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A Multiscalar and Multiagent Modelling Framework for Assessing Sustainable Futures in a Globalised Environment

"MULTIMODE"

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT
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FINAL REPORT PHASE 1

A MULTISCALAR AND MULTIAGENT MODELLING FRAMEWORK FOR ASSESSING SUSTAINABLE FUTURES IN A GLOBALISED ENVIRONMENT "MULTIMODE"

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Acronyms and abbreviations

ABM	Agent-based Model
ACCELERATES	Assessing climate change effects on land use and ecosystems, from regional analysis to the European scale
ANT	Actor-Network Theory
ADAGE	Public Decision Support in Agriculture and Environment
AEM	Agri-environmental measure
ATEAM	Advanced terrestrial ecosystem analysis and modelling
CA	Cellular Automata (model)
CCA	Constrained Cellular Automata (model)
CAP	Common Agricultural Policy
DGA	Direction Générale de l'Agriculture (Genral Diretorate for Agriculture)
EcoChange	Biodiversity and Ecosystem Changes in Europe
ECRU	Unité d'économie rurale
ESDP	European Spatial Development Perspective
FADN	Farm Accounting Data Network
GDP	Gross domestic product
GIREA	Groupe Interuniversitaire de Recherches en Ecologie Appliquée (Inter-university Group for Applied Ecology)
GIS	Geographic Information Systems
MultiMode	Multiscalar and Multiagent Model
PRELUDE	Prospective Environmental analysis of Land Use Development in Europe
RDP	Rural Development Plan
SBM	Social Behavioural Model
UCL	Université catholique de Louvain
VITO	Vlaamse Instelling voor Technologisch Onderzoek
VLM	Vlaamse Landmaatschappij (Flemish Land Agency)
VUB	Vrije Universiteit Brussel
WFD	Water Framework Directive
WP	Work package

1. Project Network

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2. Context of research

With increasingly globalised economies, sustainable development is becoming an even greater challenge to both science and policy. Globalisation provides new opportunities, but also creates unknown risks and so, global policies must seek to balance economic growth, human development and environmental health to ensure sustainable development. Trade liberalisation and climate change are the most controversial issues on the current global political agenda because of the unequal distribution of benefits and costs. International agreements on trade and climate influence sustainable development because of their direct impacts on the environment through changes in regional consumption, production and land use patterns. However, emerging regional patterns are not only the consequence of the effects of global drivers and regional policies alone, but they are also a manifestation of the adaptive behaviour of individuals and institutions to the impacts of these drivers and policies. People possess cognitive abilities to exhaust or economise social, economic and natural resources to adapt to any changes in the environment. Such that global policies are outcomes of international political compromise, national economic gains are unequally distributed between sectors, between places and between people. Thus, governments develop strategies that will help to balance the negative impacts of globalisation (e.g. urban migration, environmental degradation, etc.) and to promote sustainable development in affected areas and communities. For example, the Common Agricultural Policy (CAP), the European Spatial Development Perspective, and the Water Framework Directive are strategies at the European level that aim to achieve these goals. Hence, sustainable development can be understood as an outcome of the decision-processes of policy-makers and communities alike to adapt to the opportunities created through or risks caused by global drivers and regional policies. In view of these issues, understanding sustainable development requires knowledge of adaptation processes, and the promotion of sustainable development demands appropriate adaptation measures. Policy should be able to provide measures to help local communities adapt in a sustainable manner, and science has the challenging task of informing policy about the future sustainability of these measures.

This project aims to contribute to the fulfilment of this task by developing an integrated modelling framework that can assess, first, the impacts of global processes on social, economic and natural environment in Belgium, and secondly, the effects of decision-processes at different institutional levels (e.g. national, regional, provincial, municipal/communal) in achieving sustainable social, economic and ecologic development of Belgian local communities. The integrated modelling framework will generate quantitative and qualitative sustainability indicators (i.e. social, economic and natural resource), and a composite index based on the three pillars of sustainable development weighted according to stakeholders' judgement and expertise. Indicators of sustainable development must capture the interaction between human system and the environment because "if a system is viable in its environment, it will be sustainable" (Bossel 1999:26). It is thus important to assess the sustainability of not only the people, but also the spatially and temporally environment on which their existence depends. Moreover, the set of indicators must represent the system's structure of hierarchy and subsidiarity (Bossel 1999:22) that reflects responsibility and the means for adapting to the changes in the environment at different levels of administration. It is thus important to assess the sustainability of not only the total system, but also the nested sub-systems that function within it with some degree of autonomy. The novelty of the project's integrated framework lies in providing a spatio-temporal links between the human system and its social, economic and natural environment, and using an embedded approach for evaluating the changes in the human system's environment at different administrative scale. Consequently, the integrated framework for assessing sustainable futures will be operated through a multiscalar and multiagent model (MultiMode) in which the national impacts of global changes are filtered out and/or trickle down to local agents through the adaptive decisions of institutional agents at the regional, provincial and communal levels. The innovation of MultiMode lies in creating a synergy between the empirical knowledge derived from various approaches that will allow a more coherent and realistic link between global changes, national impacts and local adaptation over time.

3. Objectives

MultiMode aims to promote sustainable development in Belgium in a globalised context through the development of an integrated, multi-scale modelling framework of human economic activities and associated land uses. The modelling framework will combine top-down and bottom-up models that address both urban and rural land use, but given the importance (in spatial terms) of agricultural land use, a particular focus will be on the sustainability of farming practices. The specific research objectives are:

- to construct sets of narrative storylines based on existing knowledge about global drivers of environmental change (policy, demographic, economic, climate and technological), identify European policies that respond to these global drivers to promote sustainable development, and make these global scenarios and policy options readily available for assessment using a meta-model;
- to model demographic, economic, environmental (including land use) changes at different embedded spatial scales resulting from global drivers and European policies and the adaptation, mitigation or reinforcement measures of planning and policy authorities at each level using a constrained cellular automata model;
- to evaluate the adaptive behaviour of land use decision-makers at different administrative levels in selected case studies in Belgium using an agent-based model and generate knowledge on adaptation processes to develop state transition rules in the cellular automata model;
- to represent the decision-making processes of land use agents in a social behavioural model and thus generate information for building decision rules for the agent-based model;
- to analyse the sustainable practices of farmers in selected communities by using socio-economic assessment procedures and participatory approaches based on stakeholder dialogue;
- to test and validate the scenarios, assumptions and results of the models at different scales of analysis by obtaining feedback from stakeholders through meetings with the follow-up committee, focus groups and a final project workshop; and
- to generate multi-scale measures (indicators) of social, economic and ecologic sustainability by integrating the empirical knowledge generated from the meta-model, cellular automata, agent-based model, social behavioural model and stakeholder involvement.

To achieve these objectives, a network of 5 expert research groups from Belgium and beyond makes-up the multi-disciplinary team providing complementary expertise in the fields of natural and human sciences, in particular natural and human ecology, physical and human geography, economics and statistics.

The interdisciplinary quality of the integrated framework and multi-disciplinary expertise of the research network will enable the project to make valuable contributions to the research programme on Science for a Sustainable Development (SSD). *MultiMode* is based on an innovative concept that structures sustainability research around the interface between socio-economic and environmental drivers and their consequences for land use change processes and ecological dynamics. The project gathers new datasets and makes use of existing ones, integrate model results, and develop indicators for assessing and forecasting the impacts of socio-economic mechanisms on land use and biodiversity in the context of global economic and climate change. It thus considers the complexity of interactions and provides an explicit quantitative link between the social, economic, and environmental pillars of sustainable development at different administrative levels. In doing so, *MultiMode* not only facilitates the assessment of adaptation policies and strategies at the European, federal, regional, and local levels, but also improves understanding of how to design policies to minimise the adverse effects of human activities on ecosystems and to maximise the long-term sustainability of their service-providing capability. The multiscalar characteristic of the *MultiMode* framework allows the evaluation of fundamental sustainable development principles, in particular the principle of subsidiarity as well as the principle of vertical and horizontal policy integration. Evaluating these principles will enable the project to provide scientific support for designing well-founded, coherent and prioritised policy decisions aimed at concentrating sustainable development strategies in the most crucial and immediate areas of importance.

It is not the intention of the project to duplicate existing modelling exercises, but to apply existing scenarios, cellular automata and agent-based models and agency-oriented approaches, and to integrate the empirical knowledge generated from them to improve their practical utility. The scenarios, concepts and approaches in *Multimode* are drawn from interdisciplinary projects, in which the different partners have been involved. Stakeholders are involved at different levels of the analysis throughout the duration of the project to ensure not only a valid synergy between the different concepts used in the integrated framework, but also to identify results that are of practical use for policy and decision making. The operationalisation of the MultiMode integrated approach thus requires dialogue and information exchange between scientists from various fields, decision-makers at different levels of authority, groups of individuals lobbying for a common interest, and farmers with different socio-economic attributes. Such an integration of tools and knowledge is crucial for understanding the complex and dynamic aspects of sustainability, which would not be possible if the models were applied independently. Thus, *Multimode* needs to consider crosscutting issues in different research areas to achieve systematic and optimal integration of the different models.

4. Methodology

The key innovation being carried out within *MultiMode* is its multi-scale and multi-agent integrative approach for assessing and forecasting the consequences of policies aimed at sustainable development. Integration takes place not only across different scales and agents, but also across a range of disciplines and approaches. The levels of administration and decision-making represent the scales (i.e. national, regional, provincial, municipal, and community) and the institutions and individuals that make decisions at different scales represent the agents (e.g. decision-makers, planners, farmers). The project is organised into four work packages: Meta-Model of Policy Options and Scenarios (WP1), Multi-scale Constrained Cellular-Automata Model (WP2), Landscape Scale Agent-Based Model of Decision Rules (WP3) and Stakeholder Dialogue and Feedbacks (WP4). The integration between these work packages is presented in Figure 1.

The policy options and scenarios at the global and European scale (WP1) will flow into the cellular-automata model (WP2) and agent-based model (WP3) as drivers of land use change and socio-economic decision-making processes, respectively. As the name implies, cellular automata (CA) are models based on cells with attributes that are bounded in space. The different attributes of the cell can represent physical, environmental, social, economic, infrastructural and institutional characteristics. CA is a useful tool for assessing spatial dynamics in the environment due to the impacts of global drivers and European policies. However, adaptation process of institutions and individuals are not captured in CA because human agent's, whose actions and decisions are not bounded in space, are not explicit in the model. Agent-based modelling (ABM) takes account of the adaptive decisions of agents and the impacts of their decisions on the sustainability of the local environment because the agents are the focus of the analysis. However, the empirical application of ABM is mostly limited at a community level due to the huge amount of data required. ABM links the agents to their social, economic and natural environment. Within the integrated MultiMode approach, the spatially and temporally dynamic environment created in the CA will be used to define the constraints and opportunities of the agents in the ABM. Because the agents will also include the decision-makers and planners at different administrative levels, the ABM results will inform the CA about the impacts of adaptive decisions on changes in the social, economic and natural environment. Thus, there will be a feedback between the cellular-automata and agent-based models, which will improve their practical use in assessing sustainable development.

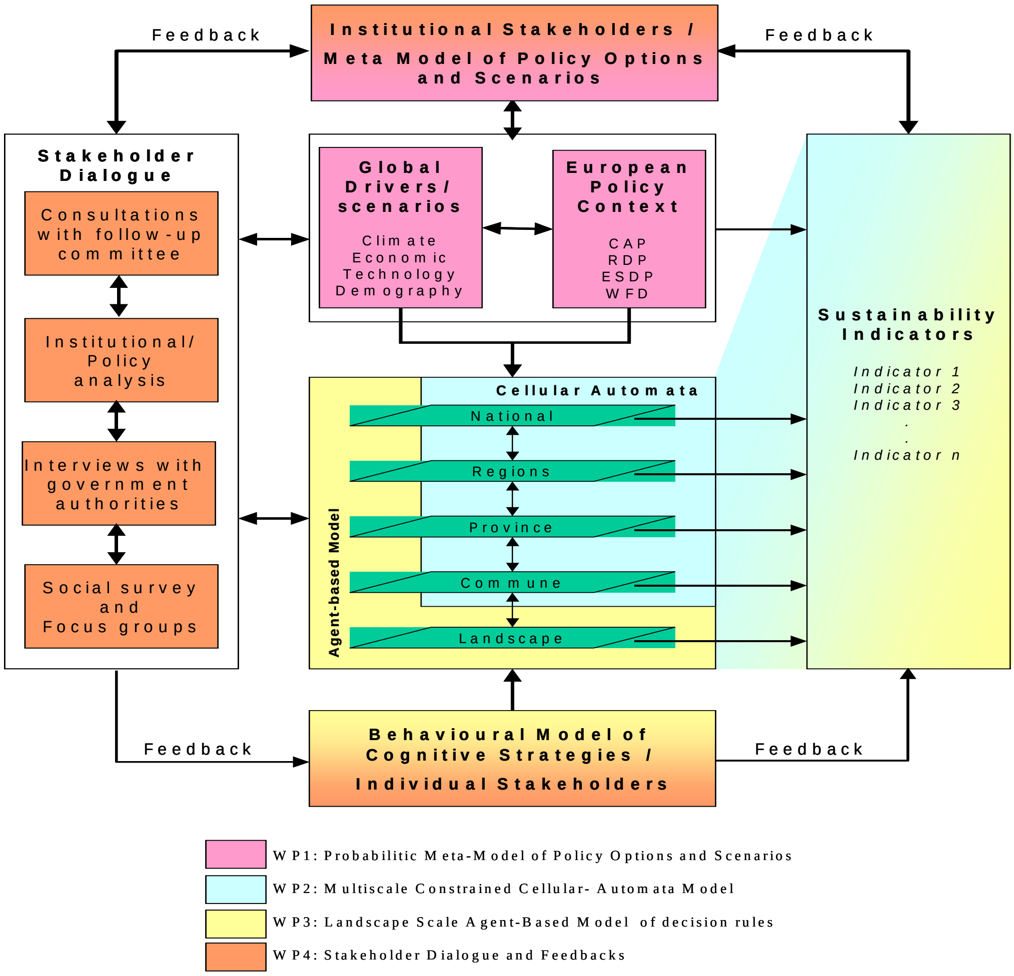


Figure 1. Flow diagram of Data, Methods and Outputs in each Work Package

The novelty of ABM lies in its ability to capture the behaviour of the agents in adapting to changes in their environment. In the ABM developed in this project these adaptive decisions will be represented by social behavioural model (SBM), which will be developed using knowledge elicited from stakeholder dialogue and feedbacks (WP4). SBM summarises both rational (e.g. economic maximization) and sub-rational (e.g. imitation, social comparison) cognitive strategies of the agents. Allowing the integration of both rational and sub-rational cognitive strategies in ABM will improve the current scientific practice of assessing future sustainability because it will allow assessment of sustainability not only according to economic and environmental, but also social factors. For example, social values and network can explain why some individuals ignore economic opportunities or environmental risks (i.e. maladaptive agents). Moreover, the strategies will identify the sources of adaptive capacity of individual agents, whether these are economic such as market, technology, services and subsidies, or social such as knowledge, network and information, or both. Considering these factors in the assessment of sustainable futures is especially important where technology, information, network, services and market are highly interlinked with the global world, such as in Belgium. Moreover, the institutional and policy analysis in WP4 will inform the ABM about the links and interactions between the institutional agents, and the influence of organisational hierarchy and subsidiarity on the sustainability of the individual agents and their environment. The successful completion of WP3 is thus largely dependent on the knowledge and information generated from WP4.

The models in the four work packages will generate various measures of sustainable development at different scales. These measures, which include spatio-temporal indicators and maps (from WP2 and WP3) at national, regional, provincial, communal and landscape levels as well as qualitative description of European generic sustainability (from WP1) and Belgian farm sustainable practices (from WP4). Table 1 presents some examples of the indicators that will be generated for the different pillars of sustainable development. The models can generate a large number of potential indicators of sustainable development from a complex system with nested subsystems. However, "the set of indicators must be relatively compact if is to be of any value… [h]ence, there must be selection and aggregation" (Bossel 1999:65). Using a stakeholder participatory approach, the indicators generated form MultiMode will be assessed in terms of relevance to sustainability debate and given weights to develop a composite index of sustainable development.

Table 1. Indicators of sustainable development from MultiMode

Pillars	Meta Model[a/]	Cellular Automata[b/]	Agent-based Model[c/]	Behavioural Model[d/]	Stakeholder participation[e/]
Social	Population growth & density	Population (total, density & potential); Employment (total, per sector & potential)	Social network; Social values; Migration	Personal and family values	Composite index of sustainable development
Economic	GDP per capita; Prices & Subsidies; Yield; Technological development	Type of economic activities; Area occupied per economic sector; Road infrastructure	Farm income & expenses; Yield; Diversification	Farm income	
Ecologic	Climate Change	Quality of residential environment; Potential disturbance of natural areas and high nature value farmland; Proximity to open and green areas; fragmentation	Nitrogen balance; Methane emission; Agri-environmental farm practices; Habitat structure	Behavioural intention towards sustainable practices	

Note: [a/]European; [b/]National, regional, provincial and municipal/communal scale; [c/]Municipal, community and individual scale; [d/]Individual scale; [a/]All scales

5. Results

During the phase 1 of MultiMode, the models in different work packages are developed with only minor integration with each other. The reason for this is that each model has its own level of complexity in terms of concept, data and analysis, which should be first addressed and developed before sensible integration of knowledge between them could be carried out. For example, the CA and ABM model require elaborate maps and codes that need to be tested and calibrated. The results discussed below thus mainly refer to the individual work carried out in each work package.

5.1 WP1: Meta-Model of Policy Options and Scenarios

5.1.1 Introduction to WP1

The scenario approach is widely used in many sciences (physical, economic, and social) in varied circumstances and for different purposes (Carter et al., 2001; Alcamo, 2001). Scenario thinking may offer solutions to complex issues for which there appears to be no simple analysis (Davis, 2002). Scenarios are coherent, credible stories about alternative futures. Importantly, scenarios are not predictions of the future. Instead, the main idea of the scenario approach is to use multiple perspectives to explore a specific problem (Rounsevell, et al., 2005). Scenarios on global trade and climate change will be given emphasis in this work package because they are important processes in globalisation and because they provide the boundary conditions for future change within Belgium. The economic literature provides several global models applied to agricultural and trade policies (van Tongeren et al., 2000), the concepts of which can be based on partial or general equilibrium. The different trade models have their pros and cons, hence, it is necessary to evaluate the applicability of their assumptions and analyses for the objectives of MultiMode. Scenarios on climate change and other socio-economic variables will be drawn from various European projects such as VISIONS (Rotmans et a. 2000), ACCELERATES (Abiltrup et al., 2006; Rounsevell et al., 2006a), ALARM (Settele et al., 2005), ATEAM ((Schröter et al. 2005; Rounsevell et al., 2006b), PRELUDE (Delden et. al, 2005). The global scenarios developed in these different projects are consistent with frameworks of the Millennium Ecosystem Assessment (MA) and Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES).

Whilst scenarios of global drivers have been generated from previous models and are published in the literature, there has been no attempt to collect and analyse these scenarios as the basis for evaluating sustainable development. MultiMode develops a meta-model of policy options and scenarios, based on look-up tables and/or simple statistical functions. The model allows key demographic, economic and climate parameters to be estimated in a flexible way from the existing knowledge base. The work package does not intend to develop new models to generate these parameters, but to take advantage of existing model outputs and scenarios. In addition to reviewing knowledge of existing drivers of global processes and constructing sets of narrative storylines that are based on these drivers, the work package also reviews global and regional policies that are currently implemented or negotiated, which are relevant for describing future changes in demographic, economic and climatic conditions. All options and scenarios, which are being collected and validated for the assessment of sustainable development, are made available for the analysis of global and regional changes through the meta-model.

5.1.2 Scenarios and storylines

A comprehensive literature review was carried out to identify both quantitative and qualitative models that are useful for developing an appropriate scenario framework for WP1. Among the most useful models include those developed in European projects including Accelerates, ATEAM, PRELUDE, etc. Like these studies, MultiMode follows closely the interpretations of the global storylines of the Intergovernmental Panel on Climate Change (IPCC) that are presented in the special report on emissions scenarios (SRES). Whilst we tried to fit in the scenarios in the SRES framework, an important contribution of this project is interpreting the storylines and downscaling the drivers to the regional scale within Belgium. The SRES framework is global in extent and therefore it is necessary to translate these global driving forces to a more local level, so that it can be applied for a smaller study area, i.e. Belgium. Qualitative description of social drivers such as social networks and farmer's sustainable behaviour is included in the storylines. In the work of WP1, the specific drivers that influence each land use type were identified through regular working sessions of the multimode project staff. We further had regular follow-up sessions with the entire advisory committee and special sessions with individual advisory committee members, both of which provide feedback on our assumptions in the MultiMode work.

Four scenarios based on SRES framework have been identified for MultiMode - Global and economic emphasis (GEE), Globalised and environmental/social emphasis (GES), Localised and economic emphasis (LEE), and Localised and emphasis on social/environment (LES). Detailed storylines for each scenario have been developed and are described below (Tables 2 – 5).

Table 2 . Scenario 1: Global and economic emphasis (GEE)

Economy	The integration in the global economy allows Belgium to achieve high economic growth and technological progress. A successful WTO agreement led to a phasing out of barriers to trade in the world and a general increase in the volume and value of trade. The WTO has a strong influence and this assists Europe's and Belgium's position in the global market place. Belgium's strategic position and port access enables it to become a centre of the increased trade flow, resulting in higher rates of employment. A strongly improved transportation network (car, train and barges), which shortens travel time for commuters reaching work in city centres or industry and services parks. Further, the increasing integration of the European continent leads to Belgium gaining importance as a political and administrative centre within the European Union. This also leads to new job creation and higher GDP growth and increased levels of per capita income. With regard to economic activities, the services sector gains in importance, with the industrial sector increasing less strongly.
Technology	The focus on the services and technology industries sweeps from Flanders into Wallonia. Lots of funding for research and development is given through grants and subsidies from the government. The need for qualified workers (especially in high tech professions) is so high that professionals from other regions in Europe and the world migrate to Belgium. Infrastructure is good anywhere in the country with improved systems of transportation and a better communication network. Belgium's transportation network improves (railroads and roads more so than canals and river locks). Both Flanders and Wallonia benefit from this strong economy, but Flanders is benefiting to a larger extent as it was initially in a better position to deal with such developments. Flanders also becomes more attractive as a centre of investment than Wallonia, both in terms of population and economic activities.
Demographics	Birth rates in Belgium stay low as young couples focus on their careers and delay starting a family, but migration leads to an overall moderate increase in the population. Lower unemployment rates are observed and fairly high income disparity between the two Belgium regions. A high standard of living is observed for some, but others remain worse off and little increase in social awareness leads to a lack of adequate health care services and retirement system. Life expectancy only increases moderately and because society does not sufficiently adapt to the growing demands of the elderly, the issue of an ageing population is less pronounced than in the other scenarios. Further, Belgium witnesses some poverty among retired people. Increased flows of money enter the educational system, as investment for the future of Belgium. In terms of the human capital, the percentage of higher educated people in rural areas increases, generating the workforce needed for the high technology and service jobs. Social and economic inequalities increase. Most people live in semi-urban areas. The increase in population and higher incomes leads to the development of more suburban types of housing and more and more land is converted for that use. Only better-off people that move out of the fairly congested city centres into the suburbs are also benefiting from the improved transportation network. People without means of acquiring more expensive plots of land in the suburbs remain in the city centres. Crime in the city

	centres increases and as a consequence more and more gated communities are developed. More car-accessible shopping malls take car of the major consumption needs of people, and local smaller shops disappear.
Policy	Regarding the government, the European Union is the main force of governance affecting people's lives and little emphasis is placed on local self control. Governance is very centralized and few limitations are put in place by the government on expansion of urban areas, industries or other economic activities. Little market intervention is observed. Liberalization and market-based solutions are emphasized. The EU strongly supports the WTO and a broad WTO agreement is in place liberalizing most trade. Consequently, little direct subsidies, market support, and rural development payments are being paid out under the EU common agricultural policy's main pillars. The EU environmental policy is affecting people's lives in that it mandates member countries' implementation of environmental programs such as the Water Framework Directive.
Environment	Agricultural land use is intense, and there is little awareness of environmental issues. Voluntary participation in agro-environmental measures is very limited as most of these measures would lead to higher costs of production and Belgium faces increased environmental problems. At a more general level, European policies such as the framework on water and climate change mitigation policies are in place but implementation of such policies move at a fairly slow place, but still lead to some positive results. Nevertheless environmental problems such as pollution and moderate impacts from climate change are still observed. These are among others increases and variation in precipitation, more severe weather events, such as flooding or droughts and a clear rise in the average temperature. Soil erosion is also an issue in sensitive areas. New technologies are in place to help deal with the mitigation of climate change and the improvement of the environmental conditions in general. Among the population, to some people the environment is important but many place limited emphasis on environmental amenities and thus have low willingness to pay for such services. In the agricultural sector, the expansion of the urban areas happens at the expense of land available for agriculture and such a change in land use is witnessed in the whole country. The land that remains in agriculture is intensively used, partly benefiting from the new technologies and practices developed in a globalised economy and from the increase flow of investments into research of development. Crop and animal yield increases are high due to the better technologies and yields available. Plots sizes increase as production intensifies and natural hedges and windbreakers or removed. But even though land use is intensive, importance of agriculture in the economy decreases to a marginal level and Belgium is a clear importer of most agricultural goods from the global market place. With regard to agri-environmental measures, farmer acceptance and participation is very low. Similarly there few extension officers present to provide technical support to farmers on the AEMs. Further, there is little financial support available to stimulate farmer participation. There is little interest in organic agriculture or renewable energy technologies, nor are there subsidies available for such causes. Therefore, only limited agricultural area is converted into wind parks or crops for bio-energy production. The average age of typical farmers is high, as there are many attractive job opportunities outside of agriculture that generate higher incomes. Thus not every farm immediately finds a family successor to continue the farm's operation leading to a concentration of farms. Farm returns are fairly low, and only the bigger operations remain viable. Little government help is available under the various CAP pillars. The availability of farmer organizations providing support and extension services are decreasing.

Table 3. Scenario 2: Globalised and environmental/social emphasis (GES)

Economy	This scenario envisions a globalised world, which has eliminated most trade barriers, but Belgium has placed little emphasis on the increased trading opportunities. Belgium maintains its position as a net importer of goods, which are produced in other regions at lower costs. The main difference to Scenario 1 is that here the government and society realize that the healthy environment is the basis for any positive future of the country and thus its protection needs to be put high up on the agenda. The country experiences moderate economic growth and also moderate GDP and personal income. Still however, unemployment is low, which is partly due to the fact that Belgium plays an increasingly important role in the European Union as an administrative centre, and partly because the country increasingly also stress social awareness, in addition to environmental protection, and creating jobs in those two sectors that become more important to the overall economy. There is still some income disparity between the two major Belgium regions but less pronounced than in scenario 1.
Technology	Some technological advances are observed, especially in the areas of environmental protection and dealing with the impacts of climate change. The more globalised economy allows the easy importation of such knowledge, as it has been developed and tested in other settings. Private and increasingly

	public spending on research and development are observed, which also helps in developing new tools. The quality of the transportation net improves along with the infrastructure more generally. The communication system improves resulting in high speed internet access into very rural areas where people increasingly decide to move to.
Demographics	In addition, some immigration is observed, which along with slightly higher birth rates leads to a small increase of the population. Little emigration is witnessed, as most young people readily look and find opportunities at home and do not move to other areas of the European Union. Therefore, even though Belgium clearly experiences an ageing population, that development is less emphasized than in the first scenario and the demographic distribution is more even. A strong social net is highly valued by the population. The generation contract (the young taking care of the elderly) is working and little poverty among the elderly is observed. Generally, the supply of hospitals, retirement homes, kindergartens, etc is adequate to meet all needs of Belgium. Increased investments are being undertaken into the education system and with regard to the human capita, workers are more able to fulfil the new jobs created in both Wallonia and Flanders. Social inequalities are less visible and people are increasingly moving to live in smaller villages or rural areas rather than big urban areas, benefiting from the improved transportation network to guarantee a quick commute to and from the work place.
Policy	With regard to the government, the European Union is still the main force of governance and its doings affect the daily lives of Belgians. The EU supports the WTO and its trade agreements. Few restrictions are placed by the government on business decisions with the exception of those pertaining to social institutions and the protection of the environment the EU is a strong factor. Strict clean air regulations have been passed and the EU's water framework is still an important factor. Otherwise, little market intervention is observed and liberalization and market-based solutions are emphasized.
Environment	Generally, awareness for environmental problems is high and dealing with the impacts of climate change is important to large parts of the population. For example, a slight increase in flooding and soil erosion are observed but quickly addressed by implementing adequate responses, such as flood-restrictive and soil-saving measures. There are also increased levels of funding for investments into preventive actions to mitigate the impacts of climate change. People do appreciate environmental amenities and show a high willingness to pay for such services. Land shifting out of agricultures is relatively limited, but the existing use of the land happens less intensively than before. There is only moderate increase in industries, services and expansion of urban areas that result in agricultural land being lost. Farmers are willing to quickly adopt agri-environmental practices, being convinced of their practical use to keep the land sustainable and through financial incentives from the EU and the national government. Some technological advances aid the farmer in adopting such measures and in decreasing his costs of complying with the measures. Conventional agriculture still is the norm, but there is increasing willingness to pay for organic products among the general population. More and more land is used for the production of renewable energy crops. The average age of farmers is lower than in scenario 1 as younger successors are available to make a living from farming. Some consolidation of farms is still observed but the average farm size increases only slightly.

Table 4. Scenario 3: Localised and economic emphasis (LEE)

Economy	This scenario is characterized by a stronger emphasis on the local market (and less globalization), which still results in strong economic growth (with little emphasis on the environment or social issues). The local country side experiences a revival. Small stores and small businesses in villages and rural areas are increasingly thought to take care of people's every day needs instead of similar business in bigger cities. This stimulus to the local economy creates wealth and growth and job creation. Even though not many gains from trade are realized in this locally oriented economy, the increased emphasis and willingness to pay for local products stimulates the economy and leads to higher GDP growth and personal income. Unemployment is low, as a highly stimulated local economy creates jobs. However, one still observes an increased disparity between incomes among groups of the population and between the Belgium regions. More business is being conducted within the country, within Flanders and Wallonia and to some extent with nearby EU member nations. The increased transport and communication network within Belgium aids in the increased economic activity in the country.
Technology	Technical progress is emphasized, not only to find local solutions but also to invest into the local infrastructure. Belgium's transportation network improves (railroads and roads more so than canals

	and river locks) and so does the communication network. Both Flanders and Wallonia benefit from this strong economy, but Flanders is benefiting to a larger extent as it was initially in a better position to deal with such developments. Flanders also becomes more attractive as a centre of investments than Wallonia, both in terms of population and economic activities. Within Wallonia urban areas that have some link to urban centres become more attractive than the mainly rural areas in the southern Ardennes. Government and private investments into new technology and research and development are high.
Demographics	The scenario is generally characterized by a revival of the countryside. People move away from the congested city centres into smaller and safer villages of Flanders and Wallonia. They increasingly consume and act locally. People live longer lives and an ageing society is the consequence. Birth rates are relatively unchanged and almost no immigration is observed with little emigration. Unemployment rates are fairly low due to the stimulus of the local economy and workers are well educated as some money flows into the educational and formational system. We observe an ageing population but less so than in scenario 2. The heavily economic-minded Belgian invests less into adequate social services, hospitals and retirement homes and some poverty among the elderly is observed.
Policy	The trust in central governance decreases. Decentralization and a higher emphasis on more locally controlled governance are the consequence. The EU as a factor in people's every day lives decreases in importance. There are some governmental payments for rural development to help stimulate the local economy. Few other mechanisms of market intervention are observed and liberalization and market-based solutions are stressed. The EU nevertheless still maintains Europe-wide environmental programs such as the water framework directive, but its effectiveness is limited.
Environment	Economic growth is emphasized at the local level and this happens to some extent at the expense of the environment. There is little demand for environmentally friendly food production and thus land use is intense leading to high impacts on the environment through pollution of streams and the groundwater. In addition the consequences from global warming are intensifying the already adverse condition of the environment. Global warming is largely ignored as local governments do not successfully address issues as soil erosion and flooding, which affect sensitive areas, water pollution and precipitation irregularities but focus on the stimulation of the local economy instead. Innovation such as lower energy housing and investments into renewable energy, which could help mitigate the impacts of climate change, are also not addressed and the general awareness and willingness to pay for environmentally sound solutions and products are low. Farming is fairly high-tech and increasingly intense. Increased innovation and investments into agriculture lead to higher yields and the production of lower value as well as higher value crops. The agricultural area will decrease as more housing developments in rural areas and industrial zones spring up. But farming intensity increases and overall output goes up. New crop varieties are developed that need less inputs and produce more. All this development also makes it more difficult for the farmer to adapt agri- environmental measures as he aims at keeping his cost of production low. Farming income is fairly stable, but not always can a successor be found. A concentration of farms and an increase in average size is the consequence. Conventional agricultural is the norm, and little forays into organic agriculture are made. However, there is increasing interest into renewable energy crops, which benefit from better technologies available. Thus in addition to losing land to housing developments, some land is also removed from food production to be used for renewable resources.

Table 5. Scenario 4: Localised and emphasis on social/environment (LES)

Economy	In this scenario only moderate economic growth is observed and overall GDP and personal income growth are smaller. This is because contrary to scenario 3, where an emphasis was placed on the economy over the environment, we now place a strong emphasis on the environment and on social issues. All this takes place in a locally emphasized environment, where the WTO and trade liberalization are less important than in other scenarios. Cost and investments into the environment and social issues take away funds that could otherwise be used to stimulate the economy. However, some new economic opportunities are created by developments and innovations that are used to deal with environmental problems and to stimulate Belgium becoming a more closely knit society. Thus, we still have a revival of the countryside, even though we do not see the same success story in terms of the economy as we have had in scenario 2. Little funding comes from the EU and most solutions are found at a local level within the country. Unemployment is higher due to the limited economic activity, but in terms of the distribution of income, there are fewer disparities within population groups and

	within Belgian regions. Increasing number of people live in the countryside and rural areas, which stimulates the local economy. Due to the people's increased awareness of environmental and social issues, many restrictions are in place with regard to the economic activities, and many businesses find the cost of entry and the cost of following the strict regulations in place too high.
Technology	The moderate rises in incomes and economic growth rates also translate into limited investments into R&D for traditional sectors of investments and thus technological advances. Even though governance is local, the decrease in economic growth translates into reduced tax income for the government and reduced public spending, also for the transport network and infrastructure. Also, limited investments from the private sector into those aspects are observed. Technological innovations also face though bureaucratic hurdles in order to proof that they are compatible with the strict environmental laws in place and thus the influx of new ideas into Belgium happens but with a lag.
Demographics	Almost no immigration is happening but increased numbers of people emigrate to look for better opportunities elsewhere. Higher birth rates are observed domestically and people live longer lives due to adequate health and retirement-related infrastructure, but overall the population is relatively stable. An ageing of the population is also observed, because younger people emigrate. A strong social net exists, and affordable housing is available in cities as well as in rural countrysides for those financially challenged. All in all the society is more homogeneous in terms of equality, but the educational system is lacking the standards to produce strong and well educated workforce.
Policy	The EU as an administrative body and a centralized government is not the dominating force in governance as it is in earlier scenarios. More localized governance is witnessed, which assists in finding local solutions to local problems. The EU is not a major factor in people's every day lives, but does control the basic framework by mandating a number of environmental regulations from its member states, thus also from Wallonia and Flanders.
Environment	The environment faces strong pressure from climate change but programs are in place to mitigate and potentially reverse those impacts. EU legislation and local governance address this point and the more localized are thus in a position to react more quickly to environmental problems, such as pollution, flooding and soil erosion. Some technological advances are brought in to deal with the environmental issues, but due to the limited investments into research and development, more could be done. People's willingness to pay for environmental amenities is higher and the government also collects special taxes to deal with urgent environmental problems. Agriculture is also helping to mitigate those problems, partly because of some innovations that enable farmers to deal with tough environmental restrictions and still keep costs of production fairly low. More generally, the population appreciates locally produced agricultural goods and is willing to pay more for them. Even though economic growth is limited and little agricultural land is lost to be converted into industrial or other non-agricultural uses, some land still is lost to housing, as more people live in the countryside. However, the land that stays in agriculture is used less intensely, partly due to environmental regulation and partly to the growth of lower value commodities. Farmers voluntarily adapt agri-environmental practices as they realize the benefit of maintaining a health resource base for their production. People increasingly demand organic agricultural products, so that these are produced in sufficient quantities to become affordable to large parts of the populations. There is also increased interest into renewable energy resources, be it biofuels and windparks. The average farm size is relatively unchanged as little concentration is happening of agricultural operations and agricultural area.

Considering the data requirements of the CA and ABM models, five groups of driving forces that determine each scenario's character were selected including economy, technology, demographics, policy and environment. These main categories of drivers influence living and working in Belgium in the future. All the drivers can be grouped according to the three pillars of sustainability, economic, social and ecological. Figure 2 presents these drivers in a web diagram to show which drivers have more emphasis in each scenario.

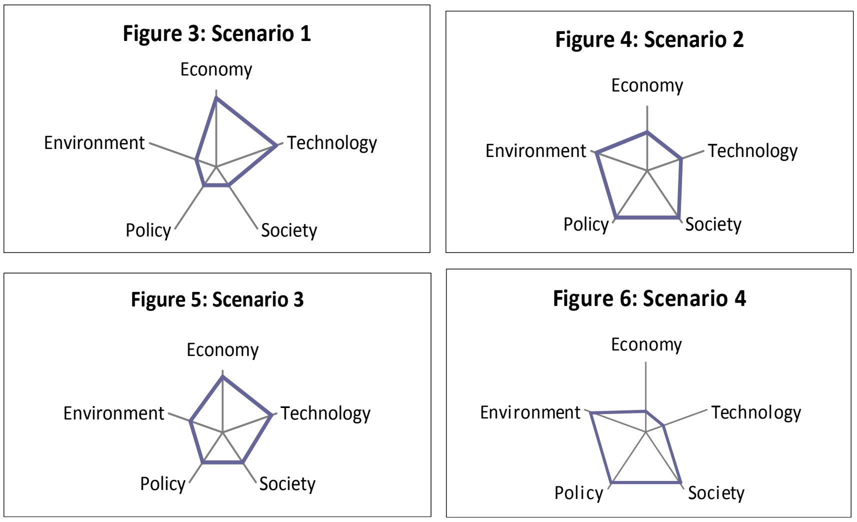


Figure 2. Web diagrams illustrating the emphasis of drivers in the four scenarios

The indicators selected to represent the different groups of drivers are relevant not only in the development context of Belgium, but also to the data requirements of the other work packages. The qualitative values of these indicators, which have been interpreted from the storylines for the Belgian context, are presented in Table 6. MultiMode aims to construct a meta-model, which requires identification of an appropriate tool to present the policy options and scenarios in a way that is transparent for stakeholder validation and sufficiently flexible for application in cellular automata and agent-based models. Depending on the size of the collected database (i.e. validated policy options and global scenarios), the meta-model can be represented in a conditional probabilistic framework. In conditional probabilistic approaches, deterministic values of scenario variables (e.g. population, GDP, prices) are replaced by probability distribution functions (PDFs) of these variables that are conditional on the scenario assumptions. Thus different PDFs are derived (in a subjective way) for different variables and for each considered scenario to reflect the available information across a range of existing scenarios. Conditional probabilistic futures are able, therefore, to better represent uncertainties in scenario variables. The information for some of the indicators identified in Table 6 may not be sufficient to construct PDFs. In this case, they will be represented in simple look-out table.

Table 6. Trends in the most relevant indicators for each driver in baseline and scenarios

Drivers	**Indicator**	**Baseline**	**GEE**	**GES**	**LEE**	**LES**
Economy						
Income level	GDP/capita	+	++	+	+	-
Urban-rural income diff.	Ratio	-	++	-	+	
Employment	Share, %	+	++	+	+	-
Input costs	Price index	-	--	+	-	++
Commodity prices	Price index	-	--	+	-	++
Foreign Trade and Investment	Import/export shares	+	++	+	-	--
Technology						
Investments in infrastr. transport&communication	Highway net, km	+	++	+	+	-
R&D investment	Actuals	+	++	+	+	--
Demographics/Equity						
Population growth	Change, %	+	+	+	-	+
Ageing population	Share, %	+	+	++	+	+
Urbanization rate	Ratio	+	++	+	-	--
Migration/Immigration	Share	+	+	+	-	-
Lifestyle changes (demand for regional products)		+	--	-	+	++
Education	Share, %	+	++	+	++	+
Income distribution	Equity share, %	-	--	+	-	++
Policy						
Influence of WTO	Protection coefficient	+	++	+	-	-
EU CAP 1st pillar (market support, direct subsidies)	Actuals	-	-	+	-	+
EU CAP 2nd pillar (rural development)	Actuals	+	-	+	-	+
EU environmental policy	Actuals	+	--	+	-	++
EU regional policy	Actuals	+				
Environment						
Emissions to air water soil	CO2, NH3	+	++	-	+	-
Investments into environmental. protection	Actuals	+	-	+	-	+
Flooding, soil erosion	Share, %	+	++	-	+	-
Biodiversity loss	# of species	+	++	-	+	-
Organic farming	Share, %	+	-	+	-	+
Bio-energy demand	Share, %	+	-	+	+	++

5.1.3 Historical data and future scenarios

One major aspect of the on-going work is the quantification of the drivers, because actual numbers are needed as inputs for the cellular automata and agent based modelling of future work in the progress. While the quantification of certain drivers is fairly straightforward (for example, the increase in the Belgian population can easily be quantified because the Belgian Planning Bureau publishes reliable estimates), other drivers are much more challenging to quantify. This concerns, for example, the impact from climate change on the major regions in Belgium. Many studies exist predicting a range of impacts in the short and longer term, but for a 50-year horizon, as is envisioned by the MultiMode project, the concrete impacts are relatively unknown. We are thus conducting a careful analysis of the existing studies to obtain the most reliable estimates for the Belgian case at hand. The description of the database of the most relevant indicators that have been so far collected is presented in Table 7. The historical data are used to estimate future values for the indicators. Figure 3 presents examples of future estimates that have already been collected and developed for employment indicators.

Table 7. Database of the most relevant indicators for CA and ABM models

	Indicator	First data	Last data	Source	Available proj.	Our proj.
Economy						
Income level	Real GDP growth	1971	2006	OECD		
	Real GDP per capita	1950	2004	Penn World Tables		yes
	Growth rate of Real GDP per capita	1970	2004	Penn World Tables		
Value added per economic sector	Annual growth of real value added	1971	2006	OECD		yes
	Value added (share of total value added)	1970	2006	OECD		yes
Urban-rural income diff.						
Employment	Employment rate (15/64 years)	1997	2007	DGSIE[1]		
		1983	2006	OECD		
		1980	2013	Fed Plan. Bureau	yes	yes
	Employment rate (15 years and more)	1980	2020	UN[2]	yes	
Employment per economic sector	Number of people	1980	2013	Fed Plan. Bureau	yes	yes
Input costs	Agricultural input prices indice	1995	2008	Ecodata		
	Price indices for raw materials	1996	2008	National Bank		
	Nominal remuneration / full-time equiv.	1970	2008	Ecodata		
	Growth of real labour cost per capita	1985	2013	Fed Plan. Bureau	yes	
	Long term interest rates	1955	2006	OECD		yes
	Arable land prices	2001	2004	DGSIE		
	Pasture prices	2001	2004	DGSIE		
Commodity prices	Consumer prices indice	1970	2006	OECD		
	Consumer prices indices: food	1970	2006	OECD		
	Consumer prices indices: energy	1970	2006	OECD		
	Producer prices indices: manufacturing	1980	2006	OECD		
Foreign Trade and Investment	Share of trade in GDP	1970	2006	OECD		yes
	Foreign direct investment, net inflows	1975	2006	World Bank		
Technology						
Investments in infrastr.	Total length of the road net	1966	2006	DGSIE		yes
Transport&Communication	Total length of the highway net	1938	2006	DGSIE		yes
R&D investment	Gross domestic expenditure on R&D	1983	2006	OECD		
Demographics/Equity						
Population growth	Total population	2000	2060	Fed Plan. Bureau	yes	
Ageing population	Population of 65 years and more (share)	2000	2060	Fed Plan. Bureau	yes	
Urbanization rate	Urban population (share)	1950	2030	UN	yes	
Migration/Immigration	"Accroissement migratoire"	1998	2007	DGSIE		
	Migration rate	1970	2006	OECD		
		1995	2050	UN	yes	
Lifestyle changes (demand for regional products)	Organic products consumption (share)??					
Education	Tertiary attainment for age group 25-64	1991	2005	OECD		yes
Income distribution	Income quintile share ratio	1995	2006	Eurostat		
	Gini coefficient	1995	2006	Eurostat		
Policy						
Influence of WTO	PSE (%)	1986	2007	OECD		
EU CAP	Agriculture support (% GDP)	1990	2005	UN		
	Agriculture support (million US$)	1990	2005	UN		
EU CAP 1st and 2nd pillar	Budgetary expenditure	1994	2006	EEA[3]		
		2007	2013	EU[4]	"yes"	
EU environmental policy	Government expenditure	1995	2006	Eurostat		
	Government expenditure (share of GDP)	1995	2006	Eurostat		
EU regional policy	Budgetary expenditure	2007	2013	EU	"yes"	
Environment						
Emissions to air water soil	CO2 of energetic origin	1989	2006	DGSIE		
		1971	2005	OECD		
	Atmospheric NH3	1990	2005	DGSIE		
	Greenhouse gas emissions	2004	2010	EEA	yes	
Investments into environmental protection	Government expenditure	1990	2006	UN		
Flooding, soil erosion	Share, %					
Biodiversity loss	Number of species					
Organic farming	Share of UAA	1998	2006	DGSIE		
Bio-energy demand (?)	Share of UAA					

[1] Direction Générale Statistique et Information Economique of SPF Economie (ex-INS)
[2] UN : United Nations
[3] EEA : European Environment Agency
[4] EU : European Union (official sources, such as European Council)

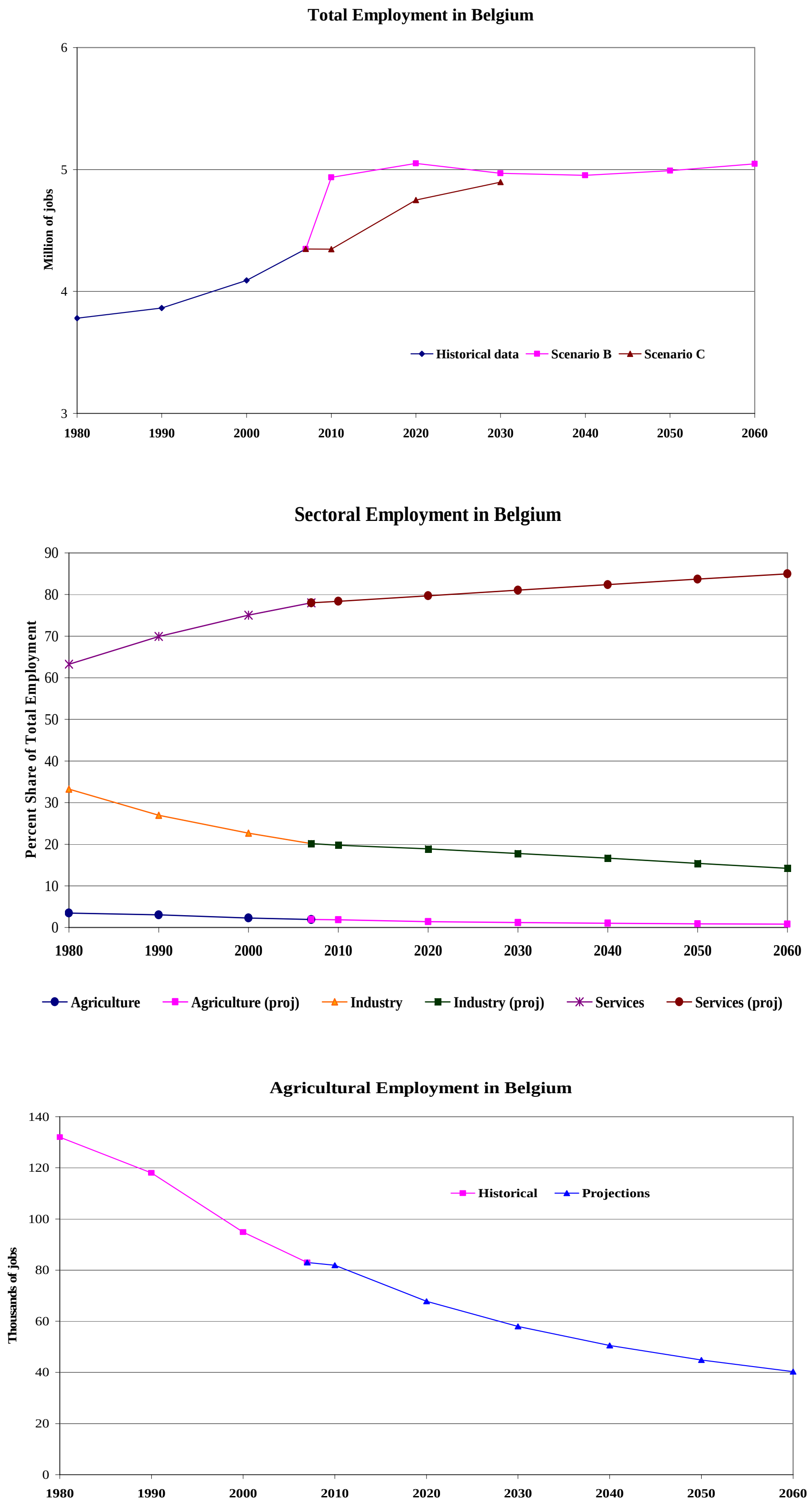


Figure 3. Projections based on the historical data

5.2 WP2: Multi-scale Constrained Cellular-Automata Model

5.2.1 Introduction to WP2

The prime objective of the work carried out in WP2 is the development and application of a constrained cellular automata (CCA) land use model for Belgium. Such application is novel in Belgium: there is currently no operational high-resolution land use model covering the entire Belgian territory known to the authors. Use is made to the extent possible of the MOLAND[1] modelling shell (Engelen et al., 2007). The CCA model is a high resolution simulation model. It calculates the yearly changes in different socio-economic activities and allocates the associated changes in the spatial land use patterns on a map of Belgium at a 300m resolution. The prime goal of the model is to explore the effects of different policy scenarios on future land use in an integrated context. Information feeding these scenarios is partly obtained from WP1 and WP4. The model is based on the systems view that spatial systems like cities, regions, countries, watersheds, etc. evolve as the result of endogenous processes combined with exogenous events including policy-induced changes. Therefore, the model incorporates a sufficient description of the autonomous processes making and changing the land use patterns of Belgium and represents policy and other constraints as elements interacting with these. Thus, integrated pictures of possible futures of the modelled system can be presented.

As the name implies, cellular automata (CA) are mathematical models represented as an n-dimensional grid of identical cells. Each cell is in a particular state: a land use in the context of this text. They are dynamic models featuring state changes. To that effect, an automaton is applied to each cell in the grid to determine its state transition. The automaton is a transition rule written as a function of the state of the cell itself and that of the cells within its immediate neighbourhood, called the CA-neighbourhood. Typically CA-neighbourhoods in two-dimensional models are limited to the 4 (Von Neuman neighbourhood) or 8 immediate neighbours (Moore-neighbourhood) (Couclelis 1997). Thus, the basic assumption underlying traditional CA-land use models is that land use dynamics can be fully explained by the land uses and associated spatial interactions in a relatively limited neighbourhood. In reality however, the behaviour of the cells and their resulting land use is determined and constrained by a variety of processes operating at larger scales (e.g. municipal, provincial, national, European and global) and by the precise heterogeneous character of the geographical environment within which they are situated.

This has led to the development of hybrid CA models constrained in their dynamics by coupled models operating at coarser spatial scales (Batty and Xie, 1994, Engelen *et al.*, 1995, White and Engelen, 1997) and evolving in a finite non-homogeneous cell space: a bounded cell space consisting of cells with different attribute values representing their physical, environmental, social, economic, infrastructural and institutional characteristics (Clarke *et al*. 1997, Li and Yeh, 2000). Such integrated models are useful because they are more than mere land use models: they allow an urban or regional system to be treated as a dynamic whole. Consequently, these hybrid models are gradually becoming important instruments for the assessment of policies aimed at improved spatial planning and sustainable development (de Nijs *et al*., 2004) as well as scenario-analysis (White *et al*., 2004, van Delden *et al*., 2005; 2007). In MultiMode WP2, we will implement the kind of hybrid CA model consisting of models operating at three linked levels: national, regional, and finally, cellular.

[1] *MOLAND has been developed for the DG EU-Joint Research Centre, IES in Ispra, Italy by the Research Institute for Knowledge Systems, the Netherlands*

5.2.2 The variable-grid activity-based CA land use model

Despite the aforementioned advantages of the integrated models, the problem with this approach is that it is cumbersome. Each individual model has a number of parameters, and additional parameters are required to link them with each other. Furthermore, all standard models of population and economic activity are either non-spatial or make use of a space subdivided into political or statistical regions which are implicitly assumed to be internally homogeneous. In other words these models have extremely low resolution compared with the CA to which they are linked. Consequently the integrated model is more difficult to calibrate and the output is not nearly as accurate or detailed as it could be.

But if the spatial dynamics of the demographic and economic activity are modelled directly in the CA, then these problems disappear. The single model is much simpler, requiring many fewer parameters, and the demographic and economic activity is modelled at the same, relatively high, resolution as the land use. Furthermore, since the CA makes use of a wide range of micro-scale data—e.g. neighbourhood quality, land quality, accessibility, land use regulations, etc.—the activity estimates should normally be better. But to model them within the CA would require expanding the neighbourhood to include the entire region. On the other hand such a neighbourhood would typically include a half million or more cells, and the run time of the CA would be so degraded that the model would be useless. However, use of a variable-grid in the CA eliminates the run time problem and enables the use of the large neighbourhood.

Thus, as an alternative to the layered *fixed-grid* representation of the CCA (discussed in section 4.2.1) in which models of different types are nested to represent processes at various geographical scales, the applicability and performance of a so-called *variable-grid* Cellular Automata (Anderson et al., 2002a; 2002b) is assessed in WP2. Contrary to the fixed-grid CCA, the variable-grid CA applies a CA-neighbourhood consisting of the full modelled area. It is defined in terms of cells which become progressively larger towards the periphery of the neighbourhood, so that the number of cells in the neighbourhood remains small even though the neighbourhood always covers the entire modelled area. Larger cells are in fact summed or averaged values of cells that behave like entities in the CA-neighbourhood. Moreover, in MultiMode the application of an *activity-based* variable-grid Cellular Automata model is analysed as an alternative to the classic CCA. In the latter, the state variables in the model are no longer the dominant land use of the individual cells, rather the density of each activity (residential, economic and natural) located in the cell. The model determines, at each iteration (typically representing one year), the land use and corresponding activity levels on each cell as a function of land use and activity levels in the entire surrounding area (i.e. all of Belgium), as well as other factors such as the inherent suitability of the cell for the activity, accessibility to the transport system, land use regulations, and externalities such as congestion costs and land prices. Because the activity on each cell influences activity on every other cell, the dynamics are complex but realistic. The activity-based variable-grid CA land use model thus combines the characteristics of cellular automata models (as it operates on individual cellular entities) and traditional gravity based models (as it features spatial interactions spanning the entire territory and its variables represent activities).

It will be analysed whether the latter is the more appropriate type of model for areas with a mixed and messy land use like Belgium. Further, the integration of the agent behaviour (WP3) in the CCA-model could be enhanced as it may well be more related to levels of activity rather than dominant land uses. The work carried out on the activity-based variable-grid CA is still in its early stages. For the in depth comparison of its behaviour it currently is applied on the high-quality dataset for the larger Dublin area available from the MOLAND project and the EU Joint Research Centre in Ispra, Italy (Lavalle, et al. 2002). For Dublin a layered *fixed-grid* CA land use model similar to that developed for Belgium is available

(Engelen et al., 2007). A more elaborate description of the work carried out thus far can be found in Chapter 7 in Uljee et al. 2008.

5.2.3 The fixed-grid layered CA land use model

The fixed-grid layered CA land use model represents socio-economic activities and processes operating at three nested geographical levels (Figure 4). At each level, a representation is chosen which is adequate to represent the main spatial processes, to fit the available data, and to tackle the problems studied: the National (one spatial entity: Belgium), the Regional (43 entities: *arrondissements*) and the Local (some 715000 cellular units each 300 m^2). A more elaborate description of the model can be found in the Chapters 2 to 5 in Uljee et al., 2008.

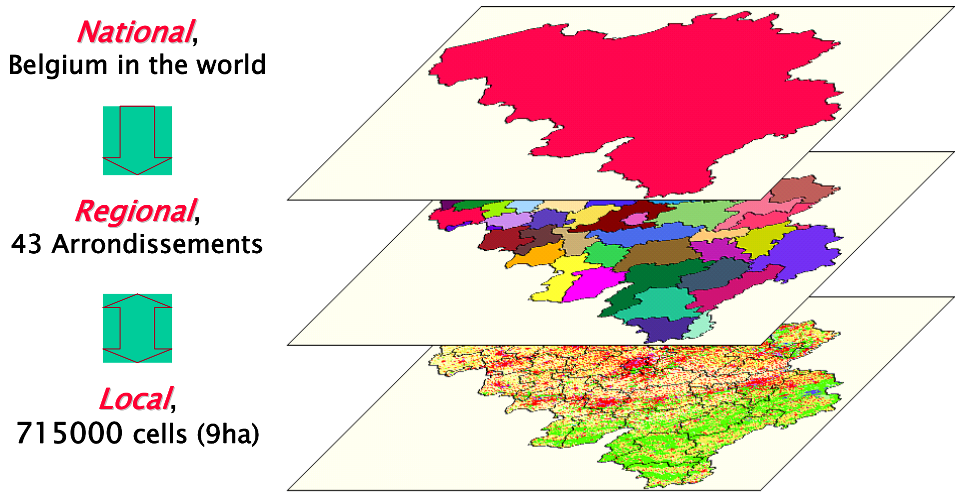
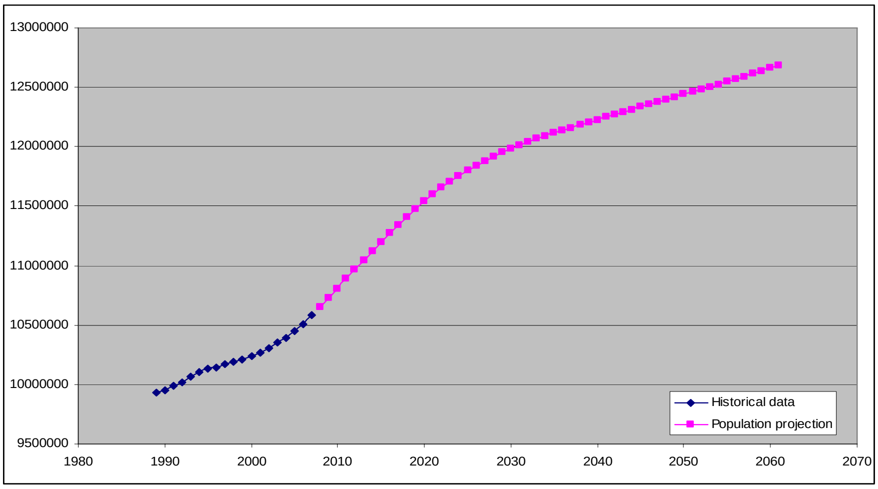


Figure 4. The CCA-model consists of hierarchical embedded sub-models at three levels

National level

At the National level, the scale of Belgium, the model runs on exogenously provided time series. It integrates data taken from economic, demographic and nature related growth scenarios. Sophistication in producing these remains external to the modelling framework proper. For the reference scenario, time series, like the one for population represented in Figure 5, are obtained from the various national and regional agencies such as the Federal Planning bureau (Federaal Planbureau / Bureau Fédéral du Plan). For the four additional scenarios developed in WP1, associated time series are provided by WP1.



Source: Bevolkingsvooruitzichten 2007-2060 / Perspectives de population 2007-2060 Federal Planning Bureau and Directorate-general Statistics and Economic Information

Figure 5. The population projections until 2060

The base year of the model is 2000. It is the year for which both a land use map (CORINE 2000) and statistical data are available in Belgium. Hence, the match between the numbers reported in the statistics and the spatial expansion on the ground for the various activities can be made. A typical simulation run will look 30 years ahead in time, but 40 or 50 years are possible if this would be required by the scenarios of WP1. The simulation steps through time in yearly time steps. For every year, output can be generated and stored for further analysis.

The model deals with economic and demographic activities in practically the same manner. They are both 'activities requiring space'. In this text the term 'activity' is thus used to refer to either economic sectors or population. The population consists of a single cohort and is represented in two residential categories, namely: inhabitants in continuous urban fabric and inhabitants in discontinuous urban fabric. The latter sub-division is inspired by the CORINE land use classification scheme.

The economic activity is represented in three aggregated sectors, namely: agriculture, industry, and services based on the available data as well as typical locational preferences, spatial behaviour, and use of the land. The classification scheme to that effect is that of the European System of Accounts 1995. Regional total employment (ESA 1995, 11.11) is used in the model. It comprises all persons – both employees and the self-employed – engaged in some productive activity in a specific region.

The aggregated class 'agriculture' consists of the NACE branches:
  A_B Agriculture, hunting, forestry and fishing.
The aggregated class 'industry' consists of the NACE branches:
  C_D_E Mining and quarrying; manufacturing; electricity, gas and water supply,
  F Construction.
The aggregated class 'services' consists of the NACE branches:
  G_H_I Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods; hotels and restaurants; transport, storage and communication,
  J_K Financial intermediation; real estate, renting and business activities,
  L_P Public administration and defence, compulsory social security; education; health and social work; other community, social and personal service activities; private households with employed persons

While economic and population figures are posed in terms of numbers of people, or jobs, the natural land-use categories are expressed in terms of total area occupied by each category. The area occupied can be imposed on either the National or Regional level of the model by means of scenarios. This is justified by the fact that in densely populated areas, like Belgium, the expansion of areas occupied by natural land-use, in particular biodiversity-rich natural areas, is an act of deliberate policy, rather than a spontaneous process. Policy also protects such valuable natural areas from the expansion of other (socio-economic) land-uses that generate a higher added value per unit of area. There are three natural land use classes, namely (1) wetlands, (2) forests, and (3) shrubs and herbaceous vegetation. This choice is based on the available information on the CORINE land use maps as well as the scenario's to do with the expansion and/or preservation of natural land use.

Regional level

At the Regional level, consisting of the 43 *arrondissements*, the national growth figures are a constraint for models catering for the fact that regional inequalities will influence the location and relocation of residents and economic activity and thus drive regional development. The same activities are modelled at the regional and the national level.

Three coupled sub-models can be distinguished at the Regional level:

- For the regional allocation and relocation of the population and the economic activities per sector, a standard potential based interaction model is applied (see for example: White, 1977; 1978; Allen and Sanglier, 1979a; 1979b). It represents the *arrondissements* as competitors for residents and activity in each economic sector based on their geographical position relative to one another, their employment level, their population size and the type and quantity of the activities already present. In addition to these, and novel in the context of interaction based models, three summarized cellular measures, obtained from the model at the Local level, characterise the regional attractiveness. They are the abundance of good quality land (expressed in the suitability), the institutional status of that land (expressed in the zoning), and the overall access of the territory relative to the transportation infrastructure (expressed in the accessibility).
- A *density sub-model* translates the activity and population numbers per sector and arrondissement into claims for land, expressed in numbers of cells. The latter are passed on to the model at the Local (cellular) level for their detailed allocation. The principle of supply and demand applies to regulate the densification of the land used. Alternatively, and in particular for the natural land categories and recreational land, a claim for land is fixed and passed on as a hard constraint thus reflecting the fact that policies determine the amount of land to be allocated per region.
- A simple *transportation sub-model*, linked dynamically in the modelling framework, implements changes in the characteristics of the transportation infrastructure, the effects thereof on interregional distances and accessibility, and, the flows of people travelling over the networks.

The model at the Regional level is a strong simplification of reality. It assumes that an activity will grow in regions with a relatively high attractivity for the activity. An increase in activity implies an increase in the pressure on the land, which causes a densification. Densification has an impact on the attractivity of the regions for the same and/or other activities. In this way regions can loose activities to other, more attractive, regions. Besides density, attractivity is also determined by the population, employment and activity of the same type in the region. Additionally, the quality of the cellular space (Local level) in terms of physical suitability, policy (zoning) and accessibility is important. Figure 6 shows the most important variables and feedbacks in the layered model.

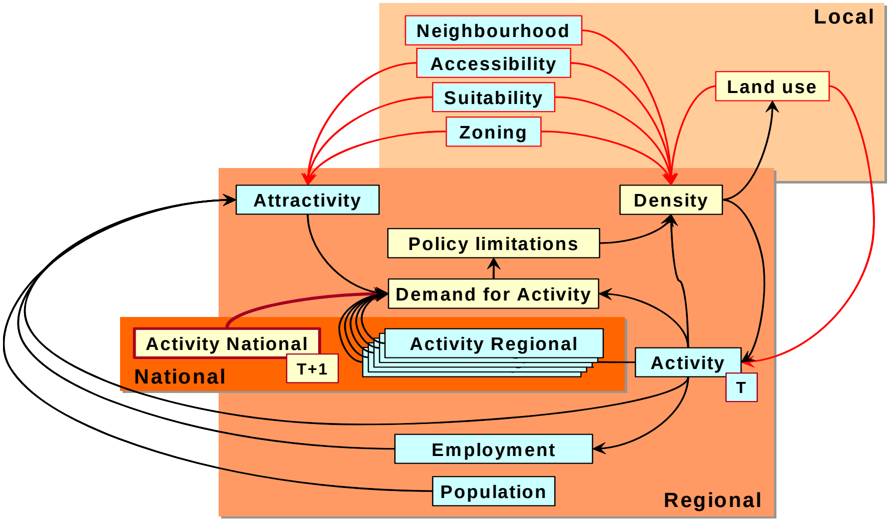


Figure 6. Important variables and their feedbacks at different levels of the layered model

Local level

At the Local level, the detailed allocation of land associated with economic activities, residents and natural land cover in each arrondissement, is modelled by means of a cellular automata based land-use model of the kind developed by White, Engelen and Uljee (White and Engelen, 1993; Engelen *et al.,* 1995; White *et al.,* 1997). The territory of each arrondissement is represented as a regular grid of cells representing parcels of land covering an area of 300 m^2. Thus in total, Belgium consists of a grid of 768 rows by 934 columns. Out of the 717,312 cells 340,685 are inside the modelled area. The 300 m resolution is a compromise between model performance and accuracy. It is considered sufficiently small to enable working with the dominant land use per cell. This is more the case in the Walloon than the Flemish part of the country.

Land use is aggregated in 19 categories based on the CORINE land cover 2000 (CLC2000) seamless vector database (EEA, 2007). At its most detailed level the CORINE distinguishes 44 land cover classes. Not all classes are found in Belgium nor are all relevant to the model. Table 8 provide a list of the 19 land uses currently retained in the model as well as the area they occupy. The resulting land use map at the Local level is shown in Figure 7.

Table 8. The land uses at the Local level of the model

Name	CLC-code	Type	Area (ha)
Forest	3.1	vacant/passive	609939
Scrub and/or herbaceous vegetation associations	3.2	vacant/passive	33948
Arable land	2.1	function/active	672867
Permanent crops	2.2	function/active	8217
Pastures	2.3	function/active	355779
Heterogeneous agricultural areas	2.4	function/active	727803
Continuous urban fabric	1.1.1	function/active	4833
Discontinuous urban fabric	1.1.2	function/active	509751
Industrial or commercial units	1.2.1	function/active	50670
Artificial, non-agricultural vegetated areas	1.4	feature/static	23868
Road and rail networks and associated land	1.2.2	feature/static	10890
Port areas	1.2.3	feature/static	6957
Airports	1.2.4	feature/static	5760

Name	CLC-code	Type	Area (ha)
Mineral extraction sites	1.3.1	feature/static	8460
Dump sites	1.3.2	feature/static	1440
Beaches, dunes, sands	3.3.1	feature/static	1098
Inland wetlands	4.1	feature/static	8928
Maritime wetlands	4.2	feature/static	612
Water bodies	5	feature/static	19467

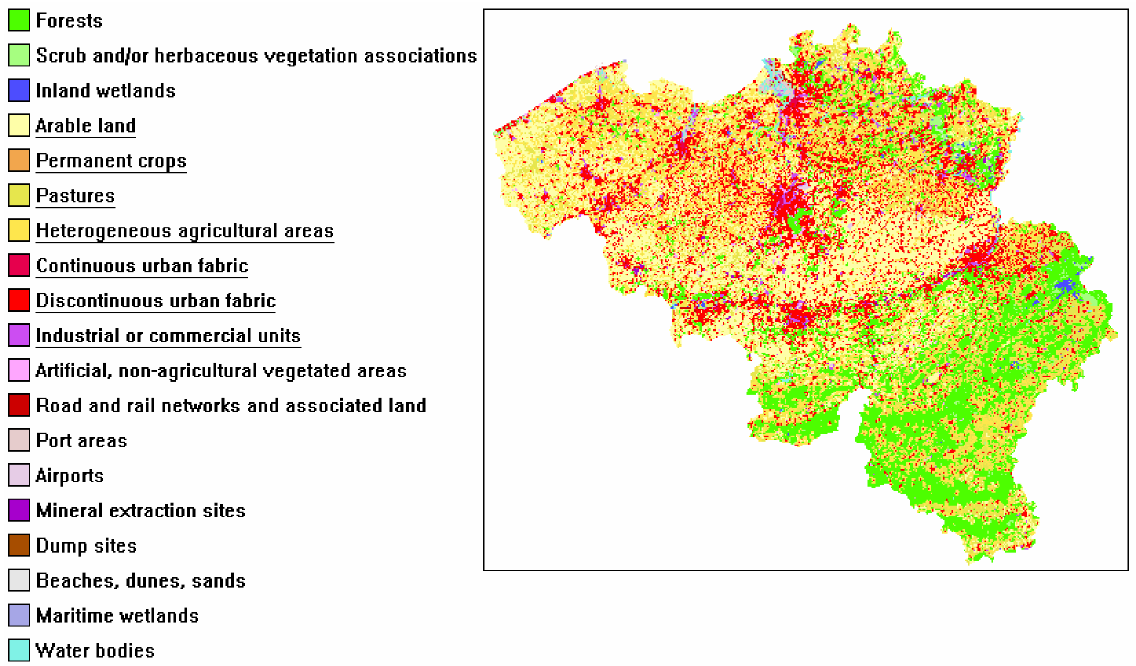


Figure 7. The land use map in Belgium

Land use is subdivided in 'feature/static states' (land uses that do not change dynamically), 'function/active states' (land uses changing dynamically as the result of the Local and the Regional dynamics) and 'vacant/passive states' (land uses changing dynamically due to the Local dynamics only). The function states are chosen with a view to guarantee to the extent possible a one-to-one relationship with the economic and residential categories at the Regional level.

The model calculates at every simulation step for each arrondissement and for each cell in a vacant or function state, the *transition potential* for each possible (function and vacant) land use function. Cells will change to the land-use function for which they have the highest transition potential, until demands for that land-use function are met in the arrondissement. In the latter case, they will change to the land use for which they have the second to largest transition potential, and so on. The transition potentials are a proxy for the land rent reflecting the pressures exerted on the land. It accounts for the fact that the presence of complementary or competing activities and desirable or repellent land uses is of great significance for the cell's locational quality and thus for its appeal to particular land use functions. To that effect, the model assesses the quality of the cell's neighbourhood: a circular area with a radius of maximally eight cells. This is substantially bigger (196 cells) than the typical CA-neighbourhoods discussed in the introduction. For each land-use function, a set of rules determines the degree to which it is attracted to, or repelled by, each of the other functions present in the neighbourhood. The rules articulate inertia, action at a distance, push and pull forces, and economies of scale, in short, the strength of the interactions as a function of the distance separating the land-use functions within the neighbourhood. The neighbourhood covers a distance of 8 x 300 m = 2400 m. Thus, spatial interactions between land uses at the Local level have an immediate effect over this distance. Or, to put it differently, landowners in need of a (new) location value the land uses present within this radius in their assessment of alternative locations.

In addition, the transition potential comprises characteristics of the cell proper: its physical *suitability*, *zoning status* and *accessibility*. Physical suitability and zoning status are represented in the model by one map per land-use function modelled. Suitability (see Figure 8) refers to the degree to which a cell is physically fit to support a particular land-use function and the associated economic or residential activity. Zoning status (see Figure 9) specifies whether a cell can or cannot be taken in by the particular land use during a particular period of time. It is important that suitability and zoning are handled separately in view of analysing policy and planning alternatives. Both suitability and zoning are composite measures, prepared in a GIS on the basis of a series of physical, ecological, and environmental maps respectively master plans and other planning documents.

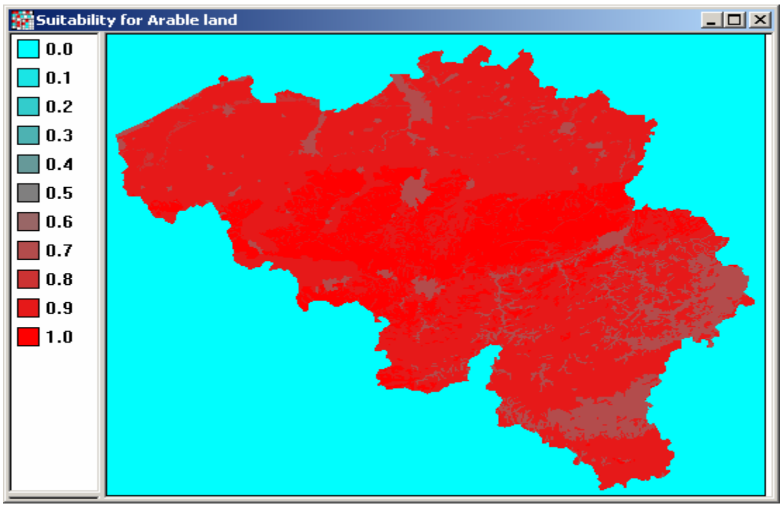


Figure 8. Suitability map for Arable land in Belgium

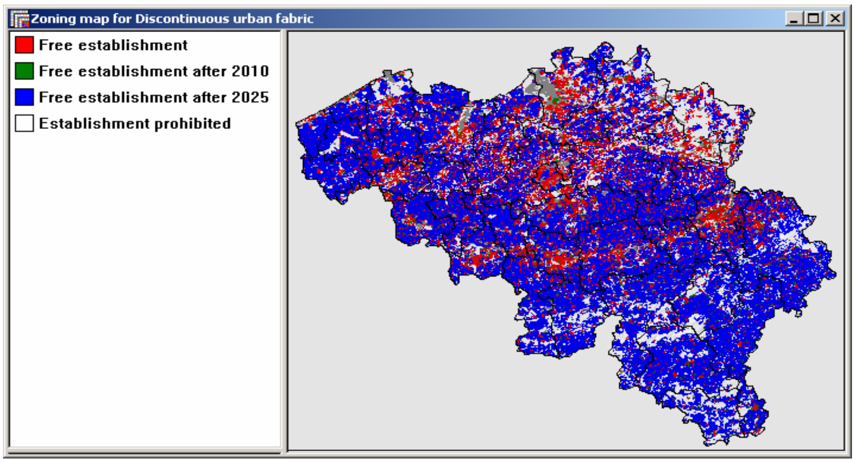


Figure 9. Zoning map for Discontinuous urban fabric enabling vast expansion after 2025

Finally, *accessibility* (see Figure 10) for each land-use function is calculated relative to the transportation infrastructure: the road and railroad networks and the navigable waterways. It is an expression of the ease with which an activity can fulfil its needs for transportation and mobility in a particular cell and accounts for the distance of the cell to the nearest link or node on each of the networks, the importance and quality of that link or node, and the particular needs for transportation of the activity or land-use function.

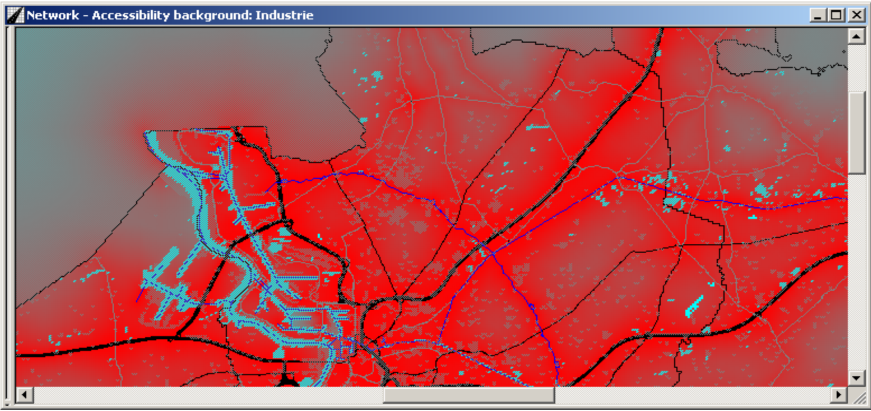


Figure 10. Accessibility for industry shown for part of Antwerp province

In short in the transition potential, four elements determine whether a cell is taken in by a particular land use function (Figure 11):

- *Spatial interaction rules* determining the interactions at a distance between all possible pairs of land uses;
- Physical *suitability* characterized by one map per land-use function modelled.
- *Zoning* or institutional suitability also characterized by one map per land-use function.
- *Accessibility* relative to the transportation infrastructure for each land-use function, calculated by means of a built-in model, and resulting in one map per land use function modelled.

Interlinked dynamics structuring space

The linkage between the models at the National, Regional and Local levels is very intense: the National figures are imposed as constraints on the Regional model, the Regional model distributes and allocates National figures to the regions and imposes the resulting Regional figures on the cellular model. Finally, the cellular model determines land use at the highest level of detail. Vice versa, the cellular model returns to the Regional model aggregated information on the quality and availability of space for each type of economic or residential activity. It is an input into the spatial interaction calculations at the Regional level and influences the relative attractiveness of the individual arrondissement. *Arrondissements* running out of space for an activity will loose part of their competitive edge and exert less attraction. This framework constitutes a flexible and powerful instrument for representing non-linear spatial dynamics operating across a range of scales.

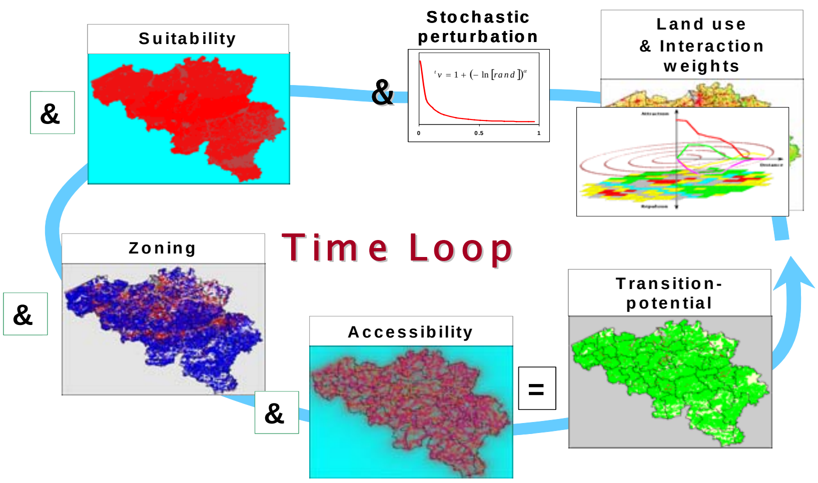


Figure 11. Four elements determine propensity for a cell to change to a particular land use

The model generates alongside the changing land use a series of social, economic and environmental indicators, each of which becomes available in the course of the simulation as a time series of maps, both at the Regional and the Local level. The indicators facilitate the assessment of the appropriateness of spatial policies, planning options and policy measures in the contexts of the scenarios developed in WP1. They enable in particular to assess the level of sustainability attained.

5.2.4 Linkages with WP1

A first prototype of the model is currently available for test runs and for calibration. Its availability has demonstrated the feasibility of setting up the kind of model for Belgium. Elementary robustness and consistency tests have already been carried out successfully. The calibration will be dealt with more explicitly in phase 2 of the project.

The model developed is considered to meet closely the needs of the other WPs in MultiMode. In particular, it is to calculate and visualise the scenario's developed in WP1. To that effect a methodology is under development in a collaborative effort between WP1 and WP2. It is to quantify the scenarios from WP1 in terms of the parameters and variables of the model. In part it builds upon the work done in the VISIONS (White et al., 2004) and the European Environment Agency's PRELUDE project (van Delden et al., 2005).

With a view to estimate parameter values it is important that each scenario, in particular the story-line associated with it, describes in a qualitative sense the behaviour of the activities and land uses over time as well as the reasons for this behaviour. For example, if the income level changes, the scenario should describe why, when and how it changes. Also why and how it changes the spatial behaviour of the inhabitants. Are they spreading out over the countryside? Or, are they clustering in small villages? Or, are they all living in a few mega-cities? What is the reason behind this choice and does it have other causes or consequences? For example is it caused by the costs of mobility?

Next, the scenarios are quantified, meaning to say that the model parameters are calculated and/or estimated. This is not an easy exercise given the highly technical and rigorous nature of the parameters as opposed to the vagueness and flexibility of the quantitative scenarios. Also, the scenarios may well show inconsistencies in the assumptions made with regards to aspects dealt with by the model. Hence, a gap needs to be bridged between the model and modellers on the one hand and the scenario's and scenario-developers on the other.

The resolution of the model developed and the land uses modelled is also considered adequate to set the spatial constraints within which the agents of the ABM model of WP3 can operate. If however the definition and/or performance of the model would be below expectations then it could still be adapted in a number of ways. For example, the population, the economy, or the transportation sub-system may be modelled in greater or lesser detail. Also the land use classes may be chosen differently. Finally, the spatial resolution of the model at both the regional and the cellular level may change. Changes in the definition of the model would primarily be based on the following considerations:

- the representation of the linked socio-economic, transportation and land use sub-systems modelled should match the requirements of the scenario's developed in WP1 to a sufficient degree;
- for each additional land use modelled at the *Cellular level*, sufficient GIS-data have to be available to quantify the physical, institutional and accessibility qualities of the cellular space on the basis of the representative map-layers. The availability of the latter may be problematic;
- there is no intention to include a full-blown transportation model in the model. Hence, sophisticated calculations to do with accessibility and mobility are excluded as part of this project.

5.3 WP3: Landscape Scale Agent-Based Model of Decision Rules

5.3.1 Introduction to WP3

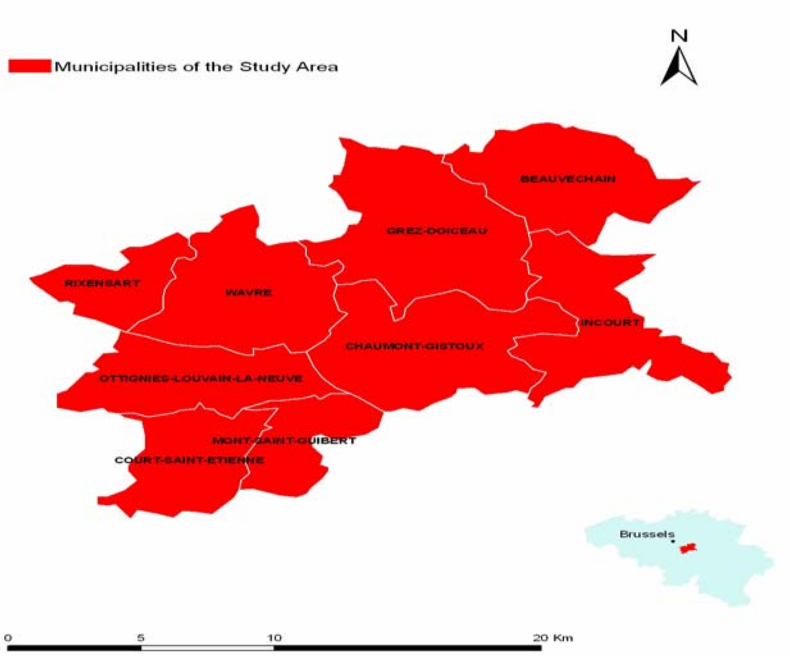
Multiagent systems, a concept that originated in the computer sciences (i.e. artificial intelligence research) in the 1970s, have recently gained popularity in the social sciences. Some of the recent applications of agent-based model (ABM) include: (a) reproducing spatial and demographic features to understand the evolution of society (e.g. Gilbert and Doran 1994; Axtell et al. 2002); (b) evaluating economic systems when rational agents and equilibrium conditions are not limiting assumptions (e.g. Duffy 2001; Axtell 2002); (c) simulating of production decisions to assess adoption of new agricultural practices (Balmann 1997; Berger 2001; Polhill et al. 2001); (d) linking human and natural systems at both spatial and temporal scales to understand changes in land cover and land use changes (e.g. Huigen 2004; Evans and Kelley 2004, Acosta-Michlik et al. 2005); evaluating policy support (e.g. Berger 2001); and assessing vulnerability to the impacts of globalisation and climate change (e.g. Acosta-Michlik and Rounsevell 2008). The increasing application of ABM to answer research questions that link human to natural system underpins their usefulness in assessing sustainable development. Their novelty lies in the ability to capture the heterogeneity of agents, the dynamics of their interactions and their adaptive behaviour to the changes in environment. However, almost all these studies have used artificial agents and thus applications of the ABM have little empirical basis. A recent empirical application of agent-based models in a real context includes Acosta-Michlik and Rounsevell (2008).

A key innovation in the use of ABM in *MultiMode* is developing and validating behavioural models in selected Belgian communities through stakeholder involvement, and including a farm model to capture the economic maximization objectives of farmer agents; these being one of the more important agent groups in land use decision making. ECRU has developed a farm-level economic model for the Walloon Region in Belgium based on FADN data (Polomé et al, 2005; Henry de Frahan et al, 2006) called ADAGE. This model is intended to represent farmers' economic adaptive behaviour at a detailed level, including activity choice (crop, animal, subsidized environmental productions), reaction to price and yield uncertainties, and reaction to subsidies and quota changes. The model will therefore help improve the ABM by refining the economic decision rules of farmers. However, as the development of ADAGE revealed, there are farmers' decisions that cannot be captured by purely economic factors alone (e.g. retirement, lack of successor, knowledge, etc.). For example, the spread of knowledge often has a geographical component because a powerful driver for innovation on a farm is innovation on a neighbouring farm. This is the case for new crops (e.g. chicory) or for available subsidies (e.g. agri-environmental measures). Knowledge about the non-economic cognitive strategies of farmers will be drawn from the activities in WP4. Moreover, the empirical application of ABM will be significantly improved in MultiMode by validating the cognitive strategies through stakeholder feedbacks (WP4).

5.3.2 Concepts and methods

The concept followed the "intervulnerability" framework that captures the dynamics of human-environment interactions. Through the empirical application of ABM in a sustainability context, MultiMode contributes to the improvement of this framework by including the concept of arena in the social network analysis and combining economic, social and environmental objectives of the farmers in a utility function. The ABM framework combines three levels of information to assess sustainability of farm communities in the regions of Wallonia and Flanders – (1) at the global and/or regional levels, the drivers of global changes describing the current state of economic, social, institutional, physical and climatic environment as measured by (generic) indicators as well as the future changes in these indicators as represented by scenarios; (2) at the community level, the socio-economic and bio-physical environment that is directly influenced by the global drivers and their changes; and (3) at the agent level, the attributes or profiles that determine adaptive decisions of individuals (or group of individuals) in the community to the changes in their immediate socio-economic and bio-physical environment. The data required for the first level of information as well as the indicators related to the socio-economic environment (i.e. second level of information) will be derived from WP1. The biophysical environment is represented by high resolution GIS maps in the model. 5x5 meter raster maps on sectoral land use, agricultural land use, erosion risks, soil association, AEM locations, Natura 2000, and slope have all been collected (Figure 12). Moreover, GIS maps on farm boundaries and farm locations are already available. The maps have already been converted into ASCII files for direct input into the ABM model. The third level of information was generated from the results of the survey and the preliminary analyses including farm typologies, farm decision rules and social networks are presented and discussed in the working paper. These are the most time-consuming part of the data collection, but also the most crucial information required for the ABM.

The case study area comprises 9 municipalities located in the province of Brabant-Wallon, in the centre of Belgium, just south of Brussels (Figure 12). It is the smallest Belgian province, with an area of 1091 km^2 and 364,000 inhabitants. The population density is high with 334 persons per km^2 and the province has a strong peri-urban character, with a large part of the population commuting to Brussels. Housing is relatively dispersed ('habitat en ruban': in 'ribbon' along roads), with the higher densities in the central municipalities that are closest to Brussels and areas most accessible to transport. Population in the province is growing fast and it has the highest growth rate in the country. The province is attractive to investors and activities are mainly clustered in industrial, economic activities, and scientific parks located next to the main towns of Wavre, Nivelles, Tubize, and Ottignies-Louvain-la-Neuve. The accessibility of these towns to Brussels, main transport axes and international airports is a key to their success. The 9 municipalities in the case study area are part of the river Dyle's catchment. The main soil types are silt loams and sandy loams. The area extends on a low plateau (110-150m) intersected by a number of small rivers (mostly in the centre and North of the province), with the valley bottoms lying at about 40m above sea level. This gives an overall impression of a gentle relief with small rolling hills. There are 14 Natura 2000 sites for a total of 5000 ha (less than 5% of the total area). Ten of these sites consist of zones in the valleys, directly along rivers. Although the Natura 2000 network of sites is well-defined and described in terms of species and habitat vulnerability, it seems that there is a lack of funds to implement the necessary conservation or restoration measures.


Municipalities of the Study Area
N
BEAUVECHAIN
GREZ-DOICEAU
RIXENSART
WAVRE
INCOURT
CHAUMONT-GISTOUX
OTTIGNIES-LOUVAIN-LA-NEUVE
MONT-SAINT-GUIBERT
COURT-SAINT-ETIENNE
Brussels
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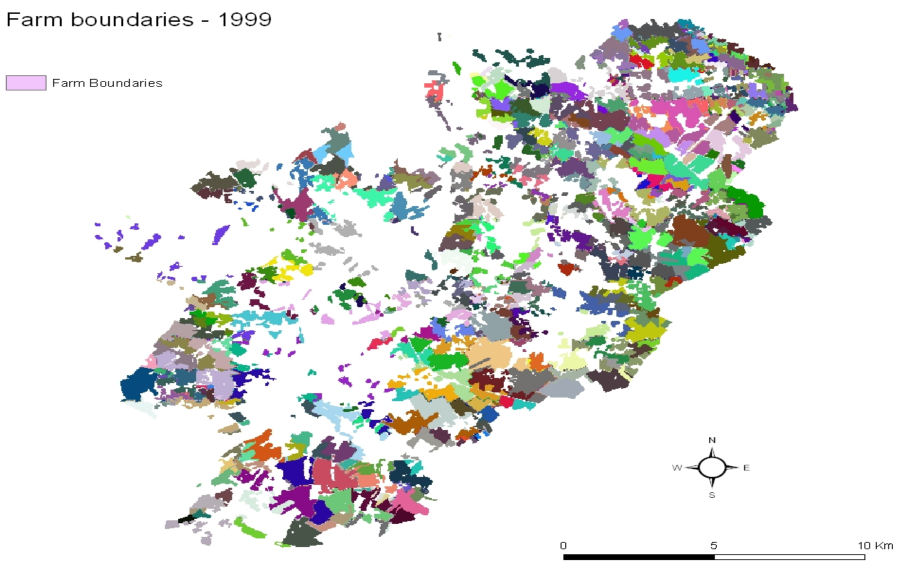
Farm boundaries - 1999
Farm Boundaries
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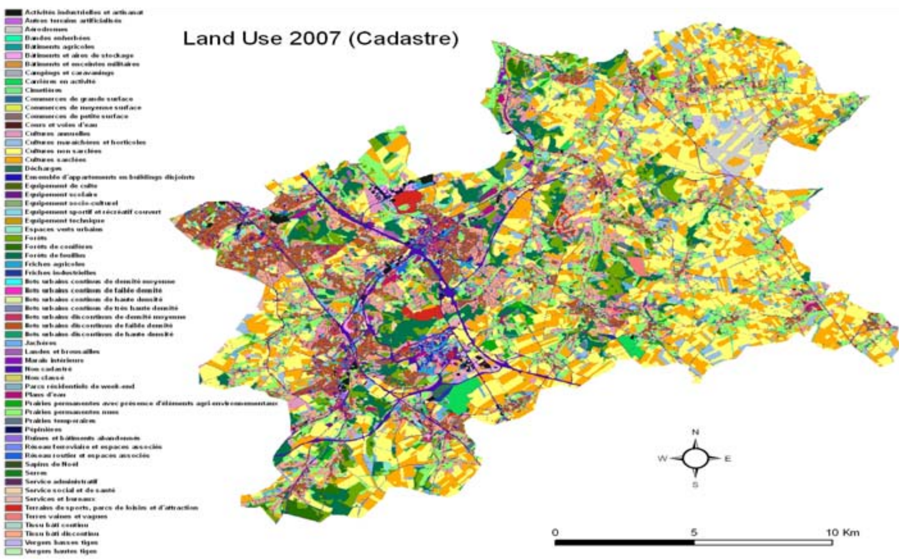
Land Use 2007 (Cadastre)
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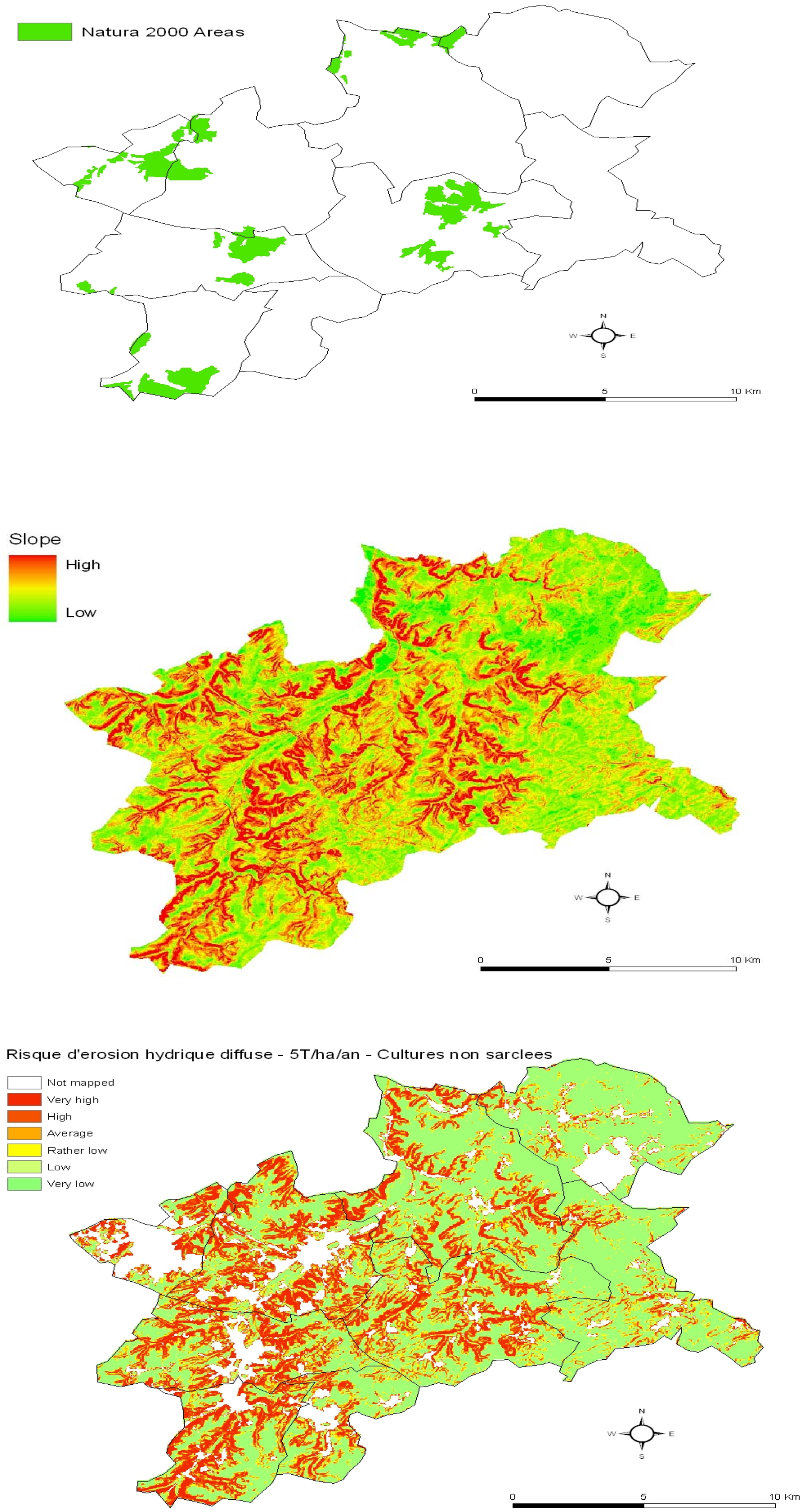

Figure 12. Biophysical environment of the case study area in the Walloon region

Considering the complexity of combining comprehensive knowledge on social, ecological and economic decisions of groups of agents with heterogeneous attributes in a single model, we decided to construct an agent-based model (ABM) in two steps (Figure 13). The first step dealt with the construction of a prototype-ABM, which aim to make operational the conceptual framework introduced above for assessing sustainability and to make a realistic representation of the social, physical and economic environment of the agents in the case study area. We interviewed farmers and planners to gain an initial understanding of not only the economic, but also the social and ecological considerations on land use change decisions. Given the voluntary nature of application and the environmental sustainability objectives of agri-environmental measures (AEM), analysing the links between AEM integration in farming practices and land use decisions can provide valuable insights on the motivations and objectives of the farmers. A semi-structured interview guides were thus designed to understand the social, ecological and economic objectives for the application and non-application of certain types of AEM. We combined the information collected from the interviews with the knowledge based on economic literature in developing a farm utility function that considers these possible three objectives of the farmers. Due to differences in attributes, the farmers are assumed to have different social, ecological and economic motivations in their sustainable farming practices and land use decisions. Qualitative analysis of the interview results was thus carried out to develop initial farmer typologies for the prototype-ABM. A more detailed description of the methods for developing both farm utility function and farmer typology are presented below because of their importance in the empirical application of ABM in this study. Actual GIS maps on farm parcels and location, land use types and soil characteristics are used to construct a prototype model that is representative of the case study area. These maps are also used to define land use conversion rules and initial physical constraints (to be further improved in the second step of the model construction) of the prototype-ABM.

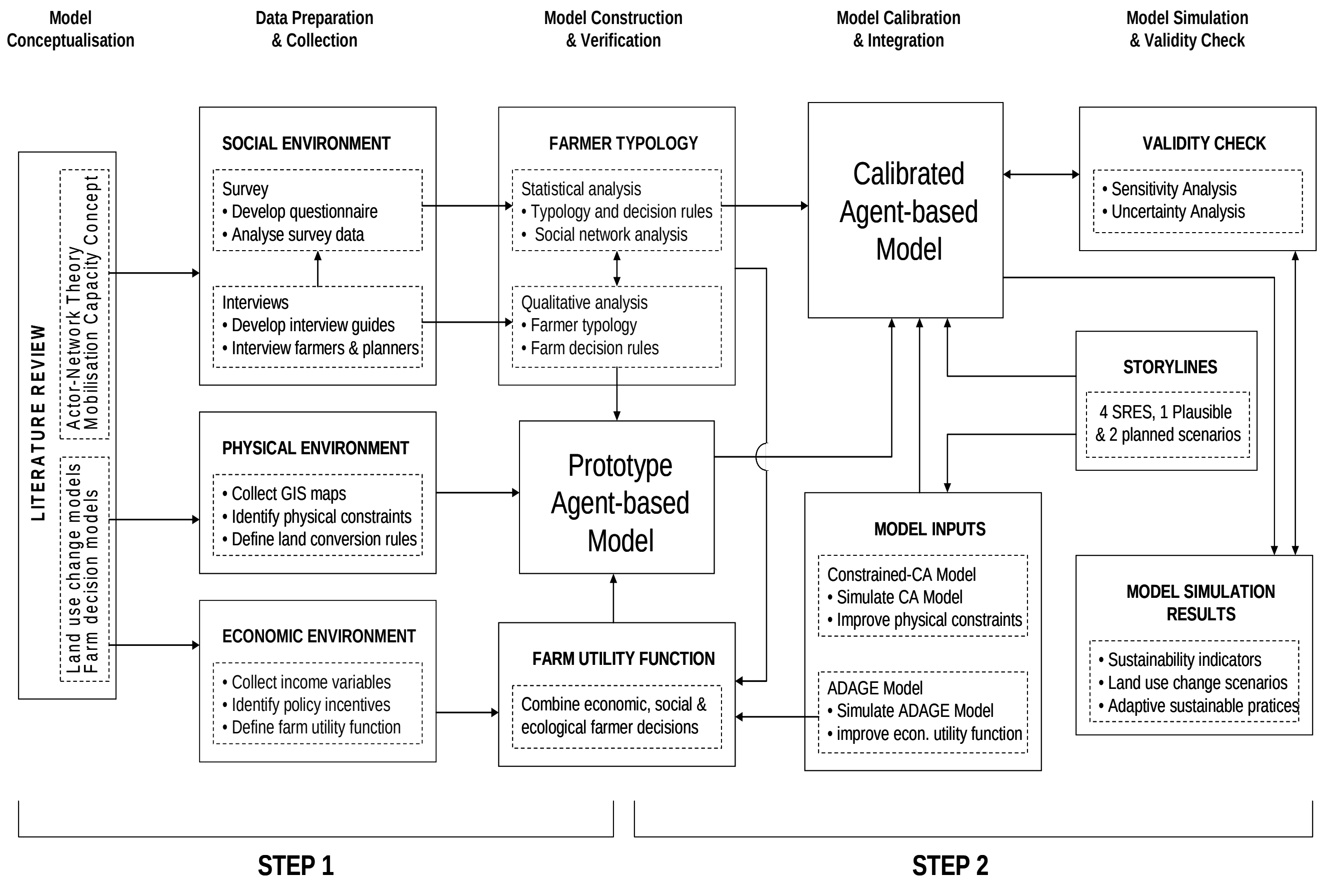

Figure 13. Methods for constructing, calibrating, integrating and validating the ABM model

The second step, which will be carried out in the second phase of the MultiMode project, aims to develop a calibrated-ABM that integrates the results of the survey and other relevant models (i.e. CA and ADAGE). The results of the interviews will be used to develop a structured questionnaire that will be sent to all the farmers in the case study area. The survey will seek to: (a) increase the number of farmer respondents and thus allow the development of statistically tested farmer typologies and decision rules, (b) identify the networks that influence farmers' decisions on farming practices and land use and thus facilitate the integration of detailed a network analysis in the calibrated-ABM, and (c) collect from a wider farm population information that can be used to develop parameters for the farm utility function. The first two objectives are aimed at improving the representation of the social environment of the farmers in the case study area. The last objective intends to extend the empirical application of utility maximization in the calibrated-ABM beyond the narrow limits of economic theories through inclusion of non-economic parameters. In addition, the model will have a better representation of the economic environment by developing an economic utility function that is based on a farm level optimisation model applied in the case study area. The farm model, which is developed through the ADAGE project, consists of production cost function which parameters have been estimated from economic time-series data of the FADN farmers or farmers with AEM contracts in the case study area. A reduced optimisation function will be developed for the calibrated-ABM from the simulation results of the ADAGE farm model. Finally, the representation of the physical environment will also be improved by using physical constraints that are based on the cellular automata-based (CA) land use model for Belgium. The simulation results of the CA model, which is constructed in the other work package of the project, will generate urbanization trend to inform the ABM how much of the land, which are currently used for agriculture will decrease in the future. The urban pressure on agriculture will cause some farmers to give up their farms for urban use. To ensure consistency between the calibrated-ABM and its model inputs, the CA and ADAGE models will use the same storyline assumptions in the simulations runs. Detailed descriptions of these models are available elsewhere. We will carry out validity check on the calibrated-ABM before applying it to generate sustainability indicators, adaptive sustainable practices and land use change projections.

Initial results of farm typology and farm utility function are presented below.

5.3.3 Identification of farm typologies and decision rules

Farm typologies are widely applied in rural research to assess trends in farming practices, identify constraints to productivity for a specific development policy, identify beneficiaries of development projects and use as a technical tool for advising farmers (Gibon 1994 as mentioned in Gaspar et al. 2007). Whilst developing farm typologies is a goal by itself in this field of research, it is only a means to achieve a goal in others. Farm typologies have been increasingly developed to capture heterogeneity of farmers and diversity in farm decisions in agent-based land use research. This paper follows the latter application to improve the representation of the agents and their decisions on sustainable farming practices and land use in a multi-agent system. Following the stepwise construction of the agent-based model, the farm typologies are also developed in two stages. The first stage develops farm typologies using a qualitative analysis of the results of interviews with 22 farmers in the case study area. Two types of typologies were created, one relating to AEM participation styles and the other to land use decisions. Among the information collected to build the former typology type include motivations for applying AEM, practical experiences in AEM application, suggestions for improving AEM design and distribution, the role of communications with advisors, other farmers and the public, and future intentions on AEM application. The latter farm typology was built on information relating to the decisions for changing land use in the past, adaptive responses to the impacts of global environmental changes (e.g. decrease in yield due to climate change, decrease in prices due to global trade), influence of social network (e.g. neighbours decisions), and responses to the changes in AEM technical and financial support. To facilitate statistical validation of the farm typologies developed in the first stage, the MultiMode project envisages carrying out survey and applying cluster analysis on its results in the second stage. Cluster analysis is a fundamental data mining method that can be defined as the process of organizing objects into clusters (groups) such that objects within the same cluster have a high degree of similarity, while objects belonging to different clusters have a high degree of dissimilarity (San et al. 2004). It is widely used in various research fields, including biology, archaeology, computer science, economics, and health psychology (e.g. Clatworthy, 2005). In this paper, the clustering technique will be employed as a two-step approach (Heir et al., 1995), combining both hierarchical and non-hierarchical clustering procedures to derive the most realistic cluster solution for the data set. The appropriate number of clusters for the survey data will be summarized in a dendogram. After the optimal numbers of clusters were identified, a graphical analysis of the attributes, which showed the largest divergence between the clusters, was used to facilitate matrix scoring. Matrix scoring is a common technique that has been widely used in participatory research for assessing the relative importance of different activities in people's livelihoods. It also provides a framework for analysis and a method to synthesize the collected data (DFID 2002).

Four types of farm typologies for both AEM participation styles and land use decisions were identified from the interview results. Opportunist, modifying, catalysing and engaged participation are the typologies identified for AEM participation, whilst conservative, innovative, follower and adaptive behaviour were classified based on the farmers' land use decisions.

For farmers with ***opportunist typology***, applying AEM is a way to earn money from existing (or intended) practices. The maintenance of hedges is a typical example of existing practice on which the farmer may increase his or her income through AEM. Likewise, winter cover is a practice that some farmers already applied before entering AEM, but there were also farmers who started with it after they had damage due to heavy rains (including water erosion) or had difficulties with tilling the land in spring. For example, one farmer regarded the subsidies an extra income for existing environmentally sensitive practices. Farmers with ***modifying typology*** are encouraged to adopt new environmental practices due to the monetary incentives for applying AEM. However, their interest in the environmental effects is rather low and the AEM chosen are most often easy to integrate in their existing practices. In the case study area, taking advantage of the monetary incentives of the AEM is seldom the only reason for engaging in new practices. The practices should preferably also support existing activities on the farm, for example, "tournières" for producing fodder and land use that favour hunting like beetle banks. This participation style is also associated with great concerns about reforms in the payments system (if the monetary incentives decrease they would probably leave the system). Farmers with ***catalysing typology*** generally show a moderate or strong interest in the environmental effects targeted by AEM. However, they do not want to lose or invest money in environmental management. AEM then effectively acts as a facilitator for work that would not otherwise be undertaken. Catalyzing participation was most prominent in AEM like grass strips, "tournières" and erosion strips. The farmers were most confident about the beneficial effects like erosion control and biodiversity (birds, insects, game). The farmers also thought of AEM as something that could improve the image of agriculture. Some applied flower strips just because it is much appreciated by the public. Many stress the extra work AEM require, both administrative and practical. In the event the amount of AEM subsidies would decrease or stop, part of them would consider leaving the system. Finally, farmers with ***engaged typology*** is convinced of the long-term interest of AEM, which also extends beyond the farm level. They support the beneficial aspects of AEM that are not directly connected to the interplay of conservation and economy. Some are just motivated to engage in environmentally sensitive farming because, for example, it fits well with organic farming. For them, AEM offers a structured programme, including professional advice, which enables an effective way of organising these practices. In general, they explicitly stress the societal value of AEM. They also have regular contacts with the public through direct selling at the farm or on the market. One farmer in the case study area has demonstrated the AEM to children who came to visit the site at the occasion of open door events. Another tried to encourage other farmers to adopt AEM. Their engaged participation is also related to more demanding AEM like beetle banks, natural meadow, planting new hedgerows and an integrated farm plan. In the event the AEM subsidies stop, they would continue employing the practices, but eventually alter or limit them.

In terms of typologies relating to land use decisions, the ***conservative farmers*** are not very responsive to economic (i.e. market, policy) and social (e.g. neighbours or community decisions) changes. Land use is relatively constant over a long period, so in terms of land use decisions these farmers have a repetitive behaviour. In some cases, farming is a tradition that is passed over generations. However, due to differences in attributes of farmers (e.g. age, education, networks), children inheriting land and adopting the same farming activities may not necessarily have the same attitude towards farming as their parents. For some farmers with conservative typology, diversifying land use is a means to minimize economic risk such as price fluctuations, so they are generally high risk averse. The ***adaptive farmers*** are very responsive to economic signals. Land use is changing frequently depending on the market situation and policy incentives. Land use decisions are based on past price signals, so they are ready to take risks (i.e. low risk averse). They will tend to allocate most of their land on farming activities that will give the maximum level of economic profit. This could mean engaging in monoculture and intensive farming if this will give them the best option. Compared to the conservative farmers, they would be more willing to adopt bio-energy crops if there is high demand for this product. The ***imitative farmers*** also respond to economic signals, but indirectly. They imitate the land use decisions of others that show evidence of economic success. However, imitation is driven not only by concrete evidence, but also by the influence of trust. Neighbours, family members or farm organisations may convince them to adopt land use decisions not only due to economic, but also environmental benefits. In this case, the farmers are high risk averse and are generally followers. The ***innovative farmers*** are more "leaders" than followers. They take initiative to learn about and apply land uses that are not commonly observed in their neighbourhood or community. The farmers anticipate changes in the market and make decisions based on available knowledge and future expectations so they are low risk averse. However, motivation to innovate may not necessarily be driven by economic goals only. Innovation may also be intended to improve environmental condition of their farms, or for other personal reasons.

From the interviewed farmers, three fall under each of the opportunist and engaged typologies and seven each for both modifying and catalysing typologies. For some farmers, it is however difficult to exactly separate the last two typologies. The interviews reveal that the typologies according to the above participation styles differ from one AEM to the other. This is important to bear in mind when applying these results in the ABM modelling. About half of the interviewed farmers (13) are conservative, four are innovative, and five are adaptive. Some farmers show some signs of imitation, but this behaviour is less evident. The distribution of the interviewed farmers to these farm typologies is presented in Table 9. Note that some farmers have been categorised under two typologies. More information has thus to be collected from such types of farmers to be able to assign the most appropriate typology. Out of the 16 possible combinations of typologies on participation styles and land use decisions, only 8 are represented by the interviewed farmers (excluding imitative typology due to little evidence). Most of them have conservative-modifying typology, followed by conservative catalysing. This exercise has two objectives; first is to identify specific farm decision rules for the different possible combinations of AEM participation styles and land use decisions, and second to qualify not only the economic, but also environmental and social benefits derived from both AEM adoption and land use decisions. The second objective poses an analytical challenge and is discussed in details in the next section.

Farmers with different typologies make different decisions because of their differences in human attributes and personal motivations. Farmers land use decisions are presented in ABM as rule-based (i.e. "if-and-then") statements, which creates the dynamics in the model. As described in the methods, these decisions are influenced by the changes in the social, economic and physical environment, which are represented in scenarios (generated from Work Package 1 of MultiMode Project). However, the farmers' decisions also change over time because of the changes in their own attributes (e.g. age, farm size, etc.). The rule-based statements or "decision rules" of the farmers belonging to different typologies were generated from the qualitative analysis of the interview results. The following are examples of decisions rules identified for the combination of typologies in Table 9:

Table 9. Farm typologies according to AEM participation styles and land use decisions

AEM participation styles	Land use decisions			
	Conservative	Adaptive	Innovative	Imitative
Opportunist	F2	F10, F12		
Modifying	F4, F5, F13, F14, F16, F19, F21, F22	F18		
Catalysing	F1, F6, F11, F19, F20, F21	F17	F3	(F3, F17)*
Engaged			F7, F8, F9	

Note: Fs represent the farmers. *There is some minor evidence of imitation. The above are only preliminary results.

- *Conservative-opportunist*: The farmer will continue his current land use and uncertain about decision to continue applying AEM given the current market and policy conditions. If subsidies are reduced, then he will stop applying AEM.
- *Conservative-modifying*: The farmer will not change his land use and farming practices, primarily due to old age. If subsidies will increase, he will not implement new AEM. If subsidies of his current AEM decrease, then he will stop applying it.
- *Conservative-catalysing*: The farmer will continue his current land use. He will apply environmental management beyond the AEM requirements if constraints in the system diminish and if subsidies increase. If technical advice on AEM is not available anymore, then he will stop applying AEM.
- *Adaptive-opportunist*: The farmer will change land use based on market prices and economic profits. If income from bio-energy crops will increase, then he will adopt it. He will apply AEM only if it does not require changes in his land use and farming practices. AEM should not interfere with his farming practices.
- *Adaptive-modifying*: The farmer will change land use based on market prices and economic profits. He will apply AEM only if fits with his current land use and farming practices. He will stop applying current AEM if rules on its application change. If prices of cereals increase, and AEM is not anymore profitable, he will stop applying AEM.
- *Adaptive-catalysing*: The farmer will change land use based on market prices and economic profits. He will adopt bio-energy crops only due to its profitability, but also if he is convinced of the positive environmental effects. He will continue his AEM even without advisers and would shift to AEM that is easy to apply if subsidies diminish.
- *Innovative-catalysing*: The farmer will try new land use that is less labour intensive. He will adopt bio-energy crops at a large scale. He will try new AEM, and will definitely do more if subsidies increase. He will not stop applying AEM even if subsidies diminish due its contribution to public satisfaction in terms improved landscape.

- *Innovative-engaged*: The farmer will shift to organic farming in a near future and also produce bio-energy crops. His AEM is linked to land use (management), like shifting to spring cereals. He will do more AEM in the future and will continue even if subsidies stop. He will encourage other farmers to do the same.

These decision rules will have to be validated through further survey and cluster analysis. The latter will guide the selection of attributes of farmers that will most likely follow one or combinations of the above decision rules.

5.3.4 Specification of farm utility function

Based on the interviews, land use decisions of the farmers are rarely influenced by AEM application; it is more the other way around. The choice of AEM is dependent on the existing farming practices, and economic profits remain the most important objectives of the farmers. Nonetheless, the identified farm typologies and decision rules informed that farmers have also some environmental and social considerations in their decisions for AEM application and land use. This has some implications on measuring the utility function of the farmers in the ABM. The research challenge is how to measure and link the environmental and social components, which appeared to be minor considerations for most farmers in terms of their land use decisions, and hence also in their objective functions. Thus, further information through comprehensive survey may help to reveal this knowledge that remains vague at this stage of the research. One method that could support this investigation is the used of conjoint analysis, which is usually applied in combination with survey research to identify consumer preferences. Through set of survey questions, the economic, environmental and social values attached to their land use decisions will be revealed and weighted.

A series of discussions have been made to identify the appropriate farm utility function, which will be the core decision rule of the farmers in the ABM. The discussions were necessary for several reasons: (1) to indicate what data inputs are required for the farmer objective function and to verify that these data are possible to acquire; (2) to indicate the method and techniques that will be used to construct the farmer objective function and to make sure that they are consistent with sound economic modelling principles; and (3) to describe what outputs are possible from the model and to determine from the ABM modellers whether this is adequate. Using the following simplified economic farm model, the farmer chooses which activities to undertake on-farm so as to maximize profits:

$$\max_{y_{mft}} U = P_{mft} Y_{mft}(x_{imft}) x_{6mft} - C_{ft}(y_{mft} x_{6mft}, w_{ift})]$$

subject to a regional land constraint

$$\sum_{f \in r} x_{6mf} \leq \sum_{f \in r} x_{6mfb},$$

where

$$P_{mft} = \text{Price (random) for crop } m \text{ on farm } f \text{ at time } t \text{ (euros)}$$

$$Y_{mft}(x_{imft}) = \text{Yields (random) (tons/are)}$$

$$C_{ft}(y_{mft}, w_{ift}) = \text{Total variable costs (euros)}$$

$$x_{imft} = \text{Quantity of input } i \text{ for crop } m \text{ demanded by farm } f$$
$$\text{at time } t \text{ (} x_{6mfb} \text{ is the input land (ares) in the reference year } b\text{)}$$

$$y_{mft} = \text{Observed yields (tons/are)}$$

$$w_{ift} = \text{Input prices (euros).}$$

Non-economic valuation of agri-environmental measures, non-economic decision rules, agronomic conditions, and response to risk will be incorporated into the above equation. Agri-environmental measures are considered activities. For example, growing wheat with a buffer strip is a separate activity *m* than growing wheat without a buffer strip. When an activity *m* includes an AEM, the market price *Pm* includes the premium for the AEM. Note that the model will ultimately include additional, spatially explicit constraints that will influence land allocation. These constraints will relate to rotation, quota, timing of operation, disease effects, legal structure and rules (AEM, Natura), land suitability (slope, erosion, wetness, location, etc. Farmers are the decision-makers in the ABM model. Thus the economic farm model needs to be farm-specific. The ABM model has spatially explicit agronomic and ecological information by field from GIS maps and spatially explicit information on farmer preferences/decision rules from the conjoint analysis survey. Other inputs to the economic farm model are the following:

- Long-run supply elasticities for each crop in the model. "Long-run" elasticities for 12 years are available from the ADAGE model. They could be adjusted for the very long-run (50 years). Another possible source is long-run elasticities calculated by other research projects.
- Unit production costs. These can be calculated from the FADN data (2004-2006 average).
- Actual output prices, yields, and hectares planted in each crop (2004-2006 average). Although it would be possible in theory to acquire this information from farmers who respond to the conjoint analysis survey, responses to such detailed questions are unlikely to be reliable. The better source of data for this would be the FADN data.
- Data on biofuel crops.
- Information on other crops that might be introduced in Belgium in response to climate change. Sunflowers, more maize, and more rapeseed have been suggested.
- In addition, some scenarios envision changing environmental conditions, regulations, and trade conditions, which will affect Belgian agriculture, and specifically the first three economic model inputs listed above.

The farm economic model described above will be able to produce crop/activity mix (including agri-environmental measures undertaken) and farm size/number of farms.

5.4 WP4: Stakeholder Dialogue and Feedbacks

5.4.1 Introduction to WP4

Another important innovation in MultiMode is the participation of stakeholders not only in providing data and information for the models, but also in judging the accuracy of the assumptions and the policy relevance of the model results. Stakeholder dialogue such as social survey and interviews are well-known techniques to collect information from people who are the foci of investigation. For the stakeholder dialogue with individual agents, WP4 will adopt an agency-oriented approach to analysing sustainable land use practices in agriculture (van der Ploeg, 1994; Busck, 2000). This is based on the assumption that farmers' decisions are influenced by structural circumstances, but maintains that structural factors do not determine farmers' behaviour (Long and van der Ploeg, 1994). Even when farmers experience the same overall institutional, market and cultural circumstances, it is possible for each owner to choose very different strategies, depending on their individual values and priorities, and the physical conditions of the farm. For the stakeholder dialogue with institutional agents, face-to-face interviews were carried out. The identification of appropriate stakeholders for this purpose were supported by a qualitative approach for institutional and policy analyses. The results of these analyses are presented in the next sections.

5.4.2 Concept and methods

Actor-Network Theory (ANT)

ANT was originally developed by sociologists of science – in particular, Bruno Latour and Michel Callon - as a set of methodological and conceptual tools to uncover the way in which scientific ideas and technologies were developed to the point they are accepted and adopted. Applied to our study, ANT raises the challenge to study the implementation of AEM as a process that takes shape via the manifold linkages that relevant actors make with each other. Along this process, AEM and the networks of support are built up gradually and simultaneously when initiating actors – in this case the regional government bodies responsible for AEM - succeed in mobilising other participants (politicians, farmers, scientists, etc.) as supporters of their definition or agenda. So, achieving a particular goal is bound up with the active construction and continuous activation of a network of support around one's definition or agenda. Before unpacking the mechanisms by which AEM take form and become applied, it is important to recognise that implementation of AEM involves a number of largely different processes. These range from designing a high quality instrument, over recruiting a sufficient number of farmers, to supporting and controlling them in their application. Each of these stages in the implementation process has its own agendas and networks mobilised around them.

To depict the idea that several social networks co-exist and interfere with each other, we use the notion of arena. Social networks are then particular configurations populating the arena. For the purpose of the analysis, we prospectively defined three types of arenas corresponding to the critical stages through which the implementation process passes: design, distribution, and application. The framework that is used in this paper to analyse the success of putting agri-environmental management, in this case AEM, into effect is what we call 'implementation chain' (Figure 14). As will become clear in the analysis, the links between these arenas are not linear and stationary, but a complex system of loops and feedbacks.

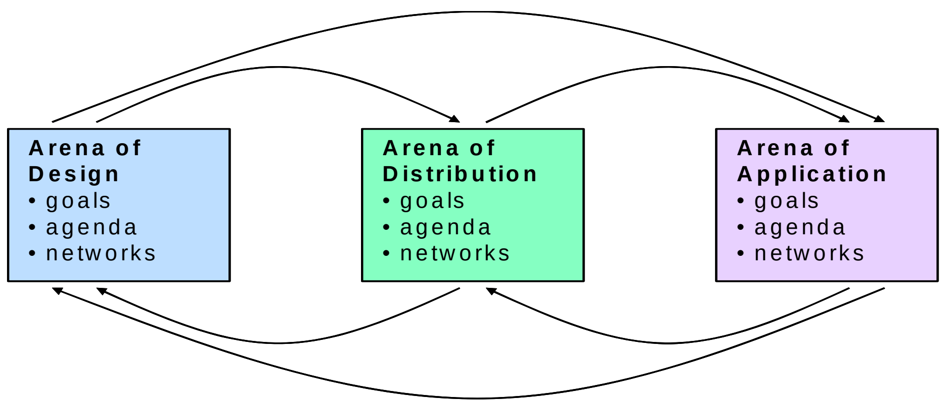

Figure 14. Implementation chain for the analysis of agri-environmental management

Study area

The study area comprises 19 municipalities located in the provinces of Vlaams Brabant (Flanders, 10 municipalities) and Brabant-Wallon (Walloon Region, 9 municipalities), in the centre of Belgium; a few kilometres to the East of Brussels. The region extends on a low plateau (100 - 150 m) incised by a number of small streams (mostly in the centre), creating a hilly topography. All municipalities are part of the river Dyle's catchment. Agriculture is the main land use but a relatively large proportion of the area (> 20 %) is built. The region is fast growing, both in economic terms and in terms of population. In general, there is a high pressure on the land from the building sector, which results in fast urbanisation. The particular morphology of the landscape in relation to the topography and land use creates frequent problems of flooding and erosion [8]. This has been recognized as one of the main environmental issues for which AEM have been designed in both regions. Other environmental issues that AEM try to tackle relate to improving water quality, and maintaining or restoring biodiversity.

Interviews

During March-June and November 2008, semi-structured interviews were conducted with 13 experts involved in AEM implementation, as well as 37 farmers who have practical experience with AEM. Two broad categories of experts were selected: those who were responsible for the design and evaluation of AEM-packages and procedures (7), and those who were in contact with farmers for advice and support (6). In some instances, however, the two tasks overlapped. The interviewed experts were directly and actively involved in one or more arenas (design, distribution, application) of the 'implementation chain'. We used two ways to locate the farmer respondents. First, technical advisors in each region were asked to provide an initial list of farmers in the study area whom we could contact. As criteria for the selection of farmer respondents we asked them to include farmers with different types of farming systems, sizes of agricultural holding, and types of AEM applied. Second, selected farmers from the list were asked during the interview to refer another farmer who may have a different opinion. Using this method, we aimed to select farmer respondents who represent a broad spectrum of viewpoints and experiences.

The semi-structured interview protocols were designed to trace the multiple linkages or relationships that render AEM a credible and effective instrument. The experts were asked to tell about their activities in relation to AEM, especially those that 'make a difference', such as prescribing rules, employing officers, promoting AEM, and the methods or strategies they used to perform these tasks. Special attention was given to recent changes or innovations (and how these came about), and any further changes they would strive for in future. Those who were in contact with farmers were also asked about the way they approach these farmers (strategies of communication). The expert interviews were also used to develop a diagram of the institutional structure (see the next section). The interviews with the farmers focused on their motivations to enter (or not to enter) particular AEM, their practical experiences with, and eventual suggestions for improving AEM, the role of communications with advisors, other farmers, the public at large, etc., and their future intentions with regard to the application of AEM. All of the interviews were held at the offices or farms of the interviewees and lasted from one to two hours. With the consent of the interviewees, the interviews were tape-recorded and notes taken.

A content analysis of the transcripts was carried out in three parts, corresponding to the critical stages and associated arenas of AEM implementation (design, distribution, application). Thus we followed AEM along its trajectories of implementation, and identified the networks of support within the different arenas, as well as those alliances that extend beyond a given arena. We described the agendas or representations that actors attempt to pursue, and the relational links (including their form and qualities) enabling them to mobilise people and resources around these agendas. Before we take up these issues, we give a short description of the institutional structure surrounding AEM.

5.4.3 Institutional structure of AEM in Belgium

In Belgium, AEM are part of the Rural Development Programmes (RDP) of the Second Pillar of the EU Common Agricultural Policy. The implementation of the EU policy is the exclusive authority of the regions. As a consequence, the Flanders and Walloon regions develop their own RDP without any consultation on a Belgian level. The division of agricultural politics within the General Division for Agriculture, Natural Resources and Environment (DGARNE) performs the coordination of the Walloon RDP. For Flanders that is the coordination cell for

European rural policy within the Department of Agriculture and Fisheries. In the Walloon region, the first programme including AEM got approval in 1994. Flanders followed six years later with the approval of the RDP 2000-2006.

In the Walloon region (see Figure 15a), AEM are developed by the DGARNE. The AEM developed so far include elements of the ecological and landscape network (e.g., hedges, trees, ponds), natural meadows, grassy headlands and margins, winter ground cover, extensive culture of cereals, conservation of local breeds, low livestock density (grouped under 'basic measures'); high biological value grassland, cultivated field margins (herbaceous flowered strip, beetle bank, erosion strip) and agro-environmental action plan (grouped under 'targeted measures'). The day-to-day management (contracting, payments, control, information) of AEM within DGARNE is mainly performed by its external services. In addition, a kind of multi-expert structure was set up which task is focused on counselling: technical advice for the implementation of the targeted measures, as well as programme evaluation. These tasks are contracted out to a series of institutions and organisations with relevant expertise (universities, nature conservation groups, etc.), and coordinated by the Interuniversity Group on Applied Ecological Research (GIREA). Technical advisors concentrate either on a specific area in the region or a specialised theme (fauna, flora, and erosion).

In Flanders (see Figure 15b), although the AEM are part of the same RDP, they are managed by two different administrations. The Agency for Agriculture and Fisheries (ALV) takes care of AEM directed at environment-friendly production methods, such as mechanical weeding, integrated fruit production, conservation of local breeds, and organic farming. The Flemish Land Agency (VLM) is responsible for AEM directed at environmental management. The AEM-packages are grouped under several themes: species protection (meadow birds, arable birds, wild hamster), field margins, restoring, maintaining and planting of small landscape elements (hedgerows, ponds), botanical management, fighting erosion, improvement of surface and ground water quality (reduced fertiliser application). Both administrations are also involved with the development of the AEM-packages, except those for fighting erosion which were written by the Administration of Land and Soil protection, Subsoil and Natural resources (ALBON). ALBON gives also advice on AEM applications for fighting erosion. VLM has employed and charged local advisors ('farm planners') with assisting farmers in their applications, and providing the administration with technical advice necessary for approval and contracting. In this context, partnership contracts were established with the 'regional landscapes'.

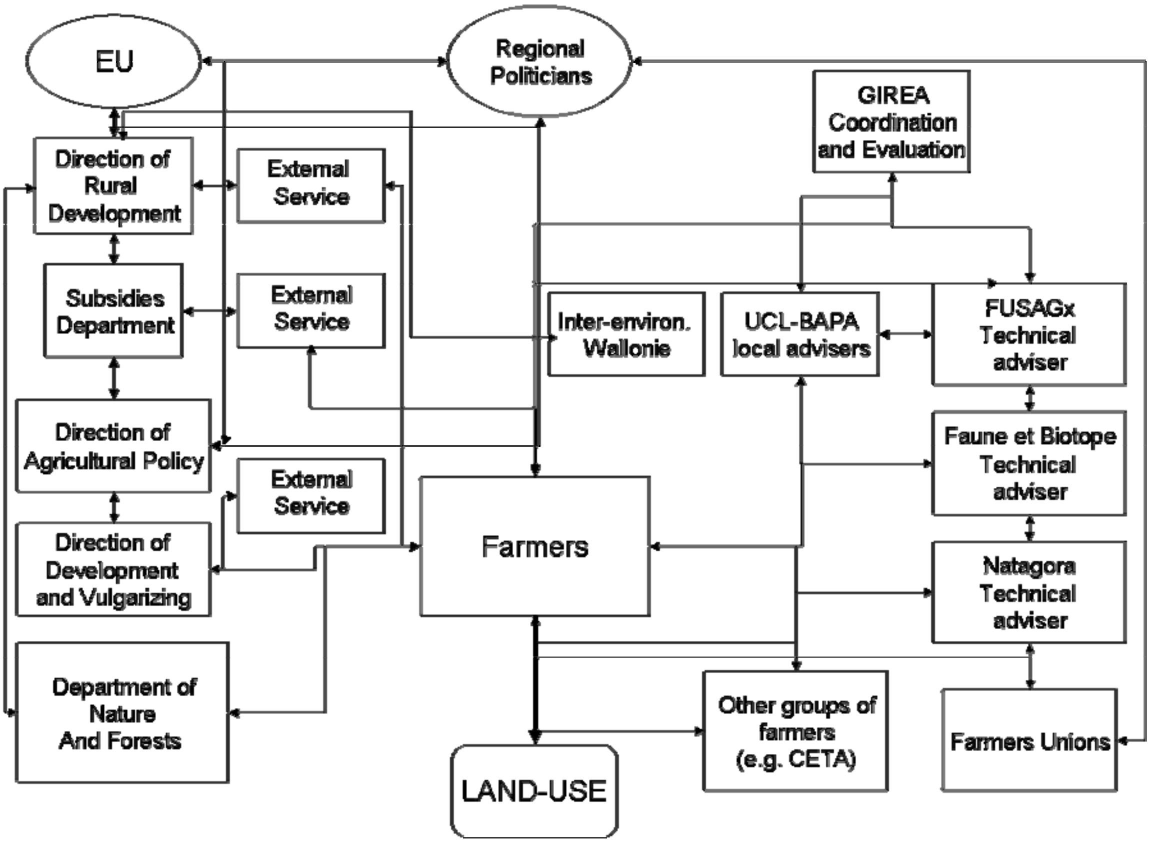

Figure 15a. AEM implementation network (Walloon region)

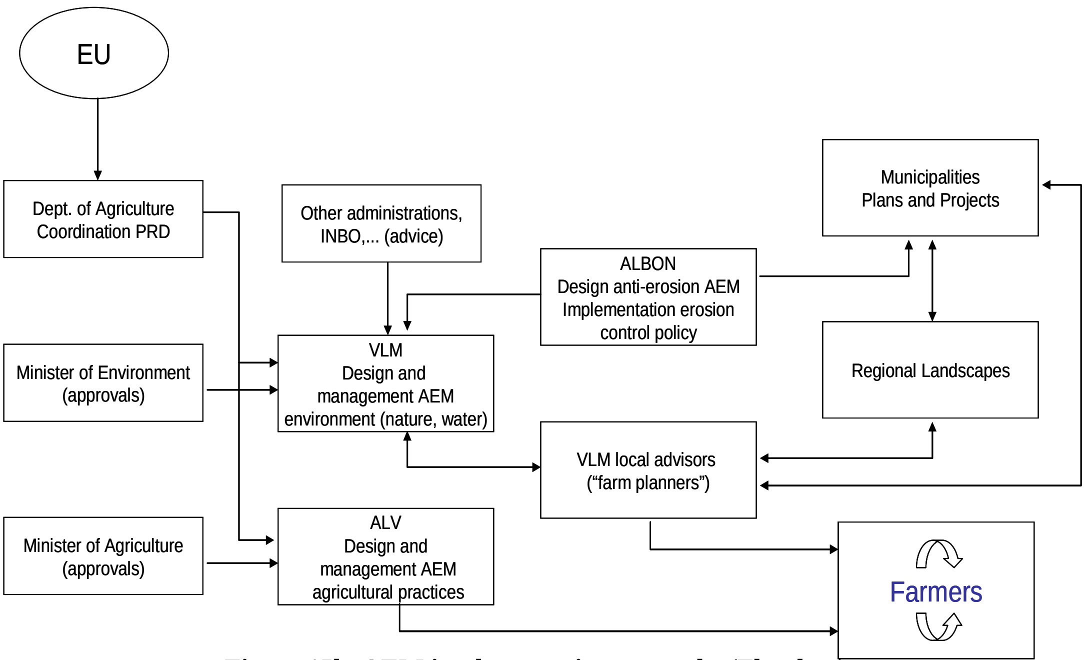

Figure 15b. AEM implementation networks (Flanders)

5.4.4 The implementation chain

The arena of AEM design

The design of AEM does not rely on one stable or centrally established agenda. In both regions, AEM reflect a wide variety of past and current policies: nature conservation, the Manure Action Plan, erosion control, etc. In comparing both regions, we also observed that there are common problems that receive different attention. The considerations can be very practical. For example, in Flanders the idea of subsidising rows of trees via AEM was not taken up because it was considered too expensive, and there are many municipalities granting these practices. But negotiations over the choice of AEM are also based on perceptions of what constitutes good agricultural practice. For example, in the Walloon region, one measure for fighting erosion was developed, but it is still highly contested as the opinion prevails that fighting erosion should be part of good agricultural practice and thus not compensated.

In Flanders, anti-erosion AEM have a clearer position because they are backed by an active erosion control policy. A major instrument is the municipal erosion control plan. Municipalities in the hilly areas of Flanders can apply for subsidies to develop such a plan and to communicate it to the farmers. In this case, a synergy between two different networks was created. On one hand, anti-erosion AEM benefit from their alignment with the erosion control network. On the other, ALBON chose AEM as an instrument since these provide them via VLM a good linkage with the farmers.

Another point to consider is that agri-environment agendas may shift over time. Regarding the future direction of AEM, there is a fundamental debate on whether to choose for quantity or quality. In the early years of AEM implementation, quantity, in terms of numbers of farmers and hectares of land enrolled, was high on the agenda, as it was a measure of success. Now that the programme has proven successful and many farmers have entered the system, the achievement of greater efficiency and effectiveness becomes increasingly important. The tendency towards quality in the agenda setting is reflected in recent changes in AEM design. In both regions approaches were developed that target at the whole of the farmstead. In the Walloon region the 'agri-environmental action plan' was developed to integrate several AEM at the farm level. In Flanders, we find a similar idea with the so-called 'farm plan'.

Finally, knowledge networks have an important role to play. The design of anti-erosion AEM within ALBON, for example, has much benefited from a guideline book resulting from an erosion control research and demonstration programme funded by the Flemish government. But also the design of other AEM tends to draw on various knowledge networks. On one hand, there are the more durable though informal contacts between and within administrations. For example, in VLM draft texts of AEM are discussed in small working groups of local advisors. The practical knowledge of advisors and their local contacts enable the designers to improve the texts on clarity and to anticipate on how AEM is going to be distributed and applied. Thus, a pro-active link is created to the next arenas.

On the other hand, we find many occasional inputs. In some instances, these result from comments and practical suggestions that conservation organisations, game management units, and so on, provide on their own initiative. But in most cases scientific knowledge and best practice have to be actively searched for or otherwise found by opportunity. Examples of the latter are the measures related to skylark plots (Flanders) and beetle banks (Wallonia), which were both inspired by initiatives in the UK.

The arena of AEM distribution

First of all, the choices made by the designers have a critical role to play in channelling the distribution of AEM in the desired direction. A number of properties will allow an AEM-package to enrol a smaller or larger number of farmers. In particular, well-paid AEM that do not require much effort or changes in farm practices are most easy to distribute. Other properties, however, are aimed to restrict uptake to certain groups of farmers. In general, there is a tendency to link eligibility of AEM with territorial zoning. This is most evident in Flanders with most AEM packages only eligible in delineated areas (e.g., anti-erosion AEM are linked to the soil erosion map for Flanders; AEM for meadow birds and hamster protection to 'management areas' and arable birds to 'core areas' and 'search areas'). In the Walloon region, eligibility of AEM is much less dependent on legal zoning requirements. Nevertheless, linkages are forged to support the main ecological structure (the regional nature policy plan) and the Natura 2000 actor-network.

Since AEM are voluntary, it seems obvious that the success of distribution depends on whether farmers accept it and let themselves be enrolled. Not surprisingly, the prime rationale for participation among farmers is actually the one already 'built in' within the instrument: farmers deliver certain environmental services for which society pays. Thus, faced with any decision on whether or not to enter a given AEM the farmer will evaluate whether the money is worth the effort (which also includes the extra paperwork involved!). However, when balancing between money and effort, farmers tend to consider the wider landscape of government rules and regulations. Several farmers welcome AEM as a means to activate 'payment entitlements' or simply to pay lower taxes on their income. Furthermore, farmers are increasingly faced with restrictions of fertilisers and pesticides use. The uptake of AEM, which entail slightly stricter conditions, can be a means of getting a financial return for the effort of reducing inputs.

Local advisors may play an active role in the distribution arena, advocating and negotiating AEM with farmers. In Flanders, the farm planners are required to delineate priority areas for AEM promotion. Such a strategy fits well with the new emphasis on quality in agenda setting. Another is to align with networks developed around local initiatives, such as erosion control and river restoration by municipalities. There is also the experience that supporting a local project is something that can be 'sold' more easily to the farmers.

In Wallonia, the advisory system is much less centralised than in Flanders. Technical advisors employed in one of the contracted institutions are charged with either a particular area or theme. Whereas the effectiveness of AEM is likely to benefit from the specialist expertise, technical advisors also tend to align distribution of AEM with the agenda of their institution (e.g., concentrating on zones that are adjacent to a particular nature reserve). The distribution of AEM may also take advantage of an institution's existing networks (contacts with farmers, hunters associations, etc.). But in pursuing their agenda other organisations too are starting to distribute AEM as a tool to develop their networks of support. One example is the managers in charge of the 'Dyle river contract'.

Other outside actors may come to influence the distribution of AEM more indirectly. In the Dyle valley in Flanders, nature associations' actions to rise the groundwater level force farmers to take up AEM as a compensation for production losses. With increasing urbanisation farmers in both regions are also faced with pressure from local residents to minimise various inconvenience (pesticides, mud flowing).

The arena of AEM application

When farmers accept a given AEM package and agree to follow its rules of application, they engage in taking up the actions, payments, penalties, etc. as specified in the contract. Since the contractual requirements are derived from AEM legislation there is little or no room for negotiation with the farmers. Designers of AEM have become increasingly aware of the rigidity of the packages. In Flanders an idea emerged to reform them to a kind of flexible 'a la carte' system by which a farmer can assemble his or her own package of actions. However, for the farmers the problem is foremost in standardisation itself, which is perceived as a too bureaucratic approach to what farming really is. For example, farmers do not usually think in terms of square and linear measures, and they feel indignant when controllers start to 'make a fuss about centimetres'. In general, farmers find AEM 'nice in theory' but far from the reality of daily farming.

What is interesting about AEM application is the learning effect. Of course, there are farmers who take up AEM such as maintaining hedgerows or winter cover to get subsidies for something they were doing already. Many farmers, however, get acquainted with new elements (erosion strips, beetle banks, etc.) and new practices and, as a consequence, they start to look at and work their land from a novel perspective. Farmers try to maximise production within the limits of new constraints. For example, those applying AEM for water protection (Flanders) learn to keep the risk of drawing a 'bad' sample to a minimum. By doing so, they also become to learn about nitrogen leaching (or soil erosion and biodiversity in other cases). Farmers also use their social networks to share and develop further the knowledge acquired (which in turn helps distributing AEM over a larger group of farmers). At the level of the whole farmstead, farmers have started to consider the potential of the land – both agronomic and environmental - as a main starting point for applying AEM. As a rule, farmers will locate less or non-productive elements like field margins and grassy headlands in sites with low production potential.

However, the learning that emerges from applying AEM has not yet permeated the farmers' social environment. In the view of the farmers AEM are hard to explain to the wider public. In both regions, many farmers point at the difficulties with horse and motorbike riders causing damage to their field margins. People think that the space is just 'empty', and when the farmer tries to explain they often react by saying that farmers get paid for doing nothing. Nevertheless, being more generally understood and appreciated is something important to many farmers.

Finally, positive effects are likely to motivate farmers if these are visible (both to themselves and the public). In this respect, erosion control AEM were appreciated the most. Many farmers, especially in Wallonia, do also notice a clear effect of AEM like grassy headlands and beetle banks on the abundance of game species (hare, pheasant, partridge, etc.) and insects.

6. Recommendations in terms of support to the decision

The work carried out in the MultiMode project has initiated and supported directly the development and deployment of a nearly identical Cellular Automata Land use model for the Flemish region of Belgium (including Brussels). This model is currently supported and used by three government agencies, namely INBO (Instituut voor Natuur en Bosonderzoek), VMM (Vlaamse Milieumaatschappij) and the Ministerie voor Ruimtelijke Ordening (as the end-user in the Steunpunt Ruimte en Wonen). In a number of projects carried out for these agencies, this model is currently used to analyse the spatial consequences of scenarios related to (1) the development of natural land use (for the NARA-S-2009 report), (2) the evolution of the state of the environment (for the MIRA-S-2009 report), and (3) to carry out analysis aimed at upgrading the Ruimtelijke Structuurplan Vlaanderen.

The results of policy analysis and ABM have potential use for VLM and GIREA considering the interest they are showing on the project. The project would be able to provide valuable knowledge on how to improve the implementation and increase the acceptance of AEM in both regions in Belgium.

7. Prospects for phase 2

The second phase of the project will involve continuation of data collection, calibration of the models for different scales of application, fine tuning the integration of the calibrated models, and identification and improvement of the practical use of the sustainability measures for policy support. Most of these activities will require eliciting feedbacks from the stakeholders as well as more consultations between the project partners. Specifically:

a) For WP1, WP2 and WP3, generate a more complete database supporting the modelling work. As for the socio-economic data, this will involve mostly gathering data that may become available from federal and regional agencies, as well as from literature research. The data will be used to quantify and fine-tune the technical parameters of the model;

b) For WP2 and WP3, develop a more advanced operational prototype of the cellular automata and agent-based models. At the different spatial levels this prototype will feature more representations (e.g. demography, economic sectors, land uses, resolution) that are close to definite. The models will undergo extensive calibration;

c) For WP3 and WP4, generate additional socio-economic data at the farm levels through survey. In collaboration with the University of Edinburgh, the data will be used for cluster and conjoint analyses. GIS data for Flanders will also be collected;

d) In collaboration with WP1 the definition and quantification of scenarios will be continued. The model can be used to simulate the scenarios developed so that immediate feedback is available;

e) For WP2 and WP3, the possibilities for the incorporation of the spatial behaviour of agents (obtained from exercises with the ABM model) in the cellular automata transition rules will be analysed. Vice versa, the coupling between the ABM model and the CA-land use model with a view to set the spatial constraints within which the agents can operate will be analysed. Again, the conceptual and empirical work carried out will be supported to the extent possible with the model (within the set limitations of the model definition and its software framework).

f) In collaboration with VITO's subcontractor, Prof. White of MUN, the work will continue on the activity-based variable-grid Cellular Automata algorithm. The technical implementation of the algorithm will be finalised and its extensive testing will begin. By the end of 2009 a good documentation will be available. Moreover, with MUN an appropriate calibration strategy and procedure to calibrate the cellular automata land use model developed in WP2 will be discussed and decided.

g) For all WPs, a more elaborated documentation of the following will be prepared as part of valorisation of the results:

- A final version of the GIS- and other databases available on the PC platform. Dissemination will depend on the limitations defined in the licenses of the owners of the original data. Arrangements for the continued existence and usage of the database will be discussed with the owners. Target user groups of the database are research groups, consultants and administrations carrying out analyses with or without the model at (administrative) levels different from their own.

- Final versions (integrated and validated) of the models: meta-model of policy options and global scenarios; multi-scalar cellular automata model at the national, regional, provincial and municipal/communal levels; landscape scale agent-based models for the case study areas in the Flemish and Walloon regions, and behavioural models for selected farming communities in the Flemish and Walloon regions.

The models will be useful for scenarios analysis by administrators and planners at all levels, scientists and interests groups dealing with sustainability issues: environment, social, economic, spatial planning. However, the use of the cellular and agent-based models will require scientific and technical support. The cellular model will need to be used in conjunction with (commercial) GIS-software. Its usage will be subject to a license fee with the developers of the METRONAMICA modelling shell, the GIS-package, and the GIS-data used. The agent-based model will use Netlogo, which is a free software downloadable from the internet.

- A series of documented model runs. Each run will consist of time series of the sustainability indicators and maps at the European, national, regional, provincial, communal/municipal and farm levels. These runs will be made available digitally to the public at the end of the project on the website, FTP-servers or CD-Roms.

- Reports or working papers with full documentation of the work carried out, the main results obtained, and recommendations for further analysis. This report will be made available to the follow-up committee, Belgian Science Policy and the public through the website.

- A minimum of 2 presentations in international conferences and a minimum of 2 publications in internationally refereed journals or books by each partner.

8. Follow-up Committee

We acknowledge the valuable support of the following Follow-up Committee Members who have been very supportive during the phase I of the MultiMode project:

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