DynaLearn – Identifying causal relations of bioenergy production in the potential floodplain

by

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Abstract

The EU Water Framework Directive sets the target to meet at least good ecological status or good ecological potential of all rivers by 2015 respectively 2027. Therefore, rivers with moderate to bad status have to be restored. To achieve this target, also agricultural use has to be changed, for example to minimize nutrient inputs as well as to re-initiate dynamic processes and at the same time adapt agricultural land use practices.

According to the EU Directive on Renewable Energies, which came into force in 2009, Austria emphasizes to increase the share of renewables, in which agricultural bioenergies have high development potentials.

As a consequence, an intensification of agriculture is expected; also leading to an increasing land use conflict between agriculture and river management.

The newly established modelling software DynaLearn (prototype software; Bredeweg, 2009) enables to generate and display basic causal models about socio-environmental effects of bioenergy production in the potential floodplains. Based on the thereby gained knowledge, possible synergies between bioenergy production and river-floodplain restoration can be identified: A sustainable alternative to currently prevailing agricultural bioenergy plants, such as maize or short rotation poplar may be the utilization of endemic plants at buffer strips and the use of cutting from extensively cultivated riverine grasslands. Another alternative is the energy recovery of riverine neophytes, such as the Himalayan balsam or the Japanese knotweed.

The models developed with the help of DynaLearn software proved to be a strong tool in explaining complex relations. Therefore, DynaLearn can contribute in decision support as well as decision-making.

Kurzfassung

Um die Vorgaben der EU Wasserrahmenrichtlinie zu erfüllen, sollen alle Fließgewässer bis 2015 beziehungsweise spätestens 2027 zumindest einen guten ökologischen Zustand beziehungsweise ein gutes ökologisches Potential erreichen. Dieses Ziel einzuhalten erfordert jedoch teils umfangreiche Verbesserungen des Zustandes zahlreicher österreichischer Gewässer. Dafür sind diverse Maßnahmen auch in Hinblick auf die landwirtschaftliche Nutzung erforderlich, um beispielsweise den stofflichen Eintrag zu minimieren sowie die dynamische Entwicklung von Fließgewässern durch angepasste Nutzungen wiederum zu ermöglichen.

Entsprechend der 2009 in Kraft getretenen EU Richtlinie Erneuerbaren Energien, gilt es in Österreich den Anteil an Erneuerbaren Energien weiter zu erhöhen, wobei der Gewinnung von Bioenergie aus landwirtschaftlicher Produktion große Ausbaupotentiale zugesagt werden.

Dies würde jedoch zwangsläufig zu einer weiteren Intensivierung der Landwirtschaft führen, was auch zunehmende Flächenkonkurrenz zwischen Landwirtschaft und Fließgewässermanagmement zur Folge haben kann.

Mit Hilfe der neu entwickelten Modellierungs-Software DynaLearn (Prototyp Software; Bredeweg, 2009) werden in dieser Arbeit die sozio-ökologische Folgewirkungen des konventionellen Bioenergieanbaus für die Fließgewässer und deren Auenbereiche modellhaft abgebildet und dabei spezifiziert. Darauf aufbauend werden mögliche Synergien zwischen Anbau von Bioenergiepflanzen und Fließgewässerrestauration modelliert und beschrieben.

Demzufolge von besonderer Bedeutung für eine nachhaltige Entwicklung kann die energetische Nutzung von endemischen Pflanzen an Gewässerrandstreifen sowie die Nutzung von standortgerechter Vegetation, wie etwa von extensiv bewirtschaftetem Grünland, zukommen. Auch die Nutzung von häufig aufkommenden Neophyten, wie zum Beispiel des Drüsigen Springkrauts, oder des Japanischen Staudenknöterichs, kann zu Synergien zwischen Produktion von Bioenergie und den Anforderungen eines integrativen Fließgewässermanagements positiv beitragen.

Die mit Hilfe der DynaLearn Software entwickelten Modelle erweisen sich hierbei als nützliche Werkzeuge, um komplexe Zusammenhänge näher zu beleuchten und zu verstehen. Somit kann DynaLearn Anwendern dabei helfen, Lösungen zu finden und wichtige Entscheidungen zu treffen.

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1 Introduction and definition of aims

Global change is an ongoing phenomenon, which has to be assessed in an interdisciplinary way. However, identifying causal relations between different scientific disciplines is interlectually challenging. In this regard, science is still at early stages, which prompt to the idea to integrate different scientific disciplines that affect one another positively or negatively. Because bioenergy production perceives much attention at the moment, and negative effects are rarely discussed, the thesis wants to find out if there are any drawbacks of the promotion of bioenergy production in relation to water management. The prototype software DynaLearn may help to understand complex causal relations of various scientific disciplines in an integrated way. In bringing together aspects of environmental EU policies, agriculture and river management, the purpose of the diploma thesis is to assess the potential of the DynaLearn software in illustrating basic qualitative models about effects of bioenergy production in floodplain areas (potential floodplain) as well as a comprehensive evaluation including the usability and functionality of the different Learning Spaces of the DynaLearn software (see figure 1). The evaluation will be done in order to identify its potential for learning as well as decision-making. The models are intended to contribute to a better understanding of driving forces behind land use change and its effects on the environment, respectively river-floodplain systems. This thesis seeks to highlight and discuss selected serious effects of bioenergy production on river-floodplain systems as well as potential synergies between bioenergy production and the restoration of river-floodplain systems for more sustainable development.

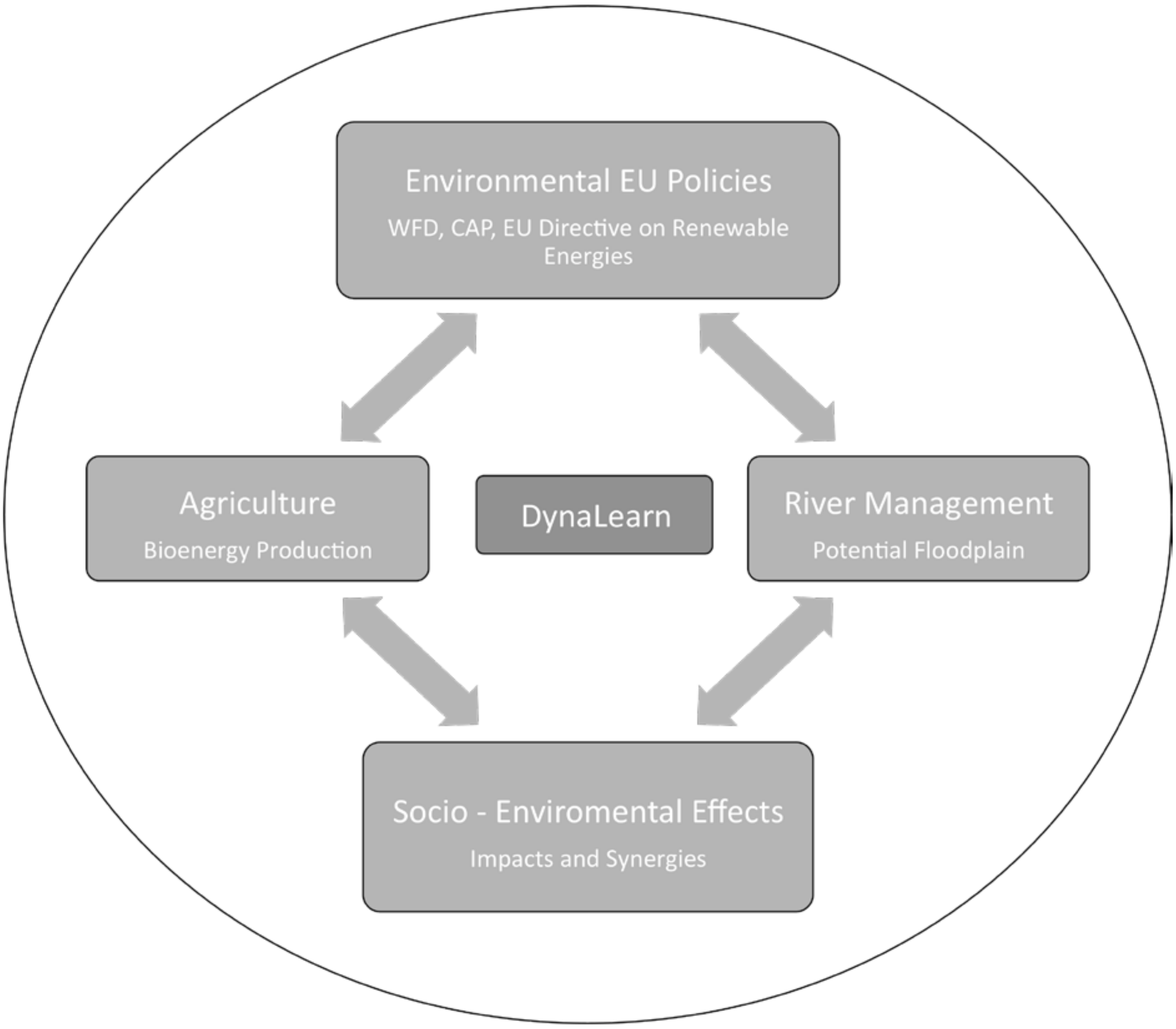


Figure 1: Concept of this thesis

In detail, the following research questions will be processed:

- What are the influences of EU policies on land use and thus on river-floodplain systems?
- Will the EU Directive on Renewable Energies have any impacts on the EU Water Framework Directive?
- To which extent will the promotion of agricultural bioenergy production affect river-floodplain systems?
- Are there any impacts of agricultural bioenergy production on potential floodplains and its adjacent rivers?
- What are the environmental effects of different energy plants?
- Are there conflicts of space likely to appear between increasing bioenergy production and the need for floodplain restoration?
- Are there any possible synergies between bioenergy production and floodplain dynamics?

Austrian floodplains have been impaired due to diverse human engineering measures targeting land reclamation for agricultural activities, housing, infrastructure and flood protection. As a result, few active floodplains are left (Muhar et al., 2009). Potential floodplains deliver important ecosystem services and they are very important for river-floodplain restoration, though (MEA, 2005). For that reason, land from within the potential floodplains is needed for the purpose of restoration to achieve the objectives defined in the EU Water Framework Directive.

Within the field of renewable energies, agricultural bioenergies show great development potentials for energy supply in Austria (Nemestothy, 2008). Much effort has been put into the promotion of bioenergies in the last few years, however very little attention put on the adverse effects of bioenergy production on aquatic ecosystems. Increased production of agricultural bioenergies has clear advantages, such as reducing greenhouse gas emissions, reducing use of fossil energies, independence from energy imports and providing of new jobs (EEA, 2006). In spite of this, the pressure on farmland will increase as a result of nutrient inputs into ground and surface waters, soil compaction and through land competition within the potential floodplains. It is clear that bioenergy production has impacts on the potential floodplains, their natural floodplain vegetation and on river dynamics, and thus poses a risk of failure to the Water Framework Directive objectives.

Integrating two different scientific disciplines to one framework is possible with the help of DynaLearn. DynaLearn – Engaging and informed tools for learning conceptual system knowledge - is a European Union Seventh Framework Programme for Information and Communication Technologies (FP7-ICT), starting in February 2009 and ending in January 2012. The target of the project is to develop an interactive software for gaining conceptual system knowledge about environmental issues in order to articulate one's own ideas about systems, to simulate scenarios and viewpoints and to confront one's ideas with expert models (Bredeweg et al., 2009; 2010). Conceptual knowledge of system behaviour is of major importance for society to be able to understand and to interact with the environment in a sustainable way. In this regard, transferring scientific knowledge with the help of DynaLearn to students, stakeholders and experts constitutes an important contribution (Poppe et al., 2010).

Eight Universities are part of the EU project:

- The University of Amsterdam
- Universidad Politécnica de Madrid
- University of Augsburg
- University of Brasilia
- Tel Aviv University
- University of Hull
- Bulgarian Academy of Sciences
- University of Natural Resources and Life Sciences

Limitations

This thesis does not go into detail in terms of soil physics and chemistry, erosion processes, climate and nutrient cycles, economic processes, time related farming practices and site-specific conditions.

2 Definition of terms and baselines

The following section will outline the theoretical background deemed important for the understanding of the modelling process. After the specification of relevant definitions, the most relevant EU directives concerning river floodplains and their implementation in Austrian law are described in detail. Next, the conflict between the importance for floodplain protection and restoration and the increased agricultural area demand for bioenergy production are discussed. Finally, funding and several subsidies are described to understand the driving forces leading to the increased use of bioenergy.

2.1 Definitions

2.1.1 Definition of floodplains

According to Tockner et al. (2005), a floodplain describes the:

> *"Entire valley bottom that is capable of flooding, including the channel network"*

Another definition states more precisely that floodplains are:

> *"areas that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation or groundwater; the resulting physicochemical environment causes the biota to respond by morphological, anatomical, physiological, phonological, and/or ethological adaptions, and produce characteristic community structures"* (Junk et al., 1989).

As *riparian zones*, floodplains are usually defined as ecotones between terrestrial and aquatic ecosystems, which also include terrestrial vegetation influenced by groundwater tables and floods (Tockner et al., 2002).

The *potential floodplain* encompasses the whole valley bottom which has been affected by river dynamics under natural conditions including aquatic and terrestrial habitats, their biota as well as any human made structures and utilization (Muhar, n.a.). Due to diverse river engineering measures, *former floodplains* have been highly impaired, thus the term *active floodplain* only applies to floodplain remnants laterally connected to the parent river. In the majority of cases potential floodplains are identical with former floodplains.

2.1.2 Definition of renewable energy, biomass, bioenergy and biofuels

In the EU Directive 2009/28/EC renewable energy is defined as: energy from renewable non-fossil sources, which apart from biomass also includes wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, landfill gas and sewage treatment plant gas.

Further, biomass is defined as a:

> *"biodegradable fraction of products, waste and residues from biological origin from agriculture, forestry, fisheries and aquaculture as well as biodegradable fraction of industrial and municipal waste."* (EU directive 2009/28/EC)

Bioenergy means:

> *"Biomass produced for heat, electricity or transport" (*EU Directive (2009/28/EC)) (see figure 2)

Bioenergy, in liquid or gaseous form, called *biofuels* are possible substitutes for petrol, diesel and other fossil fuels (EU Directive 2009/28/EC). Agricultural biomass can be "conventional" bioenergy crops such as starch crops (e.g. cereals, sugar beets, maize) or oil crops (e.g. rapeseed, sunflower) as well as perennial grasses (e.g. miscanthus, sweet sorghum) or short rotation forests (e.g. poplar, willow) on agricultural land (EEA, 2006). The so-called first generation biofuels are produced from food and feed crops. Controversially, second generation biofuels are grown specifically for biomass production and are produced from a wider range of cellulosic biomass (Keam et al., 2008).

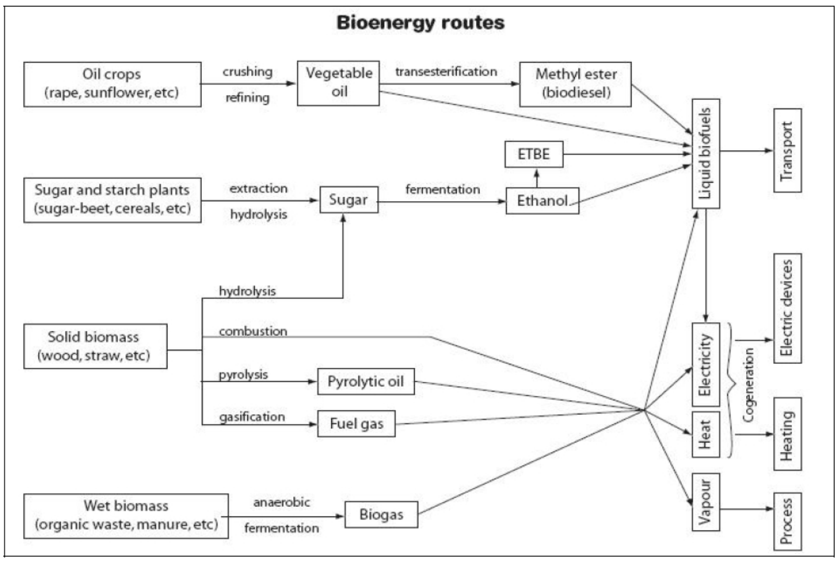


Figure 2: Bioenergy transformation processes (EC, 2010)

2.2 Policy Background

In the following, relevant environmental EU policies are described briefly in order to understand the legal background behind driving forces of land use change, despondences to environmental challenges, as well as the impact of EU policies on each other.

2.2.1 Introduction to relevant EU policies and their implementation in Austrian Law

2.2.1.1 The European Water Framework Directive

The European Water Framework Directive (2000/60/EC) came into force in 2000. Its principles are to protect and enhance the status of aquatic ecosystems, terrestrial ecosystems and wetlands that are directly depending on aquatic ecosystems and to prevent further deterioration of these, in order to achieve good ecological and chemical status by 2015. However, the WFD does not clearly state the role of wetlands. Therefore, the EU commission in 2003 published additional information about the role of wetlands in the Water Framework Directive (EC, 2003). The WFD was transformed into national law in form of the amendment of the *Austrian Federal Water Act (FWA) (Österreichisches Wasserrechtsgesetz)* 2003. *The National Water Management Plan (Nationaler Gewässerbewirtschaftungsplan)* describes how the targets of the WFD should be achieved within the specified timeframe. Furthermore, the planning processes, the target settings, the analysis of the present status and the monitoring as well as the measures to reach the targets are part of the content of the National Water Management Plan, which is legally binding (BMLFUW, 2009; Muhar, et al., 2009). The guidelines of the *EU-Nitrate Directive 91/676/EWG* are encompassed within the WFD. The nitrate directive was the first EU directive addressing diffuse pollution from agriculture as a response to growing awareness about agricultural pollution in the 1980s. Thus, it was a keystone of conflicts between agriculture and water protection. Its major target is to limit the agricultural use of nitrate to maximum 170 kg per hectare, further deterioration of groundwater quality has to be avoided (Muessner et al., 2006).

2.2.1.2 Fauna Flora Habitat Directive & Birds Directive

There are two EU policies, which have been established to safeguard biodiversity and to protect important habitats such as wetlands.

- Birds Directive (79/409/EEC) on the conservation of wild birds
- EU Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora

They led to the establishment of a network of Special Areas of Conservation for all listed species, which form the NATURA 2000 network. It covers about 20 % of the EU land surface with the protection of important nature sites. Unfortunately, many existing reserves are small and isolated. To improve biodiversity and interlinkages within the protected sites, many of these existing reserves would require additional land with habitat value or restoration potential (Schleupner et al., 2010). Additionally, through the Habitat Directive there is the need to protect residual floodplain forests (Hughes et al., 2003). More river-floodplain protection and restoration sites need to be designated to fulfil the biodiversity target of the EU Bird Protection and Fauna-Flora Habitat Directive (Schleupner et al., 2010).

2.2.1.3 EU Directive on Renewable Energies

In order to combat climate change, the United Nations Framework Convention on Climate Change created the Kyoto Protocol in 1997. Accordingly, the European Union set targets to reduce greenhouse gas emissions. As a part of the climate and energy package of the European Union, the *EU Directive on Renewable Energies* was adopted in 2009 and came into force in December 2010. The EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources is amending and subsequently repealing the directives 2001/77/EC (on the promotion of electricity produced from renewable energy sources in the internal electricity market) and 2003/30/EC (on the promotion of the use of biofuels or other renewable fuels for transport) (Directive 2009/28/EC). The Biofuel Directive had the target share of 5.75 % of biofules by 2010 (Directive 2003/30/EC). The general objectives of the Renewable Energy Directive is to achieve a 20 % share of energy from renewable sources and a 10 % share of renewable energies in transport in each Member State's energy consumption by 2020. In order to achieve this target the EU Member States had to define obligatory targets in their "National Renewable Energy Action Plan" ("Nationaler Aktionsplan 2010 für Erneuerbare Energie für Österreich"), which had to be notified to the EU commission by the 30th of June 2010 (Directive 2009/28/EC). Austria decided to increase the proportion of renewable energies of the gross final consumption to 34 % by 2020 (Karner et al., 2010). By the end of 2010, an evaluation of the directive as well as an improvement of the quality should have been done (Directive 2009/28/EC). Bioenergy from agriculture plays a key role to achieve these targets.

Sustainability Criteria

In order to ensure sustainable biofuel production, the directive also included sustainability criteria. Biofuel production, which does not follow the sustainability objectives, will not be taken into account for national goals. This measure should offer an incentive to produce bioenergy in a sustainable way. The objectives to achieve sustainable biofuel production are as follows:

Biofuel production should be avoided on:

- Biodiverse land
- Areas designated for nature conservation
- Areas designated for the protection of rare, threatened or endangered ecosystems or species
- Highly biodiverse grasslands (Directive 2009/28/EC, 2009).

Several studies have shown that the possible greenhouse gas emissions from land use change can offset carbon savings (Searchinger et al., 2001, Gallagher, 2008). Thus, areas with high carbon stocks in its soils or vegetation including wetlands and continuously forested areas should not be converted into areas for bioenergy production. Further, the directive should comply with other environmental requirements for agriculture, including the protection of groundwater and surface water quality (Directive 2009/28/EC, 2009).

The directive states that further sustainability criteria should be included to ensure a coherent approach between the energy and environmental policies. In this regard, analyses by the European Commission in 2010 concluded that the sustainability criteria within the directive should be extended to all biomass production, not only biofuels. Consequently, all biomass production would be treated in the same way. The European Commission further argues that the Member States action plans will help to monitor the biomass production and trade. It is possible that the monitoring must be strengthened for more accurate evaluation in the future. Additionally, the European Commission points out that sustainable agriculture is nevertheless ensured through environmental standards and cross compliance regulations in the Common Agricultural Policy. In addition, common environmental rules as NATURA 2000, the Water Framework Directive and the Nitrates Directive apply to agriculture (EC, 2010). The sustainability criteria are still not applied for biomass production and it is likely that Member States will not comply with these as long as there is a rigorous monitoring.

2.2.1.4 Common Agricultural Policy

The Common Agricultural Policy (CAP) was set up in 1957 in order to stabilize agricultural markets and increase profits after World War II. Since Agenda 2000, the CAP is based on two pillars: production support and rural development. In 2003, environmental standards within the Agri-Environmental Programs became compulsory. All famers who receive direct payments are subject to Cross Compliance and only those farmers who keep their agriculturally cultivated area in good ecological status and environmental conditions receive direct payments (Herbke et. al., 2006).

Furthermore, all EU Member States are bound to define minimum standards for the good ecological status (ÖPUL, 2009).

For this purpose in Austria the Agri-Environmental Program *ÖPUL* was implemented. In contrast to other EU Member States, Austria integrated the program over the whole territory and not only in ecological sensitive areas. The general objective of the ÖPUL is, to preserve good ecological status across all potential agricultural areas, including also those that are not cultivated. This program encourages farmers to cultivate agricultural areas in a more wholesome way in order to protect the natural habitat. ÖPUL 2007 has 29 measurements to achieve this target. All the measures allow farmers to receive compensation for reduced profits as a consequence of their implementation of sustainable development standards (Herbke et. al., 2006). The last period of the agro-environmental program (ÖPUL 2000-2006) has shown that the measures may also have positive impacts on water resources (Herbke et. al., 2006). In the period from 2007 to 2010 new standards were introduced; focusing on the protection and management of water in order to prevent pollution and water runoff (Dworak et al., 2009). For example, changes of permanent grasslands have to be reported and any changes of permanent grassland on the riparian zone, are prohibited. Another important measure is the protection of groundwater through nitrate leaching. It defines maximum amounts of fertilizer use (see EU Nitrate Directive): periods where fertilization is prohibited; and minimum distances to rivers. Additionally, the establishment of buffer strips is funded in order to reduce water pollution. Other measures important in this context are the soil treatment near river systems and erosion control (ÖPUL, 2009). Organic farming incorporates a wide range of measures to enhance soil fertility; preserving water quality and biodiversity. Extensive farming systems, such as environmentally oriented farming, are important for maintaining biodiversity of farmland and protecting water bodies including Natura 2000 sites (Fischer et al., 2009). The Agrarmarkt Austria (AMA) carries out the monitoring of the implementation of the ÖPUL regulations (BMLFUW, 2009). Since 2005, the Nitrate Directive, the Groundwater Directive (2006/118/EC), as well as other directives are encompassed in cross compliance. However, this does not apply to the Water Framework Directive (Fenz et al., 2006). Although the ÖPUL program has the potential to reduce water pollution, less attention is drawn to hydromorphological changes resulting from agriculture: there is still the risk that some of the measures could lead to mismanaged agricultural practices. A major concern is that increased agricultural production, for example with the promotion of bioenergy production, will lead to new uncontrolled intensification (Dworak et al., 2009). Currently it is not known, whether there will be another ÖPUL program after 2013 and if the amount of measures and subsidies will remain the same.

2.2.1.5 Subsidies for bioenergy production

Several measures based on the current Common Agricultural Policy framework led to increasing production of bioenergy crops. First of all it was the abolishment of the obligation to set-aside 10 % of the arable land (Dworak et al., 2008). Secondly, with the agricultural reform 2003, funding for the production of bioenergy plants was introduced. The EU supported the cultivation of energy plants till the year 2009 with 45 € per hectare land for a maximum area of about 2 Mio. hectares in the EU (AMA, 2009). The aid induced an increase in bioenergy in Austria (BMLFUW, 2009). Also, subsidies for bioenergy became dispensable. Thus, in 2010 no further aid for bioenergy production can be applied for (AMA, 2010). Kalt et al. (2010) recommended that some funding for bioenergy production have to be re-introduced in order to achieve the targets of 34 % of renewables till 2020. There are some policy support schemes currently implemented in Austria: heating systems and heating plants are subsidized via investment subsidies, biofuels are supported via the obligatory quotas and Combined Heat and Power plants are supported via the feed-in tariffs (Kalt et al., 2009).

2.3 Background to floodplains and bioenergy production

The background important to understand conflicts between restoration need of potential floodplains on the one hand and on the other the promotion of agricultural bioenergy production are described in this section.

2.3.1 Floodplains in Austria

2.3.1.1 Ecosystem services of floodplains

In their natural state floodplains are highly diverse ecosystems between the aquatic environments and surrounding land area. Floodplains offer diverse habitats from backwaters to floodplain forests, side arms, meadows and riparian zones etc. (UBA, 1997). They deliver important ecosystem services such as provisioning services, regulating services, cultural and supporting services (see table 1). Riparian zones are among the most biologically productive ecosystems due to the import and retention of nutrient-rich sediments from the headwaters and lateral sources. Thus, they are more productive than their parent rivers and adjacent land areas (Tockner et al., 2002). They offer high structural diversity, refugees and spawning habitats as well as an important food source (Jungwirth et al., 2003). Floodplains are important for the growth of riparian plant communities. Some riparian plant species such as willows and poplars are dependent on floods for regeneration (Stream Corridor Restoration, 2001). Because of the aforementioned characteristics, more plant and animal species occur on floodplains that in any other landscape (Tocker et al., 2002). Natural floodplains are highly influenced by hydrological processes. The dynamics of these systems depend largely on the lateral connectivity to their parent river. If the lateral connectivity is maintained, they function as natural flood retention areas, thus can attenuate floods and store sediments within their area and reduce peak runoff (Jungwirth, et al., 2003).

Table 1: Ecosystem services provided by wetlands (MEA, 2005)

Services	Comments and Examples
Provisioning	
Food	production of fish, wild game, fruits, and grains
Fresh water[a]	storage and retention of water for domestic, industrial, and agricultural use
Fiber and fuel	production of logs, fuelwood, peat, fodder
Biochemical	extraction of medicines and other materials from biota
Genetic materials	genes for resistance to plant pathogens, ornamental species, and so on
Regulating	
Climate regulation	source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes
Water regulation (hydrological flows)	groundwater recharge/discharge
Water purification and waste treatment	retention, recovery, and removal of excess nutrients and other pollutants
Erosion regulation	retention of soils and sediments
Natural hazard regulation	flood control, storm protection
Pollination	habitat for pollinators
Cultural	
Spiritual and inspirational	source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems
Recreational	opportunities for recreational activities
Aesthetic	many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	opportunities for formal and informal education and training
Supporting	
Soil formation	sediment retention and accumulation of organic matter
Nutrient cycling	storage, recycling, processing, and acquisition of nutrients

2.3.1.2 Natural dimension of floodplains

The natural dimension of floodplains depends on various factors: the topography, the geomorphologic river type as well as the discharge and bedload regime. Constrained river types, the incised meander and pendulous morphologic river types show lower potential floodplain width due to their topographic constriction, as it is the case in V-shaped valley floors. In alpine regions proximate to braided rivers larger floodplains can be found. In such systems, flooding may occur only in short durations and less frequent. As soon as slope decreases and valley floors become broader, the lateral connectivity between river and floodplains becomes more important. Hence, in meandering rivers, floodplains occur over wide areas and up to a width of 800 m. Within braided river sections the width of the potential floodplains may be broader than 2 km (see figure 3). Thus, if the dimension of the meandering and braided rivers increases, the mean width of their potential floodplains increases (Jungwirth, et al., 2003, Muhar et al., 2009).

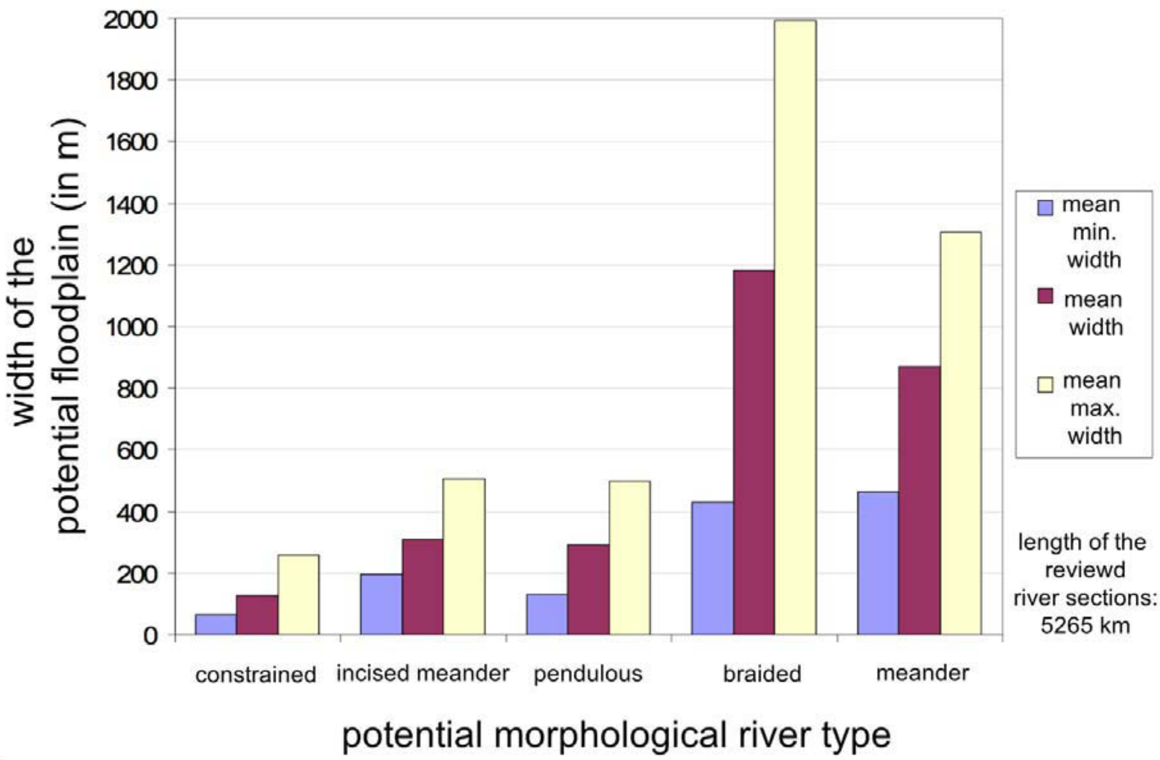


Figure 3: Morphological river types and their potential width of floodplains (catchment > 500 km^2) (adapted from Muhar et al., 2009)

Due to the fact that river-floodplain ecosystems have been highly constrained by human activities, it is difficult to define their natural dimension. Muhar et al. (2004) investigated the natural dimension of floodplains and expressed it as the potential width of floodplains. All Austrian rivers with a catchment > 500 km^2 were included in the study (see figure 4). They conclude that most natural river floodplains are not broader than 250 m. As the theory indicates (see above) these rivers are situated in the alpine regions with V-shaped valley forms. In the alpine foothills only U-shaped valleys have potential floodplains from more than 1 000 to 1 500 m. The rivers Enns, Mur and Drau are examples for this type of floodplain. Only the big rivers in the lower reaches have potential floodplains broader than 1 500 m, e.g. Danube river, March river and Inn river (Muhar et al., 2004).

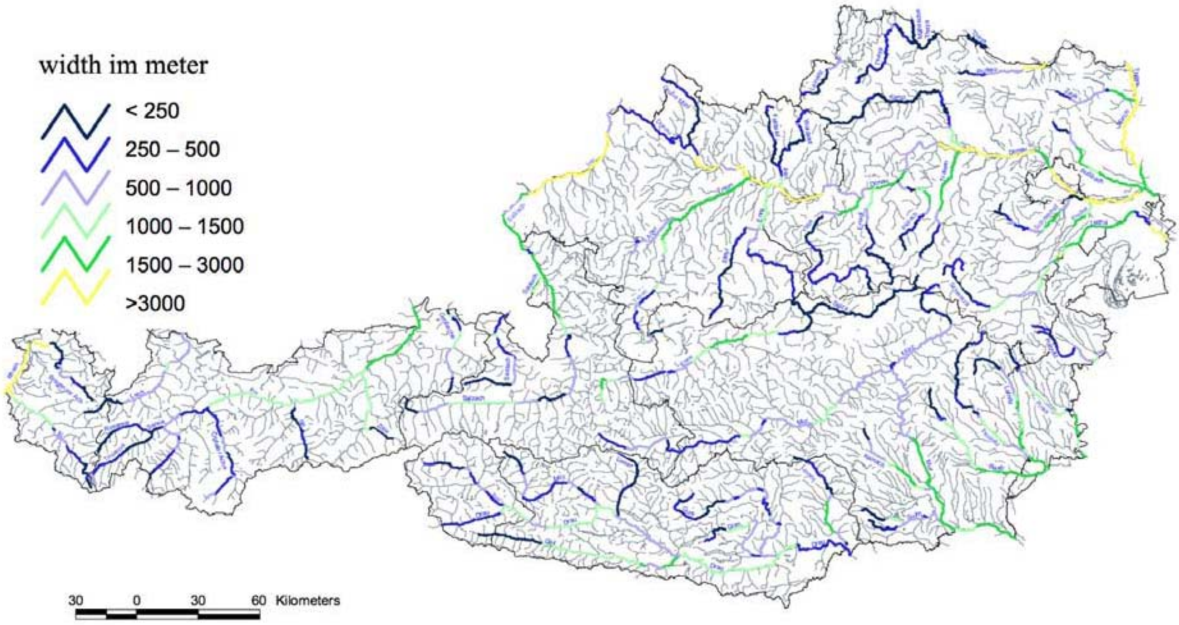


Figure 4: Potential floodplain width (in m) (catchment > 500 km^2) (adapted from Muhar, et al., 2004)

2.3.1.3 Floodplain degradation

As a result of diverse human engineering measures, the connectivity between floodplains and rivers have been highly impaired. The construction of hydropower plants, dams and land reclamations for purposes of agriculture, infrastructure and settlement since the mid of the 19th century have constricted rivers and floodplains to their current space. Agricultural drainage, either for flood control or land reclamation, is the single most important measure which has negatively affected floodplains and the hydrological balance. Channelization has degraded rivers and many of them have no connection to groundwater table and their floodplains anymore. Thus, the lateral connectivity has been impaired and natural dynamics and regular floods are missing (Poppe, et al. 2003; Muhar et al., 2004; Jungwirth et al. 2003; Habersack, 2009, Nachtnebel, 2000). Almost 26 000 km^2 of former floodplain forests along the Danube river and its tributaries have been separated by dams. In sum 68 % of all Austrian rivers (catchment > 500 km^2) have continuous or nearly continuous longitudinal control structures (Habersack et al., 2009). Substantial losses of floodplains incurred especially within sections of braided and meandering river sections, originally characterized by its wide stretching floodplains (Habersack et al., 2009). Thus, floodplains are one of the most endangered ecosystems in the world (Tockner et al., 2008).

2.3.1.4 Agricultural cultivation of floodplains

Figure 5 illustrates the modifications of a braided river to a channelized degraded river bed in order to gain fertile agricultural land. So that the floodplain area can be used for agriculture, the native vegetation has to be removed. Then, the area has to be drained to lower water tables (Stream Corridor Restoration, 2001). These alterations have major consequences on stream flow by modifying runoff pathways: Conversion from floodplain forests to agricultural area generally reduces interception, reduces infiltration due to lower water holding capacities and lower groundwater recharge which results in higher surface runoff into streams. This may increase erosion, the transport of contaminants, degraded habitats and the risk of more severe floods due to less water retention in the area (Allan et al., 2007; De Fraiture et al, 2002; Stream Corridor Restoration, 2001). This scenario is illustrated in model "modelling impact of intensive energy maize production" (see chapter 4.3.2).

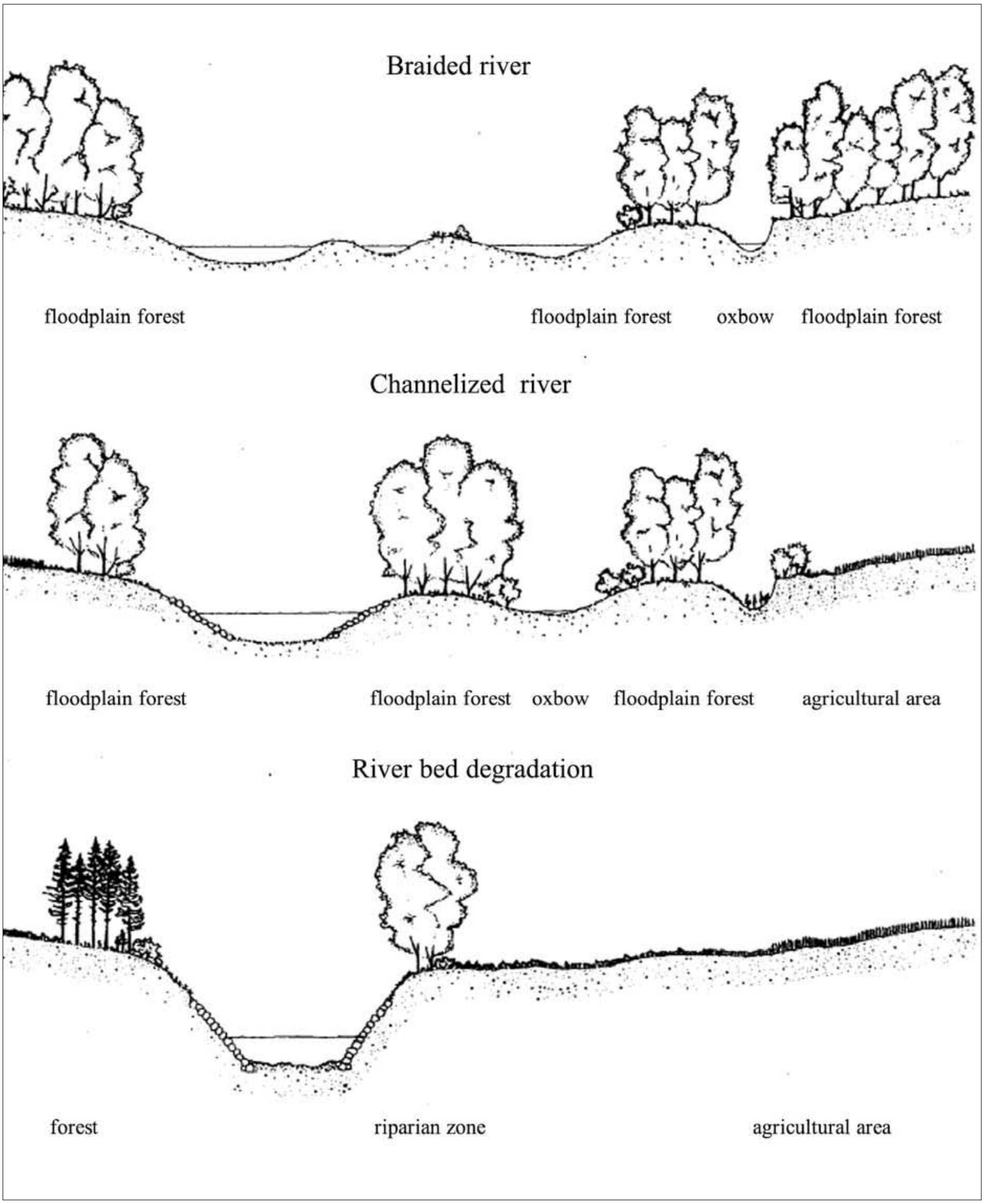


Figure 5: River channelization for purposes of agriculture (adapted from Wiesbauer, 1992)

Between 1980 and 1990 more than 37 % of wetlands have been degraded to gain fertile agricultural land in Austria (Herbke et al., 2006). Thus, agriculture is the dominating land use on former floodplains today. In 2004 about 70 % or 3 317 km^2 of floodplains were cultivated. Thereof, about 27 % were permanent grasslands, 40 % were intensively used and only 15 % or 77 000 ha were floodplain forests (see figure 6). The share of intensive agriculture in valley bottoms is higher in the Eastern part of Austria, than in the Western part (Muhar et al, 2009). Especially in the East, up to

70 % of the potential floodplain are intensively cultivated (Habersack et al., 2009). In sum almost 10 % of the total agricultural area is located within floodplains, which clearly indicates the importance of fertile floodplain soils for agricultural activity (Muhar et al, 2009).

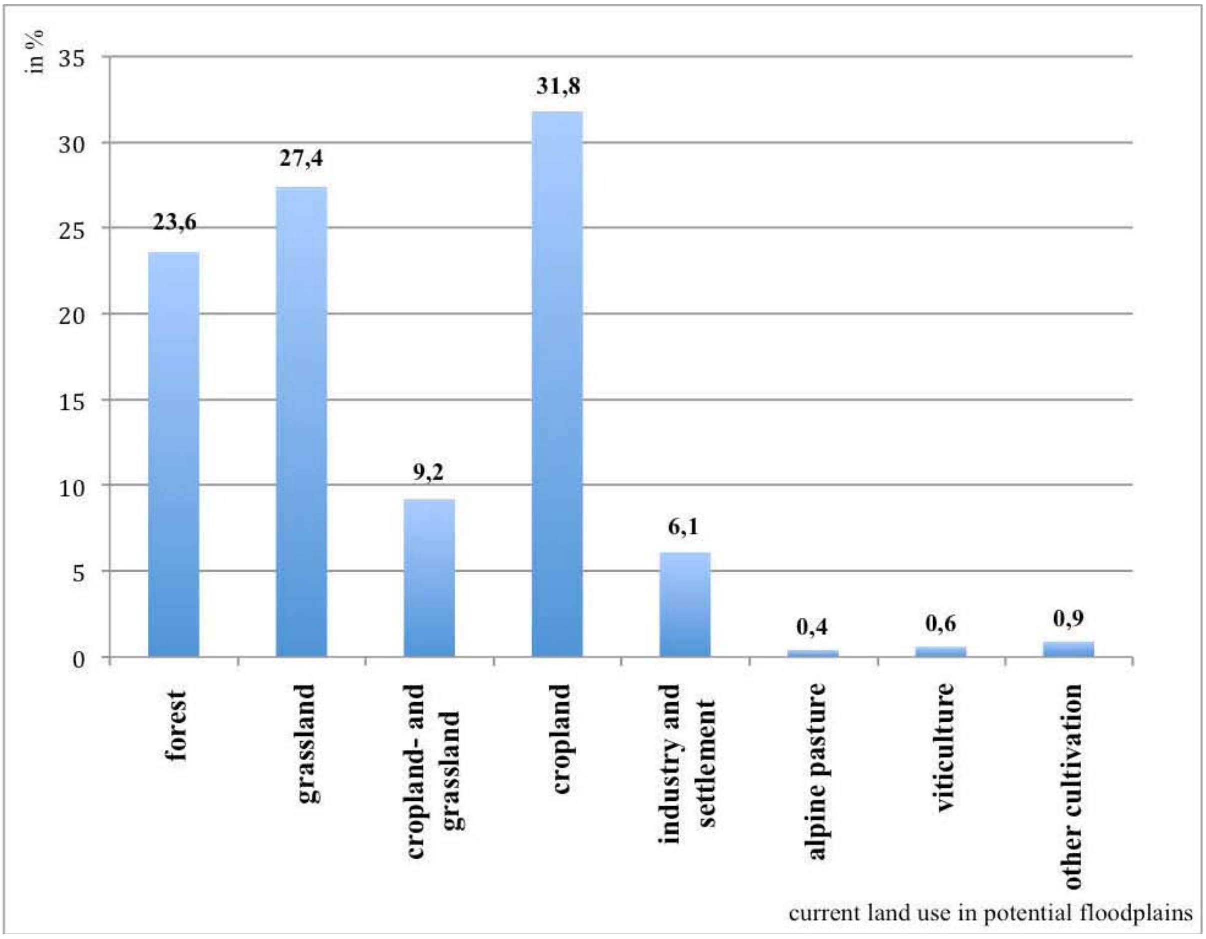


Figure 6: Current land use of potential floodplains (catchment > 500 km^2) in Austria (in %) (adapted from Poppe et al., 2003)

Intensive agriculture can also be found within HQ_{30} areas. Although forests dominate adjacent to rivers, intensive agriculture occupies up to 25 % of the potential floodplains. Beyond HQ_{30} areas the proportion of intensive agriculture increases and forests decrease, whereas grassland has nearly the same proportion (Muhar et al., 2009).

Primarily, in intensive used valley floors the rivers and their potential floodplains are highly modified and riparian vegetation is missing. In areas with higher proportion of grassland, the hydromorphological status is significantly better (see figure 7) (Muhar et al., 2009). Hence a correlation between morphologically changed river sections and intensive land use can be distinguished (Poppe et al. 2003).

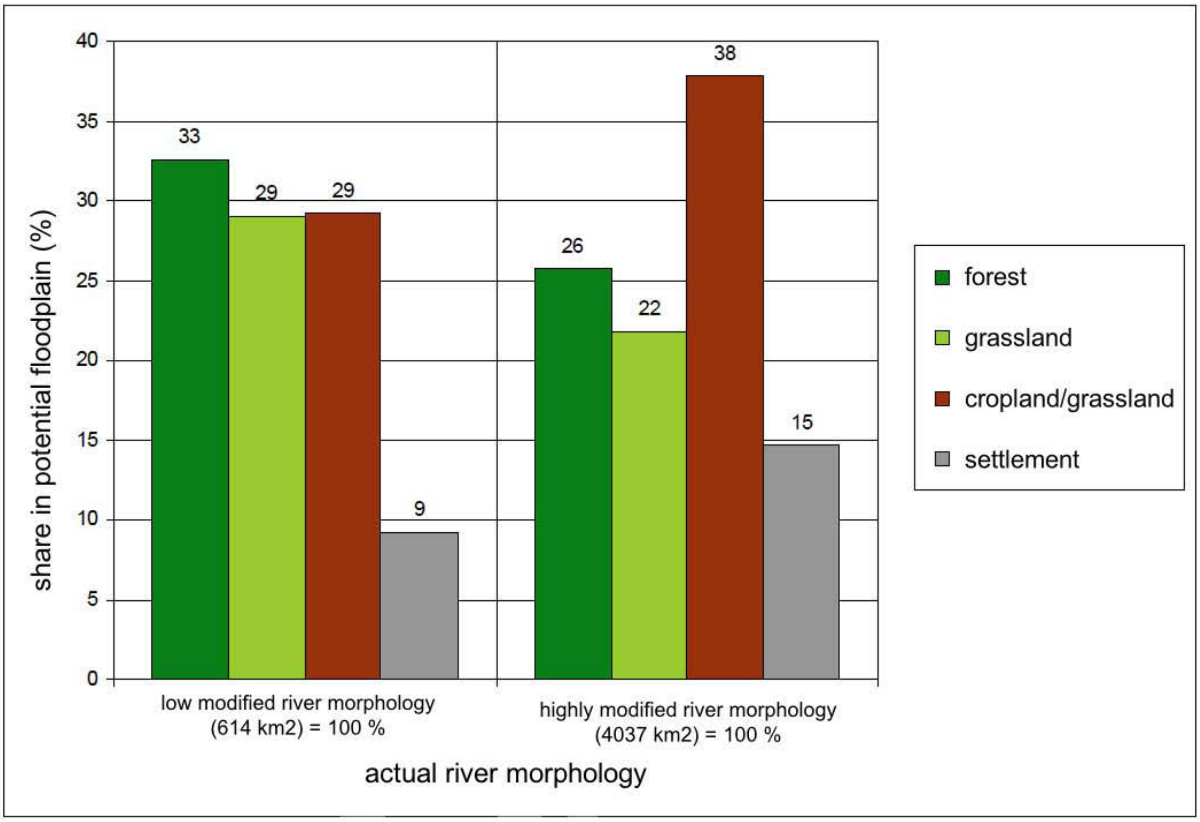


Figure 7: Distribution of land use classes in the potential floodplain (catchment > 500 km^2), differentiated in low and highly modified river morphology (adapted from Muhar et al., 2009)

2.3.1.5 Current floodplains in Austria

Today floodplains have become rare or have lost their pristine characters. In total only about 15 % of active floodplains (catchment > 500 km^2) are left (see figure 8) (Poppe et al., 2003). About 37 % of the total remaining floodplain forests can be found along the Danube River. The floodplain forests in the Central and Western part of the Northern Alps (e.g. Inn river, Lech, Salzach river) and in the Southern Alps (e.g. Gail river and Drau river) as well as in the Eastern Northern Alps and the North East of the Alpine foothills are relatively large. However, nowadays most of the floodplain forests are only found as riparian woods (Poppe, et al., 2003 and Muhar et al., 2004). Often the remaining floodplain forests fell dry and cannot sustain within a controlled river system. Thus, besides the protection of the remaining floodplains, restoration of floodplains is requested.

Many existing floodplains have been put under protection. The well-known “Donau – Auen” National Park covers the biggest floodplain of central Europe (UBA, 1997). Most of the existing floodplains are protected under the Natura 2000 network and the Ramsar Convention.

River	potential floodplain (km2)	actual floodplain as % of potential floodplain
Ager	14,78	26
Aist	24,89	34
Bregenzer Ache	43,88	15
Donau	833,21	34
Drau	196,99	14
Enns	159,00	13
Erlauf	23,66	17
Feistritz	50,17	7
Fischa	26,28	29
Gail	90,69	21
Glan	41,25	7
Grossache	26,93	7
Grosse Muehl	11,41	27
Gurk	55,33	17
Ill	60,63	22
Inn	374,08	5
Isel	17,68	32
Kainach	48,46	2
Kamp	40,34	24
Lafnitz	89,40	15
Lainsitz	14,75	11
Lavant	45,25	5
Lech	45,75	33
Leitha	177,78	19
Lieser	6,93	12
Mährische Thaya	2,89	5
March	335,87	11
Möll	28,76	12
Mur	308,30	16
Mürz	35,86	11
Ötztaler Ache	25,25	20
Pielach	35,33	9
Pinka	67,59	5
Pulkau	83,94	4
Raab	85,57	2
Rabnitz	33,88	9
Rhein	197,33	2
Rußbach	81,13	4
Saalach	62,99	8
Salza	13,96	34
Salzach	226,62	11
Sanna	22,35	12
Schwarza	38,74	12
Schwechat	42,92	17
Sill	7,45	29
Steyr	18,49	30
Sulm	42,61	12
Thaya	111,86	11
Traisen	107,78	17
Traun	76,37	29
Ybbs	52,59	23
Zaya	43,78	6
Ziller	29,33	4
TOTAL	4.739,12	15

Figure 8: Potential and actual floodplains in Austria (adapted from Muhar et al., 2004)

2.3.1.6 Restoration of floodplains

Because of the aforementioned facts, there is an urgent need to preserve existing floodplains and to restore others that retain some level of ecological integrity. Otherwise, a dramatic extinction of aquatic and riparian species and of ecosystem services is expected (Tockner et al., 2000). Due to the fact that land use is very important within potential floodplains it is clear that a total restoration is not requested, whereas a good status should be enabled (Müller-Wenk et al., 2003).

To achieve the Water Framework Directive objectives, a significant role of wetlands can be derived. Riparian zones directly influence the ecological and hydromorphological status of rivers. Hence, management plans to achieve good status should include protection or restoration measures for floodplains (Meyerhoff et al., 2004). The “Leitbild” – concept is important to determine reference conditions prior to systematic alteration of the river-floodplain ecosystem. It refers to undisturbed river-floodplain systems, to define the dimension of floodplains prior to the introduction of intensive agriculture. This information is important for restoration and monitoring (Muhar et al., 2008). The classification of high habitat quality of the WFD refers to the reference conditions. It is set very high and only few rivers meet these requirements. The floodplains with high status show no or only little human impacts and their site-specific conditions as well as the natural dynamic such as erosion, sedimentation is maintained. The good habitat quality is defined to identify those floodplain-river ecosystems that retain their overall character with some human alterations as for example extensive agricultural use (Muhar et al., 2000).

2.3.2 Bioenergy in Austria

The dependency on fossil energy sources is evident, with more than 70 % energy imports in Austria (Bachler, 2009). Greenhouse gas emissions due to the use of fossil energies are responsible for climate change. Thus, several incentives to increase the proportion of renewable energies and to increase energy efficiency have been taken to limit CO^2 emissions and to secure energy supplies. On behalf of the Austrian government the so-called "EnergieStrategie" has been prepared for the purpose of achieving the goal of 34 % of renewable energies by 2020. The promotion of renewable energies has lead to a significant increase in production recently (BMLFUW, 2009).

2.3.2.1 Renewable energy production and consumption

In 2007 about 76.4 % of total inland energy production originated from renewable energies, thereof mostly hydropower and biomass production. However, only about one third of the total energy production could meet its demand. Thus, about 70 %, mostly fossil but also renewable energy had to be imported to meet its total energy demand (BMWFI, 2009).

The gross national energy consumption in Austria (see figure 9) has a more homogeneous mix of energy sources. In 2007 the gross national energy consumed was 1 421 PJ. Still, the consumption of energy is dominated by fossil energy sources. Renewable energies had share of about 25.3 % or 359 PJ (Basisdaten Bioenergie Österreich, 2009). Till 2008, the share of renewable energies increased to 28.8 % (BMLFUW, 2009).

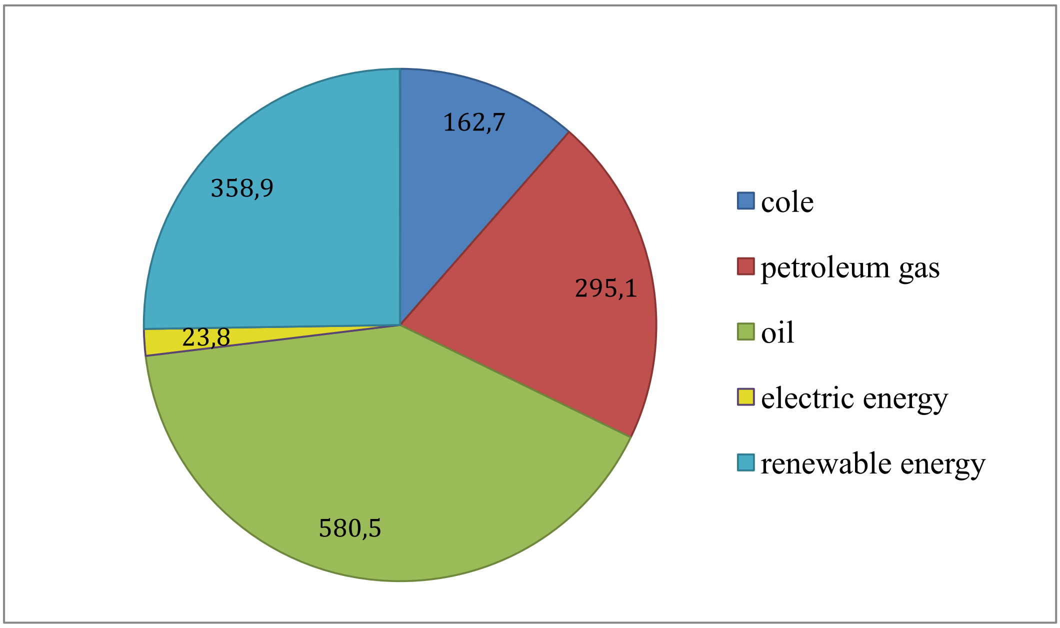


Figure 9: Gross national energy consumption [PJ] in Austria 2007 (adapted from Basisdaten Bioenergie Österreich, 2009)

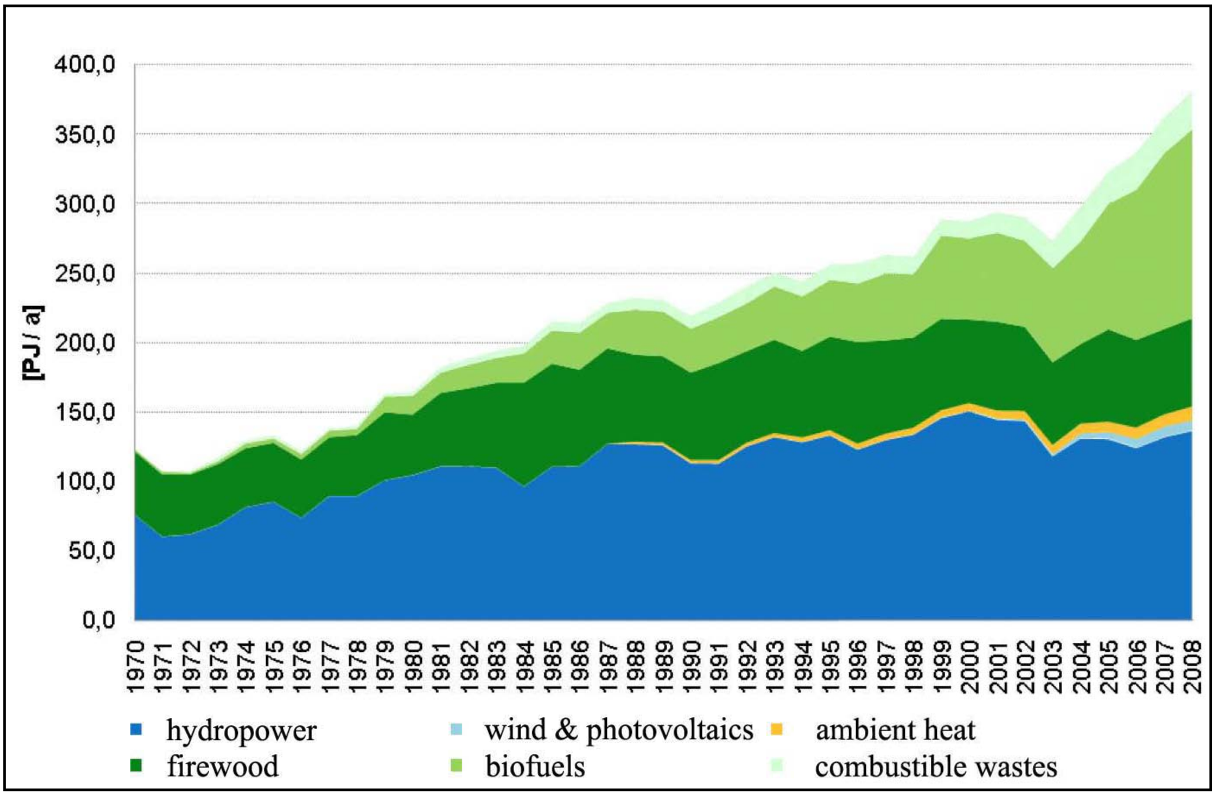


Figure 10: Renewable energy consumption from 1970 to 2008 (adapted from Nemestothy, 2010)

Biomass use was limited to heat production, till the 20th century. But in recent years, it has become increasingly important for power generation and in the transport sector (Kranzl, et al. 2008). Hence, since 1970 bioenergy consumption was increasing rapidly (see figure 10). While the share of firewood and hydropower was relatively stable, biofuels more than doubled and combustible wastes increased by 80% till 2008 (Basisdaten Bioenergie Österreich, 2009). Reasons for that are policies on climate change as well as the introduction of EU policies on renewable energies and subsidies for bioenergy production. Additionally, increasing costs for fossil energies as well as incentives for investments in renewable energies favoured the increased use of agricultural biomass (Kalt et al., 2010; Kranzl et al., 2008). Biomass has several advantages compared to other renewable energies: it can easily be stored, is one of the few options to create renewable heat and is currently the only option to create renewable transport fuels (Dworak et al., 2008).

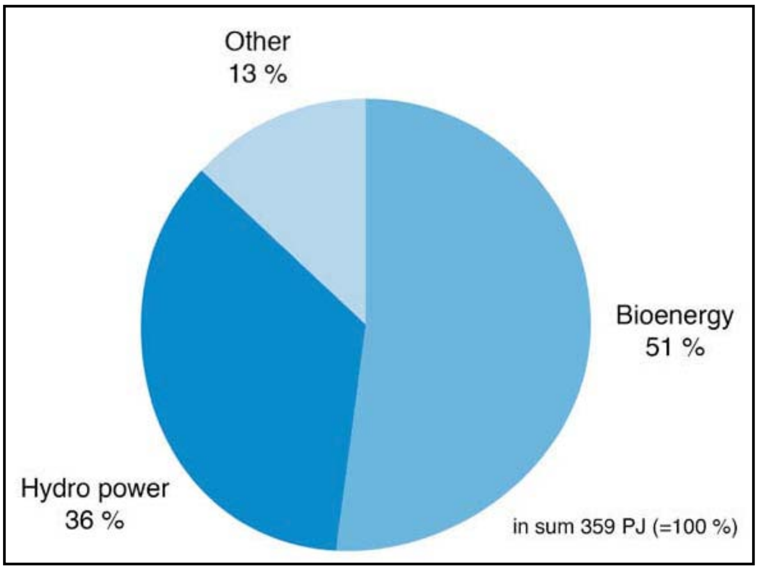


Figure 11: Gross national renewable energy consumption in Austria (adapted from BMLFUW, 2009)

In 2007, within renewable energies, biomass (including forest and agricultural biomass) was dominating with a proportion of 51 % or 213.1 PJ followed by hydro power with a share of 36 % or 129.6 PJ, and the remaining 13 % were from photovoltaic, solar energy, wind power and geothermal power (see figure 11) (BMLFUW, 2009; Basisdaten Bioenergie Österreich, 2009).

2.3.2.2 Agricultural bioenergy potentials

Future predictions indicate high development potential in bioenergy production. To comply with the EU target of 34 % share of renewables, in sum about 200 PJ have to be produced, additionally. Thereof, the highest share is projected to come from bioenergies 105 PJ (53 %) followed by hydropower 25 PJ (13%) and wind, solar and photovoltaic (Bachler, 2009; Nemestothy, 2010). Therefore, additional agricultural area will be required to achieve the targets for more agricultural bioenergy production.

Agricultural bioenergy sources

Currently, the most important bioenergy sources are split logs, pellets and combustible waste (Basisdaten Bioenergie Österreich, 2009). Although, the agricultural bioenergy production has a lower proportion than split logs, they show considerable increases (BMLFUW, 2009). The largest share of bioenergy crops are from maize, followed by rapeseed, sunflower and winter wheat (UBA, 2010). The cultivation of 2nd generation bioenergies, as for example Miscanthus, short rotation coppice and straw have a lower share but high potential for the future (AMA, 2009). The "EnergieStrategie Österreich" expects, that short rotation coppice, straw, intercrops and grassland will be the most important bioenergy sources used for bioenergy production in the future (BMWFJ, 2010).

Available area for bioenergy production

Historically, area distribution to forestry, agriculture and grassland show a highly dynamic process. Since the 60s of the 20th century, agricultural areas and grasslands are declining continuously, whereas forests are increasing. Extensively used grasslands are more and more limited to mostly mountain pastures and areas with fewer yields. However, according to Kranzl et al. (2008) intensively used grasslands are currently increasing.

In 2008, in sum about 3.19 Mio. hectares of land were used for agricultural purposes, of which 1.39 Mio. ha were cropland (equals about 16 % of the Austrian territory) and 1.73 million ha were grassland (BMLFUW, 2009). Generally, the highest share of cropland can be found in the East of Austria, namely in Lower Austria and Burgenland. Whereas, the highest share of extensively cultivated grassland is located in the Western part of Austria (BMLFUW, 2009).

Between 2007 and 2009, area for subsidized bioenergy production was increasing from about 17 000 to 25 000 ha. Partly, the use of set-aside areas is reason for the increase. In 2010, short rotation coppice plantations were cultivated on an area of about 1335 ha (Statistik Austria, 2010). Actually, the total areas used for bioenergy production are estimated much higher. Langthaler (2007) calculated the area used for bioenergy production between 50 000 to 55 000 ha in 2007 (Langthaler et al., 2007). Predictions of how much area will be needed to satisfy bioenergy demands significantly deviate from each other in literature:

- The EEA (2006) evaluated that about 300 000 ha area could be available for biomass production till 2030.

- The draft design of the Austrian Biomass Action Plan (2006) evaluated, that about 1 Mio. hectare land would be needed for a 45 % share of renewables by 2020, which would occupy about one third of the currently cultivated area (Indinger et al., 2006).

- Another study of Brainbows evaluated the area demand with the help of three scenarios: In the so-called Reference scenario the current development is extrapolated by the year 2020. An increase of intensive farming is calculated in the Biomass scenario and an increase in organic farming is predicted in the Environmental scenario.

    - Reference scenario: 320 000 ha
    - Biomass scenario: 456 000 ha
    - Environmental scenario: 200 000 ha (Langthaler et al., 2007)

It is assumed that an area of about 210 000 to 235 000 ha can produce about 21 to 26 PJ (BMLFUW, 2009b). The "EnergieStrategie Österreich" (2010) projected, that about 22 to 37 PJ of agricultural bioenergy could be produced by 2020 (BMWFJ, 2010). These predictions presume considerable land requirements for bioenergy production in Austria.

3 Methodology

3.1 DynaLearn software

According to Bredeweg et al. (2009; 2010), the main objective of DynaLearn is to develop an integrative learning environment that motivates learners. It was developed as a response to decline in science curricula. Reasons for this include the perceived complexity, the idea that these subjects are uninteresting and tedious; resulting in a lack of motivation. Some scientists believe that building causal models and simulating them helps students to improve their understanding of system behaviour. Therefore, DynaLearn seeks to address these problems by allowing learners to construct computer-based, qualitative models to simulate system behaviour. When working with DynaLearn, students can choose between different Learning spaces; depending on their knowledge as well as on the kind of information they are dealing with. In this regard, modelling environments can contribute to advanced science teaching and learning.

The software is based on qualitative reasoning, a research area within artificial intelligence, which operates without any numerical information and excels in representing principles of cause and effect. The conceptual models can be valuable tools for both, for pre-mathematical modelling as well as stand-alone models, which are developed for understanding, predicting and explaining systems behaviour.

There are three main components of the DynaLearn software (Bredeweg, 2009):

- Conceptual modelling allows learners to capture their own knowledge about system behaviour and simulating it. In doing so, it should improve the ability to understand and explain the behaviour of scientific systems.

- Semantic Technology assists in the automatic comparison between models, which are content-wise to models created by other students or their instructors, providing information with regard to possible improvements.

- Virtual Characters are agents to interact as hamsters, which provide knowledge support to learners and should motivate studying by interacting with them during modelling exercise. Further, they can compete with each other and in this way supports social skills.

The software is organised in six Learning Spaces (LS) with increasing complexity in terms of modelling ingredients a learner can use to construct knowledge: The Concept Map, the Basic Causal Model, the Basic Causal Model with State-Graph, Causal Differentiation, The Conditional Knowledge and the Generic and Reusable Knowledge. Each Learning Space is an interactive workspace, where learners are able to create cause and effect representations about real-world systems. Hence, learners can be confronted with the logical consequences by simulation of their building environment. In the following, the Learning Spaces relevant to this thesis are described in detail.

3.1.1 Concept Map (Learning Space 1)

Learning Space 1 acts to express general causal relations with the chosen topic. It consists of two primitives: entities (nodes) and configurations (arcs). Nodes reflect important concepts, while arcs show the relationships between those concepts (see figure 12). This Learning Space represents the root from which more complex models can be built, but no simulations can be run.

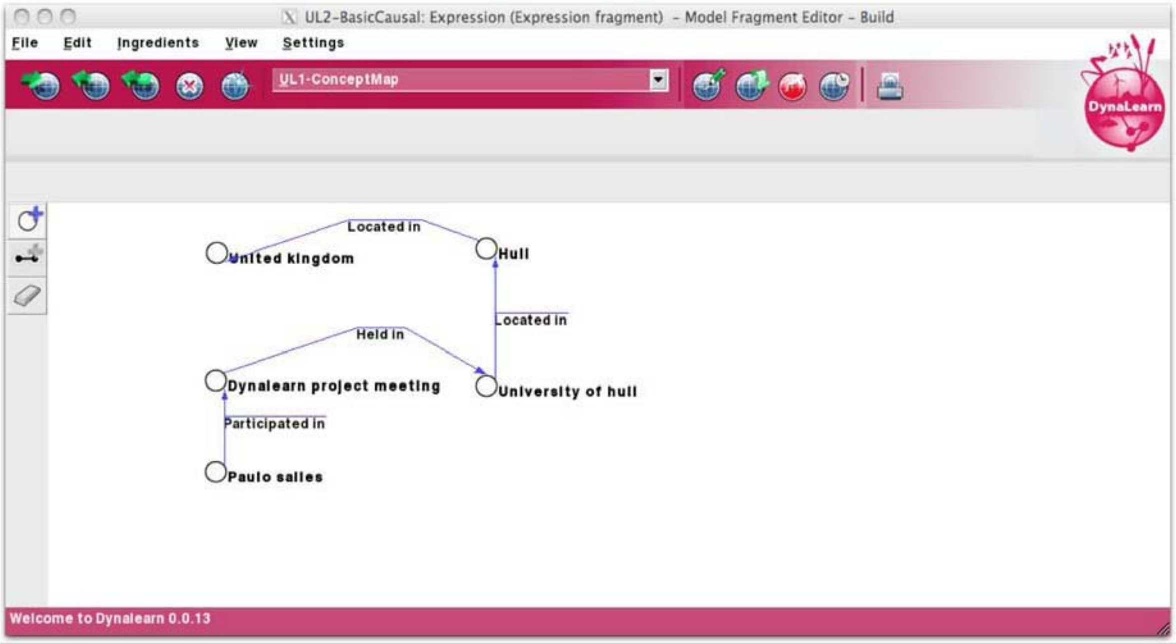


Figure 12: The concept map (Liem et al., 2010)

3.1.2 Basic Causal Model (Learning Space 2)

Learning Space 2 consist of entities, which have a defined variety of quantities. The focus thereby is on how the entities influence each other; in form of quantities, which are connected through causal dependencies, either (+) or (-). The basic causal model is the first Learning Space, which allows simulation. Pressing the simulation button in the expression workspace simulates the model, whereas the visualization is almost identical to the building workspace. Simulation at this stage means to calculate for each quantity derivatives one of the following options: increase, steady, decrease, ambiguous (because of opposing influences), or unknown (because of missing information) (see figure 13 and figure 14) (Liem et al., 2010).

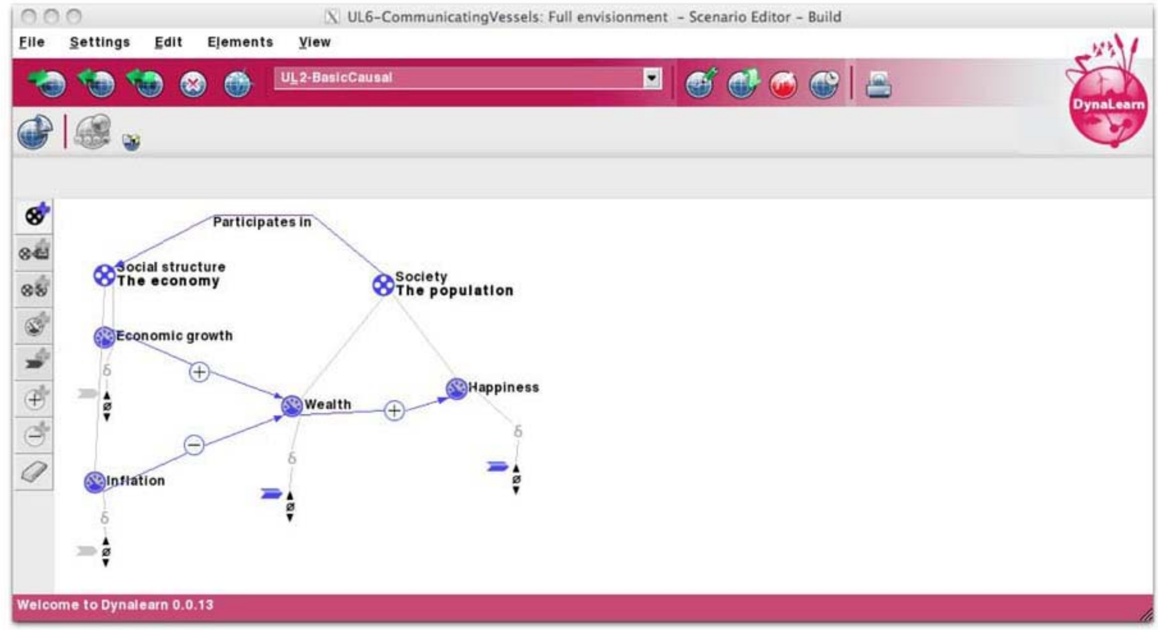


Figure 13: Simulation with increasing outcome in Learning Space 2 (Liem et al., 2010)

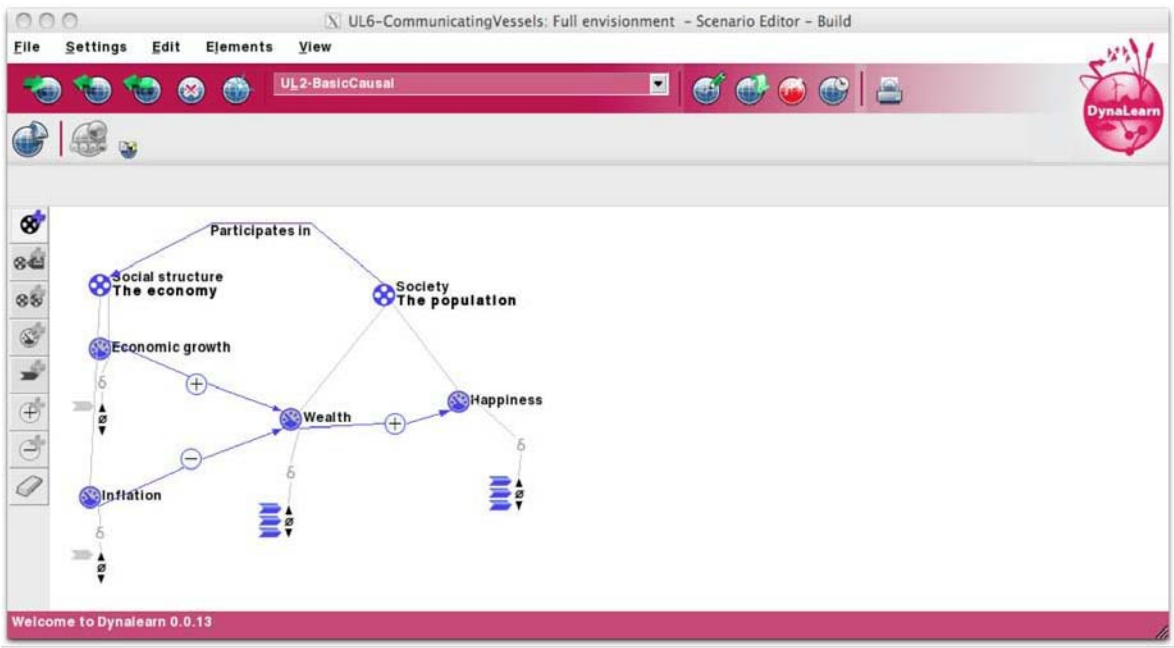


Figure 14: Simulation with ambiguous outcome in Learning Space 2 (Liem et al., 2010)

3.1.3 Causal differentiation (Learning Space 4)

This Learning Space features quantity spaces which can be assigned to quantities (see figure 15). Adding this feature has a significant impact on the simulation results and necessarily introduces state-graph (see figure 16) and value history (see figure 17). Besides, causal refinements into influence (P) or rate (I), which can be either positive or negative, are introduced.

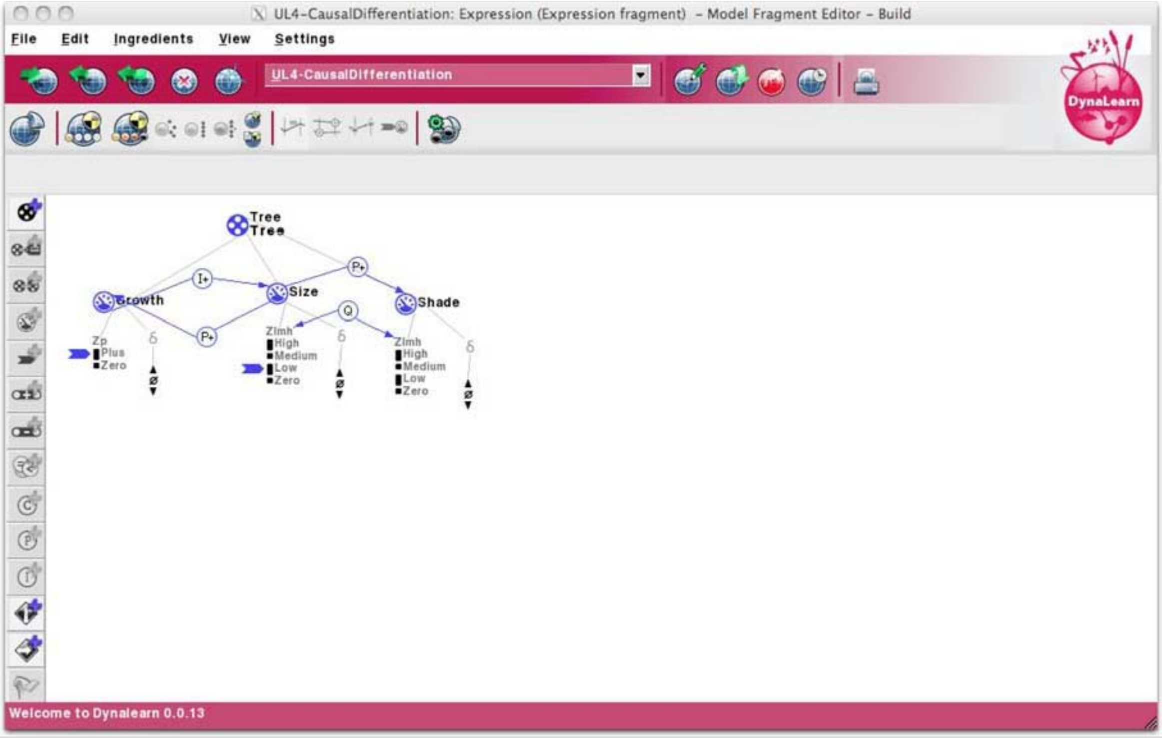
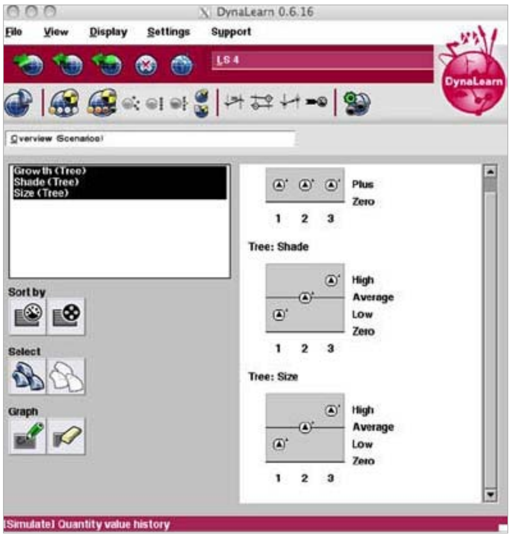


Figure 15: Work space of Learning Space 4 (Liem et al., 2010



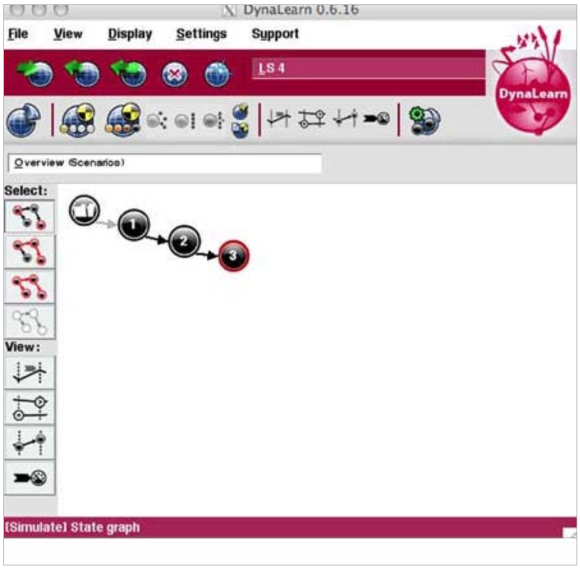


Figure 16: Simulation of Learning Space 4 – state graph (adapted from Liem et al., 2010)

Figure 17: Value history in Learning Space 4 (adapted from Liem et al., 2010

3.1.4 Conditional knowledge (Learning Space 5)

All representation details from the preceding Learning Spaces apply to Learning Space 5, as well. The main difference is the option to specify conditions, under which specific sets of details is assumed to be true. Therefore, "if-then" relationships can be expressed. It allows learners to specify each ingredient, weather it is a condition (red coloured), or a consequence (blue coloured) (see figure 18).

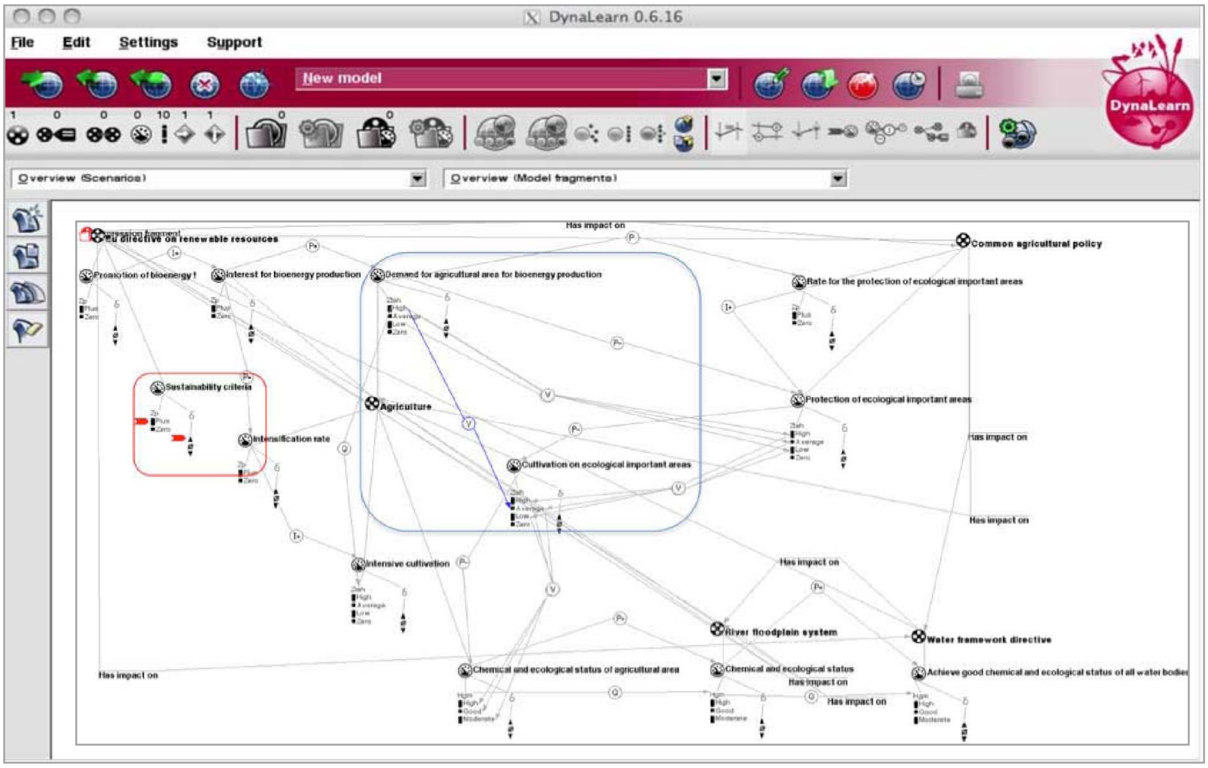


Figure 18: conditional expression in Learning Space 5

3.1.5 Generic and reusable knowledge (Learning Space 6)

Here, the conceptual modelling environment has the same features as the current version of Garp3 software (Bredeweg et al., 2009). This Learning Space provides a hierarchical structure, which consists of a library of model fragments (see figure 19 and figure 20) and processes (see figure 21) and a set of scenarios from which the simulation starts. Different and even opposite views on the same topic may coexist in the library of model fragments and the knowledge captured can be reused to create more complex scenarios and simulations. It allows formulating and displaying hypotheses; explaining how a system behaves. In this way it provides representations for alternative hypotheses and their comparison.

The DynaLearn project utilizes the Garp3 software developed in the NatureNet-Redime project. Currently realised components include the conceptual modelling environment, grounding as a simple version of the quality feedback and the teachable agent and quizmaster.

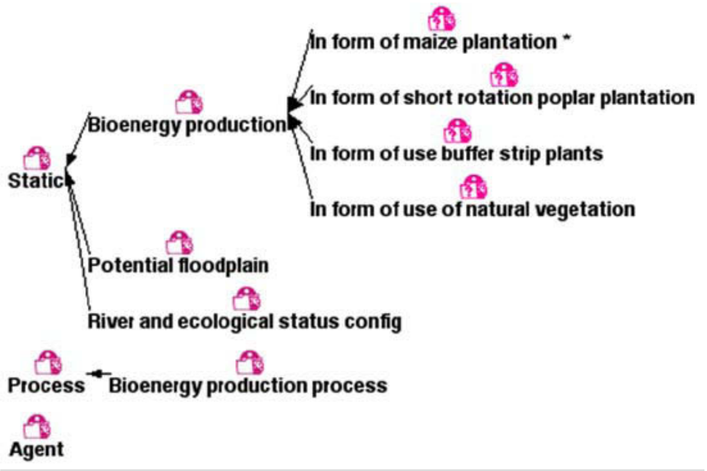


Figure 19: Library of model fragments in Learning Space 6

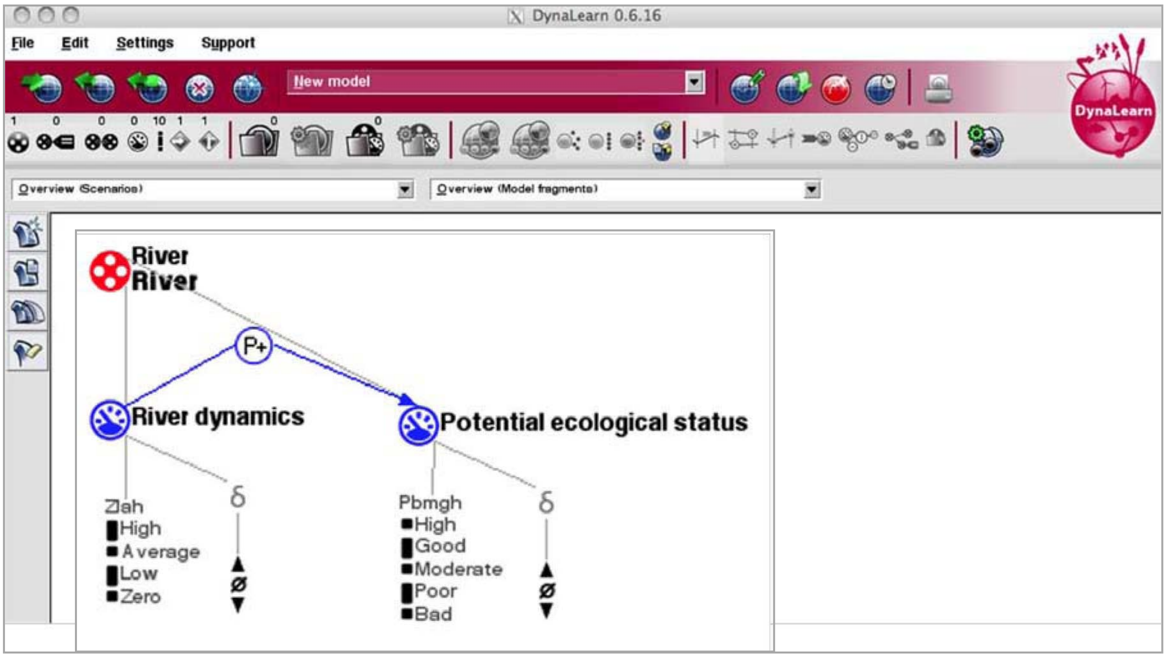


Figure 20: Static model fragment in Learning Space 6

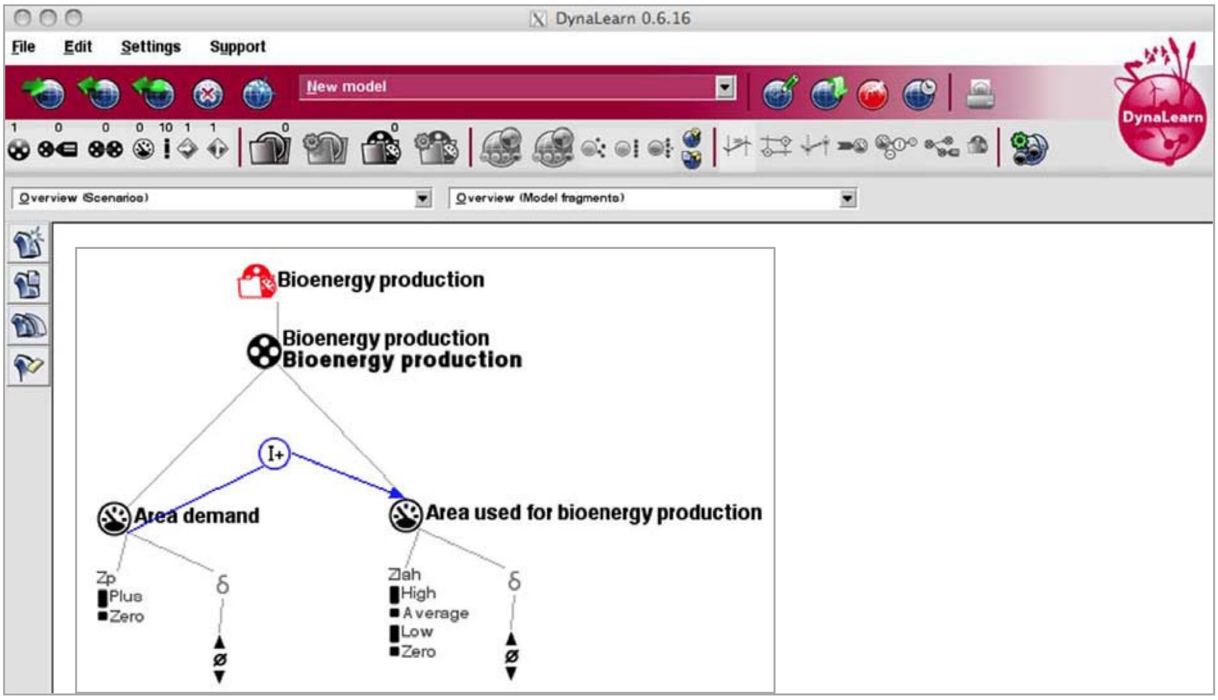


Figure 21: Process in Learning Space 6

3.2 Thesis approach

First, literature research on the topic was generated to allocate a literature survey and to define specific research questions. Before modelling, deeper literature research was necessary to select system parts (entities and quantities) for modelling in DynaLearn software. Then, it was clarified which Learning Space suits best to the particular research question in terms of display and understanding of information. Feedback and discussions with the advisors followed to improve the models. In the end the models were documented and discussed followed by a conclusion.

3.3 Model development

Primarily, the models were designed under work package 6 of the DynaLearn project. The main purpose of work package 6 was to develop a repository of models for testing and evaluating the DynaLearn software. The research questions are assigned to those individual Learning Spaces, where they suit best in displaying the relevant core information.

The selected models were built to gradually analyse interdependencies of bioenergy production in the potential floodplains. The research questions already mentioned in chapter 1 are partitioned to different Learning Spaces as follows:

Learning Space 5: Modelling land use change induced by EU policy goals • What are the influences of EU policies on land use and thus on river-floodplain systems? • Will the EU Directive on Renewable Energies have any impacts on the EU Water Framework Directive?
Learning Space 1: Modelling effects of agricultural bioenergy production on river-floodplain systems • To which extent will the promotion of agricultural bioenergy production affect river-floodplain systems? • Are there any impacts of agricultural bioenergy production on potential floodplains and its adjacent rivers?

Learning Space 2: Effects of different land use in potential floodplains 1. Modelling natural floodplain forests 2. Modelling impact of intensive energy maize production 3. Modelling impact of short rotation poplar production • What are the environmental effects of different energy plants?
Learning Space 4: Modelling land use conflicts for bioenergy production and floodplain restoration • Are there conflicts of space likely to appear between increasing bioenergy production and the need for floodplain restoration?
Learning Space 6: Modelling synergies between bioenergy production and floodplain dynamics • Are there any possible synergies between bioenergy production and floodplain dynamics?

For the construction of models the ever-improving prototype of the DynaLearn software was used and adequate entities and quantities were selected to gather the relevant processes of cause and effect. According to the research questions, each model includes background information and the rationales and goals important for the understanding of the modelling process.

4 Selected Models

4.1 Modelling land use change induced by EU policy goals (Learning Space 5)

There is the risk that the newly established Renewable Energy Directive with its objective to promote renewable energies including agricultural bioenergy production will harm other environmental objectives at the EU level (EEA, 2007). Thus, this chapter identifies potential links and conflicts of relevant EU policy goals and its impacts on land use change. In detail, it clarifies the interactions between the policy goals of the EU Renewable Energy Directive, the Common Agricultural Policy (CAP) and the Water Framework Directive (WFD).

4.1.1 Background

Europe faces many challenges in its environmental, energy and agricultural policies. Recently, these policy fields have undertaken important changes for sustainable development (see chapter 2.2). However, the targets of the different EU policies were often not specifically linked to each other at the time of their implementation. However, this would have been important in order to support each other rather than to restrain each other.

Main conflicting EU policy goals

- The pressures on water quality and quantity caused by agriculture are considered to be one of the main sticking points for successful realisation of the Water Framework Directive objectives of good chemical and ecological status of all water bodies (Dworak et al., 2009).

- Besides, the newly established Renewable Energy Directive puts additional pressure on agriculture. Agricultural bioenergy production areas have to be extended and existing agricultural areas have to be cultivated more intensively to achieve the objectives (Schleupner et al., 2010). This is likely to cause severe impacts to river-floodplain systems. Thus, achieving the targets of the Renewable Energy Directive may induce risk to fail the targets of the Water Framework Directive and the Habitat Directive (Fenz et al., 2006).

- Therefore, the Common Agricultural Policy and the Water Framework Directive are important policies of the European Union in the context of conflicts between agriculture and aquatic ecosystems. Due to cross compliance regulations, especially since the 2003 reform of the Common Agricultural Policy the opportunities for reducing environmental pressures have been improved and may contribute to Water Framework Directive objectives (Dworak et al., 2009) (see chapter 2.2.4).

- However, recent developments within the Common Agricultural Policy tend to more liberalization of its environmental standards. One first step in this direction is the reintroduction of agricultural cultivation on set-aside areas (see chapter 2.2.5).

Land use change and intensification of agriculture

Land use change is both: the conversion from one land use to another (e.g. the conversion from floodplain forest to agricultural land), as well as changes in land management such as intensification of agriculture (Schubert et al., 2009). Because, bioenergy production is profit oriented and less attention is given to environmental standards, agricultural intensification and land use conversion with less area used extensively are most likely to occur (Nitsch et al., 2008). As a direct consequence of increased demand for bioenergy, an intensification of agriculture has already been observed in Germany over the past few years (Schöne, 2008).

Intensive agriculture means:

- More use of fertilizers and pesticides

- Intensive use of former extensively used areas (e.g. set-aside areas, permanent grasslands)

- Ploughing up of grassland

- Cultivation of inappropriate areas

- Negative effects on aquatic ecosystems

Intensification of agriculture is often the largest single cause of floodplain degradation and biodiversity loss (Oates, 2002; Schöne, 2008). Forest clearing to gain agricultural land changed the natural water retention capacities leading to higher discharges and increased erosion on unprotected soils (Patt et al., 2009). Besides, species composition and productivity of floodplains are highly influenced by the water quality. In case of intensive cultivation, potential floodplains serve as a major source of nutrients and pesticides due to fertilization. The consequential high nutrient input to the parent river often has severe implications, not only for aquatic ecosystems (Buijse et al., 2002). According to Herbke et al. (2006), diffuse pollution with nutrients and hydromorphological changes are the main challenge in fulfilling the objectives of the EU Water Framework Directive objectives.

Many plants and animal species are dependent on extensive farming (EEA, 2008). Thus, land use change may result in habitat loss, which consequentially is the main reason for biodiversity loss (Schuber et al., 2009).

Set-aside areas

In order to increase area for bioenergy production, the Common Agricultural Policy liberalized its regulations and introduced a special aid for energy crops (AMA, 2009). It was recognised that an extension of area for bioenergy production can be achieved with the use of areas formerly set-aside. Set-aside area can be defined as ecological important areas in intensive farming areas, which are important for biodiversity (EEA, 2006). Formerly, areas at risk of erosion and areas with high concentrations of nitrate were declared to set-aside. These sites provided important functions in terms of reduced inputs, buffering, linking habitats, protecting soils and the protection of water resources (Dworak et al., 2009; Nitsch et al., 2008). However, since 2003, it is allowed to use set-aside areas for non-food production, including bioenergy plants, again. Fortunately, the percentage of obligatory set-aside areas has constrained this purpose (BMLFUW, 2009). Though, since 2008 the EU Commission has abolished the provision to set-aside areas (AMA, 2009). Since then there is no duty to declare set aside areas, anymore; potential areas are used for cultivation again. As a consequence, set-aside areas as important refuges and for ecological compensation have lost its effect. Beyond that, also surrounding areas face severe environmental pressures (Dworak et al., 2009).

Permanent grassland areas

Increasing demand for bioenergy production may also lead to the conversion of permanent grassland. In fact, in potential floodplains and in Natura 2000 areas, as well as other nature conservation areas the share of permanent grassland is high (EEA, 2007). Such areas are important in terms of recreation and ecology, too. Because in grasslands nutrient leaching is low compared to cropland (Rösch et al., 2007), particularly in catchments they play a preventive role for clean and sustainable drinking water supply. Under Natura 2000 regulations the conversion of permanent grassland is allowed as long as there is no deterioration of the habitat, respectively bird distinction. The monitoring may be difficult in many cases, though (Osterburg et al., 2009). Additionally, under cross compliance regulations ploughing up of grassland is forbidden with some limitations: The share of permanent grassland must not decrease by 10% compared to the year 2003. In case of a decrease of more than 5 % counteractions have to be taken. However, on the regional scale often much more permanent grasslands are ploughed up than it is allowed. This is also the case in Natura 2000 areas (Schöne, 2008). About 16 % of all permanent grassland habitats listed in the Habitat Directive (Annex I) are depending on extensive farming, whereas one third of them are threatened by an intensification of agriculture (EEA, 2007).

Conversion of ecological important areas

The conversions from ecological important areas like set-aside areas and permanent grasslands to areas for bioenergy production is harmful to floodplains and its parent rivers with major impacts on the ecology of the area and the chemical and ecological status of adjacent water bodies (Oates, 2002; Nitsch et al., 2009). Ploughing up of biodiverse grasslands for energy maize production within Natura 2000 networks has already been observed in Germany (Schöne, 2008). A study undertaken in Germany found out that the share of set-aside areas within protected Natura 2000 floodplains was decreasing due to increased cultivation of maize for biogas production between 2005 and 2007 (Osterburg et al., 2009). Also in Austria, a small decrease in permanent grassland areas can be observed by now (Kiefer et al., 2008). Hence, ploughing up of grassland poses significant impacts on water protection, soil protection, change in species composition and loss of biodiversity (Rösch et al., 2007; Osterburg et al., 2009).

4.1.2 Concepts and goals

- In Learning Space 5 relevant EU policy goals and their objectives are modelled.

- The promotion of agricultural bioenergy through the EU Renewable Energy Directive increases the interest for bioenergy production. Increase in production is either possible with an intensification of agriculture and/or land use change of ecological important areas (set-aside areas and permanent grasslands).

- The Renewable Energy Directive impacts the Common Agricultural Policy and may lead to a liberalization of cross compliance regulations. Ecological important areas (set aside areas and permanent grassland areas) may then be used for bioenergy production.

- If ecological important areas are cultivated, there is the risk that the objectives of the Water Framework Directive cannot be achieved.

- This model should show that even small changes in the legal formulation of policies may have drastic implications for the environment.

- Further this model should illustrate that policy goals of different EU policies influence each other, fundamentally.

Table 2: Entities and quantities used in Learning Space 5

Entity	***Quantities***	***QS***	***Remarks***
EU Directive on Renewable Energies	Promotion of bioenergy	*Zp*	Zero, plus
	Sustainability criteria	*Zp*	Zero, plus
Common agricultural policy	Rate for the protection of ecological important areas	*Zp*	Zero, plus
	Protection of ecological important areas	*Zlah*	Zero, low, average, high
Agriculture	Intensification rate	*Zp*	Zero, plus
	Intensive cultivation	*Zlah*	Zero, low, average, high
	Demand for agricultural area for bioenergy production	*Zlah*	Zero, low, average, high
	Interest for bioenergy production	*Zp*	Zero, plus
	Cultivation on ecological important areas	*Zlah*	Zero, low average, high
	Chemical and ecological status of agricultural area	*Mgh*	Moderate, good, high
River floodplain system	Chemical and ecological status	*Mgh*	Moderate, good, high
Water Framework Directive	Achieve good chemical and ecological status of all water bodies	*Mgh*	Moderate, good, high

4.1.3 Model expression

The model in Learning Space 5 (see figure 22) consists of one expression and one conditional statement.

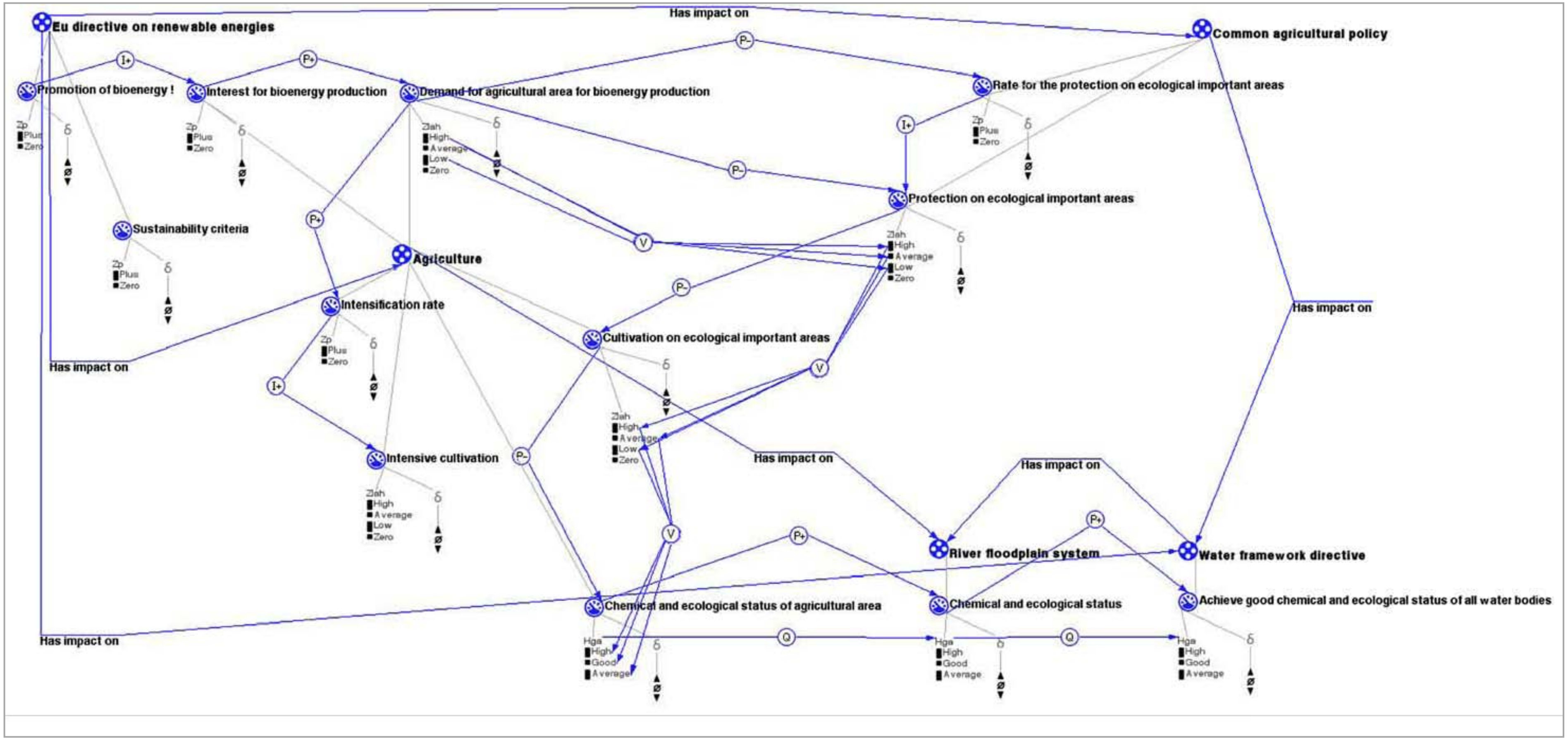


Figure 22: Model expression Learning Space 5: Land use change induced by EU policy goal

Initial values

The simulation starts with the assumption that the area demand for agriculture and the cultivation of ecological important areas are low. The chemical and ecological status of the river floodplain system is high and the initial value for the promotion of bioenergy is also high (see figure 23).

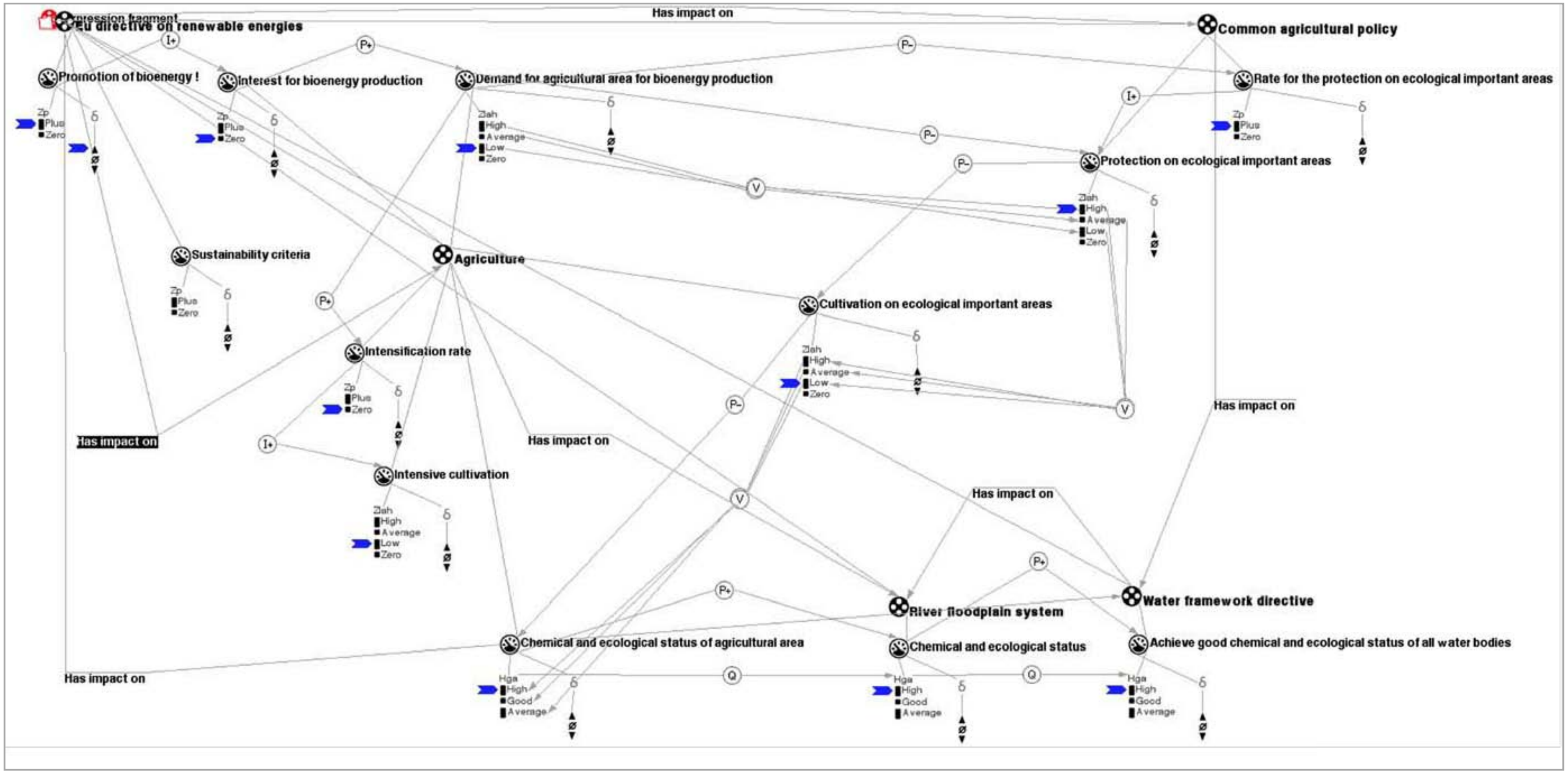


Figure 23: Initial values of Learning Space 5: Land use change induced by EU policy goals

Condition

The condition states, that if sustainability criteria are implemented into the renewable energy directive (red arrows), fewer ecological important areas will be used (blue arrow) (see figure 24). It is assumed that the criteria are monitored, well within the member states.

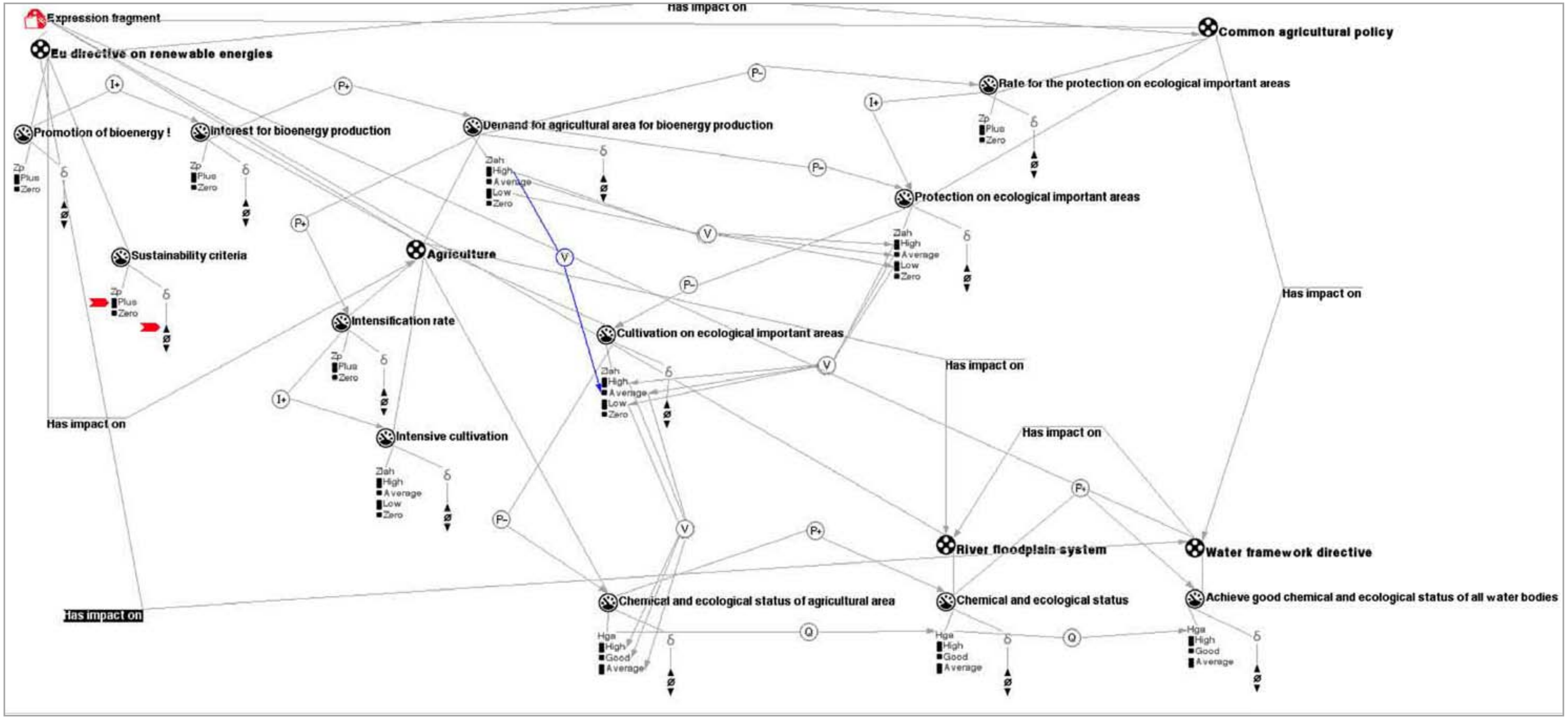


Figure 24: Condition: Sustainability criteria Learning Space 5: Land use change induced by EU policy goal

4.1.4 Scenarios and simulation

The condition “sustainability criteria” moderates the cultivation of ecological important areas. If sustainability criteria are implemented into national laws and if they are monitored well, there is less pressure on the cross compliance regulations of the common agricultural policy and ecological important areas are protected in a sustainable way. If fewer ecological important areas are converted into areas for bioenergy production, there are fewer impacts on the chemical and ecological status of agricultural areas and thus the chemical and ecological status of rivers remains good. Therefore, sustainability criteria may limit liberalization rates of the common agricultural policy and in this way contribute to the objectives of the Water Framework Directive.

However, if sustainability criteria are not monitored and maintained well enough within the EU Member States, the renewable energy directive may have severe impacts on the objectives of the Water Framework Directive and the environmental standards of the common agricultural policy: If the model is simulated without the condition “sustainability criteria” more ecological important areas are used for bioenergy production, leading to decreasing chemical and ecological status of rivers. Hence, the risk to fail the objectives of the Water Framework Directive would be high.

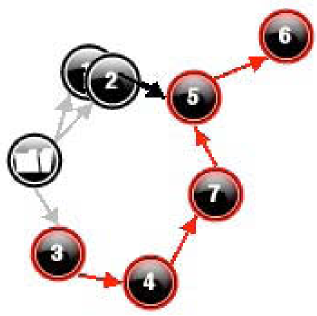


Figure 25: State graph of Learning Space 5: Land use change induced by EU policy goals

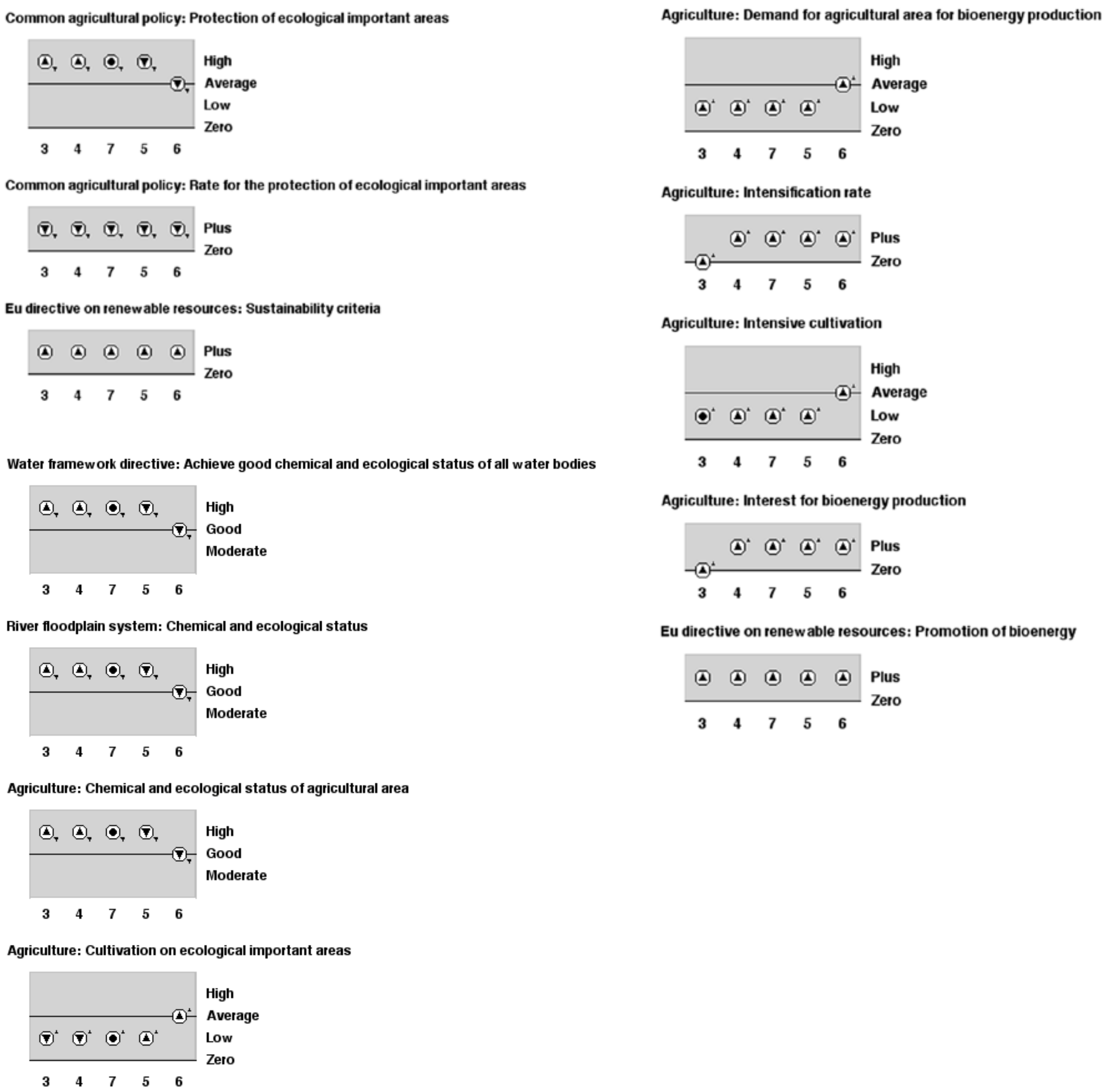


Figure 26: Value history of Learning Space 5: Land use change induced by EU policy goals

4.1.5 Improvements and Uncertainties

- Not only the promotion of renewable energies has an impact on the interest for bioenergies but also the markets prices for food, oil and bioenergies.

- Subsidies for bioenergy production, for extensive agricultural cultivation and for the protection and restoration of river-floodplain ecosystems can be included; additionally the outcome is closer to reality.

- Not only the EU policies have an influence on land use, but also their implementations into national laws as well as other policies of the EU Member States have a huge impact.

- At the moment there are uncertainties how to ascertain the ecological and chemical status of agricultural areas, respectively its soils. Therefore, further research has to be undertaken.

4.2 Modelling effects of agricultural bioenergy production on river-floodplain ecosystems (Learning Space 1)

4.2.1 Background

In the past century, upcoming intensive agriculture already had severe impacts on river-floodplain ecosystems (see chapter 2.3.4). Nowadays, ongoing land use change and intensive bioenergy production continues to successively constrict and replace the remaining floodplain patches (Muhar et al., 2000). In general, the more intensive the production is, the lower the biodiversity will be in the areas concerned. As mentioned above, there will not only be negative impacts within the bioenergy production area but also impacts on the adjacent areas (Müller-Wenk et al., 2003). Thus, bioenergy cropping may increase the pressure on floodplains; with negative impacts on the chemical and ecological status of rivers (Dworak et al., 2008). A difficulty in identifying the environmental effects of agricultural bioenergy production arises from the fact that most effects strongly depend on the location factors. To be mentioned in this context are the former land use, the crop types, the farming practice applied as well as on the environmental vulnerability to soil erosion, nutrient leaching, etc. In this thesis the effects of agricultural bioenergy production on river-floodplain ecosystems are only discussed in general terms.

4.2.2 Key themes

The complex effects of agricultural bioenergy production on the river-floodplain ecosystem derive from:

- Hydromorphological changes (lateral connectivity, drainage, etc.) (see chapter 2.2.3)
- Land use change
  The environmental impacts depend to a large extent on the selection and the amount of areas that are used (see chapter 4.4.1)
- Crop types (see chapter 4.3)
- Farming practice (soil treatment, fertilization, etc.) (EEA, 2008)

4.2.3 Concepts and goals

This model gives an overview of several selected effects of bioenergy production on river-floodplain ecosystems. It describes the conversion of floodplains for the purpose of agricultural land for bioenergy production, including hydromorphological changes. It pictures that bioenergy production on potential floodplains may severely affect biodiversity and water quality and quantity in a number of ways.

4.2.4 Model expression

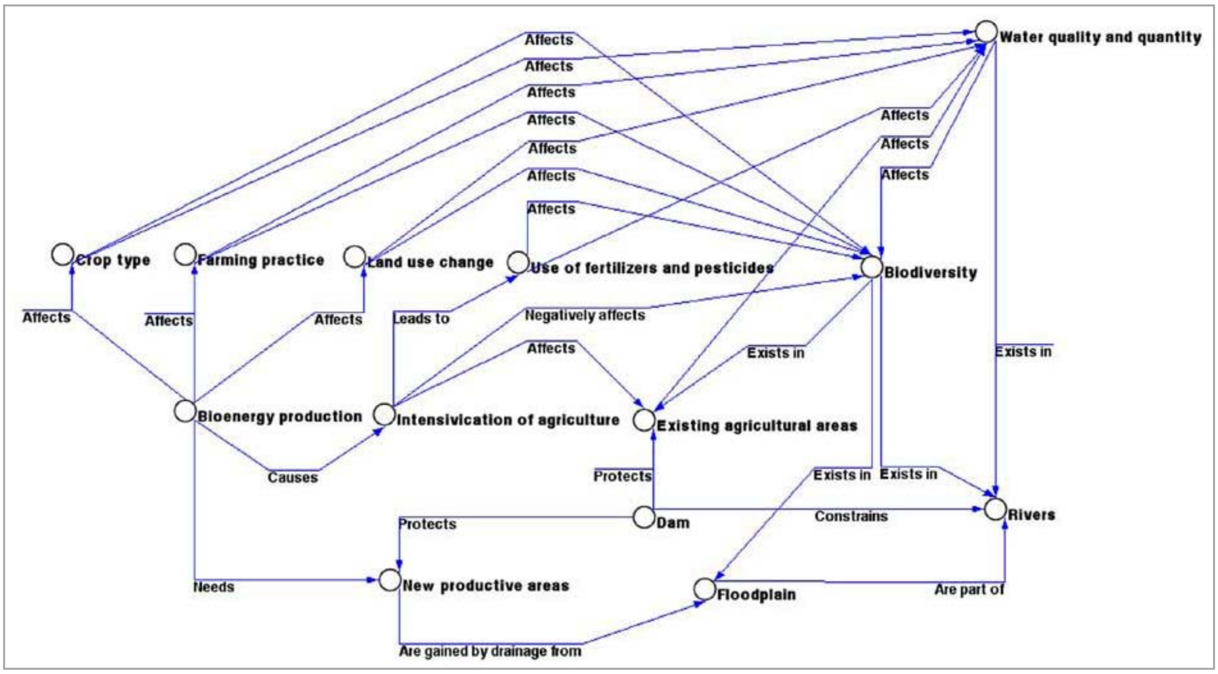


Figure 27: Model expression of LS1: Effects of agricultural bioenergy production on river-floodplain ecosystems

4.3 Effects of different land use in potential floodplains (Learning space 2)

In theory, bioenergy can be produced from all types of plants. However, in practice only a few sources from agriculture are used due to present technical limitations, confirmed habits of farmers or limitations in growth by reason of different requirements to climate, soils, water, nutrients etc. (Dworak et al., 2008). Thus, current agricultural bioenergy production is mainly based on first generation technologies, such as fermentation of crops to produce ethanol, biogas and combustion to produce heat and power. The cultivation of “classical” food crops can lead to severe environmental pressures, particularly if land use intensity or area need is increased (Dworak et al., 2009). In future a shift from first-generation biofuels to second-generation biofuels and eventually to third-generation biofuels, which have prospects for more sustainable production, is expected (EEA, 2006). The following models compare the main environmental pressures of energy maize production as well as the production of short rotation poplar plantations to a natural floodplain forest stand. The considered main pressures are: soil erosion, soil compaction, nutrient input into ground and surface water and biodiversity. It should be noted that some potential impacts cannot be analysed in detail, because of lack of data and/or modelling capacity. The natural floodplain vegetation was chosen as a reference state, because they are recognized as being the pristine character of most actual agricultural areas in river valleys.

4.3.1 Modelling natural floodplain vegetation

4.3.1.1 Background

Land use change for the purpose of agricultural use has isolated floodplain forests to their current space. In the Habitat Directive, floodplain forests are listed as priority forest habitat typed, due to the fact that they are very threatened ecosystems, nowadays (Hughes et al., 2003).

Generally, floodplain forests only occur in river valleys adjacent to aquatic ecosystems and provide habitat for a huge variety of plant and animal species (Hughes et al., 2003). In their natural state floodplain forests are dominated by fluvial dynamics including the expansion and contraction of surface waters (flow/flood pulse concept), which are important to maintain the connectivity of floodplains to their parent river (Tockner et al, 2000, Ward et al., 2002). Laterally connectivity is a precondition for vital riverine floodplains, enabling the transfer of energy, organic matter, nutrients, sediments and organisms (Neary et al., 2009). The riverine and floodplain fauna and flora are depending on the dynamic interaction between water and land (Stream Corridor Restoration, 2001). Thus, only small changes in connectivity may drastically alter biodiversity and species composition (Tockner et al., 2000).

Floodplain forests are characterized by deep rooting systems and extensive canopy coverage. These conditions create soils with high infiltration rates, resulting in less surface runoff, higher subsurface flow and groundwater recharge. Furthermore, the deep rooting of natural floodplain forests contributes to riverbank fixation. Moreover, the shadowing, as well as the interception and transpiration of water by extensive canopy regulate the temperature of rivers and riparian areas (Allan et al., 2007). In case of floods, peak flows are mitigated and water is restored within these areas (Neary et al., 2009). Especially softwood trees are depending on saturated soils, resulting in faster growth rates of trees and higher species richness if groundwater tables rise (Tockner et al., 2000). When hydromorphology changes and on-site conditions become drier, softwood floodplains are often replaced by hardwood floodplain (Muhar et al., 2004).

In the groundwater and in the temporally saturated anoxic soils, microbial activity leads to denitrification processes. These processes attenuate nitrate leaching vertically from the root zone and infiltration laterally to the river, respectively. Also nitrate uptake by plants contributes to the retention of nutrients (Krause et al., 2008). Thus, they represent important buffer zones between agricultural area and the river. Further, the year-round vegetated soil cover protects soils from erosion and the sedimentation of suspended sediments is supported. Due to their function as buffer zones, water originating from floodplain forests is known to be of best water quality (Neary et al., 2009).

4.3.1.2 Key themes

- Floodplain forests are natural buffer zones between the adjacent land and river (high nutrient retention in the area)

- High water retention in floodplain vegetation, due to soil characteristics (thus, moderate floods)

- High biodiversity of fauna and flora, due to a variety of habitats

- Delivery of important ecosystem services

4.3.1.3 Concepts and goals

This model represents natural floodplain vegetation without any anthropogenic alterations. The causal relations between soil and the ground- and surface water are modelled. It should trigger thinking about the effects of conversion from natural floodplain forests to other land uses. Despite this, it is very important to understand these ecosystems functions in order to restore floodplains, properly. It should be kept in mind that a natural floodplain forest contributes to maintain good chemical and ecological status of a river.

Table 3: Entities and quantities used in Learning Space 2: Natural floodplain vegetation

Entity	***Quantities***
Floodplain forest	Amount of area
	Soil treatment
	Nitrate uptake
	Rooting
Soil	Soil compaction
	Water infiltration
	Surface runoff
	Erosion
	Soil coverage
	Nitrate leaching
	Nitrate runoff
	Water retention
	Soil degradation
Groundwater	Groundwater table
	Groundwater contamination
River section	Surface water contamination
	Ecological status
	Chemical status
Biodiversity	Amount of fauna and flora

4.3.1.4 Model expression and simulation

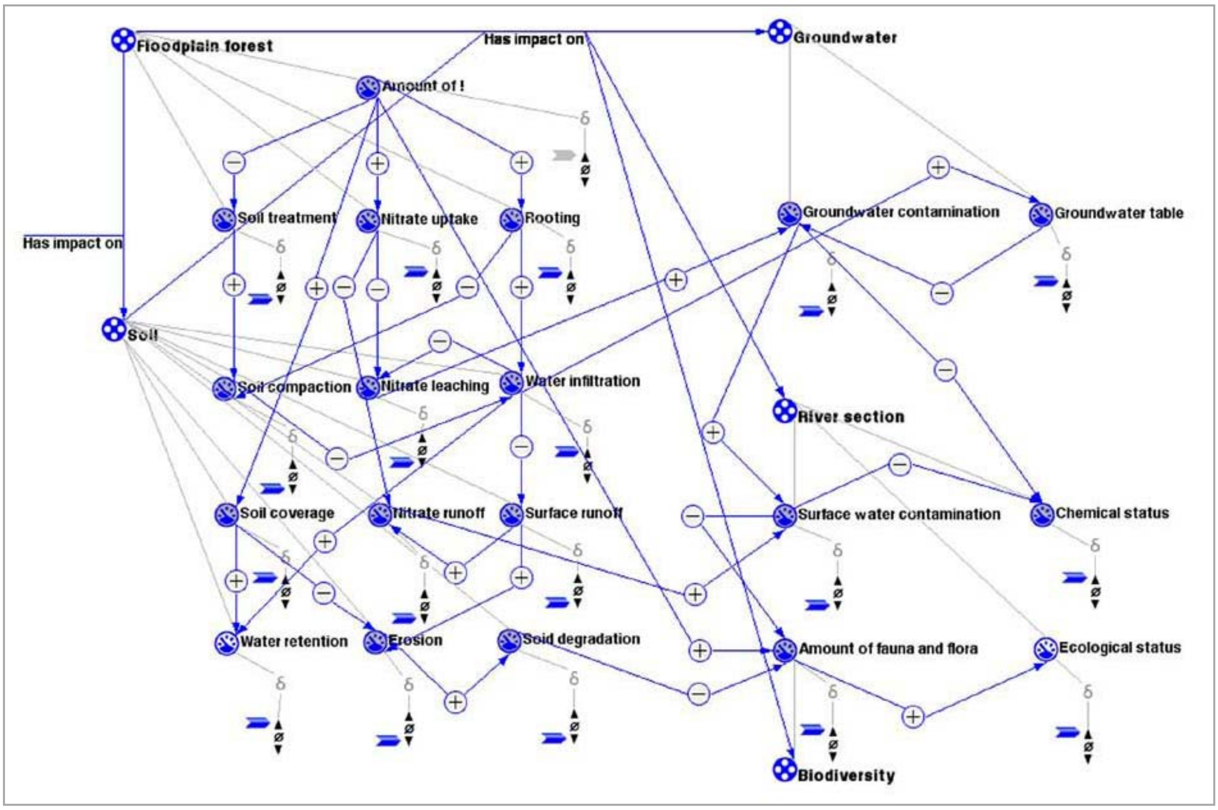


Figure 28: Model expression and simulation for Learning Space 2: Natural floodplain vegetation

4.3.1.5 Simulation

The simulation starts with the assumption that the amount of floodplain forest (grey arrow) increases. Then, soil compaction, nitrate leaching or nitrate runoff decreases and water infiltration, soil coverage and water retention increases amongst others (see blue arrows). Because of that, groundwater- as well as surface water contamination with nutrients decreases and the chemical status will increase. If the amount of natural floodplain forest rises within the potential floodplain, also the amount of fauna and flora will increase with it; leading to higher ecological status of the river section. Hence, the simulation shows that an increase in natural floodplain vegetation contributes to the maintenance of a good ecological and chemical status of the river.

4.3.1.6 Improvements

- To show dynamic interaction with river (lateral connectivity)
- To show impact on evapotranspiration and local climate
- To show carbon storage of trees and soils
- Due to a variety of effects within soil types, the effects are simplified in the model

4.3.2 Modelling impact of intensive energy maize production in the potential floodplain

4.3.2.1 Background

The area dedicated to energy crops for bioenergy is increasing strongly in parts of Europe, with maize as the main plant grown for biogas. In the last few years, a significant increase in biogas plants has been observed. Many farmers changed from conventional food production to energy maize production, due to higher profits. However, intensive maize production has severe adverse impacts. The most important impacts concerning the chemical and ecological status of the river-floodplain system are highlighted in the following.

Due to the characteristics of maize plants, their cultivation has severe impacts on the environment. Energy maize is an annual plant with a shallow rooting system and short time period of active nutrient uptake (Nitsch et al., 2008). Additionally, maize starts its uptake of nutrients later than other plants. Intensive farming is profit oriented. As a matter of fact, crop rotations are oriented on yield increase. Due to intensive farming, diseases and weed pressure occur more often, requiring more pesticide use (Dworak et al., 2008). Especially, maize but also rapeseed requires high amounts of fertilizers, pesticides and herbicides (Nitsch et al., 2008).

As a consequence of this, groundwater and surface waters bear an extreme risk of diffuse pollution (Nitsch et al., 2008). Particularly of concern are nutrients such as nitrates and phosphates (EEA, 2008). The nitrate loads to downstream aquatic ecosystems as a result of maize production are considered to be highest among all crop types. Also phosphor losses tend to be higher than form any other crops (Simpson et al. 2009). In Austria, about 52 % of total phosphor inputs are derived through erosion (Herbke et al., 2006). However, the losses depend on the soil type and content of organic matter, the slope, the depth to groundwater and the climate, as well. Nutrient losses pose particular problems in terms of eutrophication, oxygen depletion and disruption of ecological function and thus pollution of river ecosystems and groundwater. Furthermore, nitrate fertilizers have a complex biogeochemical cycle. Through their transformations and partitioning, they contribute not only to eutrophication of surface waters and groundwater's, but also to acid rain and climate change (Powers, S.E., 2007).

Many environmental impacts can be observed downstream, rather than on the terrestrial ecosystems, where energy maize is actually grown. An increase in production of maize could be particularly damaging to downstream aquatic ecosystems and so contributing to a decline in diversity of aquatic and terrestrial species (Sala et al., 2009). In rivers where intensive agriculture covers more than half the upstream catchment, nitrate levels are three times higher than in rivers were the upstream intensive agriculture covers less than 10% (EEA, 2005).

Furthermore, the production of maize requires high amounts of water. Particularly in areas which are already affected by water shortage, irrigation of agricultural land causes additional pressure on the existing water resources. However, in Austria the impacts of irrigated agriculture can be neglected, due to advantageous climate characteristics. However, it has to be considered that there is the possibility that climate change may cause the need for increased agricultural irrigation in Austria in the future, as well (UBA, 2011).

In general, soil erosion is defined as the soil loss due to wind and water (Weidanz et al., 2007). Thereby the erosion rate is very sensitive to climate, precipitation intensity, precipitation frequency, slope and topography. Soil erosion drastically alters soil quality, fertility and productivity and can have negative effects on watercourses as a consequence of increased sediment and nutrient transport (Rowe et al., 2009).

The removal of a protective vegetation cover (floodplain forest, floodplain meadows etc.) for maize production increases the potential for erosion (Herbke et al., 2006). Particularly in spring, due to late soil coverage, maize crops cannot protect soil from the pressure of raindrops and the risk for erosion is high (Kiefer et al., 2008). Harvesting of energy maize principally depends on the bioenergy demand. As a consequence of this, fallow time is longer due to early harvest. If no other crops are cultivated then, the risk of erosion increases dramatically due to unprotected soils (Kiefer et al., 2008). Increased soil treatment using heavy machinery furthermore causes soil compaction, which results in lower infiltration rates. Thereby, the share of surface runoff increases, depending on the tillage direction up or downslope (Kiefer et al., 2008). Table 4 summarizes the most important environmental impacts of intensive energy maize production on the adjacent terrestrial and aquatic ecosystem.

Table 4: Environmental impacts of energy maize (adapted from EEA, 2008)

Aspect	**Score**	**Reason**
Erosion	C	soil is unconverted over long period, row crop
Soil compaction	B	poorly developed root system; average machinery use
Nutrient inputs into surface and groundwater	C	high demand and often highly fertilized
Pesticide pollution of soils and water	C	high pesticide use due to poor competitive ability; subject to many diseases
Water abstraction	A/B	high water efficiency but often irrigated
Increased fire risk		n/a
Link to farmland biodiversity	C	low weed diversity some shelter in autumn

Note: A means low risk, B means medium risk, C means high risk, n/a means not applicable

4.3.2.2 Key themes

- Interest for bioenergy production may lead to increase of intensive maize production in the potential floodplain area

- Higher amounts of fertilizer use may pollute surface water through nitrate runoff and groundwater through nitrate leaching

- Increased risk of erosion through soil treatment and low soil coverage

- Intensive energy maize production adversely affect terrestrial and aquatic biodiversity

- Adverse impacts on ecological and chemical status of the river-floodplain systems

4.3.2.3 Concepts and goals

In this model it is assumed that intensive maize production will increase within the potential floodplain. Due to nearly same parameters used as in model natural floodplain forest (see chapter 4.3.1), the models can easily be compared to each other.

Table 5: Entities and quantities used in Learning Space 2: Intensive maize production in the potential floodplain

Entity	***Quantities***
Intensive maize production	Amount of
	Fertilization
	Soil treatment
	Nitrate uptake
	Rooting
	Water demand
Soil	Soil compaction
	Water infiltration
	Surface runoff
	Erosion
	Soil coverage
	Nitrate leaching
	Nitrate runoff
	Water retention capacity
	Soil degradation
Groundwater	Groundwater table
	Groundwater contamination
	Water abstraction
River section	Surface water contamination
	Chemical status
	Ecological status
Biodiversity	Amount of flora and fauna

4.3.2.4 Model expression and simulation

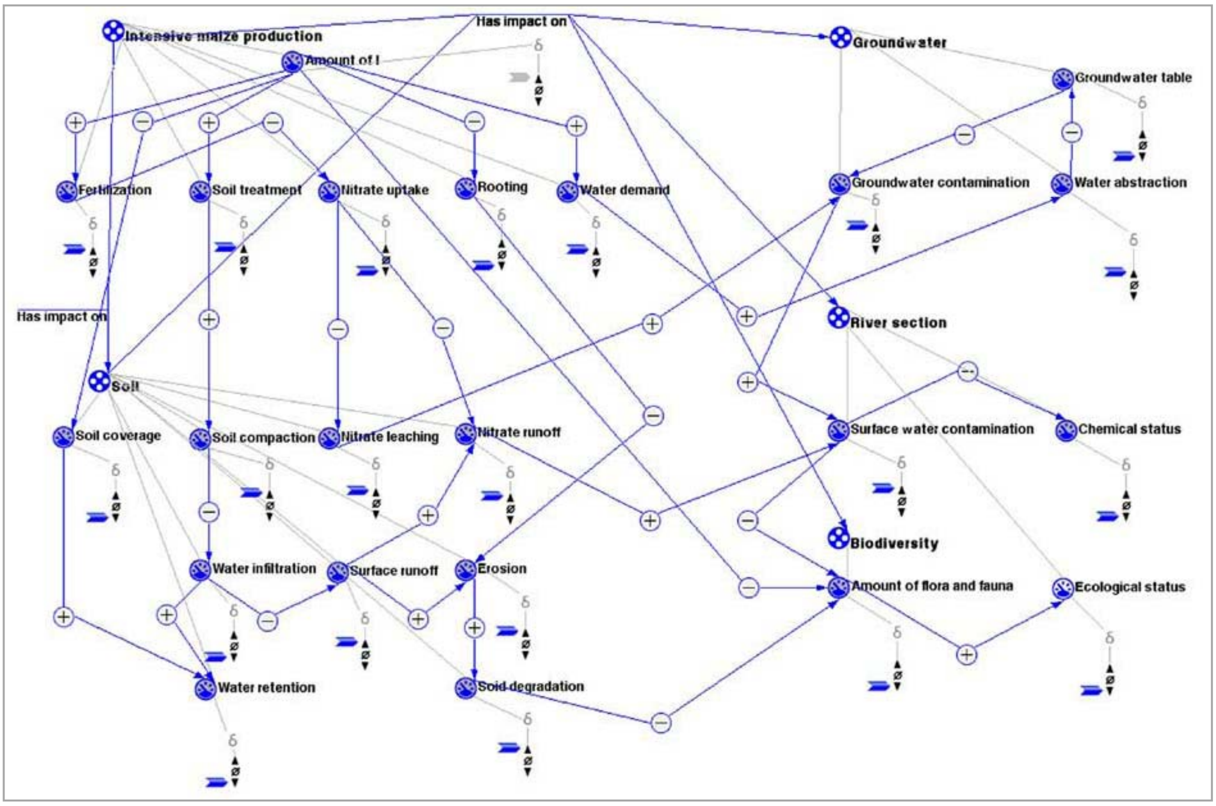


Figure 29: Model expression and simulation in Learning Space 2: Intensive maize production in the potential floodplain

4.3.2.5 Simulation

The simulation shows that an increase of intensive agriculture with maize rotation (grey arrow) leads to severe impacts on the environment, including negative effects on soil properties, biodiversity and water quality compared to a natural floodplain forest. Moreover, the chemical and ecological status of downstream rivers is highly impaired.

4.3.2.6 Improvements and uncertainties

- To show impacts of other farm managements (extensive- or organic farming) and compare them to each other
- To show impacts on evapotranspiration and local climate
- To show carbon fluxes due to soil treatment for maize production
- Due to a variety of processes within soils, the effects are simplified in the model and thus, uncertain to some extent

4.3.3 Modelling impact of short rotation poplar production in the potential floodplain

4.3.3.1 Background

Recently, a rising demand for wood pellet and wood chips increases the cultivation of so called short rotation coppice plantations on potential floodplain areas (Hildebrandt et al., 2010). Partially also natural floodplain forests were replaces by them. The cultivation of short rotation coppice may have severe impacts on its environment, however. These impacts are discussed and modelled in the following.

Perennial crops comprising ligno-cellulosic crops, as for example short rotation coppice from polar and willow and energy grasses, as for example miscanthus and switch grass. Generally, the so-called 2nd generation bioenergies are recognized as being more sustainable than 1st generation bioenergies (EEA, 2008; EC, 2010). Thus, short rotation coppice may be more consistent with the concept of „green“ or „bio“-energy than energy maize production. If they are used as monocultures, they can contribute to more homogeneous landscapes, however (Bielefeldt et al., 2008). There are different rotation durations depending on the production target. For chip production the trees are harvested after 3-5 years, for industrial timber after around 20 years. Frequently planted tree species are poplars (Populus sp.), willows (Salix sp.) and their hybrids, which feature high growth rates (Schubert et al., 2009).

However, the cultivation of short rotation coppice is limited at present. There are a number of reasons for that:

- Lack of knowledge about cultivation
- Farmers have to invest in expensive machineries (Dworak et al., 2009)
- Comparably longer periods of no revenue (in contrast to annual plants) etc.

In 2009, only about 1335 ha were cultivated as short rotation plantations in Austria (Statistik Austria , 2009). Although their cultivation is limited currently, policies to boost more sustainable bioenergy production lead to the assumption that there will be an increase in the near future. A study done by Asamer et al. (2009) compared different rotation durations and evaluated that the highest increments of growth can be achieved in the eastern and southern parts of Austria; with a 3-year rotation in case of the use of fertilizers. However, the ecological consequences have not been studied, yet. Another study undertaken in eastern Germany revealed that best growth conditions are found in valleys, adjacent to rivers e.g. Elbe and Oder. The soils in these areas are mostly floodplain and till soils characterized by good water availability (Lasch et al., 2009).

Perennial cropland shows higher evapotranspiration rates than conventional arable farmland. This may have positive effects on declining nutrient transport, but may have negative impacts in dryer regions (Dworak et al., 2006). In addition, some tree species used for short rotations coppice, have high water requirements; extracting water from depths between two to three meters. Thus, deep-rooted energy crops may lead to sinking groundwater tables (Dworak et al., 2009). Also Hall (2003) says that short rotation poplar plantations have high water demands, leading to potential adverse effects in terms of hydrology and ecology. There are some poplar species, which have less water demand such as aspen, though (Lasch et al., 2009).

On the one hand high risk of water shortage will be mostly during summer in smaller catchments, where plantations are planted densely, because of their smaller water storage potential. Moreover, smaller rivers may dry up sooner and for longer periods than before short rotation coppice were planted. Upstream from floodplains, short rotation coppice would reduce inflow and may threaten these ecosystems during water shortages, as well. On the other hand, the high water demand may be used to reduce peak flows and delay and moderate flooding compared to maize (Hall, 2003). Thus, accurate decisions where to plant short rotation poplar plantations have to be made, so that they can be either used for flood retention to attenuate floods or as buffer zones (see chapter 5.4.1.2).

The risk of nitrate leaching is assumed to be less than on land with maize production or other intensive agriculture (Hall, 2003). Nevertheless, a study done by Asamer et al. (2010) points out that growth rates are higher with the use of fertilizers. At sites rich in nutrients, no fertilization is required. Therefore, short rotation poplars can contribute to reduce nutrients in areas important for water protection (Nitsch et al., 2008). At present there are uncertainties, due to the fact that only few field studies exist about this topic, yet. Nitrate leaching may be considered mainly in the first years of planting, because ground cover is poor and soil organic matter is mineralized. This could also be the case when the plantations are replaced (EEA, 2007). Summing up, impacts of short rotation poplar plantations on the water quality compared to intensive maize production areas are positive (Nitsch et al., 2008).

Beyond that, perennial short rotation poplar plantations require less soil treatment, reducing soil compaction and erosion compared to annual crops (Dworak et al., 2009). Due to their expanded deep rooting system they lower soil compaction (EEA, 2008). Additionally, the increased evapotranspiration rates and improved soil infiltration, which were observed in short rotation poplar plantations, reduce surface runoff and thus decreased erosion, as well (Rowe et al., 2009). For example in New Zealand short rotation poplar plantations have been used in order to reduce bank erosion (Rowe et al., 2009). Thus, improvements of soil functions and of water balance compared to maize production are evident (Nitsch et al., 2008).

The soils of short rotation plantations are recognized as transition forms between arable soils and forest soils. They offer filter and puffer functions for example for nutrients, sediments as well as for the retention of floods (Nitsch et al., 2008). Due to their function as buffer, short rotation coppice plantations can be used for phytoremediation due to their function as buffers. Especially, poplar species are able to accumulate high rates of heavy metals (Bielefeldt et al., 2008). Rowe et al. (2009) even suggested that short rotation poplar plantation could be used as buffer strips alongside watercourses to reduce nitrate inputs into rivers.

A number of studies found out that short rotation poplar plantations contained higher species richness and abundance in comparison to conventional arable farming. However, the frequency of harvesting influences species abundance and composition. This fact highlights the conflict between the management of short rotation poplar plantation for biodiversity and economic profit (Rowe et al., 2009; Schöne et al., 2008). A major influencing criterion for biodiversity is how much area the plantation encompasses. Generally, it is assumed that the bigger and more homogeneous the plantations (> 20 ha), the lower the biodiversity is. Thus, smaller plantations including many different habitat structures show higher biodiversity rates (Bielefeldt et al., 2008). Additionally, the more extensive the plantation is cultivated, the higher the biodiversity is. Compared to natural floodplain forests, the biodiversity is lower, though.

Aspect	**Score**	**Reason**
Erosion	A	Permanent crop, hence good soil cover
Soil compaction	A	Deep rooting, permanent crop
Nutrient inputs into surface and groundwater	A	Significant nutrient demand but good uptake also; low fertilizer use; permanent soil cover
Pesticide pollution of soils and water	A	In later stage very competitive, hence no pesticide use necessary; during the first years, weed competition has to be tackled
Water abstraction	B	High water demand, but no irrigation expected
Increased fire risk	—	Not suitable for arid conditions
Link to farmland biodiversity	A/B	No/low pesticide use; nesting habitat and provides winter shelter; but can have negative impacts on open landscape structures

Note: A means low risk; B means medium risk; C means high risk; — means that the criterion is not relevant.

Table 6: Environmental impacts of short rotation poplar plantations (EEA, 2008)

4.3.3.2 Key themes

- Due to environmental benefits, there may be a shift from 1st generation bioenergies to 2nd generation bioenergies, leading to an increase of short rotation plantations

- Perennial bioenergies serve for better soil properties compared to intensive maize production

- There may be higher water demands with impacts on the hydrological balance

- Low impacts on the chemical status of rivers

- Depending on the farm management and the dimension of plantation there may be impacts on the ecological status of rivers

- May be used in flood retention areas and as buffer strips

4.3.3.3 Concepts and goals

It is assumed that no fertilizers are used within the short rotation poplar plantation and that the farming practice is extensive, which means that there is only little soil treatment.

The model illustrates the environmental impacts of perennial short rotation poplar plantations on floodplains. Due to nearly same parameters used, this model can be easily compared to model “natural floodplain forest“ and to model “intensive maize production“.

Table 7: Entities and quantities used in Learning Space 2: Short rotation poplar production in the potential floodplain

Entity	***Quantities***
Short rotation poplar production	Amount of
	Fertilization
	Soil treatment
	Nitrate fixation
	Rooting
	Water demand
Groundwater	Groundwater table
	Groundwater contamination
	Water abstraction
Soil	Soil compaction
	Water infiltration
	Nitrate leaching
	Nitrate runoff
	Surface runoff
	Erosion
	Soil coverage
	Water retention
	Soil degradation
River section	Surface water contamination
	Chemical and ecological status
Biodiversity	Amount of

4.3.3.4 Model expression and simulation

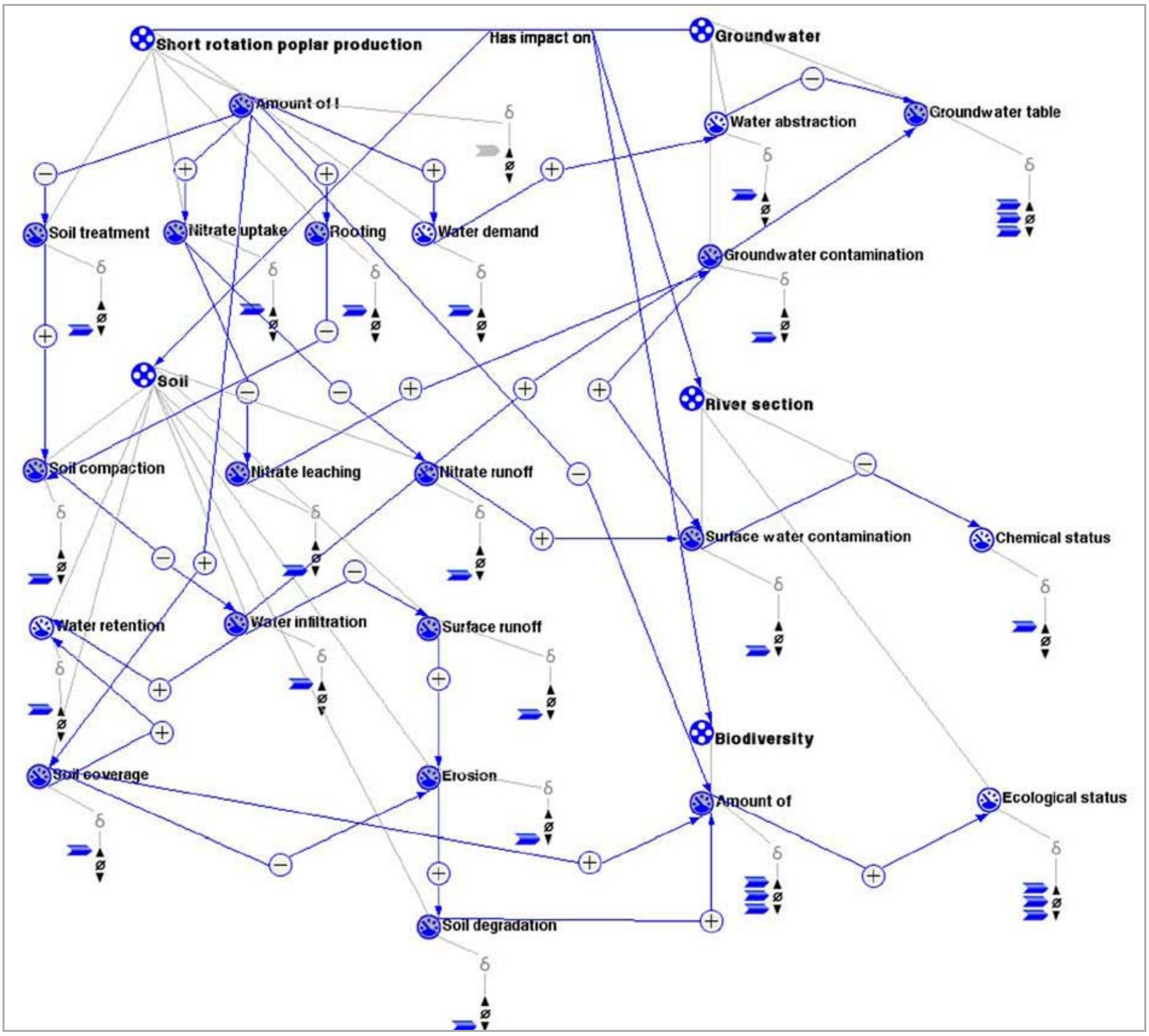


Figure 30: Model expression and simulation in Learning Space 2: Short rotation poplar production in the potential floodplain

4.3.3.5 Scenarios and simulations

Compared to intensive maize production, short rotation poplar production has less negative impacts on the environment. Moreover, there may be positive impacts on the chemical status of rivers. Because of their high water and nutrient retention in the area, they may serve for flood retention and as buffer strips. That should be recognised in finding a compromise between river restoration and bioenergy production. If they are cultivated as monocultures, there may be negative impacts on the ecological status of rivers, though. Depending on the site conditions, there may be positive or negative impacts on the groundwater table, as well. Because of that, the model does not give a general conclusion about the amount of biodiversity, the groundwater table nor the ecological status if poplars are cultivated as short rotation coppice.

4.3.3.6 Improvements and uncertainties

- Compare the model to a model where short rotation plantation is cultivated with the use of fertilizers

- Take into account carbon storage and carbon losses

- It is not known what will happen to biodiversity and the ecological status of rivers, if the amount of short rotation poplars will increase. Because of that, further research has to be done and accurate decisions concerning hydrologically suitable locations have to be taken.

4.4 Modelling land use conflicts between bioenergy production and floodplain restoration (Learning Space 4)

4.4.1 Background

The aim of this model is to have a look on the conflicts between land for bioenergy production and area need for floodplain restoration.

Land allocation for bioenergy production competes directly or indirectly with land use either for food production, or nature conservation, such as floodplain protection (EEA, 2006). If additional cropland is available through the conversion from floodplains, set-aside areas or permanent grasslands, it is called direct land use change. It is called indirect land use change, when agricultural land currently used for food production is diverted to areas for bioenergy cultivation and the newly allocated are for food production displaces conservation land (Searchinger et al., 2008). Consequently, expanded bioenergy production will continue to compete with land for conservation and negatively affect biodiversity (Sala et al., 2009). Moreover, it is assumed that increased bioenergy production in the potential floodplain will hinder restoration of these areas in the future (Müller-Wenk et al., 2003).

First of all, it has to be clarified, which areas could be used for floodplain restoration and which areas are potential areas for bioenergy production.

4.4.1.1 Potential available area for floodplain restoration

Due to land use change in the floodplains, the river-floodplain systems have to be restored in order to achieve the targets of the EU European Water Framework Directive. For restoration, additional area is needed from the potential floodplains, which should retain some integrity or rehabilitation potential (Tockner et al., 2000, Muhar et al., 2008). Further, these areas are often used for agriculture, nowadays (see chapter 2.3.4). Therefore, farmers are important contact persons with respect to restoration measures. Mostly, the willingness to give up their lands for river widening is of course rather small, because farmers depend on the crop yields.

Generally, there are two options to gain area for river restoration in Austria: The potential floodplain, cultivated for agricultural production remains in the property of farmers, or it is bought via the public water property from private land owners. Although they have the right for compensation, the second option is from an economic point of view less advantageous for farmers, because their yearly revenue from the respective area is lost (ÖWAV, 2006). Moreover, farmers are more willing to give up marginal lands for example set-aside areas. But if the areas are suitable for bioenergy production, which generates regular profit, they are less willing to give up their property.

For them it would be more interesting that the area remains in their properties and will be conformed to a more extensive cultivation, which would be also the interest for river restoration. Then, farmers earn profits from their land and they have the chance to receive subsidies by ÖPUL. The ÖPUL measures are depending on the interest of spending money into subsidies for farmers, however after the year 2013 it is not clear how much the subsidies remain, yet. Besides, Habersack et al. (2009) even demands new ÖPUL measures, to secure compatible agricultural land for riparian zones and retention areas.

However, there are not only monetary challenges, but also social ones. The willingness to give up agricultural land depends on cultural and personal values, as well. Personal preferences of farmers play an important role. For example, if farmers have lost property due to floods they are more willing to give up their land for river widening to attenuate floods. Land use conflicts for river restoration always have to be resolved with the participation of farmers and all other stakeholders involved.

4.4.1.2 Potential available area for bioenergy production

Due to limited area available, the area demand for increased bioenergy production can be satisfied with the cultivation of former ecological important areas (set-aside areas, permanent grasslands) from the potential floodplains (Austrian Biomass Association, 2006). Generally, the potential land available for bioenergy production is concentrated in the eastern part of Austria e.g. in Lower and Upper Austria, Styria and Burgenland (Kranzl et al., 2008). In Natura 2000 areas, the share of set-aside areas and grasslands is very high (Osterburg et al., 2009). However due to changed regulations set-aside areas are decreasing dramatically (see chapter 4.1).

Figure 31 shows the correlation between subsidized bioenergy production and the amount of set-aside areas (in ha) from 1995 to 2009. It illustrates a steady increase of bioenergy production areas of about 5000 ha in 2004 to 25 000 in 2009 and correlated decrease of set-aside areas (AMA, 2010).

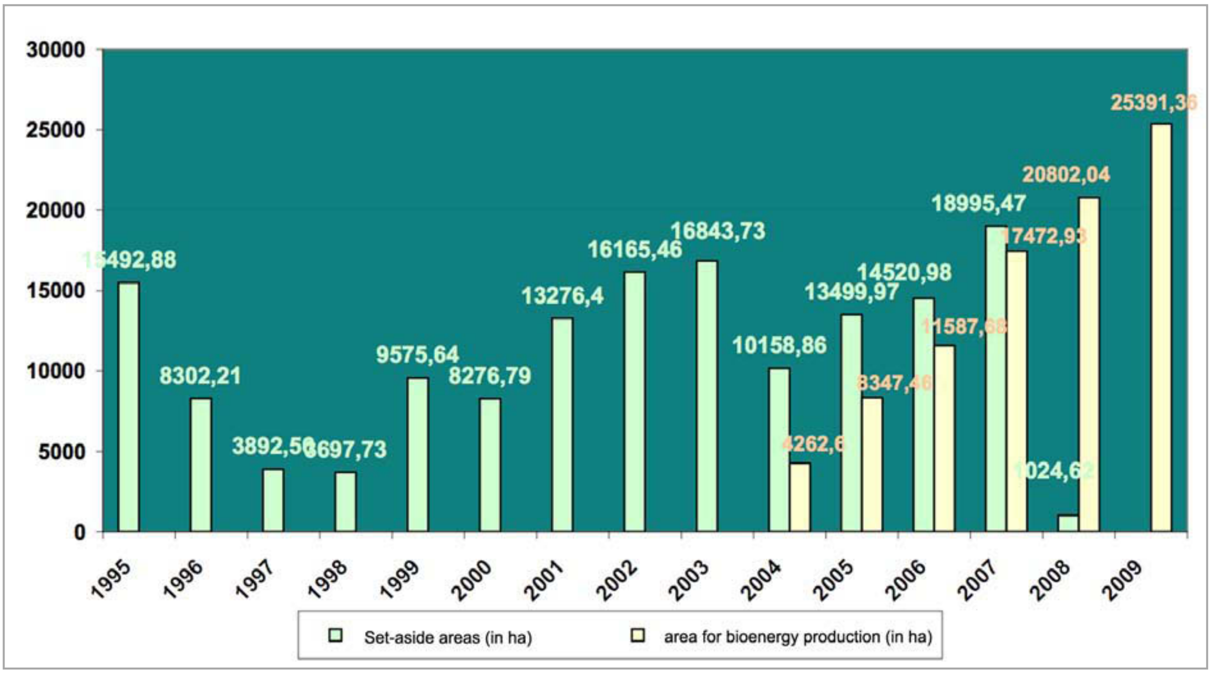


Figure 31: Use of set-aside areas and bioenergy production areas in 2009 (in ha) (AMA, 2010)

4.4.2 Concepts and goals

The model represents conflict between increasing area demands for bioenergy production on the one hand and increasing area demand for floodplain restoration on the other hand.

It illustrates that there is limited area available for both, river-floodplain restoration and bioenergy production. Increase in area for the production of bioenergy limits restoration potential and vice versa. Therefore, it should trigger thinking about the sustainable use of land, so that areas are available for river dynamics in the future. Alternatives should be found to enable sustainable bioenergy production, as well as the restoration of river-floodplain systems.

Table 8: Entities and quantities used in Learning Space 4

Entity	***Quantities***	***QS***	***Remarks***
Agriculture	Area demand for bioenergy production	*Zp*	Zero, plus
Potential floodplain	Area used for bioenergy production	*Zlahm*	Zero, low average, high, max
	Available area for restoration	*Zlahm*	Zero, low, average, high, max
River	Potential ecological status	*Bpmgh*	Bad, poor moderate, good, high
Restoration management	Restoration need	*Zp*	Zero, plus

4.4.3 Model expression

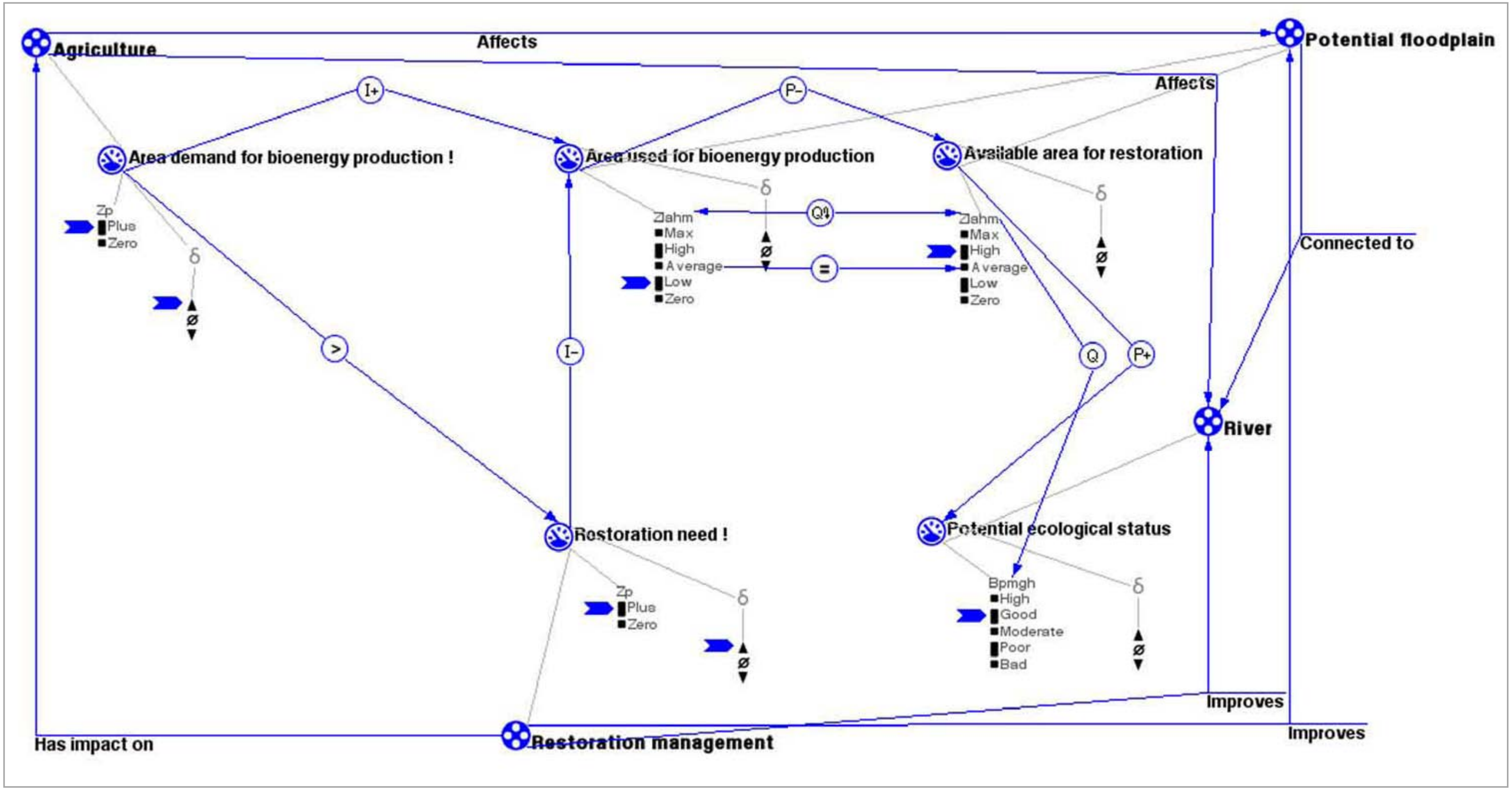


Figure 32: Model expression Learning Space 4: Land use conflicts for bioenergy production and floodplain restoration

4.4.4 Scenarios and simulation

In the scenario, the area demand for bioenergy production, as well as the restoration need is increasing. If the area demand for bioenergy production is higher than the restoration need, more area is used for bioenergy production, resulting in less area available for restoration. As a consequence of this, the potential ecological status of rivers will decrease.

However, in another scenario, if the restoration need is higher than the area demand for bioenergy production, the area available for restoration is higher. In this case, the potential ecological status will not be affected.

Figure 33: State graph in Learning Space 4: Land use conflicts for bioenergy production and floodplain restoration

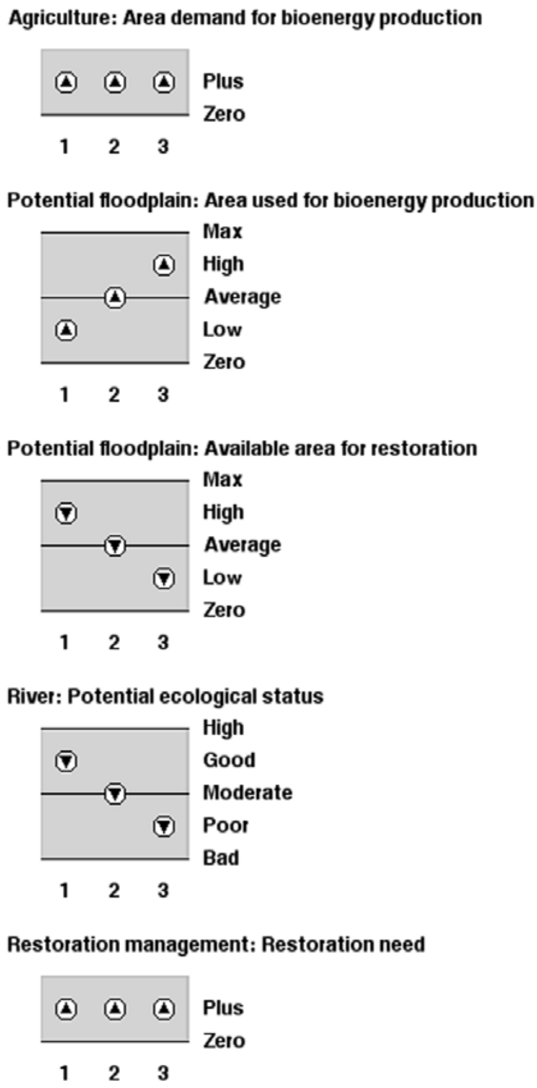


Figure 34: Value history in Learning Space4: Land use conflicts for bioenergy production and floodplain restoration

4.4.5 Impacts and uncertainties not assumed in modelling

- The market price of land and the yearly yield of the area play an important role in the willingness to give up land for river restoration. These facts should be included in a sophisticated model.

- Also social factors (e.g. the willingness to give up land by farmers) may be included in following models.

- Other factors leading to conflict of area are population growth, settlement, soil sealing, changes in diet, degradation and salinisation of current cultivated land

4.5 Modelling synergies between bioenergy production and floodplain dynamics (Learning Space 6)

4.5.1 Background

Based on the environmental effects of bioenergies on river-floodplain systems (see chapter 4.2) and on land use conflict between bioenergy production and floodplain restoration (see chapter 4.4) discussed before, this chapter wants to find out alternatives for conventional bioenergy production. Bioenergy production not only involves risks to river ecosystems but also serves opportunities for more sustainable land use. It should be an ambition that synergies between bioenergy and river dynamics should be promoted, whereas risks should be prevented.

4.5.1.1 Use of energy crops on buffer strips and for flood retention

Flood retention areas

Compared to other land uses, active floodplain forests have high water retention capacities within the area. During floods, floodplain forests contribute to reduce flow velocities and peak discharge is reduced. Furthermore, due to natural aggradation and erosion processes, the natural dynamics within the river-floodplain system are maintained. Because floodplains and with it flood retention areas have been diminished due to human engineering measures, the severity of floods has been increased due to missing river dynamics and flood retention areas (Habersack et al., 2009). Especially in the last decade the higher risks and damages of floods have been noticed. However, achieving good ecological status of rivers requires to re-initiate river dynamics.

There are several measures for passive flood control. The study FLOODRISK II, recommended to establish buffer strips and restoring flood retention areas along rivers for passive flood control. Establishing flood retention areas is reasonable in areas without settlement or industry. Particularly, agricultural areas are appropriate for flood retention (Habersack et al., 2009).

Buffer zones

Between agricultural area and river, buffer strips are effective zones to reduce nutrient inputs into rivers and thus, improve water quality. Generally, buffer strips help to:

- Reduce nutrient inputs, thus improve water quality
- Help to prevent erosion
- Regulate water temperature by its canopy

- Increase landscape diversity
- Enhance biodiversity in agricultural area
- Improve ecosystem network

Research has also shown, that the effectiveness of such strips is strongly dependent on the slope, their width, the type of plants and the type of pollution (Dworak et al., 2009).

Farmers often resisted establishing buffer strips, because they lose their yields. Thus, compensation measures, such as ÖPUL measures promote buffer strips since the new period for the first time. France has even made buffer strips obligatory. They have to have a share of 3 % buffer strips of their total agricultural area (Dworak et al., 2008). Fortunately, it is expected that in the year 2012, buffer strips will become mandatory under cross compliance regulations along all water course adjacent to agricultural areas in Europe (Dworak et al., 2009).

Besides, there are uncertainties in literature about the optimal width of buffer strips to attenuate nutrients and sediments. However, there is no doubt, that buffer zones add considerable value to restoration of river-floodplain systems (Hughes et al., 2003). Moreover, in an environmental perspective, establishing buffer strips will become even more important, if set-aside areas will be cultivated for bioenergy production.

4.5.1.2 Vegetation on flood retention areas and buffer zones

Vegetation has an enormous impact on discharge of rivers, which reduces flow velocity and increases the water table. The broader and denser the riparian vegetation is, the greater this effect will be (Habersack et al., 2005). Other important characteristics of vegetation are, that it protects soils from erosion and it boosts sedimentation of wash load (Habersack et al., 2009).

Different vegetation types have different impact on floods. The riparian vegetation can lead to reduced discharge rates and increase water tables. The most important parameters in this context are the width and density of the surrounding vegetation. The broader and denser the vegetation, the more water will be impounded and the higher the water table will be (Habersack et al., 2008).

There is the possibility, that buffer strips and flood retention areas can be cultivated with bioenergy crops. Benefits are, that farmers obtain income from bioenergies grown on buffer strips or flood retention areas. Thus, they would not suffer from yield losses. Further, compensation measures would become dispensable. Land use change and land use conflicts would become minor, as well. Hence, an important win-win situation could be created between agricultural bioenergy production and river restoration.

Maize production

In areas with increased risk of flood, yield losses may occur more frequent. Especially, if annual crops are planted, yield losses may be high and the flood event may be more severe (Wagner et al., 2008). Areas where maize is produced intensively, nutrients are added in ground- and surface waters and these areas have lower water retention capacities, as discussed in chapter 4.3.2. Thus, the cultivation of maize crops would not be suitable on buffer strips nor on flood retention areas.

Short rotation poplar plantation

As shown in chapter 4.3.3 short rotation poplar plantations can improve water quality by attenuating nutrients. Further, they serve for water retention in the area. A few studies consider, that short rotation plantations are dedicated for flood retention because perennial bioenergy crops, such as perennial short rotation poplar plantations would add important properties as buffers and for flood retention (Dworak, 2007; Nitsch et al, 2008; EEA, 2008). Moreover, they can be planted as buffer strips between the intensively cultivated agricultural area and the floodplain forest or river (Baaske et al., 2007). Planting perennial short rotation plantations may reduce yield losses, because they can withstand floods better than annual crops as for example maize crops (Baaske et al., 2007).

Higher water demands by poplars or other tree species require accurate decision about the design and the cultivation of buffer strips, though. It is important that characteristics of site conditions and the catchment of the river have to be included in decision-making (Hughes et al., 2003). It is well known, that short rotation poplar plantations have higher water demand than annual crops due to higher growth rates, higher transpiration rates, longer seasonal growth and increased rooting depth. A field study of the UK (Rowe et al., 2009) concluded, that transpiration rates in short rotation poplar plantations are higher than annual crops. Planting riparian strips of short rotation poplar plantations will have little effect on most rivers. However, in small streams, headwater streams and areas upstream from wetlands the effects can be higher. Thus, it is better to avoid planting in such areas. Then again, the high water demand can be taken as an advantage in flood management, helping to reduce risk of flooding (Rowe et al., 2009).

Some scientists recommend caution, so that short rotation plantations must not replace actual floodplains or other ecological important areas in any case (Nitsch et al., 2008; Baaske et al., 2007). Furthermore, the characteristics of tree species and site conditions have to be considered before planting (Dworak et al., 2008). In some cases woody trees have disadvantages established in riparian zones. If so, weeds as for example Miscanthus sinensis may be preferred. Thus, Miscanthus sinensis offers great potential for future bioenergy production (BMLFUW, 2010; Scheurlen, 2008).

4.5.1.3 Use of biomass residues from landscaping

The use of all sorts of biomass residues from landscaping for bioenergy production can be an appropriate solution to overcome land use conflicts. Several sources are availabe:

- Use of cuttings from buffer strips adjacent to rivers

Till 2012, buffer strips have to be established along all watercourses in intensively used agricultural areas (see chapter 4.5.1.1). The planted vegetation has to be mowed regularly; the gained material can be used for bioenergy production, as well. For this purpose, particularly Miscanthus sinensis is being suggested, mainly because of its habitat requirements (BMLFUW, 2010). Short rotation coppice for example poplar, but also willow would be appropriate, too.

- Use of neophytes

For example Japanese knotweed, *(Fallopia japonica)* or Himalayan balsam *(Impatiens glandulifera)*, which have the potential to replace native vegetation prefer riparian zones. Generally, they should be cut 4-5 times a year to weaken its stock. Another invasive neophyt Robinia *(Robinia pseudoacacia)* has to be cut regularly, as well. However, further management actions have to be taken to hinder vegetative multiplication (ÖGG, 2010).

- Cuttings of hedges and shrubs

Hedges or shrubs have to be cut regularly to hinder afforestation.

- Grassland cuttings

Grasslands are characterized by high water retention capacities during floods. Thereby, water retention is possible without major damages. Grassland cuttings can be used as a bioenergy source, too. The natural vegetation of ecological important areas (set-aside areas, permanent grasslands), which have to be mowed regularly (about 2 times a year) to maintain proper management of extensive farmland can be used for bioenergy production. In this way these areas are cultivated in a sustainable way (Hildebrandt, 2010). Last but not least the use of grassland cuttings for bioenergy production can provide economic benefit to farmers (EEA, 2006).

The use of natural vegetation compared to „real bioenergies“ has enormous advantages: They are habitats for many animal species, are an important food source, provide canopy and contribute to biodiversity (Hildebrandt, 2010). Moreover, additional bioenergy can be generated. Land use change, conflicts of land and adverse impacts on floodplain-river system can be prevented. Summing up, the use of natural vegetation from landscaping meets practical synergies between bioenergy production and floodplain restoration.

4.5.2 Concepts and goals

The general target of this model is to evaluate synergies between bioenergy production and floodplain dynamics. The model scenarios help to compare different sources for bioenergy production, to reduce environmental risks (loss of biodiversity, loss of flood retention area, loss of river dynamics) and to achieve good ecological status of rivers. Further, this model should be a decision support on, which bioenergy sources to choose in the potential floodplain, so that flood retention is maintained and the river has space for its natural dynamics.

4.5.3 Model expression

Table 9: Entities and quantities in Learning Space 6

Entity	*Quantities*	*QS*	*Remarks*
Bioenergy production	Area demand	*Zp*	Zero, plus
	Area used for bioenergy production	*Zlah*	Zero, low average, high
Potential floodplain	Available area for restoration	*Zlah*	Zero, low, average, high
	Area for flood retention	*Zlah*	Zero, low, average, high
	Water retention within the area	*Zlah*	Zero, low, average, high
	Temporal usage of naturally growing floodplain vegetation	*Zlah*	Zero, low, average, high
	Amount of Miscanthus	*Zlah*	Zero, low, average, high
	Amount of poplars	*Zlah*	Zero, low, average, high
	Amount of maize	*Zlah*	Zero, low, average, high
River	Potential ecological status	*Bpmgh*	Bad, poor, moderate, good, high
	River dynamics	*Zlah*	Zero, low, average, high

Library of model fragments

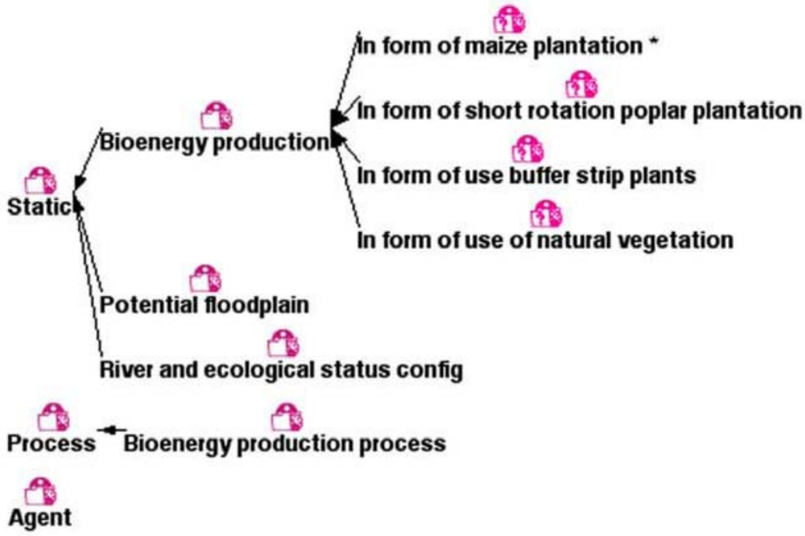


Figure 35: Library of model fragments in Learning Space 6: Synergies between bioenergy production and floodplain restoration

4.5.4 Scenario Bioenergy production with maize not to be flooded

Static model fragment potential floodplain

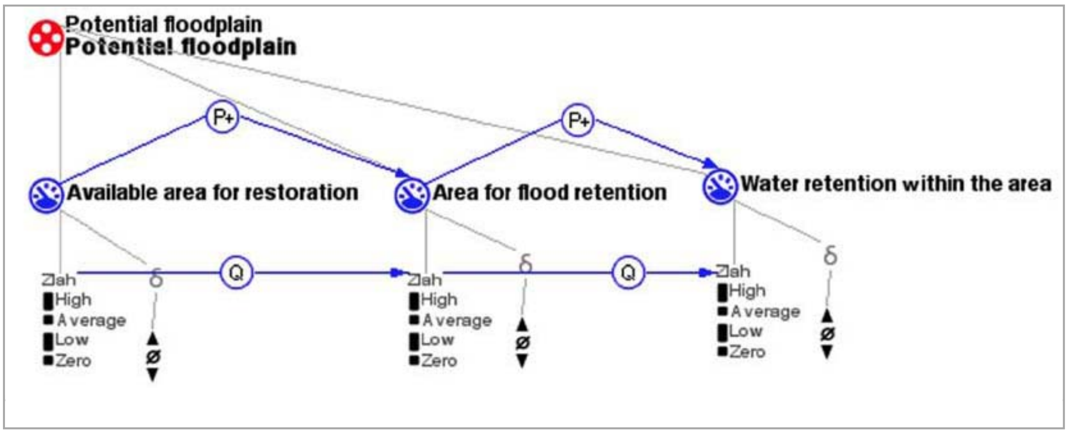


Figure 36: Static model fragment in Learning Space 6: Potential floodplain

Static model fragment river

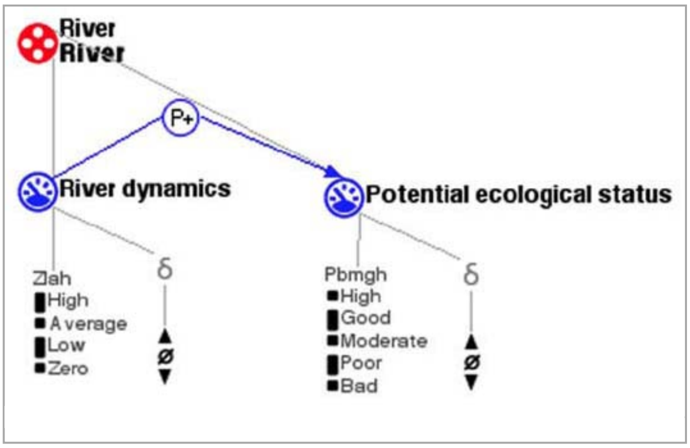


Figure 37: Static model fragment in Learning Space 6: River

Process fragment bioenergy production

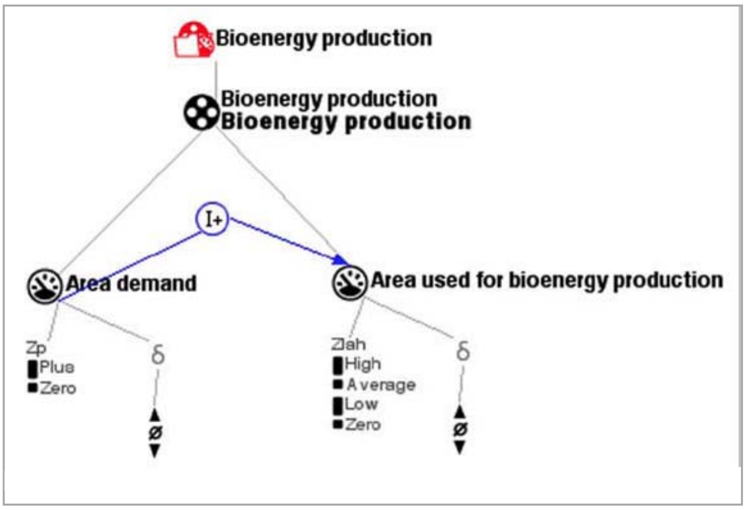


Figure 38: Process fragment in Learning Space 6: Bioenergy production

Assumptions

In the scenario bioenergy with maize not to be flooded it is assumed, that increased area demand for bioenergy production requires more area to be cultivated with energy maize. Further, a dam has to be built to prevent area from flooding.

Model fragment maize

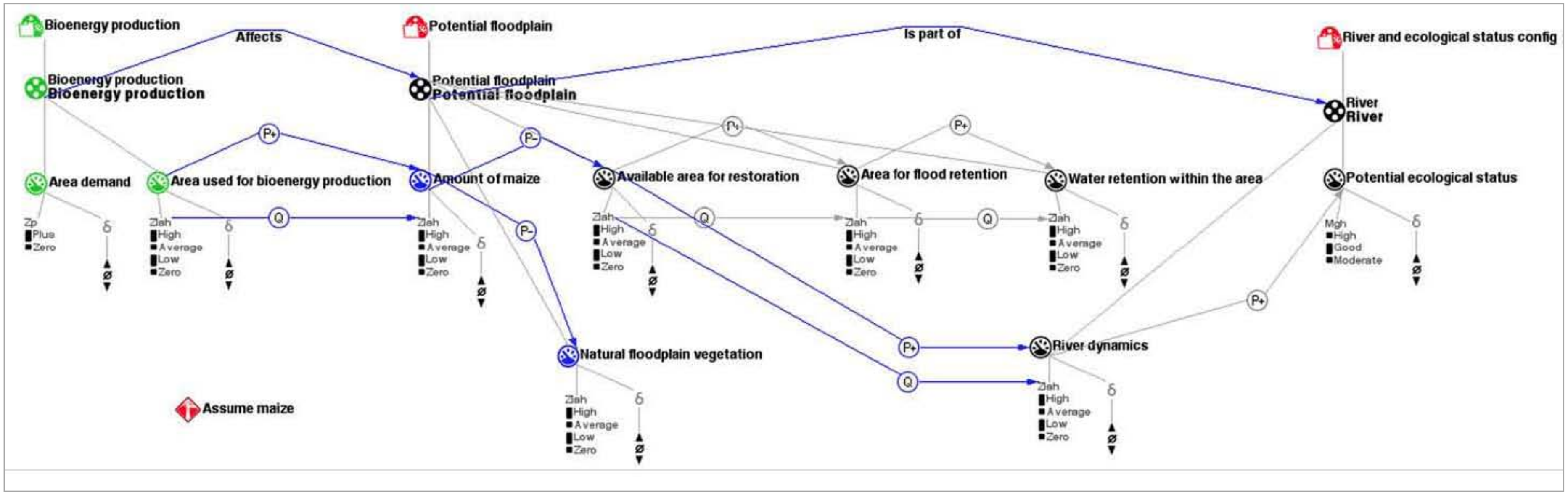


Figure 39: Model fragment in Learning Space 6: Maize

Scenario expression maize not to be flooded

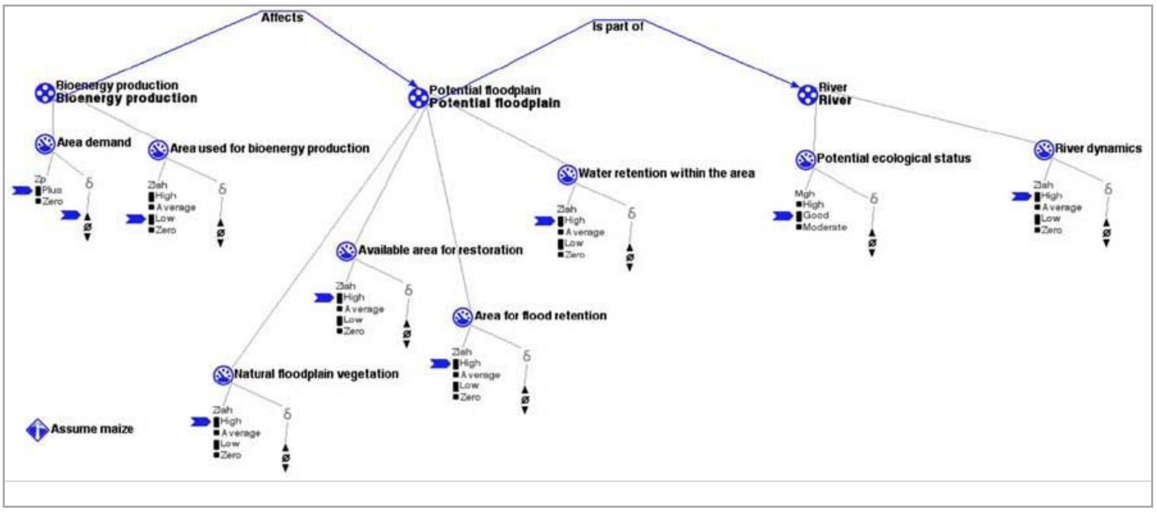


Figure 40: Scenario expression in Learning Space 6: Maize not to be flooded

Scenarios and simulations

The simulation yields 4 states. Area demand increases the area used for bioenergy production and concurrently increases the amount of maize produced. In this case, the available area for restoration constantly decreases. Within areas for maize production, flood retention is reduced and thus, water retention within the area decreases, as well. If no area is available for river restoration, any river dynamics are disabled causing the potential ecological status of the adjacent river to decrease.

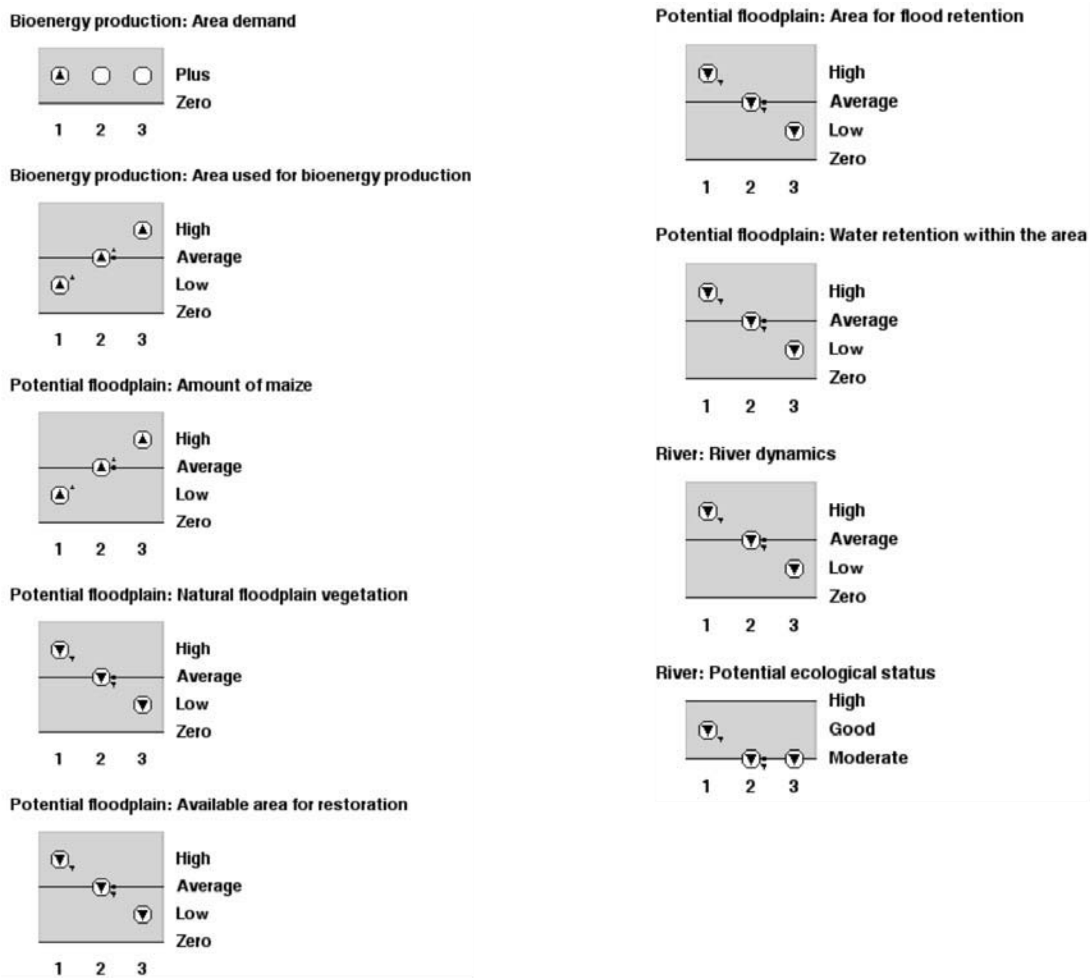


Figure 41: State path in Learning Space 6: Maize not to be flooded

Figure 42: Value history in Learning Space 6: Maize not to be flooded

4.5.5 Scenario cultivation of short rotation poplar plantation without dam

Assumptions

In this scenario, it is assumed that instead of maize, poplars are cultivated for bioenergy production. Due to the fact, that poplars can withstand floods, no dam between the river and the agricultural area is needed.

Model fragment short rotation poplar plantation

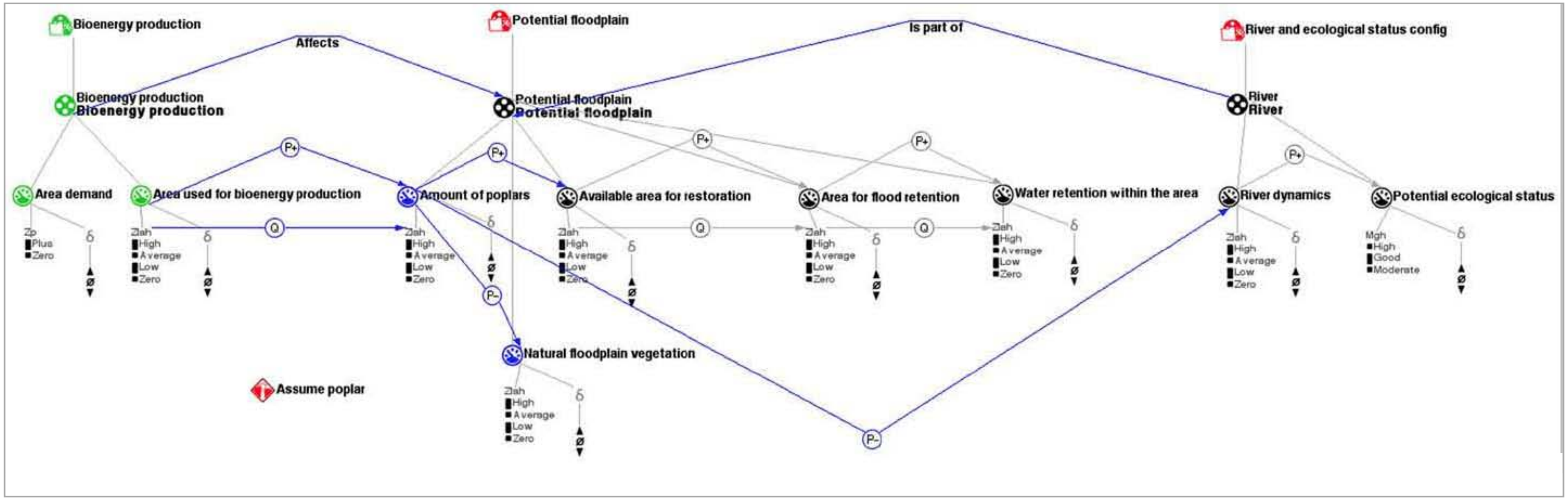


Figure 43: Model fragment in Learning Space 6: Short rotation poplar plantation

Scenario expression cultivation of short rotation poplar plantation without dam

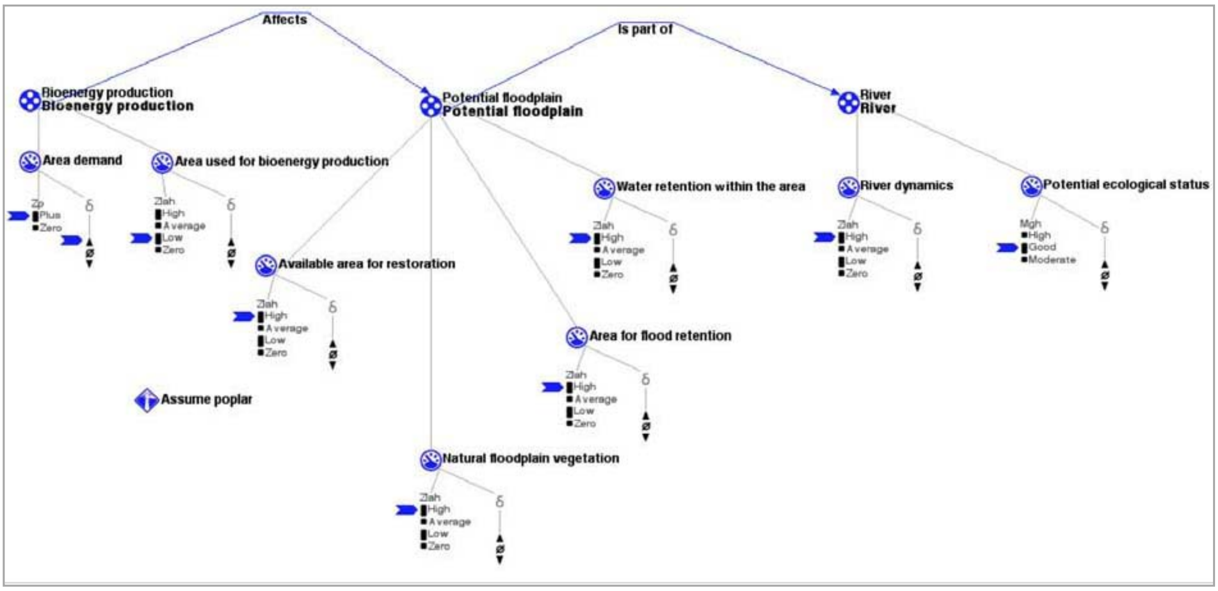


Figure 44: Scenario expression in Learning Space 6: Short rotation poplar plantation

Scenarios and simulation

In this scenario, bioenergy is produced with short rotation poplar plantations. Benefits are, that no dam has to be built and water retention is maintained within the area. Thus, the total area is sustained for any restoration management. Furthermore, flood retention is high in any state. River dynamics are inhibited as long as poplars are produced in the area and the natural floodplain vegetation decreases, however. That is why the potential ecological status decreases.

Figure 45: State graph in Learning Space 6: Short rotation poplar production

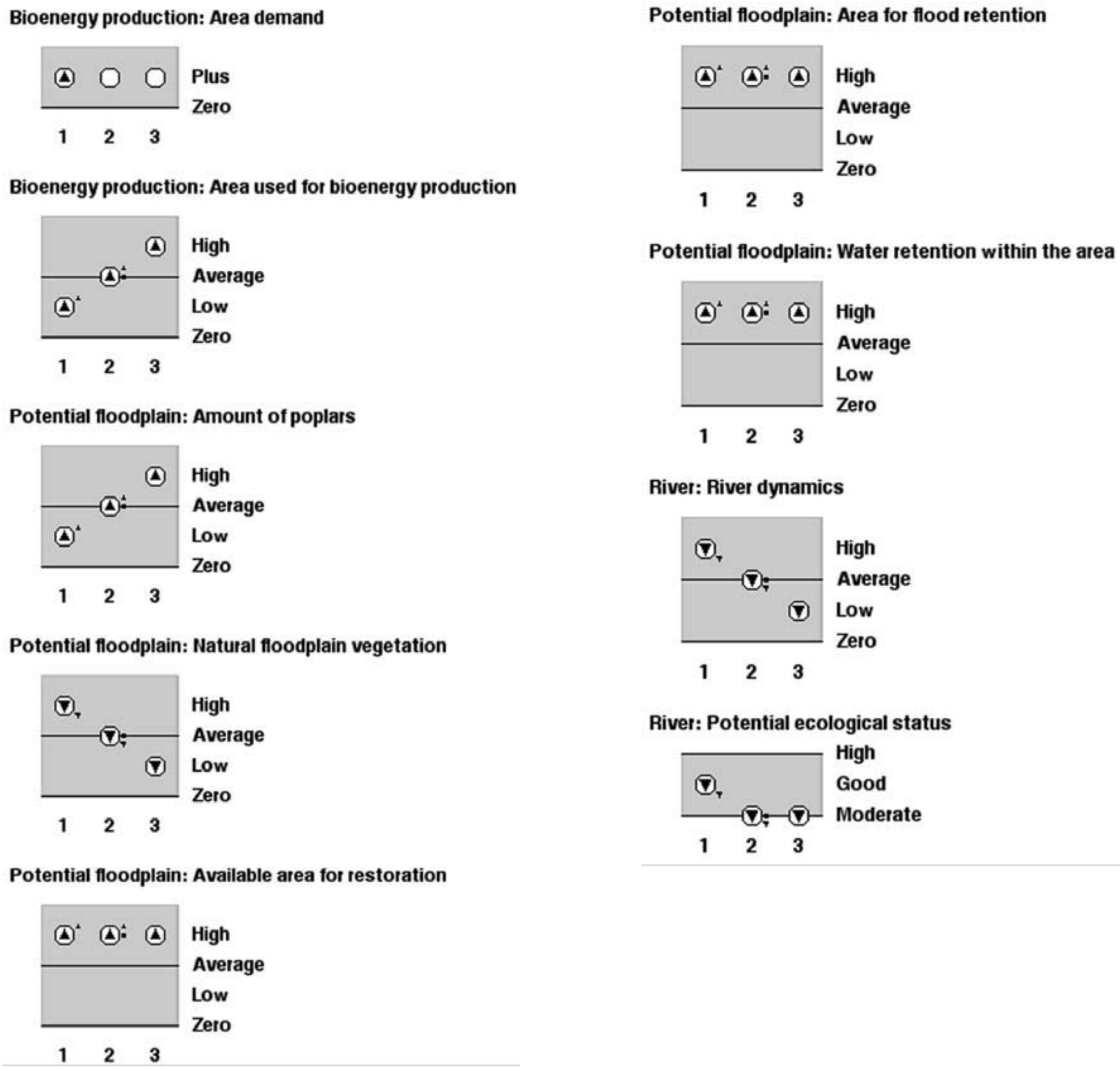


Figure 46: Value history in Learning Space 6: Short rotation poplar plantation

4.5.6 Scenario production of bioenergy on buffer strips

Assumptions

Bioenergy can be produced from vegetation for example, Miscanthus grown on buffer strips, which have to be established by 2012 along all watercourses.

Model fragment production of bioenergy on buffer strips

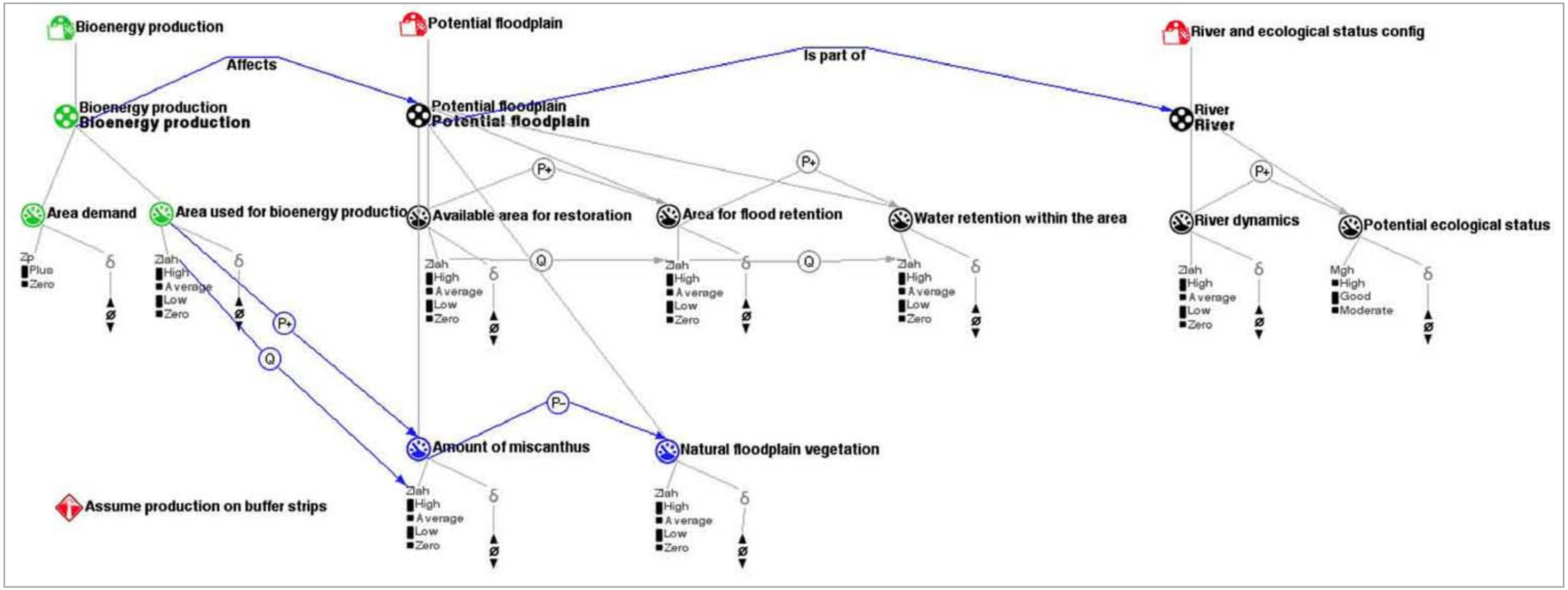


Figure 47: Model fragment in Learning Space 6: Production of bioenergy on buffer strips

4.5.6.1 Scenario expression production of bioenergy on buffer strips

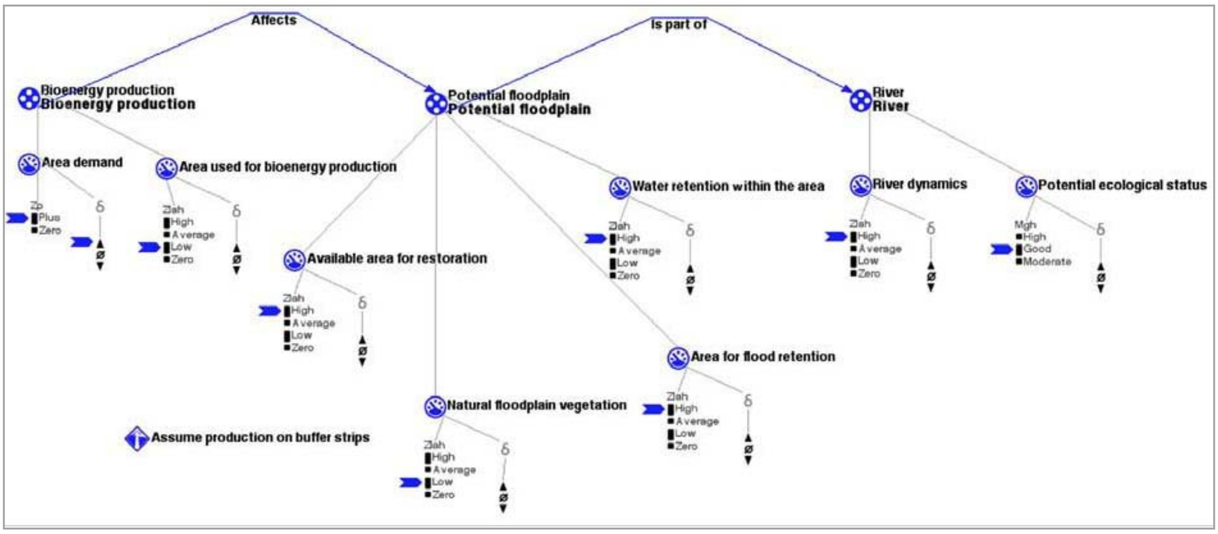


Figure 48: Scenario expression in Learning Space 6: Production of bioenergy on buffer strips

Scenarios and simulation

The scenario energy production from buffer strips yields three states. More buffer strips are cultivated for bioenergy production. Thus, the amount of Miscanthus grown adjacent to rivers increase and the available area for restoration is sustained in all states. Water retention, and thus area for flood retention is maintained, as well. The more buffer strips are cultivated with Miscanthus, the more space the river has for its dynamics and the potential ecological status of the river reaches is good.

Figure 49: State graph in Learning Space 6: Production of bioenergy on buffer strips

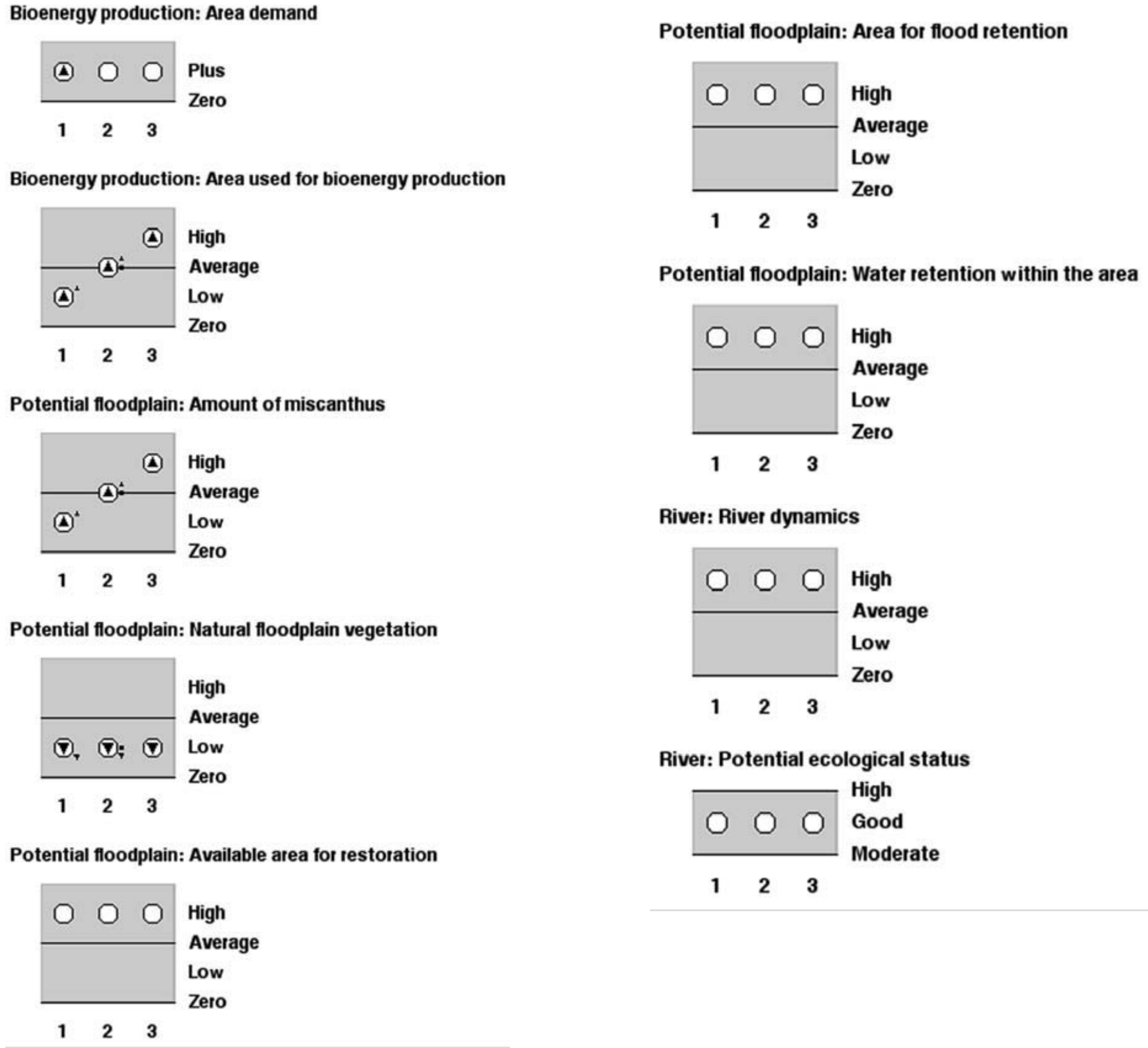


Figure 50: Value history in Learning Space 6: Production of bioenergy on buffer strips

4.5.7 Scenario bioenergy production with use of natural vegetation

Assumptions

In this scenario it is assumed, that cuttings from landscaping, including all kinds of natural growing vegetation from within the potential floodplain can be used for bioenergy production. Further, it is assumed that no other areas are used for bioenergy production.

Model fragment use of natural growing vegetation

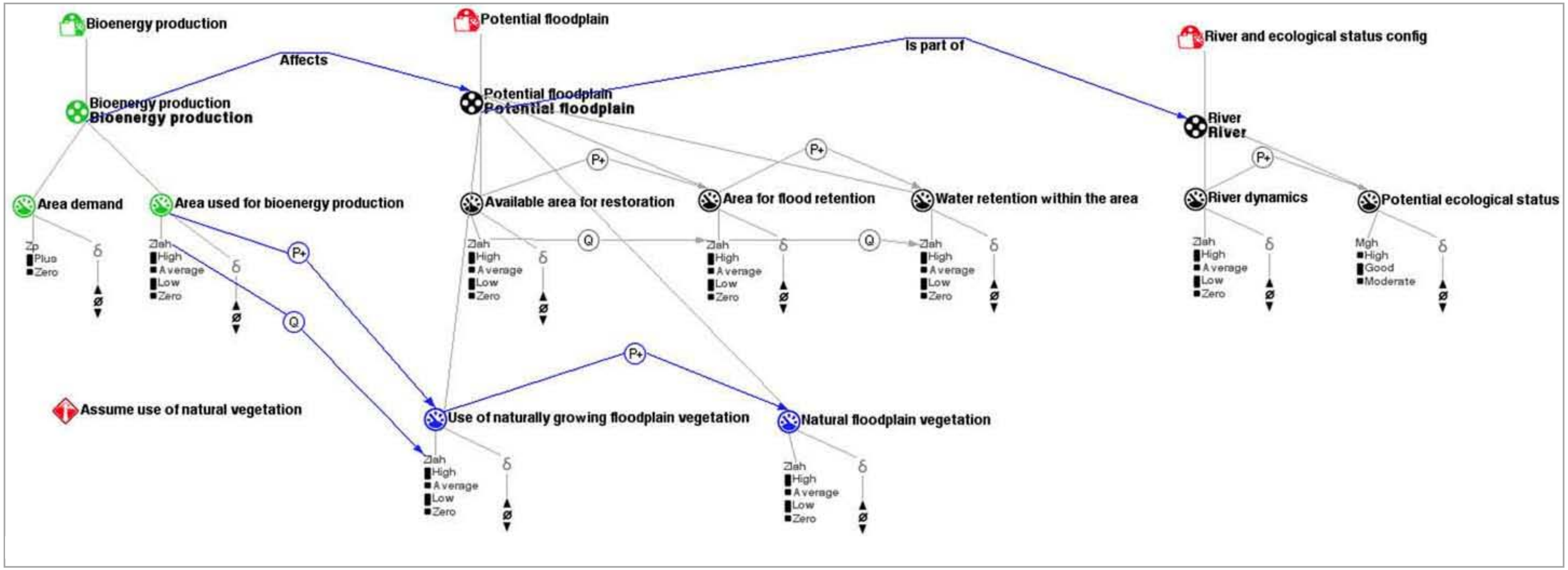


Figure 51: Model fragment in Learning Space 6: Bioenergy production with use of natural vegetation

4.5.7.1 Scenario expression use of natural vegetation

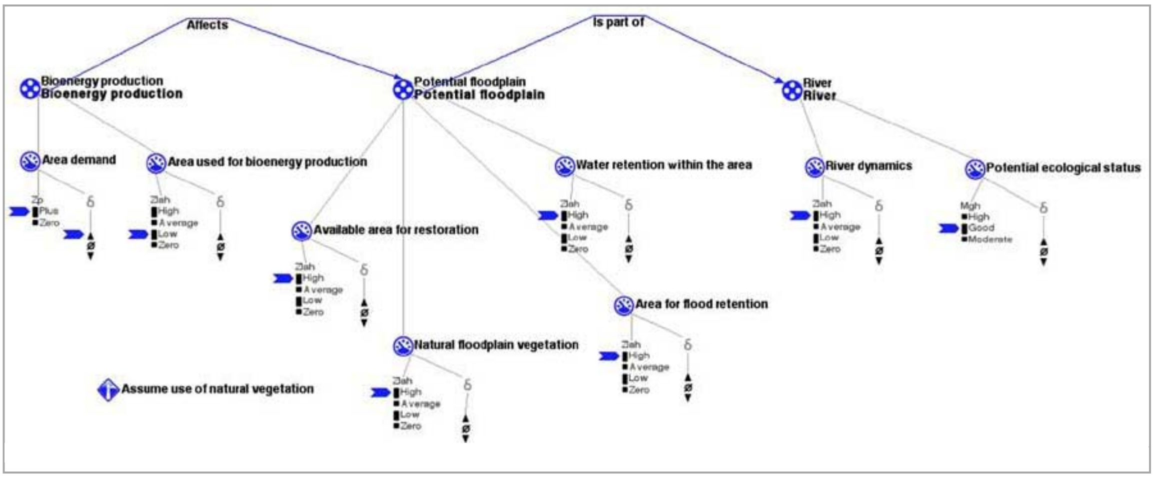


Figure 52: Scenario expression in Learning Space 6: Bioenergy production with use of natural vegetation

Scenarios and simulation

The simulation yields 3 states. If area demand increases, the use of naturally growing floodplain vegetation increases likewise. By reason, no additional area for the production of bioenergy is needed; the available area for restoration remains high. With it, also water retention respectively flood retention area as well as river dynamics are maintained and the ecological status of river is in a good condition.

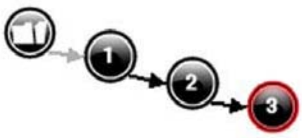


Figure 53: State graph in Learning Space 6: Bioenergy production with use of natural vegetation

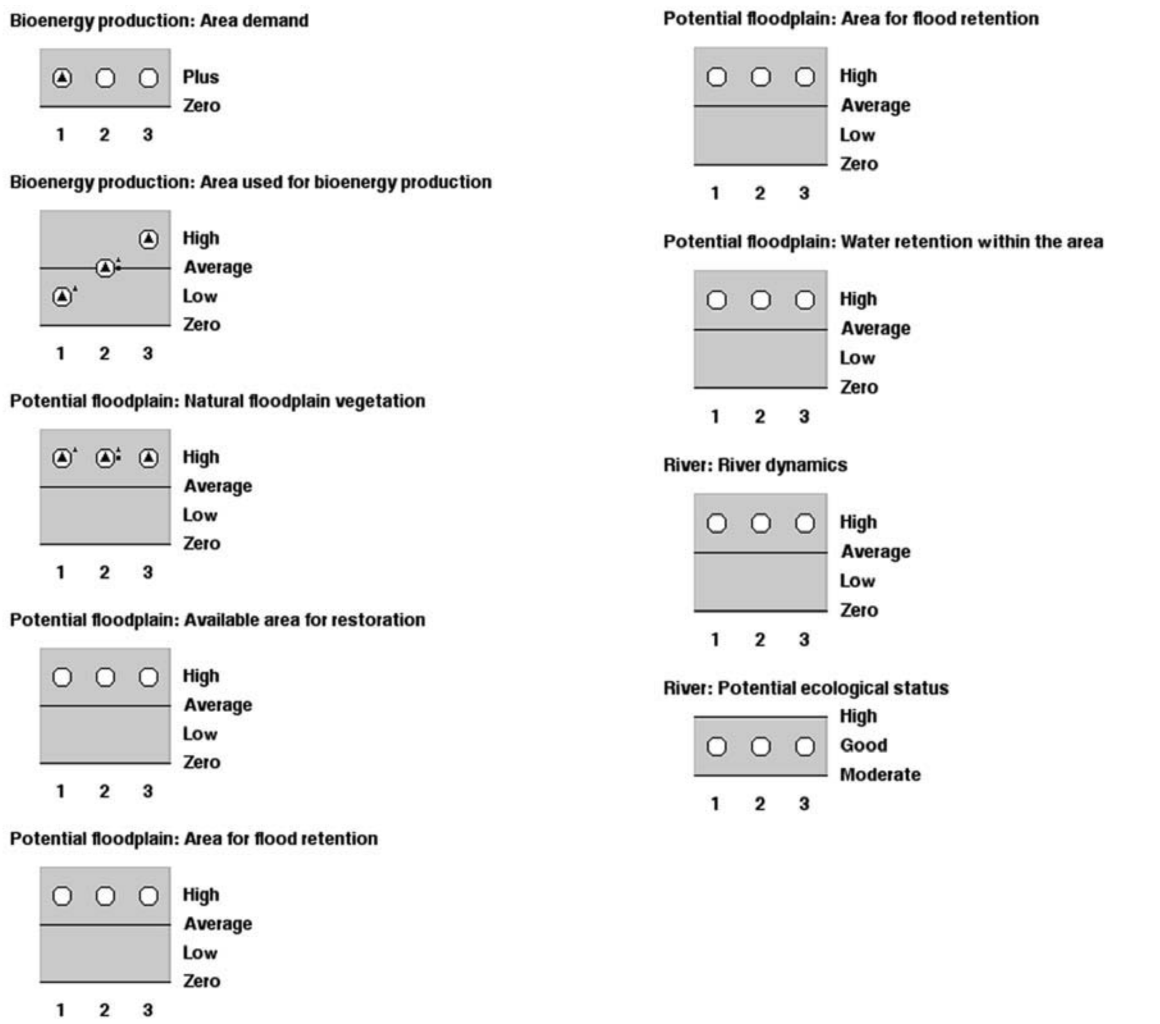


Figure 54: Value history in Learning Space 6: Bioenergy production with use of natural vegetation

4.5.8 Improvements and uncertainties

- Include further environmental impact of energy plants on the ecological status of rivers
- Include impacts of management practice (extensive or intensive cultivation)
- Include age of the vegetation and its planting density
- In practice not only one crop is cultivated, moreover, several different energy plants are cultivated at the same time (e.g. short rotation coppice and maize or additional use of vegetation from landscaping)

5 Discussion

5.1 DynaLearn Software Discussion

5.1.1 Discussion of models applied

Learning Space 1 gives an introduction into the most important effects of bioenergy production in the potential floodplain. Generally, it serves as an important overview of the topic, and the main parameters are included. However, the graphic layout restricts the size of the model and many parameters make the model too complex and learners get distracted from the main processes. Thus, a balance between model information and model complexity has to be found.

In building simple causal models, Learning Space 2 enables the description of certain processes in a basic way and so contributes to clear understanding. However, selected processes often constrain each other and often causing ambiguity. Such results can be very instructive from a learning point of view, whereas the visual feedback is limited.

In Learning Space 4-6, generic causal models can be built which includes a high amount of details. Learning Space 4 provides instrument to display more realistic processes with the opportunity to implement rates (see model “Land use conflicts for bioenergy production and floodplain restoration”; chapter 4.4). In terms of modelling design (see model “Land use change induced by EU policy goals”; chapter 4.1) Learning Space 4 was not appropriate, because a non-linear process concerning „if-then“ relations of parameters should be displayed. Therefore, it was necessary to switch to Learning Space 5.

Learning Space 5 enables builders to specify causal relations.

Learning Space 6 offers the greatest potential to build real-world causal relations. It not only offers the possibility to build hierarchical models and offers the highest amount of features but also allows the presentation of versatile scenarios and simulations in a model. The generic and reusable knowledge model enables the user to build a large library of model fragments and thus, very complex scenarios can be presented.

Some of the models created in this thesis may be too specific for their application in schools. Others may serve as a generic introduction to the topic (e.g. Learning Space 1). Some have also the potential to serve as an important manual for stakeholder information (Learning Space 4 and Learning Space 5), and some may even serve as an important support to information and in decision making during proceedings with different stakeholders (Learning Space 5 and Learning Space 6).

The models of this thesis are developed with focus on a sustainable aquatic management. In this regard it is obvious that experts in agriculture or renewable energies may come up with completely different models as they are presented in this thesis. It would be a further challenging task to study how models change if they are given to other experts or stakeholders, who change entities and quantities or expand models from their own point of view.

Preparing the models on different Learning Spaces was an interesting task, and required detailed understanding of single parameters to select and represent the content in the Learning Spaces. Identifying the most important parameters worth being represented for system understanding is one of the most important and challenging tasks in modelling, however.

For beginners, Learning Space 1-4 enable quick understanding of the DynaLearn software and modelling progress and progress in learning is fast. However, Learning Spaces 5-6 require in-depth knowledge of the software and as such slower progress in learning is presumable. Hence, each of the Learning Spaces contributes to understanding of complex causal relations between bioenergy productions in potential floodplains in different aspects.

5.1.2 DynaLearn compared to other model applications

Former modelling environments concentrated on mathematical models and derived numerical results. However, such programs have failed to capture crucial aspects of modelling, to capture conditions under which a model is applicable and as such they are relatively inaccessible to younger learners. Other scientist groups have developed similar model building environments to the DynaLearn software, the VModel and the Homer/VisiGarp and Betty´s Brain. Likewise, these software programs support learners by constructing conceptual models of systems and their behaviour using qualitative reasoning.

Betty´s Brain developed at Vanderbilt University focused on teachable agents, though only concept maps can be built and simulated (Biswas et al., 2005). This system proved to be highly motivating for students. The main focus of VModel is to enhance education, especially for middle school students. The project has the targets to enable the development of broadly applicable principles and processes, and to enable qualitative understanding of the systems behaviour. Like Betty´s Brain, VModel only allows the user to build concept maps. The simulation yields three different sources of feedback: a visual step-by step animation of the simulation, an English summary and an assessment of how well the model supports their hypotheses. A model library is included within the software, similar to DynaLearn software. Students in the Chicago Public School have been involved in evaluating the applicability of VModel software since 2001. The closest software to VModel is Betty´s Brain. However, the VModel incorporates physical processes better and supports the creation of new abstractions and features from student models, which Betty´s Brain software is not able to.

Like DynaLearn, Homer and VisGarp, are based on the qualitative reasoning engine Garp and use diagrammatic representation. The evaluation results of Homer and VisGarp have been used to improve the development of DynaLearn software.

The benefits of the DynaLearn software compared to the Garp 3 software are, that it integrates the interface into a single screen, adds Learning Spaces and incorporates improvements such as allowing multiple simulations, storing selections in state graphs and saves simulations to a model (Liem et al., 2009). Particularly, the Learning Spaces introduced in DynaLearn are very important due to the fact that beginners get to know the software more and more from Learning Space 1 to others. The weakness of the Garp3 software has been successfully been reduced. Still, the DynaLearn software is under development and there only exists a prototype, which is upgraded every several months.

Further improvements of the DynaLearn software depend on the availability of resources and requirements put forward by the user community, developed under work package 6 and 7. It has to be noted that several software improvements have been made during this thesis (e.g. the software does not shut down, when changing derivatives in the simulation of the scenario, a software manual has been developed). However, there are several software bugs, which limit the applicability of DynaLearn, by now. Thus, during the modelling process, several ideas to improve the software and to limit software bugs have been generated.

5.1.3 Software Improvements

- Copy/paste functionality
- Possibility to switch between Learning Spaces and import entities/quantities/models instead of building a complete new model
- A sum of different symbols to choose from (different colour, bold, etc.)
- Graphical improvements and animations
- To allow arrows in both directions (Learning Space 1)
- No possibility to go a step back in modelling nor cancel the last step (Undo button)
- Save model automatically, when the software shuts down (now: no reconstruction of model, when it shuts down)

- It would be good to see, which models were opened and changed the last session (Overview of models already done)

- For the purpose of faster working process, an option to make changes in scenario simulation would be beneficial.

5.1.4 Assets and Drawbacks

The DynaLearn software has several assets and drawbacks (user point of view):

Drawbacks

- A lot of exercise and knowledge about the software especially from Learning Space 4-6 is needed

- It is difficult to picture all relevant parameters in a model and at the same time present the content accurately and comprehensible

- Software is under development

Assets

- Learning by doing/modelling

- The benefit of serving as a supportive tool for learning has already been assessed and approved in an evaluation done at the University of Life Sciences and Natural Resources in 2010 (Zitek et al., 2010b).

- It is interesting to see how much and how detailed information you need to know for the different Learning Spaces

- Causal relations have to be understood before modelling

- The focus on concepts and their relations rather than to focus on numbers is a challenging and complex task, Thus, it forces to think about environmental processes.

- It is interesting for teaching as well as learning

- Own ideas can be modelled and it allows for choosing between the design of a rough overview or a detailed process. Thus, there is the choice between analytical completeness and clarity in the presentation of results

- The knowledge about natural systems behaviour can be checked for oneself

- Potential for decision support as well as to build future scenarios

5.1.5 Outlook

In this thesis focus was on the construction of conceptual models, but the aim of the DynaLearn project is to integrate three, yet independent technologies to create an engaging cognitive tool for acquiring conceptual knowledge. The semantic technology grounds model building with the help of an online lexicon such as Wikipedia and compares models. The virtual character technology provides individualized feedback to enhance motivation of learners and will be implemented. The virtual characters will be represented by hamsters and will be able to communicate with the users. Special focus of the ongoing research will be based on knowledge feedback and the development of an integrated coherent dialogue (Bredeweg et al., 2010).

5.2 DynaLearn modelling know-how in education and for decision-making

In two pilot evaluations of the DynaLearn software by students in high school (IHTL) and at the University of Natural Resources and Life Sciences, Zitek et al. (2010b) identified that generally causal reasoning and clear abstracted conceptual understanding on environmental issues has been improved during modelling. However, students at University tend to use more graphical descriptions, whereas high school students tend to use more causal verbal expressions. Reasons for this could be that high school students are not used to graphical descriptions, but are more trained to verbalize forms of knowledge representation. Hence, using graphical and more abstracted forms of knowledge representation can be a mid- to long-term goal in education. Further findings on how modelling improves conceptual system understanding are being investigated at the time of writing.

DynaLearn offers some great potential in decision support and decision-making. Zitek et al. (2009) developed models within DynaLearn regarding “hydropower production and its effects on fish” and “sustainability management” to support decision making at the Kamp river, in Austria, where a severe flood occurred in August 2002. In this participative project the local population, state authorities and other stakeholders were involved. The models were adapted according to experiences gained in the context of the participation process and were evaluated for their potential use in education and decision making by experts. The evaluation results were promising. Most people believe that qualitative reasoning within the DynaLearn software represent complex knowledge in an understandable way. Some believe that it might be too complex for certain user groups and additional information would be needed, while others think that it represents a beneficial learning tool for understanding real world causal sustainable development relations in riverine landscapes. In sum most participants mentioned that there is high potential within the DynaLearn software, mainly for education and decision-making.

5.3 Topic Discussion

5.3.1 Cooperation of EU policies

Considering the effects of recently developed EU policies on the environment, the importance of policy making in respect to sustainable development becomes apparent. The newly established EU policy on renewable energy contributes to a rapidly increasing bioenergy production sector. Besides other area demands such as food production, forestry, settlement and nature conservation, bioenergy production adds significant pressure on farmland and negatively affects aquatic ecosystems. To counteract this, the EU Water Framework Directive aims to improve the ecological status and avoid deterioration of aquatic ecosystems. However, considering only fish, macrozoobenthos, macrophytes and algae and as biological criteria, the surrounding vegetation only affects the ecological status indirectly (providing habitat for fish). For a more sustainable approach, a wider view including the potential floodplain and its land use is needed. This indicates that the adjacent vegetation also should be included in the Water Framework Directive objectives. Achieving good water status of all water bodies additionally to hydrological and morphological restoration measures requires more sustainable agricultural land management. Therefore, intensification of riverine agriculture and land use conflicts have to be limited. As a consequence, the Common Agricultural Policy and its environmental instruments as well as the EU Directive on Renewable Energies have to be adjusted to meet the objectives of the Water Framework Directive. Otherwise, there is the risk that increasing area demand for bioenergy production not only affects the ecological status of rivers, but also limits the realization of river-floodplain restoration projects (Schleupner et al., 2010). However, if sustainability criteria are implemented into the EU renewable energy directive and monitored within the member states, so that they can be maintained, the risk to fail the objectives of the Water Framework Directive will decrease.

Due to the fact that future developments are uncertain, a sum of scientific studies were undertaken (see EEA, 2006; Fischer et al., 2009; Langthaler et al, 2007; Kranzl et al., 2008). Thereby, future developments were assumed with the help of different scenarios; e.g. that *no changes in policy will be undertaken*, that *bioenergy will be financially promoted,* or that *nature conservation will be promoted in the future*.

Nevertheless, it is uncertain how the Common Agricultural Policy will further respond to the EU directive on renewable energy and which impact it will have on land use change in the near future. Also the policies of nature conservation have to respond to unsustainable practices of bioenergy production. At the moment it is very doubtful if sustainability criteria within the EU directive on renewables will be extended and converted into national laws and if there will be implemented an efficient monitoring so that they are maintained on a national scale. Also if the Water Framework Directive objectives in future will include the potential floodplains, is still not known, yet.

All those questions cannot be answered by now, but future decisions in this regard will have major effects on sustainable development within the European Union. Beyond doubt future EU policies and decision-making must consider impacts of land use change on water resources, so that impacts on the aquatic environment can be reduced or mitigated. Hence, cooperation and coordination are required between four policy areas: energy, agriculture, nature conservation and water resources. In this way already implemented directives can be conformed to the newly established directives and vice versa.

5.3.2 Drivers for bioenergy demand

Not only policies have influence on the bioenergy demand but a sum of other effects will have an influence on agricultural bioenergy demand, as well. The demand is driven by economics such as oil prices, the costs to produce bioenergy and the costs of other renewable energies (e.g. photovoltaic, wind energy, electric vehicles). Moreover, high food prices and food insecurity may drive the focus away from agricultural bioenergies to other renewable energy sources. Technological development will have an influence on the production of agricultural bioenergies or other preferred renewables. Last but not least, investigations about the suitability of different forms of bioenergy for carbon capture within the whole life cycle of biofuel production may have a significant impact on its future development. Besides, federal monetary fundings always had influence on the amount of environmentally oriented farming, river restoration projects as well as on the amount of agricultural bioenergy production leading to unknown consequences on the ecological status of rivers.

5.3.3 Different land use for bioenergy production

Most important, intensive agricultural use of ecological important areas (set-aside areas, permanent grasslands) and active floodplains for bioenergy production has to be prohibited because they provide irreplaceable ecosystem services. Furthermore, energy crops should not replace land uses that are known to support aquatic ecosystems or areas that have the potential to be restored (Dworak et al., 2008). A first important step in this regard was the inclusion of sustainability criteria in the EU Directive on Renewable Energies, which limit land use change in areas such as wetlands, areas important for nature conservation and areas with high carbon stocks (Directive 2009/28/EC). Also, other EU policies such as the Common Agricultural Policy should include such criteria and should prohibit the use of former set-aside areas, as well. In practice such areas often are converted for bioenergy production, however. It also has to be taken into consideration that agricultural products, including food as well as resources for bioenergy production, are international trading goods. This implies that here discussed land use changes and land use conflicts may be easily transferred to other, mostly less developed countries with often poor legal and ecological standards (Nitsch et al., 2008). Therefore, it is important to establish sustainability standards for bioenergy production worldwide.

Environmental effects of different energy crops are varying, depending on the local situations, the farming practice applied and the former land use. Therefore, a meaningful evaluation has to be done in comparison with other land use and adjusted to site-specific conditions (Nitsch et al., 2008).

5.3.3.1 Intensive maize production

Until now, predominantly maize is cultivated for bioenergy production. Maize production, especially if cultivated intensively has clear drawbacks on ecosystem services: Nutrients contaminate ground- and surface waters above average, erosion is high, biodiversity in such monocultures is low and the water retention capacity is lacking. Further, dams are built to prevent area from flooding and the river has little space for its natural river dynamics. Because of the aforementioned reasons, no further increase in intensive maize plantations is suggested and other forms of bioenergy production should be preferred. It is possible, that there may be better effects with more extensive farming practices, for example by using intercrops or catch crops, however.

5.3.3.2 Short rotation poplar production

In contrast to conventional cropland, short rotation coppice can withstand floodings better and may represent important flood retention areas. Promoting synergy effects between flood protection and economics, it would be favourable to introduce short rotation poplar plantations as buffer strips and flood retention areas. Moreover, when used as buffer strips, they can provide for protection of floodplain forest from nitrate and pesticide inputs (Baaske et al., 2007).
The use of former cropland for the production of short rotation coppice may have ecological benefits, as well. Perennial short rotation coppice may not only serve as erosion control and buffer for nutrients, but compared to intensive maize production they are in general also characterized by higher biodiversity. However, beyond doubt the biological diversity is lower compared to natural floodplain forests.

Because of the aforementioned characteristics, short rotation coppice can be seen as accurate temporary solutions for bioenergy production. However, more research has to be done concerning short rotation coppice. It is possible, that the perennial trees may stabilize soils and river banks, therefore little river dynamics would be enabled, which may become more severe when trees grow older. Because little information is available for sustainable farming techniques, more investigations have to be done in this research field. For river management it would be of major importance to know, if these plantations may serve as blocker of deadwood; protecting downstream infrastructure. So far, no practical experience is available, to which extent short rotation coppice may withstand floods. Last but not least, high water demand by some tree species has to be considered in planning and decision-making, as well.

5.3.4 Other effects on bioenergy production

There are other effects of bioenergy production on river-floodplain systems, which however are not specifically discussed in this thesis.

5.3.4.1 Greenhouse gas emissions

Conversion and ploughing up of biodiverse lands has also negative impacts on greenhouse gas emissions. The highest share of greenhouse gas emissions worldwide is due to deforestation; in Germany mostly due to ploughing up of grasslands. Loss of carbon and other gases from soil can offset carbon savings (Lind et al., 2009). According to that, also conversion processes from bioenergies to energy end use (fuel, heat or power) is important from an emission perspective (McKendry, 2001). However, further work is required also on a national scale, because set in the context of a life cycle analysis, there is the risk that bioenergy production may offset carbon savings (Gallagher, 2008; Searchinger, 2008).

5.3.4.2 Irrigation

Nowadays, several parts of Europe are already affected by water shortage. However, bioenergy production largely depends on water availability. Over-abstraction due to irrigation needs may become an increasing problem.

5.3.4.3 Genetic Modified Organisms

Special attention has to be paid to environmental risks of new plant varieties. For example, energy maize has more vegetative mass, due to larger leaves than conventional maize. As a consequence of this, they have higher demands of water and fertilizers (Dworak et al., 2008). Moreover, there is alarming risk, that genetic modified organisms have huge impact on native vegetation (Baaske et al., 2007).

5.3.4.4 Landscape characteristics

It has to be considered that an increase in bioenergy production may alter landscape characteristics. Intensive use of grasslands may change species composition and flowerage. Further, Miscanthus can grow up to 2-3 meters and energy maize will be much higher than conventional maize species. These changes in landscape characteristics may have impacts on tourism, recreation and regional added values (Lind et al., 2009). In the past, small patches, shrubs and hedges were often removed to intensify agricultural cultivation. Consequently, important habitats and refugees were lost. To avoid further loss of important landscape structures, respectively to improve them, areas for bioenergy production should become limited to maximum sizes.

5.3.4.5 Soil conservation

Concerning farming practice, more attention has to be placed on sustainable soil treatment. Soil conservation is of major importance for sustainable development. However, the environmental status of soils was not evaluated in Europe, so far. Taking this into consideration, Blum (2011) underlines the importance for the formulation of a framework directive for soil protection in Europe and reminds the importance of soil protection for sustainable river basin management.

5.3.5 Standards for good agricultural practice in bioenergy cropping

The environmental effects of bioenergy production always depend on the farming practice, too. Especially, for maize production the impacts are significantly varying with management practice applied. Concerning energy crops like short rotation plantations, only little information is available in these terms, yet (EEA, 2008). Mulch systems or minimum- to no till systems are examples for environmentally oriented farming. In such systems soil treatment, is reduced to a minimum, year round soil coverage is enabled. Soils under such practice are characterized by increased infiltration, reduced soil erosion and higher water retention within the area (EEA, 2008; Dworak et al., 2008). Furthermore, cover crops can additionally reduce the risk of erosion (Weidanz et al., 2007).

In other extensive farming systems such as row strip or alley cropping, perennial plants are grown in linear strips (around fields and along rivers); mitigating erosion by wind and water, as well as nutrient leaching (Dworak et al., 2008). Moreover, the positive effects on landscape diversity are also beneficial from an ecological point of view.

Multiple cropping systems, which could enhance diversity and reduce nutrient inputs into rivers, have also high potential in bioenergy production. If applied extensively, they can combine low environmental pressures and high yields. For bioenergy production, also intercrops as well as catch crops can be cultivated. For example, maize and Girasole can be cultivated side by side. Pest plants can be used for bioenergy production, as well (Nitsch et al., 2008). In this regard, no pest control is necessary and diversification of biodiversity may be possible. Many of these techniques are funded by the Agri Environmental Program and can help to improve bioenergy production in a sustainable way.

Besides, Habersack et al. (2010) suggest, that a minimum of three to seven times of the river width should be without any use. In areas where it is possible the maximum of the potential floodplain should be kept free from any use.

5.3.6 Benefits of bioenergy production in the potential floodplain

Several potential benefits and even synergies between bioenergy production and the ecological status of river-floodplain systems were identified.

5.3.6.1 Buffer strips

Buffer strips contribute to water retention and uptake of excessive nutrients. Some perennial plants can withstand floods better than others and therefore should be preferred in flood retention areas, allowing farmers to gain profit. Site-specific condition and plant characteristics have to be included in decision-making, so that any adverse effects will be minimized. Further scientific investigations have to be undertaken concerning the dimension and plant composition of buffer strips.

5.3.6.2 Use of natural vegetation and biomass residues

Biomass residues such as straw or grassland cuttings are of growing importance for sustainable bioenergy production in Europe. There are several advantages concerning the use of natural floodplain vegetation: Farmers can earn income from marginal lands, whereas no compensation measures are necessary. Most important, land use change and land use conflicts will be minimized and the area would be available for flood retention. Moreover, the natural floodplain vegetation will be sustained.

Contrariwise, there are several uncertainties concerning the use of biomass residues. The increased extraction of biomass may deteriorate soil organic matter and soil fertility, which also can lead to potential negative impacts on aquatic ecosystems. Therefore, it has to be clarified at first how much residues actually can be removed for bioenergy production without affecting ecosystem services.

There are ambiguities about the sustainable use of biomass from grassland cuttings. While scientific investigations are undertaken, precautionary measures have to be applied: Limits for biomass extraction have to be assessed as well as time of cutting has to be adjusted to the breeding season. Thus, extensively used grasslands or any natural floodplain vegetation must not be over-harvested (Hildebrandt et al., 2010).

There are other factors which lead to precariousness about the economical profitability, as well. Biogas plants are often built nearby areas for bioenergy production. Biogas plants have to be adapted to a variety of different plant species, whether they are ligneous or gramineous (Liebl, 2007). Furthermore, the quality of the biomass harvested, its availability as well as the amount varies over the year. As a result, the use of bioenergy from landscaping has not only to be oriented on ecological standards, but also on economic profit to achieve strong synergies between bioenergy production and the ecological status of river-floodplain systems. Adapted planning and management would be of major importance to enable sustainable bioenergy production in such areas. If all the above mentioned is taken into consideration, a sustainable alternative to conventional bioenergy production is possible.

6 Conclusions

Currently, the necessity to minimize greenhouse gas emissions leads to growing interest in renewable energies as alternatives to fossil fuels. A supportive legal instrument for this development is the Directive on Renewable Energies. In particular with regard to biogas and biofuel production this directive strongly promotes agricultural products as source for energy. As a clear consequence of this, agriculture focussing on production of bioenergy will be intensified in the near future. However, European environmental resources have already been deteriorated from intensive land use in the past and there is the risk that increased agricultural bioenergy production will aggravate the situation.

As stated in the EU Water Framework Directive, sustainable management of river-floodplain systems not only protects habitats, biodiversity and regulates nutrient cycling, but also contributes to passive flood control by restoring flood retention areas within the potential floodplains. An essential precondition to meet the directive's goals of at least good ecological status of waters by 2015, respectively 2027, is to limit intensification of agriculture, though.

By now, only few literatures exists which combine bioenergy production and its effects on river-floodplain systems. This thesis should contribute to sustainable development of agricultural bioenergies supporting the goal to achieve good ecological status of rivers. The thesis not only focuses on river-floodplain systems but chose an integrated approach, including land use, renewable energy production, as well as impacts on biodiversity, soils and water resources and the policies managing these resources. Identifying causal relations of bioenergy production in the potential floodplain with the help of DynaLearn was a challenge due to a variety of environmental effects. Modelling in the different Learning Spaces required deep understanding of the effects bioenergy production has on river-floodplain systems. Enabling the graphical modelling and display of causal relations of bioenergy production in the potential floodplain on different levels of complexity, the DynaLearn software beyond doubt is a strong tool for intradisciplinary as well as interdisciplinary studies. Not only learner benefit, moreover the models may contribute to in-depth understanding of socio-ecological systems for a wide range of users. However, finding out the main processes in complex systems and integrating different science approaches in DynaLearn models remains a challenging task. A library of expert models integrating different fields of science approaches serves as an important source of information for education, policy making as well as management, though (Zitek et al., 2009).

The comparison of different energy plant species provides indications allowing for a differentiation between unsustainable land use and sustainable land use. Research on site-specific conditions would be highly important to provide profound scientific knowledge on socio-environmental effects, however. In particular, soil condition, climate conditions, land use practices and the resilience of the ecosystem have to be taken into consideration in further research works. Moreover, life-cycle analyses of energy plants are essential to identify socio-environmental effects in an integrated way.

Summing up, this study shows that 2nd generation bioenergies have the potential to better preserve soils and water resources than 1st generation bioenergies. Alternative agricultural bioenergy production, for example the use of cutting from extensively cultivated riverine grasslands as well as the use of endemic vegetation on buffer strips may contribute to more sustainable agricultural practices. Overall, it should be an ambition to produce bioenergy plants more eco-friendly so that intensification of agriculture, land use change and land use conflicts are mitigated. Research in this area is still in early stages and questions remain unanswered. Further research is needed concerning the effects of short rotation coppice on water resources, on river dynamics as well as whether short rotation coppice may serve as blocker of deadwood. In respect to the use of floodplain vegetation for bioenergy production a cost-benefit analysis has to be conducted in order to identify the economical profitability. Additional studies have to be undertaken about the optimal plant composition of buffer strips.

Therefore, it is of major importance that research has to be fostered and environmental risks of bioenergy production are taken into account in implementation and revision EU policies and water management strategies. In this regard, assets and drawbacks of certain bioenergy plants and farming practises should be considered at a water basin level. Taking into consideration all the environmental effects of agro-bioenergy production in the potential floodplain may detain that today’s solutions will become tomorrow’s problems.

List of Abbreviations

CAP	Common Agricultural Policy
EEA	European Environment Agency
EU	European Union
MtOE	Million tonnes of oil equivalent
PJ	Petra Joule
SRC	Short-rotation coppice
SRF	Short-rotation forestry
SRP	Short-rotation poplars
WFD	Water Framework Directive

References

Allan, D., Castillo, M. (2007): Stream Ecology. *Structure and functions of running waters*. Second edition. Springer.

AMA (2010): *Entwicklung der Stilllegungs- und Energiepflanzenflächen*. Agrarmarkt Austria (AMA) Received August 17 2010 from: http://www.ama.at/Portal.Node/ama/public?gentics.am=PCP&p.contentid=10007.21512

AMA (2010): *Cross Compliance - Einhaltung anderwertiger Verpflichtungen*. Merkblatt 2010 der Marktordnungsstelle Agrarmarkt Austria (AMA).

Asamer, V., Stürmer, B., Strauss, F., Schmid, E. (2009): *Integrated assessment of large-scale poplar plantations on croplands in Austria*.

Austrian Biomass Association (2006): *Biomassse-Aktionsplan für Österreich unter Einbeziehung der Solarthermie, der Windenergie und der Wasserkraft*. Österreichischer Biomasse-Verband. Received August 18 2010 from: http://www.biomasseverband.at/biomasse?cid=20426#id2

Baaske, M., Plattner, G. (2007): *Biomassenutzung – Chance oder Gefährdung für nachhaltige Waldwirtschaft und Biodiversität?* Received October 7 2010 from: *http://*www.oebf.at/.../KurzzusammenfassungBiomassestudie.pdf

Bach, M. (2000): *Gewässerrandstreifen – Aufgaben und Pflege*. In: Konold, W., Böcker, R., Hampicke, U. (Hrsg.) (1999): Handbuch Naturschutz, Landschaftspflege.

Bachler, A. (2009): *Bioenergie 2020. Potential der Landwirtschaft.* Landwirtschaftskammer Österreich. Received October 8 2010 from: res.dada.at/oekl/gems/1Bachler090513.pdf

Barbosa, M., Ramos, C.G., Grilo, A., Sousa, S., Capela, I., Arroja, L., Leitao, J.H., Nadais, H. (2009): Bioenergy Production from Complex Wastewater. Energy, Environment, Ecosystems, Development and Landscape Architecture, University of Aveiro. Portugal.

Bielefeldt, J., Bolte, A., Busch, G., Dohrenbusch, A., Kroiher, F., Lamersdorf, N., Schulz, U., Stoll, B. (2008): *Energieholzproduktion in der Landwirtschaft. Chancen und Risiken aus Sicht des Natur- und Umweltschutzes.* Naturschutzbund Deutschland (NABU).

Biswas, G., Leelawong, K., Schwartz, D., Vye, N. (2005): *Learning by teaching: A new agent paradigm for educational software.* Standford University and Vanderbilt University. Applied Artificial Intelligence.

Blum W.E. (2011): Role of soils in integrated river basin management under climate change. Chapter3.4. The Water Framework Directive. Action Programmes and Adaption to Climate Change. The Royal Society of Chemistry.

BMWFI (2009): *Energiestatus Österreich 2009*. Bundesministerium für Wirtschaft, Familie und Jugend.

BMWFI (2010): *Energie Strategie Österreich*. Bundesministerium für Wirtschaft, Familie und Jugend und Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft.

BMLFUW (2009): *Grüner Bericht 2009.* Bericht über die Situation der österreichischen Land- und Forstwirtschaft. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Abteilung II 5. Wien.

BMLFUW (2009b): *Erneuerbare Energie 2020.* Potentiale und Verwendung in Österreich. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft. Wien.

BMLFUW (2010): *Ufervegetationspflege unter Berücksichtigung schutzwasserwirtschaftlicher und ökologischer Anforderungen.* Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und Amt der NÖ Landesregierung, Abteilung Wasserbau.

Bredeweg, B., Forbus, K. (2003): *Qualitative Modeling in Education.* American Associaition for Artificial Intelligence. Vol. 23 Nr. 4.

Bredeweg, B., Gómez-Pérez, A., André, E., Salles, P. (2009): *DynaLearn – Engaging and Informed Tools for Learning Conceptual System Knowledge.* Association for the Advancement of Artificial Intelligence.

Bredeweg, B., André, E., Bee, N., Bühling, R., Gómez-Pérez, J. M., Häring, M., Liem, J., Linnebank, F., Nguyen, B., Trna, M., Wißner, M. (2009): *DynaLearn - Technical desing and architecture*. University of Amsterdam.

Bredeweg, B., Liem, J., Linnebank, F., Bühling, R., Wißner, M., Gracia del Río, J., Salles, P., Beek, W., Gómez-Pérez (2010): *DynaLearn: Architecture and Approach for Investigating Conceptual System Knowledge Acquisition*. Springer-Verlag, pp. 272-274.

Buijse, A.D., Coops, H., Staras, M., Jans, L.H., VanGeest, G.J., Grift, R.e., Ibelings, B.W., Oosterberg, W., Roozen, F.C.J.M. (2002): *Restoration strategies for river floodplains along lowland rivers in Europe.* Freshwater Biology 47, 889-907.

Clifton-Brown, J.C., Stampfl, P.F., Jones, M.B. (2004): *Miscanthus biomass production for energy in Europe and its potential contribution to decreasing fossil fuel carbon emissions*. Global Change Biology. Vol. 10., p. 509-518.

Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. December 1991.

De Fraiture, C., Berndes, G. (2009): *Biofuels: Environmental Consequences & Implications of Changing Land use.* Biofuels and Water.

Dworak, T., Eppler U., Petersen J.E., Schlegel S., Laaser C. (2008): *A review of the possible impact of biomass production from agriculture on water.* Background paper for the conference "WFD meets CAP – Looking for a consistent approach". European Environment Agency

Dworak, T., Berglund, M., Liesbet, V., Campling, P., Kampa, E., Ribeiro, M.M., Thaler, T. (2009): *WFD and Agriculture Linkages at the EU Level*. Summary report on an in-depth assessment of RD-programmes 2007-2013 as regards water management. Final report. Ecologic.

EC (2003): Common Implementation Strategy for the Water Framework Directive (2000/60/EC) - *The role of wetlands in the Water Framework Directive*. Guidance document n.° 12. European Commission.

EC (2010): *Impact Assessment*. Accompanying document to the Report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling.

EEA (2005): *The European Environment. State and Outlook.* Integrated Assessment. European Environmental Agency.

EEA (2006): *How much bioenergy can Europe produce without harming the environment?* Copenhagen, European Environmental Agency.

EU Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market. September 2001.

EU Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. October 2000.

EU Directive 2003/30/EC of the European Parliament and the Council on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal of the European Union. May 2003.

EU Directive 2006/118/EC of the European Parliament and of the council on the protection of groundwater against pollution and deterioration. December 2006.

EU Directive 2009/28/EC of the European Parliament and of the Council. Official Journal of the European Union. April 2009.

Ersahin, M.E., Gomec, C.Y., Dereli, R.K., Arikan, O., Ozturk, I. (2010): *Biomethane Production as an Alternative Bioenergy Source from Codigesters Treating Municipal Sludge and Organic Fraction of Municipal Solid Wastes.* Department of Environmental Engineering, Istambul Technical University.

Fenz, R., Schwaiger, K. (2006): *Spannungsfeld Gewässerschutz-Landwirtschaft*, The Area of Tension Between Water Conservation and Agriculture. Österreichische Wasser- und Abfallwirtschaft.Vol. 58, 9-10.

Fischer, G., Prieler S., Velthuizen, H., Berndes, G., Faaij, A., Londo, M., Wit, D. (2009): *Biofuel production potentials in Europe*: Sustainable use of cultivated land and pastures. Part II: Land use scenarios. Biomass & Bioenergy.

Gallagher, E. (2008): *The Gallagher Review of the indirect effects of biofuels production.* Renewable Fuels Agency. UK.

Hall, R. (2003): *Short Rotation Coppice for Energy Production Hydrological Guidelines*. Centre for Ecology and Hydrology.

Heaton, E., Dohleman, F.G., Long, S.P. (2008): *Meeting US biofuel goals with less land: the potential of Miscanthus.* Global Change Biology, Vol. 14., p 2000-2014.

Herbke, N., Karaczun, Z.M., Langrebe-Trinkunaite, R., Dworak, T. (2006): *WFD and Agriculture Linkages at the EU Level Beyond 2007*. Ecologic – Institute for International and European Environmental Policy.

Herbke, N., Dworak, T., Karaczun, Z.M. (2006): *WFD and Agriculture – Analysis of the Pressures and Impacts Broaden the Problem´s Scope.* Interim Report. Version 6.

Hildebrandt, C., Ammermann, K. (2010): *Energieholzanbau auf landwirtschaftlichen Flächen – Auswirkungen von Kurzumtriebsplantagen auf Naturhaushalt, Landschaftsbild und biologische Vielfalt.* Bundesamt für Naturschutz. Leipzig.

Hughes, F.M.R. (ed.) (2003): *The Flooded Forest: Guidance for policy makers and river managers in Europe on the restoration of floodplain forests*. FLOBAR2, Department of Geography, University of Cambridge, UK.

Indinger, A., Leutgöb, K., Lutter, E., Mader, S., Nemestothy, K., Peherstorfer, N., Proidl, H., Sattler, M., Tretter, H., Veigl, A. (2006): *Vorstudie für einen nationalen Biomasseaktionsplan für Österreich.* Austrian Energy Agency. Wien.

IUCN (2008): *Implementing Sustainable Bioenergy Production.* A Compilation of Tools and Approaches. International Union for Conservation of Nature and Natural Resources. Switzerland.

Junk, W.J., Bayley, P.B., Sparks, R.E. (1989): *The Flood Pulse Concept in River-Floodplain Systems.* In: D.P. Dodge (ed.) Proceedings of the International Large River Symposium.

Keam, S., McCormick, N. (2008): *Implementing Sustainable Bioenergy Production. A Compilation of Tools and Approaches.* Gland, Switzerland, IUCN.

Kalt, G., Kranzl, L., Adensam, H., Zawichowski, M., Stürmer, B., Schmied, E. (2010): *Strategien für eine nachhaltige Aktivierung landwirtschaftlicher Bioenergie-Potentiale.* Energie der Zukunft. Wien.

Kranz, L., Haas, R., Kalt, G., Diesenreiter, F., Ludger, E., König, A., Makkonen, P. (2008): *Strategien zur optimalen Erschließung der Biomassepotenziale in Österreich bis zum Jahr 2050 mit dem Ziel einer maximalen Reduktion an Treibhausgasemissionen.* Energiesysteme der Zukunft. Bundesministerium für Verkehr, Innovation und Technologie. Wien.

Krause, S., Jacobs, J., Voss, A., Bronstert, A., Zehe, E. (2008): *Assessing the impacts of changes in landuse and management practices on the diffuse pollution and retention of nitrate in a riparian floodplain.* Science of the total environment 389. 149-164.

Langthaler, M., Plunger, E., et al. (2007): *Biomasse Ressourcenpotential in Österreich*. Studie im Auftrag der RENERGIE Raiffeisen Managementgesellschaft für Erneuerbare Energie GmbH. Brainbows Informationsmanagement GmbH.

Lasch, P., Kollas, C., Rock, J., Suckow, F. (2009): *Potentials and impacts of short-rotation coppice plantation with aspen in Eastern Germany under conditions of climate change*. Springer.

Lechner, H. (2009): *Bioenergie in der österreichischen Energiepolitik*. Austrian Energy Agency. Received August 5, 2010 from http://www.nachhaltigwirtschaften.at/.../20091112_01_bioenergie_id_oesterreichischen_energiepolitik_herbert_lechner.pdf.

Liebl, L. (2007): *Nachwachsende Rohstoffe und Naturschutz. Chance oder Problem.* Studienarbeit. GRIN Verlag. Germany.

Liem, J., Beek, W. B., Bredeweg B. (2010): *DynaLearn – Multi use level workbench*. University of Amsterdam.

Lind, B., Stein, S., Kärcher, A., Klein, M. (2009): *Where have all the flowers gone? Grünland im Umbruch.* Hintergrundpapier und Empfehlungen des Bundesamts für Naturschutz (BfN). Bonn.

Lue, G., Xie, L., Zhou, Q., Angelidaki, I. (2011): *Enhancement of bioenergy production from organic wastes by two-stage anaerobic hydrogen and methane production process.* Elsevier Ltd.

Meyerhoff, J., Dehnhardt, A. (2004): *The European Water Framework Directive and Economic Valuation of Wetlands. The Restoration of Floodplains along the River Elbe.* Working Paper on Management in Evironmental Planning. Received October 17 2010 from: www.landschaftsoekonomie.tu-berlin.de/fileadmin/.../wp01104.pdf

Muessner, R., Karaczun, Z., Dworak, T., Marsden, K. (2006): *WFD and Agriculture Linkages at the EU Level.* Final Report about Cross Compliance and the WFD. Ecologic.

Muhar, S., Schwarz, M., Schmutz, S., Jungwirth, M. (2000): *Identification of rivers with high and good habitat quality: methodological approach and applications in Austria.* Hydrobiologia 422/423: 343-358.

Muhar, S., Poppe, M., Egger, G., Schmutz, S., Melcher A. (2004). *Flusslandschaften Österreichs - Ausweisung von Flusslandschaftstypen anhand des Naturraums, der Fischfauna und der Auenvegetation.* Bundesministerium für Bildung, Wissenschaft und Kultur. Wien.

Muhar, S., Jungwirth, M., Unfer, G., Wiesner, C., Poppe, M., Schmutz, S., Hohensinner, S., Habersack, H. (2008): *Restoring riverine landscapes at the Drau River: succession and deficits in the context of ecological integrity*. Gravel-Bed Rivers VI: Process Understanding to River Restoration. Elsevier. 779-803.

Muhar, S, Poppe, M., Weiss, M., Preis S., Pohl, G., Hohensinner, S., Hein, T., Mair, M. (2009): Vertiefung und Vernetzung zukunftsweisender Umsetzungsstrategien zum integrierten Hochwasserschutz. *FloodRisk II, TP 4.3. Ökologie & Hochwasserschutz*. Institut für Hydrobiologie und Gewässermanagement. Received August 10 2010 from www.umweltbundesamt.at/.../FRII_oekologie_Hochwasserschutz_Muhar_Poppe.pdf

Müller-Wenk, R., Huber, F., Kuhn, N., Peter, A. (2003): *Landnutzung in potentiellen Fliessgewässerauen – Artengefährdung und Ökobilanzen.* Schriftreihe Umwelt Nr. 361. Bundesamt für Umwelt, Wald und Landschaft. Bern.

Nachtnebel, H.P. (2000): *The Danube river basin environmental programme: plans and actions for a basin wide approach.* Water Policy 2: 113-129.

Neary, D.G., Ice, G.G., Jackson, C.R. (2009*): Linkages between forest soils and water quality and quantity.* Forest Ecology and Management 258, 2269-2281.

Nemestothy, K. (2009): *Energiesysteme im Umbruch – Internationale Vorgabe, nationale Strategien und Aktionspläne*. Wood Energy Congress. Landwirtschaftskammer Österreich. Received January 10 2011 from www.kaerntnermessen.at/.../Abstrcat_DI_Kasimir_Nemestothy.pdf

Nemestothy, K. (2010): *Energiestrategie Österreich.* Welche Rolle spielen die Bauern im künftigen Energiesystem. Landwirtschaftskammer Österreich. Received August 5 2010 from http://www.leader-austria.at/lum/veranstaltungen/download-2010/energie-und-klima-forst/euk_nemestothy

Nilsson, C., Renöfält, B.M. (2008): *Linking Flow Regime and Water Quality in Rivers: A Challenge to Adaptive Catchment Management*. Ecology and Society 13 (2):18.

Oates, R. (2002): *Wise use of floodplains*. Policy Analysis: Analysing Barriers to Change: a tool to assist river basin planning. Technical Report on Policy Analysis. The Wise Use of Floodplains Project. Received October 17 2010 from: http://www.floodplains.org/default.htm.

Osterburg, B., Nitsch, H., Laggner, B., Roggendorf, W. (2009): *Auswertung von Daten des Integrierten Verwaltungs- und Kontrollsystems zur Abschätzung von Wirkungen der EU-Agarreform auf Umwelt und Landschaft*. Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei. Johann Heinrich von Thünen-Institut. Braunschweig.

ÖGG (2010): *Invasive Neophyten in Östereich. Östereichische Gartenbau Gesellschaft*. Received 13 January 2011 from http://www2.oegg.or.at/_docs/Neophytenfolder2_web.pdf

ÖPUL (2009): *Österreichisches Programm für die Entwicklung des Ländlichen Raums 2007-2013*. Fassung nach 3. Programmänderung. Bundesministerium für Land und Forstwirtschaft, Umwelt und Wasserwirtschaft.

ÖWAV (2006): *Fließgewässer erhalten und entwickeln – Praxisfibel zur Pflege und Instandhaltung*. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und Österreichischer Wasser- und Abfallwirtschaftsverband (ÖWAV), Wien.

Patt, H., Jürging, P, Kraus, W. (2009): *Naturnaher Wasserbau. Entwicklung und Gestaltung von Fließgewässern.* 3. Aufl., Springer, Berlin.

Poppe, M., Muhar, S., Egger, G., Schmutz, S. (2003): *The present state of the Austrian River Landscape: Survey and Analysis of Anthropogenic Impacts and Uses.* ÖWAW 0/6. Heft 7-8.

Poppe, M., Zitek, A., Salles, P., Bredeweg, B., Muhar, S. (2010): *How can we cope with the complexity of the environment? A "Learning by modelling" approach using qualitative reasoning for developing models and simulations with focus on Sustainable River Catchment Management.* Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Applied Life Sciences. Vienna. Geophysical Research Abstracts. Vol. 12. EGU General Assembly.

Powers, S.E. (2007): *Nutrient Loads to Surface Water from Row Crop Production.* Int. J LCA 12 (6). 399-407.

Pölking, A., Stiepel, A., B. (2006): *Bioenergy and Biogas Support Based on the new EEG and its Effect on Nature and Lanscape.* IAMA Forum 2006.

Ravindranath, N.H., Manuvie, R., Fargione, J., Canadell, P., Berndes, G., Woods, J., Watson, H., Sathaye, J. (2009): *GHG Implications of Land Use and Land Conversion to Biofuel Crops*. SCOPE Biofuel Report.

Roos, T. (2007). In: Schöne, F. (2008): *Auswirkung der Flächen-und Nutzungskonkurrenz auf die biologische Vielfalt in Deutschland – Maßnahmen zum Erhalt der Biodiversität in der Kulturlandschaft.* Technikfolgenabschätzung-Theorie und Praxis. Herausgeber: Institut für Technikfolgenabschätzung und Systemanalyse (ITAS). Nr. 2, p. 60-66. Received October 29 2010 from: http://www.itas.fzk.de/tatup/082/scho08a.htm.

Rowe, R., Street, N., Taylor, G. (2009): *Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK*. Renewable and Sustainable Energy Reviews 13. 271-290.

Rösch, C., Raab, K., Skarka, J., Stelzer, V. (2007): *Energie aus dem Grünland-eine nachhaltige Entwicklung?* Institut für Technikfolgenabschätzung und Systemanalyse. Forschungszentrum Karlsruhe GmbH

Sala, O.E., Sax, D., Leslie, H. (2009): *Biodiversity Consequences of Increased Biofuel Production.* Biofuels: Environmental Consequences & Implications of Changing Land Use.

Scheurlen, K. (2008): *Optionen für KUP*. Energieholz auf dem Acker – Zwischen Eingriff und Ausgleich. Internationale Naturschutzakademie. Received November 20 2010 from www.bfn.de/.../2008-09-07-Scheurlen_OptionenKUP.pdf.

Schleupner, C., Schneider, U.A. (2010): *Effects of bioenergy policies and targets on European wetland restoration options*. Environmental Science & Policy. Article in Press.

Scholz, V., Hellebrand, H.J., Grundmann, P., Höhn, A. (2006): *Ein Hektar heizt vier Häuser – Welche Energiepflanzenarten sind energetisch, ökologisch und ökonomisch am besten?* Neue Landwirtschaft 1: 54 -58.

Schöne, F. (2008): *Auswirkung der Flächen-und Nutzungskonkurrenz auf die biologische Vielfalt in Deutschland – Maßnahmen zum Erhalt der Biodiversität in der Kulturlandschaft*. Technikfolgenabschätzung-Theorie und Praxis. Herausgeber: Institut für Technikfolgenabschätzung und Systemanalyse (ITAS). Nr. 2, p. 60-66. Received October 29 2010 from: http://www.itas.fzk.de/tatup/082/scho08a.htm.

Schubert, R., Schellnhuber, H.J., Buchmann, N., Epiney, A., Grießhammer, R., Kulessa, M., Messner, D., Rahmstorf, S., Schmid J. (2009): *Future Bioenergy and Sustainable Land Use*. German Advisory Council on Global Change (WBGU). Berlin.

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu T.H. (2008): *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land use Change*. Sciencexpress. Received January 18 2011 from www.sciencemag.org/cgi/content/full/1151861/DC1

Simpson, T.W., Martinelli, L.A., Sharpley, A.N., Howarth, R.W. (2009): *Impact of Ethanol Production on Nutrient Cycles and Water Quality*: The United States and Brazil as Case Studies. Biofuels: Environmental Consequences & Implications of Changing Land Use.

Statistik Austria (2009): *Auf dem Ackerland* 2007, 2008 and 2009.

Statistik Austria (2009): *Gross national energy consumption 2007.* In: Österreichischer Biomasseverband (ed.): Basisdaten Bioenergie Österreich 2009. ÖBV, Vienna.

Stream Corridor Restoration (2001): *Stream Corridor Restoration*. Chapter 1. Federal Interagency Stream Corridor Restoration Working Group. Received August 5 2010 from http://www.nrcs.usda.gov/technical/stream_restoration/

Tockner, K., Malard, F. and Ward, J. V. (2000): *An extension of the flood pulse concept*. Hydrological Processes, 14: 2861–2883.

Tockner, K., Stanford, J.A. (2002): *Riverine flood plains: present state and future trends.* Envrionmental Conservation 29 (3): 308-330.

Tockner, K., Bunn, S.E., Gordon, C., Naiman, J., Quinn, G.P., Stanford, J.A. (2008): *Flood plains: critically threatened ecosystems.* In: Aquatic Ecosystems, Foundation for Environmental Conservation. Received October 19 2010 from: http://www98.griffith.edu.au/space/handle/.

UBA (2010): *Neunter Umweltkontrollbericht*. Umweltsituation in Österreich. Umweltbundesamt. Wien.

UBA (2011): *Klimawandel. Kyoto und darüber hinaus.* Umweltbundesamt. Received 28 February 2011 from: http://www.umweltbundesamt.at/umweltsituation/klima/klimawandel/?&tempL=1%2F

Wagner, K., Hubert, J., Neuwirth, J. (2008): *Landwirtschaft und Hochwasser* – Teilprojekt 9.5 zum Teilpaket Raumplanung im Projekt Flood Risk II; Bundesanstalt für Agrarwirtschaft, Wien.

Weidanz, J., Mosimann, T. (2007): *Auswirkungen eines verstärkten Maisanbaus zur Biogasproduktion auf die Bodenerosion.* Simulation von verschiedenen Nutzungsszenarien mit Erosion-3D im südlichen Niedersachsen. Phsische Geographie und Landschaftsökologie. Geosynthesis online. Leibniz Universität Hannover.

Wiesbauer, H. (1992): *Störungen des Geschiebehaushaltes – Konsequenzen für die Gewässerumgestaltung und -pflege* in: Lazowski, W. (1997): Auen in Österreich, Vegetation, Landschaft und Naturschutz. Umweltbundesamt. Wien.

Zitek, A., Preis, S., Poppe, M., Muhar, S. (2009): *Evaluating the potential of Qualitative Reasoning to capture and communicate knowledge on sustainable catchment management*. Institute of Hydrobiology and Aquatic Ecosystem Management, University of Applied Life Sciences. Vienna.

Zitek, A., Poppe, M., Stelzhammer, M., Jung, A., Zacharias, M., Muhar, S. (2010): *DynaLearn – Basic Topics and Models*. D6.2.5. University of Natural Resources and Life Sciences (BOKU), Vienna.

Zitek, A., Poppe, M., Stelzhammer, M. (2010b): *BOKU evaluation of DynaLearn prototype.*D7.2.5. University of Natural Resources and Life Sciences. Vienna.

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Curriculum Vitae

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