A System Dynamics Model to explore the water-land-energy-food-climate Nexus in Latvia

Masia S.[1], Sušnik J.[1,*], Indriksone D.[2], Bremere I.[2], Vamvakeridou-Lyroudia Ls.[3,5], Brouwer F.[4]

[1] Integrated Water Systems and Governance Department, IHE Delft Institute for Water Education, Delft, The Netherlands

[2] Baltic Environmental Forum, Riga, Latvia.

[3] Centre for Water Systems, College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QF, UK

[4] Wageningen Economic Research, PO Box 29703, 2502LS The Hague, The Netherlands

[5] KWR Watercycle Research Institute, 3430BBNieuwegein, The Netherlands

[*] corresponding author: e-mail: j.susnik@un-ihe.org

Abstract

Water, energy, food/land use and climate are connected a system defined by complexity. The characteristics of the nexus change depending on the scale, location, and the sectors of interest. System dynamics modelling (SDM) is an approach developed for studying complex systems, and has found widespread application in the environmental and natural sciences. Disparate sectors can easily be combined and interlinked in one coherent modelling environment. SIM4NEXUS (www.sim4nexus.eu) is developing serious games for 12 case studies. The SDM and baseline results are presented for the Latvia case study. The principle nexus sectors of interest are land use, energy, and water quality. Of particular interest is the drive towards a low carbon economy through the cultivation of energy crops. However this may hinder other targets such as increasing food security, and improving water quality and biodiversity. The SDM captures critical elements, dynamically linking the nexus sectors with a focus towards the biofuel and energy, and the concomitant impacts on the water, land and climate sectors. Policy options, developed with local stakeholder groups, are to be included to assess nexus-wide impacts of current, and potential future, policy directions within Latvia.

Keywords: Latvia; nexus; system dynamics; water-energy-food-land-climate.

1. Introduction

Water, energy, food, land and climate exist in a 'hyperconnected' system (WEF, 2016). Globally, there is increasing interest in the nexus and potential implications for business (World Bank, 2016; IMechE, 2013; EEA, 2015). The nexus has global relevance, however global issues often require local actions. Full understanding of this nexus and characterization of its internal feedbacks is required in order to be able to make informed, meaningful (policy) decisions. Efforts are required to consider many nexus sectors together at a range of scales to develop a more general understanding of nexus behaviour. In this respect, the ongoing EC Horizon 2020 project SIM4NEXUS (www.sim4nexus.eu) is developing bespoke system dynamics models (SDMs; Ford, 2010) for 12 case studies in scale from sub-national to global. The Latvian case is the focus of this paper. The development process of the Latvian case study is presented, along with a description of the final developed SDM, presentation of initial results, and the relevance for Latvian policy.

2. Case Study

Latvia borders Estonia, Lithuania, Russia, Belarus, and the Baltic Sea. It has a population of c. 2 million inhabitants. Forests cover 48% of the land, with agricultural land occupying 38% of the surface. Wholesale, retail and transport are important economic sectors, while timber, and forestry are important industrial sectors. Low-carbon development is the key focus of the Latvia case study. Latvia is seeking opportunities to reduce energy dependency from imported fuels, increase sustainable use of renewable energy sources and ensure economic development while reducing greenhouse gas emissions. Latvia has high potential for renewable energy. At the same time along with significant reduction of total greenhouse gas (GHG) emissions since 1995, the current level of GHG emissions in Latvia remains high. Increasing use of bio-resources and renewable energy sources can be considered as one option. But such options concerns about the trade-offs of renewable energy production such as: harvesting of biomass puts pressure on forestry and growing energy plants compete with crops and food production. Growing energy plants requires a large amount of fertilizer, resulting in detrimental impacts on water quality. Preparedness to mitigate climate change and reduce adverse effects is becoming of high importance for national economy. In Latvia, low carbon development is getting increasing attention on various policy levels along with elaboration of the "National strategy on low-carbon development 2050" and the "National Energy and Climate Plan 2021-2030". Acknowledging the need to increase the use of natural resources, a national strategy "Bio-economy strategy 2030" has been elaborated. According to the strategy, the priority directions comprise promotion and

maintenance of employment level and added value of products in a bioeconomy. The SIM4NEXUS Latvian SDM will focus on these issues.

3. Development Of The Case Study

The conceptual model for the Latvian case includes the forestry, land and agricultural sectors which stand out stand out, together with the energy sector. There is a trade off in the land sector between land used for agriculture and land used for forestry, both of which contribute to energy production in Latvia. Each nexus sector is elaborated in further detail. As a brief example of this elaboration, the forestry sector specifies the area of forest cultivation, the volume of forest felled, the processing of forestry products and their demand, both for export, timber products and for energy generation purposes. The finalized conceptual model was used as the basis to develop the SDM. STELLA (www.iseesystems.com) was used to develop and run the SDM. Figure 1 shows screenshots of the developed Latvian SDM. Solid lines indicate a variable in one nexus sector (e.g. land) is recalled in another (e.g. water, food), implying that a change made to that variable in land will have an impact on results in the food and water sectors. Figure 1 shows the detailed sub-model developed for the land nexus sector. Urban and infrastructure land is quantified, as are solar and wind installations, even though the area of these land uses is very small. Agricultural land is entirely rainfed, and is broken up into two classes, wheat which is of economic importance, and others. The area of crops grown specifically for energy uses is also quantified. Forestry has its own sub-model within which this sector is defined in more detail (Figure 1). The forestry sector is represented by protected land on which no commercial activity can take place, and productive forestry land which itself is split by the area under cultivation for future felling and production, and the area actively being felled for production. The other nexus sectors (water, energy, food, climate) are similarly developed. Data within SIM4NEXUS come from a number of sources. The model is run at monthly timestep for baseline (2000-2017) and future (2018-2050) periods. The impacts of changes due to climate and local policy measures on the entire nexus in Latvia is assessed through the interactions between all nexus sectors.

4. Results

Wheat and other cereals are shown to dominate, although a small recent growth in organic crops and ‘other’ crops is shown. In terms of the forestry sector, protected areas make up a significant proportion of the total, while cultivation and felling form smaller areas, even though economically these sectors are important in Latvia. For the energy sector, imports of primary energy are dominated by oil and natural gas. In terms of exports, oil and biomass dominant. Imports are approximately double exports.

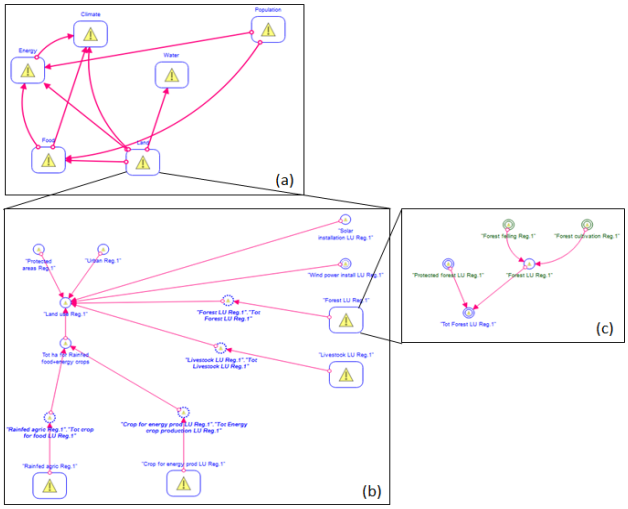

Figure 1. part of the developed SDM for Latvia, showing (a) the top-level of the nexus system; (b) the detail for the land sector and; (c) additional detail for the forestry sector within the land sector.

The importance of wheat and cereals for Latvian food production, and of forest products for Latvian energy generation is highlighted in the results. Latvia is striving towards a low-carbon economy based largely on energy from biomass. This is reflected in the area dedicated to forestry energy products, and is reflected also in the proportion of biomass-based energy exports. Considering the whole nexus, while such a shift will have beneficial impacts for the climate sector in particular by reduction of CO_2-e emissions, there are perhaps negative consequences to the water and food sectors. Increased forestry production could lead to adverse water quality impacts, and therefore needs to be strictly controlled and monitored. For food, if additional land is taken over for forestry, the implication could be less land for local food production. This could lead to greater food imports, and an increased reliance on other nations for food supply and vulnerability to global market prices. Future work will further elucidate these cross-nexus impacts and suggest nexus-wide coherent policy strategies to minimize negative impacts resulting from development and the transition to a low-carbon economy in Latvia.

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