Dynamic Land Use Change Modelling for CAP

LUMOCAP

Impact Assessment on the Rural Landscape

Final activity report

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RIKS research institute for knowledge systems · TUNG · Katholieke Universiteit Leuven · JRC European Commission

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Executive summary

As agriculture covers about half of the EU-territory, the Common Agricultural Policy (CAP) is a main driver determining land-use structure and landscape quality. It aims at ensuring adequate market prices and satisfactory income to farmers and at rural development, including the preservation of landscapes and sustainability of agri-ecosystems through agri-environmental schemes. Increasingly CAP aims at maintaining agricultural activity in less favoured and environmentally sensitive areas to avoid degradation of the associated landscapes. The LUMOCAP project directly contributes to an increased efficiency and rationality in meeting these objectives.

LUMOCAP aims at delivering an operational tool for assessing land use changes and their impact on the rural landscape according to a CAP orientation. It focuses on the relations between the CAP and landscape changes and emphasizes the spatial and temporal dimension of this process. The core of the tool is a dynamic land use model. It is calibrated to the extent possible given the current data availability and tested on historical data characterizing changes in the period 1990-2000. Furthermore it is run to asses policy development scenarios –consisting of a combination of external factors and policy measures– for 2000-2030 by forecasting the future spatial distribution of land-use/cover and related landscape indicators.

The end product is an open-ended, transparent, PC-based analytical system enabling a user to interactively enter policy options under a specific set of climate and socio-economic conditions as external driving forces, to formulate potential land use scenarios, and to assess the impact of both on the quality of rural landscapes through the analysis of selected landscape indicators. Similarly, it enables identifying areas of adverse land use related environmental change caused by non-sustainable agricultural systems.

The LUMOCAP system is built on an existing spatially explicit land use model called METRONAMICA. Based on knowledge about agricultural policies, driving forces of land use change and end-user requirements, the METRONAMICA model is adapted and improved to fulfil the requirements defined in the LUMOCAP project.

The system, together with the scenario runs and their results, have been presented to and discussed with (potential) users from DG AGRI and Member States. This interaction has taken place through presentations and training workshops in which the usefulness and usability of the LUMOCAP system were assessed. Preliminary results based on questionnaires show that the system has potential to be used in policy analysis and appears to be user friendly, but more interaction and testing by (potential) users will be required to assess its full capabilities and limitations.

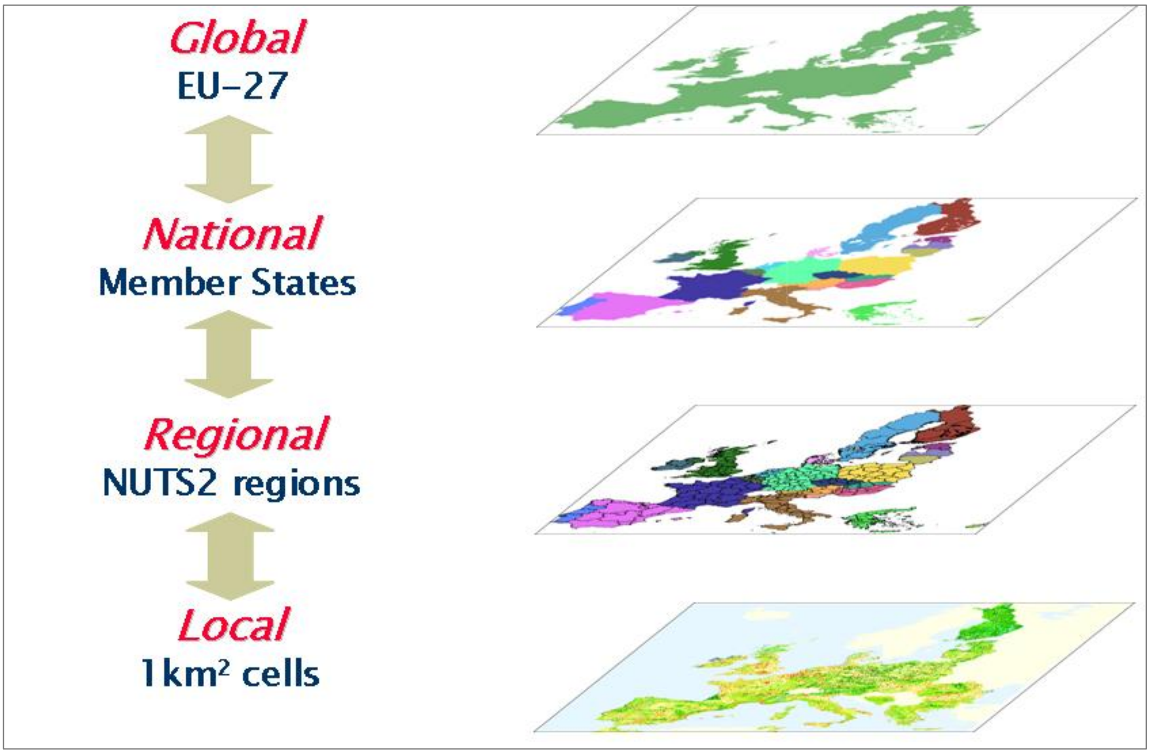

Figure 1: Different spatial scales in the LUMOCAP model

Based on the user workshops and an internal evaluation by the project team the LUMOCAP system was improved and a full documentation including a user manual and model descriptions was prepared.

Main problems encountered during the project were the lack of consistent data sets for EU-27, the development of a software system that could run on a normal PC with sufficient capacity to simulate future developments on a yearly basis on a very detailed spatial resolution (1km and 200m) by integrating a number of complex models, and the understanding of the impact of Rural Development Policies on land use change.

Main success factors have been a very committed project team with a thorough understanding of complementary disciplines and respect for each other, the interaction with DG AGRI and the facilitation of the project by the scientific and financial officer of the European Commission.

The final version of the LUMOCAP system has the following characteristics:

- Geographical extent is the current EU-27.
- The model works on 4 geographical levels: EU, national, regional (NUTS-2) and local. The resolution at the local level is a 1 km grid for EU-27 and a 200m grid for the case regions.
- Temporal horizon is 2030 and temporal resolution 1 year.
- At the level of the EU an agricultural economic model –developed by KU Leuven– calculates the change in area for the different crop types over time. The model incorporates three sets of equations to reflect the different mechanisms that drive these changes in EU-15, NMS-10 and Bulgaria & Romania. The yields used in this model are calculated based on information from the other scales.
- Climate change and expectations at EU level regarding growth of population and jobs are seen as external driving forces and can as such be entered and/or adapted by the user.
- Changes in agricultural area, jobs and population are downscaled to the national level using a spatial interaction model that allocates growth and migration based on the relative attractiveness of the different countries. Factors that determine the attractiveness are taken from the national level as well as an aggregation from the regional and local level.
- The national amounts of crop area, jobs and people are distributed amongst the different regions using a similar model as that applied on the national level. Factors that determine the regional attractiveness are taken from the regional level as well as an aggregation from the local level.
- Within the regions a constrained cellular automata model (CCA) allocates the demand for the different land use functions to cells of 1x1 km. This model is only used for aggregate land use categories (residential, industry & commerce, recreation, agriculture, forest and natural vegetation). Subsequently a crop component calculates what crop types will occupy the agricultural areas. In this crop allocation inertia, physical suitability and policies (e.g. LFA) play a major role. IUNG has developed a model to calculate dynamic suitability maps for the different crop types which are used in the allocation at the local level as well as in the calculation of the yield. Suitability is impacted by the climate change scenarios that are incorporated in the system.
- Three case regions have been selected: Silesia and Podlaskie in Poland and Overijssel/Gelderland in the Netherlands, for which the local level of the model has been set-up at 200x200 m resolution, which allows the calculation of indicators at the same level.
- To allow for impact assessment the LUMOCAP system is equipped with a user friendly interface –developed by RIKS– through which the user has access to different policy measures and external factors. An example of the user interface is provided in figure 2.
- Outputs of the impact assessment are the changes in the land use and a number of indicators, developed by JRC. Indicators are calculated at the different scales of the model.

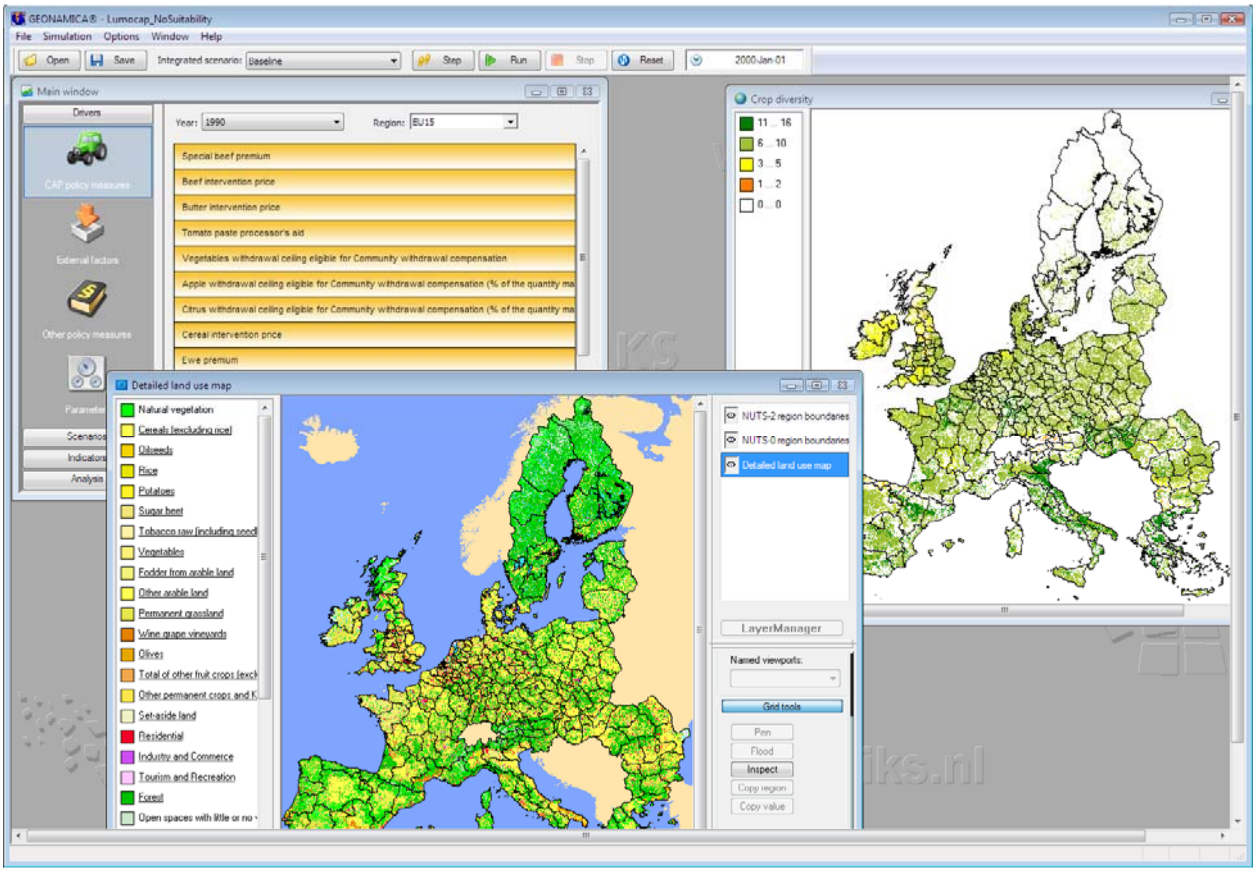

Figure 2: GUI of the LUMOCAP system

The LUMOCAP consortium consists of the following partners:

- Research Institute for Knowledge Systems (RIKS), Maastricht, The Netherlands
- Katholieke Universiteit Leuven (KU Leuven), Leuven, Belgium
- Institute of Soil Science and Plant Cultivation (IUNG), Pulawy, Poland
- Joint Research Centre – Institute for Environment and Sustainability, Ispra, Italy

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More information about the LUMOCAP project can be found on the project's web site: http://agrienv.jrc.it/lumocap

RIKS research institute for knowledge systems — IUNG — KATHOLIEKE UNIVERSITEIT LEUVEN — JRC EUROPEAN COMMISSION

Section 1 – Introduction

This report is the final activity report of the LUMOCAP project. It covers the overall objective of the project and describes per work package the main aspects of the work, the results and the conclusions. Of course, the main result of the project is the LUMOCAP system itself (Deliverable 9: Final version of the land use model), which is available upon request. It comes together with a user manual (Deliverable 10: Documentation of the system) and a report describing the models and data used, the interlinkages between the models, the calibration procedure and results, and the scenario analysis (Deliverable 17: Final report).

The LUMOCAP Policy Support System (PSS) is developed in an iterative development process that included the potential users, the scientists and the software developers. The project team would like to thank all potential users from DG AGRI and Member States who have attended presentation, workshops and training courses and who have helped us to adapt and fine-tune the system to the policy context. We would like to give our special thanks to Thierry Vard from DG AGRI, who has organised all meetings that have taken place at DG AGRI and facilitated the focus group selection.

Furthermore the project team would like to thank Dr. Danièle Tissot and Vincent De Bongnie, as scientific and financial officers of the European Commission. Throughout the project they have facilitated the management with their support and prompt replies to questions.

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- EC – Joint Research Centre – Institute for Environment and Sustainability

As part of the dissemination activities the work carried out in the LUMOCAP project has been presented at conferences and a project web site has been set up by the JRC: http://agrienv.jrc.it/lumocap. The publication of the work in scientific journals has started and will continue during the coming year.

Section 2 – Project objectives

The main aim of the LUMOCAP project was to develop a system to calculate the impacts of agricultural policies on land use in a time horizon extended until 2030. By developing a dynamic, spatially explicit model that includes different policy alternatives as well as different external factors the system was expected to be able to provide a state-of-the-art assessment on the impacts of (agricultural) policies on the landscape under different external conditions such as climate change and socio-economic developments.

The geographical area for model implementation is current EU-27. The main objective was to develop a model that could distribute demographic growth, jobs and hectares per crop type from the EU level among countries and subsequently among NUTS 2 regions. Within these regions a cellular automata model complemented with a crop type model would be used to allocate regional demands on a 1x1 km grid. The modelling work was intended to be based on the existing METRONAMICA land use modelling framework.

Besides applying the model to EU-27 at a 1x1 km resolution, 3 study areas were selected where the model would be applied at a 200x200 m resolution: Podlaskie and Silesia/Śląskie in Poland and a region in The Netherlands consisting of two Dutch provinces (NUTS 2 regions): Overijssel and Gelderland. The different spatial scales of the model are presented in figure 3.

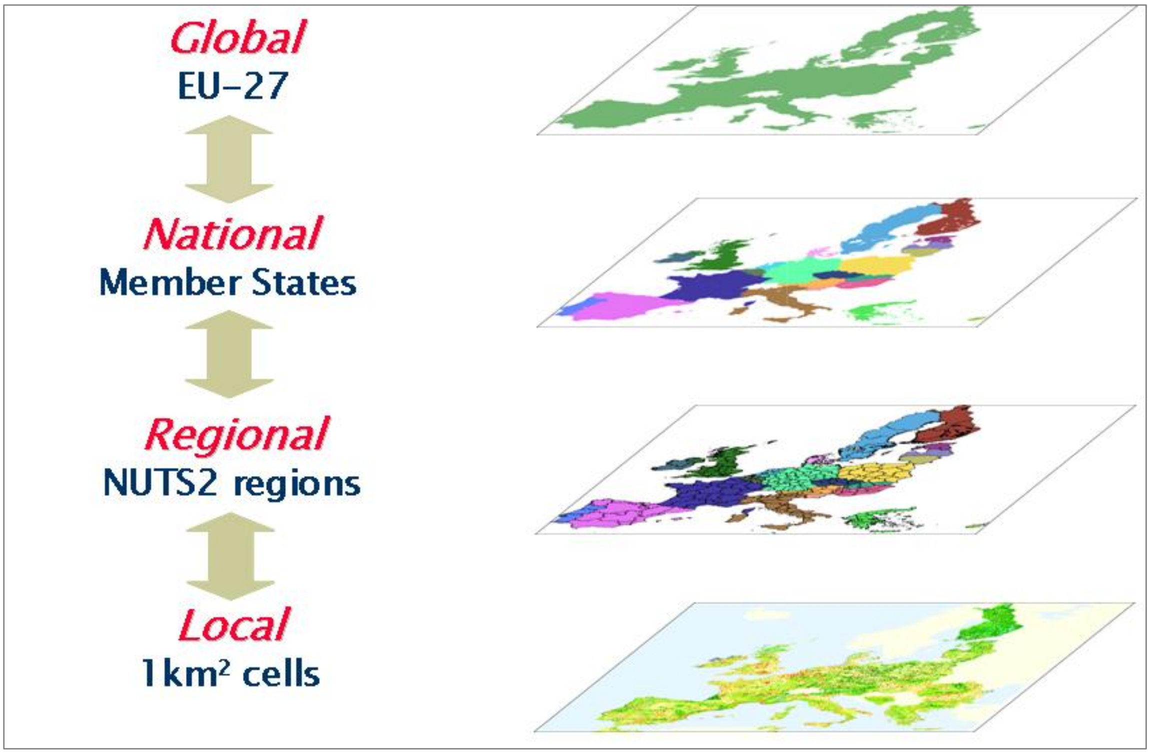

Figure 3: Different spatial scales in the LUMOCAP model

Section 3 – Work carried out in different work packages

WP 1 – Policy analysis

Objectives

WP 1 had two main objectives:

1. Identify linkages between CAP measures and land use patterns
2. Formulate parametric rules, based on the identified linkages between CAP measures/policies and indicators

Progress towards objectives

Both of the objectives were accomplished. Two deliverables were finalized as part of the WP1. The first deliverable "Report on relationships between CAP measures and land use change" was delivered in January 2007, and the second deliverable "Parametric rules for CAP induced land use dynamics" was delivered in April 2007.

In order to accomplish the objectives, the work carried out under the WP1 was split in three tasks. Because of interlinkages and due to efficiency reasons these tasks were carried out in parallel. Task 1 and 2 were carried out to achieve objective 1 of the WP1: *Identification of the linkages between CAP measures and land use patterns*. Task 3 was carried out to achieve objective 2 of the WP1: *Formulation of the parametric rules*.

<u>Task 1: Data gathering and analysis of CAP</u>

This task included:

- Description of CAP policies to identify the mechanisms in which they operate. Policy descriptions were done for all main agricultural sectors. Considered sectors are listed in task 3. The results of this task are reported in the Deliverable 1 "Relationships between CAP Measures and Land Use Change."
- Data gathering on CAP (e.g. intervention prices, area payments, quotas etc.). The main problem encountered when collecting policy data was the difficulty in obtaining consistent time series. This was the case of some first pillar instruments, of Rural Development Polices, and of polices applied before accession in New Member States (NMS). To address this problem various sources were used (such as official documents of the European Commission, OECD reports, and other relevant publications) to complement the missing data. In the case of NMS, PSE data from OECD was used as a proxy for polices before accession.

Task 2: Identification of the impacts of CAP on land use patterns

This was an analytical task. It included theoretical work (but is also based on evidence) with the aim to identify the link between the policies and the direction of change of land use indicators. The results of this task are reported in the Deliverable 1 “Relationships between CAP Measures and Land Use Change”.

A theoretical framework was developed to analyse how the CAP measures affect production of agricultural commodities and land allocation. The main analytical unit used to evaluate the policy impacts is the farm. A farm is assumed to maximise its profits. A farm decides about the production of agricultural outputs that affect its profits, i.e. market outputs (private goods), by taking into consideration prices, policies, the quality of land used in the production process, and the available technology. A farm also decides about the input use necessary to produce these outputs. In general, the overall effect of policies on agricultural production and on environmental outputs will be larger in the long-run than in the short-run because in the short-run a lot of the inputs are fixed (e.g. land, labour, etc.).

In order to identify the impact of policies on farm behaviour and as result on production and land allocation, five key policy measures were analysed, which form the basis of the CAP and were subject to substantial changes under the 1992 reform, Agenda 2000 and the 2003 reform:

- Market price support
- Direct payments
- Area/headege limitations
- Set-aside
- Rural development policies (second pillar policies)

Task 3: Formulation of the parametric rules

Based on the identified linkages between the policies and land use indicators, the parametric rules were formulated. They form the agricultural model of the LUMOCAP system. The results of this task are reported in Deliverable 2 “Parametric Rules for CAP Induced Land Use Dynamics.”

The agricultural model of the LUMOCAP project is a dynamic, multi-product, supply model of EU agriculture. It represents annual land allocation, production levels, yields, animal stocks and prices. The model covers all agricultural area. The overall design of the model focuses particular attention to the potential influence of agricultural policies on land use change. The main variables that drive land use change and form the linkage between sectors are returns, policy instruments, and macro variables. Domestic prices are endogenous and are represented by relationships that link them to world market prices. World prices are exogenous in the model.

The basic structure of the model is provided in table 1. The model contains four levels which represent the farm land allocation decision process. At level 1 a decision is made on the amount of land allocated to agricultural activities, on the amount of abandoned land, and on the amount of land transferred to non-agricultural uses. At level 2 land allocation is made among three main sectors: arable land, permanent grassland, and permanent crops. Each of these four sectors is further split in more specific sub-sectors at level 3. At level 4 there is only a land allocation decision for cereal-oilseeds area. Farms decide about the split of land to cereals, oilseeds and set-aside.

In order to take into account the differences in policies applied among different EU member states, three separate agricultural models were constructed:

- EU-15 model including the 15 old Member States
- NMS-10 model including the 10 New Member States which joined EU in 2004 (the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia)
- NMS-2 model including the 2 New Member States which joined EU in 2007 (Bulgaria and Romania)

The three regional submodels follow the general structure of the model presented in table 1. The three submodels are interlinked mainly through prices. Prices of the New Member States (NMS) are assumed to converge to EU-15 price level after accession.

The model covers all agricultural area and all major crop and animal sectors of the agricultural economy. The following crop sectors are included: cereals, oilseed, rice, potatoes, sugar beet, tobacco, vegetables, fodder from arable land, other arable land, wine, olives, fruit crops, and other permanent crops. Additionally set-aside area is modelled. To take account of the competition for resources between the agricultural economy and the non-agricultural economy, agricultural land loss to urban areas and abandoned land are also modelled (table 1). The animal sector covers beef, dairy, sheep and pigs.

Each crop sectoral model contains four main elements (1) land allocation equation, (2) yield equation, (3) price equation, and (4) production equation. The animal sector models contain animal stocks, slaughter weight and price equations.

The methodology used for the formulation of rules was:

1) Econometric estimation
2) Calibration
3) Coefficients taken from economic literature

Econometric estimation was used to obtain coefficients for yield, slaughter weight, price, and animal stock equations. The main problem faced when estimating the coefficients was the low degree of freedom especially when estimating land allocation equations. For this reason, to obtain coefficients for land allocation equations, the combination of estimation, calibration, and economic literature approach was applied.

Main data sources were Eurostat and the European Commission. Other sources used were FAOSTAT, OECD, UN, and the economic literature, which supplemented the missing data from Eurostat and from the European Commission. The main problem encountered when collecting data for the model was the difficulty in obtaining consistent time series, similar to the problem encountered for policy data. This was the case of some old member states and especially of NMS. To address this problem FAO data were used. In some cases an estimation procedure was used to obtain data for missing years.

Table 1. General model structure

Level 1	Level 2	Level 3	Level 4
Agricultural land loss to urban areas			
Abandoned land			
Usable agricultural area (UAA)	Arable land	Cereal-Oilseed area	Cereals
			Oilseeds
			Set-aside
		Rice	
		Potatoes	
		Sugar beet	
		Tobacco	
		Vegetables	
		Fodder from arable land	
		Other arable land	
	Permanent grassland		
	Land under permanent crops	Wine	
		Olives	
		Fruit crops (excluding wine and olives)	
		Other permanent crops	

List of deliverables

Table 2: Deliverables List

Del. no.	Deliverable name	Lead contractor
D1	Relationships between CAP Measures and Land Use Change	KU Leuven (2)
D2	Parametric Rules for CAP Induced Land Use Dynamics	KU Leuven (2)

WP 2 – Bio-physical and socio-economic analysis

Objectives

WP 2 originally had five main objectives. To ensure a good integration of the work and to contribute to unforeseen activities, during the course of the project objectives 6-8 have been added:

1. Assess existing land use trends as a function of bio-physical and socio-economic variables;
2. Parameterise bio-physical and socio-economic variables impacting on land use;
3. Define inputs to the land use model at the test areas and country level;
4. Define inputs to the land use model at the EU level.
5. Adapt and test soil/land quality index for different scales;
6. Investigate changes in land suitability driven by climate change
7. Develop crop grid maps for EU-27 for 1990 and 2000
8. Test LUMOCAP in case study regions

Progress towards objectives

Objectives 1 and 2: Assess existing land use trends and parameterise variables impacting on land use

Relationships between biophysical and socio-economic conditions and land use changes have been established. The work was structured into two steps: (1) to cover land use change throughout the EU-27 and (2) within selected test regions, representing different socio-economic and environmental settings.

An EU level analysis was conducted for NUTS 2/3 regions as used by Eurostat for statistical surveys – combining NUTS 2 and NUTS 3 units was decided to cover EU by a network of regions of a similar size to enable a stochastic analysis of the land use change trends and their relationships with socio-economic and biophysical variables. Drastic differences in land use change and socio-economic patterns across Europe were observed. Therefore our approach was based on combining regions into geographically and economically similar clusters, which may require a different type of management and policy instruments in order to promote their economic and social coherence.

Test areas reflected different historical and economic background of European regions. Slaskie and Podlaskie regions (NUTS 2) of Poland were chosen to investigate land use change dynamics within the last decade, which was driven by factors other than CAP as these instruments were introduced in 2004. Münster, which is a NUTS 2 region in western Germany and the Dutch NUTS 2 regions Gelderland and Overijssel, were chosen to represent land use change processes in former EU-15 countries.

The Eurostat database was used as a main data source for NUTS 2/3 within EU-27. All essential parameters were collected at the largest possible temporal range to study their trends – usually from 1995/1997 up to 2004. To account for biophysical conditions within EU-27 we used climatic data such as length of vegetation period, precipitation, and average temperatures obtained from the IPCC.
The data characterizing the Podlaskie and Slaskie test areas was collected at the resolution of gmina (NUTS 5) from national sources. This dataset of above 150 variables was chosen for further analysis. Demographic or labour data was very well represented, as was economic data, whereas waste production and industrial emission data was less complete. Biophysical conditions were represented by Land Quality Index – which is an aggregated parameter describing land productivity. Additionally the soil erosion index and soil contamination with metals were calculated for each NUTS 5 unit as a weighted mean.

Landscape metrics were calculated for both the EU-27 regions as well as for test areas as indicators of landscape heterogeneity and pattern. High landscape diversity is considered to be indicative of land buffering capacity and resistance to various anthropogenic pressures.

Land use change analysis was based on the CORINE layer of changes obtained from EEA – this layer characterizes land use conversions between 1990 and 2000.

Cluster analysis was performed to recognize relatively homogenous groups of regions within EU-27 and test regions, which would represent a similar environmental, socio-economic, agricultural and geographical profile. Trend analysis was performed within clusters to assess changes in population density, GDP and employment structure within these homogenous areas throughout Europe and test regions. Correlation coefficients were calculated to evaluate significance of relationships between land use changes and biophysical and socio-economic variables. Stepwise regression models were generated to find indicators that explain trends in land use transition between various land cover classes.

Land use change size and pattern between 1990 and 2000 strongly depends on the geographic location and a specific setting of socio-economic, historical and environmental conditions, which vary greatly throughout the EU. In our analysis we delineated five distinct European clusters of different characteristics and behaviour with regard to land use, population density, GDP and social structure.

It is evident that a conversion of agricultural land into artificial surfaces such as into urban and industrial/commercial units is mainly driven by population density and natural population growth as well as GDP, however the latter appears to be a stronger driver in eastern more rural areas relative to other parts of the EU. Multiple regression models can explain well over 60% of variability of agricultural land conversion into artificial surfaces, as a function of GDP, population density and growth rate. Based on these trends robust projections of the rate of changes within the next 10 years can be provided, due to the fact that strength of temporal trends of these simple socio-economic variables is very high. A strong dependence of agricultural land use conversion into other functions on economic and demography variables indicates that policy variables related to CAP were of smaller importance. It is expected that CAP instruments will have a stronger impact on changing structure within agricultural land through a specific crop choice or conversion into forest and this response will be directly related to maximization of profits driving farmer's decisions.

Objectives 3 and 4: Define inputs to the land use model at the test areas, country level and EU level

In the light of our work it is apparent that losses of agricultural land to supply space for urban and industrial development are strongly driven by economic factors, demographic structures and social conditions – these factors interact and control the attractiveness of a region for investment and its urbanization potential. An expansion of urban and industrial areas can be satisfactorily described as a function of a few variables such as GDP, population density, population growth, employment figures, or other closely related variables serving as surrogates for land use change drivers.

System dynamic modelling seems to be a useful tool capturing complex processes that drive agricultural land use change. *Ex-post* analysis of agricultural land change into artificial surfaces for the period 1990-2000 shows that the prototype dynamic model can explain very well trends in land use change for the EU and country level (close to 80% of observed flows at the aggregation level of a country). Calculating claims for different land use functions such as urban and industrial/commercial in test regions seems to be feasible and reflects the size of the economy, its growth potential as well as demographic patterns and their evolutions. The robustness of the model at the test regions needs to be verified by using data at a better resolution – the oncoming CORINE layer will be essential with regards to this validation. In the proposed modelling scheme land use changes are calculated from regression equations, reflecting their relationships with socioeconomic factors such as GDP, employment and demographic indicators. System dynamics is captured through feedbacks affecting GDP, which is influenced by migration processes – in such a way the temporal evolution of the system is considered. Results of the modelling exercises demonstrate that the complexity of land use change processes can be retrieved by a relatively simple model, which is quite robust for a national-level major regions analysis (such as test regions in this study) forecasting the size of urban and industrial functions. Modelling changes in forest area as a function of socioeconomic variables produces acceptable results at a resolution of major clusters and fails at lower aggregation level, such as for a country. This is likely due to the influence of local biophysical and economic factors playing a major role in decision making with regards to afforestation.

Predictions for 2020 indicate that an expansion of urban and industrial areas in the EU-15, relative to the year 2000, will be 30%-40% higher as compared to most of the EU-10. Such differences are also evident for the test regions showing a significant gap driven by the economic performance and historical socio-economic background. Considering the larger size of these land use functions in the EU-15 in 2000, it is evident that the biggest losses of agricultural land are expected in the EU-15 and western test regions as opposed to new member states. A relatively small increase of urban areas predicted for new member states can be explained by migration to former EU-15 countries, as well as by negative demographic trends, regardless the fact that these economies demonstrate a considerable growth rate and attract industry/commerce thanks to a competitive advantage of lower labour cost, lower land prices etc.

The largest increase of urban areas at the expense of agricultural land, relative to their size in 2000, is predicted for the Iberian Peninsula, Ireland, parts of France, the UK, Italy, Greece and a few regions in new member states. Among new member states such countries as the Czech Republic, Slovenia, Malta, Cyprus and Hungary will face the largest pressure on agricultural land as a consequence of economic developments. Area-wise, however, the largest urbanization pressure on agricultural land is forecasted for regions in Belgium, the Netherlands, Germany, the UK, Italy and Hungary. The prototype model shows that with regards to test regions such as Overijssel and Gelderland the area wise consumption of agricultural land and associated pressures will be much larger as compared to Silesia and Podlaskie. The prototype requires further testing and calibration in order to account for regional interactions between land use claims and biophysical features.

Objective 5: Adapt and test soil/land quality index for different scales

In order to facilitate distribution of crop areas generated by the model into a grid a land suitability (LS) layer was developed for the EU-27. The LS for over 20 crops was modelled by accounting for components that control yields – climate and water balance. Dry mass production in the model (DM) is restricted by soil available water, driven by precipitation, evapotranspiration and water retention characteristics of soil cover. Evapotranspiration in the model is calculated according to the FAO approach (Allen et al., 2000). Yields are also restricted by temperature and terrain conditions (slope) – a numerical solution of LS calculation followed the methodology tested in a previous work. The equation relating LS to dry mass production, temperature and slope is given below.

$$LS = \left(1 - \frac{slope}{90}\right)^{\alpha} \cdot \left(\frac{T_{mean}}{T_{opt}} e^{1-\frac{T_{mean}}{T_{opt}}}\right)^{\beta} \cdot \left(\frac{DM}{DM_{\max}}\right)^{\gamma}$$

The first term in the LS equation is a function which produces a value of 1 if the slope is 0˚, as there are no terrain constrains for crop growth. For a slope of 90˚, it equals 0 and for intermediate slopes, the LS value depends on the α coefficient. The second term in the LS equation characterizes the impact of temperature on yields. This function is of a skewed bell shape – its maximum value is 1 – reached at a temperature optimal for a plant growth ($T_{opt.}$), whereas the value of 0 is reached at 0˚C, which is a temperature at which growth processes are stopped. The third term represents the ratio between the biomass produced in a vegetation season (DM) and the biomass that could be produced in optimal conditions - if there is no water stress this term would equal 1. There is an assumption that the dry matter produced is proportional to the amount of evapotranspiration (de Wit, 1958). Within this term there is a water balance calculation included, relating the stage of crop development to the water available to plants in the soil, the amount of precipitation and actual evapotranspiration (Thornthwaite, 1955). Numerical solutions were done according to Donker's scheme (Donker, 1987).

Climate data for the model was obtained from the Intergovernmental Panel on Climate Change (IPCC), a soil map in 1:1 M scale was used for modelling water balance throughout the vegetation season. The climate data represented 30 year monthly means and this determined a calculation interval. The calibration of the model by a multiple linear regression was based on the Eurostat yield data for NUTS-2 regions. In order to compare output values with observed yields, a correction was introduced by accounting for a reduction of potential biomass caused by a level of management and inputs, which vary greatly across Europe – the less technologically and economically advanced the region is, the larger the discrepancy between observed and potential yields. To account for this impact, GDP was used as a proxy of management level. A calibration of the model after correcting for GDP allowed for explanation of over 70% of yield variability observed in NUTS-2 regions.

Objective 6: Investigating changes in land suitability driven by climate change

It is likely that the current distribution of crops across the EU and within regions will change considerably in the near future responding to the climate change. Land suitability for crops is calculated as a function of temperature, precipitation and soil water retention and therefore common assumptions of different climate change scenarios allows for the assessment of future land productivity. In fact, rapid changes reflected in temperature increase and more frequent drought events have been observed throughout the last two decades in many European regions, not only in the south but also in the northern parts. If this trend continues, depending on the scenario, the spatial pattern of crops and land abandonment may be significantly different compared to their current distribution. Predicting these distributions is crucial for the assessment of the impact of policies, keeping in mind that in extreme cases some of the areas may become marginal, whereas others will require extensive adaptation – e.g. changing cropping systems, improving water management and/or introducing new compensation mechanisms. For the assessment of possible climate change impact on land suitability for crops, we considered 4 different scenarios published by the UN Intergovernmental Panel for Climate Change (IPCC) and generated by the Hadley Centre Global Circulation Model (HadCM2). The time frame for the assessment was 2020. Outputs of HadCM2 represent a spatial resolution of 2.5° x 3.75° (latitude by longitude). Land suitability maps for 2020 were generated as an output. Comparative analysis shows that there will be a need for adaptation of farming practices and cropping structure particularly in southern Europe. All scenarios analysed produce significant difference in land suitability compared to the land suitability in 2000. There are also noticeable differences in land suitability between scenarios in 2020. However, differences in land suitability between scenarios in 2020 are smaller than individual differences, regardless of the scenario, compared to 2000. The climate scenarios have been incorporated in D9: Final version of the land use model.

Objective 7: Developing crop grid maps for EU-27 for 1990 and 2000

During the LUMOCAP project it became clear that no crop maps for 1990 and 2000 for the LUMOCAP crop types were available for EU-27. For this reason IUNG has committed itself to the task to develop a disaggregation mechanism enabling automated generation of crop grid maps for EU-27 based on historic data at NUTS-2, NUTS-3 and NUTS-4 level for 1990 and 2000, the Corine Land Cover maps for 1990 and 2000, and the suitability maps prepared by IUNG earlier in the project.

The following methodology was used: It has been established that the distribution of crops from aggregate levels (NUTS-1, NUTS-2 or NUTS-3) into a grid requires recognition of land suitability since it is a fundamental factor in real decision making with regards to crop choice. The assumption made here is that there is a strong interaction between crop choice and land suitability and high suitability land is likely to be used for crops demanding better habitat conditions. For disaggregation we therefore used the land suitability maps developed in the previous years of the project which are based on a crop model considering the impact of precipitation, temperature, soil water retention characteristics and relief on a given crop productivity. Moreover we take into account the Corine Land Cover maps and the area information that is provided at NUTS-2, NUTS-3 and NUTS-4 level. It is assumed that crops compete for space; however several crops can be present within a 1x1 km grid cell. The algorithm developed assigns shares of crops to individual grid cells – the share of a given crop is proportional to its suitability ranking and the agricultural category found on the Corine Land Cover map. The crop type maps have been incorporated in D9: Final version of the land use model.

Objective 8: Testing LUMOCAP in case study regions

The LUMOCAP model was tested for several case study areas focusing mainly on the Podlaskie and Slaskie regions of Poland. The main objective was to evaluate the performance of the model for 200x200 m grid cells and to check its utility for supporting regional decision making regarding the planning of new road infrastructure. Authorities face serious conflicts between different stakeholders and interest groups and need an objective quantified assessment of urban growth impacts on land resources. Testing two scenarios of the Via Baltica highway variants has shown that there are significant differences in their impact on soil resources and the development of the region. In Podlaskie one of the variants is promoting more balanced growth of the whole region, whereas the alternative is benefiting mostly the capital city. In Silesia the urbanization of agricultural land tends to be placed mainly on contaminated land. In consequence local population faces significant exposure to health risks related to fugitive soil dust contaminated with heavy metals. The results of these tests have been demonstrated to regional authorities, which generated a serious interest in implementing the presented modelling approach and tools for decision support in the planning process.

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List of deliverables

Table 3: Deliverables List

Del. no.	Deliverable name	Lead contractor
D3	Establishment of the relationships between bio-physical conditions and land use change	IUNG (3)
D4	Establishment of the relationships between socio-economic variables and land use change	IUNG (3)
D5	Preliminary quantitive land use model at the test regions level	IUNG (3)
D6	Preliminary quantitive land use model at the country level	IUNG (3)
D7	Preliminary quantitive land use model at the EU level	IUNG (3)

WP 3 – Dynamic land use model

Objectives

Main objectives of WP 3 were:

1. Adapt a previously developed integrated dynamic spatial land use modelling framework to make it capable of representing land use changes caused by CAP at high spatial resolutions (4ha – 1km^2), on a yearly basis, and for the EU27
2. Integrate the bio-physical, institutional and socio-economic CAP related processes developed in this project in a single land-use model
3. Encapsulate the land use model in a user-friendly, transparent and interactive software and decision support environment running on the PC platform

Progress towards objectives

Objective 1: Adapt a previously developed integrated dynamic spatial land use model

To run the different models that are part of the system in a spatially explicit manner with the required resolution (1000 and 200 m grid cells), the METRONAMICA modelling framework and accompanying GEONAMICA software environment had to be redesigned and for the latter work had to be carried out to improve the running speed and reduce the memory required. In the final year a lot of time was devoted to testing and bug solving. For the latter a bug tracking system was set-up in which project partners and (potential) users could report their bugs and were updated on the solution found.

Ensuring a dynamic integration of the different (spatial) model components turned out to be a major challenge from a software point of view. Although previous work had been carried out at country level, developing a system at EU-27 at 1x 1 km with several spatial components of which some would run at the more detailed 200 x 200 m resolution turned out to be a bigger task than expected.

The final system is provided as Deliverable 9: Final version of the land use model. To assist the user in working with the system all functionality has been thoroughly documented in a user manual, which is included in Deliverable 10: Documentation of the system. All model desciptions, integration between models, data included, data manipulations carried out, calibration procedures and results, and linkages from policy relevant drivers to the integrated model and from the integrated model to policy relevant indicators, are documented in Deliverable 17: Final report.

Objective 2: Incorporation of different model components:

The LUMOCAP system has been developed in an iterative manner. Whenever new components became available they were integrated into the overall framework. The following components have been included:

- The climate change component developed by IUNG (see WP 2)
- The socio-economic scenarios provided by KU Leuven and RIKS
- The agricultural economics model at EU level developed by KU Leuven (see WP 1)
- The national interaction and disaggregation model developed by RIKS
- The regional interaction and disaggregation model developed by RIKS
- The local land use model, the original METRONAMICA, developed by RIKS
- The local crop choice model developed by RIKS and filled with crop type maps constructed by IUNG (see WP 2)
- The physical suitability model at local level developed by IUNG (see WP 2)
- The indicators at different spatial levels constructed and provided by JRC (see WP 4)

During the final year the case regions were implemented into the overall system. This required both scientific and software activities. Scientific activities related mainly to the boundary effects of the locations where coarse (1x1 km) and detailed (200x200) models met. Software development related to the actual incorporation of the case regions in the LUMOCAP system, which tested both the flexibility of the system as well as its capacity to handle several millions of cells at local level in a dynamic manner.

To be able to link agricultural economics at EU level to local land use, two new model components had to be developed: The national interaction and disaggregation model and the regional interaction and disaggregation model. These components are based on the existing socio-economic interaction model available in the METRONAMICA modelling framework, but have been adapted to be able to deal with the agricultural sector. Main innovations and improvements were to find and incorporate appropriate factors that influence the attrativeness of regions for certain crop types. The following factors have been incorporated in the final version of the system: physical suitability of the (existing and potential) agricultural locations in a region, the number of large farms (to take into account economies of scale for those crops for which this is relevant – e.g. cereals), number of jobs in agriculture, relevant advantages related to the way policies (subsidies) are implemented and tradition (existing practices).

To provide the level of detail on the land use maps that was desired by our potential users, a crop choice component had to be developed that could allocate regional totals to local agricultural cells. Since very often there is a diversity of crops in an area of 1x1 km (the cell resolution for EU-27), it was decided that each cell could be occupied by several crop types. The initial crop type maps (1990 and 2000) consisted of crop shares for each cell for the different crop types and were developed by IUNG in WP 2.

In setting-up the integrated system we experienced problems in ensuring data consistencies and furthermore a lot of time was devoted to fill in the gaps in the data at NUTS-2 level. Data inconsistencies mainly occurred between the numerical/statistical data provided by Eurostat and the maps provided by EEA, but we also experienced problems within the Eurostat database in the form of inconsistencies between different scales (NUTS-1 and NUTS-2). All data used, inconsistencies found and manipulations carried out are documented in Deliverable 17: Final report. Details on data issues are provided in the annex of this report.

Setting-up the system included setting up a version for calibration purposes with start year 1990 and setting-up the final system for ex-ante policy impact assessment with start year 2000.
We also set up applications for parts of the system. For calibration and testing purposes we have set-up separate applications for each model components as well as applications for groups of components. Since the full system has a running time in the order of hours for simulating 30 years into the future we also decided to set-up applications for parts of the system for ex ante policy impact assessment studies. The final deliverable of the LUMOCAP system (Deliverable 9: Final version of the land use model) therefore includes the following project files:

1. Entire system for EU-27 with case regions
2. Entire system for EU-27 without case regions
3. Entire system for EU-27 without case regions with static suitability

This selection has been made based on the running speed of the different applications and the relevance for policy users, e.g. for analysis at European level the case regions do not always provide much added value and running the system without them saves a lot of running time.

The approach used for calibration included a calibration over an historic period and testing the system on its long-term behaviour. Individual partners have first calibrated each individual component and afterwards groups of components were tested on their long-term behaviour which sometimes resulted in fine-tuning of the parameters of the individual models. In other cases adaptations have taken place to the way the integration between models was implemented.
The calibration procedure and its results are decribed in Deliverable 17: Final report.

The final system is provided as Deliverable 9: Final version of the land use model.

<u>Objective 3: User interaction and development of graphical user interface</u>

To ensure the development of a system that is scientifically correct and also fulfills the necesarry user requirements, first an inventory of all requirements has been made. Scientific requirements have been discussed amongst the project partners during the project meetings. For the user requirements a user meeting has been organised at DG AGRI in Brussels (07.02.2006), which was attended by a number of potential (end-)users from DG AGRI as well as the partners of the LUMOCAP project. To present the potential (end-) users with an initial idea for the LUMOCAP system a strategy paper had been prepared to which all partners contributed. During the meeting the ideas for the overall LUMOCAP system were discussed and it was decided to have bi-annual end-user meetings to tune requirements and system development during the course of the project in an iterative process. We decided to maintain a strategy paper that was updated after each iteration round. This turned out to be very successful in keeping one overall goal for the development of the system and also in informing users what has been done with their comments and to what changes in the system this has lead. If comments could not be included in the system the reason for this was also explained. The final strategy paper can be found on the LUMOCAP web site.

During the course of the project, meetings have been organised with DG AGRI and the project team to discuss and define:

- Important elements for inclusion in the LUMOCAP system:
  - External driving forces (in collaboration with WP 1 & WP 2)
  - Policy interventions (in collaboration with WP 1)
  - Policy relevant indicators (in collaboration with WP 4)
  - Identify model improvements (in collaboration with WP 1 & WP 2)
- The design of the Graphical User Interface (GUI) with the following elements:
  - Easy access to input and output for policy-makers as well as scientists
  - The design of a policy user friendly interface that gives access to available input, relevant policy interventions and relevant output
  - The design of a modeller interface that gives access to all underlying data and parameters and that is structured by model block
  - Hierarchical development of scenarios, to facilitate to user in organising a number of scenarios and to allow to develop integrated scenarios by including user from different disciplines, each who would be responsible for one of more disciplines and accompanying sub-scenarios
  - A user friendly presentation, visualisation and analysis of results

When the LUMOCAP system opens, the interface in figure 4 is visible. The main window is organised according to drivers, scenarios, indicators and analysis (see left side of the main window). The drivers are divided into CAP measures, other policy measures, external factors and parameters. The first three elements are most relevant for the policy makers. In the parameter part the user finds a system diagram that gives access to the underlying models and their parameters. This part is especially suited for the scientist who can fine-tune the parameters of his/her own model or incorporate new data.

For all policy relevant intputs (CAP measures, other policy measures and external factors) the user can save specific subscenarios, e.g. subscenarios for population growth, subscenarios for CAP and climate subscenarios. In the scenario part of the GUI the user can combine the different subscenarios into an integrated scenario. By constructing the scenarios in a hierarchical manner the user is facilitated in keeping track of the different input values and can easily combine different subscenarios to create integrated scenarios.

Outputs are organised under the indicator part of the GUI. Indicators are organised according to economic, environmental and social indicators. Figure 4 shows the crop diversity indicator (an environmental indicator) and the detailed land use map. All indicators are updated on a yearly basis.

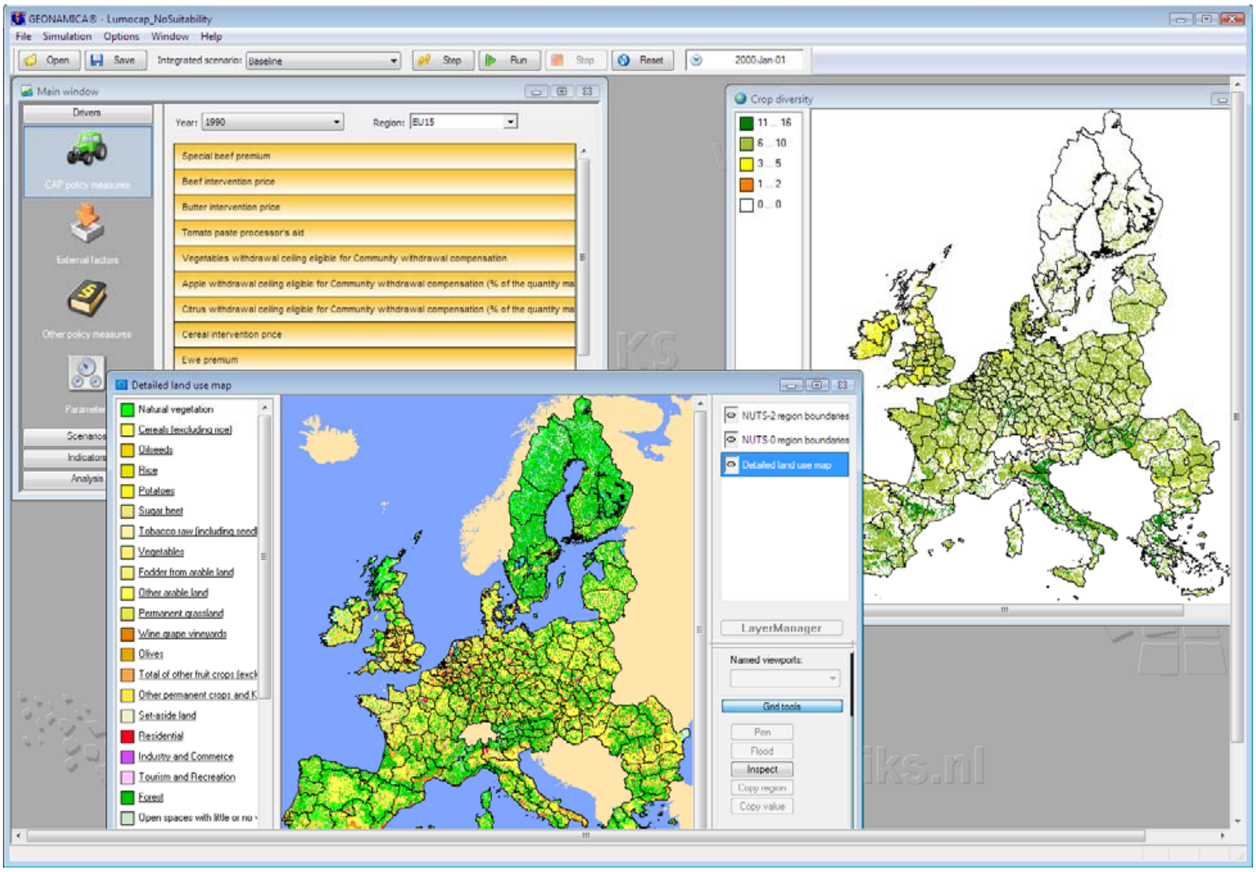


Figure 4: GUI of the LUMOCAP system

In July 2008 practical exercises were developed that allowed (potential) users to test the system on its user-friendliness. In general the system was evaluated user-friendly, especially compared to other systems developed in scientific projects. Some suggestions were provided and problems detected that were solved before the end of the project. The user evaluation can be found on the LUMOCAP web site.

List of deliverables

Table 4: Deliverables List

Del. no.	Deliverable name	Lead contractor
D8	Prototype of the land use model	RIKS (1)
D9	Final version of the land use model	RIKS (1)
D10	Documentation of the system	RIKS (1)

WP 4 – Indicators

Objectives

The objective for WP 4 was to develop a methodology for implementing in the LUMOCAP system landscape indicators relevant for the impact assessment of land cover/use changes following scenarios of CAP implementation.

Progress towards objectives

The first part of the work focused on the analysis of the existing indicator frameworks and tests for calculating a selection of indicators given the resolution provided by the LUMOCAP system.

A revision of recent literature was carried out, to contribute to the discussion on the theoretical framework of the landscape concept to be used for the definition of appropriate landscape indicators, in particular addressed to agricultural landscapes but also in a broad sense to all landscapes. When studying and evaluating agricultural landscapes, one needs to identify landscape aspects or dimensions to be monitored through indicators (aesthetic, cultural and ecological).

Addressing the visual dimension implies mainly the use of methods and techniques to assess the perception of landscape values by selected strata of the society or an expert panel. From a cultural perspective, landscape is the product of the interaction between human beings and their surrounding environment, so the identification of cultural features of the built heritage but also of field structures and farming practices (as part of the culture linked to farming) are addressed. The functional perspective addresses the influence of agricultural human activities shaping the landscape, the ecosystem processes at landscape level and their interrelation. Besides the three aspects or dimensions mentioned above, landscape is also spatial explicit, so the study of its biophysical cover allows addressing land cover-land use dynamics as well as changes in its structure or pattern.

Another important issue in this discussion is the definition of the framework for the interpretation of the indicators. First, their interpretation within an administrative framework has the drawback of the artificial boundaries and the difficulty of defining which level is relevant to the analysis of landscape indicators. However, most of relevant statistical information is produced or compiled in administrative units. Second, taking into account that agriculture has significantly contributed to shape landscapes, farming systems could act as a reference for the interpretation of the indicators. In fact, traditionally farming systems were adapted to particular biophysical conditions and so, landscape features were differentiated and managed through farming practices according to their functional roles in the land use system, giving place to a particular spatial arrangement. Though there are ongoing initiatives to set up a typology of farming systems, there is not yet detailed spatial information available. Third, there is the possibility of using homogeneous units in terms of biophysical conditions such as landscape character areas (or landscape units), environmental zones or catchments from which there is available data that has been recently produced at European level.

Regarding the policy framework, relevant work has been carried out in recent years by international institutions and within EU-funded projects in order to define frameworks of indicators for defining the state and monitor trends of change in the rural landscape, in particular when these are driven by the implementation of EU policies.

The final indicator framework for the LUMOCAP project is presented in figure 5.

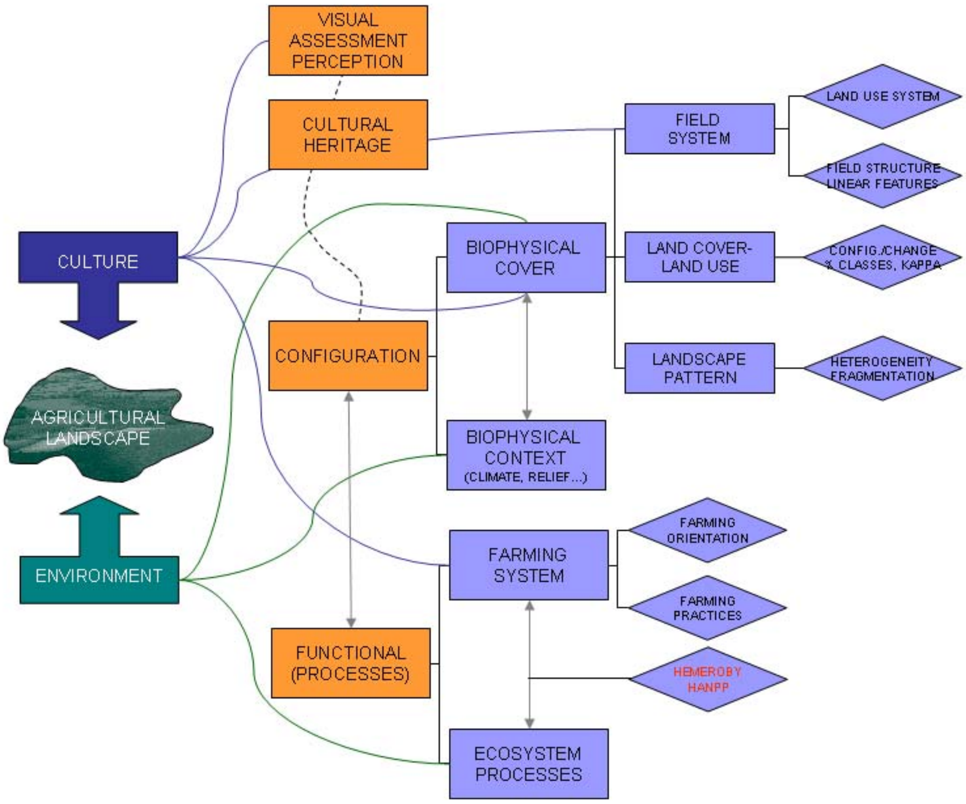


Figure 5: Theoretical framework showing the different aspects or dimensions that characterize the landscape

From the literature study, the most relevant indicators for the LUMOCAP project are the agri-environmental indicators compiled by OECD (OECD, 2001, Environmental Indicators for Agriculture); the IRENA framework (COM 2001(144) - Statistical Information needed for Indicators to monitor the Integration of Environmental concerns into the Common Agricultural Policy); the ELISA (EnvironmentaL Indicators for Sustainable Agriculture) and the ENRISK (Environmental Risk Assessment for European Agriculture) projects, both coordinated by ECNC. To this list a very important framework has to be added, which is still under discussion: the Common

Monitoring and Evaluation Framework for monitoring the implementation of Rural Development Policy (2007-2013).

A first draft list of possible indicators has been prepared and presented during a meeting of the project with DG AGRI (07.02.06), which has been identified as one of the main potential end users of the system. The selected indicators describe two of the identified dimensions of the landscape: the spatial configuration and functional aspects. In particular, these indicators refer to the domains of biophysical cover, farming systems and to the relation between farming system/farming ecosystems. There is a inherent difficulty in approaching the modelling of the cultural dimension, linked to the difficulty of measuring the landscape perception, which is partly due to the high component in subjectivity and the subsequently lack of operational indicators at European level on this dimension. These factors are a constraint to include the perception dimension into the LUMOCAP framework, however such dimension should be taken into account indirectly, as there are some general patterns of configuration that are appreciated widely by the society. In the presented framework the main cultural aspects associated to agricultural landscapes in LUMOCAP will be the field systems.
Furthermore, for the definition and selection of appropriate indicators to assess landscape state and change at European level an assessment of the effectiveness of selected landscape indicators through crosschecking with available regional data is carried out. This implies the selection of landscape indicators analysed from a structural and functional perspective. In order to analyse the constraints of using European datasets, implying the effect of scale on the result of the indicators, and the potential limitations to capture landscape processes which are produced at local scale, a test has been carried out on the Region of Galicia, based on the Regional land cover map, which has a higher thematic and geometric resolution than Corine Land Cover map. The same will be applied, if a suitable land cover map is available, on the Polish Silesia region, which is one of LUMOCAP test areas.

Based on the bibliographic research and the tests carried out, a list of indicators has been drawn on the basis of the framework described above and for implementation in the LUMOCAP system, which referred to two of the previously mentioned dimensions of the landscape: the spatial configuration and functional aspects. In particular, these indicators refer to the domains of biophysical cover, farming systems and to the relation between farming system/farming ecosystems.

Synoptic tables containing the indicator lists are presented on the next page.

Domain		Indicator	Change	Aggregation results		Resolution	
				Cell basis	Aggregated	1 km	200 m
BIOPHYSICAL COVER	Composition	Crop diversity					
		Crop distribution					
		Land cover stock and change					
		Degree of openness					
		Genetic biodiversity					
	Spatial pattern	Patch Size					
		Patch Density					
		Edge Density					
		Interspersion and Juxtaposition Index					
		Largest Patch Index					
		Diversity					

Domain		Indicator	Change Analysis	Aggregation results		Resolution	
				Cell basis	Aggregated	1 km	200 m
FARMING SYSTEM	Management intensity	Extensive crops, extensive grazing					
		Soil erosion (using PESERA results)					
	Farmer characteristics	Age structure					
	Farm characteristics	Nº of farms					
		Income/ ha					
	Trends	Specialization-Diversification Farmland Abandonment Intensification/Extensification Marginalization					

Domain		Indicator	Change	Aggregation results		Resolution	
				Cell basis	Aggregated	1 km	200 m
FARMING-ECOSYTESMS		Hemeroby					
		Ecological Footprint					
		HNV					
OTHER		Agricultural areas under Natura 2000					
		Less Favoured Areas					

Shading in grey is used to indicate which aspects regarding change analysis, aggregation of results and spatial resolution apply to each indicator. Some indicators related to farming systems could not be incorporated in the current version of the system and are placed on the wish list for later versions.

An analysis of the indicators resulting from the LUMOCAP system has been carried out, on the basis of the base year situation and the policy scenario results. This type of assessment was also used in the implementation phase of the overall modelling system. A description of the work carried out can be found in Deliverable 17: Final report. The description of the indicators, formulas and implementation is described in detail in D11 – "Report on landscape indicators development and formal description of algorithms".

List of deliverables

Table 8: Deliverables list WP 4 – Indicators

Del. no.	Deliverable name	Lead contractor
D11	Report of landscape indicators development and formal description of algorithms	EC-DG JRC-IES (4)

WP 5 – Policy impact assessment

Objectives

WP 5 had two main objectives:

- Methodologies for policy impact assessment at different spatial (grid, NUTS, Country, EU level) and temporal resolution,
- Application of the land use model to analyse the impact of CAP on land use and rural landscapes.

Progress towards objectives

Objective 1: Methodologies for policy impact assessment:

This activity aimed at providing a comprehensive analysis of the impact of EU agricultural policies on land use dynamics, landscape and environment.

The list of activities carried out as part of the objective 1 are provided below and described in "Deliverable 12: Methodologies for policy impact assessment" under chapters with same names as the following headings:

1. Public Goods and Externalities in Agriculture

Besides producing traditional commodities such as food and fibre, the agricultural sector also supplies several other goods to society. Society gets several benefits from agricultural activities such as landscapes, biodiversity and maintenance of traditions. This is also known as multifunctionality. Multifunctionality refers to the fact that agricultural activates produce multiple outputs which may address different needs of society. OECD uses the term non-commodity output to distinguish non-traditional commodities (landscapes, biodiversity, maintenance of traditions, etc.) from traditional agricultural commodities (wheat, maize, meat, etc.) for which markets exist and for which farmers can internalise benefits (OECD, 2001b).

2. Multifunctionality, Market Failure, and Policy Choice

For most non-commodity outputs there are no markets where transactions exist. Farmers cannot exchange these commodities in return for a reward (or for a cost in the case of negative externalities). Farmers do not have information about their value to the society and moreover they do not have incentives to supply the desired level of quantity because they are not rewarded for their provision (or do not incur costs in the case of "negative" non-commodity outputs). In these circumstances the supply of non-commodity outputs is ad-hoc and could be lower or smaller than the welfare maximisation level. The supply is dependent on the way non-commodity outputs are joined to the production of commodity outputs. For this reason policy intervention may be desirable to address the market inefficiency.

The following issues were analysed related to multifunctionality, market failure, and policy choice:

- Jointness between non-commodity outputs and commodity outputs.

Jointness in production occurs when production of two or more products are interlinked. A change in production of one output also changes the production of other output(s).
The jointness between agricultural production and non-commodity outputs occurs due to three main reasons: technical interdependencies, non-allocable factors and allocative factors.
The main non-commodity outputs are produced jointly with commodity outputs:

Table 3: Positive and negative non-commodity outputs

"Positive" non-commodity outputs	"Negative" non-commodity outputs
– Landscape and open space amenities – Cultural heritage – Rural economic viability – Enhanced food security – Prevention of natural hazards – Groundwater resource recharge – Preservation of biodiversity – Land conservation	– Loss of biodiversity – Water pollution from nutrients and erosion – Animal welfare – Irrigation-related problems (water overuse, salinization) – Greenhouse gas emissions

Detailed analyses were conducted and described in this section in "Deliverable 12: Methodologies for policy impact assessment" to show welfare effects of different policies which address market failure related to non-commodity output provision.

- Economic costs of policies

For a comprehensive analysis of alternative policies, it is essential to incorporate the costs agricultural policies inflict on economy. Munk (1994, p.79) defines economic costs as "the sum of the real income effects for farmers, consumers, and taxpayers created by governmental intervention". Munk (1994, p.79) divides the economic costs in distortionary costs and transaction costs. Distortionary costs include costs that emerge due to misallocation of resources in economy caused by the agricultural policies. Transaction costs include administrative and compliance costs that government, farmers, and other agents must incur in relation to agricultural policies. For example these costs include administrative costs, compliance costs incurred by farmers when applying for subsidies, etc. Further, the economic costs of agricultural policies can be split in two categories: 1) direct and 2) indirect costs (Munk 1994, p.80). Based on these two classifications, economic costs can be split in four categories: direct distortionary costs, direct transaction costs, indirect distortionary costs and indirect transaction costs (Munk 1994, p.80).

Table 4: Classification of economic costs

	Direct costs	Indirect costs
Distortionary costs	*Direct distortionary costs* include distortions in the agricultural sector caused when implementing agricultural policies	*Indirect distortionary costs* include distortions in other sectors caused when collecting taxes necessary to finance agricultural policies
Transaction costs	*Direct transaction costs* include administrative and farm compliance costs incurred for implementation, monitoring and enforcement of agricultural policies	*Indirect transaction costs* include administrative and compliance costs related to tax collection

This section in "Deliverable 12: Methodologies for policy impact assessment" analyses each policy in detail and based on the evidence from economic literature it quantifies the economic costs of policies.

- Territorial aspect of policies

The jointness between commodity and non-commodity outputs is location specific. The number as well as the level of non-commodity outputs produced jointly with agricultural production strongly differs between regions. Some regions are more endowed in supplying non-commodity outputs than other regions. For example, erosion and landscape is more important in mountainous regions than in regions with flat landscapes. These factors complicate the design of policies addressing market failures.

An efficient policy requires implementing regionally differentiated policies in order to be able to target policies to locations where non-commodity output is produced. However better targeting of policies increases transaction costs.

This section in "Deliverable 12: Methodologies for policy impact assessment" analyses how the design of efficient policy complicates when jointness of non-commodity output differs between regions.

- Non-agricultural supply of non-commodity outputs and economics of scope

This section summarises the option of non-agricultural supply of "positive" non-commodity outputs.

An alternative way of supplying non-commodity outputs is through non-agricultural provision. When designing a policy addressing multifunctionality this option also must be taken in consideration. Non-agricultural provision concerns only "positive" non-commodity outputs. "Negative" non-commodity outputs are undesirable for society therefore the issue of non-agricultural provision is not relevant for these commodities.

Table 5: Non-agricultural provision of non-commodity outputs and their level of jointness

	Level of jointness	Examples of non-agricultural provision	Possibility of non-agricultural supply
Landscape and open space amenities	Medium	Parks, wild nature	Low
Cultural heritage	High	Museums,	Medium
Rural economic viability	Low	Development of non-agricultural sectors in rural areas	High
Enhanced food security	Medium/low	Promotion of international trade, transport infrastructure, sufficiently high income level	High
Prevention of natural hazards	Medium/low	Dams, natural regeneration	-
Groundwater resource recharge	Medium/low	Through natural process	-
Preservation of biodiversity	Medium	Parks, programs provided by nature and conservation groups	Medium
Land conservation	High	-	Low

- Equity and rent distribution effects

This section in "Deliverable 12: Methodologies for policy impact assessment" discusses equity and rent distribution effects of policies.

3. Casual Effects between Market Developments, Policies and Multifunctionality

Market developments and policies affect farmers' incentives which results in changes in production of both commodity and non-commodity outputs. The objective of this section was to identify the interrelated factors that impact multifunctional agriculture. Specifically, the DPSIR methodology is applied to identify causality between market forces and commodity and non-commodity output provision as well as to analyse the role of policies in this respect.

Originally, the DPSIR methodology was formulated on the bases of the PSR (Pressure – State – Response) framework developed by OECD (1994, 1997). The PSR concept was expanded during the 1990s by the European Environment Agency and Eurostat (EEA, 1999) to include drivers and impacts: The Driver – Pressure – State – Impact – Response framework (DPSIR). This methodology has gained international prominence and its advantage is that it can be used to describe interactions between different types of factors and also observe feedback effects. In the same time its advantage is that it can be applied at a national level, at subnational (regional and local) level, at project level or for sectoral analysis.

According to the DPSIR framework there is a chain of causal links from driving forces over pressure to the state of the agricultural sector and the impact on farmers and non-commodity provision, finally leading to political response:

i. *Driving forces*: indicate what is causing certain patterns of development in agriculture
ii. *Pressures*: are effects of driving forces and represent the pressure on the agricultural sector
iii. *State* is directly caused by the pressures, and represents the state of the agricultural sector
iv. *Impacts* are effects on farmers and non-commodity output provision
v. *Responses*: are given to alleviate the impacts, the state, the pressures, or the driving forces

- Driving forces

Indicators of driving forces describe the social, demographic and economic developments. Driving forces are the underlying causes which change farm incentives and lead to pressures within the agricultural sector on the use of natural resources, farm technology, input use, emissions and other factors related to multifunctional agriculture. The main link through which pressure is exerted on farm incentives is through change in relative input and output prices, change in income level, access to markets, the level of competition, etc.

Main driving forces of agriculture are:

- Domestic macro developments
- International trade developments
- Change in consumer preferences
- Market structure
- Bio-energy
- Agricultural policies

Section 4.2 in “Deliverable 12: Methodologies for policy impact assessment” discusses in detail each driving force in relation to its impact on the agricultural sector.

- Pressures

Pressures are effects of one or more driving force(s). The pressures represent the incentives induced on the agricultural sector by driving forces. Incentives determine the behaviour of the farm sector and ultimately lead to changes of the provision on non-commodity outputs. From a policy perspective, the pressures often represent targets of agricultural policies.

Main pressures caused by driving forces are:

- Agricultural output prices
- Agricultural input prices
- Use of natural resources
- Market power
- Vertical coordination
- Incentives of family and hired labour
- Standards and food quality

Section 4.3 in “Deliverable 12: Methodologies for policy impact assessment” discusses in detail the link between driving forces and pressures.

- State and impacts

State and impacts are directly caused by pressures. Pressures create incentives in the agricultural sector. The incentives induce certain farmers’ behaviour by affecting the state and impacts in the agricultural sector which affects the supply of non-commodity outputs.

Several linkages can be identified between pressures and farm behaviour and hence between incentives created by pressures and the state of the agricultural sector and non-commodity output provision: output effect, input effect, farming practices effect, resource base effect, and technology effect.
Section 4.4 in “Deliverable 12: Methodologies for policy impact assessment” discusses the state and impacts in detail.

- Responses

Section 4.5 in “Deliverable 12: Methodologies for policy impact assessment” discusses factors affecting the efficiency of policy responses taken to alter undesired development in the agricultural economy.

Responses represent measures taken to alter impacts, state, pressures, or driving forces. In general, responses can come from two sources. They can be implemented centrally by state intervention through policy measures (e.g. legal or administrative instruments, economic instruments such as market regulations) or through markets (e.g. market coordination and institutions). In this project the analysis focused on the first group of responses, i.e. on policy measures.

From the efficiency point of view, a policy targeting driving forces or pressures is more efficient in achieving its objectives then a policy targeting state and impacts. The state and impacts are the results of driving forces and pressures. In general, undesired developments in the state and impacts induce policy response. The state and impacts are usually targets of policies.

The efficiency of policies also depends on the mechanism through which they affect driving forces, pressures and particularly farm incentives. The key factors are whether policies are voluntary or compulsory, the level of coupling of policies, and the territorial and institutional dimension of policies.

Objective 2: Application of the land use model for the ex-ante assessment of CAP

The coverage of this activity was to test the LUMOCAP model and to assess the impact of CAP on land use in EU-27. More specifically, the objective of this activity was to analyze how macro changes and changes in agricultural polices affect land use changes in EU. The simulation results were provided up to 2030 for three scenarios: baseline, macro scenario, and policy scenario.

The baseline scenario assumed continuation of past polices, the macro scenario assumed an increased GDP of 50% relative to the baseline scenario, and the policy scenario assumed that direct payments, intervention prices, rural development payments, and quotas are cut by 50% relative to the baseline.
Simulation results for the macro scenario and the policy scenario indicate that changes in GDP have a stronger effect on land use changes than CAP in NMS and EU-15. Higher GDP growth by 50% relative to the baseline growth leads to higher decrease in UAA and stronger changes among different land use categories than the policy scenario which assumes a reduction in policy support by 50% relative to the baseline. These results indicate that structural changes in the economy are strong drivers of aggregate land use changes in agriculture. On the other hand, agricultural policies are more important in affecting the allocation of the agricultural area among different crops.
Agricultural models used in the literature were reviewed and a comparison of results between these models and LUMOCAP was carried out. There are various models and analytical frameworks applied to analyze the impact of CAP on EU agricultural markets. The following agricultural models and analytical frameworks were reviewed: ESIM, CAPRI, AGMEMOD, AGLINK, SCENAR 2020, GENEDEC, IDEMA.

Results of objective two are described in Deliverable 13 - Ex-ante assessment of CAP impact.

List of deliverables

Table 6: Deliverables List

Del. no.	Deliverable name	Lead contractor
D12	Methodologies for policy impact assessment	KU Leuven (2)
D13	Report on ex-ante assessment of CAP impact	KU Leuven (2)

WP 6 – Training and dissemination

Objectives

The objectives of WP 6 were the following:

1. Creation and maintenance of a web-site for the dissemination of the material developed during the project
2. Creation of a logo and document templates
3. Development of training material
4. Organisation of hand-on workshops with selected potential end-users of the land use model and associated methodologies
5. Preparation of the final report

Progress towards objectives

Objective 1: Creation and maintenance of a web-site

The web pages have been incorporated in the existing Agri-Env web site http://agrienv.jrc.it/lumocap/ (figure 10). It is structured in a public and a password protected part. In the public part the description of the project and the different work packages is available and was updated regularly during the development of the project.

In the password protected part internal documents are uploaded (minutes of meetings etc.) and the site is also used by project partners as location for exchanging files.

JRC has maintained and updated the LUMOCAP project web site (http://agrienv.jrc.it/LUMOCAP/) throughout the project (Deliverable 16: Web site).

Objective 2: Creation of a logo and document templates

In figure 10 the logo of the project is visible at the top of the page; it is used in project templates (for documents, presentations, posters). Templates for documents and presentations have been prepared.

Objectives 3 and 4 : Training material and training workshops

The following training activities have taken place:

- A LUMOCAP presentation targeted to DGI AGRI has been organised at DG AGRI premises in June 2008
- A LUMOCAP workshop/training course targeted to DG AGRI has been organised at DG AGRI premises in July 2008
- A LUMOCAP workshop/training course targeted to Member States experts has been organised at JRC premises in July 2008

JRC has taken care of the organisation of the workshop in Ispra and RIKS of the organisation of the workshop at DG AGRI. All partners have contributed to training and dissemination activities by attending the training workshops, preparing and giving presentations, assisting workshop participants in working with the system and actively participating in the discussions (Deliverable 15: Workshops).

RIKS has developed training exercises that were used during the training workshops. These exercises are provided in Deliverable 14: Hands-on training material.

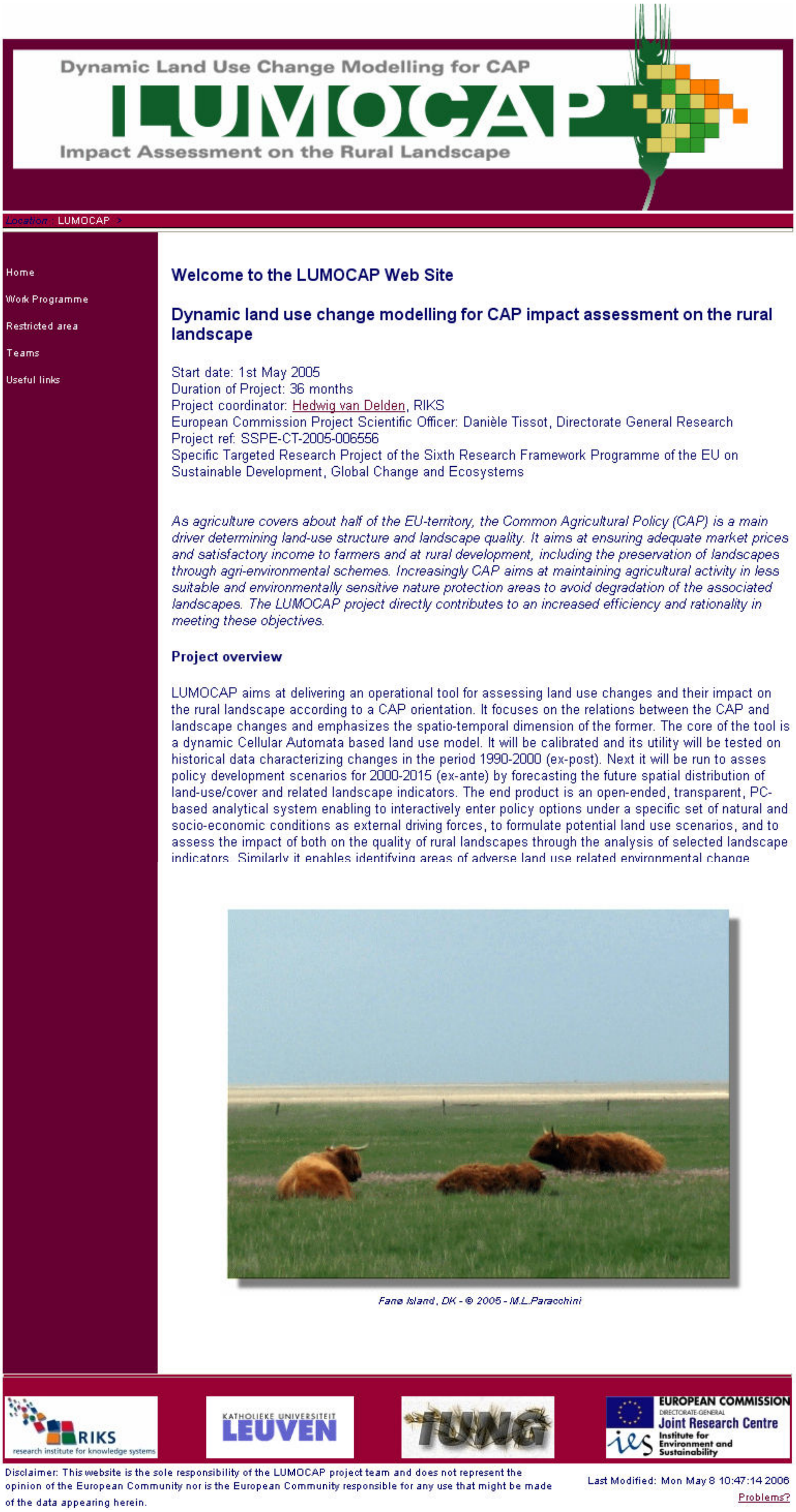
Objective 5: Preparation of the final report

JRC has compiled the final report with contribution from all partners. Deliverable 17: Final report describes the models and data used, the interlinkages between the models, the calibration procedure and results, and the scenario analysis.

List of deliverables

Table 8: Deliverables List

Del. no.	Deliverable name	Work package no.	Date due (project month)	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
D14	Hands-on training material	WP 6	33	39	n.a.	n.a.	RIKS (1)
D15	Workshops	WP 6	36	39	n.a.	n.a.	EC-DG JRC-IES (4)
D16	Web site	WP 6	36	40	n.a.	n.a.	EC-DG JRC-IES (4)
D17	Final report	WP 6	36	40	n.a.	n.a.	EC-DG JRC-IES (4)



Dynamic Land Use Change Modelling for CAP

LUMOCAP

Impact Assessment on the Rural Landscape

Location: LUMOCAP >

Home
Work Programme
Restricted area
Teams
Useful links

Welcome to the LUMOCAP Web Site

Dynamic land use change modelling for CAP impact assessment on the rural landscape

Start date: 1st May 2005
Duration of Project: 36 months
Project coordinator: Hedwig van Delden, RIKS
European Commission Project Scientific Officer: Danièle Tissot, Directorate General Research
Project ref: SSPE-CT-2005-006556
Specific Targeted Research Project of the Sixth Research Framework Programme of the EU on Sustainable Development, Global Change and Ecosystems

As agriculture covers about half of the EU-territory, the Common Agricultural Policy (CAP) is a main driver determining land-use structure and landscape quality. It aims at ensuring adequate market prices and satisfactory income to farmers and at rural development, including the preservation of landscapes through agri-environmental schemes. Increasingly CAP aims at maintaining agricultural activity in less suitable and environmentally sensitive nature protection areas to avoid degradation of the associated landscapes. The LUMOCAP project directly contributes to an increased efficiency and rationality in meeting these objectives.

Project overview

LUMOCAP aims at delivering an operational tool for assessing land use changes and their impact on the rural landscape according to a CAP orientation. It focuses on the relations between the CAP and landscape changes and emphasizes the spatio-temporal dimension of the former. The core of the tool is a dynamic Cellular Automata based land use model. It will be calibrated and its utility will be tested on historical data characterizing changes in the period 1990-2000 (ex-post). Next it will be run to asses policy development scenarios for 2000-2015 (ex-ante) by forecasting the future spatial distribution of land-use/cover and related landscape indicators. The end product is an open-ended, transparent, PC-based analytical system enabling to interactively enter policy options under a specific set of natural and socio-economic conditions as external driving forces, to formulate potential land use scenarios, and to assess the impact of both on the quality of rural landscapes through the analysis of selected landscape indicators. Similarly it enables identifying areas of adverse land use related environmental change

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RIKS research institute for knowledge systems
KATHOLIEKE UNIVERSITEIT LEUVEN
IUNG
EUROPEAN COMMISSION DIRECTORATE-GENERAL Joint Research Centre ies Institute for Environment and Sustainability

Disclaimer: This website is the sole responsibility of the LUMOCAP project team and does not represent the opinion of the European Community nor is the European Community responsible for any use that might be made of the data appearing herein.

Last Modified: Mon May 8 10:47:14 2006
Problems?

Figure 6: LUMOCAP project web site and logo

Section 4 – Publishable results of the final plan for using and disseminating the knowledge

Plan for using the knowledge

The LUMOCAP Integrated Spatial Decision Support System is a software system for the analysis of future impacts of the Common Agricultural Policy of the land use and landscape in EU-27. It takes into account many spatial and non-spatial drivers and facilitates what-if analysis for a wide range of indicators. It provides policy organisations with a platform for quantitative assessment and deliberation of policy proposals.

The underlying models and software implementation are at pre-beta phase. The next step to take towards a useable product is to further involve end-users, assess the applicability of the current functionality, identify crucial shortcomings and adress them, in order to produce the first-generation mature product. The LUMOCAP consortium is actively looking for sources of funding for this development, and/or partners with market knowledge who can add value in the market introduction process of the product.

For further information, please contact Hedwig van Delden, project coordinator of the LUMOCAP project and Director of the Research Institute for Knowledge Systems BV, at hvdelden@riks.nl or +31 43 350 1750.

Dissemination of knowledge

During and after the LUMOCAP project a lot of attention has been given to disseminating the work carried out during the project. There have been a number of meetings at other universities, research organisations and policy organisations and the results of the project have been incorporated in MSc courses. Furthermore the work has been presented at several workshops and conferences. As can be seen from the table below, this work has started during the project, but also continues after the official closing date of the project. We have made a start in writing journal articles and also this work will continue after the project.

During the project we have had several meetings with DG AGRI and experts and policy makers from Member States. We intend to organise one or more follow-up meetings after the project, to disseminate the knowledge and to explore future possibilities. The number of workshop will depend on the interest of potential users and the budget and time available from the partners.

Table 2: Overview of dissemination of knowledge

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
Updated thoughout the project	Project web-site	General public	EU-27		JRC
09-2005	Organisation of International Workshop on ‘Integrating agriculture and environment: CAP driven land use scenarios’, Villa Carlotta, Belgirate, Italy	Research	EU-27	50	JRC
09-2005	Presentation ‘CAP and land abandonement in Poland’ at the International Workshop on ‘Integrating agriculture and environment:	Research	EU-27	50	IUNG

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
	CAP driven land use scenarios', Villa Carlotta, Belgirate, Italy				
09-2005	Presentation 'Modelling the impacts of policy interventions on land use dynamics with Spatial Decision Support Systems' at the International Workshop on 'Integrating agriculture and environment: CAP driven land use scenarios', Villa Carlotta, Belgirate, Italy	Research	EU-27	50	RIKS, JRC, IUNG, KU Leuven
03-2006	Proland International Workshop "Soil Protection Strategy – needs and approaches for policy support", Pulawy, Poland Presentation: 'Land use changes in polluted areas as a response to CAP instruments - food chain risk aspects' Posters: 'Land-use changes in Silesia region in relation to key sustainability issues using cluster analysis' 'Using selective generalization for improving land-use change analysis of Silesia'	Research	EU-27	75	IUNG
18-20 April 2007	Conference presentation 'The LUMOCAP PSS, providing support to agricultural policy making in an integrative context' Conference: Framing Land Use Dynamics II, Utrecht, The Netherlands http://www.geo.uu.nl/homegeosciences/research/researchinstitut/pgri/fludii/41058main.html	Research, Higher educaton Politicians	International	300	RIKS, JRC, IUNG, KU Leuven
19-20 April 2007	Poster 'A simple approach to Land Suitability assessment for delineation of LFA in	Expert meeting	EU-27	100	JRC

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
	the EU' JRC, Ispra				
From April 2007	pdf file Restricted expert web-site: http://agrienv.jrc.it/activities/lfa/restricted/agenda_april2007.html	Experts, Higher educaton Politicians	EU-27	Restricted for interest group	JRC
May 2007	Publication 'Assessment and modelling of land use change in Europe in the context of soil protection'	Research, Higher educaton Politicians	EU-27		IUNG
4- 6 July 2007	Poster 13th EC-GI & GIS Workshop, Porto - PT "Landscape Change Analysis at Regional Level using Corine Land Cover. The examples of Galicia (Spain) and Silesia (Poland)"	Research Higher education	International	300	JRC
20-22 September 2007 AR Kraków, Poland	Conference article 'Modele zmian użytkowania gruntów i ich wykorzystanie jako narzędzie wsparcia decycji' (Land Use change models and its use for policy support) Conference: Aktualny stan, zadania i kierunki przekształceń wsi i rolnictwa w kontekście polityki Unii Europejskiej; (Actual state and changes directions of countryside and agriculture in EU policy context)	Research	Poland	80 (planned)	IUNG
2007	Ciaian, P. "Land use changes in the EU: Policy and macro impact Analysis." Agricultural Economics – Czech, 53(12) pp. 567–579.	Research	International	Scientific community	KU Leuven
January 29th - February 1st, 2008 Sevilla, Spain	Ciaian, P. and J. F.M. Swinnen. "Credit Market Imperfections and the Distribution of Policy Rents: The Common Agricultural Policy in the New EU Member States." Paper presented at the 107th EAAE Seminar on "Modelling Agricultural	Research, Higher educaton Politicians	International	120	KU Leuven

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
	and Rural Development Policies." Organized by IPTS - Institute for Prospective Technological Studies and Universidad Pablo de Olavide.				
August 26-29, 2008 Gent, Belgium	Ciaian, P. and J. F.M. Swinnen. "Credit Market Imperfections and the Distribution of Policy Rents." Poster presented at the 12th EAAE Congress on "People, Food and Environments: Global Trends and European strategies." Organized by EAAE.	Research, Higher educaton Politicians	International	800	KU Leuven
6-9 April 2008 Berlin, Germany	Conference presentation 'The LUMOCAP PSS, impact assessment of agricultural policies in an integrative context' Conference: Impact Assessment of Land Use Changes http://www.sensor-conference2008.eu/	Research, Higher educaton Politicians	International	300	RIKS, JRC, IUNG, KU Leuven
10 June 2008	Presentation and discussion at DG AGRI in the premises of DG AGRI (Rue de la Loi, Brussels) to discuss the usefulness of the final version of the system	DG AGRI	EU-27	15	RIKS, JRC, IUNG, KU Leuven
15 July 2008	Training session in the premises of DG AGRI (Rue de la Loi, Brussels), open to DG AGRI personnel.	DG AGRI	EU-27	10	RIKS, JRC, IUNG, KU Leuven
17 July 2008	LUMOCAP training workshop in the JRC training facilities in Ispra (Italy).	Ten experts / policy makers from different Member States, plus interested JRC/IES staff	EU-27	16	JRC, RIKS, IUNG, KU Leuven
10-12 March 2009 Egmond aan Zee, The Netherlands	Conference presentation 'The LUMOCAP PSS, impact assessment of agricultural policies in an integrative context' Conference: Integrated Assessment of Agriculture and Sustainable Development http://www.conference-agsap.org/index.htm	Research, Higher educaton Politicians	International	300	RIKS, JRC, IUNG, KU Leuven

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
13-17 July 2009 Cairns, Australia	Conference presentation ‘Lessons learnt in the development, implementation and use of ISDSS’. In: B. Anderssen et al. (Eds), 18th IMACS World Congress - MODSIM09 International Congress on Modelling and Simulation. Cairns, Australia. ISBN: 978-0-9758400-7-8. http://www.mssanz.org.au/modsim09/	Research, Higher educaton Politicians	International	1000	RIKS
2009-2010	Van Delden, H., Ciaian, P., Paracchini, M.L., Stuczynski, T., Hurkens, J., Lopatka, A., Gomez, O., Shi, Y. and Vanhout, R. (submitted). The LUMOCAP Policy Support System: Impact assessment in an integrative context. Agricultural Systems.	Research	International	Scientific community	RIKS, JRC, IUNG, KU Leuven
2009-2010	Van Delden, H., Van Vliet, J. and Kirkby, M. (submitted). Scaling issues in integrated modelling for policy support: lessons learnt and current challenges. Agriculture, Ecosystems and Environment.	Research	International	Scientific community	RIKS
2009-2010	Van Delden, H., Seppelt, R., White, R., and Jakeman, A.J. (submitted). A methodology for the design and development of integrated models for policy support. Environmental Modelling and Software.	Research	International	Scientific community	RIKS
2009-2010	Van Delden, H., Stuczynski, T., Ciaian, P., Paracchini, M.L., Hurkens, J., Lopatka, A., Gomez, O., Calvo, S., Shi, Y. and Vanhout, R. (submitted). The LUMOCAP Policy Support System: Dynamic land use change modelling for impact assessment of agricultural policies on	Research	International	Scientific community	RIKS, JRC, IUNG, KU Leuven

Planned / actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible / involved
	the rural landscape. Ecological Modelling.				