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Exploring land use trends in Europe: a comparison of forecasting approaches and results

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Abstract: Over the past years several studies have explored future land use trends for Europe. This paper presents a comparison of six land use studies for Europe that explore land use changes until 2020/2030. We compared these studies with respect to qualitative as well as quantitative aspects. The qualitative analysis shows that many studies focus on agricultural land uses and therefore draw on detailed agricultural models, while only few include urban developments. The purpose of about half of the studies is to provide land use outlooks, while the other half used scenarios to test the behaviour of scientific models or show their potential applicability. For the quantitative comparison we considered the results of their reference and alternative scenarios. This comparison shows that there is a large difference between the projected results provided by the different outlooks. We even found that alternative scenario outcomes *within* a single outlook study are more similar than the results of reference scenarios *between* outlook studies. To a large extent this can be traced back to the differences in initial data sources, data pre-processing and model assumptions. To exclude the impact of differences in initial data, also relative changes were computed. Results from this analysis show a large range of values, which indicates a large uncertainty in the results of land use outlooks. We suggest using all results as the plausibility space for future land use changes. Many studies have kept the values of drivers within a rather limited range, while in reality larger shocks may well be possible.

***Keywords**:* land use change; integrated modelling; land use modelling; comparative analysis; forecasting; Europe.

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1 INTRODUCTION

Over the past decade modelling land systems has evolved from a disciplinary science with models such as CLUE (Verburg et al., 1999), Sleuth (Clarke et al., 1997) and Metronamica (RIKS, 2009) to an interdisciplinary science in which the original land use models are coupled with other disciplinary models related to the land system, thus creating integrated models such as the Environment Explorer (Engelen et al., 2003), MedAction (Van Delden et al., 2007), SEAMLESS (Van Ittersum et al., 2008), SENSOR-SIAT (Sieber et al., 2008), and LUMOCAP (Van Delden et al., 2010). Besides a focus on model integration, enhanced software capabilities also facilitate modelling larger areas, which has resulted in a number of large scale integrated land use models. Using these systems a range of land use outlooks for Europe has been prepared. However, it is unclear to what extent results from these studies are similar or different. Currently studies are available that qualitatively compare various integrated modelling approaches (Helming et al., 2012) or quantitatively compare the results of disciplinary land use (allocation) models (Pontius et al., 2008). However, no information is yet available on the comparison of the different land use outlooks for Europe, nor about a quantitative comparison of a range of (integrated) land use models to the same area. This study aimed to provide such a comparison based on a review and analysis of existing land use outlooks for Europe for the period 2020/2030. The overview focuses on the qualitative and quantitative aspects of the various studies and provides information on the scope, drivers, methods and results, with the intention to discuss to what extent existing studies could be used for general statements on the future of European land use.

Section two describes the methodology, including the criteria for selecting land use outlooks and the characteristics based on which they are compared. Section three provides the results of the qualitative and quantitative comparison. The paper concludes with the main findings of this study in section four.

2 METHOD

For the selection of land use outlooks, we considered the following criteria:

- The study area should preferably cover the 32 member countries of the EEA plus the countries of the West Balkans that have participated actively in the European Environmental Information and Observation Network (EIONET) for many years.
- The studies should be able to provide information for the period 2020/2030.
- Quantitative results from the studies should be available for the comparison and have preferably been presented in reports, presentations and/or scientific publications.
- The range of selected studies should show a balance in the organisations commissioning the studies and the organisations providing the service.
- The range of studies should provide information on both land use patterns (including a wide range of land uses) and intensity trends in individual land use types.

According to the criteria set above, we selected 6 outlook studies for which qualitative and quantitative information was available for comparison[iii]. These studies are:

1. SCENAR 2020-II (SCENAR-II): outlooks study for DG Agriculture and Rural Development on the future of agriculture and associated trends in rural areas. An update of this study was carried out in 2009 (Nowicki et al., 2009).

[iii] The study included 11 land use outlook studies for Europe, but only for 6 of them quantitative information was available. We therefore decided to focus this paper on 6 studies.

2. Land-use modelling – Implementation (LUM-Implementation): a study commissioned by DG Environment to develop a framework for land use modelling for DG Environment (Pérez-Soba et al., 2010).
3. Fertilizers Europe (previously known as EFMA) studies (EFMA Forecast) presenting forecasts of food, farming and fertilizer use in the European Union for ten years in the future (EFMA, 2009).
4. Results of the ETC-LUSI outlook study that focuses on the influence of biofuels on land use in 2020, commissioned by EEA (Elbersen et al, 2012).
5. SENSOR: an EC RTD FP6 project on sustainability impact assessment: tools for environmental, social and economic effects of multifunctional land use in European regions (Helming et al., 2008).
6. LUMOCAP: an EC RTD FP6 project on dynamic land use change modelling for CAP impact assessment on the rural landscape (Van Delden et al., 2010).

The selection of land use outlooks was compared on several characteristics. These characteristics cover the results as well as the methods (models) that were used to generate these results.

Quantitative results of the studies were not directly comparable, in terms of the definition of their land use classes and spatial units. Additionally some studies provided results as time series while others only yielded information for a specific year. Therefore results were processed to make them more comparable. For this we aggregated land uses in mutually exclusive classes (built-up land, cereals, oilseeds, set aside & fallow, fodder, other arable land, grassland and permanent crops and the average yields for cereals and oilseeds) and compared results on a time graph. As all studies used the country level as one of the spatial units, data was processed at this level and next aggregated to selected groups of countries: EU-15, NMS-10 and NMS-2[iv] for presentation purposes.

3 RESULTS AND DISCUSSION

3.1 Focus

The purpose of the studies varies between policy support, scientific advancement and societal debate (schematised following the approach from Helming et al., 2012) . Most studies are in between policy support and scientific advancement either as research project focusing on policy support, or as policy support project including advanced technologies.

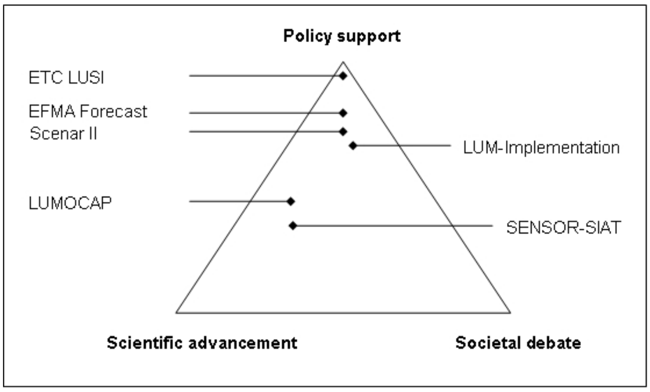

Figure 1 Schematic overview of the purpose of each outlook study

It should be noted that only half of the studies had the aim to provide land use outlooks, while the other half use scenarios to test the behaviour of tools developed or show their potential applicability. It is important to realise the aim of the studies,

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[iv] EU-15 comprises all countries that were a part of the European Union after the 1995 enlargement: Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Denmark, Ireland, the United Kingdom, Greece, Portugal, Spain, Austria, Finland and Sweden. NMS includes the new member states that entered the EU in 2004: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. NMS-2 finally are Bulgaria and Romania, which entered the EU in 2007.

because it explains why certain drivers were selected and why detail was given to specific land use classes. The focus of most projects on tool development rather than on scenario development also explains why often limited attention was paid to the development of scenarios or explanation of indicator results. Furthermore, it is worthwhile to mention that in most studies scenarios were developed by the project team and agreed upon in consultation with a (often limited) group of people from a policy organisation.

All studies put a strong emphasis on the agricultural sector and for about half of the studies only land uses related to this sector are included (EFMA Forecast, ETC-LUSI and SCENAR-II). This focus is likely to be a consequence of the strong EU support for agriculture, making it the land use that is most affected by policy decisions at European level and thus providing a need for impact and outlook studies with this focus. When we look at the studies with a more integrated approach to rural areas (LUMOCAP, LUM-Implementation and SENSOR) we see that these include a combination of agricultural, natural and urban land uses. However, urban land uses are not included with the same level of detail as agriculture or environmental land uses. A reason that none of the EU-wide studies has a strong emphasis on urban land use might be because urban processes are difficult to capture at this scale.

All studies make use of a reference scenario to which alternatives are or can be compared. Scenarios are generally constructed using a range of drivers that include a number of external factors, such as socio-economic trends and technology, as well as a range of (European) policies such as the CAP, the Birds and Habitats Directive, the Nitrates Directive or the Water Framework Directive. However, the extent to which these policies are incorporated and their level of sophistication greatly varies. Climate change is largely omitted from the scenarios in the land use outlooks. Most studies mention climate change and make some assumptions, but only LUMOCAP includes various climate scenarios.

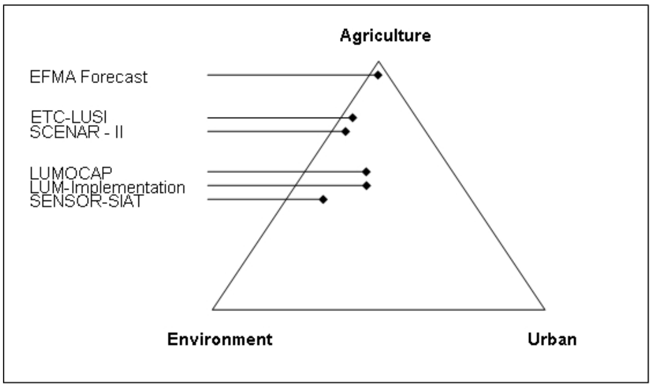

Figure 2 Schematic overview of the focus area of each outlook study (adapted from Helming et al., 2012)

3.2 Modelling approaches

Most studies rely heavily on input from models for analysing the impacts of external and policy drivers on land use change and related social, environmental and economic indicators. These models are typically integrated models, in that they consist of several more or less independent model components. Some of these model components are used in several integrated models and hence land use outlooks. The EFMA forecast is an exception to the other outlooks, as their forecast is mainly based on national experts from their respective countries. Starting from a European reference scenario they give their personal indication for expected developments. Only for a selected number of countries where no experts are located, results are derived from an agricultural model from DG Agriculture and Rural Development.

As a result of the agricultural focus, almost all studies include an agricultural economic model calculating the area taken in by the various agricultural land uses. By contrast, other land uses, such as urban land or forestry receive little or no attention. Similarly the policies and other drivers that are used in the scenarios are all expected to affect agricultural land use, as most studies explicitly include scenarios for CAP developments or biofuel policies.

The approach selected for model integration relates to the paradigms of the individual models incorporated. Studies including partial or general equilibrium models calculate an (equilibrium) end-condition and use iterations to obtain the results for a selected end year (SENSOR, SCENAR-II, ETC-LUSI). In LUM-Implementation, comparative static approaches have been combined with a dynamic land use model. LUMOCAP includes simulation models that calculate future developments in yearly time steps based on the set of drivers incorporated. Results for each time step build on the results from the previous time step.

The outlook studies also use different approaches to link the various spatial scales. Most land use outlooks use a top-down approach in which land use demands are calculated by models at global/national level and subsequently allocated to 1 km grid cells. LUM-Implementation and LUMOCAP, however, incorporate top-down as well as bottom-up interaction.

3.3 Quantitative comparison

The quantitative comparison of the reference scenarios of the various studies shows that most studies expect an increase in the yield for cereals and oilseeds (Table 1). This increase is mostly due to technological improvements, which are to a large extent external input to the models. We do see differences between the different studies in the rate with which the NMS-10 and NMS-2 countries are expected to catch up with the production in EU-15 countries.

In terms of land use areas there is some agreement in the reference scenarios. The area for grassland is likely to decrease in all groups of countries in all but one study (LUM-Implementation). Most studies also expect a decrease in cereals, fodder and permanent crops. The expectations for other agricultural uses vary per study. Generally there is a trend towards a declining agricultural area. Some of the

Table 1 Annual changes in area and yield between land use outlooks.

	Cereals		**Oilseeds**		**Fodder**	**Other arable**	**Set aside & fallow**	**Perm. crops**	**Grass-lands**	**Built up**
	area	yield	area	yield	area	area	area	area	area	area
EU-15										
EFMA	-0,3%	0,1%	1,3%	0,2%	-0,7%	0,2%	0,4%	-0,9%	-0,1%	
ETC-LUSI	-0,1%		1,1%		-0,7%	-1,7%	-2,8%	-0,4%	-0,3%	
LUMOCAP	0,5%	0,7%	0,9%	0,5%	-0,2%	-0,4%	-4,8%	-1,3%	-0,8%	0,7%
SCENAR-II	-0,6%	0,6%	-1,9%	0,6%		1,5%	-1,0%	0,0%	0,1%	
SENSOR	0,0%	0,4%	0,4%	0,7%	-1,1%	-0,3%	-0,2%	-0,1%	-0,6%	0,3%
LUM-IMP	-0,7%		-0,1%			-0,4%		-0,3%	0,1%	0,3%
NMS-10										
EFMA	-0,4%	0,7%	0,8%	0,8%	0,5%	0,0%	-3,7%	-0,2%	-0,2%	
ETC-LUSI	0,0%		-0,4%		-0,5%	-1,0%	1,6%	-0,5%	-0,6%	
LUMOCAP	-0,1%	2,9%	0,4%	2,0%	-3,1%	-1,3%	0,0%	-1,1%	-1,4%	0,7%
SCENAR-II	-0,4%	0,8%	-0,3%	1,4%		0,0%	2,3%	0,0%	-0,7%	
SENSOR	-0,3%	0,7%	0,3%	1,8%	-1,0%	0,1%	1,8%	0,4%	-0,7%	0,7%
LUM-IMP	0,1%		0,1%			-0,2%		-0,2%	0,7%	0,2%
NMS-2										
EFMA	0,9%	1,2%	-0,9%	1,0%	-0,1%	-0,3%	0,0%	-0,2%	0,0%	
ETC-LUSI	-0,5%		0,1%		0,7%	0,8%	0,6%	-1,2%	-0,1%	
LUMOCAP	-0,3%	4,1%	0,1%	2,7%	-0,7%	-0,7%	0,0%	0,0%	-2,0%	0,7%
SCENAR-II	-0,4%	0,5%	-1,0%	1,9%		-0,5%	2,3%	-0,6%	-0,2%	
SENSOR	-0,8%	1,4%	0,5%	2,2%	-2,1%	0,1%	3,2%	-0,8%	-0,8%	1,2%
LUM-IMP	-0,1%		-0,1%			0,0%		0,0%	0,5%	0,0%

models used are able to simulate this conversion and can show an actual decline in agriculture (LUMOCAP and LUM-Implementation), in other models this is reflected in an increasing area of set-aside and fallow. Studies that include urban land use all indicate an increase in urban land.

However, the quantitative comparison shows that there is a large difference between the projected results provided by the different outlooks (Table 1 and Figure 3). Scenario results within a single outlook study are often more similar to each other than to the reference results of other outlook studies. This is to a large extent caused by the initial data and the processing thereof, as these differences

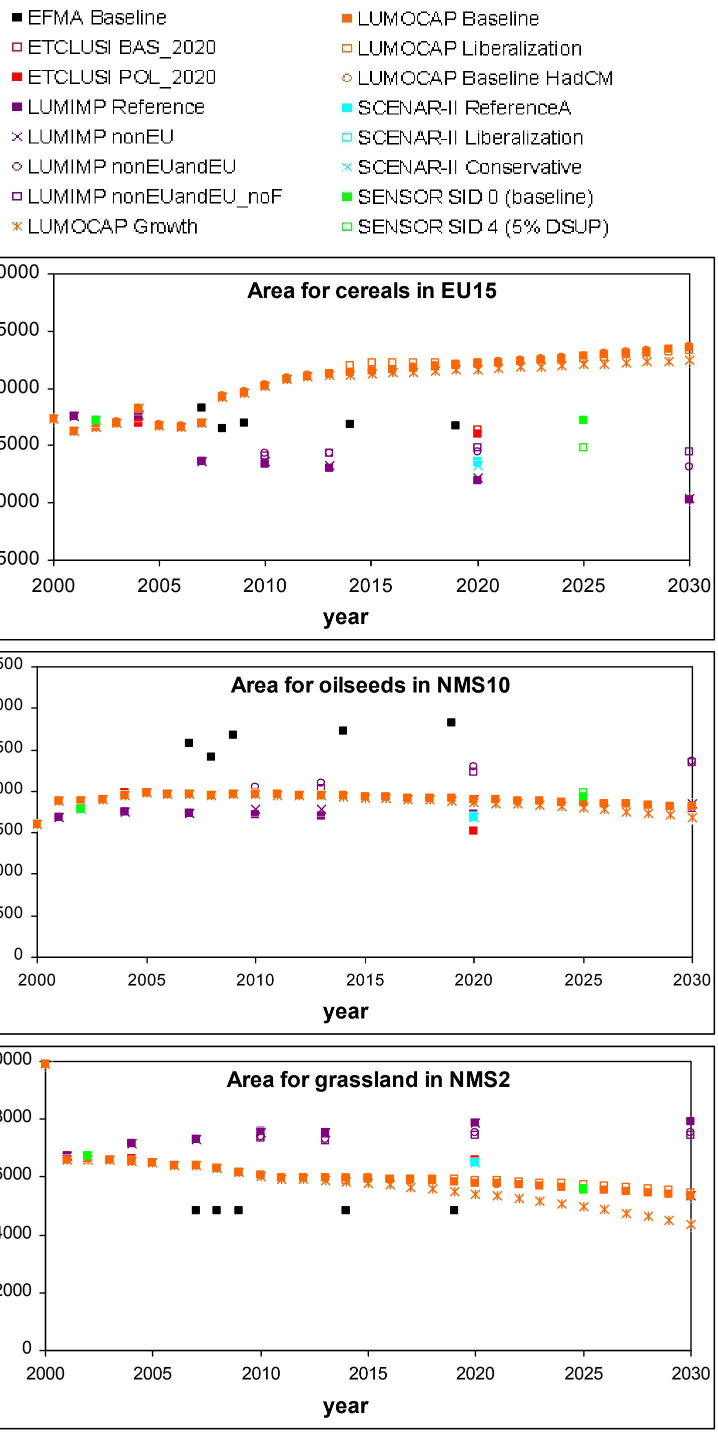

Figure 3 Results for all references and additional scenarios for the area for cereals in EU-15, oilseeds in NMS-10 and grassland in NMS-2. Reference results are indicated with solid squares, while other scenario results are indicated with wire frame symbols. When the latter is not visible, it coincides with the reference result.

appear already in the initial years of the studies and not only in the final year. Different databases are the source for each of the studies and large differences can be found between those datasets. Most of the studies that are included use statistical data for their outlook study, while some use information that is derived from land use maps. The difference between the two is that the first is based on net area, and the second on gross area per land use type. Hence the studies based on land use maps will generally yield a larger area for the agricultural land uses. Furthermore, land use maps show the dominant land use and therefore aggregating information from land use maps to derive surface totals per region is likely to over- or underestimate the share of some land use types.

To exclude the impact of differences in initial data, relative changes were computed, representing the percentage of change per year for those years included in the study (Table 1). These figures confirm the results from the graphs and show a large range of values, and in several occasions one study results in an increase of a certain land use type whereas the other expects a decrease in the same type.

Two policy measures that are included in several outlooks and for which quantitative results were available are CAP liberalisation and biofuel policies. The impacts of the biofuel policies are consistent among the different studies, as these scenarios foresee an increase in oilseeds at the cost of other arable crops. The impact of the CAP liberalisation differs however between studies.

4 CONCLUSIONS

The comparison presented in this study gives an overview of six different land use outlooks for Europe. For a proper interpretation of their results, it is crucial to understand their background: why are they developed? by whom? for what use? what models and integration mechanisms are included and how does this selection impact on the results? Answers to these questions have large implications on the scope and implementation of the study and therewith also affect the final results of the outlooks.

The studies compared all have a strong agricultural focus, which is also reflected by the models used to calculate scenario results, the selection of the policies and the detail by which agriculture is represented. The focus on agriculture and agricultural economic models could be due to the scale of the study (EU wide) and the data and models available at this scale. However, it can also originate in the fact that in the agricultural sector and particularly at DG Agriculture and Rural Development there is a longer tradition to use models in outlook studies due to the importance of the Common Agricultural Policy at European level. This focus has of course implications on the type of results that can be provided, the approach by which they will be generated and hence their wider applicability.

What stands out from the quantitative analysis is that differences between the reference results of the various studies are much larger than differences between scenarios within a study. Also comparison of relative changes does not provide us with a consistent forecast amongst the different outlooks. It is for this reason that we conclude that the uncertainty in the results is too large to come to a mid range of results. We therefore suggest using the results as the plausibility space for land use change. However, due to their agricultural focus and the rather limited range of driver values, the plausibility space could be much larger than provided based on the results from these outlooks.

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