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<tr>
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Abstract

In this phase of the DynaLearn project, the CLGE partners involved in WP6 developed simple models and educational material about basic concepts in each topics presented in this deliverable. For each model, a meta-description is provided, along with supporting scientific literature about the concepts addressed in the model. This deliverable discusses a set of models for the DynaLearn Environmental Science curriculum.
Acknowledgements

We would like to thank the University of Amsterdam and the partners of the project for their contributions during the discussion and preparation of this deliverable, particularly to Bert Bredeweg, Jochem Liem and Paulo Salles.

Internal Review

- Richard Noble, Freshwater Fisheries Laboratory, University of Hull, International Fisheries Institute Hull, United Kingdom.

- Bert Bredeweg, Wouter Beek, Human Computer Studies, Informatics Institute, Faculty of Science, University of Amsterdam (UvA), The Netherlands.
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1. Introduction

The Environmental Science curriculum created for the DynaLearn project is based on seven main themes: Earth systems and resources, The living world, Human population, Land and water use, Energy resources and consumption, Pollution, and Global changes. Each of these themes consists of a collection of topics. This deliverable describes qualitative models about a subset of these topics. Deliverables D6.2.1 through D6.2.5 describes the full set of topics.

The curriculum topics addressed in this deliverable are the following:

**Earth systems and resources**
1. Water cycle
2. Thermal dynamics in freshwater bodies

**The living world**
1. Biodiversity
2. Reproductive strategies

**Human population**
1. Urbanization
2. Legislation

**Land and water use**
1. Land – use and conflicts
2. Intensive agriculture

**Energy resources and consumption**
1. Secondary production
2. Fossil fuels

**Pollution**
1. Dynamic aspects of dispersion and distribution of conservative pollutants
2. Dynamic aspects of dispersion and distribution of non-conservative pollutants
1. Climate changes
2. Atmospheric oxygen and ozone
2. Links to DynaLearn Curricula

The DynaLearn deliverable D6.1 identified and described a series of topics in Environmental Science that cover the seven main themes identified in the project description of work. Table 1 summarizes the themes and topics allocated to CLGE for development. Of these topics some were initially allocated to D6.2.3 as being those that may represent basic topics and models within the curricula. Within these topics models were developed in all suitable learning spaces available in the prototype DynaLearn software.

**Table 1** Summary of themes and topics assigned to CLGE in from the D6.1 curricula in Environmental Sciences and the simple topics and models covered in D6.2.3

<table>
<thead>
<tr>
<th>Theme</th>
<th>Topic</th>
<th>Sub-topic</th>
<th>LS01</th>
<th>LS02</th>
<th>LS03</th>
<th>LS04</th>
<th>LS05</th>
<th>LS06</th>
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<td>ESR</td>
<td>Thermal dynamics in freshwater bodies</td>
<td>Temperature vs. density</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water cycle</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fossil fuels</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
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<tr>
<td>TLW</td>
<td>Biodiversity</td>
<td></td>
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<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>Reproductive strategies</td>
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<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>-</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>Land – use and conflicts</td>
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<td>✓</td>
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<td>-</td>
<td>✓</td>
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<td></td>
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<td>Erosion</td>
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<td>-</td>
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<tr>
<td></td>
<td></td>
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<td>-</td>
<td>-</td>
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<td>P</td>
<td>Dynamic aspects of dispersion and distribution of conservative pollutants</td>
<td></td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td>Dynamic aspects of dispersion and distribution of non-conservative pollutants</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
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<tr>
<td>GC</td>
<td>Climate changes</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Atmospheric oxygen and ozone</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
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Earth Systems and Resources (ESR), The Living World (TLW), Human Population (HP), Land and Water Use (LWU), Pollution (P), and Global Changes (GC)
3. Topics and models addressed in this deliverable

3.1. Topic Urbanization (Theme: Human Population)

Human population growth is of special interest to Environmental Science studies. It is the major driving force behind anthropogenic changes in Earth systems. Decisions on how many children to have are influenced by many factors, such as food security, housing, culture, religion, social services and so on. Understanding the social aspects of human population growth is an essential requirement for the DynaLearn project. The curriculum and contents developed within DynaLearn will explore these as important factors that may contribute to sustainability.

Figure 1 shows a concept map of urbanization, i.e. the process associated with population growth in cities (urban area) and population decline in rural areas due to migration. The population growth in urban areas leads to increasing sewage production, and results in a significant increase of the main nutrients elements in the water bodies (rivers and lakes). This leads to eutrophication and algal blooms, which in turn increases fish mortality (thereby decreasing fish population sizes). When the growth of the human population decreases, this will significantly reduce the nutrients (nitrogen and phosphorous) in water bodies, and will restore the water quality.

Figure 1 Concept map of model “Urbanization”

3.1.1. Summarize the topic and the literature

The urbanization is the continuous process of increasing the population size in the city. The population growth is associated with many environmental impacts. One of them is pollution with nutrients and the resulting eutrophication of surrounding water bodies. Eutrophication is the anthropogenic import of nitrogen and phosphorous, which upsets the natural balances in the lake, and causes an increase in primary production. This process may lead to algal blooms [1]. “Therefore, urbanization is important topic, which has a great scientific and applied importance. The Americas (North America, Latin America and the Caribbean) had the highest percentage of their population living in urban centres in 2003 (78%). The urbanization in these countries has increased rapidly. That leads to increase of sewage production. The problems are the most of the wastewater, however, receives only primary treatment before it is discharged in water body. Consequently, a large volume of untreated sewage is discharged into surface waters, creating serious environmental problems” [2]. The is a growing data set about North American the cities having carbon gains and losses in vegetation and soils following urbanization [3]. Natural water bodies around cities have historically been dumping grounds for all manner of waste. Consequently, this pollution has had varying effects of water quality. One of them is loss of habitats and species diversity [4]. The good example for consequence of urbanization is Chivero Lake in Zimbabwe. The combination of poor planning, multiplicity of justification, mismatch between rate of urbanization and waste management investment, recent in the local climate and a permissive, immature political
system that called for no public accountability resulted in environmental management breakdown leading to hypereutrophication of the lake [5].

3.1.2. Model objectives

The objectives of the models are to represent characteristic features of urban areas and show how nutrients cycle affect on water bodies nearby to the cities. The models demonstrate the main effects of an increasing population in urban areas (Urbanization) on water quality.

The main question is:

How does urbanization and consequential increase in sewage production affect the water bodies surrounding the city?

3.1.3. Model structure (LS2-6)

Figure 2 represent system structure of model about urbanization implemented in learning space 6.

The entity hierarchy for model “Urbanization” is presented of Figure 3. The main entities are divided into 4 groups “Area”, “Community”, “Population” and “Water body”. The main entities involved are “Rural area” and “Urban area” as area entities. “Algae community” and “Fish community” as expression of communities in the water body. “Rural population” and “Urban population” are relevant to human populations. An over view of the entities, quantities and their quantity spaces are shown in Table 2.

Figure 3 Entity hierarchy of a model about Urbanization in LS6
Table 2 Entity, Quantity and Quantity space used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural population</td>
<td>Size</td>
<td>Zpm {zero, plus, maximum}</td>
<td>The size of the rural population</td>
</tr>
<tr>
<td>Rural area</td>
<td>No;</td>
<td>No;</td>
<td>An isolated area with low population density</td>
</tr>
<tr>
<td>Urban area</td>
<td>Urbanization</td>
<td>Zp {zero, plus}</td>
<td>Migration of people from rural to urban areas</td>
</tr>
<tr>
<td>Urban population</td>
<td>Size</td>
<td>Zpm {zero, plus, maximum}</td>
<td>The size of the urban population</td>
</tr>
<tr>
<td></td>
<td>Sewage</td>
<td>Zp {zero, plus}</td>
<td>The production of sewage that contaminates of natural ecosystem</td>
</tr>
<tr>
<td>Water body</td>
<td>Nutrient</td>
<td>Zpm {zero, plus, aximum}</td>
<td>The concentration of nitrogen and phosphor in the water body</td>
</tr>
<tr>
<td>Algae community</td>
<td>Biomass</td>
<td>Zp {zero, plus,}</td>
<td>The biomass of individuals the algae population</td>
</tr>
<tr>
<td></td>
<td>Algal blooms</td>
<td>Zpm{zero,plus, maximum}</td>
<td>The rapid increase of the number of algae in the water body caused by an inflow of nutrients.</td>
</tr>
<tr>
<td>Fish community</td>
<td>Number of</td>
<td>Zp {zero, plus}</td>
<td>The number of individuals the fish population</td>
</tr>
<tr>
<td></td>
<td>Mortality rate</td>
<td>Zp {zero, plus}</td>
<td>The death rate of the fish population</td>
</tr>
</tbody>
</table>

The algae bloom occurs when a population becomes very large. In the model bloom is said to occur if the biomass of a population is equal or greater than plus. An important effect of algal bloom is the covering of the water surface.

3.1.3.2. Quantity space definition (LS3 – 6)

Values in the quantity space are representations of “qualitative states” of the quantity. The QS is a set of points and intervals. Determining the relevant quantity space for each quantity is an important aspect of constructing a qualitative model because it is one of the features that determines the variety of possible behaviours that will be found by the simulator when the model is simulated.

These models use the quantity spaces {zero, plus} and {zero, plus, maximum}. For instance, the following quantity: size of rural population, size of urban population, nutrients in water body and algal bloom of algae community can be represent as having three possible magnitudes: QS = {zero, plus, maximum}. The values of this quantity can be interval (plus), but they can to have values above this interval: point (maximum). For other quantities we choose QS = {zero, plus}. These QS are very important and useful, because they describe different
behaviour of the system. Furthermore, they can be used to define process rates \{active, inactive\}. That meant active or inactive.

The QS of urbanization is \{zero, plus\}. At zero the urbanization process is inactive, while at plus the process is active. Note that a landmark such as maximum is not used, since there is no theoretical maximum to the urbanisation process. The QS used for size of urban area (and size of rural area) is the same with the urbanization QS. The QS of urban population and rural population are QS= \{zero, plus, maximum\}. The main idea is that, if urbanization is plus, then urban population increases, and rural population decreases. When nutrients is plus, then algal blooms can be zero or plus. The QS of sewage production is \{zero, plus, maximum\}. The possible situations are three: If sewage production= 0, then nutrients=0; If sewage production=plus, then nutrients=0; If sewage production=maximum, then nutrients= maximum. Finally, if nutrients= maximum, then algal blooms will be maximum also. The QS of number of and mortality rate of fish community are \{zero, plus\}. If mortality is zero, then number of fish community will be plus. If mortality is plus, the number of fish community decreasing.

### 3.1.3.3. Model fragments

The library of the model about Urbanization consists of 6 model fragments (MF). A MF01 Algae community introduces the entity with the same name algae community. This MF also introduces the quantity Algal blooms and Biomass (related with algae community). It is assumed that there is correspondence between the QS plus and maximum of quantities Algal blooms and Biomass.

The MF02 Algae blooms introduced entity Water body and quantity Nutrients and repeat MF01 Algal community. MF02 establishes that increasing Nutrients increases the Algal blooms (P+) in water body, and that increasing the biomass of algae community. It is assumed that there is a full correspondence between the QS of quantities Nutrients and Algal blooms.

The most important is MF03 Urbanization. A MF03 introduces entities Rural area, Rural population, Urban area and Urban population. This MF represent how process of urbanization influence on size of Urban and Rural population. Furthermore, between Urbanization and size of Urban and Rural population, have a direct influences (Urbanization →I+→ Urban population; Urbanization →I-→ Rural population).

The model fragment04 Sewage production illustrates direct influence (I+) between quantities Sewage production and Nutrients and full correspondence between their QS.

The MF05 introduces entity Fish community and quantities Number of and Mortality rate. This MF establishes that increasing Mortality rate decreases the Number of (I-).

Finally, MF06 Urban population size establishes that increasing Size (associated with Urban population) increases the Sewage production (related with the same entity) (P+).

In this model, model fragments have not children. Furthermore, no model fragments are imported in other model fragments.

### 3.1.3.4. Assumptions explicitly represented in the model (LS6)

This model has one assumption. This assumption is applied by including the assumption with label "Increase of urbanization" in Sc01 Urbanization. If this assumption holds, the urbanisation rate is set to plus.
3.1.3.5. Scenarios and simulations

The LS4 model represents the consequences of the increase of urbanization. Figure 4 shows the initial scenarios. The LS6 model about Urbanization has only one scenario – Sc01 Urbanization. Figure 5 shows the initial scenario of this model. The main aim of this scenario is to represent the consequences of the increase of urbanization on the quality of water bodies nearby cities. If the process of urbanization increases, then the size of urban population increases and size of rural population decreases. This leads to an increase of sewage production and nutrients. These organic compounds are food for the algal community. They increase algal biomass, which leads to algal blooms. As a result, the mortality rate of the fish community increases and the number of fish decreases. Overall, the process of Urbanization has a negative effect on water bodies nearby to urban area. Figure 6 represents the causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.

Figure 4 Expression with a model about the Urbanization implemented in LS4

Figure 5 Initial scenario model about Urbanization implemented in LS6
Figure 6 Causal relations in the model about Urbanization

The behaviour path represents the main objective of this model: effects of an increasing population in urban areas (Urbanization) on water quality.

Figure 7 represent value history diagram of the quantities in behavior path of the full simulation of the scenario "Urbanization". The increase of human population leads to an increase of sewage production. As a result, the nutrients in water body increase, the number of algae increases also. That leads to algal bloom and damages water quality.

Figure 7 Value history diagram of the relevant quantities in a selected behaviour path of the full simulation of the scenario "Urbanization"

Figure 8 shows the state graph of the simulation results, with full behaviour path. The simulation produces one initial state, has one end state [2], and in totals 4 states.

The end state of the simulation of the LS6 urbanisation model is state 2.
3.2. Topic Legislation (Theme: Human Population)

While resources are becoming scarce and the Earth’s carrying capacity approaches, there is a tendency to develop and to apply environmental oriented legislation in order to discipline organization and functioning of companies, institutions and the government and to protect the environment and the future generations.

Figure 9 Concept map of model “Legislation”

This model present how introduced of EWFD (European Water Framework Directive) influence on water quality. Here we present aspect – water intakes (for example: irrigation). When the quantity of water intakes is increasing, then river runoff will decrease. That leads to a decrease of the water habitats and reduce species diversity. Water quality also will be negatively affected. The introduction of EWFD will limit the water intakes. Figure 9 represents concept map of this model.

3.2.1. Summarize the topic and the literature

The EWFD (2000/60/EC) identified the protection, restoration and enhancement of the water needs of wetlands as part of its purpose at Article 1(a): “to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater… which prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems” [6].

“*The Bulgarian Environmental Protection Act declared protection and use of water and water bodies as a long-term state policy based on rational water management at national and basin level aiming at: achievement of good status of all waters to ensure sufficient quantity and quality of water for the present and future generations, to establish favourable conditions and development of the ecosystems and the wetlands, and for economic and social activities (Art. 35). Further, it stated that the protection of water and water bodies ensures the balance between water use and its natural renewal, conservation and improvement of the quality of surface and ground water, and of the aquatic ecosystems associated with surface waters (Art. 37)” [7].

The implementation of the EWFD and the development of RBMPs (River basin management plans) require the solution of set of problems related to the water resources quality and quantity. As a result of the changed economic conditions in the country and particularly in Bulgarian water economy, water resource system balances...
were calculated for the main river basins. In many ways the pattern of applied research and implementation of planning and control in river basins will form a model for other forms of environmental management. “In order to conserve the essential river environment where influenced by urban or semi-urban areas, institutional change must now facilitate policies which integrate catchments drainage from point of rainfall to the sea, including flow control of the drainage elements of highways and property development planning.” [8].

The reduction of irrigation areas in Bulgaria at present and the pessimistic prognoses related to the land reclamation development in the near future, one part of the reservoir usable storage could be left empty for water retaining during the summer floods which occur in the past years. This result could be considered as one measure to achieve some of the Directive’s environmental objectives e.g. flood control [9].

“The project proposed that the basis for water quality management and regulation be the river basin. The river basin is the smallest natural unit of water protection which can take into account the needs of those using the area, assist reasonable and economic solutions reducing pollution and enable the goals regarding water quality to be achieved through gradual, tolerable economic burden to local inhabitants” [10].

3.2.2. Model objectives

The objectives of the models are to represent how protection process particularly EWFD, influence on biodiversity in water bodies. The models demonstrate the main effects of an increasing of government pressure and protection process on water quality.

The main questions are:

How does protection process and consequential affect the water bodies?

What is the happen if Government pressure increase?

What is the happen if Economic pressure increase?

3.2.3. Model structure

Figure 10 Configurations relating the different entities

Figure 10 represent the system structure of model about Legislation, implemented in LS6.

3.2.3.1. Structure, entities and quantities

The entity hierarchy for model “Legislation” is presented of figure 11. The main entities are divided into 4 groups “Economic”, “Government”, “Human activities” and “Water intakes”. These entities describing mainly the direction and type of influence (Table 3).
Figure 11 Entity hierarchy of model about Legislation in LS6

Table 3 Entity, Quantity and Quantity space used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Economic pressure</td>
<td>{zero, plus}</td>
</tr>
<tr>
<td>Government</td>
<td>Government pressure</td>
<td>{zero, plus}</td>
</tr>
<tr>
<td>Water intakes</td>
<td>Amount of</td>
<td>{zero, plus, maximum}</td>
</tr>
<tr>
<td>River</td>
<td>River runoff</td>
<td>{zero, plus, maximum}</td>
</tr>
<tr>
<td></td>
<td>Habitat diversity</td>
<td>{zero, plus}</td>
</tr>
<tr>
<td></td>
<td>Species diversity</td>
<td>{zero, plus}</td>
</tr>
<tr>
<td>Human activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>River basin management plan</td>
<td>Protection process</td>
<td>{zero, plus}</td>
</tr>
<tr>
<td>Water framework directive</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.3.2. Quantity space definition (LS3 – 6)

The QS of river runoff is {zero, plus, maximum}. If river runoff is zero, then habitat and species diversity will be zero. If river runoff is plus/maximum, then QS of habitat and species diversity will be plus. For instance, the Economic and Government pressures can be {zero, plus}. If Government pressure is zero, then amount of water intakes will be plus/maximum, and river runoff will decrease. If Government pressures is plus, then water intakes will decrease and river runoff will be plus or maximum. The Economic pressure has opposite of Government pressure effect.

3.2.3.3. Model fragments

This model contains 7 Model fragments (2 static and 5 processes).

MF01 introduces entities River with quantities River runoff, Habitat diversity and Species diversity. However, MF01 establishes that increasing River runoff and consequence increasing of Habitat diversity increases the Species diversity (P+). All of these quantities are associates with entity River.

A MF02 is used to implement the knowledge needed for determining the amount of water intakes and river runoff magnitude and derivative. Furthermore, amount of water intakes has changing proportionality (P-) on river runoff. Between QS of these quantities has opposite full correspondence.

MF03 introduces entities Economic, Human activity and Government with quantities Economic pressures (associates with entity Economic) and Government pressures (related with entity Government). This MF has three children MF04, MF05 and MF06. They represent three different situations. For instance, what is the happen if Government pressure > Economic pressure amount, if Government pressure < Economic pressure amount, and if Government pressure= Economic pressure.
The most important MF is MF07 Economic and Government pressure. For instance, if Government pressure dominates on Economic pressure Amount of Water intakes will decrease, and River runoff – increase.

3.2.3.4. Assumptions explicitly represented in the model (LS6)

This model has three assumptions. These assumptions are applied by including the assumption with label “Economic pressure dominants government pressure” in Sc01, “Economic pressure is equal to government pressure” in Sc02 and “Government pressure dominants Economic pressure” in Sc03.

3.2.3.5. Scenario and simulation

The model about legislation implemented in LS2 represents how EWFD influence on water quality. The protection process has positive effect on river runoff and habitat and species diversity (Figure 12).

Figure 12 Expression with a model about the Legislation implemented in LS2

LS4 model represent two opposite processes – government and economic pressure (Figure 13).

Figure 13 Expression with a model about the Legislation implemented in LS4

The model implemented in LS6 includes 3 scenarios that separately simulate process such as Economic pressure = Government pressure, Economic pressure < Government pressure (Figure 14), Economic pressure > Government pressure. The Sc01 Economic pressure > Government pressure represent the initial values, which include stable Government process and plus and increasing Economic process. For other quantities (Amount of Water intakes, River runoff, Habitat diversity and Species diversity) the initial values are plus. Figure represents the most important scenario with initial values. Figure 15 represent Causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.
Figure 14 Initial scenario 03 "Government pressure dominates economic pressure" model about the Legislation implemented in LS6

Figure 15 Causal model, Sc03

The relevant behaviour path is [5, 3, 12] (Figure 16). This path represents the main objective of this model: effects of an increasing government pressure on water quality. The increase of government pressure leads to decrease of water intakes. As a result, river runoff and habitat diversity increases. That leads to increase of species diversity.

Figure 16 Value history diagram of the quantities in behaviour path [5→3→12] of the simulation of the Sc03 “Government pressure dominates economic pressures”

The end-states in model about legislation in LS6, Sc03 are [12] and [13] (Figure 17).
Figure 17 Behaviour graph and end states obtained of the simulation in model about “Legislation” in LS6, Sc03

3.3. Topic Fossil fuels (Theme: Earth systems and resources)

In Environmental Science curricula, the Earth is seen as part of the living systems and the source for many of vital resources, both for biological processes and for the economic basis of human societies. There are many opportunities for DynaLearn tools to be used in Environmental Science curricula, exploring marine systems, continental systems, which include both land and freshwater systems, and their interaction with the atmosphere [1].

Figure 18 is a concept map of the “Fossil fuels” topic. The solar radiation produces light and heat. The plants use this light in the process of photosynthesis for creation of their biomass. In this process, the plants use carbon dioxide from air or water. The plant’s biomass after their death can be converted in biofuels, through the process of biodegradation. The biofuels are a renewable sourced of energy. They emit amount of carbon dioxide in the air and do not lead to greenhouse effect and warming. When these plants die, they could become fossil fuels after millions of years. During the burning process of fossil fuels are emit the highest emission of carbon dioxide in atmosphere. This leads to increasing of greenhouse gases and as a consequence global warming.

Figure 18 Concept map of model “Fossil fuels”
3.3.1. Summarize the topic and the literature

This literature review examines the role that fuels from renewable biomass might play as a strategic option to address concerns of climate change by replacing fossil fuels, and thus the CO2 that is emitted when they are used. In principle, biomass-based fuels need not be a net source of CO2 emissions because CO2 released during combustion would be cycled back into plant materials by photosynthesis. In response to the concern that increases in atmospheric greenhouse gases may lead to adverse climate change, a number of proposals have been made to stabilize and ultimately reduce anthropogenic emissions of greenhouse gases. Most focus has been on reducing CO2 emissions from the use of fossil fuels. They include calls for near-term efforts to increase the efficiency of energy use, to reduce energy use, and to switch from high-carbon to lower no-carbon fuels. Algae can fix CO2 in the atmosphere. Under natural growth conditions, algae assimilate CO2 from the air and can tolerate and utilize substantially higher levels of CO2 [12]. Biological CO2 mitigation has attracted much attention as an alternative strategy because it leads to production of biomass energy in the process of CO2 fixation through photosynthesis. “This review strives to provide a systematic account of recent developments in the field of algal CO2 bio-mitigation, with a focus on algal strains for the fixation of CO2 from different sources, the combined CO2 mitigation and biofuel production strategy, the combined wastewater treatment and CO2 mitigation strategy, algal nutrition and cultivation, and algal biomass harvesting. CO2 fixation using fast-growing algal species provides a very promising alternative for mitigation of CO2, the most prominent greenhouse gas. The primary merit of this strategy lays in the fact that, via the cultivation of algae, CO2 mitigation and biofuel production could be combined in an economically feasible and environmentally sustainable manner. The feasibility of this strategy could be further enhanced by fixing CO2 from industrial exhaust gases such as flue gases and by integrating algal cultivation with wastewater treatment” [13].

A secure supply of energy resources is generally agreed to be a necessary but not sufficient requirement for development within a society. Furthermore, sustainable development demands a sustainable supply of energy resources that, in the long term, is readily and sustainable available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts [14].

3.3.2. Model objectives

The goal of the model is to demonstrate the main effects of use of fossil fuels and compare with biofuels and effect on greenhouse effect and global warming.

The main questions are:

1. How influence the change of fossil fuels with biofuels on greenhouse effect and global warming (damage of environmental)?

2. What happens if you use fossil fuels?

3. What happens if you use biofuels?

3.3.3. Model structure

Figure 19 Configurations relating the different entities
Figure 19 shows the system structure of the model about Fossil fuels.

### 3.3.3.1. Structure, entities and quantities

The entity hierarchy for the model “Fossil fuels” is presented in Figure 20. The main entities are divided into 6 groups: “Algae”, “Atmosphere”, “Chemical”, “Environment”, “Fuels” and “Industry”. The main entities involved are “Fossil fuels” and “Biofuels” as fuels entities. “Biofuels plants” and “Transport sector” as expressions of the industry of human kind. “Carbon dioxide” is a relevant entity in chemical. These entities describe mainly the direction and type of influences (Table 4).

![Diagram showing entity hierarchy of model about Fossil fuels in LS6](image)

#### Table 4: Entity, Quantity and Quantity space used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>No;</td>
<td>No;</td>
<td>The plants absorbed carbon dioxide from atmosphere or water, through photosynthesis process.</td>
</tr>
<tr>
<td>Carbon dioxide in air</td>
<td>Amount of</td>
<td>Znch {zero, normal, critical, hazardous}</td>
<td>The level of carbon dioxide in air or shifts or flows of carbon over time from one pool to another.</td>
</tr>
<tr>
<td>Fossil fuels</td>
<td>Burning rate</td>
<td>Zp {zero, plus}</td>
<td>The quantity (level) of emit carbon dioxide during the burning of fossil fuels in transport.</td>
</tr>
<tr>
<td>Transport</td>
<td>No;</td>
<td>No;</td>
<td>The transport is a human activity, which uses the fuels (fossil fuels or biofuels).</td>
</tr>
<tr>
<td>Human activity</td>
<td>Global warming</td>
<td>Zp {zero, plus}</td>
<td>The warming of the earth's surface, driven by either natural or anthropogenic forces.</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Greenhouse effect</td>
<td>Zp {zero, plus}</td>
<td>Greenhouse gases in the atmosphere contribute to global warming by absorption and reflection of atmospheric and solar energy. This natural phenomenon is what we call the greenhouse effect.</td>
</tr>
<tr>
<td>Biofuel plants</td>
<td>No;</td>
<td>No;</td>
<td>The plants for production of biofuels.</td>
</tr>
<tr>
<td>Algae</td>
<td>Photosynthesis rate</td>
<td>Zp {zero, plus}</td>
<td>The rate of photosynthesis of algae community.</td>
</tr>
<tr>
<td>Biomass</td>
<td>Zp {zero, plus}</td>
<td></td>
<td>The biomass of algae community</td>
</tr>
<tr>
<td>Transport sector</td>
<td>Biofuel usage</td>
<td>Zp {zero, plus}</td>
<td>Biofuels usage in transport sector</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Degradable biomass</td>
<td>Zp {zero, plus}</td>
<td>Degradable biomass of algae</td>
</tr>
<tr>
<td>Environment</td>
<td>No;</td>
<td>No;</td>
<td></td>
</tr>
<tr>
<td>Water body</td>
<td>No;</td>
<td>No;</td>
<td></td>
</tr>
</tbody>
</table>
3.3.3.2. *Quantity space definition (LS3 – 6)*

QS of amount of carbon dioxide in the atmosphere has QS = zero, normal, critical and hazardous. At zero and normal there are no high values of carbon dioxide in the atmosphere. The critical is minimal hazardous values and hazardous there definitely high values of CO$_2$. For other quantities are used QS = \{zero, plus\}.

3.3.3.3. *Model fragments*

The library of model about Fossil fuels includes 7 Model fragments. One of them is MF Biofuels usage photosynthesis relationship, have three children. Each of them represents different situations: Biofuels usage = Photosynthesis, Biofuels usage > Photosynthesis, Biofuels usage < Photosynthesis.

3.3.3.4. *Assumptions explicitly represented in the model (LS6)*

This model has three assumptions. These assumptions are applied by including the assumptions with labels:

Assumption in Sc03: Biofuels usage equal to photosynthesis rate. If this assumption holds, the biofuels usage and photosynthesis rate will be plus.

Assumption in Sc04: Biofuels usage greater than photosynthesis rate. If this assumption holds, the biofuels usage will increase.

Assumption in Sc05: Biofuels usage smaller than photosynthesis rate. If this assumption holds, the biofuels usage will decrease.

3.3.3.5. *Scenario and simulation*

Figure 21 show both biofuels usage and fossil fuels usage. If amount of biofuels is increase, then carbon dioxide will decrease. That leads to decrease of Global warming and Greenhouse effect.

Figure 21 Expression with a model about the Fossil fuels implemented in LS2
Figure 22 Expression a model about the Fossil fuels implemented in LS3

The figure 22 show what is the happen if burning rate of fossil fuels is increase. The plants absorb the carbon dioxide from air or from water, during the process photosynthesis for create their biomass. When this plants dead, after the millions of years became fossil fuels. The fossil fuels are used from humankind mainly for fuels of transport. During the burning process, these fuels emit in atmosphere high values of carbon dioxide. This carbon dioxide is consists of greenhouse gases. In consequence of emit of high value of carbon dioxide in atmosphere, the values of greenhouse gases increase also. That leads to increase of air temperature and global warming. Figure 23 show expression with a model about the Fossil fuels implemented in LS4

Figure 23 Expression with a model about the Fossil fuels implemented in LS4

The photosynthesis rate is a greater biofuel usage. That leads to decrease amount of the carbon dioxide in the air.

Figure 24 show initial values Sc01 model about Fossil fuels implemented in LS6
Figure 24 Initial scenario 01 model about the Fossil fuels implemented in LS6

Figure 25 Causal model, Sc01 model about Fossil fuels

Figure 25 and 26 represents causal models in different scenarios. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.

Figure 26 Causal model, Sc02

The increase of photosynthesis leads to an increase of algal biomass. Degradable biomass will increase also. That leads to decrease of amount of carbon dioxide in the atmosphere (Figure 27).
Figure 27 Value history diagrams of the quantities in behaviour path [1→2→3] of the full simulation of the scenario 01.

The end-states in model about fossil fuels in LS6 is one – [3] (Figure 28).

Figure 28 Behaviour graph and end states obtained of the full simulation in model about “Fossil fuels” in Sc01-LS6.

3.4. Topic Land – use conflicts (Theme: Land and water use)

Figure 29 represents concept map of model about Land-use and conflicts.

Figure 29 Concept map “Land – use conflicts”

3.4.1. Summarize the topic and the literature

Land-use planning is important human activity. The goal of this kind of planning is to ensure that uses of the land are appropriate and sustainable, and do not cause unacceptable social, economic and/or environmental disruptions or degradations of the site or landscape.
Achievement of a successful and sustainable pattern of land-use requires planning, regulation, and monitoring, as well as effective resolution of unanticipated conflicts as they arise. "Land-use planning in rural areas must also focus on identifying and avoiding unacceptable environmental damages and conflicts among resource users. For example, in planning agricultural land use, it is critical to consider land capability and whether particular agricultural systems might cause excessive erosion, resulting in degradation of the agricultural resource, and unacceptable damage to nearby aquatic ecosystems." [15]

3.4.2. Model objectives

The goal of the model is to demonstrate the main effects of construction of buffer zones (in this case – a forest area) between two areas/ecosystems (agriculture area/field and river course) on water quality. The consequence of making buffer zones is in minimization of the human impact and in protecting natural environment, which leads to improvement of water quality.

The main questions are:

1. How the construction of the buffer zones influences the water quality?
2. What happens in case of intensive afforestation?
3. What happens in case of intensive deforestation?

3.4.3. Model structure

Figure 30 represent system structure of model about Land-use conflicts

![Figure 30 Configurations relating the different entities](image)

3.4.3.1. Structure, entities and quantities

The entity hierarchy for model “Land – use conflicts” is presented of Figure 31. The main entities are divided into 3 groups “Human activity”, “Land” and “Water body”. The main entities involved are “Afforestation” and “Deforestation” as Human activity entities (Table 5).

![Figure 31 Entity hierarchy of model about “Land - use conflicts” in LS6](image)
Table 5 Entity, Quantity and Quantity space used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantities space</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human activity</td>
<td>No;</td>
<td>No;</td>
<td>The activity of human kind.</td>
</tr>
<tr>
<td>Intensive</td>
<td>Nutrient run off</td>
<td>zpm {zero, plus, maximum}</td>
<td>Amount of nutrient compounds.</td>
</tr>
<tr>
<td>agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forestry</td>
<td>Afforestation</td>
<td>zpm {zero, plus, maximum}</td>
<td>Planting of trees to make a forest on land</td>
</tr>
<tr>
<td></td>
<td>Deforestation</td>
<td>zpm {zero, plus, maximum}</td>
<td>Deforestation is the clearance of naturally</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>occurring forests by logging and burning.</td>
</tr>
<tr>
<td>Land</td>
<td>Buffer zone</td>
<td>zp {zero, plus}</td>
<td>A zone or an area that serves not for any</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>anthropogenic use but as a conserved natural</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>habitat where plants and animals can thrive.</td>
</tr>
<tr>
<td>River</td>
<td>Water quality</td>
<td>zp {zero, plus}</td>
<td>Water quality is the physical, chemical and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>biological characteristics of water.</td>
</tr>
</tbody>
</table>

3.4.3.2. Quantity space definition (LS3 – 6)

In these models are used the follow QS: QS = {zero, plus} and QS = {zero, plus, maximum}. The quantities: Afforestation and Deforestation (relevant to entity Forestry) can be represent as having three possible magnitudes: QS = {zero, plus, maximum}. The values of this quantity can be interval (plus), but they can to have values above this interval – point (maximum). For quantity Buffer zone and Water quality are used QS = {zero, plus}. Furthermore, these QS can to be used to define process rates {active, inactive}.

The QS of Nutrient runoff is {zero, plus, maximum}. At zero have not nutrient runoff in the water bodies. QS plus there definitely is an normal level of Nutrient runoff. Note that a landmark such as maximum described critical level of nutrients in the water.

The QS of Afforestation and Deforestation are QS= {zero, plus, maximum}. The main idea is that, what is the happen in case intensive Afforestation (QS = maximum) and case intensive Deforestation (QS= maximum). If the process Afforestation dominates, then construction of buffer zones will increase. The process Deforestation has an opposite effect compare with Afforestation.

3.4.3.3. Model fragments

The library of the model about Land – use conflicts consists of 5 model fragments (MF).

The first MF01 represent the connected between Buffer zone (associate with Land) and Biodiversity (referring to Water body). This MF introduces the mentioned entities and quantities. Furthermore, between them have a positive proportionality.

MF02 afforestation vs. deforestation introduces the entities Land and Human activity. This MF also introduces the quantity Afforestation and Deforestation (related with entity Human activity) and quantity Buffer zones (associated with Land).

The next MF – MF03, MF04 and MF05 are children of MF02. They represented different situation of that what is the happen happens in case of intensive afforestation, what happens in case of intensive deforestation and what is the happen if between this processes have balance.

MF03 represent the effects of intensive Deforestation on construction of Buffer zone and consequences decrease of Biodiversity and water quality. This MF establishes that increasing Deforestation decrease construction of
Buffer zone, and that decreasing the Biodiversity in Water body. Furthermore, between above mentioned quantities has direct influence (Deforestation $\rightarrow$ I - $\rightarrow$ Buffer zone).

The MF04 show the influences of intensive Afforestation on construction of Buffer zone and consequences increase of biodiversity. Furthermore, between Afforestation and Buffer zone, have a direct influences (Afforestation $\rightarrow$ I + $\rightarrow$ Buffer zone).

Finally, MF05 establishes that what is the happen if have balance between Afforestation and Deforestation (associated with Human activity).

3.4.3.4. Assumptions explicitly represented in the model (LS6)

This model has three assumptions. These assumptions are applied by including the assumptions with follow label:

Assumption: “Afforestation dominates deforestation” in Sc01 “Afforestation dominates deforestation”;

Assumption: “Deforestation dominates afforestation” in Sc02 “Deforestation dominates afforestation”;

Assumption: “Afforestation vs. deforestation” in Sc03 “Afforestation vs. deforestation”;

3.4.3.5. Scenario and simulation

Intensive agriculture and forestry can exist together, when we use land useful. The intensive agriculture increase the nutrient compounds in water body. That leads to damage of water quality and decrease of biodiversity. This negative effect can be reduced, if you build the buffer zone between river and agriculture area. That will decrease nutrient run off and will increase forest area. This will leads to reduce of conflict between intensive agriculture and forestry (Figure 32).

![Diagram](image)

Figure 32 Initial scenario 03 model about the Land - use conflicts implemented in LS6
Figure 33 Causal model, Sc03

Figure 33 represent causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.

The increase of process deforestation and decrease of afforestation leads to decrease of buffer zone. As a result, biodiversity in water body decrease. That leads to damages of water quality (Figure 34).

Figure 34 Value history diagram of the relevant quantities in behaviour path of the full simulation of the scenario “Land – use conflicts”

Figure 35 represent the state graph of the simulation results obtain of scenarios 02 Deforestation, with full behaviour path.

Figure 35 shows the state graph of the simulation results, with full behaviour path. The simulation produces one initial state, has one end states [2].
3.5. Topic Atmosphere oxygen and ozone (Theme: Global changes)

Figure 36 represents concept map of model about Atmospheric oxygen and ozone.

Figure 36 Concept map of model ‘Atmospheric oxygen and ozone’

3.5.1. Summarize the topic and the literature

The atmosphere is an ocean of air and a precious natural resource for sustaining life on earth. Unfortunately, human activities based on national and personal interests are causing harm to this common resource, notably by depleting the fragile ozone layer, which acts as a protective shield for life on earth [16].

“Radiation is the driving force for the general circulation of the atmosphere and controls the Earth's climate. Ozone is responsible for the warm stratosphere and protects life on Earth from harmful solar ultraviolet radiation” [17].

It was discovered that chlorofluorocarbons (CFCs) are agents that can destroy stratospheric ozone under the influence of ultraviolet light. However, the government refused to act since the mechanisms involved in ozone destruction were by then not fully understood [18].

3.5.2. Model objectives

The goal of the model is to demonstrate the main effects of chlorofluorocarbon flow on depletion of ozone layer. The consequence of ozone layer depletion is damage of human health.

The main questions are:
1. How chlorofluorocarbon flow influence ozone depletion?
2. What happens in case the ozone production process dominates?
3. What happens in case of the ozone reduction process dominates?
4. How does ozone depletion influence human health?

3.5.3. Model structure

System structure of the model about Atmospheric oxygen and ozone is show of figure 37.
3.5.3.1. Structure, entities and quantities

The entity hierarchy for model “Land – use conflicts” is presented in Figure 38. The main entities are divided into 3 groups “Human activity”, “Land” and “Water body”. The main entities involved are “Afforestation” and “Deforestation” as Human activity entities (Table 6).

Table 6 Entity, Quantity and Quantity space used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>UV radiation</td>
<td>zp {zero, plus}</td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>Reduction rate</td>
<td>zp {zero, plus}</td>
<td>Reduction rate of ozone</td>
</tr>
<tr>
<td></td>
<td>Production rate</td>
<td>zp {zero, plus}</td>
<td>Production rate of ozone</td>
</tr>
<tr>
<td></td>
<td>Ozone amount</td>
<td>zp {zero, plus}</td>
<td>Amount of ozone in the atmosphere</td>
</tr>
<tr>
<td>Human</td>
<td>Health</td>
<td>lph {low, point, high}</td>
<td>Health of human kind</td>
</tr>
<tr>
<td></td>
<td>Chlorofluorocarbon flow</td>
<td>zpm {zero, plus, maximum}</td>
<td>Emit of chlorofluorocarbon of human</td>
</tr>
</tbody>
</table>

3.5.3.2. Quantity space definition (LS3 – 6)

In these models the following QS are used: QS = {zero, plus}, QS = {zero, plus, maximum} and QS = {low, point, high}. The quantities: Reduction rate and Production rate (relevant to entity Ozone) are represented as having two possible magnitudes: QS = {zero, plus}. The values of this quantity can be interval (plus), but they cannot to have values above this interval – point (maximum). For quantity Ozone the QS = {zero, plus} is used.

The QS of Chlorofluorocarbon runoff is {zero, plus, maximum}. At zero there is no Chlorofluorocarbon runoff into the atmosphere. At QS plus there definitely is a normal level of Chlorofluorocarbon runoff. Note that the landmark maximum describes the critical level of Chlorofluorocarbon runoff in the atmosphere.

The QS of human health is QS = {low, point, high}. If the chlorofluorocarbon flow is at maximum, then the depletion of ozone will decrease.
3.5.3.3. Model fragments

The Atmospheric oxygen and ozone model consists of 4 model fragments (MF). Three of them are children of MF01 Ozone production.

MF01 introduces the following entities: Ozone, Atmosphere and Human. The quantities, which represent this MF are Production rate, Reduction rate and Amount of ozone (related with entity Ozone); UV radiation (related with entity Atmosphere) and Health (associate with entity Human). Furthermore, between Reduction rate and Amount of ozone there is a negative direct influence (Reduction rate $\rightarrow$ Amount of). Production rate increases Amount of ozone, and between them there is a positive influence.

The next MF – MF03, MF04 and MF05 are children of MF02. They represent different situations of that what is the happen happens in case of intensive afforestation, what happens in case of intensive deforestation and what is the happen if between this processes have balance.

3.5.3.4. Assumptions explicitly represented in the model (LS6)

This model has three assumptions. These assumptions are applied by including the assumptions with follow label:

Assumption: “Production rate dominates reduction rate” in “Sc01 Production dominates”;

Assumption: “Reduction rate dominates production” in “Sc02 Reduction dominates”;

Assumption: “Reduction rate is equal to production rate” in “Sc03 Production is equal to reduction”;

3.5.3.5. Scenario and simulation
Figure 39 Initial scenario Sc01 model about the Atmospheric oxygen and ozone implemented in LS6

Figure 39 represent a scenario implemented in LS6. In this scenario production rate dominates the reduction rate.

Figure 40 Causal model, Atmospheric oxygen and ozone

Figure 40 represent causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.

Figure 41 represent the value history diagram of the relevant quantities in behaviour path of the full simulation of Sc01. The process production increases the amount of ozone and the process reduction decreases the amount of ozone, which leads to increase of amount of ozone and decrease of UV radiation in the earth. As a result, human health will increase.

Figure 41 Value history diagram of the relevant quantities in behaviour path of the full simulation of the scenario “Atmospheric oxygen and ozone”

Fig. 42 shows the state graph of the simulation results, with full behaviour path. The simulation produces one initial state, has one end states in Sc01 Ozone production

Figure 42 represent the state graph of the simulation results obtain of scenarios Sc01 Ozone production, with full behaviour path.
3.6. Topic Reproductive strategies (Theme: The Living world)

Figure 43 shows the main entities of the model about Reproductive strategies. The focus is on asexual reproduction, particular parthenogenesis.

Figure 43 Concept map of model “Reproductive strategies”, Asexual reproduction, Parthenogenesis

3.6.1. Summarize the topic and the literature

Parthenogenesis is a form of asexual reproduction found in females, where growth and development of embryos occurs without fertilization by a male. Parthenogenetic animals receive all of their genes from one parent and therefore no new gene combinations are created. It may seem that this method of reproduction would put species that use it at a competitive disadvantage to sexually reproducing animals but it may be advantageous in some cases. To reproduce, a sexually reproducing organism must first find a mate and then combine gametes with this mate. This process requires a great deal of time and energy, and it may well result in no offspring. Parthenogenesis organisms do not experience this cost of reproduction and therefore usually can reproduce sooner after birth and produce more offspring [19].

3.6.2. Model objectives

The goals of the model are to demonstrate the main effects of environmental conditions on the type of reproductive strategies.

The main questions are:

1. What happens to the reproductive strategies in case of favourable conditions?
2. What happens to the reproductive strategies in case of unfavourable conditions?
3.6.3. Model structure

Figure 44 represent the system structure of model about Reproductive strategies.

![Figure 44](image)

Figure 44 Configurations relating the different entities

3.6.3.1. Structure, entities and quantities

The entity hierarchy for model “Reproductive strategies” is presented of figure 45. The main entities are divided into 3 groups “Environment”, “Population” and “Reproductive strategies”. The main entities involved are “Female individuals” and “Male individuals” and “Offspring” as Population entities (Table 7).

![Figure 45](image)

Figure 45 Entity hierarchy of model about “Reproductive strategies” in LS6

Table 7 Entities, Quantities and Quantity spaces used in different LS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Conditions</td>
<td>Fzu {favourable, zero, unfavourable}</td>
<td>The size of the rural population</td>
</tr>
<tr>
<td>Female individuals</td>
<td>Number of</td>
<td>Zp {zero, plus}</td>
<td>The number of individuals the female population</td>
</tr>
<tr>
<td>Male individuals</td>
<td>Number of</td>
<td>Zp {zero, plus}</td>
<td>The number of individuals the male population</td>
</tr>
<tr>
<td>Offspring</td>
<td>Number of</td>
<td>Zp {zero, plus}</td>
<td>The number of individuals the offspring population</td>
</tr>
<tr>
<td>Reproductive strategies</td>
<td>Sexual reproductive</td>
<td>Zp {zero, plus}</td>
<td>Form of reproduction in which an organism creates a genetically-similar or identical copy of itself without a contribution of genetic material from another individual.</td>
</tr>
</tbody>
</table>
Asexual reproductive Zp \{zero, plus\} Process of biological reproduction by which organisms create descendants that have a combination of genetic material contributed by two different gametes, usually from two different organisms.

3.6.3.2. Quantity space definition (LS3 – 6)

The QS, which are used in these models, are QS = \{zero, plus\}. The Number of male and female individuals and offspring have QS = \{zero, plus\}. Asexual and sexual reproductive strategies have QS = \{zero, plus\}. Furthermore, they can to exist or not exist. They cannot to be below zero or above plus.

For quantity Conditions, QS = \{favourable, zero, unfavourable\} is used.

3.6.7.4 Model fragments

The Reproductive strategies model consists of 5 model fragments (MF).

MF01 introduces the following entities: Population, Male individuals and Female individuals and Offspring. The quantities, which are represented in this MF are Number of (associated with Male individuals), Number of (associated with Female individuals) and Number of (related with entity Offspring). Furthermore, between Number of and Female individuals there is a positive proportionality (P+).

MF02 represents the entity Reproductive strategies, and quantities sexual and asexual reproductive strategies. Between them there is a negative proportionality (Asexual → P- → Sexual).

MF03 introduces the entity environment and its quantity condition.

The most important MF are MF4 and MF5. MF04 represents the main effects of environmental conditions on the type of reproductive strategies. Furthermore, between the value favourable (associated with the quantity condition) and the value plus (Asexual reproductive rate) there is a correspondence. There is a similar correspondence between the value unfavourable (associated with quantity condition) and the value plus (sexual reproductive rate).

MF05 represent the effect of conditions on the different populations.

3.6.3.3. Assumptions explicitly represented in the model (LS6)

In this model do not have assumption.

2.6.8.1 Scenario and simulation

In figure 46 is show model about reproductive strategies implemented in LS2 - Binary fission (asexual reproductive strategy).
Figure 46 Expression in LS2, Binary fission

Figure 47 Initial scenario Sc01 Asexual reproductive strategies vs. Sexual reproductive strategies implemented in LS6

Figure 48 Initial scenario 02 Environmental condition implemented in LS6

Figure 49 represent causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.
Figure 49 Causal model, Sc01

Figure 50 represents the value history diagram of the relevant quantities in behaviour path of the full simulation of Sc02. The increase of favourable condition, leads to increase of asexual reproductive strategies (parthenogenesis).

Figure 50 Value history diagrams of the quantities in relevant behaviour path of the full simulation of the Sc01 Asexual reproductive strategies vs. Sexual reproductive strategies

Environment: Conditions

Figure 51 Value history diagrams of the quantities in behaviour path of the full simulation of the Sc01 Environmental condition

Figure 52 represent state graph of the simulation results, with behaviour path. The simulation produces two initial states in Sc02 Asexual reproductive strategies vs. Sexual reproductive strategies. The next figure 53 represents Sc01 Conditions.
Fig. 52 state graph of the simulation results, with behaviour path. The simulation produces two initial states in Sc01 Asexual reproductive strategies vs. Sexual reproductive strategies

Fig. 53 state graph of the simulation results, with behaviour path. The simulation produces two initial states in Sc01 Environmental condition

3.7. Topic Biodiversity (Theme: The living world)

While resources are becoming scarce and the Earth’s carrying capacity approaches, there is a tendency to develop and to apply environmental oriented legislation in order to discipline the organization and functioning of companies, institutions and the governments and to protect the environment for future generations.

Figure 54 Concept map of the model “Biodiversity”
This model presents how the introduction of invasive species influences the increase of food competition and the decrease of native species (Figure 54).

3.7.1. Summarize the topic and the literature

"One of the greatest threats to loss of biodiversity is invasive species. Their negative impact on biodiversity is expressed in violation of local ecosystems and their functions, as well as reduces or destroys populations of native species - through competition and predation. Invasive species cause great damage that has significant financial dimension. Cruise ships, large tankers, and bulk cargo carriers use a huge amount of ballast water, which is often taken on in the coastal waters in one region after ships discharge wastewater or unload cargo, and discharged at the next port of call, wherever more cargo is loaded. Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems. Due to factors such as human modifications to the environment, overexploitation, habitat loss, exotic species and others, aquatic biodiversity is greatly threatened. Ecosystems and species important in sustaining human life and the health of the environment are disappearing at an alarming rate. In order to preserve these threatened areas and species for future generations, immediate action in the form of aquatic biodiversity conservation strategies are necessary. In general, aquatic conservation strategies should support sustainable development by protecting biological resources in ways that will preserve habitats and ecosystems. In order for biodiversity conservation to be effective, management measures must be broad based”.

(from wikipedia)

3.7.2. Model objectives

The objectives of the models are to represent food competition between two populations – native and invasive. The models demonstrate the main effects of an increasing of invasive population.

The main question is:

What happens if the invasive population increases?

3.7.3. Model structure

Figure 55 Configurations relating the different entities

Figure 55 represents system structure of model about biodiversity implemented in LS6.

3.7.3.1. Structure, entities and quantities

The entity hierarchy for model “Biodiversity” is presented in figure 46. There is only one entity in this model: “Environment”. (Table 8)
Figure 56 Entity hierarchy of model about Biodiversity in LS6

Table 8 Entity, quantity and quantity space

<table>
<thead>
<tr>
<th>Entity</th>
<th>Quantity</th>
<th>Quantity space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Food competition</td>
<td>zsml {zero, small, medium, large}</td>
</tr>
<tr>
<td></td>
<td>Invasive population</td>
<td>zsml {zero, small, medium, large}</td>
</tr>
<tr>
<td></td>
<td>Native population</td>
<td>zsml {zero, small, medium, large}</td>
</tr>
<tr>
<td>Anthropogenic activity</td>
<td>Discharged of ballast water</td>
<td>zp {zero, plus}</td>
</tr>
</tbody>
</table>

3.7.3.2. Quantity space definition (LS3 – 6)

The QS of quantities food competition, native population and invasive population are {zero, small, medium, large}.

3.7.3.3. Model fragments

This model contains 2 Model fragments (1 static and 1 process).

MF01 introduces entity Environmental with quantities Native species, Invasive species and Food competition. Furthermore, MF01 establishes that if River runoff increases, the Native species will decrease, and the invasive species will decrease..

A MF02 is used to implement the knowledge needed for determining the amount of water intake and the river runoff magnitude and derivative. Furthermore, amount of water intake has a proportionality relationship (P-) with river runoff. Between QS of these quantities there is an opposite full correspondence.

3.7.3.4. Assumptions explicitly represented in the model (LS5 and LS6)

This model has not assumptions.

3.7.3.5. Scenario and simulation

This model’s version includes one scenario (Figure 57), which includes initial values: large native population and small number of invasive population, small food competition between these populations and an increasing discharge of ballast water.
Figure 57 Scenario about the Biodiversity implemented in LS6

Figure 58 Causal model – Biodiversity

Figure 58 represent causal model. The causal model indicates all the entities (square boxes) and quantities (rounded boxes) involved in the simulation and their values and derivatives in the state.

Figure 59 shows the value history diagram of the quantities in selected behaviour path. If the discharge of ballast water increases, then invasion population will also increase. As a result, food competition will increase, which leads to a decrease of the native population and loss of biodiversity.
Figure 59 Value history diagram of the quantities in selected behaviour path of the simulation of the Sc01 “Biodiversity”

The end-states in model about biodiversity in LS6 is one – [15].

Figure 60 Behaviour graph and end states obtained of the simulation in model about “Biodiversity” in LS6
4. Discussion

This phase of the DynaLearn project, CLGE partners involved in WP6 developed simple models and educational material about basic concepts in each topics presented in this Deliverable. For each model, the domain expert has provided model meta-description, along with supporting scientific literature about the concepts addressed in the model. CLGE developed learning curricula for two most common categories of water bodies – rivers and lakes, which are the main source of water resources for humans (Earth Systems & Resources) including their riparian/fringing communities (The Living World).

For each topic, different models were developed in different learning spaces to accentuate different aspects of the system. The foci correspond with the learning goals associated with the models. The learning spaces used to implement the models in this deliverable are as follows:

- Learning space 1: Concept map. This LS consist of nodes and relationships, and aims to define the vocabulary used to talk about the system.

- Learning space 2: Basic Causal model. LS2 focuses on the causal relationships between the quantities in the system. This LS allows construct of simple models with structural systems and relations (e.g. see model about Binary fission). The learner can create simple models with small number of entities and quantities, and continue with more complex level.

- Learning space 3: Basic Causal Model + State Graph. LS3 aims to define the qualitatively distinct states that are important in the system. That is, it defines quantity spaces for the most important quantities. This learning space enables the learner to identify the real qualitative values and thresholds in ecological systems (e.g. see models about Urbanization and/or Legislation).

- Learning space 4: Causal differentiation. LS4 makes a distinction between processes and quantities that propagate causality (it distinguishes influences from proportionalities). As such, processes can now be correctly represented. This LS provides learners with different forms of qualitative causal relations (e.g. see models about Land-use conflicts and/or Fossil fuels).

- Learning space 5: Conditional knowledge. LS5 is similar to LS4, but allows the modelling of conditional knowledge.

- Learning space 6: Generic and reusable knowledge. LS6 models the knowledge in the model in separate model fragments. The scenarios describe different initial situations of the system from which different simulations can be run. This learning space allows construct a model using generic and reusable knowledge (e.g. see Biodiversity and/or Atmospheric oxygen and ozone models).

The developed models are part of a larger set which covers the most important topics in the Environmental Science curriculum. For a complete overview of the topics in this curriculum consult D6.2.1 through D6.2.5.
5. Conclusion

This deliverable discusses a set of successfully implemented qualitative model for the DynaLearn Environmental Science curriculum. The model topics come from the themes Earth systems and resources, Water cycle, Thermal dynamics in freshwater bodies, The living world, Human population, Land and water use, Pollution, Global changes. Particularly the following topics are addressed: Biodiversity, Reproductive strategies, Urbanization, Legislation, Land – use and conflicts, Intensive agriculture, Energy resources and consumption, Secondary production, Fossil fuels, Dynamic aspects of dispersion and distribution of conservative pollutants, Dynamic aspects of dispersion and distribution of conservative pollutants, Climate changes, Atmospheric oxygen and ozone.
References


[3] Pataki D., Alig G., Fung A.,


[7]. Uzunov Y, 2005, Ecosystem approach in integrated water management in Bulgaria: bridging the objectives of CBD and WFD in biodiversity of aquatic biota. Expert Workshop CBD & WFD, Isle of Vilm, Germany


