (if both uses reach high intensity). Only management actions combined with the availability of enough sediment areas (increasing restoration actions) can provide both functions for ecology and society.

Figure 7.2: Human use of gravel banks in a braiding river system (S. Chiari).

7.3. BOKU_recreation UL 2.hgp

7.3.1. Concepts and goals

Content

- **This model tries to strengthen the understanding of restoration needs and actions in a degraded riverine system. Another goal is to convey the understanding of multifunctional aspects and ecosystem services of riverine systems and to highlight the potential use conflicts.**

Modelling

- **To use the ambiguity in the simulation to discuss different possibilities, pointing out the need of a more specific model prepresentation which leads to LS 4 or LS 5.**

Assumption

The river is situated in the alpine braiding river process zone.

Table 7.1: Entities and quantities used in the model BOKU_recreation UL 2.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Human	Recreational use of gravel banks		
Birds	Population of gravel breeding birds		
River	Amount of gravel banks		
	Ecological status		
	Breeding habitats		
	Recreational attraction		
River management	Restoration		

7.3.2. Model expression

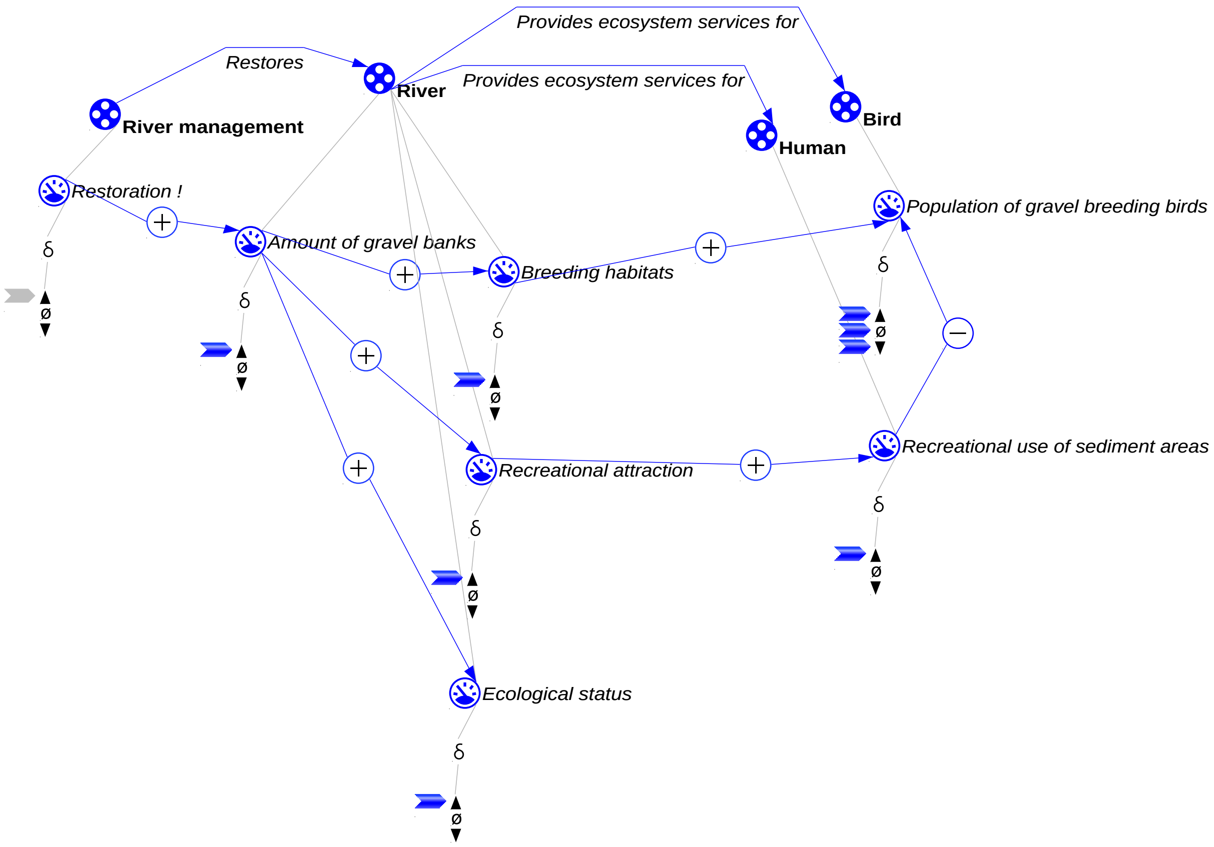


Figure 7.3: Model expression for BOKU_recreation UL 2.hgp.

7.3.3. Scenarios and simulations

The restoration of gravel banks leads to an increase of breeding habitats for gravel breeding birds, to an overall increase of the ecological status and to an increase of recreational attraction. The increase in gravel habitats positively influences the population of gravel breeding birds, whereas human recreational use of sediment areas has a negative effect on the population density of gravel breeding birds. This shows the principle of a conflict between recreational use and ecological targets.

7.4. BOKU_recreation_LS4_regulation.hgp

7.4.1. Concepts and goals

The goal of this model is to highlight potential use conflicts when overusing a natural resource as well as to offer a management option for this conflict by access regulation.

Assumption

The river is situated in the alpine braiding river process zone.

Table 7.2: Entities and quantities used in the model BOKU_recreation_LS4_regulation.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Human			Included as an entity via configuration
River	Actual amount of area used by humans	zlmhm	zero, low, medium, high, maximum
Birds	Population size of gravel breeding birds	zcvhm	zero, critical, viable, high, maximum
River Management	Access regulation	mzp	minus, zero, plus
	Defined minimum area to sustain a viable bird population	zlmhm	

7.4.2. Model expression

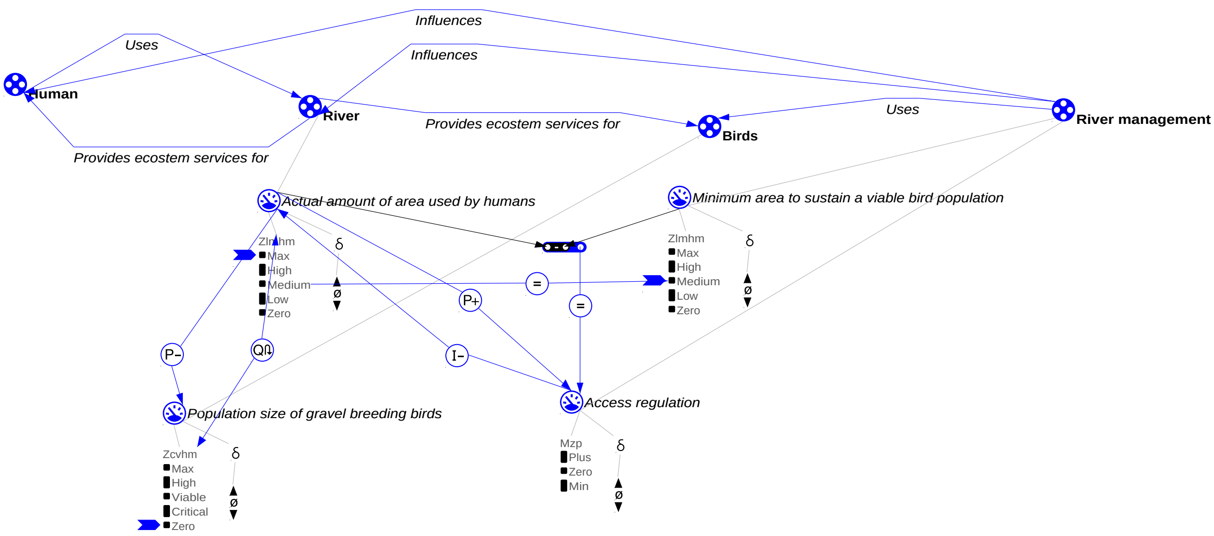


Figure 7.4: Model expression for BOKU_recreation_LS4_regulation.hgp.

Because of the high recreational value of the restored river sections human use for recreation is usually high. Therefore population of gravel breeding birds will normally be threatened by extinction if management actions are taken. The management has to define a minimum area that can sustain a viable bird population.

7.4.3. Scenarios and simulations

The scenario shows that the management has to define a specific minimum area sustaining a viable gravel breeding bird population, and take action to regulate the recreational overuse of gravel banks. This finally leads to the development of a viable bird population and therefore to a sustainable recreational use of gravel banks.

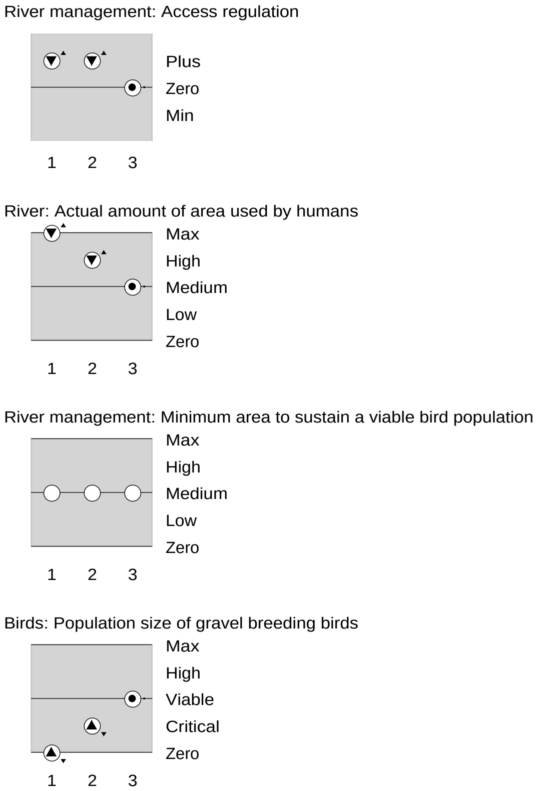


Figure 7.5: Value history for the full simulation of BOKU_recreation_LS4_regulation.hgp.

Table 7.3: Scenario information – causes and conditions

Type	Details
Exogenous control	none
(In)equality	none
Ambiguity	none

7.5. Conclusion of the topic

7.5.1. Planned improvements

- **To develop a broader view on recreational use of our environment, including**
  - **the benefit of an healthy environment for recreation on human health and well being**
  - **other problems caused by human recreation.**
- **To include further management actions to achieve sustainable recreational behaviour while maximising human well-being.**

7.5.2. Links to other models

This model links well to human well-being, general management models and population models. Besides content on recreational use of parts of our environments, it includes the idea of minimum habitat and viable populations.

8. Flood protection

8.1. Topic and model metadata

Topic	Flood Protection		
Author(s)	Andreas Zitek Michaela Poppe Michael Stelzhammer	Version(s)	Final draft 15/07/2010 DynaLearn 0.6.8(CM) (LS 4) DynaLearn 0.6.11(CM) (LS 5)
Model files	Increase of flood risk_land sealing_LS4.hgp Increase of flood risk_deforestation_LS4.hgp Flood protection LS 5.hgp		
Target users	Secondary school, bachelor & master students		

8.2. Topic rationale

8.2.1. Background

Introduction

"Flooding is the most common natural disaster in Europe, and, in terms of economic damages, the most costly one. There has been an increase in the number of reported events since the mid-1970s (Fig. 8.1). European vulnerability to flooding was highlighted by the loss of life and economic damage from flooding events of the Rhine, Meuse, Po, Danube, Elbe and Oder rivers in the 1990s and early twenty-first century" (WHO 2002).

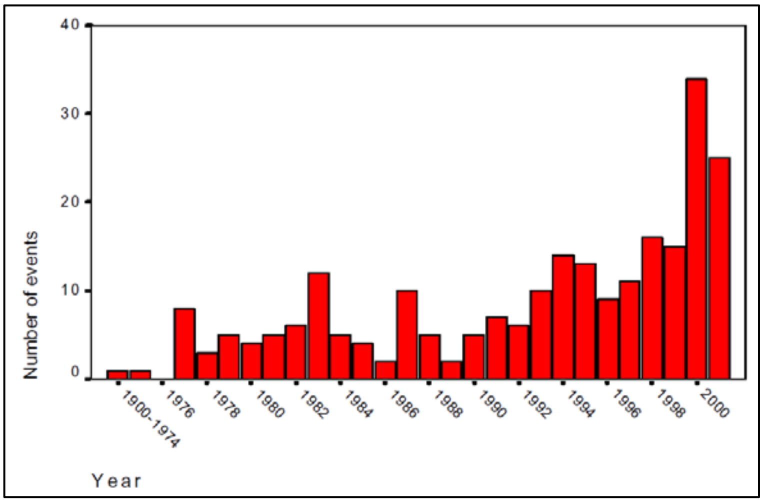


Figure 8.1: Number of flood events in Europe (WHO 2002).

As the need for an integrated management of floods became obvious in 2007, the Flood Directive 2007/60/EC (EC 2007) has been launched aiming at a coordinated assessment and management of flood risks throughout the European Union, mainly because

(1) Floods have the potential to cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities of the community.

(2) Floods are natural phenomena which cannot be prevented. However, some human activities (such as increasing human settlements and economic assets in floodplains and the reduction of the natural water retention by land use) and climate change contribute to an increase in the likelihood and adverse impacts of flood events.

Figure 8.2: Flood damages in Austria in 2002: flooded villages (Habersack et al. 2004).

Figure 8.3: Flood damages in Austria in 2002: a destroyed bridge (Habersack et al. 2004).

Figure 8.4: Flood damages in Austria in 2002: destroyed train dam (Habersack et al. 2004).

Flood events in relation to human land use

Water transport through a landscape is heavily affected by human land use activities. Alterations of the natural pathway of water may cause catastrophic flood events harming humans and their infrastructure. Land use can have a great effect on hydrologic processes, such as surface-runoff patterns. A natural environment, e.g. forest land in the catchment and alongside a stream, can improve the retention capacity and reduce the flooding event. Depending on the degree of watershed impervious (sealed) cover, the annual volume of storm water runoff can increase by 2 to 16 times compared to its predevelopment rate increasing flood risk, with proportional reductions in ground water recharge (Schueler 1995).

The hydrology of urban streams changes as sites are cleared and natural vegetation is replaced by impervious cover such as rooftops, roadways, parking lots, sidewalks, and driveways. One of the consequences is that more of a stream's annual flow is delivered as storm water runoff rather than baseflow. Depending on the degree of watershed impervious cover, the annual volume of storm water runoff can increase by up to 16 times that for natural areas (Schueler 1995). In addition, since impervious cover prevents rainfall from infiltrating into the soil, less flow is available to recharge ground water. Therefore, during extended periods without rainfall, baseflow levels are often reduced in urban streams (Simmons and Reynolds 1982). Storm runoff moves more rapidly over smooth, hard pavement than over natural vegetation. As a result, the rising limbs of storm hydrographs become steeper and higher in urbanizing areas (Fig. 8.4). Recession limbs also decline more steeply in urban streams. The discharge curve is higher and steeper for urban streams than for natural streams.

Some studies prove that flood protection at a catchment scale can be improved by extensive land use (i.e., grassland, flood plain forest). Retention capacity raises because of increased infiltration, evapotranspiration, interception, surface roughness, soil`s permeability and decreased surface runoff.

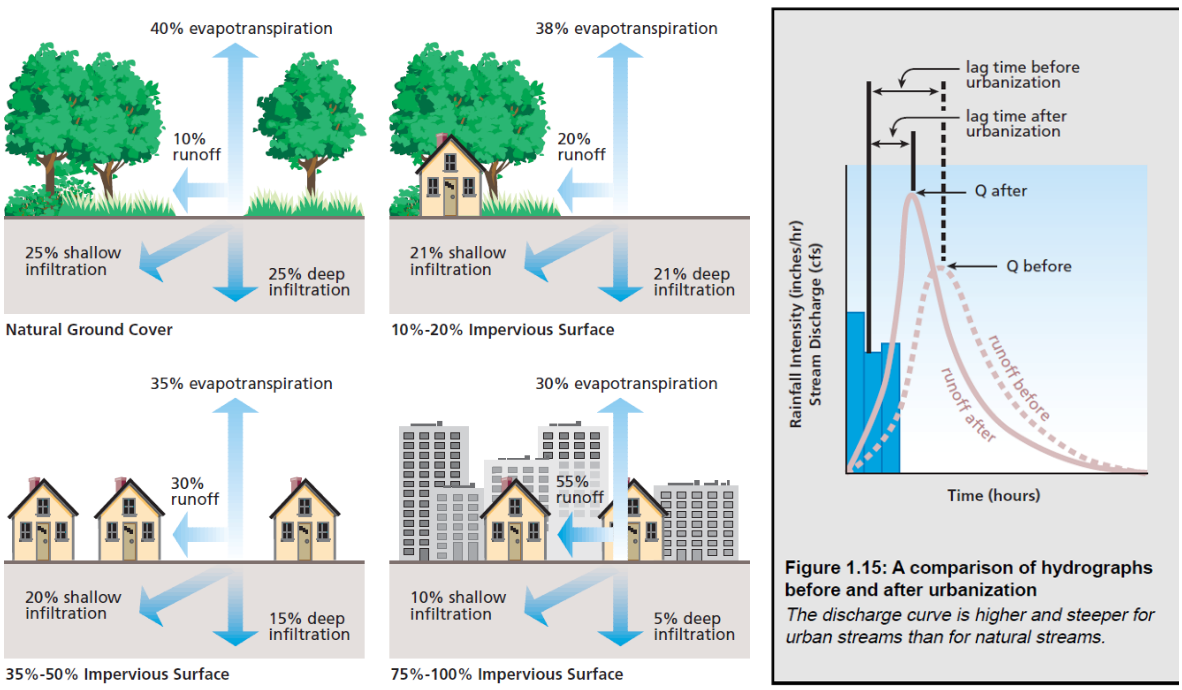


Figure 8.5: Influence of land sealing on runoff, height and timing of floods (FISRWG 10/1998).

Good practices for flood prevention and protection

<u>Example: retention of water on the soil</u>

"1. Retaining water on the soil should have priority over swift water run-off.

2. Natural wetlands, forested marshlands and retention areas in the river basin should be conserved, and where possible restored or expanded.

3. Former flood plains and lakes, when possible, should be reclaimed, for example by relocating dykes to reincorporate these areas as natural retention areas into the discharge dynamic.

4. Soil sealing as part of urbanization (e.g. built-up land in residential areas and on industrial and business estates, and the construction of traffic routes and areas) should be limited. Unsealing measures encourage rainwater infiltration.

5. The water absorption capacity of the soil should be conserved and excessive soil compaction and erosion should be avoided through proper and site-specific agricultural land use. This leads at the same time to a reduction in nutrient and pesticide input into rivers.

6. The forest population in the river basin should be maintained and expanded by semi-natural reforestation, particularly in mountain and hilly ranges, as forests are the greatest natural water storage basins and contribute considerably to reducing soil erosion.

7. The required run-off capacity should be taken into consideration when restoring developed river courses to their "natural" state. If, however, the development of a watercourse, including the construction of dykes, is unavoidable to protect people and valuable properties, compensation measures should be made available.

8. Manageable flood polders, which should preferably be used as extensive grassland or to restore alluvial forests, should be developed at selected locations of former flood plains to lower flood peaks.

9. The effectiveness of measures on flood wave run-off, particularly dyke relocation and the development of flood polders, should be measured by surveys in the longitudinal section of the main watercourse.

10. In some river basins, there are technical structures to manage water flow in retention areas. The operation of such structures should follow a holistic approach to take due account of the whole catchment area. The management of these retention areas should not exclusively serve the purpose of local flood reduction but also flood reduction in the whole affected area. Organizational schemes in accordance with this goal are to be developed" (WHO 2002).

8.2.2. Key themes

<u>Physical factors of flooding</u>

When does flooding occur?

1. **Water overflows river banks onto surrounding area.**
2. **Occurs when water runoff (from snowmelt and/or precipitation) is more than retention capacity.**

When does water overflow?

1. **Intense precipitation.**
2. **Prolong rainfall in saturated soil, i.e. clay prone to overland flow (smaller pores) or soil already saturated thus reduce infiltration capacity.**

3. **Sudden increase in temperature (rapid snow melt, eventually with rain)**

<u>Human factors of flooding</u>

Which factors increase the risk of flooding

1. **Land use (reducing the retention capacity of soil e.g. draining).**
2. **Urbanisation (increasing the amount of impervious cover).**
3. **Deforestation (reducing the interception and evaporation capacity of a catchment).**
4. **Dam burst.**

<u>Flood protection measures</u>

Which factors decrease the risk of flooding?

1. **Land use change (increasing the retention capacity of a catchment by e.g. increasing forest cover and decreasing the amount of impervious cover and/or increase the amount of area available for flood retention)**
2. **Damming (the flood protection cannot be guaranteed, the flood protection by dams is limited by the amount of water that can be contained between the dams; if this capacity is reached, water flows over the dam and flooding occurs)**

8.3. Increase of flood risk_land sealing_LS4.hgp and Increase of flood risk_deforestation_LS4.hgp

8.3.1. Concepts and goals

Content

- **Demonstrating the main effects of two different land use types with regard to flood risk.**
- **Showing, how flood risk will increase by intensive land use in the catchment due to the reduction of the retention capacity. Vice versa flood protection at a catchment level can be enhanced by different extensive land use strategies.**
- **Stimulating discussion on flood protection measures and strategies.**
- **Introduction of different types of correspondences and feedback loops to the rates of change by the state variable changed.**

Modelling

- **Introducing a structured way of expressing more or less linear causality like in the DPSIR scheme.**
- **Introduction of the idea of a simple feedback loop.**

Table 8.1: Entities, quantities and quantity spaces used for the models in LS 4.

Entity	*Quantities*	*QS*	*Remarks*
Catchment	Deforestation rate	mzp	minus, zero, plus
	Land sealing rate	mzp	minus, zero, plus
	Amount of forest	zlahm	zero, low, average, high, maximum
	Amount of sealed catchment surface	zlahm	
	Water retention capacity	zlahm	
	Flood risk for human infrastructure	zlahm	

8.3.2. Model expression

Deforestation increases the risk of flooding by the reduction of the retention capacity of vegetation and soil (via parameters as infiltration rate, percolation, interception, evapotranspiration, surface runoff) in the catchment.

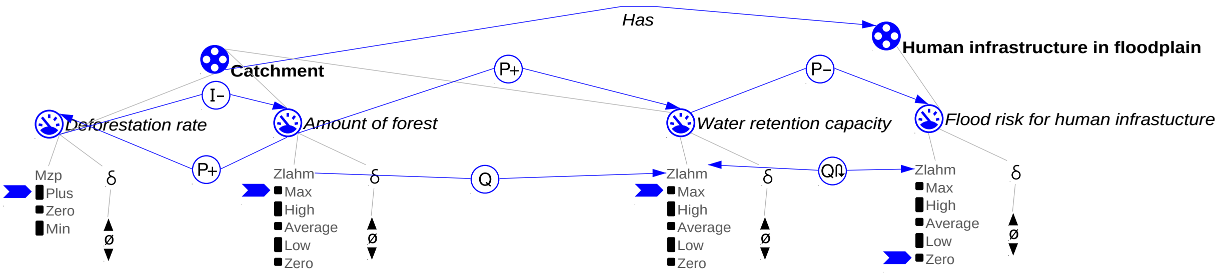


Figure 8.6: Model expression for the model Increase of flood risk_deforestation_LS4.hgp.

The land sealing rate increases the amount of impervious cover (sealed surface) which enhances the risk of flooding. Precipitation leads through an impervious surface directly to an increase of the surface runoff, which intensifies the risk of flooding at a catchment scale.

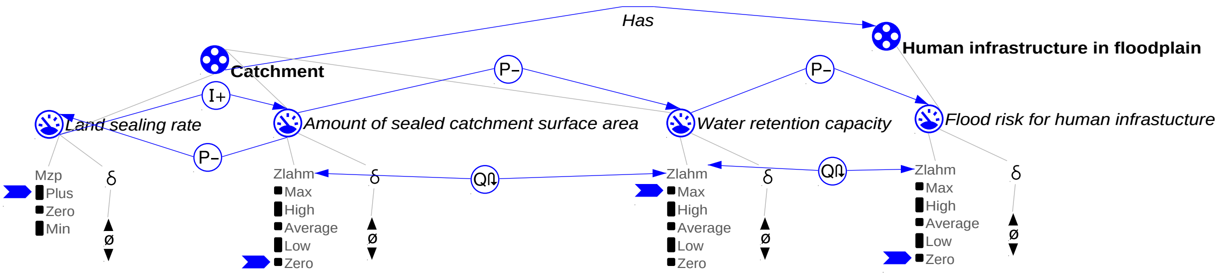


Figure 8.7: Model expression for the model Increase of flood risk_land sealing_LS4.hgp.

8.3.3. Scenarios and simulations

Due to the feedback loop the simulations shows four end states (3, 5, 7, 9). Both simulation paths look the same as the general structure of the model remains the same. The reduction of the forest and the increase of sealed land surface lead to a decreased retention capacity of the catchment, why the flood risk for human infrastructure in floodplain increases

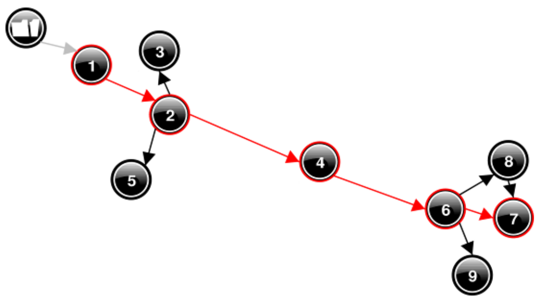


Figure 8.8: Model expression for the models in LS4.

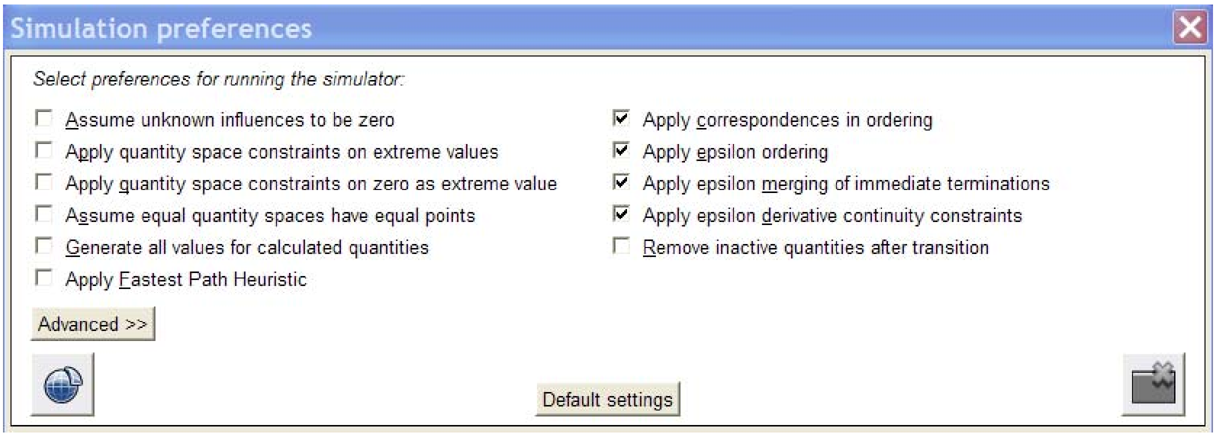


Figure 8.9: The simulation preferences of the two models in LS4.

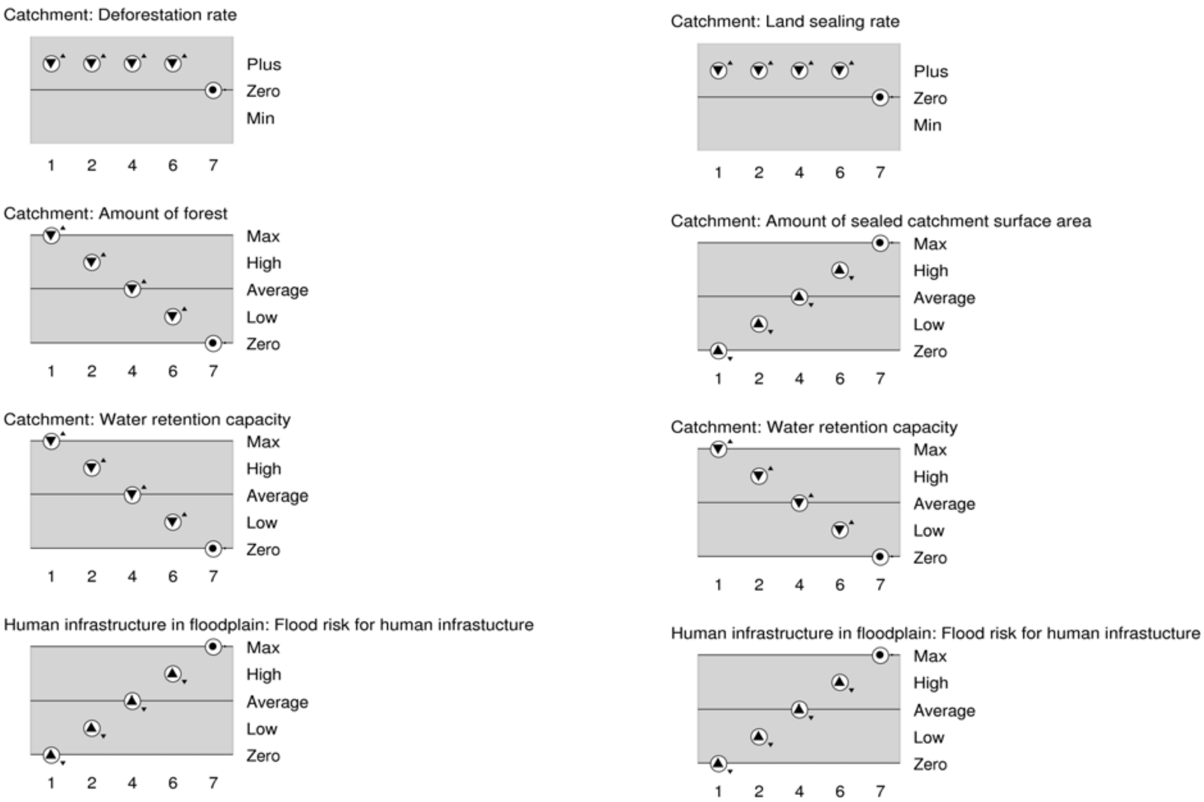


Figure 8.10: Value history of all variables included in the simulations of the two LS 4 models.

Table 8.2: Scenario information – causes and conditions.

Type	Details
Exogenous control	Land sealing rate, deforestation rate
(In)equality	none
Ambiguity	Yes, due to the feedback loop the simulation yields different end states; the simulation preferences allow the Q-spaces to reach zero and maximum

8.4. Flood protection LS 5.hgp

8.4.1. Concepts and goals

The LS5 model shows when flooding occurs:

Content

- **Water is delivered by surface runoff (how the surface runoff is created is shown in a model related to the topic of natural processes).**
- **Water overflows river banks at bankfull (=maximum) stage.**
- **The amount of water that can be contained by dams can be individually set; lowering the dam leads to earlier flooding of the surroundings.**
- **As long as water is contained between the dams the dam has the capacity to prevent the water from flowing into the surrounding area.**
- **The model also shows that there is no absolute prevention from flooding, as even in the highest dam situation flooding occurs at a certain point, given an positive delivery rate of surface runoff.**

Modelling

- **This model is well suited to introduce conditional statements as modelling tool. Conditional statements of system behaviour represent a valuable tool for building qualitative simulations, which is usually not available in numerical simulations.**

Assumption

The increasing delivery of water leads to a local increase of the amount of water in the river bed. One could also model the local increase of water in the river bed by a relation between the water delivered from upstream to the water transported further downstream (via an inequality statement or the calculation of a rate).

Table 8.3: Entities, quantities and quantity spaces (QSs) used in the model Flood protection LS 5.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Water in river	Water delivery rate from surface and subsurface runoff	zp	zero, plus
	Amount of water	Zlahmo	zero, low, average, high, bankfull, overflow
	Overflow rate	zp	zero, plus
	Amount of overflow water	zlah	zero, low, average, high
Dam	Amount of water tha can be contained by dams	zlah	zero, low, average, high
Floodplain	Dam overflow rate	mzp	minus, zero, plus
	Amount of flooded area	zlah	zero, low, average, high
Human infrastructure	Amount of destroyed human infrastructure in floodplain	zlah	zero, low, average, high
	Economic recovery costs	zlah	zero, low, average, high

8.4.2. Model expression

Expression

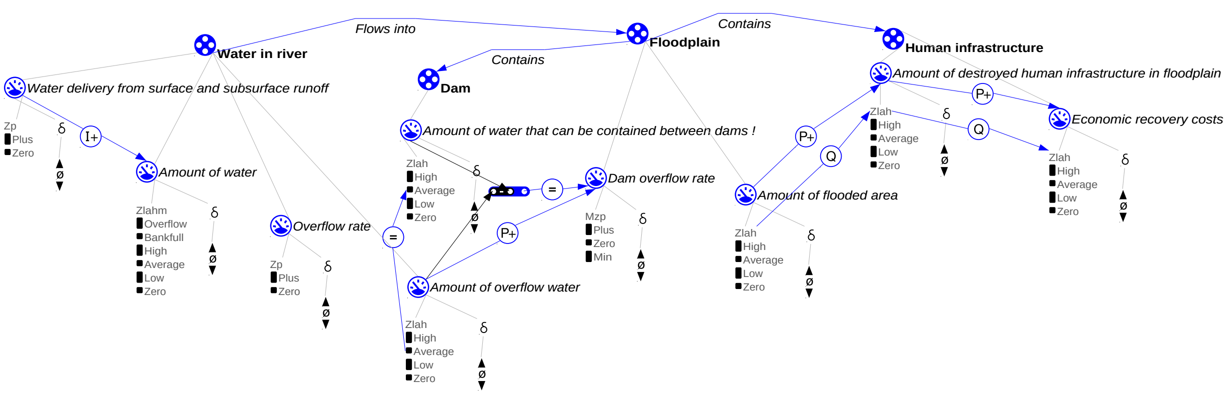


Figure 8.11: Model expression for the model Flood protection LS 5.hgp.

Initial values

For rates no initial values were set, as this leads to an unwanted behaviour of rates, why they were defined in conditional expressions.

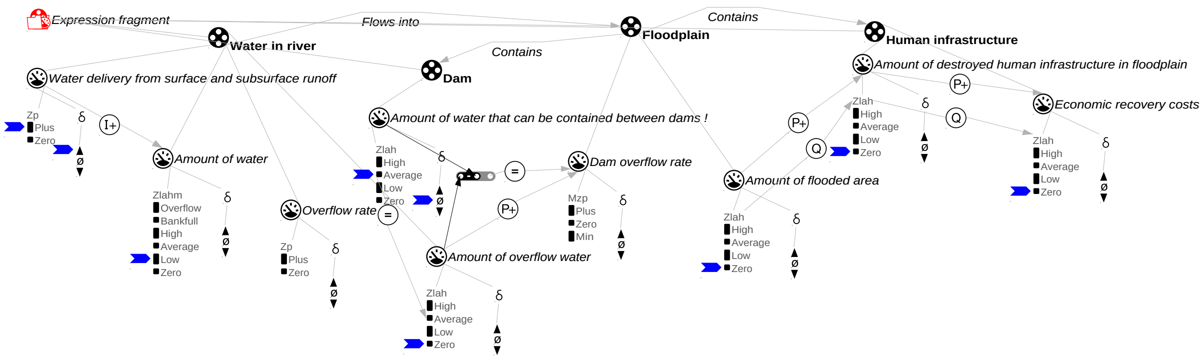


Figure 8.12: Model expression for the model Flood protection LS 5.hgp.

Conditional statements

The model contains two conditional statements, which determine the onset of overflow over river banks and dam overflow.

Dam overflow
Overflow of river banks

Amount of water in riverbed bigger bankfull and therefore flooding rate plus

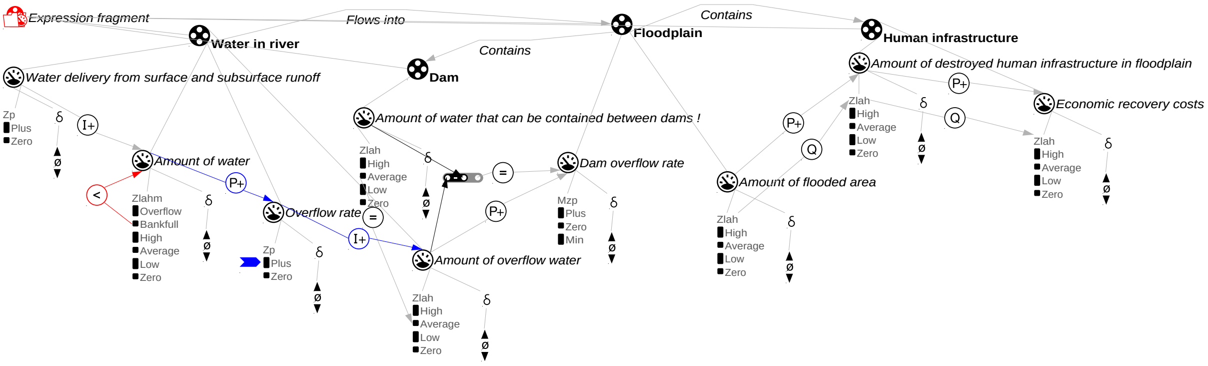


Figure 8.13: Conditional statement of the model Flood protection LS 5.hgp.

Dam overflow is calculated as amount of water flowing over river banks and the amount of water that can be maintained by dams – when the dam overflow rate is bigger than zero, the rate becomes active

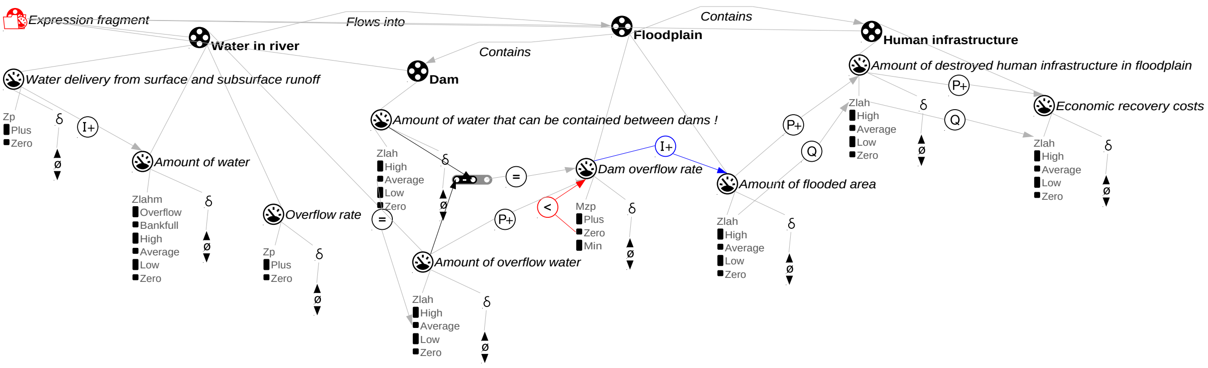


Figure 8.14: Conditional statement of the model Flood protection LS 5.hgp.

8.4.3. Scenarios and simulations

The simulation yields 12 states, when the amount of water contained between the dams is set to average.

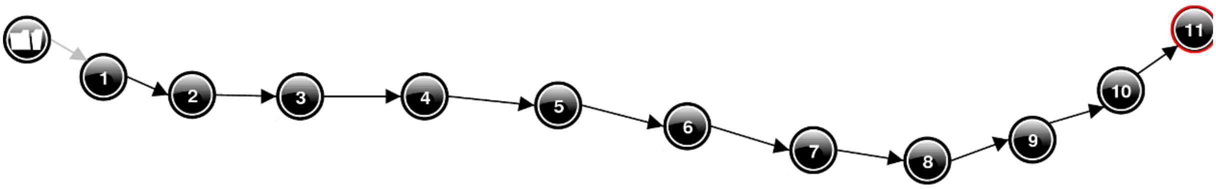


Figure 8.15: Behaviour path of the model Flood protection LS 5.hgp.

The length of the simulation can be changed by changing the amount of water that can be contaied between the dams determining the point when flooding of human infrastructure occurs. Setting the amount of water that can be contained between dams to *high* yields a simulation with 13 states. Flooding also occurs when the amount of water contained between dams is set to high, referring to the principle that dams cannot provide a 100% safety from flooding.

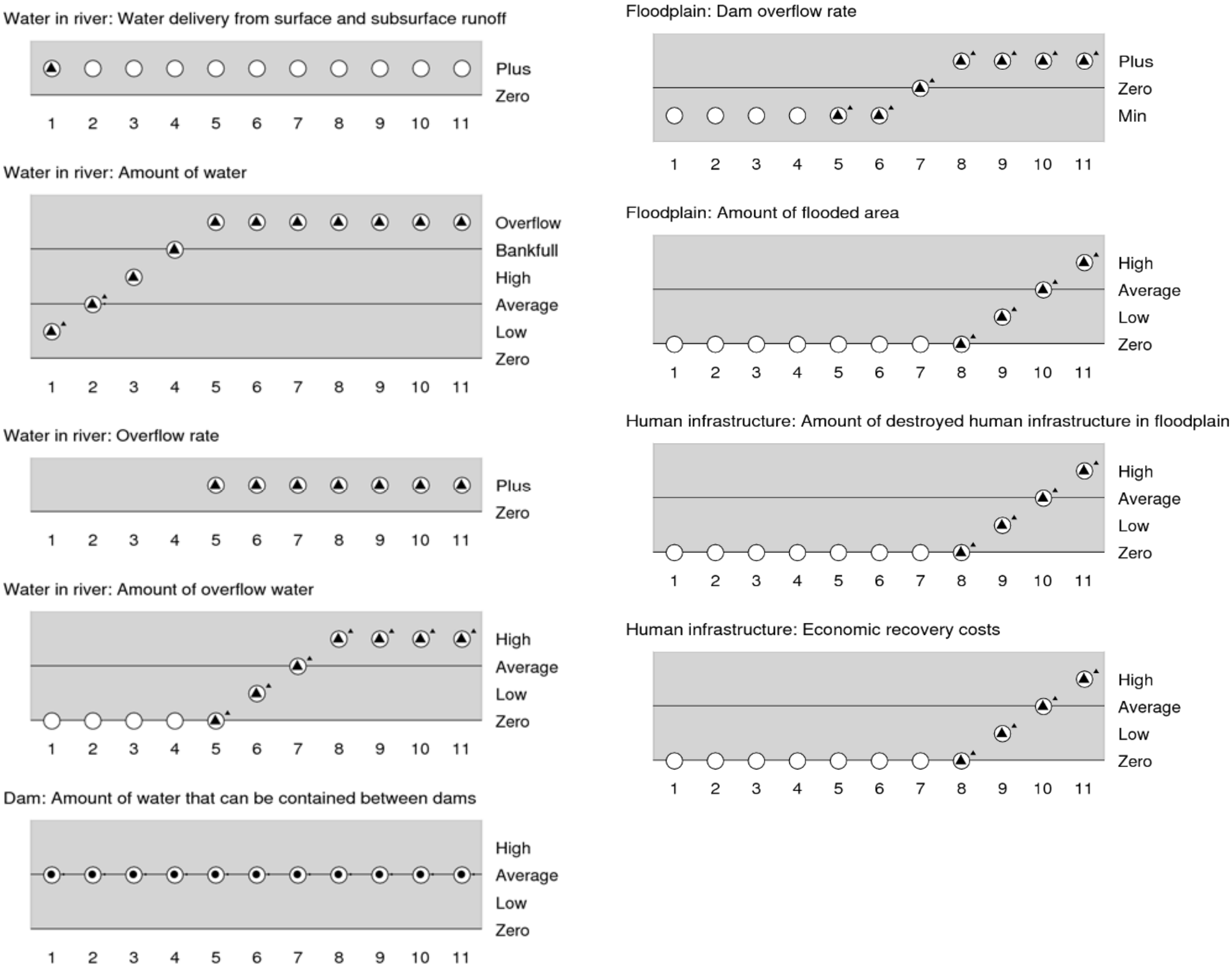


Figure 8.16: Value history of all variables included in the simulation.

Table 8.4: Scenario information – causes and conditions.

Type	Details
Exogenous control	Water delivery from surface and subsurface runoff
(In)equality	none
Ambiguity	none

8.5. Conclusion of the topic

8.5.1. Planned improvements

- **To include different factors that influence the occurrence of floods in a river catchment.**
- **To include effects that locally influence the balance between water delivered from upstream and water further transported downstream.**
- **To include different strategies of flood protection.**
- **To include the delivery of water as an exogenous control that fluctuates, which should allow for the simulation of increase and decrease of a flood.**

8.5.2. Links to other models

- **This model links especially to the topic of natural processes and integrated management models. It also might be linked to ecological components of rivers, as some species only can reproduce and build up populations if regular flooding occurs.**

9. Integrated plans for management of catchment areas

9.1. Topic and model metadata

Topic	**Integrated plans for management of catchment areas**		
Author(s)	**Andreas Zitek**	**Version(s)**	**Final draft 26/07/2010 DynaLearn v0.6.11(CM)**
Model files	**DPSIR LS5.hgp Control circuit_management_LS4.hgp**		
Target users	**Secondary school students, bachelor and master students**		

9.2. Topic rationale

9.2.1. Background

"The Integrated River Basin Management(IRBM) can be defined as a "process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems. The main objective of the Integrated River Basin Management is to establish a balance between the existing natural functions of the river system and the developed aspects of the system. The management actions should fulfil the expectations of the society for industrial use, recreation, nature management, and agricultural purposes.

The Integrated River Basin Management is the main aim promoted by the European Water Framework Directive (WFD), which came into force in December 2000. It is a holistic approach addressing, in addition to quality of rivers, lakes, transitional waters, coastal waters and groundwaters, pressures within the catchment that may cause deterioration or provide risk to water and its ecology. The sustainable management of both terrestrial and aquatic habitats is an integral part of the WFD. It requires better understanding of pressures and their impacts on waters and the response of aquatic systems. Effective, reliable, and transparent management requires a collaborative planning and decision-making process in cooperation with all stakeholders in the river basin. It is an iterative process, where decisions are to be made throughout.

The planning process required by the Water Framework Directive can be described as a cycle, where stakeholders play a substantial role.

Integrated drainage basin approach in river basin management is based on the fact that the soil and river channel within a basin form an unity. During the last decades general river ecology has pointed out that the biotic networks in a river ecosystem are strongly dependent on the organic matter produced in the soil ecosystems of the drainage basin (detritus). Most of the rivers in the world have been characterised as heterotrophic in terms of their energy balance. On the other hand, the river systems are also characterised by continuous material transport from the drainage basin into the river channel, and finally to the sea. This

transport has multiple impacts on the river biota. Knowledge of river systems at this general level should increase the general motivation to approach river basins as entities". [10]

Key issues for understanding the meaning of integrated plans for management of catchment areas are, besides an understanding of the natural processes being active within a specific catchment, the needs and interests of local human populations and stakeholders. To achieve an integrated management, a strong integration of different scientific disciplines and a structured way of integrating the local population and different stakeholder groups are needed.

The DPSIR (Driver-Pressure-State-Impact-Response) scheme offers a structured way of capturing essential indicators of environmental change for developing adequate response actions to achieve a desired environmental status and has been established as an approach for analysing environmental problems, with regards to the implementation of the EU-WFD.

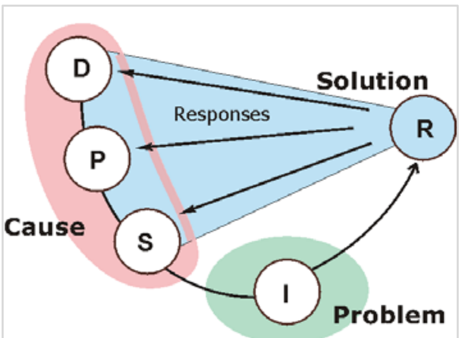
Hence, 'Driving Forces' are considered normally to be the economic and social policies of governments, and economic and social goals of those involved in industry. 'Pressures' are the ways that these drivers are actually expressed, and the specific ways that ecosystems and their components are perturbed, i.e. for the ecosystem effects of fishing, the central pressure would be fishing effort. These pressures degrade the 'State' of the environment, which then 'Impacts' upon human health and ecosystems, causing society to 'Respond' with various policy measures, such as regulations, information and taxes; these can be directed at any other part of the system. Likewise, ideally, a pressures-and-impacts assessment will be a four-step process (Borja et al. 2006):

- **describing the 'driving forces', especially land use, urban development, industry, agriculture and other activities which lead to pressures, without regard to their actual impacts,**
- **identifying pressures with possible impacts on the water body and on water uses, by considering the magnitude of the pressures and the susceptibility of the water body,**
- **assessing the impacts resulting from the pressures, and**
- **evaluating the risk of failing the WFD objectives.**

Furthermore, adaptive management has to be applied, including the control of the ecological status and a continuation of rehabilitation measures until the good ecological status is achieved.

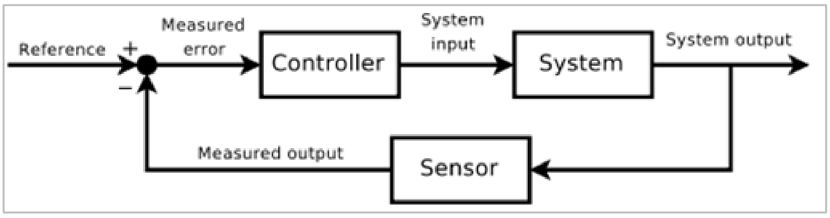
9.2.2. Key themes

- **Examples for the application of the DPSIR scheme with regard to unsustainable intensification of agriculture and its effect on the ecological status and restoration need for the EU WFD (Figure showing the principle of the DPSIR scheme on the right side from: Giupponi 2002).**



10 http://toolbox.watersketch.net/page_view.php?page=132&open=0

- **Showing how the principle of a control circuit (or feedback control systems) might apply to management (Norton und Reckhow 2008).**



9.3. DPSIR LS5.hgp

9.3.1. Concepts and goals

Content

- **To show how unsustainable intensification of agriculture puts a pressure on the environment causing the degradation of the ecological status, and creating a restoration need.**

Modelling

- **To introduce the use of system patterns for modelling.**
- **This model is well suited to introduce conditional statements. Conditional statements of system behaviour represent a valuable tool for building qualitative simulations, which is usually not available in numerical simulations.**

Table 9.1: Entities, quantities and quantity spaces (QSs) used in the model DPSIR LS5.hpg.

Entity	*Quantities*	*QS*	*Remarks*
Indirect driver	Need for food	mzp	minus, zero, plus
Direct driver	Unsustainable agricultural intensification		minus, zero, plus
Pressure	Use of fertilizers and pesticides	lmh	low, medium, high
State	Amount of fertilizers and pesticides in rivers	lmh	low, medium, high
Impact	Ecological status	gw	good, worse than good
Response	Restoration need	zp	zero, plus

9.3.2. Model expression

Expression

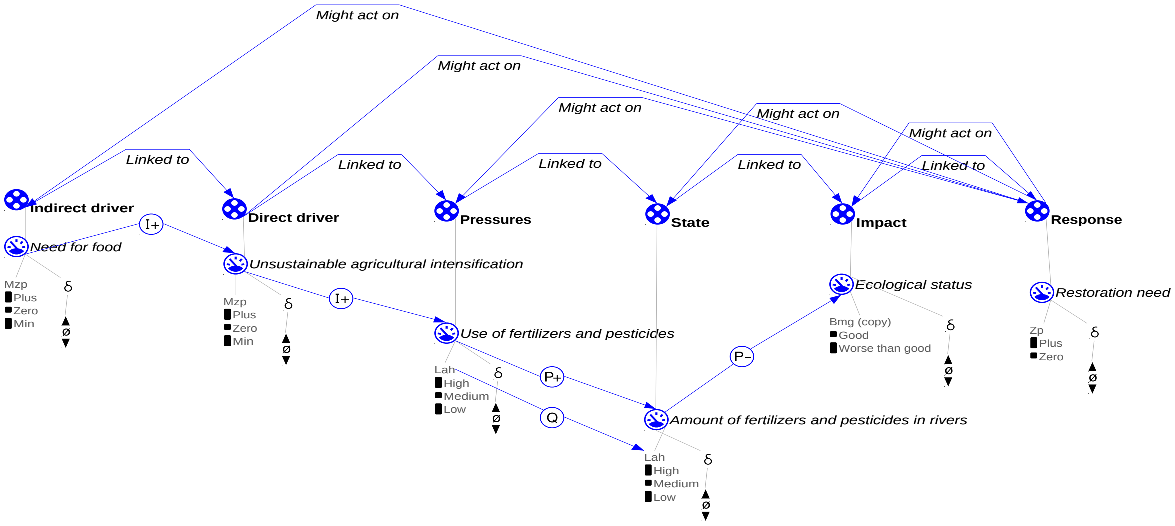


Figure: 9.1: Model expression of DPSIR LS5.hpg.

Initial values

At the beginning of the simulation the environment is in a good ecological status with low uses of pesticides and a low amount of pesticides in the river, the need for food is set to plus.

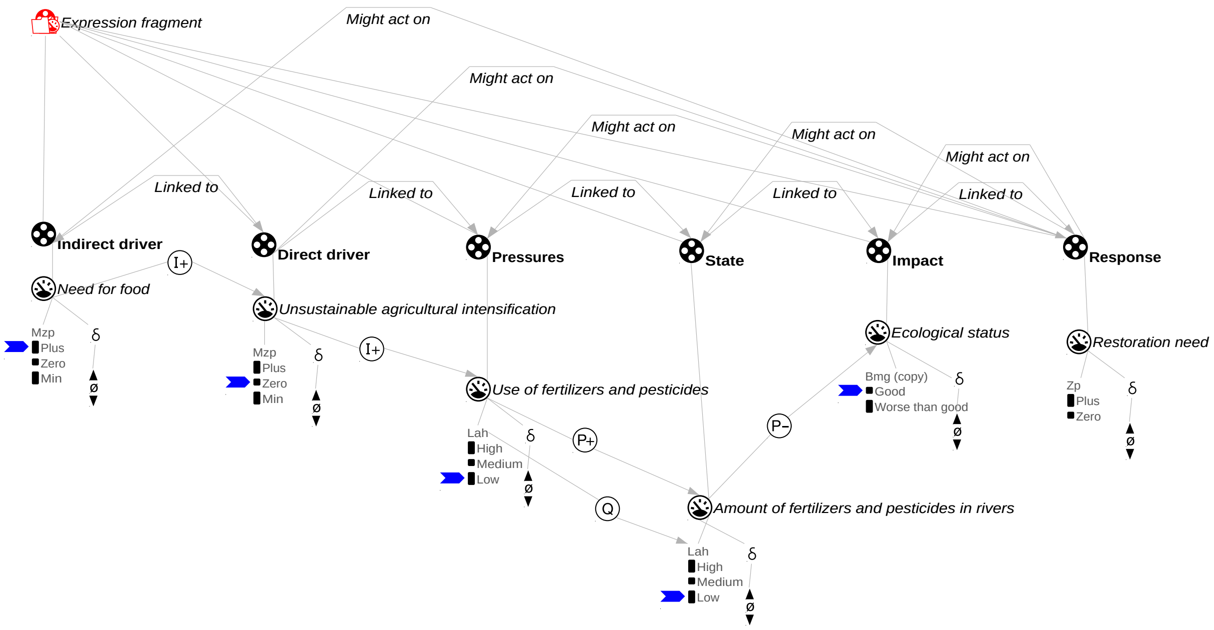


Figure: 9.2: Initial values of DPSIR LS5.hpg.

Conditional statements

The model contains one conditional statement, which determines the onset of restoration needs when the ecological status gets worse than good.

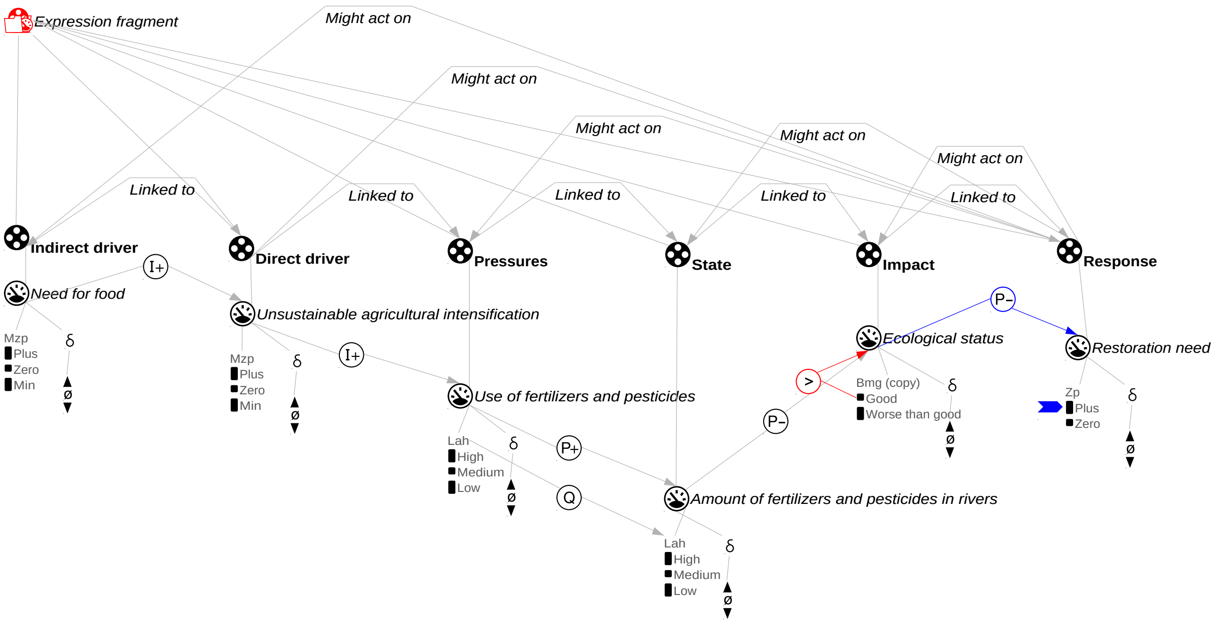


Figure: 9.3: Conditional statement of DPSIR LS5.hpg.

9.3.3. Scenarios and simulations

The simulation yields five states, showing how the use of fertilizers and pesticides increases followed by an increase of the amount of fertilizers and pesticides in rivers, causing the ecological status to decline. Finally, when the ecological status is worse that good, restoration need is activated.

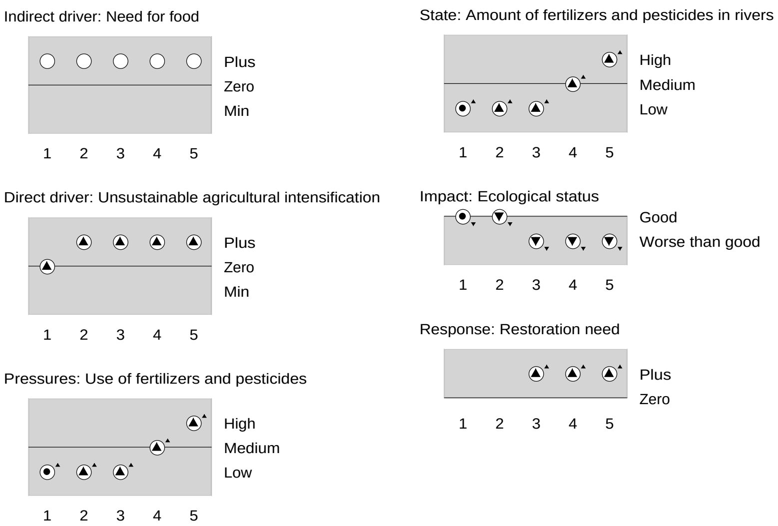


Figure: 9.4: Value history of the model DPSIR LS5.hpg.

Table 9.2: Scenario information – causes and conditions.

Type	Details
Exogenous control	Yes, need for food is set as external indirect driver
(In)equality	none
Ambiguity	none

9.4. Control circuit_management_LS4.hgp

9.4.1. Concepts and goals

Content

- **To show how the principle of a control circuit can be applied to an adaptive management cycle.**

Modelling

- **To create interest for typical system patterns.**
- **To steer discussion on already known system patterns and their potential use in management.**

Table 9.3: Entities, quantities and quantity spaces (QSs) used in the model Control circuit_management_LS4.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Ecological status according to wfd	Target value	bpmgh	bad, poor, moderate, good, high
	Restoration rate	mzp	minus, zero, plus
Monitoring	Measured value	bpmgh	bad, poor, moderate, good, high

9.4.2. Model expression

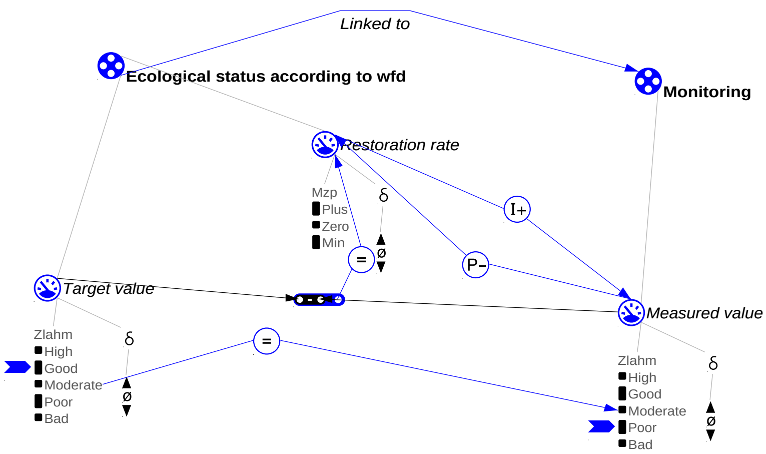


Figure: 9.5: Model expression of Control circuit_management_LS4.hgp.

9.4.1. Scenarios and simulations

At the beginning of the simulation, the measured value differs considerably from the target value (the ecological status is worse than good), which triggers the restoration rate which remains active until the good ecological status is reached. At this moment, the restoration activity stops.

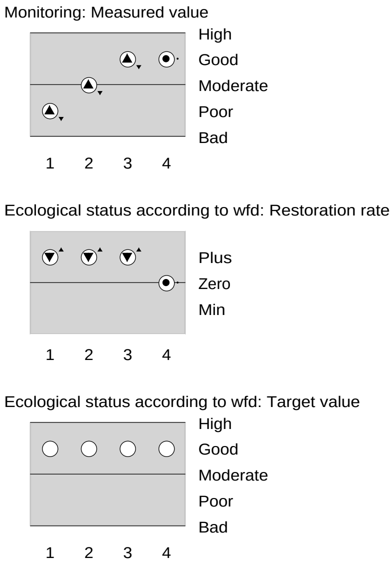


Figure: 9.6: Value history of the model Control circuit_management_LS4.hgp.

Table 9.4: Scenario information – causes and conditions.

Type	**Details**
Exogenous control	**none**
(In)equality	**none**
Ambiguity	**none**

9.5. Conclusion of the topic

9.5.1. Planned improvements

- **To include restoration actions into the DPSIR model.**
- **To explore the use of qualitative system archetypes models for management.**
- **To develop a broader picture of issues related to integrated management.**

9.5.2. Links to other models

- **This model is especially linked to land and water use.**

10. Food webs and energy flow

10.1. Topic and model metadata

Topic	Energy flow in ecosystems		
Author(s)	Andreas Zitek Michael Stelzhammer	Version(s)	Final graft 13/07/10 DynaLearn v0.6.8(CM)
Model files	FoodWebs_concept.hgp FoodWebs_LS2.hgp FoodWebs_LS4.hgp		
Target users	Secondary school students Bachelor students		

10.2. Topic rationale

10.2.1. Background

Ecosystems and the biosphere are sustained through a combination of *one-way energy flow from the sun* through these systems and *nutrient cycling of key materials* within them – two important natural services that are components of the earth's natural capital. These two scientific principles of sustainability arise from the structure and function of natural ecosystems, the law of conservation of matter, and the two laws of thermodynamics. Each trophic level on a food chain or web contains a certain amount of biomass. The chemical energy in biomass is transferred from one trophic level to another. But this transfer is not very efficient, because, with each transfer, some usable chemical energy is degraded and lost to the environment as *low-quality heat*. This so-called ecological efficiency ranges from 2% to 40% (loss of 60-98%), with an assumed typical loss of 10% (Miller & Spoolman, 2009).

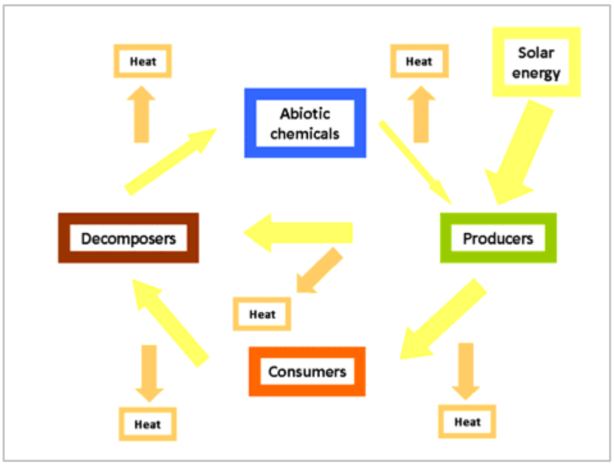


Figure 10.1: The flow of energy in an ecosystem: coming from the sun, going through organisms, loosing most of the energy to the environment in form of low-quality heat (Miller & Spoolman, 2009).

10.2.2. Key themes

- Flow of energy through several components in an ecosystem.
- Relations between different trophic levels of a food chain.

10.3. FoodWebs_concept.hgp

10.3.1. Concepts and goals

Content

- **This concept map shows the simplified structure of energy flow through the different elements of an ecosystem. It contains the key components of a food chain (producers, consumers, decomposers) as well as the sources and the loss of energy, and the processes between them.**

Modelling

- **Looking at circular and regular patterns in models.**

Table 10.1: Entities used in the model FoodWebs_concept.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Solar energy			
Primary producers			
Plants			
Phytoplankton			
Algae			
Heat			
Primary consumers			
Secondary consumers			
Final consumers (Top preditors)			
Decomposers			
Bacteria			
Fungi			
abiotic chemicals			

10.3.2. Model expression

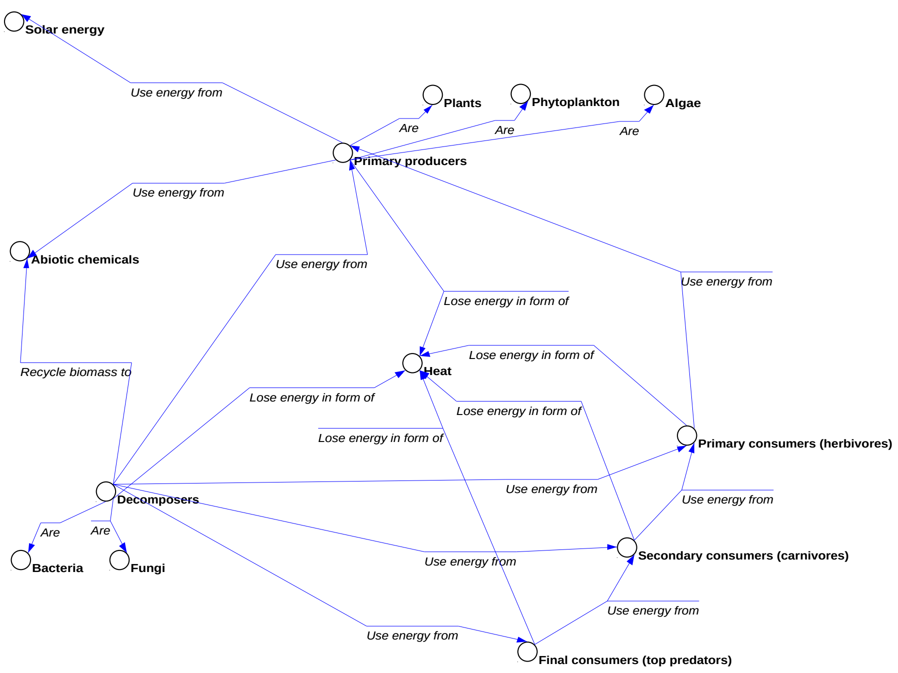


Figure 10.2: Model expression for FoodWebs_concept.hgp

This LS gives a very general review about the trophic concept of ecosystem structure.

10.4. FoodWebs_LS2.hgp

10.4.1. Concepts and goals

LS 2 concretizes the concept map. It shows a more detailed image of what happens between the food chain links, and of the consequences of the lack of energy sources. Table 10.2 shows the list of the entities and quantities of this model.

Table 10.2: Entities and quantities used in the model FoodWebs_LS2.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Sun	Solar energy		
Producer	Amount of		
Primary consumer	Amount of		
Secondary consumer	Amount of		
Top predator	Amount of		
Decomposer	Amount of		
Abiotic chemicals	Amount of		
Abiotic chemicals form decomposition	Amount of		

10.4.2. Model expression

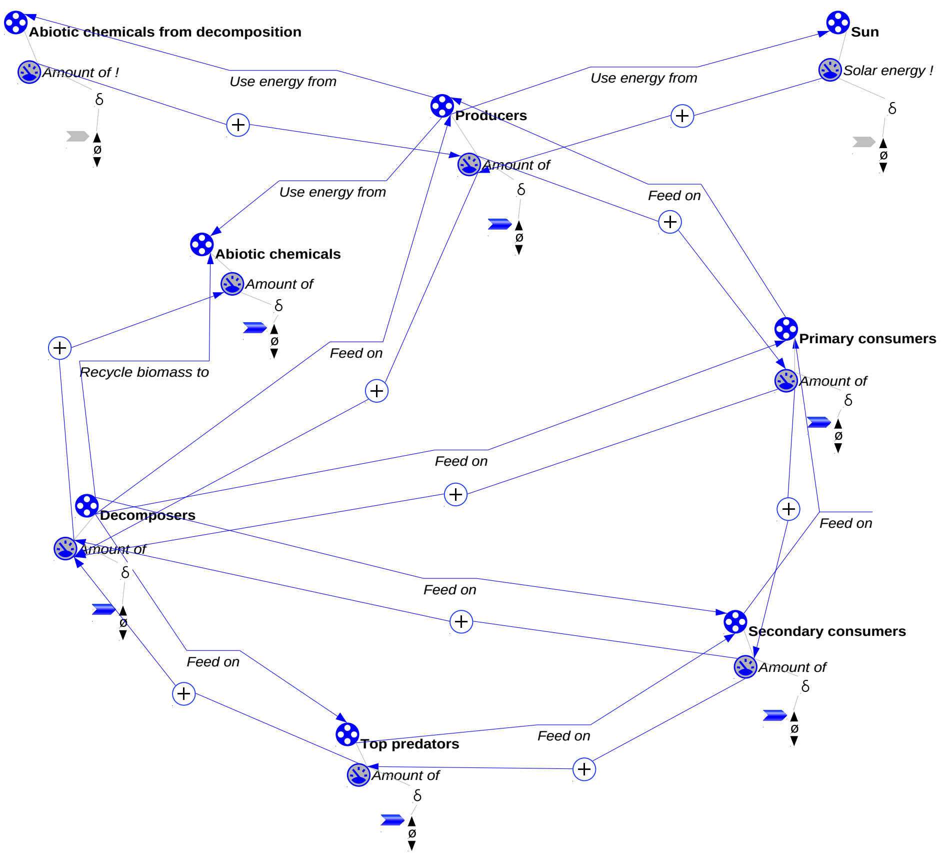


Figure 10.3: Model expression for FoodWebs_LS2.hgp.

10.4.3. Scenarios and simulations

There are two sources of energy that are used by producers: the sun and abiotic chemicals from decomposition. Both of them are essential to keep the chain going. With input of both, the amount of each food web member is increasing. The missing of one of those two sources causes a lack of reaction within the food chain showing the necessity of both energy sources.

Table 10.3: Scenario information – causes and conditions.

Type	Details
Exogenous control	Solar energy (Sun) *increase* Amount of abiotic chemicals from decomposition *increase*
(In)equality	none
Ambiguity	none

10.5. FoodWebs_LS4.hgp

10.5.1. Concepts and goals

LS 4 further concretizes the idea of a food web showing a predator-prey food chain including secondary consumers and a top predator. The population size of the predator is determined by a population growth rate that is determined by the relationship between the number of born individuals and the number of dead individuals. The number of born individuals is positively influenced by prey availability and the number of dead individuals is negatively influenced by prey availability (which means increased survival). The relationship of the number of secondary consumers produced and secondary consumers consumed yields the population growth rate of the secondary producer (=prey). The model, a typical predator-prey model following the Lotka-Volterra equation, represents an example of a typical food web structure.

***"The Lotka Volterra is frequently used to describe the dynamics of biological systems in which two species interact, one a predator and one its prey. They evolve in time following a specific pattern. In the model system, the predators thrive when there is plentiful prey but, ultimately, outstrip their food supply and decline. As the predator population is low the prey population will increase again. These dynamics continue in a cycle of growth and decline".*[11]**

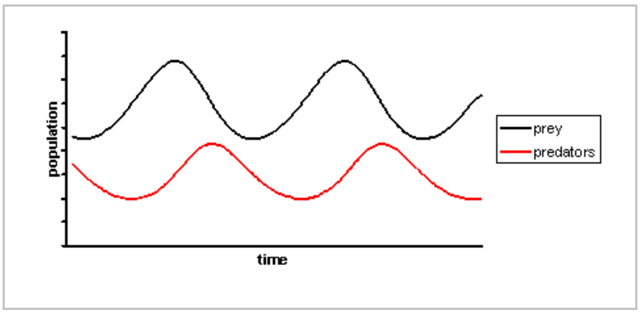


Figure 10.4: Periodic fluctuations of the predator-prey populations following the Lotka-Volterra model[1].

The Lotka-Volterra model makes a number of assumptions about the environment and evolution of the predator and prey populations:

1. **The prey population finds ample food at all times.**
2. **The food supply of the predator population depends entirely on the prey populations.**

[11] http://en.wikipedia.org/wiki/Lotka%E2%80%93Volterra_equation

3. **The rate of change of a population is proportional to its size.**
4. **During the process, the environment does not change in favour of one species and the genetic adaptation is sufficiently slow.**

Table 10.4: Entities, quantities and quantity spaces (QSs) used in the model FoodWebs_LS4.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Secondary consumers	Population size	p	plus (only allows the population to increase and decrease)
	Population growth rate	mzp	minus, zero, plus
	Number of consumed secondary consumers produced	lah	low, average, high
	Number of consumed secondary consumers consumed	lah	low, average, high
Predators	Population size	p	Plus (only allows the population to increase and decrease)
	Prey availability rate	mzp	minus, zero, plus
	Population growth rate	mzp	minus, zero, plus
	Number of individuals born	lah	low, average, high
	Number of individuals dead	lah	low, average, high

10.5.2. Model expression

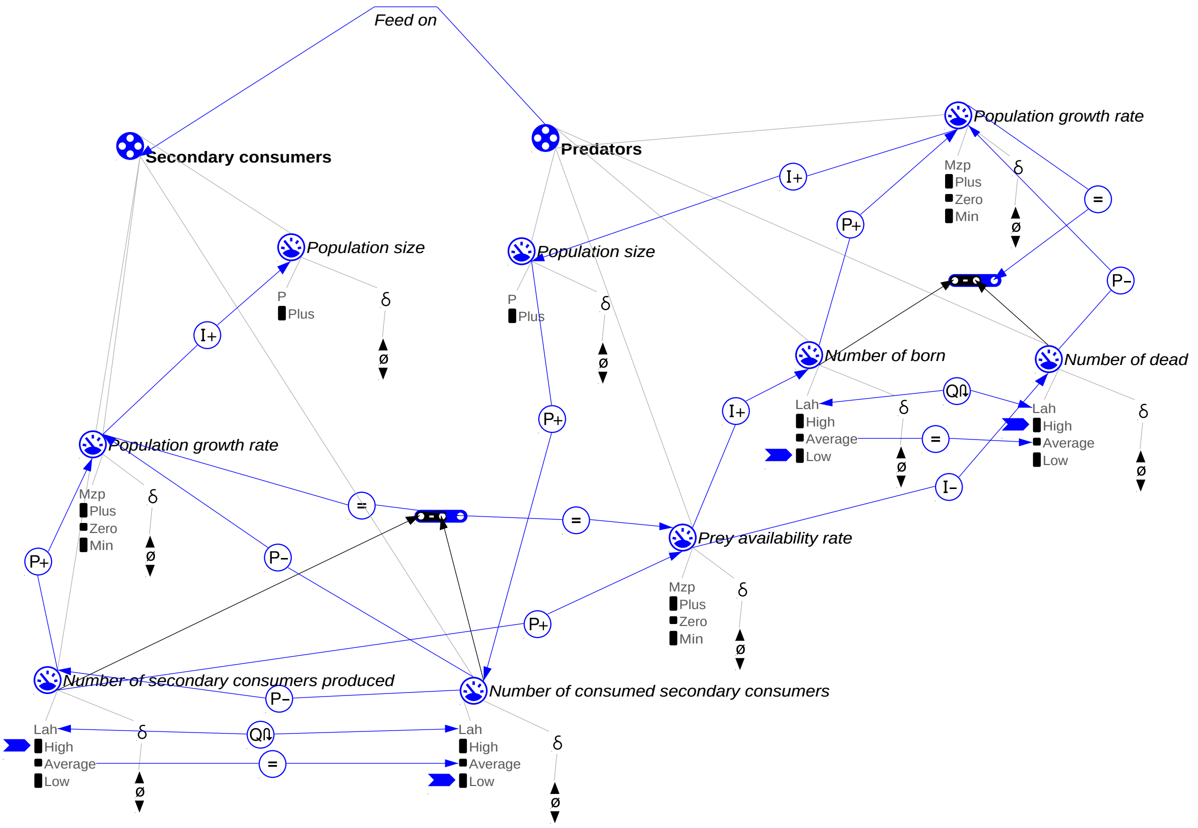


Figure 10.5: Model expression for FoodWebs_LS4.hgp.

10.5.3. Scenarios and simulations

The scenario shows the reaction of the predator population size to prey availability and the effect of the increased predatory activity on the population size of the secondary consumer. As described by the Lotka-Volterra model, first the prey (=secondary consumer) population increases, and with some delay then the size of the predator population increases while the population of the prey starts to decrease, followed by a decrease by the predator. The simulation shows a typical circular behaviour.

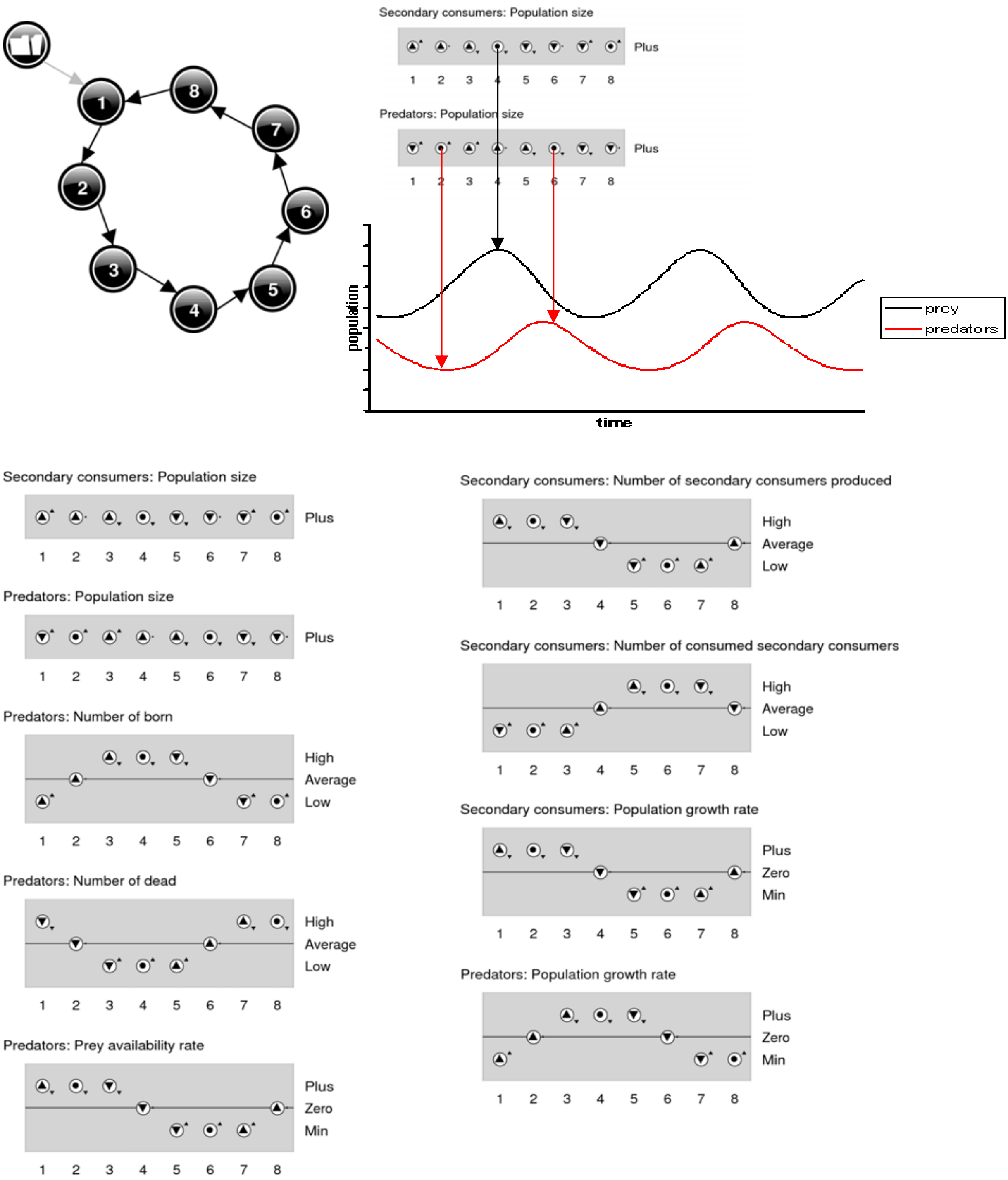


Figure 10.6: Behaviour path and value history (combined with Fig. 10.4) of all variables included in the simulation.

Table 10.5: Scenario information – causes and conditions.

Type	Details
Exogenous control	none
(In)equality	none
Ambiguity	none

10.6. Conclusion of the topic

10.6.1. Planned improvements

- **Concretion of the model on certain species.**
- **Description of an aquatic food web / chain.**
- **Displaying an aquatic predator-prey relation.**

10.6.2. Links to other models

This model links especially to models simulating development processes of population.

11. Hydropower generation

11.1. Topic and model metadata

Topic	**Hydropower generation**		
Author(s)	**Andreas Zitek**	**Version(s)**	**Final draft 26/07/10 DynaLearn 0.6.11(CM)**
Model files	**Boku_Water abstraction_LS2.hgp**		
Target users	**Secondary school students, bachelor students**		

11.2. Topic rationale

11.2.1. Background

"Humans have been harnessing water to perform work for thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants. For more than a century, the technology for using falling water to create hydroelectricity has existed. The evolution of the modern hydropower turbine began in the mid-1700s when a French hydraulic and military engineer, Bernard Forest de Bélidor wrote Architecture Hydraulique. In this four volume work, he described using a vertical-axis versus a horizontal-axis machine. During the 1700s and 1800s, water turbine development continued. In 1880, a brush arc light dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan; and in 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. These two projects used direct-current technology. Alternating current is used today. That breakthrough came when the electric generator was coupled to the turbine, which resulted in the world's, and the United States', first hydroelectric plant located in Appleton, Wisconsin, in 1882".[12]

"Hydropower is using water to power machinery or make electricity. Water constantly moves through a vast global cycle, evaporating from lakes and oceans, forming clouds, precipitating as rain or snow, then flowing back down to the ocean. The energy of this water cycle, which is driven by the sun, can be tapped to produce electricity or for mechanical tasks like grinding grain. When flowing water is captured and turned into electricity, it is called hydroelectric power or hydropower. There are several types of hydroelectric facilities; they are all powered by the kinetic energy of flowing water as it moves downstream. Turbines and generators convert the energy into electricity, which is then fed into the electrical grid".[13]

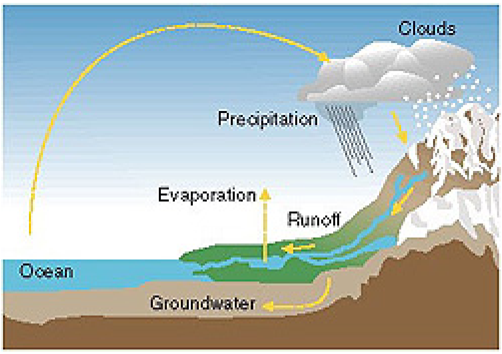


Figure 11.1: The hydrological cycle as driver for the creation of kinetic water energy, that can be used to produce energy[13].

"There are three types of hydropower facilities: impoundment, diversion, and pumped storage. Some hydropower plants use dams and some do not. The most common type of hydroelectric power plant is an

[12] http://www1.eere.energy.gov/windandhydro/hydro_history.html

[13] http://www1.eere.energy.gov/windandhydro/hydro_how.html

impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs in a s. called hydropeaking mode or to maintain a constant reservoir level.

A diversion, sometimes called run-of-river facility abstracts a portion of a river through a canal or penstock. Usually it also uses a dam to divert the water, but it may not require the use of a dam in some specific cases.

When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

Facilities range in size from large power plants that supply many consumers with electricity to small and micro plants that individuals operate for their own energy needs or to sell power to utilities. Large Hydropower can be defined as facilities that have a capacity of more than 30 megawatts. Small Hydropower can be defined as facilities that have a capacity of 100 kilowatts to 30 megawatts. A small or micro-hydroelectric power system can produce enough electricity for a home, farm, ranch, or village.

Hydropower uses a fuel— water—that is not reduced or used up in the process. Because the water cycle is an endless, constantly recharging system, hydropower is considered a renewable energy".[14]

But unfortunately, hydropower plants have severe effects on river ecosystems. As the energy demand is expected to increase considerably in the coming years as the result of population growth and economic development (EIA 2007), considerable environmental problems can be expected worldwide, if not other strategies like technological development and energy saving are first applied. Many people in the world are currently experiencing dramatic shifts in lifestyle as their economies make the transition from a subsistence- to an industrial or service-based economy. The largest increases in energy demand will take place in developing countries where the proportion of global energy consumption is expected to increase from 46 to 58 percent between 2004 and 2030 (EIA 2007).

Hydropower offers many environmental benefits and is widely used as a source of energy, and it is considered to be "clean", as the carbon released by hydropower plants is negligible. However, these plants often require large dams, created by flooding large areas of forest or rural areas. The consequences, human population displacement, habitat and biodiversity loss, and often the disappearance of sites of cultural value, are object of fierce discussions. As a result of flooding large dams also can produce a significant amount of greenhouse gasses (McCully 2002).

The movements of fish can be limited and they and other life can be killed by turbines. Hydropower systems affect the sediment transport, the natural flow regime, groundwater levels, land drainage and potentially increase the risk of flooding. Regulation of flow and fragmentation of rivers through hydroelectric power plants and other hydraulic measures have created enormous ecological problems (Dynesius und Nilsson 1994; Jungwirth et al. 2002). Hydropower production mainly influences the natural hydrologic regime of a river by abstracting water or impounding rivers for water storage in reservoirs with subsequent releases of water in a hydropeaking mode or in a constant release mode (Cazaubon und Giudicelli 1999). This human induced alteration of the natural hydrology of a river has caused significant negative effects on fish (Murchie et al. 2008). Therefore energy from hydropower production, although renewable, should not be generally considered as green energy (Welcomme und Marmulla 2008).

[14] http://www.daviddarling.info/encyclopedia/H/AE_hydroelectric_power.html

The question for policy makers and decision-makers is whether the impacts created by a hydropower facility are a reasonable tradeoff for the benefits generated according to the current value system and importance attached to both the positive and negative effects. Each future generation will have to make this judgment, according to the values it espouses (Frey und Linke 2002).

11.2.2. Key themes

- **To show unwanted side effects of hydropower production, especially how water abstraction affects fish.**
- **To show the conflict between private economic interests and the status of the environment.**

11.3. Boku_Water abstraction_LS2.hgp

11.3.1. Concepts and goals

Content

- **To show how private economic interests might affect common goods and resources (as it also known from the systems archetype "Tragedy of the Commons").**
- **To include the economic interest of the power plant owner into perspective.**
- **To trigger a discussion on economic versus ecological values.**

Modelling

- **To introduce basic causal models.**

Assumptions
Only fish are represented as indicators for the overall ecological status of a river, where water is abstracted, although there may be additonal effects on the ecosystem.

Table 11.1: Entities and quantities used in the model Boku_Water abstraction_LS2.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Power plant owner	Economic interest		
	Economic income		
	Economic satisfaction		
Power plant	Amount of abstracted water for energy production		
River	Ecological status		
Water	Depth		
	Flow velocity		
	Temperature		
Fish	Amount of large fish		
	Amount of temperature sensitive fish		
	Amount of flow velocity sensitive fish		

11.3.2. Model expression

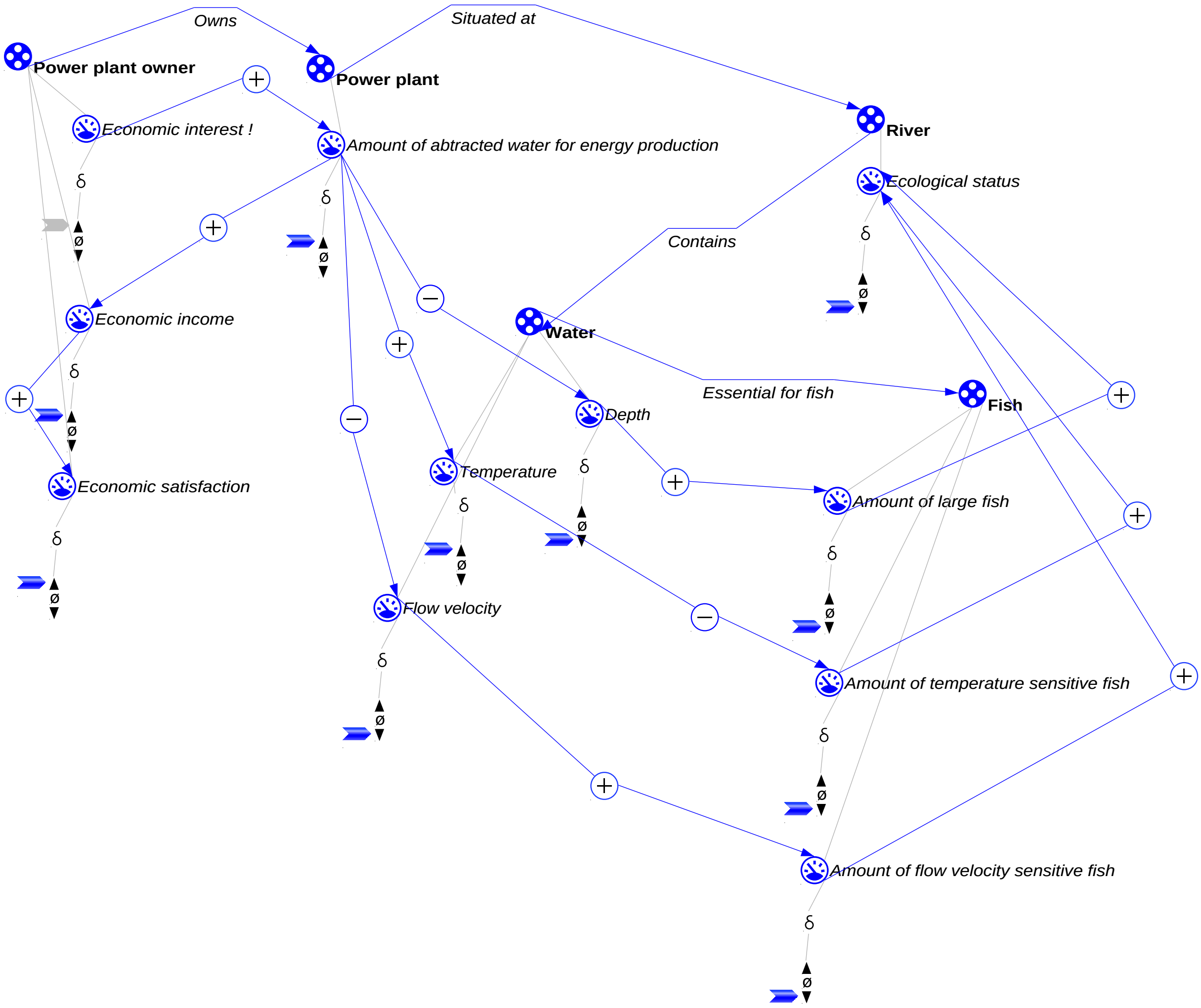


Figure 11.2: Model expression of Boku_Water abstraction_LS2.hgp.

11.3.3. Scenarios and simulations

The simulation shows, how an increase in economic interest increases the amount of abstracted water which negatively affects a diverse group of sensitive fish species and age classes. Finally the ecological status declines, whereas the economic satisfaction increases.

Table 11.2: Scenario information – causes and conditions.

Type	Details
Exogenous control	Yes, economic interest is increasing
(In)equality	none
Ambiguity	none

11.4. Conclusion of the topic

11.4.1. Planned improvements

- **To address more complex issues of hydropower production on higher use levels of DL.**
- **To include the potential conflict between the EU Water Framework Directive and the Renewable Energy Directive.**
- **To develop different scenarios of how the future increase in energy consumption might affect aquatic ecosystems.**
- **To include hydropeaking effects on the environment.**
- **To include relationships between wind energy production and hydropower production.**

11.4.2. Links to other models

This model links to natural processes, land and water use, climate change, international treaties, and integrated management.

12. Indicator species

12.1. Topic and model metadata

Topic	Indicator species		
Author(s)	Andreas Zitek	Version(s)	Final draft 26/07/10 DynaLearn 0.6.11(CM)
Model files	BOKU_indicator species_LS3.hgp		
Target users	Secondary school students		

12.2. Topic rationale

12.2.1. Background

"An indicator species is any biological species that defines a trait or characteristic of the environment. For example, a species may delineate an ecoregion or indicate an environmental condition such as a disease outbreak, pollution, species competition or climate change. Indicator species can be among the most sensitive species in a region, and sometimes act as an early warning to monitoring biologists.

Lindenmayer et al. (2000) suggest 7 alternative definitions of indicator species:

> ***1. a species whose presence indicates the presence of a set of other species and whose absence indicates the lack of that entire set of species.***
>
> ***2. a keystone species, which is a species whose addition to or loss from an ecosystem leads to major changes in abundance or occurrence of at least one other species.***
>
> ***3. a species whose presence indicates human-created abiotic conditions such as air or water pollution (often called a pollution indicator species).***
>
> ***4. a dominant species that provides much of the biomass or number of individuals in an area.***
>
> ***5. a species that indicates particular environmental conditions such as certain soil or rock types.***
>
> ***6. a species thought to be sensitive to and therefore to serve as an early warning indicator of environmental changes such as global warming or modified fire regimes (sometimes called a bioindicator species).***
>
> ***7. a management indicator species, which is a species that reflects the effects of a disturbance regime or the efficacy of efforts to mitigate disturbance effects.***

Type 1, 2, and 4 have been proposed as indicators of biological diversity and types 3, 5, 6, and 7 as indicators of abiotic conditions and/or changes in ecological processes". [15]

In 2000 the European union launched a new water legislation, the EU-Water Framework Directive (EU-WFD)[16]. This legislation represents the overriding framework for sustainable river management of surface water resources. One of the key objectives of the WFD is to achieve the "good ecological status" of running waters by 2015. Macrozoobenthos and fish are two out of four organism groups (fish, macrozoobenthos, algae, macrophytes) that are used as an indicators to describe the ecological status of running waters.

[15] http://en.wikipedia.org/wiki/Indicator_species

[16] http://ec.europa.eu/environment/water/water-framework/index_en.html

12.2.2. Key themes

The use of different indicator species or species groups (sensitive species, tolerant species) as reflectors of environmental quality.

12.3. BOKU_indicator species_LS3.hgp

12.3.1. Concepts and goals

Content

- **To show how aquatic pollution decreases the amount of sensitive species and increases the abundance of tolerant species.**
- **To introduce the notation of the EU Water framework Directive that uses different indicators to assess the ecological status of aquatic resources throughout Europe along a 5-tiered scheme.**
- **To force a discussion of adaptations of animals to their environment to sensitize students for the relevance of healthy environmental conditions for all types of living creatures.**
- **To discuss sources of pollution, and how human activity is linked to the life of indicator species.**
- **To introduce the idea of using different metrics (amount of species, abundance) for assessing the ecological status.**

Modelling

- **To introduce the use of quantity spaces.**

Assumptions

The model does not take into account, that even tolerant species extinct at a certain level of environmental degradation. It is assumed that their abundance increases as they can take advantage of the changed environmental conditions and due to the lack of other species.

Table 12.1: Entities, quantities and quantity spaces (QSs) of BOKU_indicator species_LS3.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Humans	pollution		
Environment	Amount of pollutant in the environment		
River	Ecological status	*bpmgh*	Poor, bad, moderate, good, high
Biota	Amount of sensitive species		
	Abundance of tolerant species		

12.3.2. Model expression

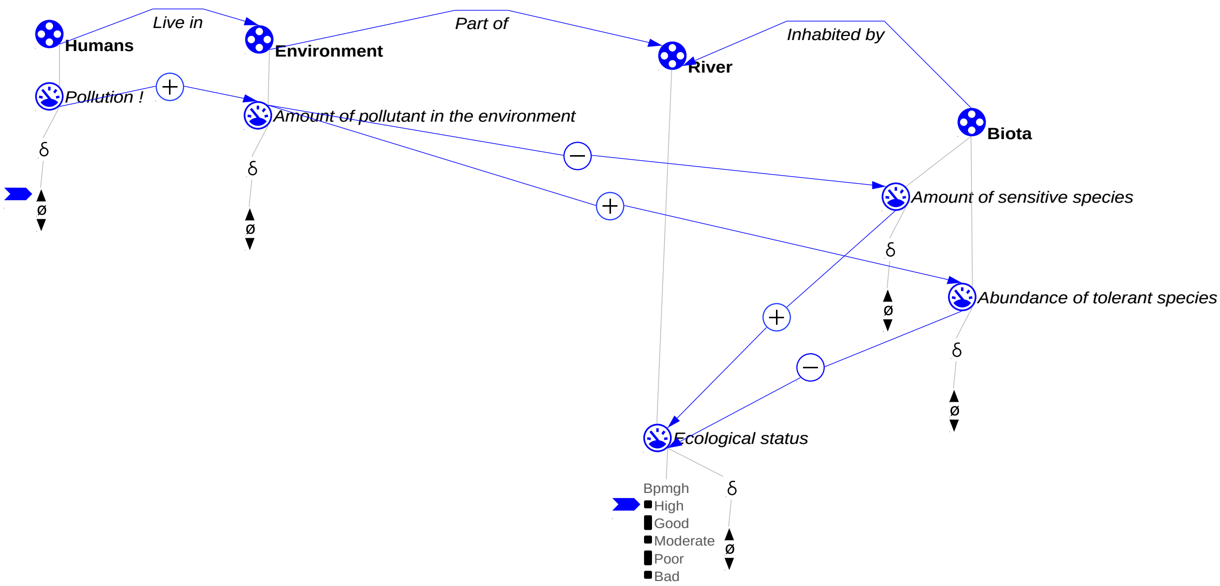
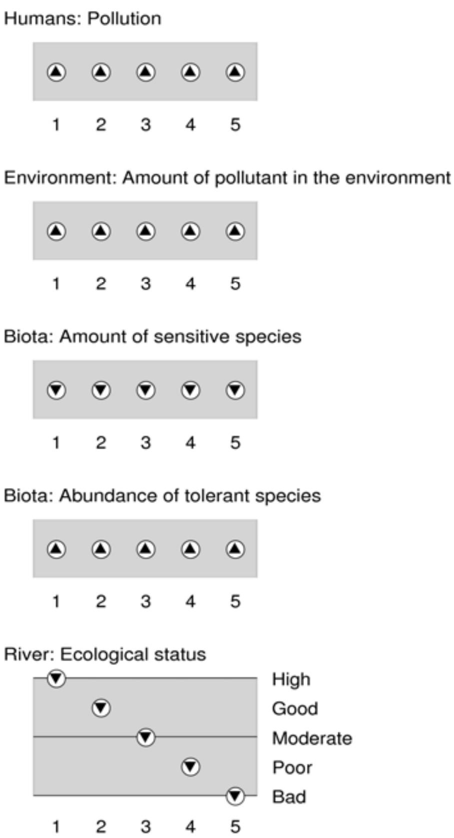


Figure 12.1: Model expression of BOKU_indicator species_LS3.hgp.

12.3.3. Scenarios and simulations



The simulation has 5 states, and shows how a continuous pollution of humans leads to the loss of sensitive species and to an increase of the abundance of tolerant species, which leads to a gradual decline of the ecological status from high to bad.

Figure 12.2: Value history of all variables included in the simulation.

Table 12.2: Scenario information – causes and conditions.

Type	Details
Exogenous control	Yes, pollution is set to plus
(In)equality	none
Ambiguity	none

12.4. Conclusion of the topic

12.4.1. Planned improvements

- **To show that at a certain level of pollution also the most tolerant species extinct.**
- **To address more in depth the effect of pollution on sensitive fish and macrozoobenthos species.**
- **To develop models on higher use levels of DL looking at different population processes affected by pollution.**
- **To try to build up a small decision support based on the saproby system for evaluating the status of a river.**

12.4.2. Links to other topics

This model links to populations, natural processes, land and water use, climate change, alien species, and integrated management.

13. Organic water pollution

13.1. Topic and model metadata

Topic	Organic water pollution		
Author(s)	Michaela Poppe Michael Stelzhammer Andreas Zitek	Version(s)	Draft 21/06/10 DL v0.6.8(CM)
Model files	Organic pollution LS2.hgp		
Target users	secondary school, bachelor students		

13.2. Topic rationale

13.2.1. Background

"Access to clean water for drinking and sanitary purposes is a precondition for human health and well-being. Most people in Europe have access to drinking water of good quality. However, in some parts of Europe the quality still frequently does not meet basic biological and chemical standards. Clean unpolluted water is also essential for our ecosystems. Plants and animals in lakes, rivers and seas react to changes in their environment caused by changes in chemical water quality and physical disturbance of their habitat. Changes in species composition of organism groups like phytoplankton, algae, macrophytes, bottom-dwelling animals and fish can be caused by changes in the climate. They can also indicate changes in water quality caused by eutrophication, organic pollution, hazardous substances or oil".[17]

"The major sources of water pollution can be classified as municipal, industrial, and agricultural. Municipal water pollution consists of waste water from homes and commercial establishments. For many years, the main goal of treating municipal wastewater was simply to reduce its content of suspended solids, oxygen-demanding materials, dissolved inorganic compounds, and harmful bacteria. In recent years, however, more stress has been placed on improving means of disposal of the solid residues from the municipal treatment processes".[18]

The most serious organic pollution problems occur in rivers that regularly receive untreated or inadequately treated wastewater from industrial plants and municipalities (Kluster et al, 2005).

13.2.2. Key themes

Chemicals used in a wide range of applications in our modern society are produced on a large scale worldwide. Because of their physical and chemical properties, many of these substances or their metabolites end up in the environment, where they can induce adverse effects on wildlife organisms. Many studies have confirmed the presence of estrogens and progestogens at concentrations of toxicological concern in the aquatic environment. Already at very low concentrations of 1ng L^{-1} endocrine disrupting effects, such as decreased fertility, feminization, and hermaphroditism of aquatic

[17] (http://www.eea.europa.eu/themes/water/water-pollution)

[18] (http://www.umich.edu/~gs265/society/waterpollution.htm).

organisms, are assigned to this class of steroidal hormones. Synthetic chemicals, resembling the action of natural hormones, find wide application in both human and veterinary medicine and in animal farming practices. Both natural and synthetic estrogens and progestogens are eliminated, either as free compounds or in their conjugated form, primarily through the urine. These substances enter the aquatic environment mainly via wastewater treatment plant effluents (after incomplete removal in the plant) and untreated discharges, and the runoff of sewage sludge used in agriculture.

13.3. Organic pollution LS2.hgp

13.3.1. Concepts and goals

Content

- **The model should illustrate simplistically the main sources of the most environmentally relevant estrogens and progestogens, their principal pathways into the aquatic environment and the effects on the aquatic organisms.**

Modelling

- **To introduce a causal model in LS 2 with a relatively high complexity.**

Table 13.1 Entities and quantities used in the model Organic pollution LS2.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Aquaculture	**Use of steroidal compounds**		
	Fish growth		
Human medicine	**Human hormone treatment**		
	Amount of estrogens in excretion		
Sewage	**Amount of estrogens and progestogens**		
Wastewater treatment plants	**Amount of estrog and progestog in sludge**		
	Amount of estrog and progestog in effluents		
	Advanced water purification techniques		
Abiotic environment	**Amount of estrog and progestog in soil**		
	Amount of estrog and progestog in food chain		
	Amount of estrog and progest in groundwater		
	Amount of estrog and progest in surface water		
Aquatic organisms	**Amount of estrog and progestog**		
	Fertility		
	Feminization		
	Hermaphroditism		

13.3.2. Model expression

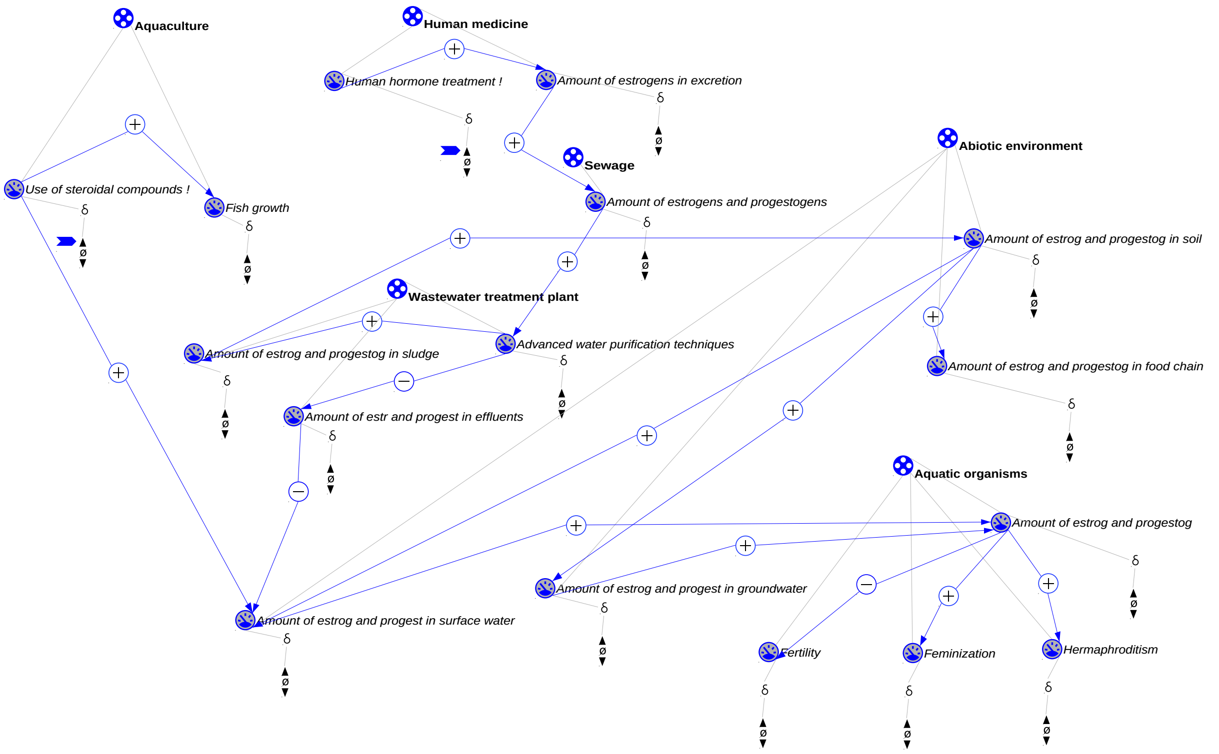


Figure 13.1: Model expression for Organic pollution LS2.hgp.

13.3.3. Scenarios and simulations

Table 13.1: Scenario information – causes and conditions.

Type	Details
Exogenous control	Yes, use of steroidal hormones and hormone treatment increase
(In)equality	none
Ambiguity	none

13.4. Conclusion

13.4.1. Planned improvements

- Include the effect of other organic pollutants on aquatic ecosystems and organisms.
- Including management actions to avoid/restore organic pollution of aquatic environment.

13.4.2. Links to other models

This model links to the topic of indicator species and management models as well as to the model describing similar problems in the marine environment (pollution and imposex).

14. Climate change effects on river catchment

14.1. Topic and model metadata

Topic	Global change effects on river catchments		
Author(s)	Michaela Poppe Maria Zacharias Andreas Zitek Michael Stelzhammer	Version(s)	Draft 25/07/2010 DynaLearn v0.6.8(CM) (LS2) DynaLearn v0.6.11(CM) (LS4)
Model files	GC LS2 floodplain forest.hgp GC LS2 maize production.hgp GC LS4 EC directives.hgp		
Target users	Secondary school, bachelor students		

14.2. Topic rationale

14.2.1. Background

Bioenergy is becoming a more important energy source for Europe in order to reduce greenhouse gas emissions and reduce reliance on foreign sources. Targets set by the EU for increasing biomass production necessitate substantial growth in agriculture production, which has led to a debate concerning potential benefits to the environment as well as possible conflicts with objectives of other EU policies, such as the Water Framework Directive (WFD). Large-scale bioenergy cropping may add considerable additional pressure on land use intensity in Europe, with negative impacts on water quantity and quality. Current bioenergy production focuses on well-established first generation technologies, such as fermentation of agricultural crops to produce ethanol and combustion of biomass to produce heat and power. Most of today's biomass agriculture production uses "classical" food crops, such as maize. There is no doubt that bioenergy cropping will increase in the future. Future decision making must consider impacts on land use and water resources, so that impacts on the environment can be reduced or mitigated.

14.2.2. Key themes

- **Increase in biomass production may lead to intensive maize production in the potential floodplain area.**
- **Intensification of land use of former set-aside areas or grassland along the rivers.**
- **Due to fertilization there may be pollution to surface water through nitrate runoff and groundwater through nitrate leaching.**
- **Increased risk of erosion through soil treatment.**
- **Through agricultural intensification effects on ecological and chemical status of water bodies.**

14.3. LS2 maize production.hgp and LS2 floodplain forest.hgp

14.3.1. Concepts and goals

Content

- **The models show the ecosystems services a natural floodplain forest provides, and which chemical and ecological impacts intensive maize agriculture may have on a surrounding groundwater.**
- **Intensive maize production in the potential floodplain area has negative effects on soil properties, biodiversity, energy balance, greenhouse gas (GHG) mitigation compared to natural floodplain forest.**
- **Planned improvements: effects of different vegetation types (short rotation coppice willow and poplar) compared to maize and floodplain forest also including different environmental parameters as e.g., different soil types, harvesting, precipitation.**

Modelling

- **To introduce a causal model in LS 2 with a relatively high complexity.**

Table 14.1: Entities and quantities used in the models of LS 2.

Entity	*Quantities*	*QS*	*Remarks*
Intensive maize production	Amount of		
	Fertilization		
	Soil treatment		
	Nitrate fixation		
	Rooting		
	Water demand		
Soil	Soil compaction		
	Water infiltration		
	Surface runoff		
	Erosion		
	Soil coverage		
	Nitrate leaching		
	Nitrate runoff		
	Water retention		
	Soil degradation		
Groundwater	Level of groundwater table		
	Groundwater contamination		
	Water abstraction		
River section	Surface water contamination		
	Chemical and ecological status		
Biodiversity	Amount of		

14.3.2. Model expression

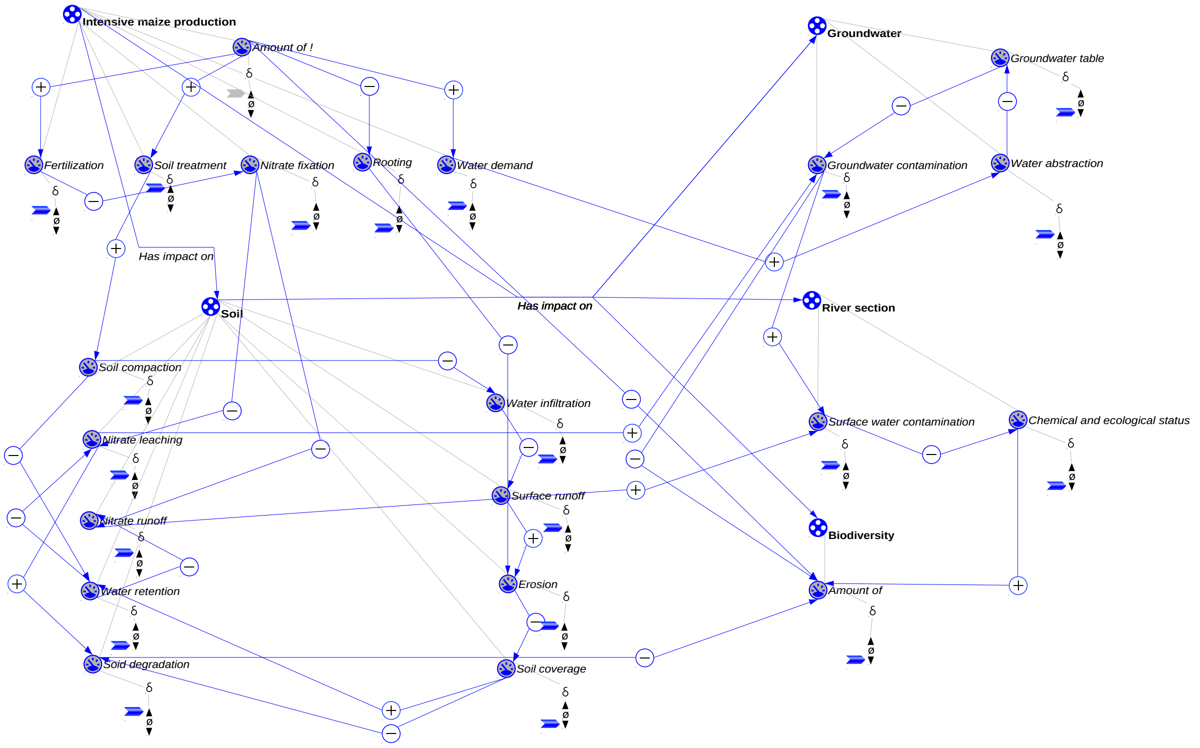


Figure 14.1: Model expression for GC LS2 maize production.hgp.

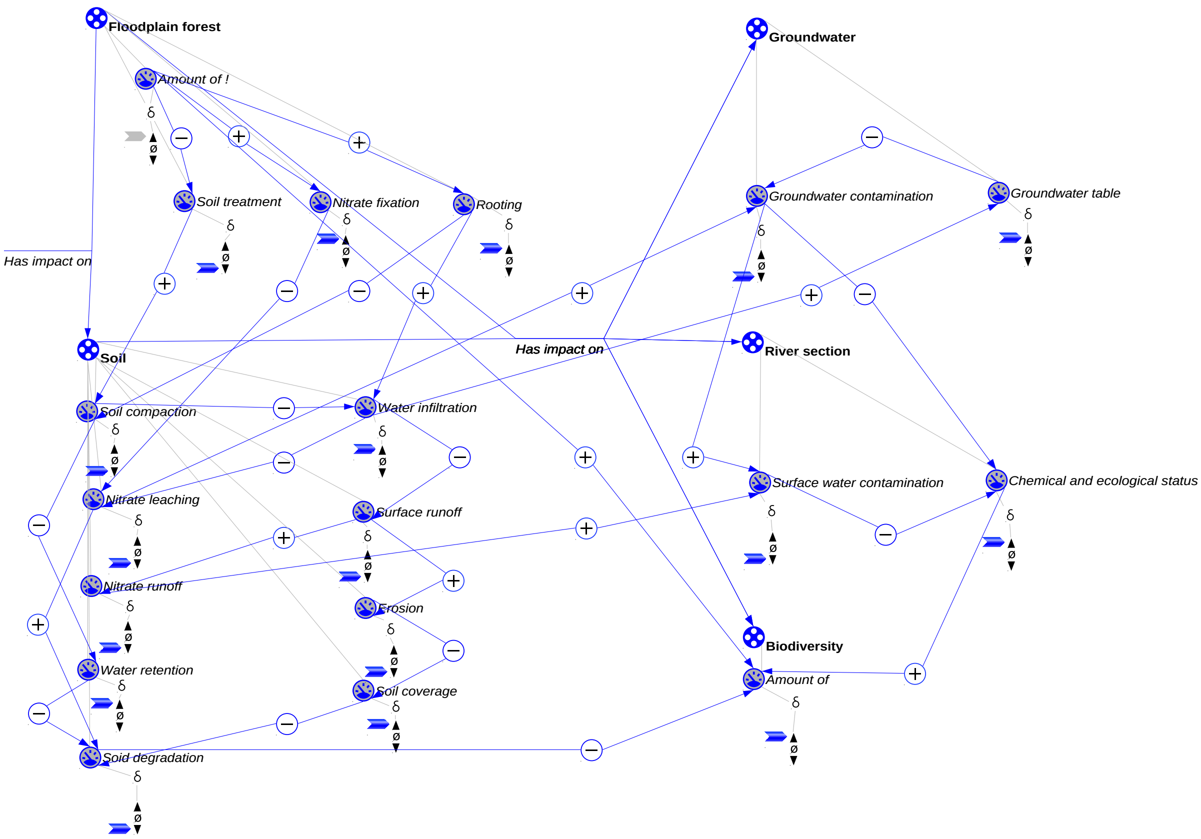


Figure 14.2: Model expression for GC LS2 floodplain forest.hgp.

14.3.3. Scenarios and simulations

Maize production

The simulation shows how an increase in maize production affects the natural floodplain system and finally the chemical and ecological status of a river.

Table 14.2: Scenario information – causes and conditions for GC LS2 maize production.hgp.

Type	Details
Exogenous control	Amount of intensive maize production increases
(In)equality	none
Ambiguity	none

Floodplain forest

The simulation shows how a natural floodplain forest contributes to the maintenance of a good ecological and chemical status of the river.

Table 14.3: Scenario information – causes and conditions for GC LS2 floodplain forest.hgp.

Type	*Details*
Exogenous control	*Amount of floodplain forest increases*
(In)equality	*none*
Ambiguity	*none*

14.4. LS 4 EC directives.hgp

14.4.1. Concepts and goals

Content

- **The model shows how two directives have impacts on land use change and highlight the potential land use conflict between the WFD and the Biomass action plan. The increase in biomass production leads to an increased demand for land. Former set-aside areas are used again for intensive agricultural production. Ecologically valuable areas along the rivers that act as buffer zones between river and agriculture will be used for biomass production.**
- **The model should trigger thinking about problems, that arise from conflicting regulations, and how short term policy might dominate over a long term sustainable strategy.**
- **The model should trigger thinking about the use of inequality statements, and how this conflict can be resolved to achieve sustainability.**

Modelling

- **To introduce the idea of competing rates and ambiguity of simulations.**

Assumptions

Ecological status and chemical status directly correspond.

Table 14.4: Entities, quantities and quantity spaces (QSs) used in the model GC LS 4 EC directives.hgp.

Entity	*Quantities*	*QS*	*Remarks*
Water framework dir.	Restoration rate	*zp*	Zero, plus
Biomass action plan	Floodplain area into agricultural area conversion rate	*zp*	Zero, plus
Water body	Floodplain area for agricultural use	*zlmahm*	Zero, low, average, high, max
	Ecological status	*zlmahm*	
	Chemical status	*zlmahm*	

14.4.2. Model expression

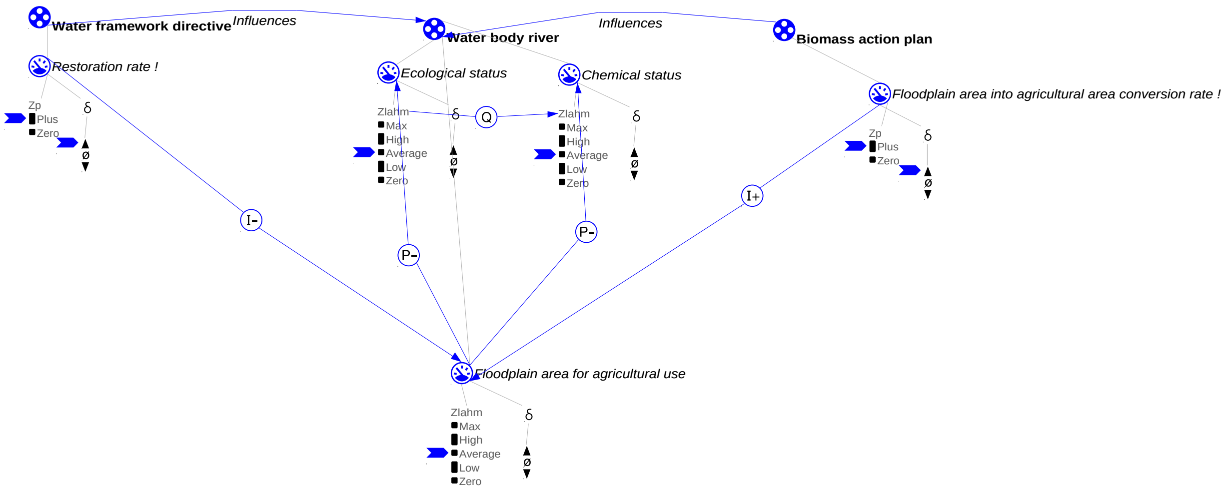
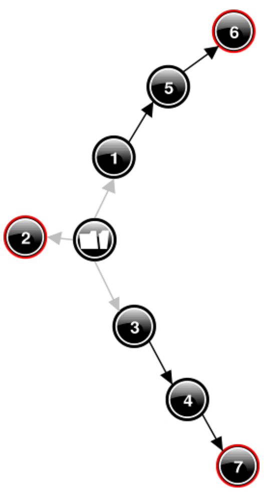


Figure 14.3: Model expression for GC LS 4 EC directives.hgp.

14.4.3. Scenarios and simulations



The simulation shows the development of the floodplain area used for agricultural production given the domination of one of two directives that trigger change along river floodplains. The simulation shows three end states, that result from the lack of definition, which influence is bigger than the other one. Finally if both are equal, the situation remains the same.

Figure 14.4: Behaviour path of the model GC LS 4 EC directives.hgp.

Table 14.5: Scenario information – causes and conditions.

Type	Details
Exogenous control	River restoration and floodplain into agricultural area conversion are both plus
(In)equality	None (should be set by students as result of a discussion)
Ambiguity	Yes, given the lack of an inequality statement

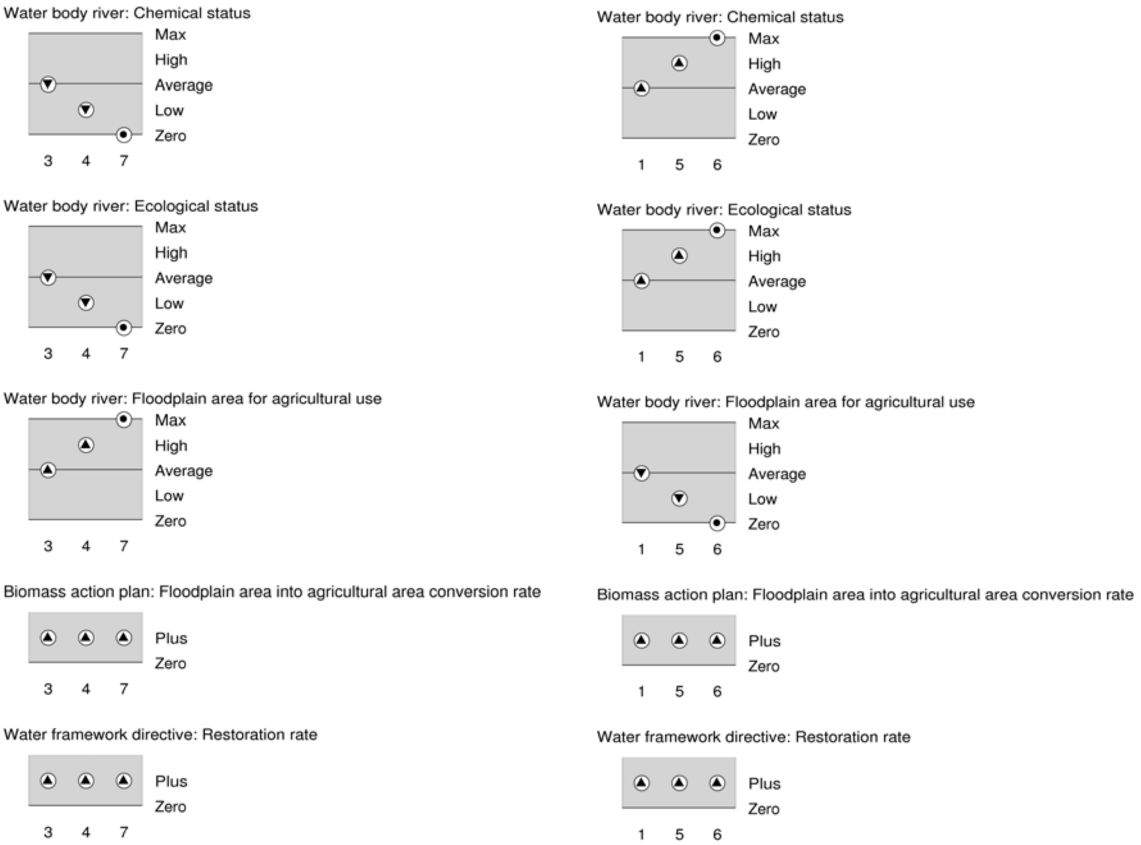


Figure 14.5: Value histories of all variables included in the simulation.

14.5. Conclusion of the topic

14.5.1. Planned improvements

To show climate change affects on

- **the safety and health of humans,**
- **the probability of flooding,**
- **the change of habitat conditions in rivers for fish,**
- **hydropower production.**

14.5.2. Links to other models

This model links especially to models describing land and water use, flood protection, the management of natural resources, energy production, pollution and international treaties.

15. International agreements and treaties on environmental issues and cooperation for sustainability

15.1. Topic and model metadata

Topic	**Interactions between conserving species and dynamic management of river catchments**		
Author(s)	**Andreas Zitek** **Michael Stelzhammer** **Michaela Poppe**	**Version(s)**	**Draft 1.07.2010** **DynaLearn 0.6.8**
Model files	**BOKU_dynamic restoration versus conservation.hpg**		
Target users	**Secondary school students, bachelor students**		

15.2. Topic rationale

15.2.1. Background

Background

Due to the overlap of different European Directives there is a potential conflict with respect to habitat management. This applies especially to riverine landscapes, where the EU Water Framework Directive (EU-WFD) enforces dynamic management of river catchments by restoring degraded or channelized rivers and by reconnecting rivers and floodplains. In some cases the aims of the WFD can cause conflicts with the EC Birds Directive and/or the EC Habitats Directive, which try to conserve habitats of endangered flora and fauna:

Figure 15.1: River Drau, Carinthia, Austria: channelized river section with high age tree population on river bank (source: S. Muhar).

"[…] in view of the threats to certain types of natural habitat and certain species, it is necessary to define them as having priority in order to favour the early implementation of measures to conserve them; […] in order to ensure the restoration or maintenance of natural habitats and species of Community interest at a favourable conservation status, it is necessary to designate special areas of conservation in order to create a coherent European ecological network according to a specified timetable" (EC Habitats Directive).

Figure 15.2: River Isel, East Tyrol / Austria: example of a near nature alpine river section with high habitat diversity (source: S. Muhar).

Article 1 of the Water Framework Directive defines: *"The purpose of this Directive is to establish a framework for the protection of inland surface waters,*

transitional waters, coastal waters and groundwater which: (a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems".

This model is based on following English and German articles and reports: Fuchs et al. (2009), EC Habitats Directive and the EC Birds Directive.

15.2.2. Key themes

The model describes the potential influence(s) of river restoration measures enforced by the EU-WFD on populations of EC Birds Habitat Directive protected species. It shows the potential of conflict between protecting species and a dynamic management of river catchments required by the EU-WFD. An example for this conflict is the conflict around populations of the Middle Spotted Woodpecker (*Dendrocopos medius,* see Fig. 15.3*)* in Austria, which often selects habitats in old tree populations on riverbanks or in degraded floodplain forests that have been disconnected from natural flood dynamics as a result of river engineering measures. The appearance of Middle Spotted Woodpecker mostly depends on the appearance of habitat trees with deeply chapped bark or strongly structured coarse woody debris. The species needs old trees like willow, poplar, alder or young oaks, which have chapped bark already in younger age, and standing dead trees for foraging. The removal of those trees by a re-conversion of degraded floodplains into dynamically riverine landscapes enforced by the EU-WFD constitutes this conflict. River restoration is needed to achieve the 'good' ecological status according a five-tiered scheme ('high-good-moderate-poor-bad').

Figure 15.3: Middle Spotted Woodpecker, *Dedrocopos medius*. (source: Marek Szczepanek, wikimedia.commons).

15.3. BOKU_dynamic restoration versus conservation.hpg

15.3.1. Concepts and goals

The model is based on a specific case study (Loss of not site specific tree habitats for a bird species (*Dendrocropos medius)* protected by the Birds/habitat directive due to river widening on Salzach River, Austria/Bavaria (Fuchs et al. 2009). The model is constructed in DynaLearn LS 4.

Content

- **It tries to convey the understanding of conflicts resulting from overlapping conservation directives (especially EC WFD and Birds and/or Habitat Directive) and the understanding of multifunctional aspects and ecosystem services of riparian forests as well as the understanding of habitat needs of certain species. Furthermore it highlights potential use conflicts, e.g. possible forest cultivation, etc.**

Modelling

- **To introduce the idea to use calculations to trigger a rate.**
- **To introduce feedback loops.**

Table 15.1: Entities, quantities and quantity spaces used in the model BOKU_dynamic restoration versus conservation.hpg.

Entity	*Quantities*	*QS*	*Remarks*
Water Framework Directive	Ecological status measured	*Zpmgh*	zero, poor, moderate, good, high
	Ecological status required	*Zpmgh*	
Dynamic management of river catchments	Dynamic restoration rate	*Zp*	zero, plus
	Difference	*Mzp*	minus, zero, plus
Functional process zone	Species diversity	*Zlmh*	zero, low, medium, high
	Habitat diversity	*Zlmh*	
Floodplain	Amount of not dynamically flooded areas	*Zlmhm*	Zero, low, medium, high, maximum
	Amount of dynamically flooded areas	*Zlmhm*	
Birds	Population density Dendrocopos medius	*Zlmhm*	
Vegetation	Density of habitat trees	*Zlmhm*	

15.3.2. Model expression

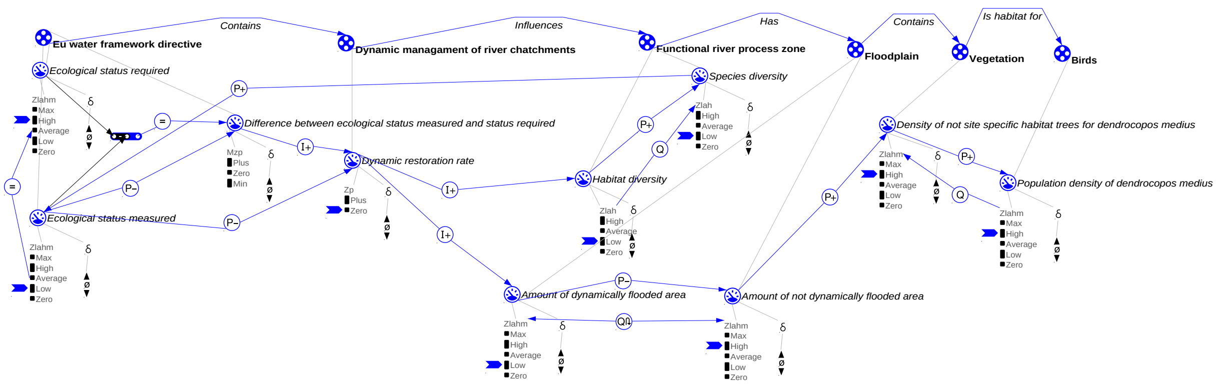


Figure 15.4: Model expression of the model BOKU_dynamic restoration versus conservation.hpg.

15.3.3. Scenarios and simulations

<u>Scenario "Dynamic management decreases population density of *Dendrocopos medius*"</u>

The scenario highlights a potential conflict between the EU-WFD and Birds Directive. With low ecological integrity and no dynamic restoration processes there is less habitat or species diversity in the river resulting in a 'poor' ecological status, but there are good conditions for habitat trees of *Dendrocropos medius* supporting a high population density. The scenario shows the effect of river restoration needed to fulfil the requirements of the EU-WFD to achieve the 'good' ecological status.

Simulation

Starting the restoration of a river site with 'poor' ecological status according to the EU-WFD increases the natural dynamics of a river site leading to naturalized flooding regime, which increases the habitat for fish and increases the ecological status, but significantly decreases the density of non site specific tree vegetation typical for degraded floodplains. This finally leads to 'high' ecological status and a disappearance of the non site specific populations of *Dendrocropos medius*. The simulation has five states, and one end-state.

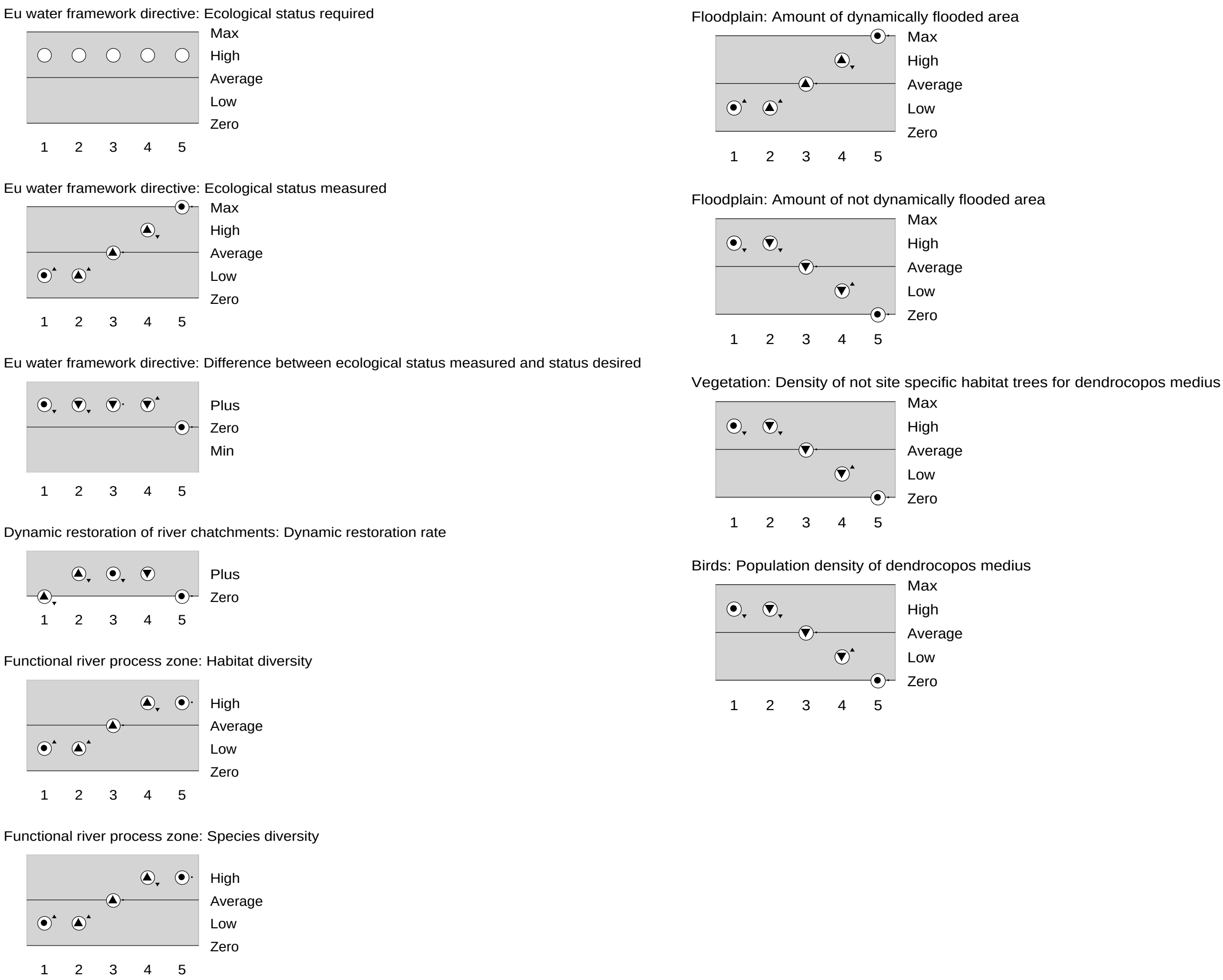


Figure 15.5: Value history of all variables included in the simulation.

Table 15.2: Scenario information – causes and conditions

Type	Details
Exogenous control	none
(In)equality	none
Ambiguity	none
Simulation preferences	Standard, but has to be run with the '*Fastest path algorithm*' on.

15.4. Conclusion of the topic

15.4.1. Planned improvements

- **Including also plant species like M*yricaria germanica* (needs gravel habitats).**
- **Including other directives (e.g. EC renewable energy directive) that show further potential for conflicts in riverine landscapes.**
- **Including integrative management to solve this conflict.**

15.4.2. Links to other models

This model can especially be linked to those describing the development of populations or those that display the usage of riverine landscapes (e.g. tourism and recreation).

16. Discussion

The 31 models prepared for this deliverable pick up certain specific topics within a bigger curriculum. The models selected from a pedagogical point of view were considered to be most suited to introduce DL successfully into classrooms. As the models also had to serve local educational needs, they might be too specific in some cases, to serve a general viewpoint. These models will be redesigned to represent more generic environmental patterns.

Preparing the models on different use levels was an interesting task, and required deep thinking on which features to select and how to represent them in the different learning spaces of DL. Identifying the most insightful systems and relationships within a given topic can be considered as a major contribution to the success of DL in classrooms.

To rethink again the information presented in models with regard to model structure, the total curriculum and to identify links to other models, exchange ideas and modelling patterns with WP 6 partners are another important issues for the development of the follow-up task 6.4 'advanced topics and models'.

17. Conclusion

Building models in different learning spaces of DynaLearn proved to be a challenging task. Especially, as the way in which content was delivered in the past had to be deconstructed and newly arranged. Specific issues had to be selected to be implemented into DL models. This reviewing process of existing material to identify issues worth being represented in DL models was a very intensive experience. However, it seems that students gain better causal reasoning and clear abstracted conceptual understanding on environmental issues, if content is presented in this new way. Details of how the DynaLearn approach contributes to learning will be presented in D7.2.5 'BOKU evaluation of DynaLearn prototype' being delivered in M22.

Within the second phase of the project, the insights gained during this first modelling phase will feed into the development of more detailed models. Furthermore the educational goals for each model within the curriculum will get better defined, when the evaluation results from the first evaluation activities are be available.

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