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Integrated assessment of agricultural policies with dynamic land use change modelling☆

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ABSTRACT

With about half of its territory being farmed, agriculture is the main land use in the European Union (EU). As over 10% of the total EU manufacturing output comes from the agri-food sector, it also is an economic factor of great importance. Moreover, EU policy in this sector has far-reaching consequences ranging from the EU's status as a global trade partner to landscape preservation and development. The LUMOCAP Policy Support System is targeted towards policy makers in the European Commission (EC) and its Member States (MS) and aims to provide support in the field of sustainable agricultural and rural development. To this end it incorporates an integrated model with socio-economic and bio-physical processes, operating at different spatial scales. For supporting integrated assessment, a large number of policy levers is included as inputs for these models and outputs are transformed into policy-relevant social, economic and environmental indicators. The whole system is framed in a flexible, modular and easy to use software package that is useable for process experts and policy-analysts alike.

This paper describes the integrated model, the individual models and a first calibration of the system. It demonstrates the system's behaviour for typical scenario runs and concludes with a reflection on the current status of the system and some recommendations for further development.

1. Introduction

As agriculture covers about half of the territory of the European Union (EC, 2007a), the Common Agricultural Policy (CAP) (EC, 2005) is an important driver for land use structure and landscape quality. The emphasis of the early CAP was to promote agricultural productivity and supporting farmers' incomes. In recent years its focus has shifted more and more to rural development, including the preservation of landscapes and sustainability of agri-ecosystems through facilitating a proper management of natural resources (EC, 2006a). The LUMOCAP project – Dynamic Land Use change MOdelling for CAP impact assessment on the rural landscape – directly contributes to an assessment of the impact of policies targeting these objectives.

The LUMOCAP Policy Support System (PSS) aims to assess how different policy scenarios will impact the land use and landscape in the 27 Member States of the European Union (EU-27). Because of the inherent complexity of land use change processes, agricultural policies at the European level have their effect not only on developments in the agricultural sector, but also on for instance regional ecological coherence and socio-economic dynamics of rural areas. This means that a model for policy impact assessment should reach beyond EU agricultural policies and include policies and processes at other levels and sectors such as local zoning regulations, infrastructure planning and interaction between sectors as well as external factors like climate change and socio-economic drivers. The LUMOCAP PSS allows investigating the relation between EU policies, agricultural economics, land suitability and land use dynamics through dynamic simulation. It incorporates an integrated model, tools to set-up scenarios for (a combination of) policy measures and external factors and tools to visualise and analyse indicators.

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Over the past years different systems have been developed with the aim to provide support to policy makers in the field of agriculture and rural development. These can be divided in two main groups: those focusing on a comprehensive modelling of the agricultural sector like CAPRI (Britz and Witzke, 2008) and SEAMLESS-IF (Van Ittersum et al., 2008), and the Integrated Decision Support Systems (IDSS) like EURURALIS (WUR and MNP, 2007), the SENSOR SIAT tool (Sieber et al., 2008) and the LUMOCAP PSS focusing on broader issues of land use and land use change. Compared to the agricultural systems, LUMOCAP includes a wider variety of sectors at the cost of detail in the agricultural sector; it has less focus on (agricultural) economics and more on the reciprocal relation between economics and land use.

As a result, different mechanisms for integrating model components have been used. CAPRI and SEAMLESS-IF calculate an (equilibrium) end-condition and use iterations to obtain the results for a selected end-year. Similar to SEAMLESS-IF and CAPRI, the SIAT tool calculates an end-condition, instead of a development over time. LUMOCAP includes a simulation model that calculates future developments in yearly time steps based on the set of drivers incorporated. Results for each year build on the results from the year before. This allows for mutual interactions between the economic and the land use components during each simulation step.

Only two systems, EURURALIS and LUMOCAP, model EU-27 at a high level of spatial detail (1 km grid cells or less). However, the interaction between models operating at different spatial scales is different. In EURURALIS land use demands are calculated by models at national level and subsequently allocated to 1 km grid cells. LUMOCAP incorporates four spatial scales (EU, national, regional and local) and there is top-down as well as bottom-up interaction. An example of the bottom-up interaction is that results from models at local level (land use and land suitability) are used in the economic model at European level.

Another distinguishing characteristic between the systems is the inclusion of models in them. EURURALIS pre-calculates different scenarios and provides the results in the EURURALIS tool, while in LUMOCAP, SEAMLESS-IF and CAPRI, the actual models are incorporated. Incorporation of the models allows users of LUMOCAP to have access to their underlying data and parameters and to create and run scenarios based on any combination of policy options and external factors included in the model, without having to resort to the developers team. The SIAT tool incorporates simplified relations – named response curves – that are derived from existing models. By incorporating the actual models instead of simplified relations LUMOCAP incorporates detailed process knowledge into the system which enables to focus on the interaction between models at each time step.

This paper gives an overview of the integrated model incorporated in the LUMOCAP PSS. First an overview of the integrated model is provided, followed by a detailed description of each of the individual models. Subsequently we describe the procedure used to test and calibrate the model and provide the main results of the calibration and typical scenario runs. The paper closes with a reflection on the current status of the system and some recommendations for further development.

2. The integrated model

The core of the LUMOCAP PSS consists of a selection of models, all linked into a single integrated model simulating the linked bio-physical and socio-economic developments in the entire European Union (EU-27) up to 30 years forward. To capture processes occurring at different spatial scales, the system includes models operating at four different levels: EU-27, country (the Member States of EU-27), region (so-called NUTS 2 regions, which approximately match provinces within the Member States; NUTS standing for Nomenclature of Territorial Units for Statistics in the European Union) and local. At local level the system operates at a 1 km grid for EU-27 and at a 200 m grid for selected case regions. The temporal resolution of the system is a year, its temporal horizon 2030. The different models and their linkages are schematised in the system diagram in Fig. 1. This section provides an overview of the models and their interactions. Details about the individual models are described in the next section.

2.1. European-wide agricultural production and socio-economic factors

At the highest spatial level of the model, EU-27, the LUMOCAP agricultural economic model (Section 3.1) calculates acreages per crop type, average yields and production. Expectations regarding growth or decline of population, Gross Domestic Product (GDP) and jobs are seen as external driving forces and can as such be entered and/or adapted in the socio-economic scenario component. Climate change scenarios can also be selected at this spatial level.

Some of the socio-economic drivers (GDP, inflation, market prices and population) are used as input in the agricultural economic model. Population, jobs and the acreages per crop type are disaggregated from EU level to the national level. Climate change (rainfall and temperature) directly impacts the land suitability model at local level.

2.2. Competition between countries and regions for allocation of activities

A spatial interaction and distribution model (Section 3.2) disaggregates population, jobs and hectares for different crop types to the second spatial level, the individual Member States. Within each country a second spatial interaction model distributes the national figures to the NUTS 2 regions. The relative attractiveness of the countries and regions plays a crucial role in the migration and distribution of activities and the allocation of crop areas. The spatial interaction models simulate the competition between countries and regions respectively and use a cross-sectoral approach, in which agricultural activities become integrated with the other socio-economic activities (jobs in other sectors and population). At regional level, activities are converted to land use demands (areas per land use category) that are then fed to the next spatial level.

2.3. Local dynamics simulating changes in land use and land suitability

Within the NUTS 2 regions, a constrained cellular automata model (CCA) allocates the area demands for the different land use categories – as calculated by the regional spatial interaction model – to cells of 1 km × 1 km (Section 3.3). This model is used for broad land use categories (residential areas, industry & commerce, recreation, agriculture, forest and natural vegetation) and simulates the competition for space between land use categories, in order to obtain the most preferential locations. Since this model is not very well suited to simulate crop choice decisions, a separate model is used to determine what crops will grow on the agricultural land, and where. The third model at local level calculates the land suitability for different crop types for each location, based on local characteristics and impacts of climate change. Results of the land suitability model are used for the allocation of the broad land use categories and crop types in the land use and the crop choice model, respectively. Aggregate suitability information is used as one of the factors determining the attractiveness of countries and regions in the spatial interaction models at regional and national level and in the agricultural economic model at EU level. In these