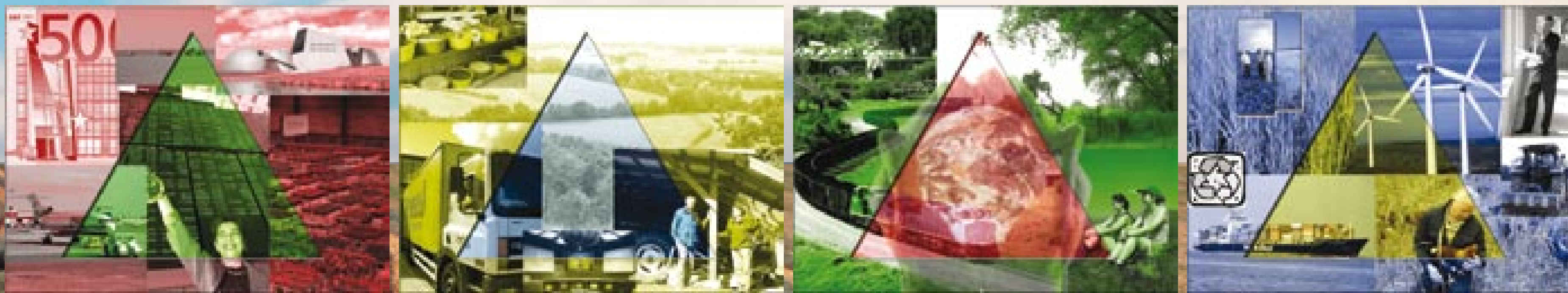
EURURALIS 2.0



TECHNICAL BACKGROUND AND INDICATOR DOCUMENTATION

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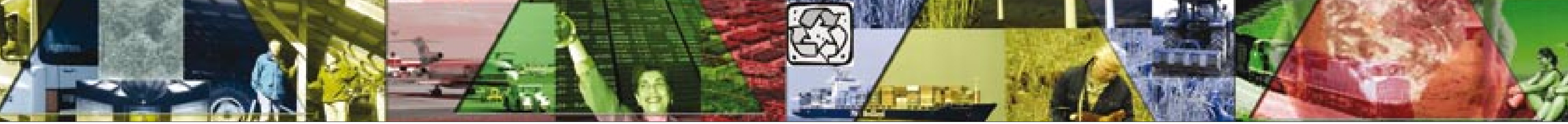

EURURALIS 2.0

TECHNICAL BACKGROUND AND INDICATOR DOCUMENTATION

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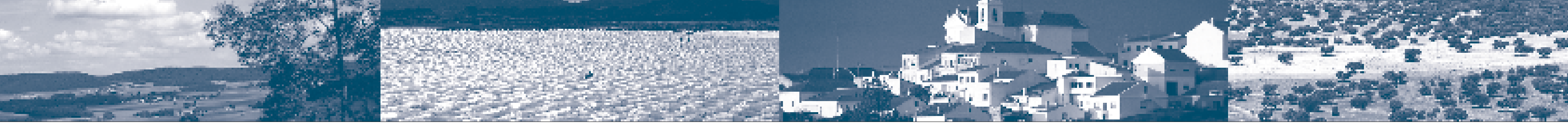

ACKNOWLEDGEMENTS

The Eururalis project was initiated in 2003 to support the Dutch presidency of the European Union (in the second half of 2004) on the subject of Europe's future agriculture and rural areas. Eururalis-1 was released in 2004 and contained a first scenario exercise on CD-ROM. The most important step of Eururalis-1 was the development of a modeling methodology that was published scientifically in a Special Issue of Agriculture, Ecosystems and Environment (2006). In 2006 and 2007 an updated version of Eururalis was developed with specific attention to policy options, better visualization and new developments like first generation biofuels. Both Eururalis-1 and Eururais-2 were primarily supported financially by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV).

During the development of Eururalis 2.0 a Scientific Advisory Group (SAG) guarded the scientific soundness of the Eururalis-project and a Policy Advisory Group (PAG) kept the project team on the path of user-friendly products. The SAG consisted of Prof. Dr. G. Meester (LNV, the Netherlands), Prof. dr. J.M. Boussard (INRA, France), Dr. M. Baranowski (UNEP-GRID, Poland), Dr. G. Bidoglio (IPTS, Italy), Dr. S. Herrmann (FAL, Germany) and Dr. T. Ribeiro (EEA, Denmark). The PAG consisted of experts from different Ministries of Agriculture and/or Rural Affairs: Mrs Dobrzynska (Poland), Mr Nesbit (United Kingdom), Mr. Blasi (Italy), Mr Schweitzer (Germany), Mr. Knobl (Austria), Mr. Bengtsson (Sweden), Mrs Munk (Denmark), Mr. Raidmets (Estonia), Mr. Haanstra (The Netherlands) and Mr. Berkowitz (European Commission).

The Eururalis project is a joint effort of Alterra (Research Institute for the Green Space), Agricultural Economics Research Institute (LEI), the Land Dynamics Group (all Wageningen University and Research Centre) and the Netherlands Environmental Assessment Agency (MNP). Eururalis greatly benefited from inputs from the SAG and PAG and inputs from several experts in Germany, United Kingdom, Poland and France, participating in several Eururalis project meetings. The Eururalis project team wants to thank Hayo Haanstra in particular for his support over the last years at the Ministry of Agriculture, Nature and Food Quality (LNV).

For the latest information on Eururalis, the reader is referred to http://www.eururalis.eu/

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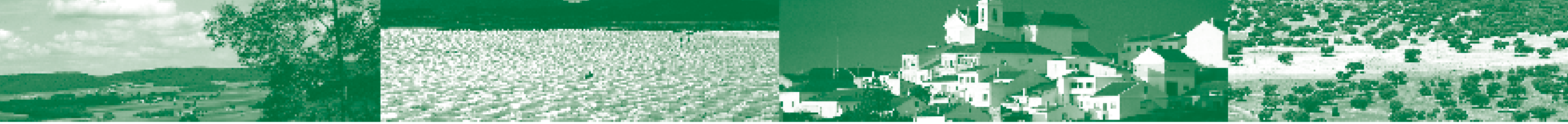


1. INTRODUCTION

The ambition of the Eururalis project is to support policy makers in discussions on the future of Europe's agriculture and rural areas. The output of Eururalis portrays what could happen to rural Europe. Eururalis 1.0 was released in 2004 as a discussion tool to give an impulse to the discussion on rural development in the European Union during the Dutch chairmanship of the EU (Klijn et al., 2005). Eururalis was used on many occasions since. Eururalis 2.0 is the follow-up of Eururalis 1.0.

The development of Eururalis 2.0 resulted in a new CD version of Eururalis (Eururalis 2.0) and a website: http://www.eururalis.eu/. The main concept and architecture of Eururalis 1.0 have been preserved in this next version. This means continuation of the same selection of four contrasting scenarios and keeping the same model framework with the major driving forces that are considered crucial for future developments. Also the inclusion of global processes (for example the increase of the Asian food consumption) and relevant data have been preserved.

However, some major improvements are included in this new version. The new version has been changed in the following aspects:

- Further development of the methodological approach of the Eururalis modeling tools. Especially the link between LEITAP and IMAGE has been improved substantially, mainly through inclusion of land supply curves in LEITAP (Eickhout et al., 2007b; Tabeau et al., 2006). For the European Union land supply curves from Cixous (2006) are used and made consistent between LEITAP/IMAGE and CLUE-s.
- Implementation of first generation of biofuels in the Eururalis modeling chain. Both in LEITAP (Banse et al., 2007) and in CLUE-s (Hellmann and Verburg, 2007) the prospect of first generation biofuels have been included. This enables an assessment in Eururalis of the economic and land-use consequences of biofuels policies introduced by the European Union.
- To obtain better food consumption projections the representation of consumer behavior in the long run has been improved in the LEITAP model.
- Dynamic simulation of the consequences of land abandonment for regrowth of natural vegetation within CLUE-s.
- Increased relevance for policy makers. By giving users of Eururalis the option to take or undo measures policy makers can explore the impacts of altered policies on Common Agricultural Policies (CAP), biofuels and Less Favoured Areas (LFA).
- Possibility to downscale information and to zoom in from country level to the level of European regions. This allows for better understanding of the relevance of future policy and driving forces for specific regions.
- More interactivity. Users can themselves browse the outcomes for different indicators and different scenarios. The results are presented in maps and graphs, completed with explanatory text.
- Possibility to get an easy insight in trade offs by using spider diagrams in the tool. These spider diagrams can show trade offs between regions, indicators and in time.

This report gives a concise overview of the Eururalis methodology, including its modeling tools and scenario approach. Most importantly, this report gives an overview of the most important indicators that determine the outcome of most of our conclusions as reported by Rienks (2007). The methodology of Eururalis 1.0 has been described in a number of scientific publications (Westhoek et al., 2006; Van Meijl et al., 2006; Eickhout et al., 2007a; Verburg et al., 2006; Verburg et al., 2008; Verboom et al., 2007) and new scientific publications on recent model improvements are underway (Banse et al., 2007; Eickhout et al., 2007b; Tabeau et al., 2007; Hellmann and Verburg, 2007). On www.eururalis.eu references to all articles will be updated regularly. The Eururalis tool can also be downloaded from this website (WUR/MNP, 2007).

This report is most suited as a background reference to help understanding

the results from the Eururalis tool. Section 2 gives a brief overview of the modeling tool used in Eururalis. The construction of the Eururalis scenarios, the resulting main driving forces and the adjustable policy options as used in Eururalis 2.0 are described in Section 3. Section 4 provides an overview of the information flow in the Eururalis modeling tool. Section 5 shows the results of the different Eururalis indicators that are needed to understand the flow of information within Eururalis.

2. MODELING TOOLS OF EURURALIS 2.0

2.1. MODELING CORE OF EURURALIS

Eururalis produces results on a detailed level within European Member States. Eururalis is strong in simulating the effects of global contexts for European agriculture and rural areas. In order to provide results on economic and ecological issues consistently, the different models are linked through land-use change. To capture all key processes necessary to explore land-use change, a combination of three models is used in Eururalis (Verburg et al., 2008): LEITAP, IMAGE and CLUE-s. By combining these three models with scenario specific inputs and several impact indicators Eururalis results are available on all the domains of people, planet and profit (Figure 1).

1. **LEITAP**: a general equilibrium model at world level. Based on expected economic growth (GDP) demographic developments and policy changes, this model calculates commodity trade, commodity price and commodity production (actual yield) for each region in the world. Trade barriers, agricultural policies and technological development are taken into account. LEITAP is based on the standard GTAP model (https://www.gtap.agecon.purdue.edu/models/current.asp). Changes in LEITAP compared to GTAP are documented in Van Meijl et al. (2006). Recent improvements on the land supply curve, biofuels and the consumption function are documented in Eickhout et al. (2007b); Banse et al. (2007) and this report (indicator Consumption) respectively.

2. **IMAGE**: an integrated assessment model at world level. IMAGE simulates greenhouse gas emissions out of the energy system and the land-use system. The land-use system is simulated at a global grid level (0.5 by 0.5 degrees), leading to land-specific CO_2 emissions and sequestration and other land related emissions like CH4 from animals and N2O from fertilizer use (MNP, 2006). IMAGE is strong in feedbacks by simulating the impacts of CO_2 concentrations and climate change on the agricultural sector and natural biomes (Leemans et al., 2002). Due to these feedbacks impacts of climate change can be assessed (Leemans and Eickhout, 2004). By combining LEITAP and IMAGE (Eickhout et al., 2006) the ecological consequences of changes in agricultural consumption, production and trade can be visualized.

3. **CLUE-s**: a spatially explicit land use change model. It allocates land use change based on competition between different land uses and the use of spatial allocation rules. Spatial and environmental policies are taken into account (Verburg et al., 2006). In an updated version of CLUE-s the allocation

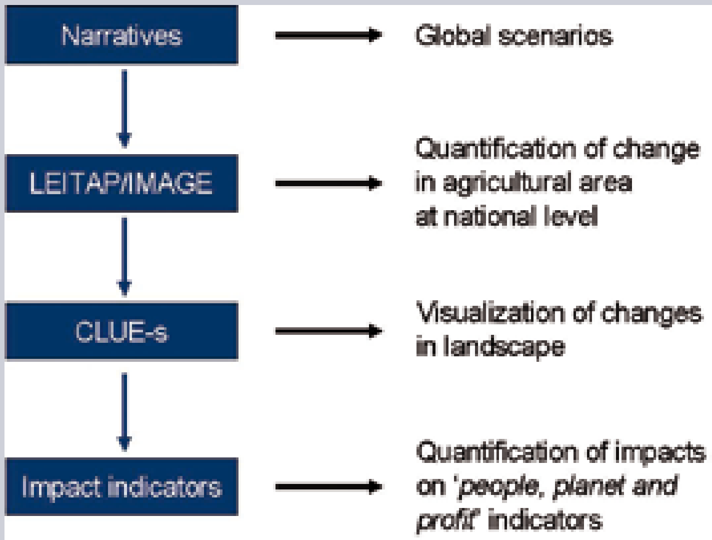


Figure 1. Overview of the Eururalis modeling train.

of biofuel areas is also accounted for (Hellmann and Verburg, 2007). CLUE-s gets its information from LEITAP/IMAGE on a European country basis and allocates land use within each European country on a grid level of 1 by 1 km.

2.2. LINKING THE EURURALIS MODELS

No single model is able to capture all key processes essential to explore land-use change in Europe at the different scales relevant to make a full assessment of driving factors and impacts. Therefore, the three models LEITAP, IMAGE and CLUE-s are linked together to account for the structure of land-use change processes (Figure 2). The demand for agricultural land in Europe is dependent on global developments in food consumption and agricultural production, world trade agreements and changes in the economy of sectors outside agriculture. The models LEITAP and IMAGE models are used to account for the effect of global changes on European land use. The global-level assessment also allows evaluating the effects of changes in Europe on other parts of the world. For instance, trade-offs to environment in developing countries when Europe decides to import biofuels instead of growing them in Europe. LEITAP calculates the economic consequences for the agricultural sector by describing features of the global food market and the dynamics that arise from exogenous scenario assumptions (see Section 3). Regional food production and impacts on productivity (through intensification or extensification) as calculated by LEITAP are used as input of IMAGE. The latter model is used to calculate the effects of land use change and climate change on yield level and simulates feed efficiency rates and a number of environmental indicators (Eickhout et al., 2006). Together, these global models result in an assessment of the agricultural land use changes at the level of individual countries inside Europe and for larger regions outside Europe (Eickhout et al. 2007a; Van Meijl et al. 2006). At the same time these models also calculate changes in other sectors of the economy which are indirectly related to land use.

Obviously, the global models are not able to make an assessment beyond the resolution of individual countries. Therefore, results need to be downscaled both socio-economically and physically. Physical land use within a country is variable as result of local variations in social and biophysical conditions. Furthermore, the driving factors of landscape pattern are often region-specific as a consequence of different contextual conditions, specific variation in the socio-economic and biophysical conditions. The actual downscaling of the national level changes to the landscape level is done by at a spatial resolution of 1 km^2 by CLUE-s (Verburg et al. 2006).

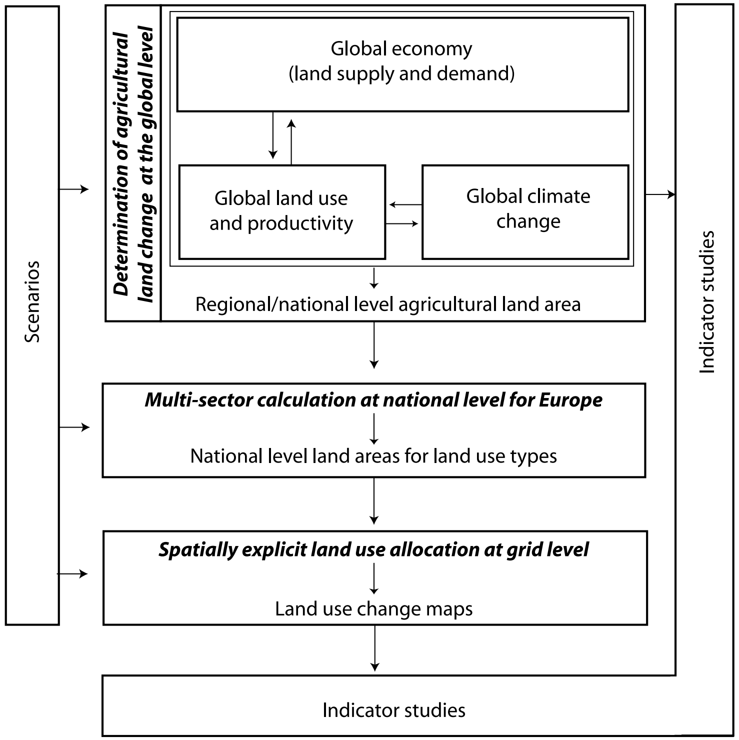
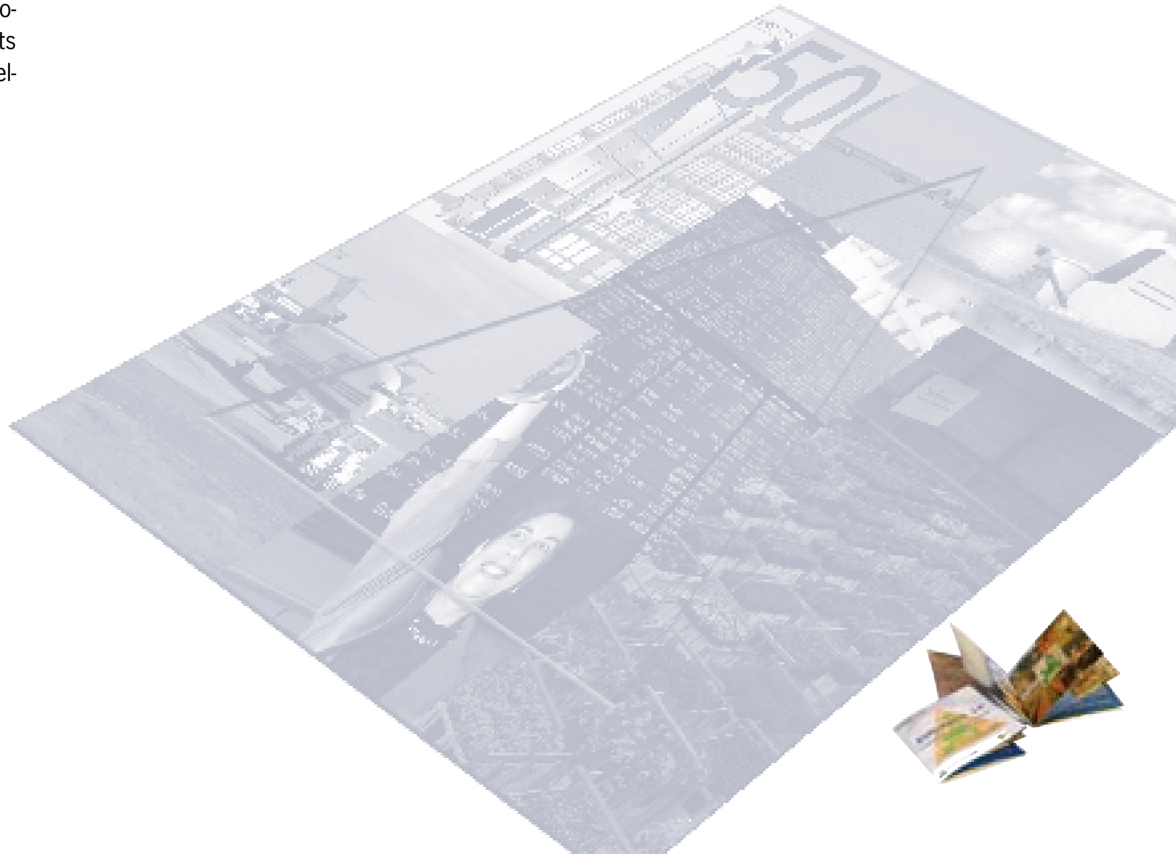
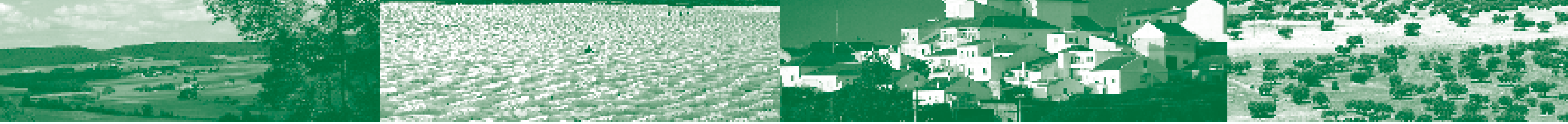


Figure 2. Overall representation of the Eururalis methodology (Verburg et al., 2008).

This results in landscape visualizations for the entire European Union (EU27), distinguishing arable land, pasture land, forest land, biofuel areas, urban areas and other nature characteristics. This information, combined with additional data that covers fields like climate change, soil carbon and nature protection, delivers results for several indicators on the physical aspects of European rural areas.
For socio-economic aspects, a down-scaling procedure was used to tell something on the socio-economic strength of European regions. Based on past trends of indicators (e.g. employment and GDP) at the regional (NUTS2/3) level, national indicators developments were downscaled. In total, Eururalis delivers opportunities to draw conclusions on future threats and challenges for rural areas, covering the full range of sustainable development (people, planet and profit; Rienks, 2007).





3. SCENARIO CONSTRUCTION AND POLICY OPTIONS

The Eururalis modeling tools can be used for long-term (two or three decades) prospects of European agriculture and rural areas. In the short term changes in European agriculture are very much dependent on small-scale policies that are not part of the modeling chain. On the very long term (100 years) changes in economic structures are possible, which cannot be covered by general equilibrium models like LEITAP. Therefore, Eururalis is most suited for a period of 20 or 30 years. To cover possible futures of Europe, in Eururalis different narratives are developed. These narratives resulted in consistent scenarios, applied in the global context. However, in a set of scenarios many indicators are different and therefore, it is difficult to identify the impact of specific policy actions. Therefore, in Eururalis 2.0 the four scenarios are broadened with four policy options, to assess the consequences of these specific policy actions. To restrict the number of modeling simulations not all policy actions are applied to the four scenarios. This resulted in 37 simulation variants in the Eururalis 2.0 version (WUR/MNP, 2007). In this section the four Eururalis narratives are introduced (Section 3.1) and the resulting exogenous driving forces are described in Section 3.2. In Section 3.3 the quantification of the narratives to get to the four scenarios is elaborated further. In Section 3.4 the four policy options are explained.

3.1. CONSTRUCTION OF THE EURURALIS 2.0 SCENARIOS

In order to capture future uncertainties in global developments four contrasting narratives are developed in the context of Eururalis (Westhoek et al., 2006). The quantification of these four narratives through exogenous drivers (economic and population growth) and model and policy assumptions resulted in four scenarios. These four scenarios are an important part of Eururalis 2.0, although the same modeling tool (Section 2) can be applied to simulate a baseline scenario as well. For example, the Eururalis modeling tools have also been used in the SCENAR 2020 study, in conjunction with additional European regional economic models (Nowicki et al., 2006).

The four contrasting narratives relate to different plausible developments defined by two axes (Nakicenovic, 2000). The two axes relate the way policy approaches problems and long term strategies. The vertical axis represents a global approach as opposed to a more regional approach, whereas the horizontal axis represents market-orientation versus a higher level of governmental intervention. This results in four narratives illustrated in Figure 3. To translate the four narratives to four scenarios exogenous drivers and model assumptions are applied to the different Eururalis models. The most important differences between the four scenarios are defined by political developments, macro economic growth, demographic developments and technological assumptions.

A1 *GLOBAL ECONOMY*

The *Global Economy* scenario depicts a world with fewer borders and less government intervention compared with today. Trade barriers are removed and there is an open flow of capital, people and goods, leading to a rapid economic growth, of which many (but not all) individuals and countries benefit. There is a strong technological development. The role of the government is very limited. Nature and environmental problems are not seen as a priority of the government.

A2 *CONTINENTAL MARKETS*

The *Continental Markets* scenario depicts a world of divided regional blocks. The EU, USA and other OECD countries together form one block. Other blocks are for example Latin America, the former Sovjet Union and the Arab world. Each block is striving for self sufficiency, in order to be less reliant on other blocks. Agricultural trade barriers and support mechanisms continue to exist. A minimum of government intervention is preferred, resulting in loosely interpreted directives and regulations.

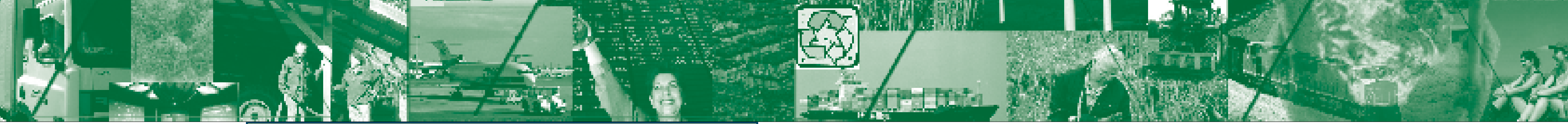


Figure 3. The four Eururalis narratives (Westhoek et al., 2006).

B1 *GLOBAL CO-OPERATION*

The *Global Co-operation* scenario depicts a world of successful international Co-operation, aimed at reducing poverty and reducing environmental problems. Trade barriers will be removed. Many aspects will be regulated by the government, e.g. carbon dioxide emissions, food safety and biodiversity. The maintenance of cultural and natural heritage is mainly publicly funded.

B2 *REGIONAL COMMUNITIES*

The *Regional Communities* scenario depicts a world of regions. People have a strong focus on their local and regional community and prefer locally produced food. Agricultural policy is aiming at self sufficiency. Ecological stewardship is very important. This world is strongly regulated by government interventions, resulting in restrictive rules in spatial policy and incentives to keep small scale agriculture. Economic growth in this scenario is the lowest of all four.

3.2. DRIVING FORCES IN EURURALIS 2.0

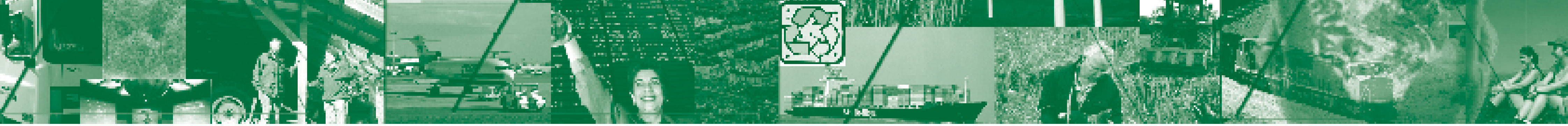
MACRO-ECONOMIC GROWTH

Macro-economic growth is an important driver (expressed as Gross Domestic Product, GDP), which influences demand for food, both the amount and the type of food. Technology development and demand for space for housing, infrastructure and recreation (urbanization) are driven by macro-economic growth. GDP growth and consequential employment and capital growth per scenario are taken from CPB (2003), which calculated these growth rates with their macro-economic model Worldscan (CPB, 1999; Lejour, 2003). In Worldscan, GDP growth is an endogenous variable, determined mainly by developments in the exogenous variables labor productivity and employment growth.

To adjust the Worldscan data for use in Eururalis, the CPB averages over the 2000–2020 period were applied to the Eururalis 2000–2010 and 2010–2020 periods, whereas the CPB data for 2020–2040 were used for 2020–2030. For the *Continental Markets* scenario, unpublished CPB results were used from a variant in which (in accordance with Eururalis) the trans-Atlantic free trade area is restricted to EU and NAFTA member states (Eickhout et al., 2004b). To streamline communication between the used models, GDP/CPB data was needed for single countries or smaller groups of countries, than available in the CPB data. Therefore, the CPB data on some country groups were recalculated for smaller aggregation units.[1] The data for "Central Europe" were adapted, assuming scenario-dependent degrees of wealth convergence to the individual countries: Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic and Slovenia. This degree of wealth convergence ranges from 25% to 75% (25% in *Continental Markets* and *Regional Communities*, 50% in *Global Economy* and 75% in *Global Co-operation*) and is expressed as the reduction of the deviation of a particular country to the average growth rate in GDP/capita in "Central Europe".

As a consequence of the assumptions described above, GDP growth rates are highest in *Global Economy* and in *Global Co-operation*. The richer countries have the lowest GDP growth rates in *Regional Communities*. The growth rates in poorer countries are the lowest in *Continental Markets* (Figure 4; Westhoek et al., 2006). Country specific figures for Europe on GDP growth rate are provided in Annex I.

[1] The Worldscan model distinguishes 16 regions of which the EU15 is divided over 8 regions (Germany, France, UK, Netherlands, Belgium-Luxembourg, Italy, Spain and Rest EU: Austria, Belgium, Luxembourg, Ireland, Denmark, Sweden, Finland, Portugal and Greece). Central Europe is one region in Worldscan. The other regions in Worldscan are Former Soviet Union, Turkey, USA, Rest OECD, Latin America, Middle East and North Africa and rest of the world (mainly Asia and Africa).

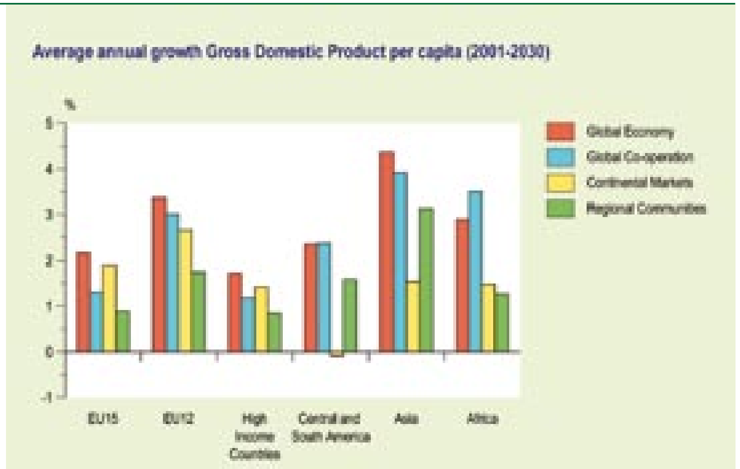


DEMOGRAPHY

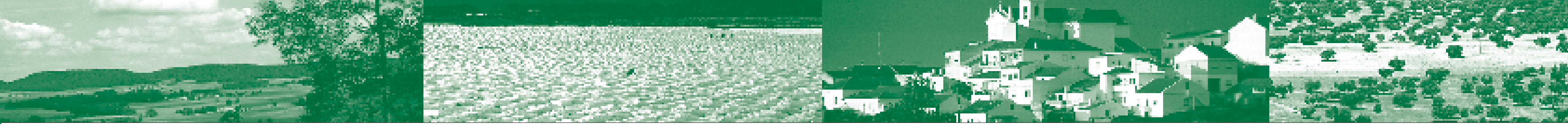
Difference in the demographical developments for all world regions are based on IPCC's Special Report on Emission Scenarios (SRES: Nakicenovic, 2000). These differences in demographical developments are caused by three fundamental demographic processes (fertility, mortality and migration). For these processes, scenario-specific assumptions have been made (Hilderink, 2004). For Europe specifically, the following assumptions are made:

- Current demographic data show Europe can be distinguished in 5 groups of countries: North (Scandinavia and Iceland), West (Netherlands, Belgium, Luxembourg, United Kingdom, Ireland, Germany, France, Switzerland and Austria), South (Spain, Portugal, Italy, Cyprus, Malta and Greece), Central (Baltic States, Poland, Czech Republic, Slovakia, Slovenia, Hungary and Croatia) and East (Rumania, Bulgaria and rest of Europe). In *Global Economy* and *Global Co-operation* EU integration is assumed to be successful, leading to convergence of the 5 European regions in 2030 to the level of the Netherlands (total fertility rate of 1.9 children per woman and life expectancy of 80 years and 83.1 years for men and women respectively). *Regional Communities* and *Continental Markets* do not show such a convergence. Total fertility rate in 2030 ranges between 1.25 and 1.82 in *Continental Markets* and between 1.17 and 1.71 in *Regional Communities*.
- Life expectancy is also lower in both scenarios compared to *Global Economy* and *Global Co-operation*. Given the lower GDP growth in *Regional Communities*, life expectancy is lowest here (68.5 years in East and 78.3 years in the EU15; for men).
- Due to an open world, migration is especially high in *Global Economy* and *Global Co-operation*. In these scenarios, migration is the most important cause of the population increase in Europe. In *Global Economy* the migration in 2030 is 3.0 net migrants per 1000 of population and in *Global Co-operation* 2.1 net migrants. Again, in *Regional Communities* and *Continental Markets* no convergence is met between the 5 European regions and migration is lower. In both scenarios there is even a negative net migration in the EU12 countries (emigration). Net migration in Europe is lowest in *Regional Communities* (0.6 net migrants per 1000 of population).
- The share of the rural population for 2030 from the UN (2004) is multiplied by the Eururalis projections of the total population per country in the different scenarios, leading to a specific number of people in rural areas. In all scenarios, the rural population decreases over time and the urban population steadily grows (UN, 2004).

Figure 4. GDP development in Eururalis scenarios in average annual growth per capita (Westhoek et al., 2006).



Total population growth in the European Union (EU27) is highest in *Global Economy*, followed by *Global Co-operation* (See Annex II for country specific figures of the EU member states). Whereas in *Continental Markets* and *Regional Communities*, the population of the European Union is declining (Westhoek et al., 2006). The overall result of the combination of these assumptions is that the population in the European Union (EU27) increases by about 3–5% in the *Global Economy* and *Global Co-operation* scenarios and declines by about 4-7% in the *Continental Markets* and *Regional Communities* scenarios (Figure 5). The differences between countries are larger, with more population increase (or slower decrease) in the old member states

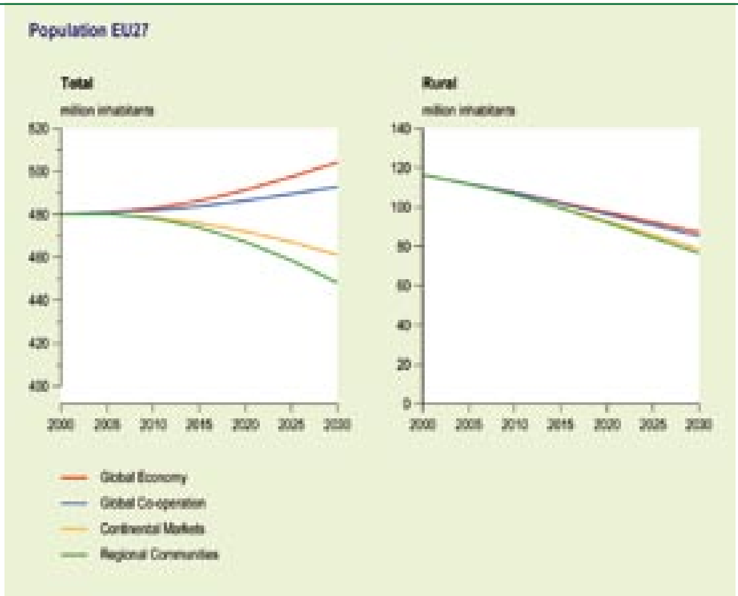


(EU15) and less population increase (or more rapid decrease) in the new member states (EU12). The grey pressure (age 65 years and over as a ratio of 15–64 years) will sharply increase. For the EU15 this increase goes from 25% in 2000 to 38% in the *Global Economy* scenario in 2030 to almost 45% in the *Regional Communities* scenario. Country-specific population data for the EU27 are given in Annex II.

The trend of the rural population is of eminent importance for the rural areas. The downscaling approach as applied in Eururalis results (using UN, 2004 data; see above) shows a strong decline in the population in most rural areas in all scenarios (Figure 5). Of course, this trend is most dominant in scenarios with a decrease in total European population (*Continental Markets* and *Regional Communities*) and particularly in most of the new member states (EU12), where a decline in total population is combined with a large initial (year 2000) share of rural population. The assumptions on the demographic development are an exogenously model input to the Eururalis modeling tools.

The global population trend is different from the trend in European population growth (Figure 6). The open world in *Global Economy* and *Global Co-operation* causes a high population growth in Europe, especially due to migration from other continents. However in developing countries, this open world results in a faster transition of demographic developments. Therefore, the growth rate of global population declines faster in *Global Economy* and *Global Co-operation* than in the Continental Market and *Regional Communities* scenarios. Therefore, the total global population is lowest in *Global Economy* and *Global Co-operation*.

Figure 5. Total population (left) and rural population (right) of the EU27 for the four scenarios (Westhoek et al., 2006).



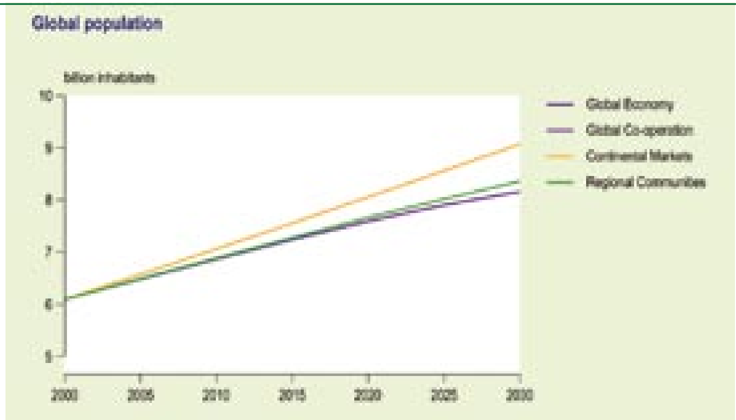
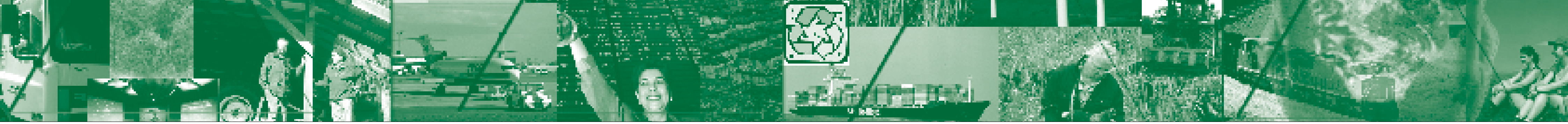


Figure 6. Total global population for the four scenarios (Hilderink, 2004).



CONSUMER BEHAVIOR:

The following assumptions on consumer behavior were made in the scenarios (summarized in Table 1):

- Due to the focus on a world of regions in the scenarios *Continental Markets* and *Regional Communities*, all consumers and producers are assumed to have a preference for regionally produced products. There is a shift in preference to regional products of 1% in 2010 and an additional 2% in 2020 and 2030. Resulting in a total shift of 5% in 2030 towards regional products. These shifts are induced by a higher price of non-locally produced products.
- In the scenarios *Global Co-operation* and *Regional Communities*, diets of people contain less meat than could be assumed based on their economic welfare. In these scenarios, people focus more on sustainability, hence the consequential animal welfare and health considerations are assumed to lead to relatively less meat consumption (-5% in 2020 and -10% in 2030 of endogenous outcome based on GDP developments).
- The high economic growth and the limited role of government in the *Global Economy* scee.g. housing, services, recreation, industry and infrastructure. Whereas in *Regional Communities* the change in built-up area per person is even negative due to low economic growth and strict spatial policies aimed at compact urbanization. The growth rate indicator (see Table 1) summarizes the effects of changes in consumer needs and spatial planning policies.

TECHNOLOGY

Technology is implied by the assumptions of GDP and endowments. Instead of assuming the same technology growth among sectors sector specific rates of productivity growth are used (CPB, 2003). In general the overall factor productivity growth in agriculture is higher than in the service sector. Productivity growth in the agricultural sector is also partly modeled endogenously by LEITAP (Van Meijl et al., 2006). However, the larger part of agricultural technology improvement is set exogenously, using information from FAO's study "World Agriculture Towards 2030" (Bruinsma, 2003). However, to take into account the scenario differences, a deviation from FAO's assumptions are made per scenario. In *Global Economy* and *Global Co-operation* more focus on technological development is assumed, and, therefore, the exogenous part is assumed to be at higher levels for most regions (Table 2). In *Regional Communities* and *Continental Markets* this level is assumed to be lower than FAO (Eickhout et al., 2004b).

3.3. IMPLEMENTATION OF POLICIES IN EURURALIS 2.0

Not only exogenous drivers are set differently per scenario, but also policies are assumed to be different in each scenario as the reasoning of world's functioning is different per narrative. For example, the vertical axis (in Figure 3) depicts a world where Doha succeeds and globalization proceeds (Global), versus a world that moves to regional economic and cultural blocks with a stronger orientation towards bilateral and regional trade agreements (Regional). The horizontal axis (in Figure 3) depicts a world ranging from a future of lean governments with little governmental interventions (Low Regula-

Table 1. Implementation of consumer behaviour in the Eururalis tool.

	Global Economy	Continental Markets	Global Co-operation	Regional Communities
Preference for regional products	no extra shift	5% shift	no extra shift	5% shift
Consumption of meat	consumption based on GDP	consumption based on GDP	10% lower than consumption based on GDP	10% lower than consumption based on GDP
Change in built-up area per person per year*	+3 m^2 per person per year	+1.18 m^2 per person per year	+0.5 m^2 per person per year	-0.1 m^2 per person per year

* Average value of trend during 1990-2000 over all EU countries is 1.18 m^2

Table 2. Deviations of agricultural productivities from FAO (Bruinsma, 2003) for the four scenarios (Eickhout et al., 2004b).

	Global Economy	Global Co-operation	Continental Markets	Regional Communities
Canada and USA	5%	0%	-5%	-5%
Rest of America	0%	0%	-10%	-5%
North Africa	0%	-5%	-10%	-5%
Rest of Africa	2.5%	7.5%	-5%	-5%
Asia	0%	-5%	-10%	-5%
Russia	5%	5%	-5%	-5%
Japan and Oceania	5%	0%	-5%	-5%
EU15	5%	0%	-5%	-5%
EU12	5%	5%	-5%	-5%
Turkey	0%	-5%	-10%	-5%

tion) to a world pursuing its goals with ambitious and extensive government regulations (High Regulation). These four worlds will implement policies differently on all levels.

AGRICULTURAL POLICIES

The scenarios also include assumptions at a European policy level: reform of the Common Agricultural Policies (CAP) is implemented according to the four different four world views (Eickhout et al., 2004b, Table 3). Therefore, border support is phased out in *Global Economy* and in *Global Co-operation* scenarios, and maintained in the other two scenarios. Income support is phased out in *Global Economy* and reduced to 33% in *Global Co-operation* (since income support is still supported in this scenario: income support to maintain environmental services). In *Continental Markets*, the income support is maintained, while in *Regional Communities*, agri-environmental payments are raised with 10%. Support in Less Favored Areas (LFA), which compensates farmers in areas with less favored farming conditions, is abol-

Table 3. Implementation of European agricultural policy settings.

	All scenarios	Global Economy	Global Co-operation	Continental Markets	Regional Communities
Border support					
Export subsidies	2003 CAP reform	Abolished	Abolished	No change	Abolished
Import tariffs	2003 CAP reform	Abolished	Abolished	No change	No change
Trade blocks	Enlargement to EU27	Rumania, Bulgaria, FSU accede EU	Rumania, Bulgaria, FSU accede EU	EU-USA	Manufacturing: FTAA (North + South America), TUR-Middle East and North Africa,
					Rest Africa, FSU
Domestic support					
Domestic subsidies	2003 CAP reform (incl. decoupling)	Abolished	-67%, rest linked to environmental and social targets	No change	+10%, linked to environmental and social targets
Milk and sugar quota	2003 CAP reform	Abolished	Abolished	Self sufficient EU	Self sufficient EU

ished in *Global Economy*. In *Global Co-operation* LFA is maintained, except for arable agriculture in locations with high erosion risk. All other support to farmers is abolished. In *Continental Markets* and in *Regional Communities* LFA is maintained, although arable areas prone to high erosion risk are excluded in *Regional Communities*.

OTHER POLICIES

Nature policy
In all scenarios, Natura 2000 areas are protected. In *Global Co-operation* and in *Regional Communities*, there is also an incentive to prevent abandonment of high nature value farmland within Natura 2000 areas. All scenarios except Continental Market contain an incentive to prevent fragmentation of nature areas. Lastly, in *Global Co-operation*, farming conditions in ecological corridor areas are less favorable due to restrictions to stimulate establishment of ecological corridors.

Spatial policy
In the *Global Economy* and the *Continental Markets* scenario, spatial policy is assumed not to pose limited restrictions in growth and planning of urban area. This leads to sprawled growth of urban areas and the expansion of small built-up areas near and within nature areas with mainly second houses and residences for the (retired) rich. In *Global Co-operation* and *Regional Communities*, restrictions in spatial urban planning leads to compact urban growth. Additionally, in these two scenarios it is not allowed to convert forest or semi-natural area into residential uses.

Erosion policy
Conversion of all land uses to arable land is not allowed in erosion sensitive areas in the *Global Co-operation* and *Regional Communities* scenarios. Additionally in these scenarios no LFA support is provided to arable land on erosion sensitive areas and compensation for conversion of arable land to grassland/permanent crops or abandonment with proper management is provided.

Energy policy
In *Global Co-operation* and *Regional Communities*, the bioenergy target is set at compulsory blending of 5,75% biofuels in transport fuel consumption and 52 Mton bioenergy in other energy consumption. In the other two scenarios, no governmental policy to reach a target is assumed, although crop residues are increasingly converted to bioenergy due to the open economy.

Climate policy
Successful climate mitigation strategies are assumed in *Global Co-operation*. The EU climate stabilization target of 2°C is implemented globally and therefore, global greenhouse gas concentration level is stabilized at 550 ppmv CO_2-equivalents. This level is reached by putting a price on carbon. IMAGE simulates in which sectors the emissions are reduced the most and how much energy efficiency is implemented (Van Vuuren et al., 2007).

3.4. POLICY OPTIONS IN EURURALIS 2.0

Once the four Eururalis baseline scenarios are set, Eururalis also allows evaluating the impact of specific policy options, applied in Europe. In the Eururalis 2.0-release (WUR/MNP, 2007) four policy options are varied: change in market support, change in income support (both policy options are part of the current CAP discussion), an obligated blending of first generation biofuels and the choice whether support of Less Favored Areas (LFA) is continued. To keep the number of model simulations limited not all policy options are varied in the four Eururalis scenarios. Moreover, some of the policy options are very unlikely in some narratives, for example an increase in income support in a fully liberalizing *Global Economy*. In the Eururalis 2.0 visualization tool (WUR/MNP, 2007) a total number of 33 variants of the four baseline scenarios are made available. In Table 5, the different variants are summarized. Logically, more variants can be performed with the Eururalis modeling framework. These variants will be released in separate publications of Eururalis.

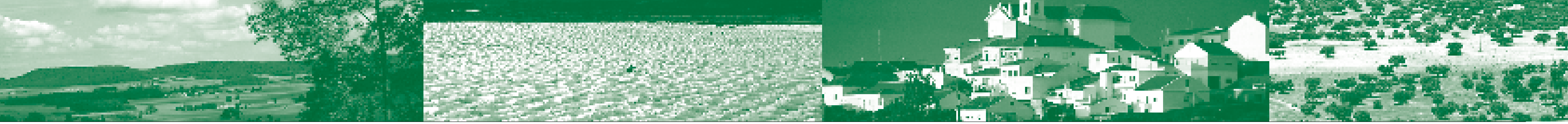


Table 4. Summary of the most important characteristics of the four EUruralis scenarios.

	Global Economy	**Global Co-operation**	**Continental Markets**	**Regional Communities**
Macro-economic growth	High	Moderate	Moderate	Low
Demographic development	Increasing	Increasing	Decreasing	Decreasing
Consumer preferences			Preference for local products	Preference for local products
Agro-technology	High	High	Low	Low
Border support	Phased out	Phased out	Stable	Stable
Income support	Phased out	Decreasing	Stable	Stable
LFA	Abolished	Current	Current	Current
Nature policy	Protection of Natura2000 + Incentive to prevent fragmentation	Protection of Natura2000 + Incentive to keep high nature value farmland, to prevent fragmentation and to establish ecological corridors	Protection of Natura2000	Protection of Natura2000 + Incentive to keep high nature value farmland and to prevent fragmentation
Spatial policy	Limited spatial restrictions	Strong spatial planning and compact urbanization	Limited spatial restrictions	Strong spatial planning and compact urbanization
Erosion policy	No policy	Incentives to limit erosion	No policy	Incentives to limit erosion
Energy policy	No target	Target: 5,75%	No target	Target: 5,75%

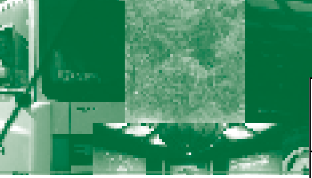



Table 5. Default settings of the four scenarios (shaded) and its available policy variants (WUR/MNP, 2007).

	CAP Market support	CAP Income support	Ambition Biofuels	Less Favoured Areas
Global Economy	1	1	1	1
			2	1
			3	1
		2	1	1
			2	1
Global Co-operation	1	2	1	1
				2
				3
			2	1
				2
				3
		3	1	2
			2	2
	2	2	1	2
			2	2
		3	1	2
			2	2
Continental Markets	2	3	2	2
		4	1	1
				2
				3
			2	2
	3	1	2	2
		2	1	2
			2	2
		3	1	2
			2	2
Regional Communities	2	3	1	2
			2	2
		4	1	2
			2	2
	3	2	1	2
			2	2
		3	1	2
				3
			2	2
		4	1	2

CAP Market Support

1 = full liberalization: in 2010 still market price support after 2020 all market price support abolished; price difference with world market = 0%

2 = in 2010 still market price support after 2020 all price support reduced by 50%

3 = constant price support: until 2020 unchanged market price support

CAP Income Support

1 = abolishment of all income support; abolished after 2010

2 = decreasing income support; budget for income support will be reduced by 50% in 2030

3 = stable income support; no change in the budget for income support till 2030

4 = increasing income support; budget for income support will be increased with 50% in 2030

Ambition on biofuels

1 = Low or no ambition on biofuels; 0% blending obligations, no taxes and no subsidies

2 = Medium ambition on biofuels; 5.75% blending obligation on share of biofuels in transport sector in 2010 and kept constant afterwards. Ambition is met by first generation biofuels only

3 = High ambition on biofuels; 11.5% blending obligation on share of biofuels in transport sector in 2010 and kept constant afterwards. Ambition is met by first generation biofuels only

Less Favored Area policy

1 = No LFA: in 2000 only LFA in old EU; from 2010 on no special LFA policy; no designated areas

2 = Current LFA: in 2000 only LFA in old EU from 2010 continuation of current LFA areas + accession countries based upon both social and physical conditions

3 = New LFA: in 2000 only LFA in old EU, from 2010 on change to new LFA area boundaries based only upon less favored physical conditions (over 600 m altitude and/or slopes over 15%)

4. UNDERSTANDING EURURALIS RESULTS

As explained in the previous section economic growth (GDP) and demographic developments (population) are the most important determining indicators. These parameters are used to quantify the consumption requirements of the EU population (including energy use) and the required urban area, which are used as input for the CLUE-s model. LEITAP calculates the food consumption using GDP and population, while IMAGE uses the same input to determine the total energy use (Van Vuuren et al., 2007). Next, consumption demand, trade and production in for the world are defined. Incorporated trade and agricultural policies in Eururalis (Section 3.3) influence the production price of commodities for all world regions.

Based on the required increase of agricultural production and an average yield per ha, IMAGE allocates agricultural land at a global grid with a 0.5 by 0.5 degree resolution; this accounts for the heterogeneity in land. Yield is affected by two processes. Firstly, climate change affects potential yield. Secondly, the expansion of agricultural land changes the average yield per crop type since a higher share of marginal land is cultivated. Due to low potential yields of these marginal croplands, average yield will be lower as more land has been cultivated (Eickhout et al., 2007a). These two effects on yield are used by the LEITAP model, which recalculates total regional agricultural production. This iteration process is continued until the output of LEITAP and IMAGE with respect to the production of arable land expansion is consistent (Figure 7; Eickhout et al., 2006; Van Meijl et al. 2006).

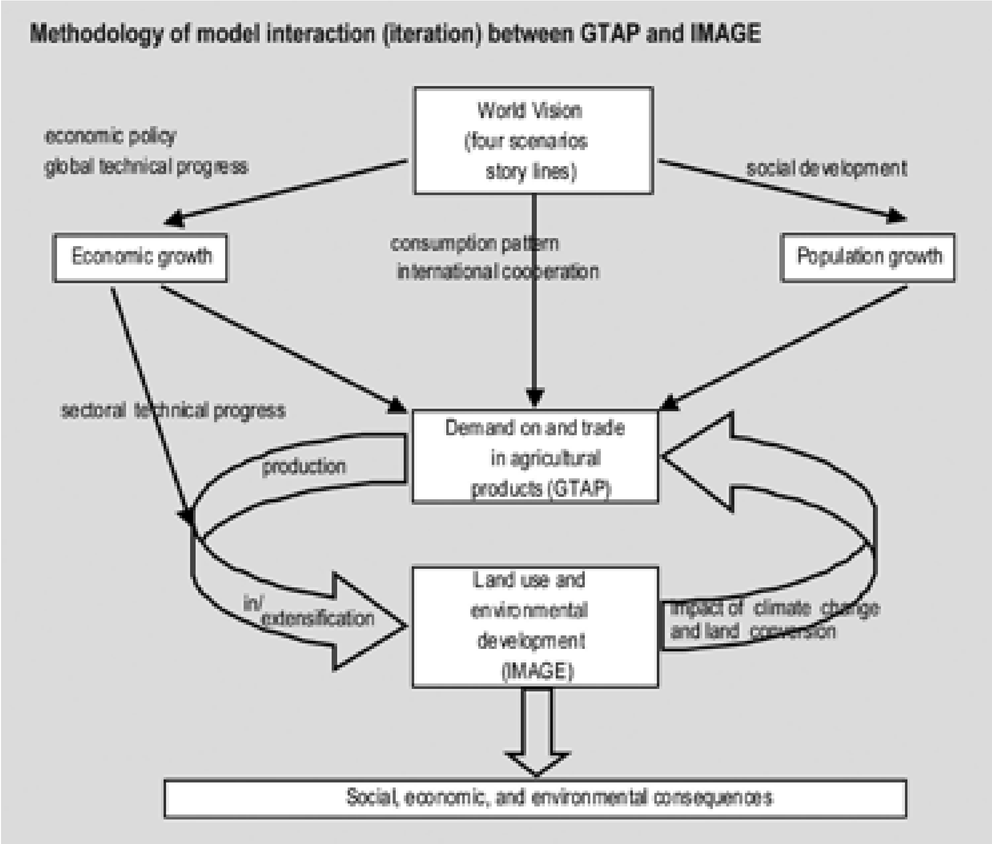
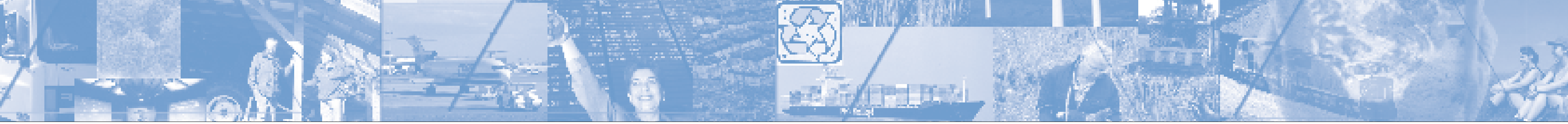


Figure 7. Methodology of model interaction between LEITAP and IMAGE (Eickhout et al., 2006).



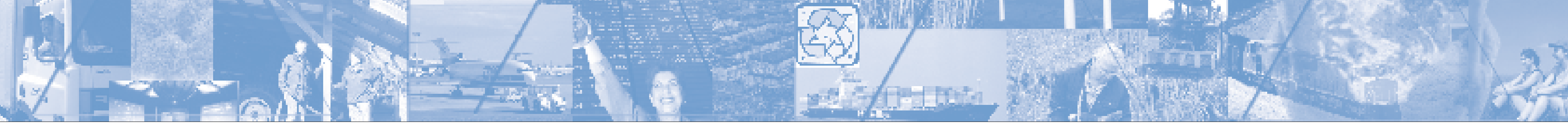
LEITAP also simulates a demand for biofuels. Biofuels are incorporated in LEITAP as a 'blend' of bio-based products and fossil resources used in the production of fuel (Banse et al., 2007). Agricultural products, such as vegetable oils, sugar-beet-cane, grains and/or wheat are assumed to be directly used as intermediate inputs next to crude oil in the fuel production. The relative importance of these two kinds of inputs (weighted on the basis of energy contents) determines the share of biofuels in the production of fuel. An increasing demand for bio-based products (e.g. increasing consumption of energy or implementation of the biofuel directive, obligating the use of bio-based products) creates an additional demand for land, resulting in a reallocation of land from food related products to industrial products (Banse et al., 2007). In this manner, LEITAP quantifies the area used for biofuel production and the level of biofuel production.
In Eururalis LEITAP and IMAGE distinguish different world regions to lower the simulation time of both models. Table 6 shows the different regions that LEITAP distinguishes. Therefore, agricultural production, consumption, trade and prices are available for all these regions. The regional disaggregation of IMAGE is slightly different[2]. Therefore, yield feedbacks (Figure 7) from IMAGE to LEITAP are not country specific for the EU27.

As result of the iteration between LEITAP and IMAGE (Figure 7) different results on a world regional level (Table 6) can be analyzed: trade, production, prices, agricultural employment, agricultural income, commodity production and agricultural area.
Change in agricultural area and change in biofuel area from LEITAP/IMAGE are used as input to the CLUE-s model (Verburg et al., 2006; Hellmann and Verburg, 2007). CLUE-s is used to translate the aggregate land use change at the national level (as calculated by LEITAP/IMAGE) to land use change at 1x1 km level for the 27 countries of the European Union. The demand for urban area is based on demographic developments and assumed changes in area requirements per household. The area requirements per household differ between the scenarios, because it is affected by household structure and economic development. Changes in nature and forest area are a result of the interplay between three land allocation processes: demand for urban and agricultural area, nature and spatial planning policies, and natural succession. The latter depends on the location of agricultural abandonment and the local livestock pressure. Based on the dynamic simulation of competition between all land use types changes in land use pattern are allocated within the 27 countries of the European Union using country-specific location factors (see Land-use pattern in Section 5). Simulations of CLUE-s result in indicator values i.e. the total land-use pattern and abandonment areas. These indicators are then used to quantify other indicators, such as the biodiversity index, N-surplus, carbon sequestration and soil degradation.

1. Belgium and Luxembourg	19. Poland
2. Denmark	20. Slovenia
3. Germany	21. Slovakia
4. Greece	22. Bulgaria and Romania
5. Spain	23. Rest of Europe
6. France	24. Russian Federation and rest of Former Soviet Union
7. Ireland	25. Turkey
8. Italy	26. Rest of Middle East
9. The Netherlands	27. United States, Canada and Mexico
10. Austria	28. Brazil
11. Portugal	29. Rest of Central and South America
12. Finland	30. Australia, New Zealand and rest of Oceania
13. Sweden	31. Japan and Korea
14. United Kingdom	32. China and rest of East Asia
15. Baltic states	33. Rest of Asia
16. Cyprus and Malta	34. Northern Africa
17. Czech Republic	35. Republic of South Africa
18. Hungary	36. Rest of Sub-Saharan Africa

Table 6. Regional disaggregation of LEITAP as applied in Eururalis.

[2] IMAGE only distinguishes two regions for Europe (EU15 and EU12). Therefore, yield feedbacks in Europe are only given on a regional level, making the yield correction identical for each country in EU15 and EU12. IMAGE distinguishes more world regions than LEITAP. Yield corrections from IMAGE are aggregated for LEITAP. Only in Africa this is not possible: LEITAP distinguishes Republic of South Africa and the rest of Sub-Saharan Africa, where IMAGE distinguishes Western, Eastern and Southern Africa. Yield corrections are aggregated for one Sub-Saharan Africa and applied to both Republic of South Africa and Rest of Sub-Saharan Africa.



In summary, from exogenous parameters GDP and population growth (Section 3.2) several agricultural indicators are simulated by LEITAP/IMAGE. Different assumptions in policies (Section 3.3) also influence the outcome of the results. Within Europe, land-related indicators are evaluated further with CLUE-s, focusing on land-use patterns. These land-use patterns influence local consequences for several impact indicators, like carbon sequestration and terrestrial biodiversity. These Europe-specific results are available on NUTS2-level and even at a finer scale of 1 by 1 km. Socio-economic results within Europe are available at a NUTS2-level (see Section 2.2). In Figure 8, the flow of information between crucial indicators is visualized. Indicators in grey are visualized with the Eururalis 2.0 visualization tool (WUR/MNP, 2007). The other indicators are also important to understand the Eururalis results. In the following Section, all indicators illustrated in Figure 8 are elaborated upon. The most important assumptions e.g. scenario policy settings, as well as the most important inputs driving the results of an indicator are summarized. To understand the data flow within Eururalis, the overview in Figure 8 is displayed in each subsection. In each section, the indicator that is described is highlighted in red to facilitate the 'causal tracing' of Eururalis results.

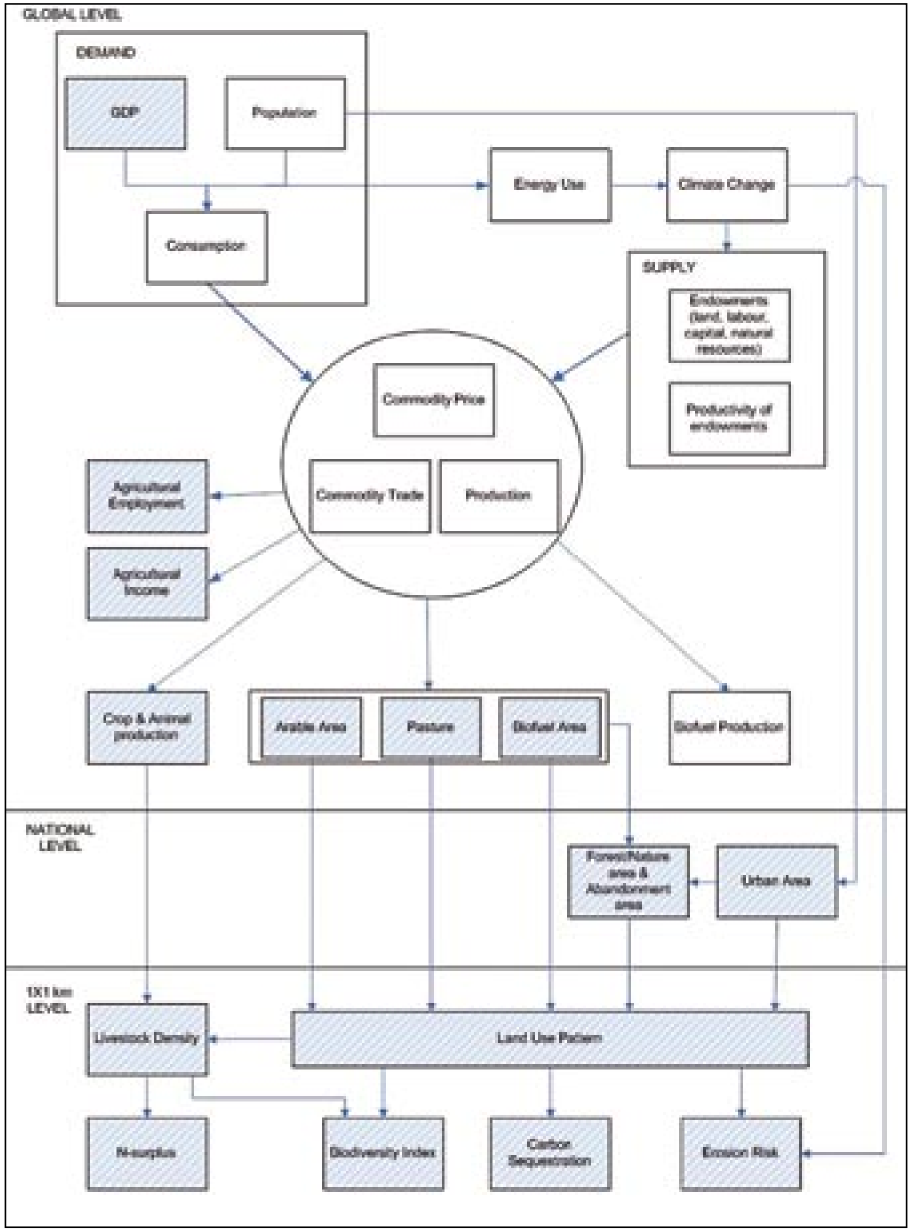


Figure 8. Flow diagram of the most crucial indicators in the Eururalis modeling chain.

5. EURURALIS INDICATORS[3]

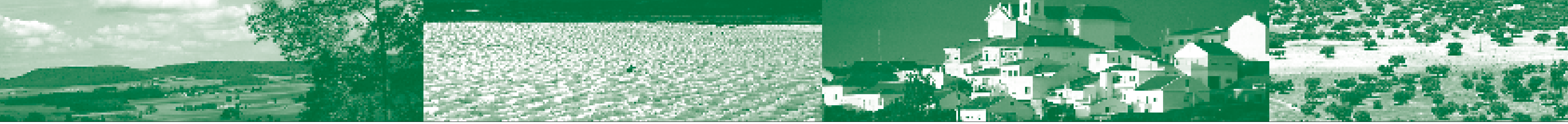
All indicators as simulated by the Eururalis modeling chain as visualized in Figure 8 are described in detail on the following pages. The descriptions of the indicators are self-explanatory. By following the flow of information as visualized in Figure 8, the explanatory factors determining the outcome of each indicator can be traced.

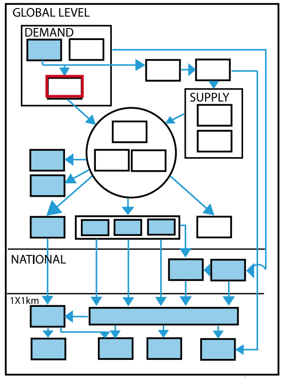
For example, the impact indicator carbon sequestration is determined by different modeling assumptions and the land-use pattern as it is simulated by CLUE-s. To understand land-use pattern the reader is referred to that part of Section 5. From the description of land-use pattern, it becomes clear that agricultural areas from LEITAP/IMAGE are key inputs determining the CLUE-s outcome, besides the allocation mechanisms as implemented in CLUE-s. Agricultural areas from LEITAP/IMAGE are determined by the interplay between commodity price, commodity trade and production. These indicators are described in different sub-sections in this Section[4]. By browsing through these descriptions the core of LEITAP can be grasped. From Figure 8 it becomes clear that supply and demand are the most important inputs of LEITAP. Again, these indicators are described separately in this Section. Logically, different policies interact with all the outcomes. These policies are described in each sub-section, but are also introduced shortly in Section 3.3. The demand-side of LEITAP is mainly determined exogenously; this is already described in Section 3.2.

Each sub-section is constructed along the same lines: *key model variables and inputs* give an overview of the most important factors that determine the outcome of the described indicator. *Model philosophy and assumptions* give a short overview of the model rationale that determines the outcome as well. In *Results*, the outcome of the indicator is given for the four baseline scenarios (Section 3.1), indicating how the model philosophy combined with crucial parameter settings delivers Eururalis results as displayed on the Eururalis 2.0 visualization tool (WUR/MNP, 2007).

[3] The term 'indicator' is used in a general way. An indicator can be an assumed parameter (e.g. GDP and population) or an impact indicator, showing results of Eururalis.

[4] In the following sub-sections results from LEITAP/IMAGE are given for several world regions. These world regions are aggregates of the simulated regions as summarized in Table 6 to facilitate the communication of results. Africa is an aggregate of Northern Africa, Republic of South Africa and Rest of Sub-Saharan Africa; Central and South America an aggregate of Brazil and Rest of Central and South America, Asia is an aggregate of China, Middle East and Rest of Asia and High Income is an aggregate of Japan and Korea, Canada, USA and Mexico and Australia, New Zealand and rest of Oceania.





■ CONSUMPTION

Consumption is an important variable in the Eururalis results. It determines the demand for all products and therefore the inputs used in the production of these products. For agriculture, the demand for food, feed and possible fuel is important.

KEY MODEL VARIABLES AND INPUTS

- GDP growth (Section 3.2 and Annex I), which influences consumption per capita. To a certain extent, people gaining more income, will eat more and choose for more luxurious food products (Section 3.2).
- Population growth (Section 3.2 and Annex II) determines total consumption growth in each region.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Income elasticity: this indicates how much of extra income is spend on a product. In general poor people spend a large part of their income on food, whereas share of food in rich peoples expenditures are low. A larger part is spent on industrial products and services. Projections with standard GTAP (Hertel, 1997) with respect to future consumption in fast developing countries like China showed that the size of the income elasticities used in the standard GTAP model is much too high. Part of the explanation of these overestimations is the constant income elasticity for each region. However, when an economy grows, it is plausible that income elasticities for food decrease. In order to solve this, the following improvements have been implemented:

  1. Real income per capita is corrected for purchasing power parities as explanatory variable for income elasticities;
  2. Dynamic income elasticities are used: at each moment the income elasticity per PPP (Purchasing Power Parity) corrected real in come level is applied (Figure 9). Negative values imply decrease of consumption when income increases. This is valid for many crop types;
  3. GTAP elasticities are made consistent with FAO estimates;
  4. A real income-related income elasticitiy does not allow for using a standard consumption function. For this reason, the income elasticities of all products are calibrated to guarantee that the income elasticity for all products together equals 1, i.e. 1% increase in income generates 1% increase in total consumption.
- Price elasticities indicate the sensitivity of consumption to price changes. If the price elasticity is high, an increase in the price of a product has a large negative impact on consumption. In general the basic food commodities (e.g. rice or grain) have a low price elasticity, whereas more luxury food products (e.g. meat) or industrial products and services have a higher price elasticity of demand. Moreover, near substitutes have higher cross price elasticities. For example, grains are close substitutes for each other, as are the meat and dairy products.

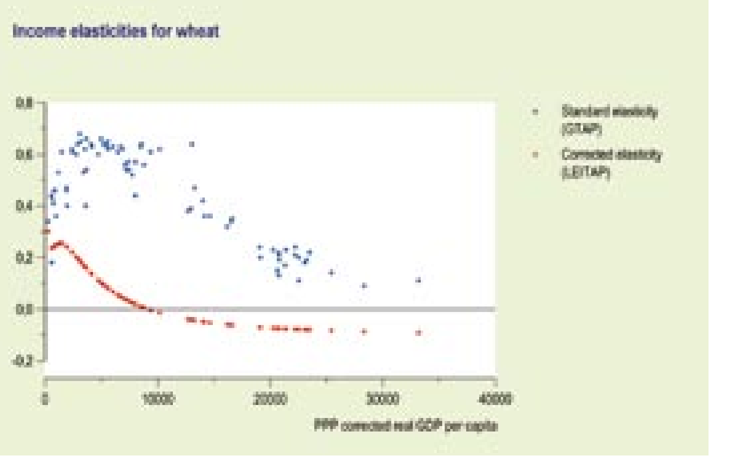
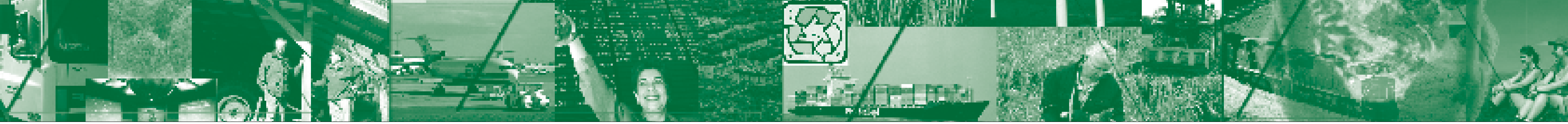


Figure 9. Income elasticities in GTAP and in LEITAP for wheat as adopted in Eururalis.



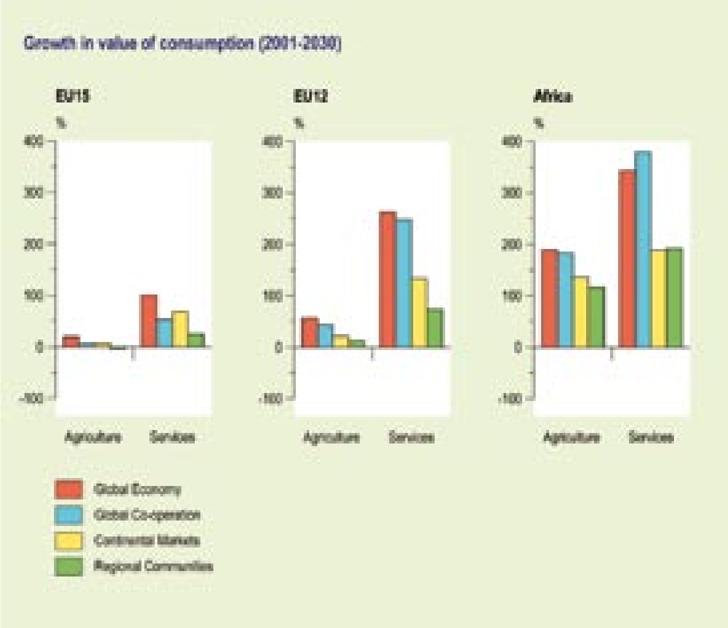
But milk and grain will not be substituted so easily, while substitution between industrial products and milk is almost 0.

- Consumption targets like the EU biofuel directive in the *Global Co-operation* and *Regional Communities* determine directly the level of consumption of biofuels in transport fuels (see also Section 3.3 and Biofuel production).
- In the scenarios *Global Co-operation* and *Regional Communities*, diets of people contain less meat than could be assumed based on their economic welfare (see Section 3.2).

RESULTS

Consumption is driven by income and population growth. So the pattern across the scenarios is proportionally to especially the GDP growth pattern. For most regions, consumption growth is higher in the *Global Economy* and *Global Co-operation* scenario (Figure 10).

Figure 10. Growth in value of consumption between 2001 and 2030 for the four Eururalis scenarios, for the regions EU15, EU12 and Africa.



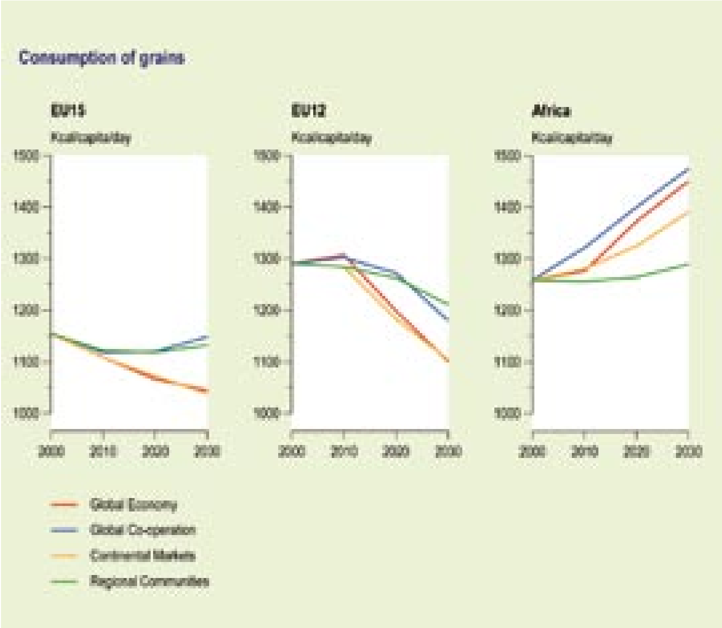
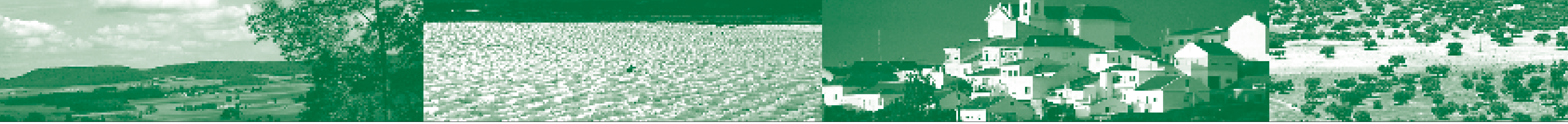
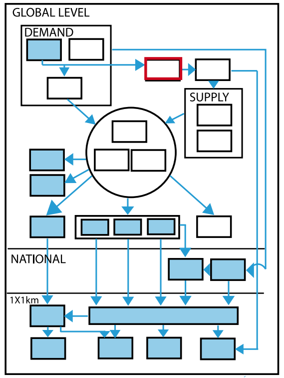


Figure 11. Consumption of grains in EU15, EU12 and Africa between 2001 and 2030 for the four Eururalis scenarios.



In high income countries, the share of food in total consumption is low and decreases further when incomes increase leading to a decrease in consumption of crops like grains in Europe (Figure 11). Total agricultural consumption increases marginally, mainly due to an increase in meat consumption like beef (figure 12). The consumption pattern of these countries shifts to higher consumption of manufactured goods and services, which growth is several times faster than growth in agricultural consumption.
In low income incomes countries (as Africa) the food consumption share is high and the food consumption level is low in 2001. In such a situation, an increase in income leads to a high increase of agricultural consumption (Figure 10). It is slightly lower than the consumption growth of industrial goods and services.

Figure 12. Consumption of beef in EU15, EU12 and Africa between 2001 and 2030 for the four Eururalis scenarios.



■ ENERGY USE

Energy use is of importance for the greenhouse gas emissions and the impact of an obligated blending obligation in the transport sector for biofuels. The energy use is simulated by the IMAGE energy model (TIMER: Van Vuuren et al., 2006). This energy use has been used for climatic consequences. Due to lack of time in the project, no consistency check with the energy part of LEITAP is made, in which the biofuel production has been calculated. So, the biofuel production as simulated by LEITAP is not necessarily consistent with total energy use used for climate change (see section 6).

KEY MODEL VARIABLES AND INPUTS

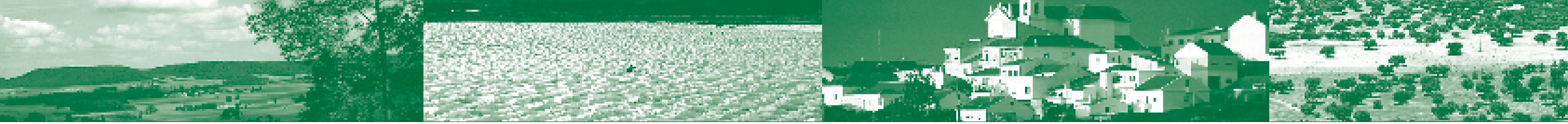
- Population and GDP: Final energy demand (for five sectors and eight energy carriers) is modeled as a function of changes in population, in economic activity and in energy efficiency.

MODEL PHILOSOPHY AND ASSUMPTIONS

- The energy use is based on the CPB/RIVM study 'Four Futures of Energy' (Bollen et al., 2004). Since the major drivers GDP and population have not changed since Eururalis 1.0 (Klijn et al., 2005), the energy profiles in Eururalis 2.0 have not changed either (Figure 13).

Energy use is based on the following assumptions:

- The energy-intensity development for each sector (i.e. energy units per monetary unit) is assumed to be a bell-shaped function of the per capita activity level (i.e. sectoral value added or GDP). This reflects an empirical observation that with rising activity levels a changing mix of activities within a sector could first lead to an increase and subsequently to a decrease in energy intensity (structural change).
- The Autonomous Energy Efficiency Increase (AEEI) multiplier accounts for efficiency improvement that occurs as a result of technology improvement independent of prices. The AEEI is assumed to be linked to the economic growth rate.
- A second multiplier, the Price-Induced Energy Efficiency Improvement (PIEEI) describes the effect of rising energy costs on consumers. This multiplier is calculated using a sectoral energy conservation supply cost curve and end-use energy costs.
- The demand for secondary energy carriers is determined by the relative prices of the energy carriers in combination with premium values. The premium values reflect non-price factors determining market shares, such as preferences, environmental policies, strategic considerations etc.
- Secondary fuel allocation is determined by a multinomial logit formulation for most fuels (Van Vuuren et al., 2006). The market share of traditional biomass is assumed to be driven by per capita income, where a higher per capita income leads to lower per capita consumption of traditional biomass. The market share of secondary heat is determined by an exogenous scenario parameter.
- Non-energy use of fossil fuels is modeled on the basis of an exogenous assumed intensity parameter (related to industry value-added) and on a price-driven competition of the various energy carriers.
- Supply of all primary energy carriers is based on the interplay between resource depletion and technology development. Technology development is introduced either as learning curves (for most fuels and renewable options) or by exogenous technology change assumptions (for thermal power plants). To model resource depletion of fossil fuels and uranium, several resource categories are defined that are depleted in order of their costs. Production costs thus rise as each subsequent category is exploited. For renewable energy options, the production costs depend on the ratio between actual production levels and the maximum production level.



RESULTS

In Eururalis, *Global Economy* shows the highest energy use and *Global Co-operation* is the only scenario where climate policy is successfully implemented. Here, it is assumed that the greenhouse gas concentration will stabilize at 550 ppmv CO_2-equivalents. This stabilization level has a good chance to coincide with the EU climate policy objective of a maximum temperature increase of 2°C over its pre-industrial level (Bollen et al., 2004). Therefore, energy use is lowest in this scenario (Figure 13).

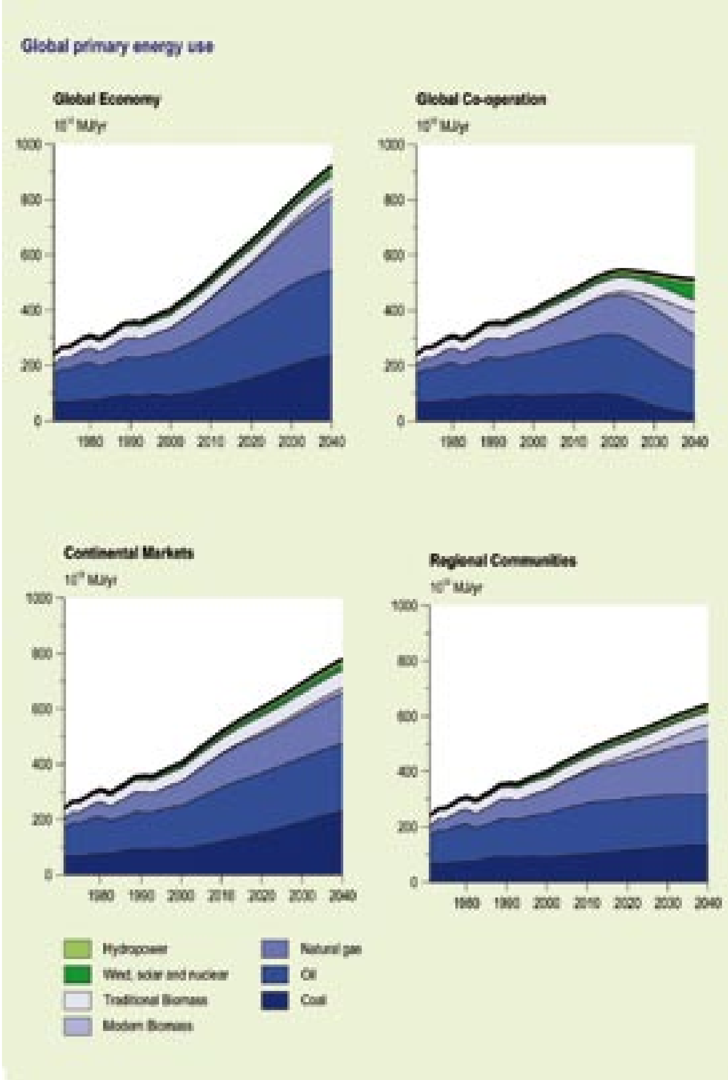
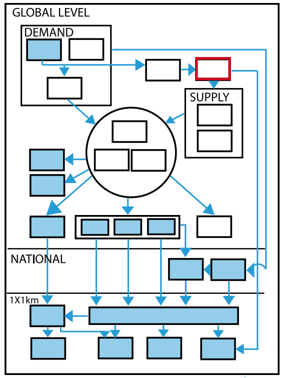


Figure 13. Global primary energy use within the four Eururalis scenarios.



■ CLIMATE CHANGE

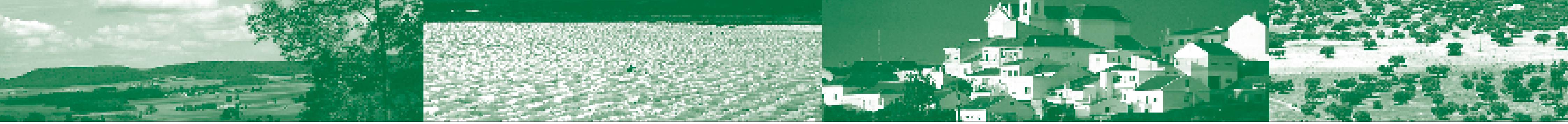
Climate change is one of the drivers changing crop yields over time. This changing crop yield will impact the production level and production price of the agricultural commodities and, therefore, of importance for the Eururalis modeling chain. Moreover, climate change will impact soil erosion, one of the planet indicators of Eururalis.

KEY MODEL VARIABLES AND INPUTS

- Energy use
- Land-use change at the global level, as determined by IMAGE on the basis of LEITAP agricultural production levels. See the Arable land and Pasture Section (Van Meijl et al., 2006).

MODEL PHILOSOPHY AND ASSUMPTIONS

- Greenhouse gas emissions are translated to atmospheric concentrations using a carbon cycle model (Leemans et al., 2002) and an atmospheric chemistry model (Eickhout et al., 2004a). These atmospheric concentrations are translated to radiative forcings (global-mean) using simple transformation equations (Eickhout et al., 2004a)
- The current climate model of the IMAGE model captures global mean climate change by means of an energy-balance, upwelling-diffusion climate model (Eickhout et al., 2004a). This current climate model lacks the capacity to address climate variability and the land-use feedbacks to the climate system (separate from climate impacts of land-use-related greenhouse gas (GHG) emissions).
- The climate-change patterns on a grid scale are not simulated explicitly in IMAGE. The global-mean surface temperature change needs to be linked to a monthly 0.5 x 0.5 degree grid. This linking is applied by using the standardized IPCC pattern-scaling approach (Carter et al., 1994). This pattern scaling returns gridded changes in temperature and precipitation. To take the uncertainties in the forcing by sulfate aerosols into account, IMAGE 2.2 uses results from the University of Illinois at Urbana-Champaign (UIUC). The approach, introduced by Schlesinger et al. (2000), takes the non-linear effects of sulfate aerosols into account (Eickhout et al., 2004a). This additional approach adds sulfate corrections for the temperature pattern only.
- Climate policies: in *Global Co-operation* successful climate policies are assumed, leading to stabilization of the greenhouse gas concentration at a level of 550 ppmv CO_2-equivalent (Section 3.3).



RESULTS

Because of inertia in the climate system the consequences for the global-mean temperature change are very similar in the four scenarios (left panel of Figure 14). The *Global Co-operation* scenario even shows the highest temperature in the first decades. This result is related to the climate policies that are implemented in the energy system: less coal not only decreases the CO_2 emissions, but also the SO_2 emissions. And since SO_2 aerosols have an instant cooling effect compared to a long-lasting warming effect of CO_2 concentrations, the decrease of SO_2 particles increases the temperature immediately (right panel of Figure 14).
Land-use emissions are responsible for 20% of the total greenhouse gas emissions. Therefore, changes in land use and the agricultural sector have an impact on the greenhouse balance through deforestation and CH4 and N_2O emissions respectively. In the LEITAP/IMAGE interaction land-use change is impacting emissions and climate impacts on crop yields. This way, LEITAP/IMAGE simulate climate change that is internally consistent: changes in the agricultural system are impacting climate change immediately.
The effect of greenhouse gas reductions is not really visible until after 2030 (not shown). Results for *Global Economy* show that this high-consumption scenario will lead to high temperature levels by 2030, having a major impact on the agricultural system through CO_2 fertilization, changes in temperature level and precipitation. Effects of climate change policies are not apparent by 2030.

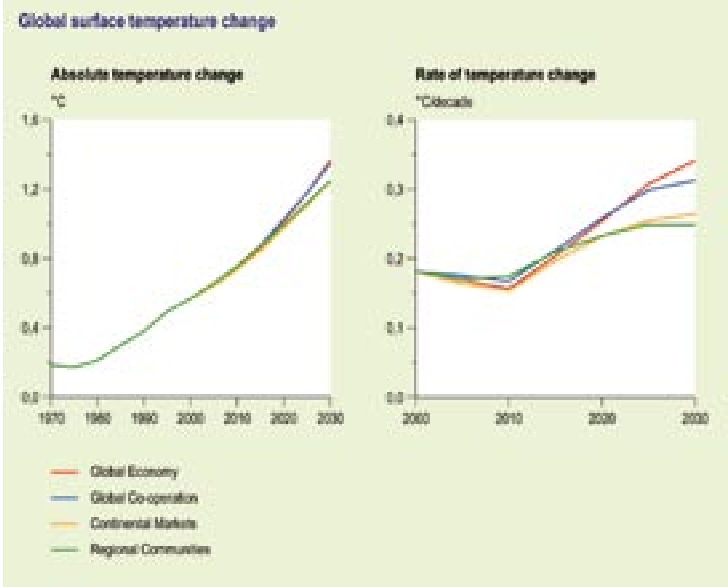
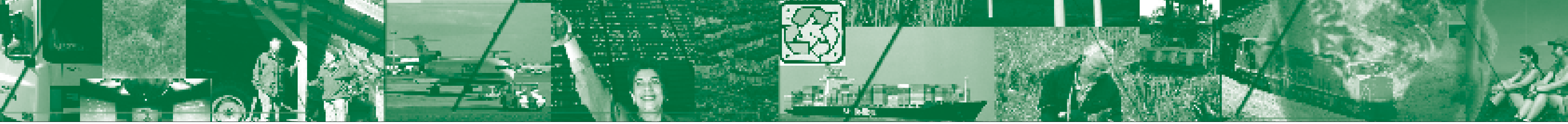
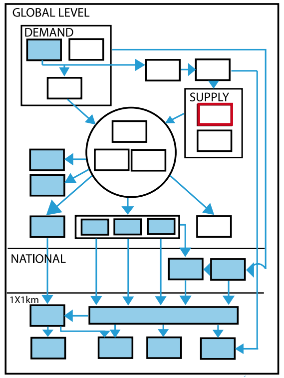


Figure 14. Global-mean temperature change (left) and rate of temperature change (right).





ENDOWMENTS (LAND, LABOR, CAPITAL, NATURAL RESOURCES)

The availability of endowments is a very important driving force, influencing the production potential in all regions. Within each region presented in LEITAP, firms produce output, employing land, labor, capital, and natural resources and combining these with intermediate inputs. Therefore, the overall amount of endowments together with their productivity determine the total production potential for each regions. In LEITAP the supply of all endowments is exogenous, except land, which is determined by the supply and demand for land.

KEY MODEL VARIABLES AND INPUTS

- Assumed growth in capital stocks and natural resources is linked to GDP growth in each region.
- Change in total labor workforce is assumed to be determined by population growth.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Capital and labor (both skilled and unskilled) are mobile between all non-agricultural production sectors but not between regions. This implies that wages and the capital rental rates are the same for all production sectors.
- All factors (except land) are fully employed in LEITAP and factor prices adjust to achieve market clearing in all factor markets. This implies there is no idle capital or unemployment and unemployment rates do not change.
- Labor and Capital factor markets for agricultural and non-agricultural sectors are separated, i.e. wage rates paid in agriculture might differ from wage rates paid outside agriculture.
- While labor and capital are considered mobile across agricultural sectors the adjustment of the factor land and natural resources is sluggish. That is, land and natural resource can only imperfectly move between alternative crop uses (Van Meijl et al., 2006).
- Total agricultural land supply is modeled using a land supply curve for each region. This curve specifies the relation between land supply and a rental rate (Van Meijl et al. 2006). The parameterization of this curve is based on IMAGE data (Eickhout et al. 2007b; Tabeau et al. 2007). The asymptote represents the total agricultural land available. Dependent on the share of agricultural land currently in use and the rate of expansion, countries move on their own curve to the right sight. With enough agricultural land available, e.g. land abundant countries such as Canada and Brazil, where total agricultural land use does not at all approach the asymptote, increases in demand for agricultural purposes will lead to land conversion to agricultural land and a modest increase in rental rates (Figure 15). However, if almost all agricultural land is in use, e.g. land scarce countries such as China or the Netherlands, increases in demand will lead to huge increases in rental rates (Figure 15).

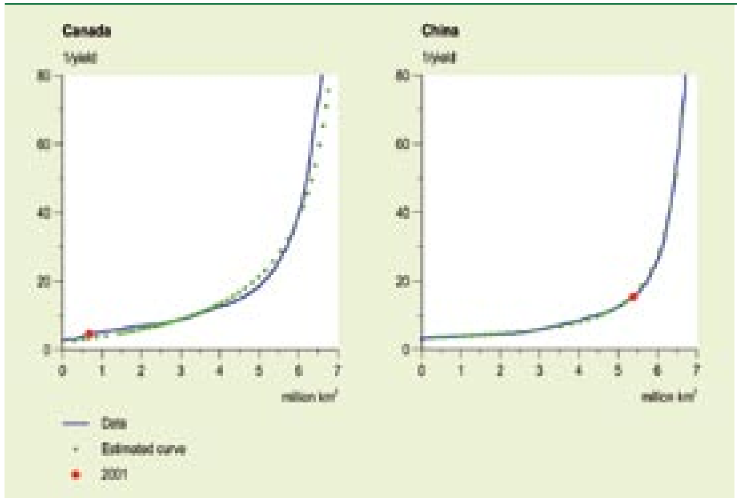
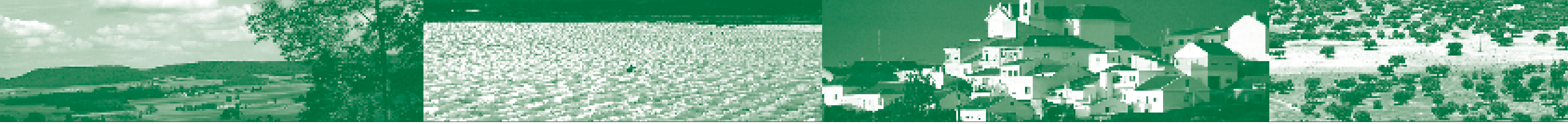


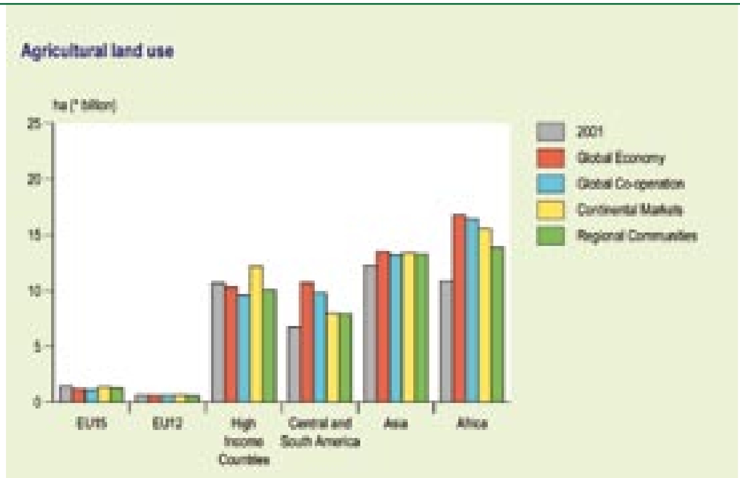
Figure 15. Examples of two land supply curves for the regions Canada and China (Eickhout et al., 2006).



RESULTS

Due to the fact the endowment growth is closely linked to population growth for employment and to GDP growth for capital and natural resources the development of available endowments is mirrored by the development of GDP and population. Figures 16 and 17 illustrate the change in agricultural land and labor and capital. Land use is an endogenous result: the decline in agricultural support in the EU and in other high income countries leads to a decline in agricultural land use under the *Global Economy* scenario (Figure 16).

Figure 16. Development of agricultural land for different regions and the four Eururalis scenarios.



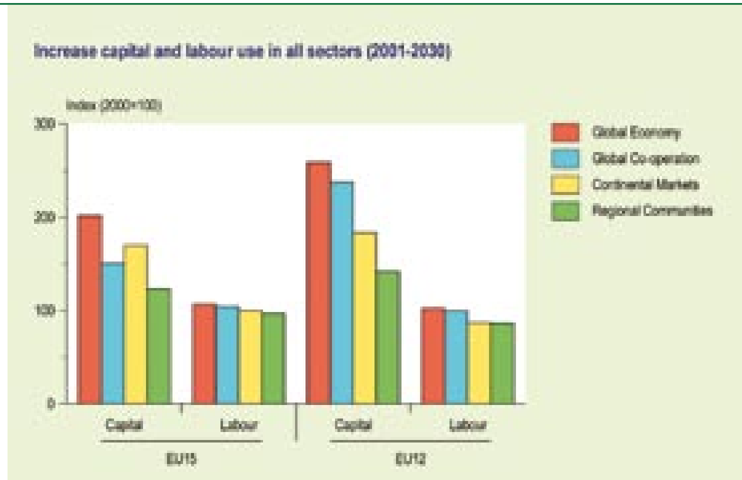
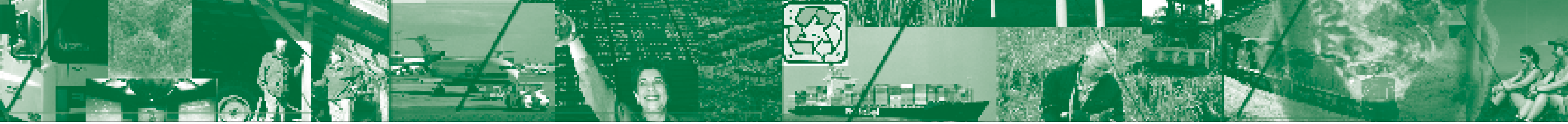
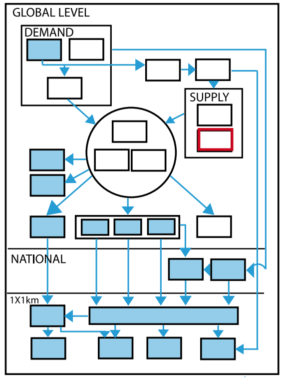


Figure 17. Change in capital and labor between 2001 and 2030 for EU15 and EU12 and the four Eururalis scenarios.





■ PRODUCTIVITY OF ENDOWMENTS

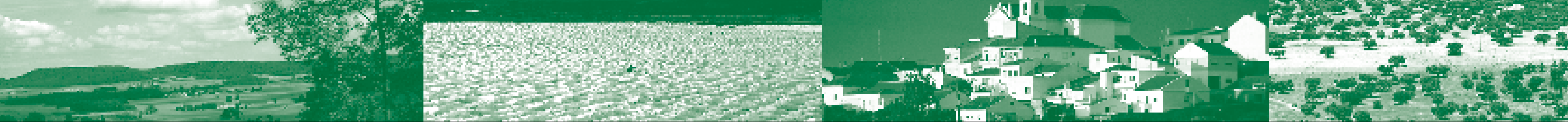
The productivity of endowments is a very important driving force, influencing the production potential in all regions. Within each region presented in LEITAP, firms produce output, employing land, labor, capital, and natural resources and combining these with intermediate inputs. Their productivity together with their availability determines the total production potential for each region. In the current approach of LEITAP the productivity of most endowments is determined by the GDP level and the availability of endowments. Land productivity is taken from FAO (Bruinsma, 2003).

KEY MODEL VARIABLES AND INPUTS

- GDP and endowment developments influence productivity of endowments. In general the higher the GDP growth, the higher the rate of productivity growth. The higher the endowment growth, the lower the rate of productivity growth. The GDP effect often dominates such that productivity growth is highest in the *Global Economy* scenario and lowest in the *Regional Communities* scenario.
- Crop yields are partly endogenous and determined by the relative price developments of land versus the prices of other endowments.
- Crop yields are partly determined in an iteration process between LEITAP and IMAGE: The agricultural production growth of LEITAP is used by IMAGE to allocate agricultural land at a global grid with a 0.5 by 0.5 resolution, which accounts for heterogeneity of land resources. Climate change calculated based on energy consumption, affects potential yield. Expansion of agricultural land causes an even larger impact on yield: the more agriculture expands, the lower the average yield, due to the use of more marginal cropland with lower potential yields (Eickhout et al., 2007a). A decrease in agricultural area causes an effect the other way around resulting in a higher average yield. These two effects on average yield are fed back to the GTAP model, which calculates new data on regional agricultural production. This iteration process between GTAP and IMAGE is carried out to get similar results for land use. See also Section 4.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Sector specific rates of productivity growth are taken from CPB (2003). In general the overall factor productivity growth in agriculture is higher than in services.
- Yield is partly an exogenous assumption that is taken from FAO (2003) (see Section 3.2), which is adjusted in the scenarios for land heterogeneity and climate change effects by an iteration with the IMAGE model (Section 4).



RESULTS

Figures 18 and 19 show changes in the total endowment productivity and, specifically, in yield growth. Given the high economic growth in *Global Economy*, productivity changes are highest in this scenario. Continental Market shows the lowest growth in developing regions like Central and South America, Asia and Africa. This is clearly caused by the high level of protection and the low exchange of technology, labor and capital between high income regions and developing regions (Section 3.2).

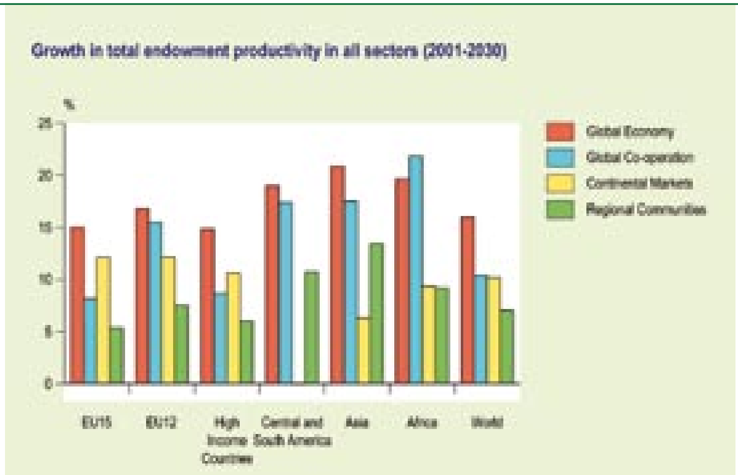


Figure 18. Growth in total endowment productivity between 2001 and 2030 in several regions.

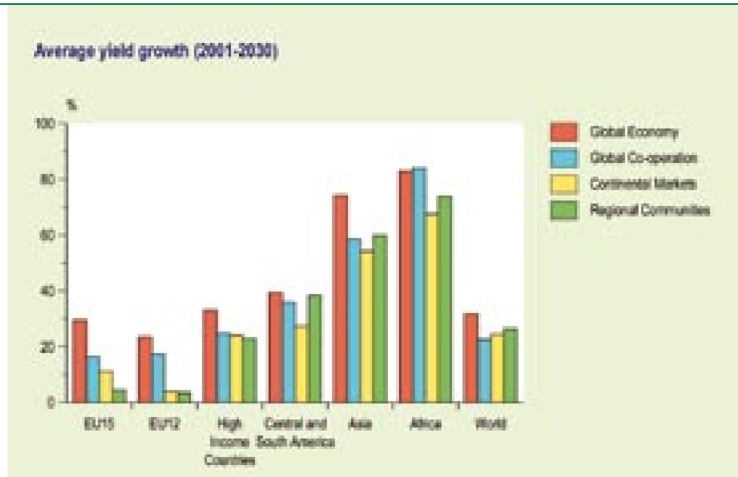
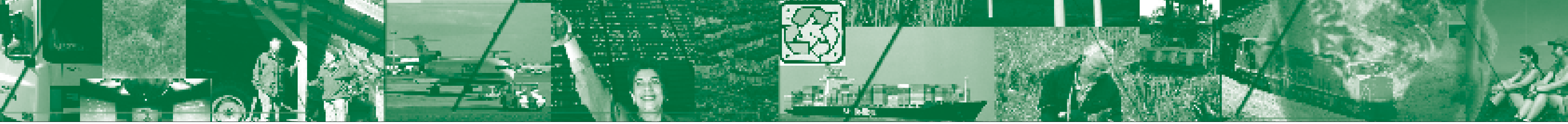
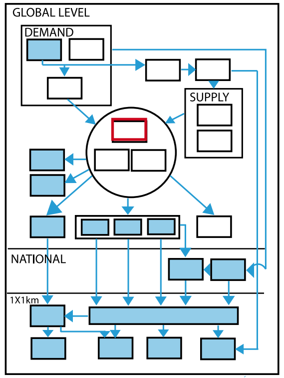


Figure 19. Average yield growth between 2001 and 2030 in several regions.





■ COMMODITY PRICE

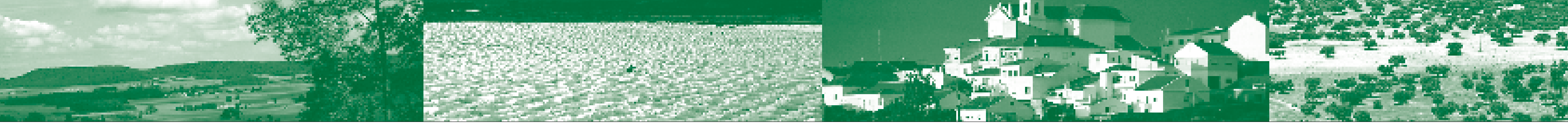
Prices are the key equilibrium mechanism in the economic general equilibrium model LEITAP. Prices are determined on the market where supply meets demand for products. The higher the demand the higher the price and the higher the supply the lower the price of a commodity. In principle, it are relative prices that matter for supply and demand. What is the price of food relative to the price of manufacturing and services is the crux in defining consumption and production. The relative price of domestic products to imported products determine the demand for domestic and imported products.

KEY MODEL VARIABLES AND INPUTS

- The commodity price is determined by the price of the various endowments (labor, capital, land), their share in the costs and their productivity. For example, services are labor intensive (high cost share of labor) and when labor costs rise relatively to the costs of other endowments, services will become more expensive.
- Prices of inputs and endowments are determined by supply and demand of a specific endowment. The higher the growth in the supply of an endowment the lower the increase in price.
- Demand for commodities: the higher the demand, the higher the price. The higher the supply, the lower the price of a specific commodity.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Share in total production costs of production factors (land, labour, capital) and other inputs (energy, material) are crucial. If a product is labour intensive (i.e.labour costs are an important part of the production costs) and wages increase a lot, the price of this product increases too the price of products that are less labour intensive. The shares in total production costs are taken from the GTAP (version 6) database.
- Assumptions on productivity of endowments as explained before (see Section Productivity of Endowments).
- Input subsidies and taxes directly influence the price of inputs and therefore the commodity price. Acreage, animal and single farm payments of the CAP lower the prices. The latter are abolished in the *Global Economy* scenario, heavily reduced in the *Global Co-operation* scenario, stable in the *Continental Markets* scenario and increased in the *Regional Communities* scenario.
- All production taxes and subsidies directly influence the commodity price. The subsidies are abolished in the *Global Economy* scenario, heavily reduced in the *Global Co-operation* scenario, stable in the *Continental Markets* scenario and increased in the *Regional Communities* scenario (See Section 3.3).
- Import tariffs and export subsidies influence the relative price of domestic versus imported commodities. The import tariffs are abolished in the *Global Economy* and *Global Co-operation* scenario, stable in the *Continental Markets* scenario and in the *Regional Communities* scenario. Export subsidies are abolished in all scenarios except for the *Continental Markets* scenario.
- Transport costs are a component of the costs\price and they increase the longer the distance between country of origin and country of destination.



RESULTS

The real agricultural prices decrease in almost all region and scenarios as a result of productivity increase and an inelastic demand. In general the decrease is highest in the high economic growth scenarios (Figure 20). Figure 21 shows real price of industrial products declines relative to the price of services. Key explanation is the higher labor productivity growth in manufacturing and agriculture relative to services and their lower income elasticity of demand.

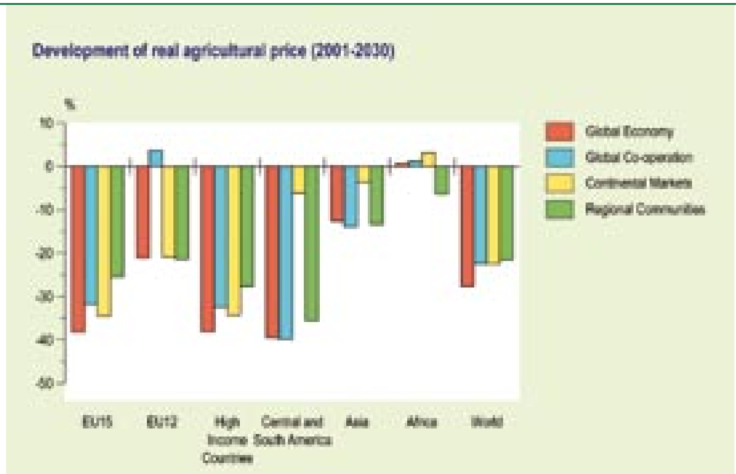


Figure 20. Growth in real agricultural price between 2001 and 2030 in several regions.

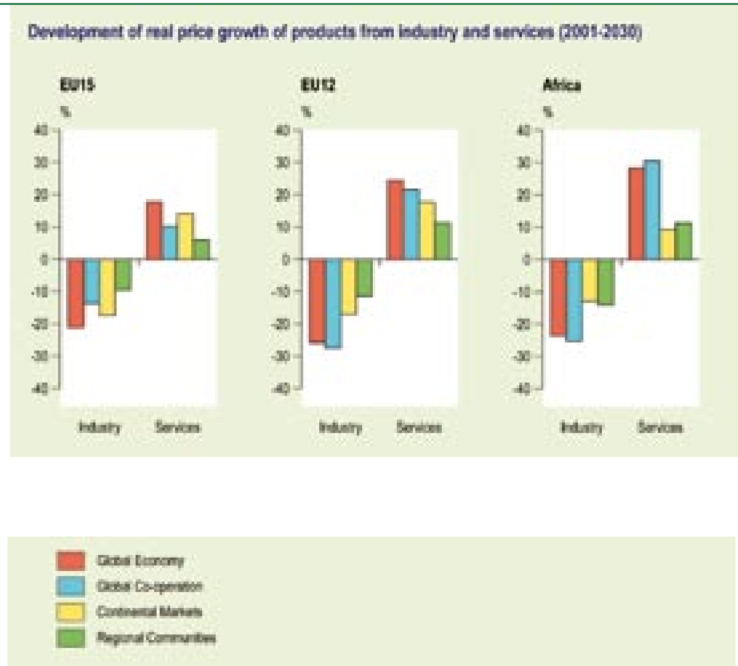
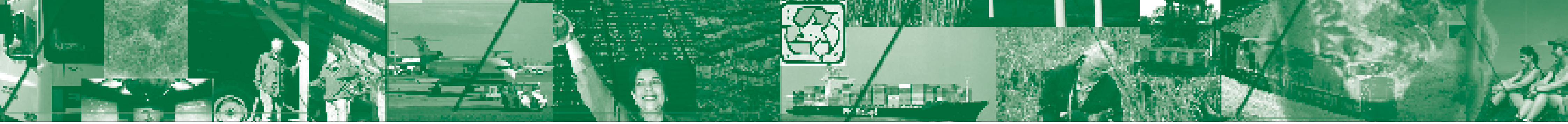
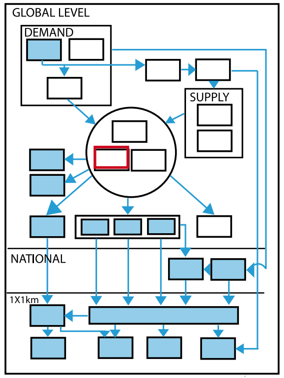


Figure 21. Growth in real price of products from industry and services between 2001 and 2030 in several regions.





■ COMMODITY TRADE

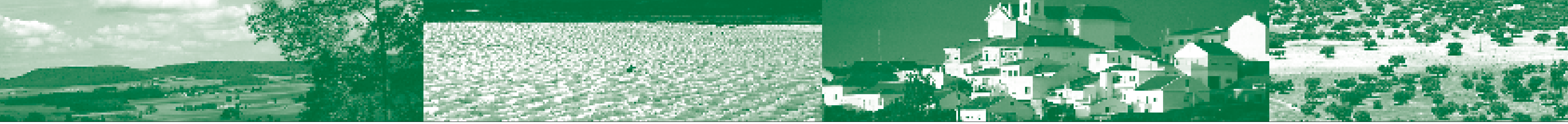
International trade is an important variable in the Eururalis results. Exports are an important demand category for firms next to domestic consumption. Imports bring firms or consumers cheaper products or products that are domestically not available. In general, when a country has a comparative advantage in a certain product, export exceed import of that product which results in a positive net trade position (exports larger than imports).

KEY MODEL VARIABLES AND INPUTS

- Imports: The level of domestic consumption and the relative prices of domestic versus foreign products.
- Exports: The level of foreign consumption all over the world and the relative prices of domestically produced commodities versus prices of all other countries.

MODEL PHILOSOPHY AND ASSUMPTIONS

- The import or Armington elasticities (Hertel, 1997) is crucial as they indicate how easily domestic and foreign products can be substituted. A high elasticity implies that a small increase of domestic versus foreign prices leads to a large increase in imports.
- Import tariffs and export subsidies influence the relative price of domestic versus imported commodities and therefore trade flows. The import tariffs are abolished in the *Global Economy* and *Global Co-operation* scenario, stable in the *Continental Markets* scenario and *Regional Communities* scenario. Export subsidies are abolished in all scenarios except for the *Continental Markets* scenario.
- Transport costs are a component of the costs or price and they increase the longer the distance between country of origin and country of destination.

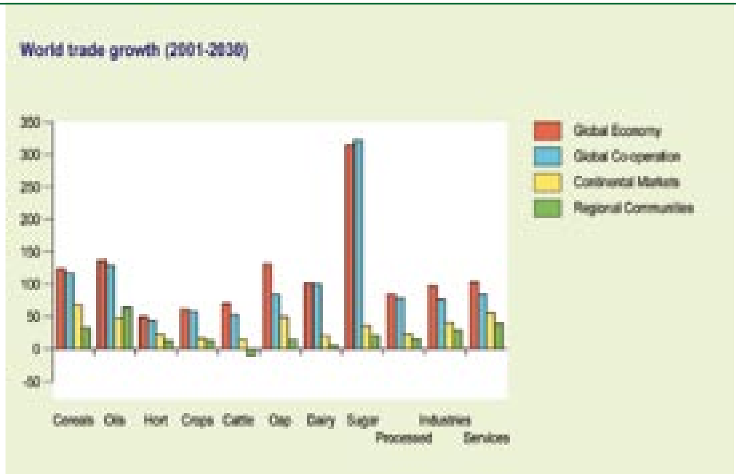


RESULTS

World trade growth increases in all scenarios, especially in the global scenarios (*Global Economy* and *Global Co-operation*; Figure 22). The difference in world trade growth between liberalization scenarios and non liberalization scenarios is striking. The increase in trade in the liberalization scenarios is caused by the higher income growth and the abolishment of border policies.
The growth in world trade is highest in sugar in the liberalization scenario due to a very high level of protection in 2001 (Figure 22). The growth is also high for pork and poultry and oilseeds. Oilseeds trade is growing faster than trade in wheat and coarse grains. This trend is expected to continue. The main exporters of oilseeds are Brazil and the USA and the main importers are located in Asia (especially China).

The reduction of border support in the *Global Economy* scenario (Section 3.3) contributes significantly to the growth of world trade in grains, beef, processed food and especially sugar. The impact is limited for oilseeds, industries and services. For industries this is caused by trade liberalization in earlier WTO rounds (e.g. Uruguay round). Therefore, changes in export are highest for all commodities in the EU27 in the *Global Economy* (Figure 23). Especially cattle (beef) and sugar are exported less, since these sectors are not supported anymore in *Global Economy*. These commodities are imported more, since competition outside EU27 can produce these commodities more efficient (Figure 23).

Figure 22. World trade growth in % between 2001 and 2030 for the four Eururalis scenarios.



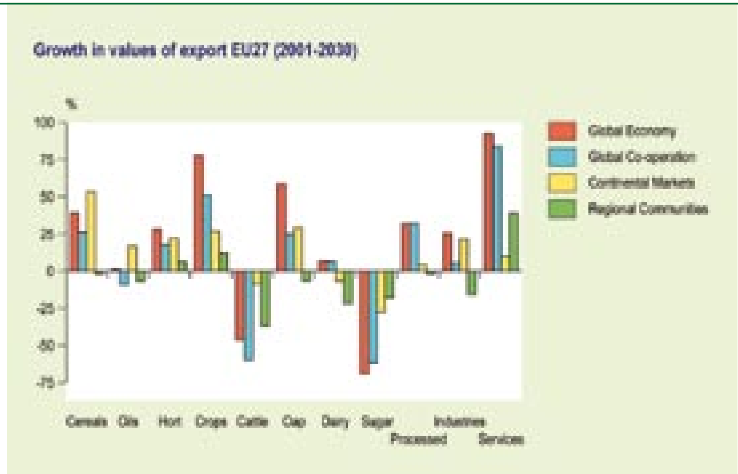
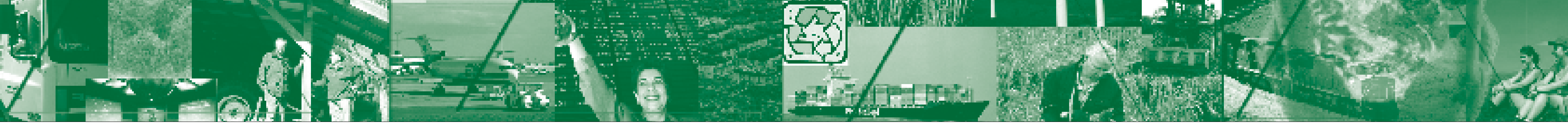
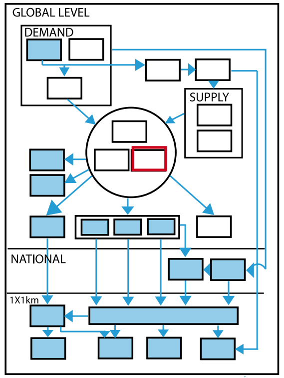


Figure 23. Growth in exports of EU27 for the different commodities and four Eururalis scenarios.





PRODUCTION

The domestic production is calculated at global level within the LEITAP/ IMAGE loop. Based on the level of demand (consumption demand, intermediate demand and exports) in the countries and the share of production within a country production is defined.

KEY MODEL VARIABLES AND INPUTS

- Production is dependent on demand for that product and the share that is produced by a country (competitiveness):
- Final consumption demand for a product depends on income and population growth (expansion effect) and the relative price of this product to other products (substitution effect) (See Section Consumption).
- The share of products that is domestically produced is determined by the relative price developments of domestically produced products to the price of imports from al other regions.
- Intermediate demand by other industries, which is determined by the growth of these other sectors.
- Export demand depends on demand growth which is driven by income and population growth in other parts of the world and the relative price developments of domestically produced products to the price of products from other regions.

MODEL PHILOSOPHY AND ASSUMPTIONS

- GDP growth induces a shift in consumption. The higher the GDP the more services and industrial products people use and eat instead of food. This shift is high in the *Global Economy* scenario and less in the *Regional Communities* scenario.
- Population growth defines the total food demand. Population growth is lower in *Continental Markets* and *Regional Communities* than in *Global Economy* and *Global Co-operation*.
- Trade policies: removing trade barriers can make it more profitable to import products. Trade barriers are less in *Global Economy* and *Global Co-operation* scenario.

RESULTS

Compared to the new member states (EU12) of the EU the group of the old member states (EU15) show a less dynamic development in agricultural, industrial and service output. The main reason for this different development is due to higher GDP growth in the EU12 and to slightly higher rates of technical progress in the countries of the EU12 (Figure 24).

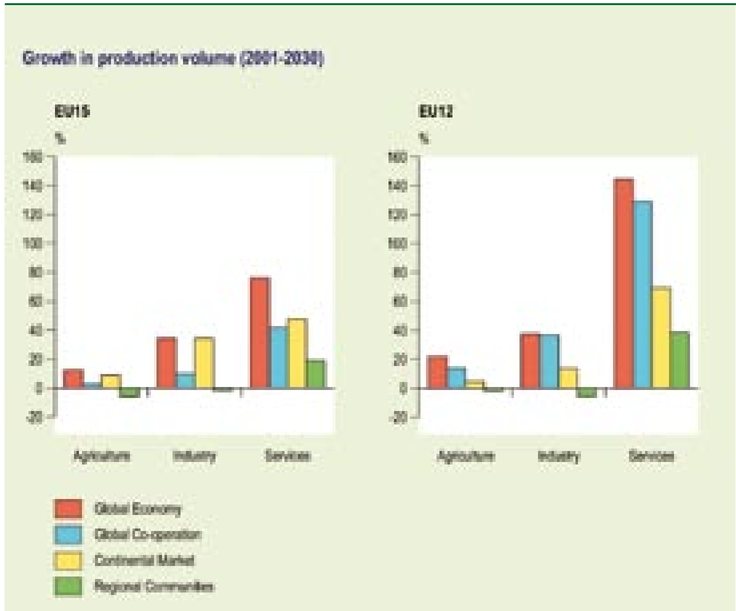
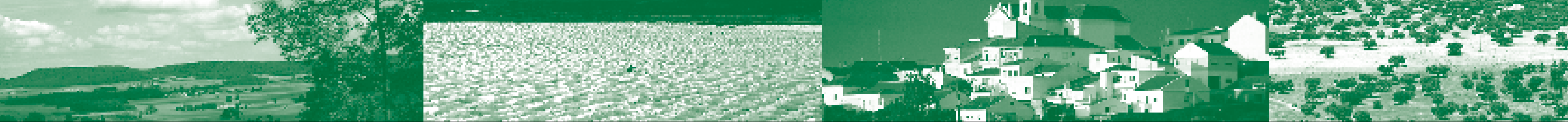
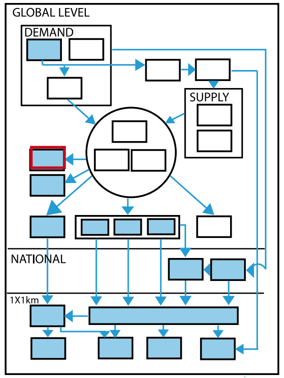


Figure 24. Development of production volume in EU15 (left panel) and EU12 (right panel) between 2001 and 2030 for the four Eururalis scenarios.





■ AGRICULTURAL EMPLOYMENT

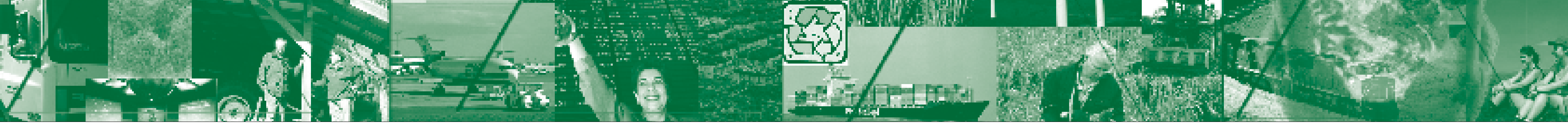
This indicator shows the relative agricultural employment compared with 2001. The agricultural employment is calculated at the global level and it is an important indicator characterizing the development of the agricultural sector and its importance for the economy. It is influenced by agricultural production and labor productivity development.

KEY MODEL VARIABLES AND INPUTS

- Agricultural production: driven by food demand depending on incomes, population growth and consumption pattern. Production is growing with demand; higher production (at the same labor productivity) requires more labor. This is called the expansion effect.
- Relative price of labor to other endowment prices: cost minimalization implies that relatively more expensive labor means that labor will be substituted for other endowments like capital and land. This is called the substitution effect.
- Labor productivity: depending on autonomous technical progress and endogenously on the substitution effect. Higher labor productivity means on the one hand that less labor is needed to produce the same amount of output. Besides a higher productivity causes a decline in the effective price of labor.

MODEL PHILOSOPHY AND ASSUMPTIONS

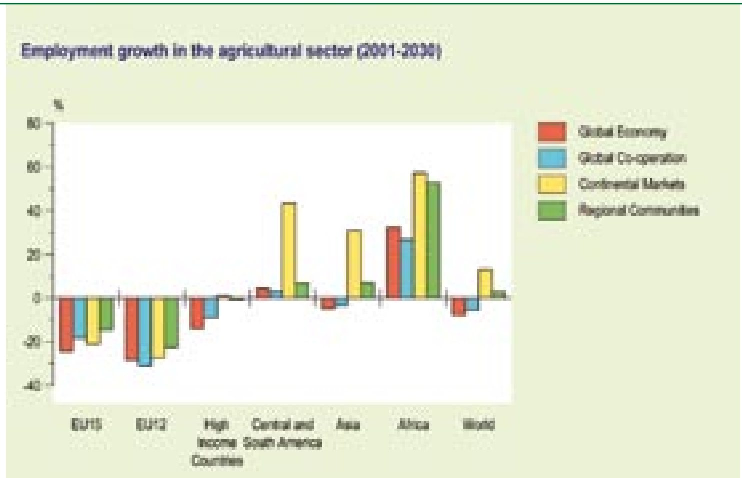
- Elasticity of substitution between endowments (labor, capital and land): The elasticity indicates how easily labor can be substituted by capital or land.
- Population growth: influences the demand for agricultural products and defines the total labor supply, which is growing parallel with population.
- Labor demand by other sectors: growth of other sectors, e.g. the service sector, induces pressure in the labor market (higher wages) and creates opportunities for people to work in another sector. Especially in the *Global Economy* and the *Continental Markets*, the growth in other sectors and so their labor demand, is high.
- Segmentation of labor market: the labor market is segmented in a market for agricultural and a market for non-agricultural labor, because different skills are required. The mobility of labor between two markets is limited and different wages exists on both markets: lower wage for agricultural and higher for non-agricultural labor market.
- Economic growth (GDP) influences consumption and in particular food demand and therefore the sectoral production.



RESULTS

Employment in the agricultural sector decreases in Europe in all scenarios due to a low production growth (people do not eat more and more when they become richer) and a high labor productivity growth (Figure 25). The decline is highest in *Global Economy*, due to relative high labor productivity growth and a high growth of other sectors. In *Regional Communities*, which has a low income growth, opportunities outside agriculture are limited and people stay in the agricultural sector.
In low income countries of Central and South America, Asia and Africa agricultural employment increases (except in *Global Economy* and *Global Co-operation* in Asia characterized by high economic growth dived by high productivity growth) .

Figure 25. Employment growth in the agricultural sector between 2001 and 2030.



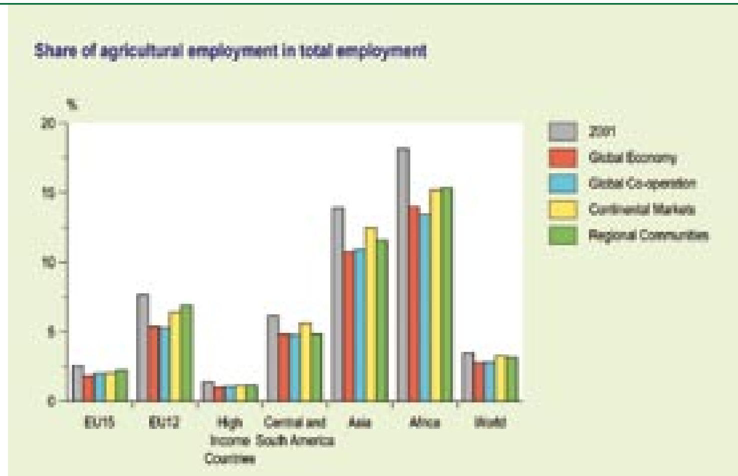
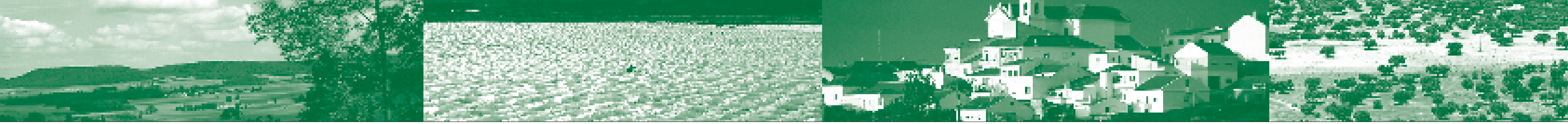
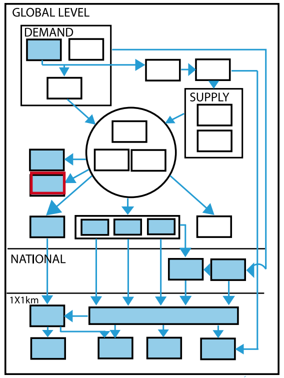


Figure 26. Share of agricultural employment in total employment in 2001 and in 2030 for the four Eururalis scenarios.





■ REAL AGRICULTURAL INCOME

Total real regional farm income indicator is as a relative change of real regional farm income compared with 2001. The farm income indicator is calculated as revenue of agricultural sectors less intermediate production (i.e. value added) plus agricultural subsidies net of taxes. Finally, they are deflated by a national GDP deflator.

KEY MODEL VARIABLES AND INPUTS

- The output (production) value is the revenue from production: this depends on agricultural production volume and commodity prices.
- The value of intermediate production is the cost for the use of goods and services in the production process: this depends on the production volume, a technical coefficient and prices of goods and services.
- National GDP deflator: Agricultural products increase in nominal values, but decrease in real values (see Commodity Price Section).

MODEL PHILOSOPHY AND ASSUMPTIONS

- GDP and population growth: these two indicators drive consumer demand and so the revenue from production.
- The volume of sectoral intermediate use of production is proportional to the total production volume.
- Agricultural policies: abolition of border or income support has a direct negative impact on agricultural income. So the term ‘agricultural subsidies’ (see before) will be less in the *Global Economy* scenario than in *Regional Communities*. Indirectly, abolition of support causes changes of output prices, which influence the level of production. Biofuel policies, which influence the level of production in a positive way, have a positive impact on farm incomes.
- GDP deflator: A relatively high rate of technical progress and a low income elasticity of demand imply that real agricultural prices decline relatively to other prices.

RESULTS

Real agricultural incomes strongly decrease in EU15, which is caused by a high decrease of real agricultural prices (see real price indicator in Section Commodity price), which is not compensated by production growth (see Section Production) in these regions. Since agricultural prices decrease more than industrial goods and services prices, the production costs increase relative more than revenue, which diminish incomes as well. Additionally, especially in *Global Economy* and *Global Co-operation* scenarios, border and income support to the agricultural sector decreases (Figure 27).

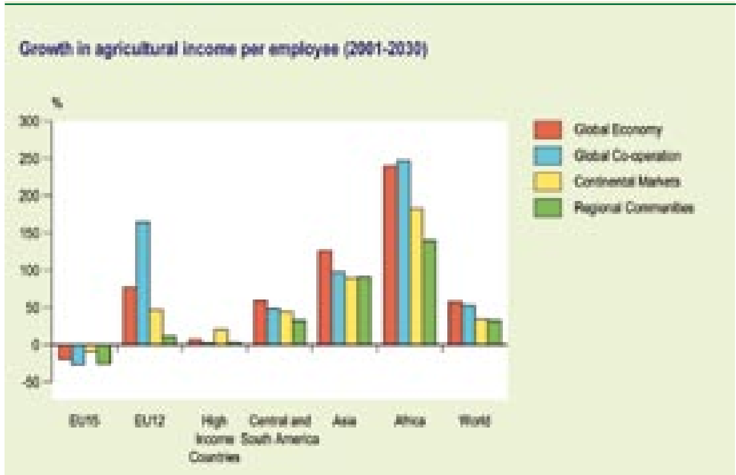
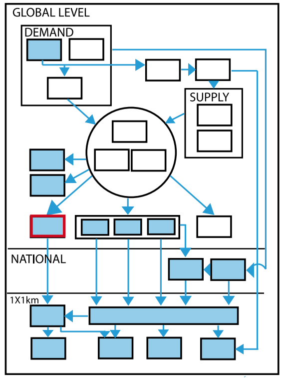


Figure 27. Growth in agricultural income per employee between 2001 and in 2030 for the four Eururalis scenarios.



■ CROP AND ANIMAL PRODUCTION

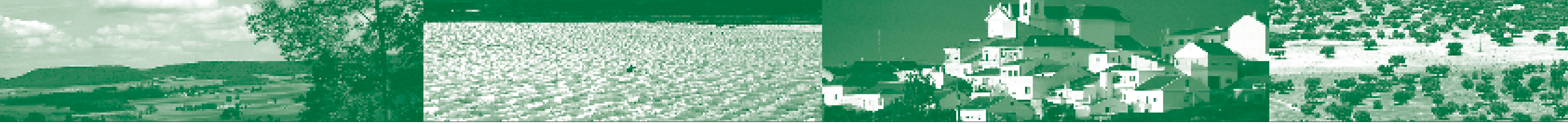
The production of animals and crops is calculated at global level within the GTAP/IMAGE loop. Based on demand and supply, production is calculated considering bilateral trade arrangements. Note that feed for animals is included within the crop production.

KEY MODEL VARIABLES AND INPUTS

- Production is dependent on demand for that product and the share that is produced by a country (competitiveness):
- Final consumption demand for a product is dependent on income and population growth (expansion effect) and the relative price of this product to other products (substitution effect) (See Section Consumption).
- The share of products that is domestically produced is determined by the relative price developments of domestically produced products to the price of imports from al other regions.
- Intermediate demand by other industries, which is determined by the growth of these other sectors.
- Export demand is dependent on demand growth driven by income and population growth in other parts of the world and the relative price developments of their domestically produced products to the price of imports from all other regions and the domestically produced product of the export region.

MODEL PHILOSOPHY AND ASSUMPTIONS

- GDP growth induces a shift in consumption. The higher the GDP the more people eat meat instead of staple food. This shift is less in the *Global Co-operation* and *Regional Communities* scenario. GDP growth (at world level) is less in those two scenarios. Besides, it is assumed that people shift less to the luxuriously diet in the *Continental Markets* and the *Regional Communities* scenario (see Section 3.2).
- Population growth defines the total food demand. Population growth in the European Union is lower in *Continental Markets* and *Regional Communities* than in *Global Economy* and *Global Co-operation*.
- Trade policies: removing trade barriers can make it more profitable to import food products. In the case importing products is cheaper than producing products in Eruope, production in Europe decreases, while it increases elsewhere in the world. Trade barriers are less in *Global Economy* and *Global Co-operation* scenario.

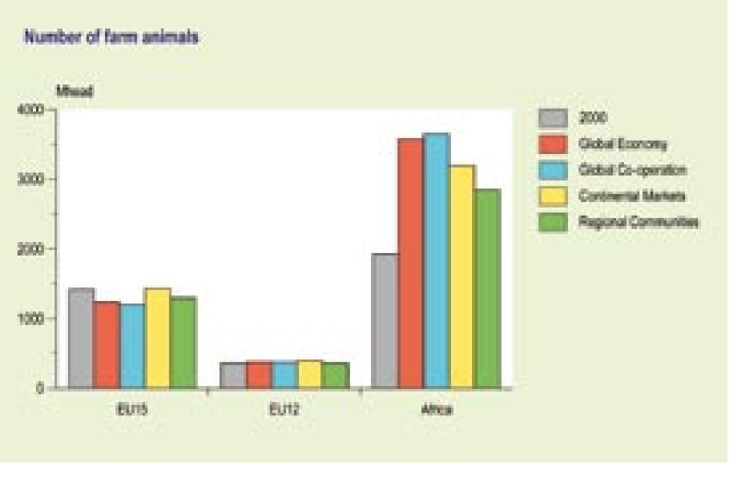


RESULTS

The production of animals is increasing in all scenarios. In *Regional Communities* this increase is the lowest due to the low macro-economic growth and the lower preference to shift to meat consumption. According to Figure 28, production is going to take place in regions like Africa. In Africa, growth in production is high, while in EU15 the number of animals is stable (*Continental Markets*) or decreases (other scenarios). Asia will produce almost 50% of world's meat. In the *Continental Markets* scenario the production share of the High Income countries and Europe is the highest, due to the assumed trade policies and the assumed population growth.
Crop production growth is low in the EU, due to low economic growth (Figure 29). Production of crops in EU15 is especially influenced by trade policies.

Production of heavily protected products (e.g. sugar and cattle) is decreasing in the globalization scenarios (*Global Economy* and *Global Co-operation*). In *Global Co-operation* and *Regional Communities* crop production is relatively low due to a lower demographic and economic growth and the lower meat production (i.e. fewer crops are needed for feed).

Figure 28. Number of animals for human consumption in 2000 and in 2030 for the four Eururalis scenarios in the regions EU15, EU12 and Africa.



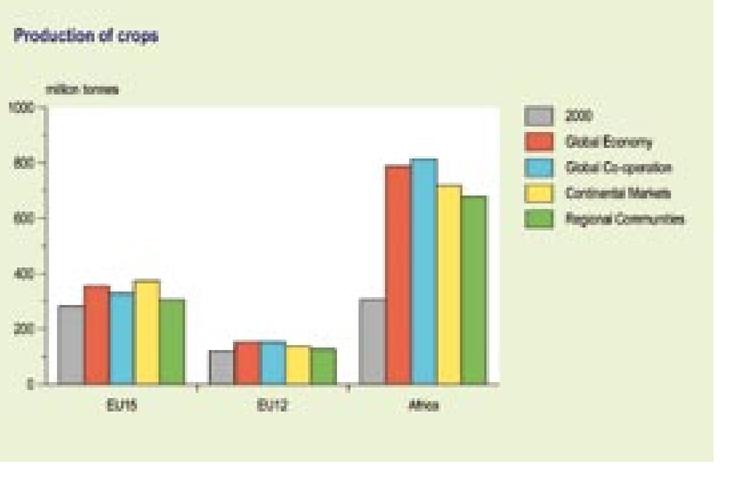
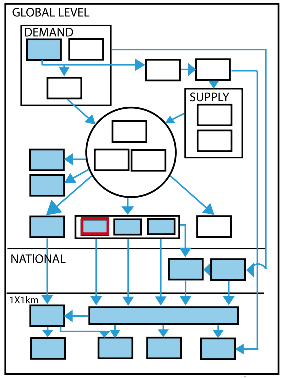


Figure 29. Production of total crops in 2000 and in 2030 for the four Eururalis scenarios in the regions EU15, EU12 and Africa.



■ ARABLE AREA

This indicator includes arable land (incl. irrigated area and biofuel area; see Section 4) and permanent crops. It shows the share of agriculture at country level in Europe.

KEY MODEL VARIABLES AND INPUTS

- Agricultural production: the production of crops and animal is defined by demand and supply.
- The productivity of land, depending on the soil type and location as well as the management in terms of irrigation, fertilizer use, crop rotation, etc.

MODEL PHILOSOPHY AND ASSUMPTIONS

- GDP and population growth both define agricultural demand, which influences production quantity.
- Trade and agricultural policies (market protection & domestic support): If the EU keeps income support or domestic support, it can be more profitable to produce goods within the EU than to import them. In that case more agricultural area is needed. Removing trade barriers can make it more profitable to import agricultural goods than to produce them in Europe.
- Productivity of land: The productivity of land is determined by different factors such as soil type, location in relation to climate, water availability but also management including fertilizer use, irrigation and crop rotation. The more land required for production means the more land is used with a lower productivity, due to soil type and location. So total average productivity is lower. Increasing productivity accounts for more agricultural production from one hectare. It is assumed that productivities in *Regional Communities* and *Continental Markets* are 5% lower than in the other scenarios.

RESULTS

Arable land in the EU27 is declining in three of the four scenarios. In *Continental Markets* arable land is increasing for the European Union, due to the combination of high population growth, the moderate economic growth with a relatively low agricultural efficiency and the Continental Market conditions (Sections 3.2 and 3.3). The other three Eururalis baseline scenarios show a decrease of crop area in the European region in the coming decades. The *Regional Communities* scenario, which is the scenario with the lowest economic growth and highest market protection, predicts the largest decrease in crop area for the EU12 (Figure 30). Apparently, the negative effect of relatively low economic growth in the *Regional Communities* scenario is more dominant than the positive effect of market protection for the EU12.

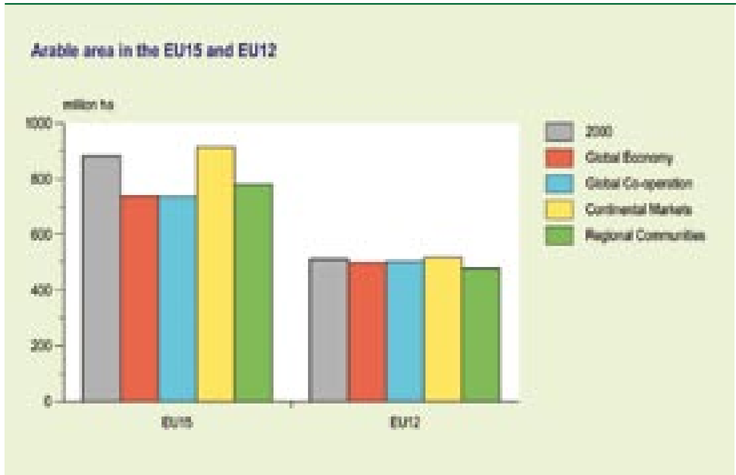
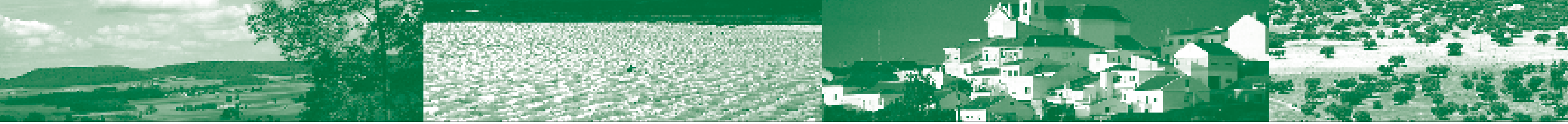
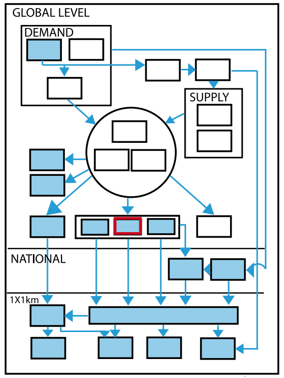


Figure 30. Size of arable area for the four baseline scenarios in 2000 and 2030.





■ PASTURE

This indicator shows the land area for permanent pasture. It is calculated at global level within the LEITAP/IMAGE loop and based on pasture needed to feed the number of animals that is required to produce the demanded quantity of animal products. The animal productivity, intensity of livestock husbandry systems and the grazing intensity determine the pasture area required to feed the animals.

KEY MODEL VARIABLES AND INPUTS

- Livestock production: the production of animal products, such as milk and meat is defined by the demand and supply.
- The productivity and intensity of the livestock sector is defined by animal productivity (kg product/animal) and the grazing intensity (kg grass per area of pasture; Bouwman et al., 2005).

MODEL PHILOSOPHY AND ASSUMPTIONS

- GDP growth induces a shift in consumption. The higher the GDP the more people eat meat instead of staple food. This shift is less in the *Continental Markets* and *Regional Communities* scenario, since GDP growth (at world level) is less in these two scenarios. Besides, it is assumed that people shift less to a luxuriously diet in the *Global Co-operation* and the *Regional Communities* scenario (See Section 3.2). More consumption of meat results in a higher animal production and therefore in a larger pasture area.
- Population growth defines the total food demand. Population growth is lower in *Continental Markets* and *Regional Communities* than in *Global Economy* and *Global Co-operation*.
- Trade and agricultural policies (market protection & domestic support): If the EU keeps income support or domestic support, it can be more profitable to produce goods within the EU than to import them and more agricultural area is needed. Removing trade barriers can make it more profitable to import agricultural goods than to produce them in Europe.
- Productivity of animals: Increasing the productivity accounts for more products from one animal. Changes are taken from Bruinsma (2003) with some additional adjustments to take the narratives into consideration (Section 3.2).
- Intensity of livestock husbandry systems: Increasing the intensity affects animal feeding. Assumed is that more intense livestock breeding means more feed crops and less grazing. In the European Region (both EU15 and EU12) all livestock husbandry systems are classified as intensive (Bouwman et al., 2005).

RESULTS

In total there is a decrease of pastureland in all scenarios (Figure 31). Market protection in *Continental Markets* results in largest areas of pastureland. The other results are a logical refection of animal production and productivity (see the sub-sections fro those results).

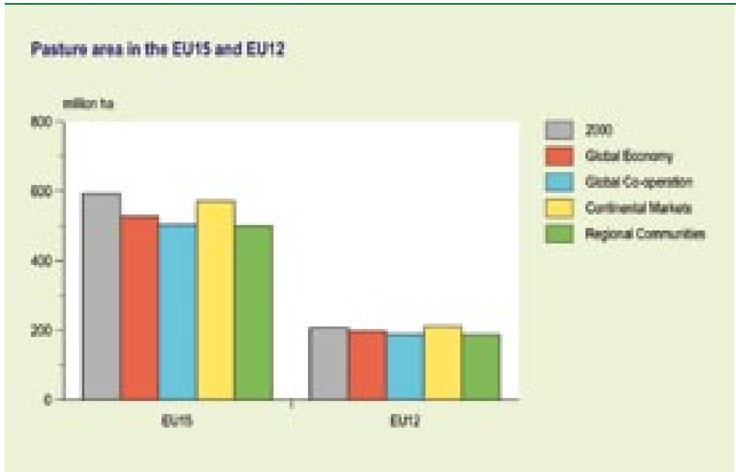
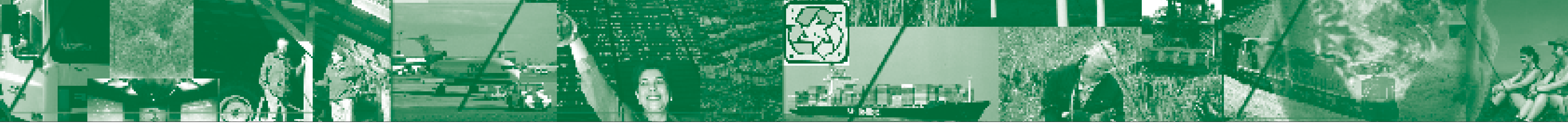
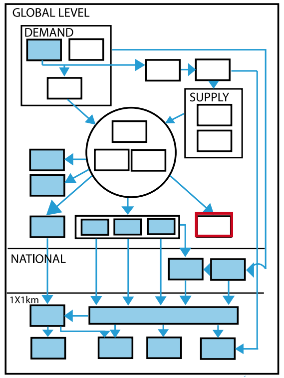


Figure 31. Size of pastureland for the four baseline scenarios in 2000 and 2030.





■ BIOFUEL PRODUCTION

This indicator shows the production of crops for biofuel production. Production is driven by the demand of the petrol sector, the price of biofuels to crude oil and biofuel policies.

KEY MODEL VARIABLES AND INPUTS

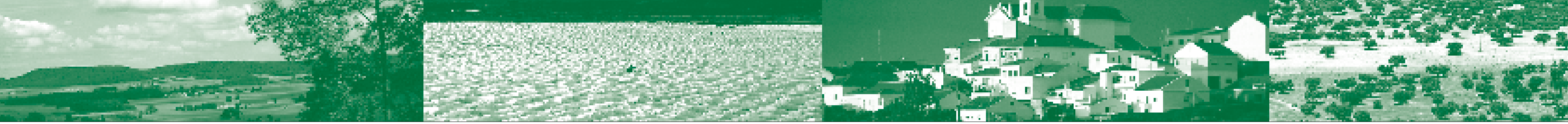
- Production of biofuels which is dependent on demand for biofuels:
- Biofuel demand is determined by the intermediary demand from the petrol sector. This demand is determined by the growth of this sector, which is dependent on income and population growth and the relative price of petrol to other products.
- The share of biofuels versus crude oil is dependent on the relative price of biofuels to crude oil and on energy policies (e.g. EU biofuel directive).
- The share that is domestically produced is determined by the relative price developments of domestically produced biofuels to the price of imports from all other regions.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Economic growth (i.e. GDP) and population define the demand for energy in a country. The relative price of biofuels to crude oil determines the share of biofuels. The crude oil price is dependent on supply and demand of crude oil.
- Biofuel policies (1): the target of 5.75% biofuels for transport sets the demand for biofuel production at a certain level. In *Global Co-operation* and *Regional Communities* this policy is assumed in the default scenarios (see Section 3.3).
- Biofuel policies (2):The blending target is modeled based on an endogenous subsidy of biofuel crop use in the petroleum sector. This subsidy is paid by the final consumers of petrol modeled by an implicit tax on fuel consumption.
- The share of biofuels versus crude oil is dependent on the relative price of biofuels to crude oil and on energy policies (e.g. EU biofuel directive).
- LEITAP does not consider biofuels such as bio-diesel or ethanol as an end-product, but as a blend to petrol. Therefore, international trade in biofuels is also 'translated' in trade in biofuel crops used as inputs to petrol production.
- Trade policies: a scenario where an open world (e.g. *Global Economy* and *Global Co-operation*) is assumed or a scenario where is aimed for self-sufficiency (e.g. *Continental Markets* or *Regional Communities*) defines the allocation of the biofuel area in the world. The higher the trade liberalization the higher the trade intensity in biofuel crops. The area needed is influences by this allocation, because of different production efficiencies.
- Initial share of biofuel crops: countries with a high initial share of biofuel crops are expected to reach the 5.75% target with less economic losses, i.e. the lower the initial biofuel share the higher the increase in consumer prices to fulfill the European Biofuel Directive target.

RESULTS

Table 7 gives the results for production of crops also used for biofuel production, e.g. sugar and grain in the four scenarios. To be able to compare the impact of the biofuel directive the results with and without the biofuel directive (BFD) are shown here. Production of these crops in EU27 is decreasing, since more will be produced outside the EU. However, implementing the Biofuel Directive diminish this decline. Compared to the initial situation production of biofuel crops increases even without the mandatory blending (Section 3.3) under all scenarios (Figure 32). To meet the target of the Biofuel Directive large scale production of biofuel crops in Europe will be necessary. In the *Global Economy* scenario the demand for biofuel crops used in the petrol sector will be 7.3 billion USD (in 2001 values) under the minimum blending of 5.75%. Around 42% of these inputs will be produced domestically and 58% of biofuel crops used in the petrol sector will come from imports. If mandatory blending is not enforced the use of biofuel crops is much lower in all scenarios; only 2.5 billion USD under the *Global Economy*



scenario and only 1.7 billion USD under the *Regional Communities* scenario. The lower demand under *Regional Communities* is due to lower increase in income compared to the *Global Economy* scenario.

Table 7. Changes in total production of crops used for biofuels in 2030 (% relative to 2001).

		Africa	Asia	Central and South America	High Income Countries	EU27	EU12	EU15	World
Global Economy	without BFD	183.8	115.6	143.6	33.6	-18.8	6.9	-28.5	70.1
	with BFD	187.8	116.5	150.9	34.7	-12.7	11.0	-21.5	73.3
Global Co-operation	without BFD	131.6	78.1	58.5	45.9	5.3	7.6	4.4	51.3
	with BFD	137.0	80.8	64.4	46.9	16.2	12.6	17.5	55.8
Continental Markets	without BFD	181.2	87.6	117.2	31.9	-20.7	7.0	-31.0	58.9
	with BFD	183.5	88.4	119.6	32.7	-17.0	10.7	-27.3	61.8
Regional Communities	without BFD	126.2	95.9	64.5	33.3	-1.5	4.7	-3.8	49.5
	with BFD	128.3	96.2	67.5	34.0	11.1	9.2	11.9	52.5

The degree of openness under both scenarios is also reflected in Figure 32. Under the *Global Economy* scenario without mandatory blending the share in imported biofuel crops used for biofuel production is 53.5% while under the higher protection under the *Regional Communities* scenario imported biofuel crops contribute only by 28.5% to total biofuel production. If the Biofuel Directive is enforced, imports in biofuel crops strongly increase even under the more protected *Regional Communities* scenario.

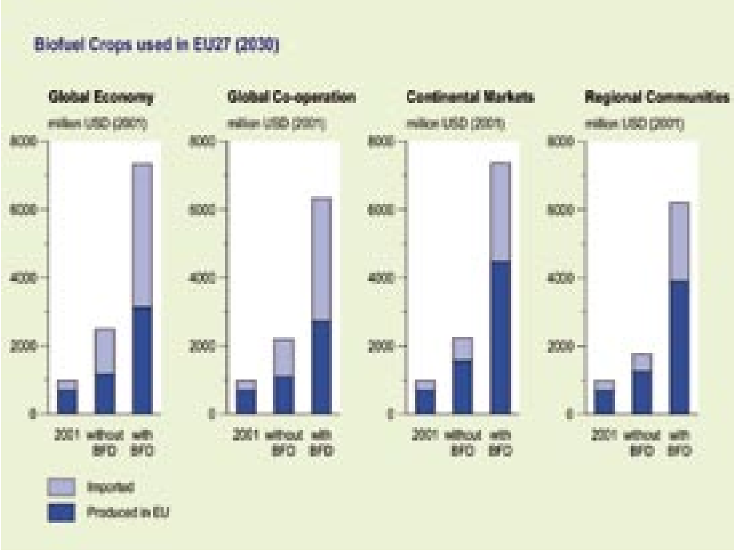
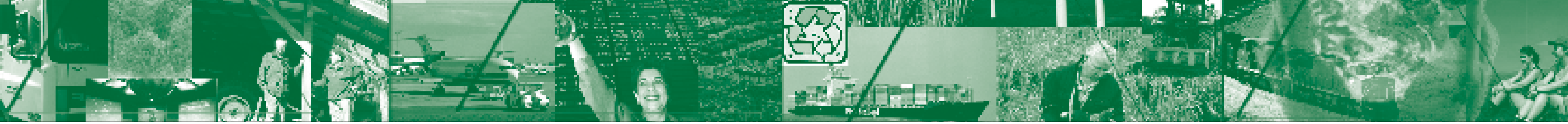
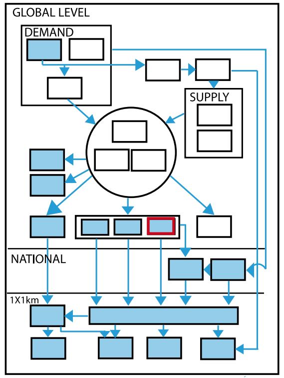


Figure 32: Biofuel crops used in EU-27 in 2030, distinguishing imported biofuels and domestically produced biofuels. The four Eururalis scenarios are shown with and without the implementation of the Biofuel Directive (Section 3.3).





■ BIOFUEL AREA

This indicator shows amount of biofuel crop cultivation. All crops used to produce biodiesel and bioethanol are included in this land cover, this includes coarse grains, oilseeds and sugar. Second generation biofuel crops, however, are not covered.

KEY MODEL VARIABLES AND INPUTS

- Production of biofuels which is dependent on demand for biofuels which is dependent on the relative price of biofuels to crude oil and on energy policies (e.g. EU biofuel directive).
- Land productivity which is determined by an exogenous yield trend and a degree of intensification driven by relative factor prices. The price of land is dependent on the availability and demand of land.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Demand for biofuels:
  - Economic growth (i.e. GDP) and population define the demand for energy in a country. The relative price of biofuels to crude oil determines the share of biofuels. The crude oil price is dependent on supply and demand of crude oil.
  - Biofuel policies: the target of 5.75% biofuels for transport sets the demand for biofuel production at a certain level. In *Global Co-operation* and *Regional Communities* this policy is assumed in the default scenarios.
  - Trade policies determine partly the share in biofuel use that is domestically produced or imported. A scenario where an open world (i.e. *Global Economy* and *Global Co-operation*) is assumed or a scenario where is aimed for self-sufficiency (i.e. *Continental Markets* and *Regional Communities*) defines the allocation of the biofuel area in the world. In case of the EU biofuel directive the higher the trade liberalization the higher the trade intensity in biofuel crops. The area needed is influences by this allocation, because of different production efficiencies.
  - Initial share of biofuel crops: countries with a high initial share of biofuel crops are expected to reach the 5.75% target with less economic losses, i.e. the lower the initial biofuel share the higher the increase in demand to fulfill the biofuel directive target.

- Productivity of land: Increasing productivity accounts for more agricultural production from one hectare. It is assumed that productivities in *Regional Communities* are 5% lower than in the other scenarios.

- Use of agricultural land for biofuel crops strongly depends on two factors:
  - Sluggishness of land: How easily land used for other crops can be converted to land cultivated with biofuel crops
  - Overall availability of arable land: Are countries abundant or scarce of agricultural land? Under tight land markets biofuel crops face fierce competition for agricultural land and domestic biofuel crop production is expected to remain small.

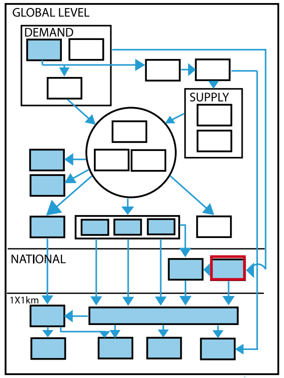
RESULTS

There are substantial differences in the dynamics of arable land cultivated with biofuel crops between the four baseline scenarios. Table 8 presents the results of area used for biofuel crops. To compare the impact of the biofuel directive the results with and without the biofuel directive (BFD) are shown here. Compared to the initial situation even without the mandatory blending area cultivated with biofuel crops increases under both scenario Under the *Global Economy* scenario with high income growth and an associated high growth in energy demand the area sown with biofuel crops more than triples at global level. Here the South and Central America show the strongest increase. The same development is shown for the *Regional Communities*, however, at a lower level which is due to lower income growth under this scenario.

Mandatory blending in the EU has a strong impact on land use in the member states of the EU but also in South and Central America where biofuel area increases by almost 40%. Area cultivated with biofuel crops in the other high income countries are only marginally affected by the EU biofuel directive. This is mainly due to the fact that biofuel crops in these are processed locally while biofuel crops produced in South America are traded on world markets (Rienks, 2007).

Table 8. Biofuel crop area (in million ha).

			EU27	**Central and South America**	**World**
2000			1.94	4.11	28.71
2030	Global Economy	without BFD	4.71	23.60	104.34
		with BFD	10.20	32.61	120.43
	Global Co-operation	without BFD	4.38	19.54	90.87
		with BFD	9.77	25.91	104.20
	Continental Markets	without BFD	5.22	10.55	84.65
		with BFD	12.77	14.26	97.89
	Regional Communities	without BFD	4.37	10.87	73.79
		with BFD	12.09	13.53	85.18



URBAN AREA

This indicator shows the amount of built-up area. This land cover contains all built-up area, including continuous and discontinuous urban areas, industrial areas, commercial areas, road and rail networks, airports, mineral extraction sites, dump sites, construction sites, green urban areas, sports facilities and leisure facilities.

KEY MODEL VARIABLES AND INPUTS

- Population growth increases total surface demand for urban area (including immigration and rural-urban migration dynamics).
- Demographic composition of population in terms of immigrants, and children (from which young autochthonous families are derived)

MODEL PHILOSOPHY AND ASSUMPTIONS

- Consumption preferences: in the *Global Economy* scenario the highest annual growth rate in area per person is assumed, followed by the *Global Co-operation* scenario. A small annual increase in area per person is assumed in the *Continental Markets* scenario, whereas the in the *Regional Communities* scenario a small annual decrease in area per person is assumed. Global rates of change in area per person were based on average growth rates in the period 1990-2000 (See Section 3.2 Consumer Behaviour).
- Population in large cities is denser than elsewhere. Immigrants tend to move to large cities, while young autochthonous families tend to move away from large cities. This makes that in scenarios where most of the population growth comes from immigrants, such as in the *Global Economy* scenario, the increase in urban area per person is less than in scenarios where population growth comes from autochthonous growth. This effect, however, is much smaller than the effect from the different annual growth rate in area per person, as described in the previous bullet.

Spatial policy: restrictive policies in *Global Co-operation* and *Regional Communities* result in compact urban areas in these scenarios and thus less area needed for built-up purposes.

RESULTS

Built-up is growing fastest in the *Global Economy* scenario, due to the high population growth and the lack of spatial policy aimed at compact urbanization (Figure 33). In the *Continental Markets* and the *Regional Communities* population growth is limited (Section 3.2).

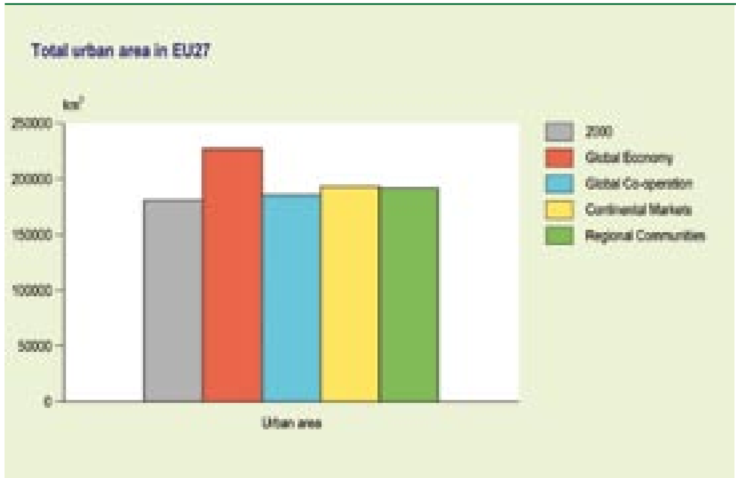
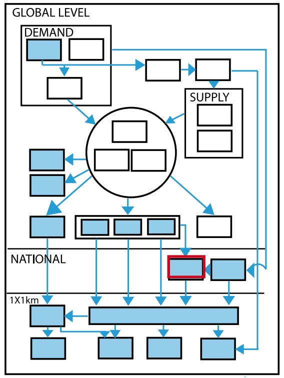


Figure 33. Total urban area in EU27 in 2000 and the four Eururalis scenarios.

Besides, in the *Regional Communities* and in the *Global Co-operation* scenarios a restrictive policy resulting in compact growth is assumed, leading to less built-up area. Figure 34 gives an illustration of the urban pattern for an urbanized part of Europe. Clearly, then *Global Economy* scenario shows the highest increase in urbanised areas. More over, this area is dispersed the most because of lack of restrictive policies.

Figure 34. Examples of geographical explicit urban area around UK and the Netherlands for the four Eururalis scenarios.



■ FOREST/NATURE AREA AND ABANDONMENT AREA

Changes in urban and agricultural area result in changes in abandonment and changes in forest and nature area. Forest/nature area includes forest, semi-natural vegetation, wetlands, glaciers and snow, rangelands, heather, moorland and natural grasslands, excluding recently abandoned farmlands. In this step forest/nature area and abandonment area together are calculated. Finally, dependent on the spatial explicit allocation, specific areas for abandonment and forest/nature area are calculated (see Section Land Use Pattern).

KEY MODEL VARIABLES AND INPUTS

- Urban area: urban pressure causes a decrease in nature area
- Agricultural area: pressure on forest/nature areas, especially in areas highly suitable for agriculture causes a decrease in nature areas, while in other areas agricultural area is abandoned.

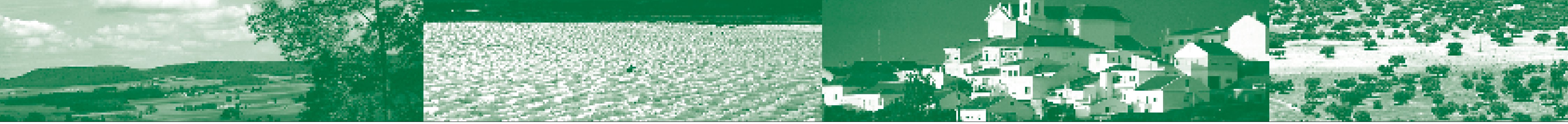
MODEL PHILOSOPHY AND ASSUMPTIONS

- Endowments productivity: a higher productivity of land causes a higher production on the same area, which results in a lower demand for agricultural area.
- Spatial policies and nature protection policies: the restrictive policies in *Global Co-operation* and *Regional Communities* account for compact urban areas and therefore for less pressure on forest/nature areas. In addition NATURA2000 areas are protected in all scenarios while fragmentation of nature is reduced in the *Global Co-operation* and the *Regional Communities* scenarios. The *Global Co-operation* scenario also assumes that ecological corridors are strengthened.
- Trade & agricultural policies, which are favorable for agriculture in Europe, cause an increase in agricultural area and therefore a decline in forest/nature area.
- Biofuel policies influence the demand for agricultural products and therefore cause a higher pressure on forest/nature area. The *Global Co-operation* and the *Regional Communities* scenario assume a biofuel policy.
- Regrowth of natural vegetation on abandoned land is based on growth rate of vegetation (according to climate and soil conditions) corrected for distance to existing forest (seedlings), grazing pressure, nature conservation and population pressure. The higher the population density the more abandoned farmland is used for hobby farming, recreation etc. and the longer the conversion of recently abandoned to semi-natural takes. However, the effect of population pressure is less in *Global Co-operation* and *Regional Communities*, due to more restrictive spatial policies.

RESULTS

The main driving forces of land abandonment include: trade (increase imports), yield increases, decreasing subsidies and relocation of agricultural production from marginal areas to more productive areas in order to maintain competitive farming. Most often such relocation is the result of increases in the scale and area under agriculture in the most productive regions and the discontinuation of farms in marginal regions. This phenomenon is especially apparent in the *Global Economy* scenario where agriculture is focused on the regions with the best production characteristics.

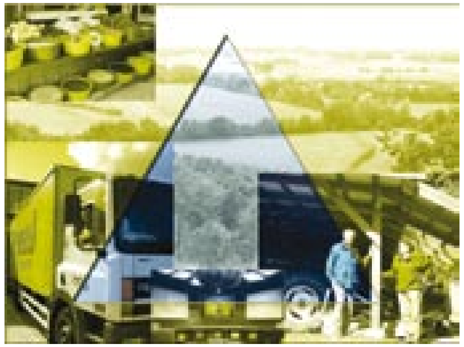
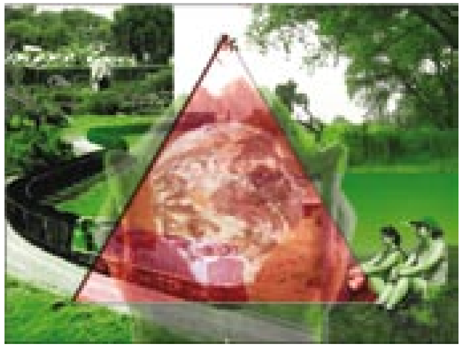
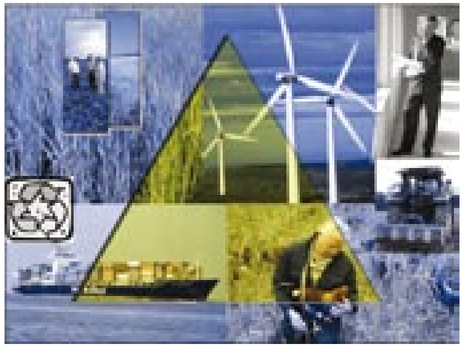
The difference in agricultural area between 2000 and in 2030 is not equal to the area of abandoned land for two reasons. The abandoned areas are all areas that were under agriculture in 2000 and that are “left behind”. Conversions from agriculture to built area are not counted as abandonment. Another reason is that agriculture may have shifted to other areas. This increases the area abandoned land, but does not necessarily decreases the area of abandoned land since it may be patches of natural vegetation that are converted for new agricultural land. Especially in Eastern Europe such changes in the location of agricultural areas are found. In a number of scenarios the agricultural area tends to increase in the period 2000-2010

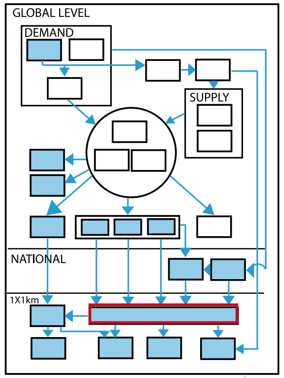


due to the benefits of joining the European Union and CAP support. This leads to the conversion of patches of natural vegetation in the most productive areas. After 2010 these countries also face abandonment of farmland. Abandoned farmlands are mostly the most marginal locations.

Table 9. Agricultural land and abandoned land for the four Eururalis scenarios.

	Global Economy	**Continental Market**	**Global Co-operation**	**Regional Communities**
Agriculture 2000 as % of all land	47.9%	47.9%	47.9%	47.9%
Agriculture 2030 as % of all land	43.6%	47.0%	41.9%	42.8%
Agricultural area change as % of all land	-4.3%	-0.9%	-6.0%	-5.1%
Abandoned areas 2030 as % of all land	4.4%	2.2%	6.7%	5.9%



■ LAND-USE PATTERN

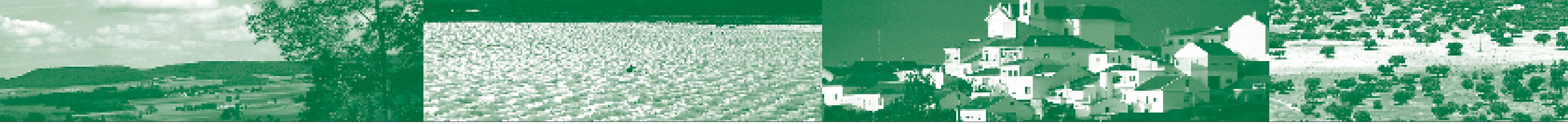
This indicator shows the allocation of the different types of land use, including arable land, pasture, biofuel, forest, nature and urban area. The pattern changes due to increase or decrease in the amount of agricultural, urban, or forest and nature area and the competitiveness of a particular type of land use at a particular location.

KEY MODEL VARIABLES AND INPUTS

- Agricultural Area including arable, biofuel area and pasture;
- Forest/Nature area & Abandonment
- Urban Area
- Location suitability: suitabilities are determined by country specific combinations of location factors and assumed preference changes according to the scenario conditions (in total approximately 100 different location factors are considered including biophysical, demographic and accessibility condition)

MODEL PHILOSOPHY AND ASSUMPTIONS

- Land-use change processes:
  - o Urbanization: agricultural land or nature/forest area changes in built-up areas;
  - o Agricultural marginalization: agricultural land changes in recently abandoned pasture or arable land, or to a natural or semi-natural vegetation;
  - o Agricultural expansion: nature or forest area changes in agricultural area;
  - o Nature development: abandoned areas will undergo succession and develop into new (semi-) natural areas;
- Agricultural policies: the indication of Less Favoured Areas keeps agriculture still in these areas, when it is actually not profitable anymore. These areas would be abandoned without this policy
- Spatial policies: In the *Global Economy* and the *Continental Markets* scenario no restriction or spatial urban planning is assumed. This leads to sprawled growth of building areas. In *Global Co-operation* and *Regional Communities* restrictions in urban planning account for compact urban growth. Protection of Natura 2000 areas is assumed in all scenarios, but fragmentation is only prevented in *Global Co-operation* and *Regional Communities* (Section 3.3).
- Allocation of biofuel area: Within countries, locations with a good transportation network are considered preferred sites for biofuel crop cultivation due to the large bulk of biofuel crops and associated high costs of transporting biofuel crops to processing facilities. Other location factors such as yield, vicinity of existing industries, and slope are also taken into account in determining the location of biofuel crop cultivation within countries.
- Allocation of agricultural area: agriculture is conducted at the most preferred locations within the country. Preferred conditions are defined based on observed current land use patterns and assumed changes in preferences as part of the scenario storylines, e.g. in the *Global Economy* scenario it is assumed that changes in agricultural structure increase the preference for highly productive areas where large scale agriculture is possible.



RESULTS

Urban area is allocated in a compact way in *Global Co-operation* and *Regional Communities*. Within countries a number of regions can be discerned that are showing most growth in biofuel production in all scenarios. These locations have in common a combination of well-developed infrastructure and large areas of suitable arable land. This makes that certain 'hotspots' of biofuels can be identified in Europe, in which substantial areas of biofuels emerge in all scenarios. In the open world scenarios biofuel production is especially allocated near harbors to enhance export possibilities.

Abandonment especially takes place in mountainous regions, due to the relocation of agriculture in the most suitable area. In the *Global Economy* and the *Global Co-operation* scenario these abandoned areas are concentrated in the EU 15. In *Regional Communities*, these areas are allocated in EU12. The indication of Less Favored Areas results in a shift of abandonment patterns. Compensation of farmers in LFA areas leads to less abandonment inside the LFA areas and more abandonment outside the LFA areas. However, due to model assumptions the total area of abandoned agricultural land is the same.

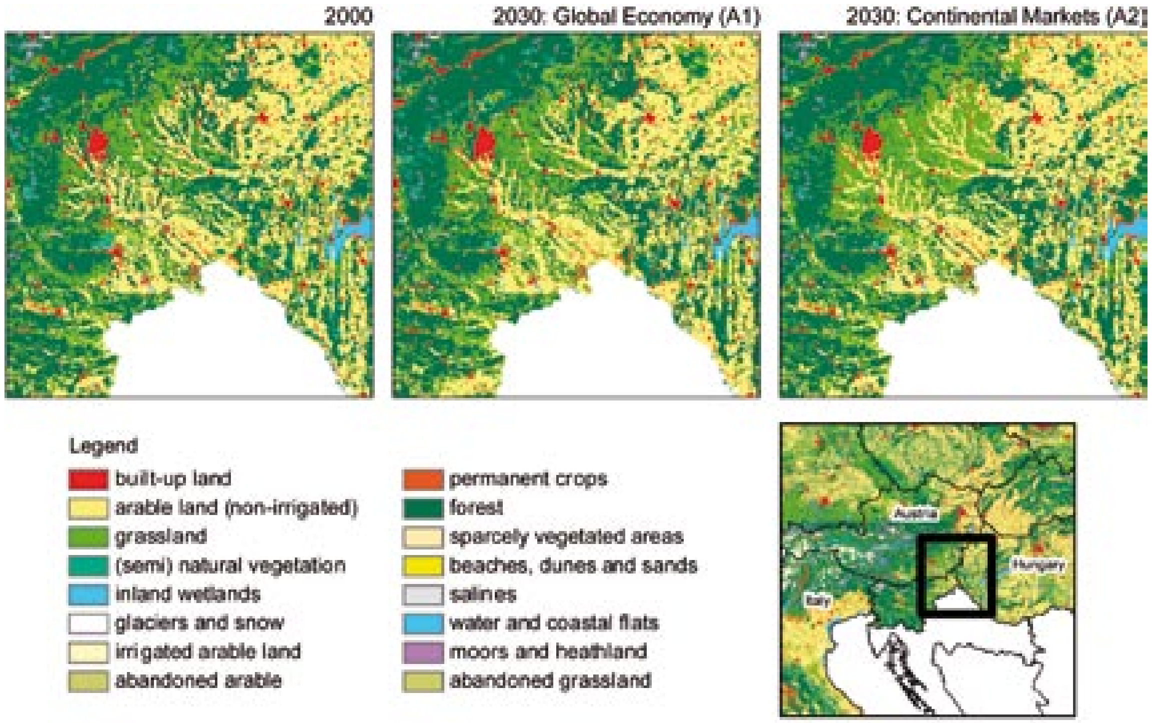
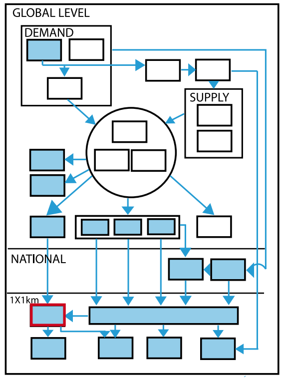


Figure 35. Examples of land-use patterns in 2000 and 2030 for Global Economy and Continental Markets.



■ LIVESTOCK DENSITY

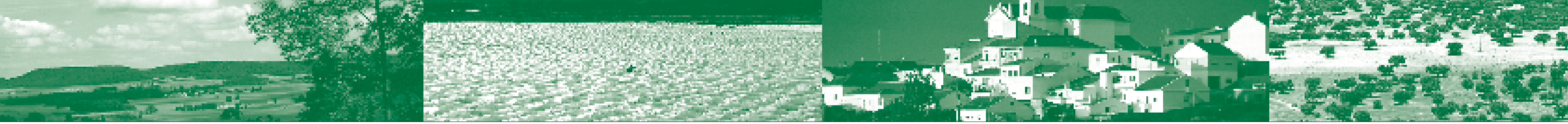
The livestock sector is the world's largest user of land. Livestock is strongly related to grassland and feed-crop production and its spatial concentration may lead to environmental problems. Livestock Density reflects the spatial distribution of different livestock types.

KEY MODEL VARIABLES AND INPUTS

- Livestock numbers.
- Land use pattern: in general, the allocation of livestock will only be at agricultural land and semi natural land. The carrying capacity differs per land-use type. Pasture and arable land have the highest carrying capacity, semi natural land has low carrying capacities (See for scenario specific settings Annex III).

MODEL PHILOSOPHY AND ASSUMPTIONS

- Carrying capacities of the land depend on the scenario chosen. In the regulated scenarios *Global Co-operation* and *Regional Communities* a strict environmental legislation is expected. Carrying capacities in these scenarios are lower (maximum 300 livestock units per km^2 for land dependent husbandry systems and maximum 700 livestock units per km^2 for land independent husbandry systems) than in the market oriented scenarios *Global Economy* and *Continental Markets* (maximum 1600 livestock units per km^2 for land dependent husbandry systems and maximum 4000 livestock units per km2 for land independent husbandry systems).
- Environmental policies: nitrate vulnerable zones are taken into account in the regulated scenarios *Global Co-operation* and *Regional Communities* by lowering the carrying capacities in designated vulnerable zones. The lowest carrying capacities are found in the *Regional Communities* scenario.
- Dependence on local land resources: dairy cows, meat cows, sheep and goats are assumed to be highly dependent on local land resources for grazing or feed production, pigs and poultry are assumed to be mainly land independent animal husbandry systems. Therefore, higher carrying capacities are used for the latter livestock.
- Location preferences for livestock production are based on the current livestock distribution. Large-scale grassland areas considerably determined producer preferences for land-based systems since it was assumed that these livestock systems derive most of their feed requirements from the local region. Landless systems, contrary, depend for most of their concentrate feeding on imports from outside the region. Furthermore, accessibilities of towns and harbors are important for feed imports and areas close to them were therefore assigned to higher producer preferences for land-less systems.



RESULTS

In the *Global Economy* and *Continental Markets* scenarios most increase in livestock numbers is found through intensification at regions that are currently most intensively used for livestock. However, in some of the most densely populated regions some spread toward other areas is seen due to reaching the maximum livestock densities that are possible given logistics and disease risk. Locations easily accessible from harbors (feed import) and towns (processing industry and consumers) are preferred as new locations for intensive livestock production in the global orientated scenarios *Global Economy* and *Global Co-operation*.

In the *Global Co-operation* and *Regional Communities* scenarios spread from the most densely populated regions towards regions with high development potential is seen. In the *Global Co-operation* scenario this effect is strongest in the nitrate vulnerable zones where policy measures are assumed to have drastically limited the maximum stocking rates. In the *Regional Communities* scenario this spread is not only limited to the nitrate vulnerable zones: both environmental, animal welfare considerations and preference for less intensive systems lead to more spread of livestock throughout the countries.

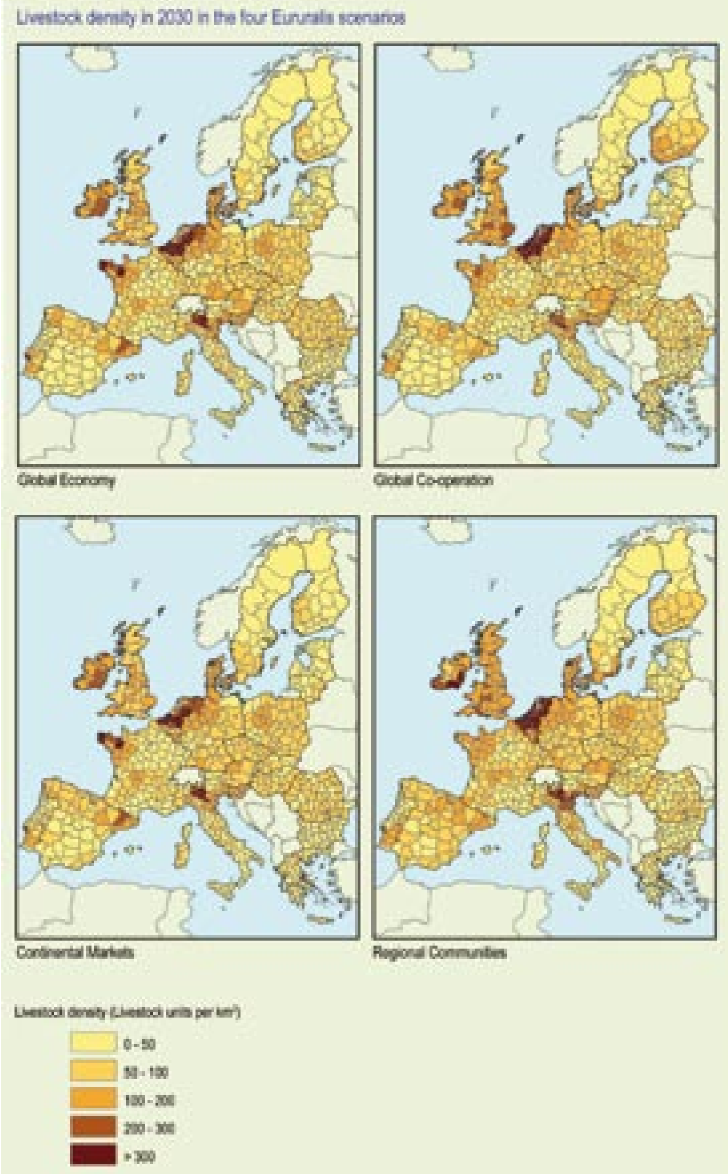
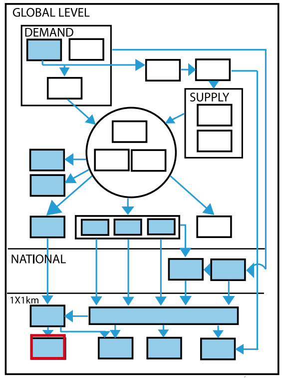


Figure 36. Livestock density maps in 2030 for the four Eururalis scenarios.



■ N-SURPLUS

The nitrogen surplus of agriculture is calculated on the regional level as the differences between the nitrogen inputs via fertilizers, manure, atmospheric deposition, and biological nitrogen fixation and the outputs via crop yield of nitrogen.

KEY MODEL VARIABLES AND INPUTS

- Livestock density.
- Land use: N-surplus is calculated per hectare of agricultural land and semi-natural land use; so only these land use types are used in the calculations.
- N-deposition map on the basis of IMAGE simulations (Bouwman et al., 2002).

MODEL PHILOSOPHY AND ASSUMPTIONS

- Nitrogen excretion of different livestock types estimated per country. Dairy and other cattle and pigs: RAINS model (Amann, 2004; www.iiasa.ac.at/rains); poultry, sheep and goats: estimated by expert judgement from RAINS model and MITERRA-EUROPE (Velthof et al., 2007) and OECD (OECD, 2001).
- Fertilizer use per hectare has been calculated for two categories of crops: grassland and upland crops (arable land, permanent crops and biofuel crops). Country specific figures on fertilizer use for these two types of crops are used on the basis of IMAGE output (Bouwman et al., 2006). Total fertilizer use on area upland crops is corrected for the area legumes, since less fertilizer is used for these crops.
- Biological N-binding and atmospheric N-deposition as simulated by IMAGE (Bouwman et al., 2006).
- Technological developments: the efficiency of N and P uptake by crops is improving over time. For the application rate of N and P fertilizer in the mid-1990s country-specific data are taken from IFA/FAO/IFDC (2003). Until 2030 an efficiency improvement is assumed for each EU-country: 10% for *Continental Markets* and *Global Economy*, 20% for *Regional Communities* and 25% for *Global Co-operation*.
- N-output is calculated by using N-uptake rates for upland crops and grassland (see Annex IV).
- No explicit N-policies are assumed.

RESULTS

In general the pattern of N-surplus correlates with the pattern of livestock density (compare Figures 36 and 37). In the high regulation scenarios *Regional Communities* and *Global Co-operation* livestock production will rather be stable in the EU27. An increase of livestock production can be observed in the EU12 and decreases in the Low Countries, Portugal and Italy. Together with lower inputs of fertilizer over time for cropping this will lead to a smaller N-surplus in general for the EU15. For the EU12 slightly higher animal production in combination with higher fertilizer use will lead to an increase of N-surpluses in the EU12.

In the low regulation scenarios *Global Economy* and *Continental Markets* livestock production will grow in general. Despite decreasing input of fertilizers over time, inputs are still higher in these scenarios compared to *Regional Communities* and *Global Co-operation*. Besides carrying capacities in the *Global Economy* and Continental Market scenario are higher (see Section Livestock Density) than in *Regional Communities* and *Global Co-operation*, which increases Nitrogen surplus.
Regions that already have high surpluses remain highest for all scenarios.

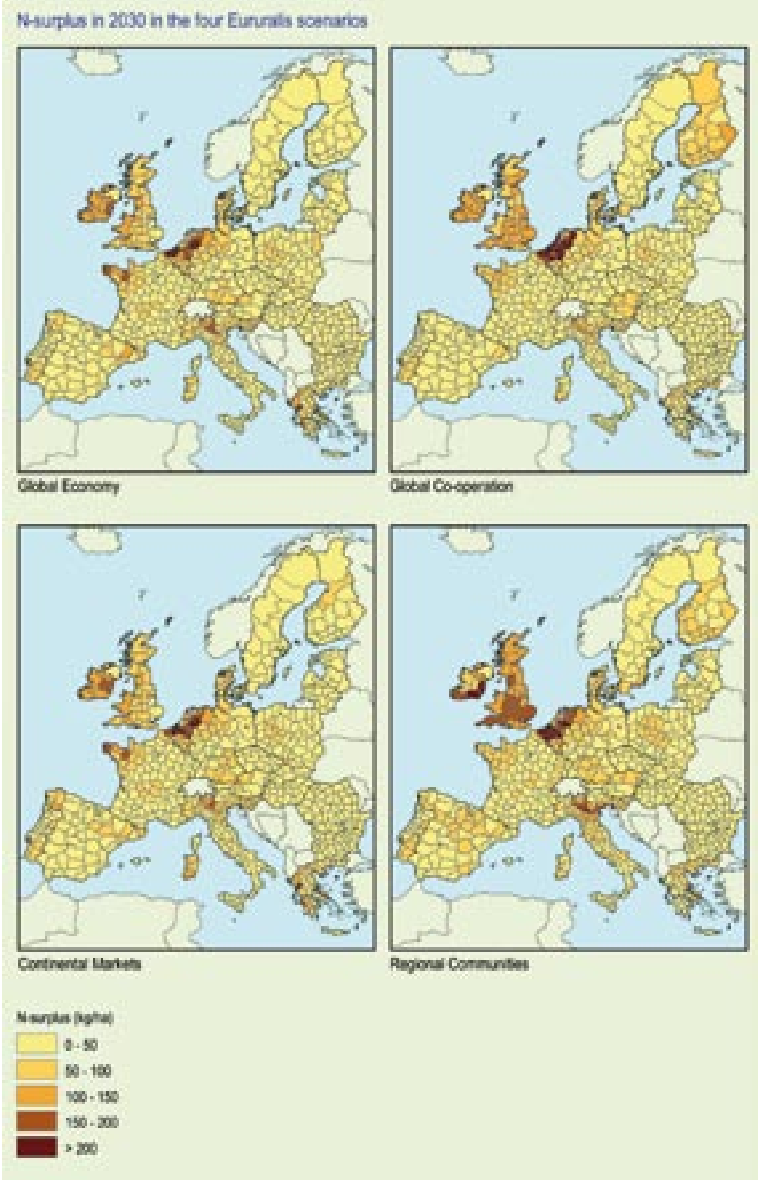
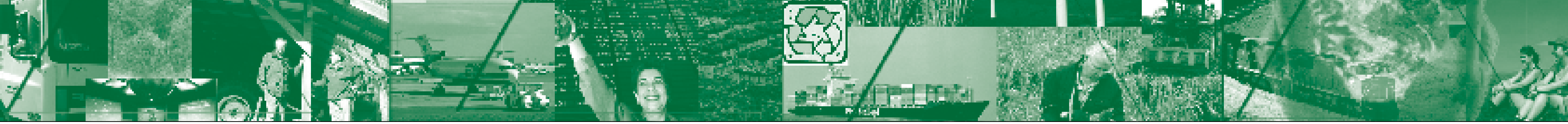
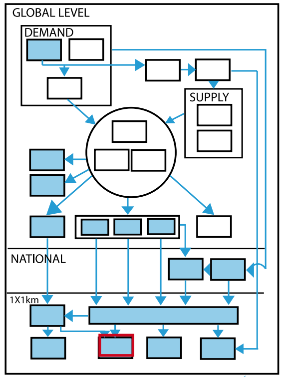


Figure 37. N-surplus maps in 2030 for the four Eururalis scenarios.





■ BIODIVERSITY INDEX

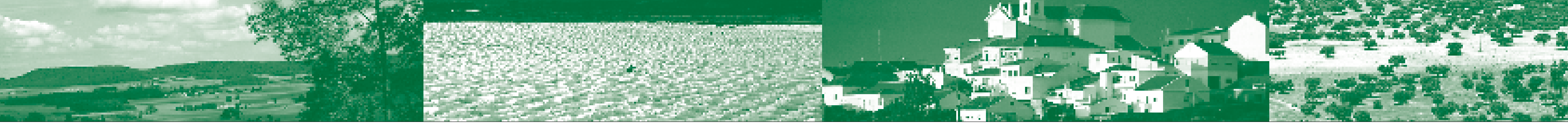
This indicator shows the impact of developments in land use on biodiversity. The value used to describe the biodiversity is the Mean Species Abundance (MSA) and the approach used is derived from the GLOBIO3 concept (Alkemade et al., 2006).

KEY MODEL VARIABLES AND INPUTS

- Land-use pattern, e.g. forest has a higher biodiversity than intensive arable land (See Annex V for Mean Species Abundance per land-use type).
- Infrastructure maps of Europe for 2000 (used for 2000 and 2010) and 2020 (used for 2020 and 2030) based on the so called TEN-Stack project elaborated by NEA Transport research and training, project coordinator (The Netherlands), and commissioned by the European Commission. GIS-maps are obtained from NEA (European Commission, 2004).
- Livestock density: extensive pastureland (based on the assumption that they are pasture land with less than 100 livestock units per km^2) are modeled to have a higher biodiversity than intensive pastures: MSA of 0.4 versus 0.1.
- N-deposition map on the basis of IMAGE simulations (Bouwman et al., 2002). When the N-deposition is higher than the critical load it will reduce the value on the biodiversity index.

MODEL PHILOSOPHY AND ASSUMPTIONS

- Fragmentation of habitats by infrastructure is more limited in the scenarios aiming at sustainability issues (*Global Co-operation* and *Regional Communities*) from 2020 onwards. The assumption is that the negative impact of infrastructure within NATURA2000 areas will fully be mitigated by tunnels and ecoducts for wildlife.
- High nature value farmlands map, which are based on Andersen et al. (2004). Agriculture areas in High Nature Value farmlands have a 25% higher biodiversity index than agricultural area outside those areas.
- In the scenarios aimed at sustainability issues (*Global Co-operation* and *Regional Communities*) more organic farming is expected to develop over time. In 2030, the growth in organic farming relative to 2000 is assumed to be 5% in *Global Economy*, 10% in Continental Market, 15% in *Global Co-operation* and 20% in *Regional Communities*. This type of farming has higher values for the biodiversity index.
- Both global scenarios (*Global Economy* and *Global Co-operation*) are expected to have a more extensive management of forest areas since in those areas self-sufficiency is not an important target. In these scenarios there is less pressure on forest areas.
- Older forests are assumed to have higher biodiversity values than young forests. Age of forests is based on the forest age map (Pussinen et al., 2001).
- Agricultural policies: income support keeps farmers in marginal areas, whereas abandonment of these areas causes a loss in biodiversity on the short term.
- Biofuel policy: biofuel policy will keep more agricultural area in production, which has a negative impact on biodiversity on the long term.



RESULTS

In future all scenarios excluding the *Continental Markets* scenario show an EU27-wide increase of the biodiversity index in comparison with the year 2000 situation. The main reason is the decline of the agricultural area in the EU. This area slowly transforms into a more natural environment. The *Global Co-operation* scenario shows the highest biodiversity. This is due to nature friendly management of forests, more organic farming in agriculture and the decrease of agricultural land. Also *Global Economy* and *Regional Communities* scenarios have an increase of the biodiversity index over time. In the *Continental Markets* scenario the biodiversity will decrease because of strong pressure on land and little attention for environmentally friendly management. These biodiversity results refer to 2030 and provide an aggregated result for the entire EU. Specific ecosystems like wetlands are not necessarily improving as well. Therefore, for conclusions on meeting the EU-target of halting loss of biodiversity in 2010, additional analyses need to be performed.

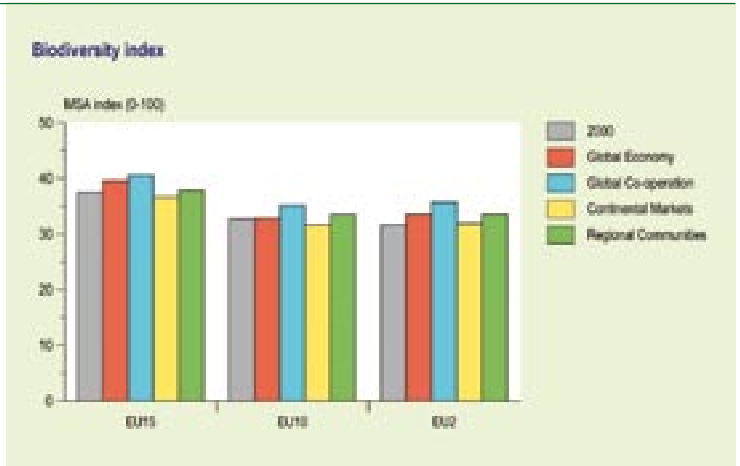
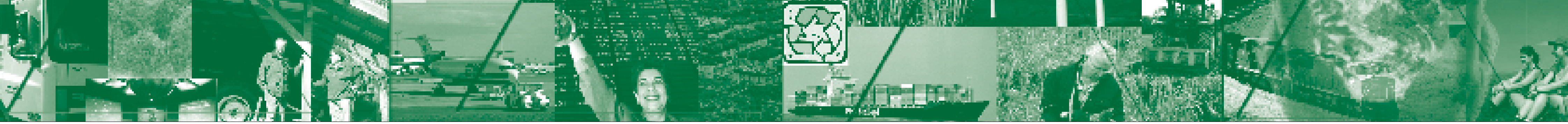
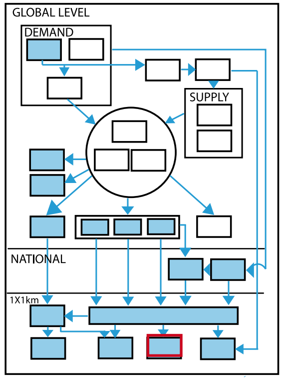


Figure 38. Biodiversity index in the EU27 for the situation in 2000 and the four baseline scenarios in 2030. Index of MSA ranging from 0 to 100.

Agricultural policies have substantial impact on the biodiversity index. Income support keeps farmers in marginal areas. On the short term abandonment of marginal areas will have a negative impact on biodiversity, due to less variation of habitats in these areas and loss of specific biodiversity connected to extensive farming. On the longer term the biodiversity index might increase again when due to succession more natural forest or shrub vegetation develops. Biofuel policies will lead to a higher amount of arable cropland. This land use has a low biodiversity value and therefore stimulating biofuels leads to a decrease in biodiversity.





■ CARBON SEQUESTRATION

Large amounts of CO_2 can be sequestered in the terrestrial ecosystem. This can contribute to climate change mitigation. This indicator represents the amount of carbon that is sequestered in or emitted from land use, land use change and forestry.

KEY MODEL VARIABLES AND INPUTS

- Land use pattern: forest areas sequester carbon and store large amounts of carbon. When deforestation takes place a lot of carbon is emitted. Crop lands emit carbon as well, while pastures sequester carbon. See Annex VI for emission factors and sequestration rates.
- Forest age map (Pussinen et al., 2001)
- Soil organic carbon map (Jones et al., 2004)

MODEL PHILOSOPHY AND ASSUMPTIONS

- Emission/sequestration is defined by an emission factor; this is a country-specific, land use type specific amount of sequestration/emission per km^2 per year. When the land use changes, the emission factor changes to the emission factor of the new land use type. Additionally, deforestation causes loss of carbon from biomass. Emission factors from Janssens et al. (2005) and Karjalainen et al. (2003) are used for arable land, pasture, wetlands and forests. Built-up area; glaciers and snow; sparsely vegetated areas; beaches, dunes and sands; salines; water and coastal flats do not sequester or emit carbon. The emission factor of heath and moorlands is the grassland emission factor.
- The emission factor of permanent crops is one-third of forest emission factor. For pastures on peat, the emission factor is the peatland emission factor. For pastures on mineral soils there is a specific emission factor. For arable lands, including non-irrigated and irrigated arable lands and biofuels, the emission factor is differentiated between soil organic carbon content (SOC) by multiplying the emission factor with a differentiation factor (Sleutel et al., 2003; Bellamy et al., 2005):

Soil Organic Carbon Content (%)	Fraction of standard emission factor	Soil Organic Carbon Content (%)	Fraction of standard emission factor
0%	No emission	12.5 - 25 %	2.0
0.01 – 1 %	0.1	25 - 35 %	2.5
1 – 2 %	0.2	>35 %	3.5
2 – 6 %	0.65	Peat (ESB)	Emission factor of peatland
6 – 12.5 %	1.6		

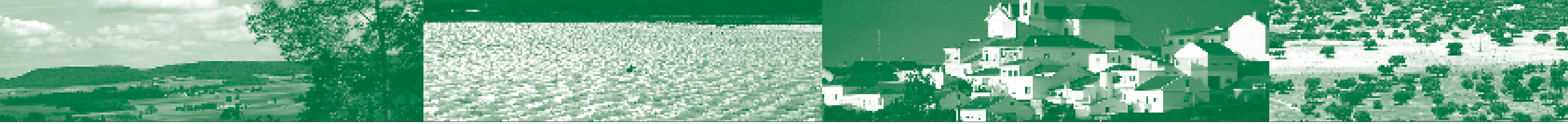
Table 10. Differentiation of cropland emission factors as a function of Soil Organic Carbon content.

- For forest and land under succession, the emission factor is differentiated between age (Nabuurs, 2001, Pussinen et al., 2001):

Age	Differentiation factor
0 – 5 years	No sequestration
6 – 21 years	(0.0525* age) – 0.085
22 – 43 years	1.05
44 – 120 years	(-0.007*age) + 1.35
> 120 years	0.50

Table 11. Differentiation factors for the forest emission factor.

- Upon deforestation, 80% of carbon in forest biomass is lost. The precise amount of biomass available at a certain location is age dependent: when the forest is younger than 50, the forest biomass carbon content is modified by 0.02*age, when forest is older than 50, the standard number is used.



RESULTS

The EU15 and EU12 differ in temporal trends and spatial distribution of future carbon sequestration (Figure 39). In the *Global Economy* scenario, carbon sequestration will decrease in EU12 and some regions will emit large amounts of carbon up to 2010. This reflects arable land expansion in the EU12 up to 2010. In the EU15 on the other hand, sequestration slightly decreases up to 2010 and after that will increase. In the *Continental Markets* scenario, agricultural land will expand in EU15 while in the EU12 it decreases slightly. Therefore sequestration will decrease dramatically in EU15. Changes in carbon sequestration in the *Global Co-operation* scenario shows a trend comparable with the *Global Economy* scenario, but amounts of sequestration are higher in as well the EU12 as the EU15. In the *Regional Communities* scenario, there is also an initial decrease of sequestration, but after that sequestration will increase strongly because of cropland abandonment and establishment of new forests all over Europe. Especially in France and Poland, differences in sequestration between the scenarios are largest. Further, the major forest areas are expected to remain sinks until 2030 while the major cropland areas, that are the strongest sources, are expected to remain sources.

Overall, carbon sequestration in land use and forestry will decrease the coming decade. After 2010 carbon sequestration will increase in all scenarios but *Continental Markets*. In the *Continental Markets* scenario, sequestration will be 6% lower in 2030 compared to 2000. In the other scenarios, there is an increase of around 15%.

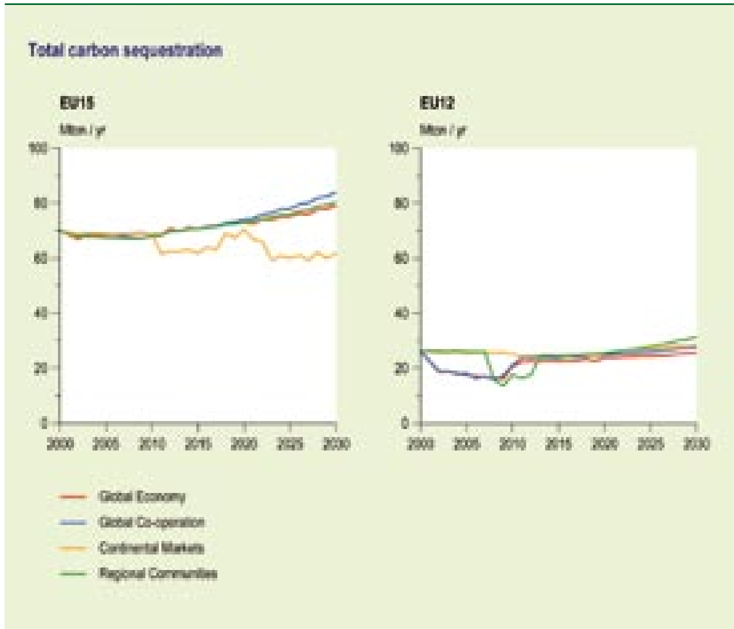
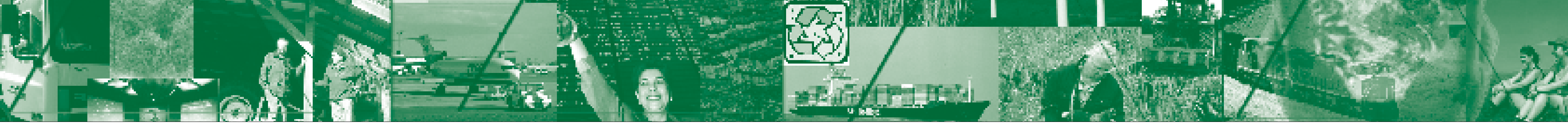
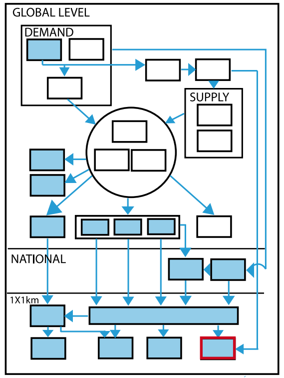


Figure 39. Carbon sequestration in the EU15 and EU12 between 2000 and 2030 for the four baseline scenarios.





■ EROSION RISK

Soil erosion (sheet and rill) is a major factor in land degradation and loss of soil quality. Furthermore, eroded sediment ends up in rivers and water bodies, where it disturbs fragile water ecosystems. Soil erosion strongly responds to land use, particularly to spatial patterns of land use.

KEY MODEL VARIABLES AND INPUTS

- Land use pattern: different land use has different erodibility values; especially arable land enhances erosion
- Rainfall regime which will change over time due to climate change: a more irregular distribution of rainfall leads to an increase in erosion. The dry periods hinder vegetation growth and soil formation, so that the heavy, intensive storms can induce severe erosion events. Climate patterns are taken from the IMAGE-model (Eickhout et al., 2004a).
- Potential erosion, based on topography and soil erodibility. These are calculated according to the USLE principle, and are considered stable in time.

MODEL PHILOSOPHY AND ASSUMPTIONS

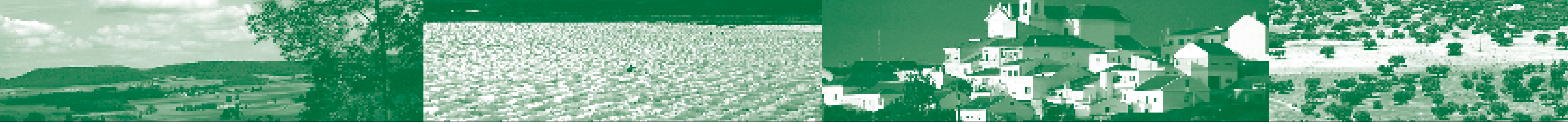
- Soil erosion is obtained based on the USLE formulae (Wischmeier and Smith, 1965), which is an empirical multiplication of kinetic energy of rainfall, a slope index, an index for soil erodibility and an index for protective vegetation cover. The equation was calibrated on plots of 30 m length, and yields in such case erosion in tons per hectare per year. At the European scale the numbers should no longer be interpreted as tons per hectare per year, but as an ordinal scale of erosion severity, since exact numbers for Europe as a whole are unavailable and this aggregation can only be used as an indicative result.
- High stone content in the soil adds to the protective cover.
- LFA policies: agricultural land use remains important in areas defined as LFA, which enhances erosion.

Land cover class	Climate zone		
	Mediterranean	Boreal	Temperate
Built-up area	0	0	0
Arable land	0.32	0.32	0.24
Pasture	0.1	0.05	0.03
(semi-) Natural vegetation*	0.1	0.03	0.03
Inland wetlands	0	0	0
Glaciers and snow	0	0	0
Recently abandoned arable land**	0.2	0.2	0.15
Permanent crops	0.25	0.15	0.15
Forest	0.005	0.001	0.001
Sparsely vegetated areas	0.25	0.15	0.15
Beaches, dunes and sands	0	0	0
Salines	0	0	0
Water and coastal flats	0	0	0
Heather and moorlands	0.005	0.001	0.001
Recently abandoned pasture land***	0.1	0.05	0.03

Table 12. Translation key for erosion risk per land cover class per climate zone.

** includes natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes*
*** i.e. “long fallow”; includes very extensive farmland not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30 cm*
**** includes very extensive pasture land not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30cm.*

- Arable area has the lowest protection against erosion. Any arable abandonment therefore results in a decrease in erosion. The relationship between protective vegetation cover and land use type differs per climatic zone (i.e. Mediterranean, Temperate and Boreal). The exact translation key are shown in Table 12.



RESULTS

Two counteracting processes affect dynamics in soil erosion by water: on the one hand a decrease in agricultural land leads to a reduction of soil erosion, while on the other hand climate change leads to an increase in soil erosion. In most scenarios the erosion-mitigating effects of land abandonment are compensating the negative effects of increased and more erratic rainfall, leading to a net decrease in soil erosion in Europe in all scenarios. The absolute decrease is particularly strong in the EU15 member states, where erosion rates are currently still quite high. The relative decrease is strongest in the EU10, but here erosion rates are already low due to the intrinsic low erosion-proneness of Poland and the Baltic States. In some regions the positive effect of land abandonment could be offset by the increased erosivity due to increased rainfall and/or longer dry periods as a result of climate change. Figure 40 shows the erosion erosivity of all regions in 2030.
Policy measures that increase the amount of arable land in Europe – a Biofuel Directive or more income support - will lead to more erosion risk. Especially when arable land is allocated in hilly or mountainous areas, this effect will be even stronger. This might be the case as a consequence of LFA policies.

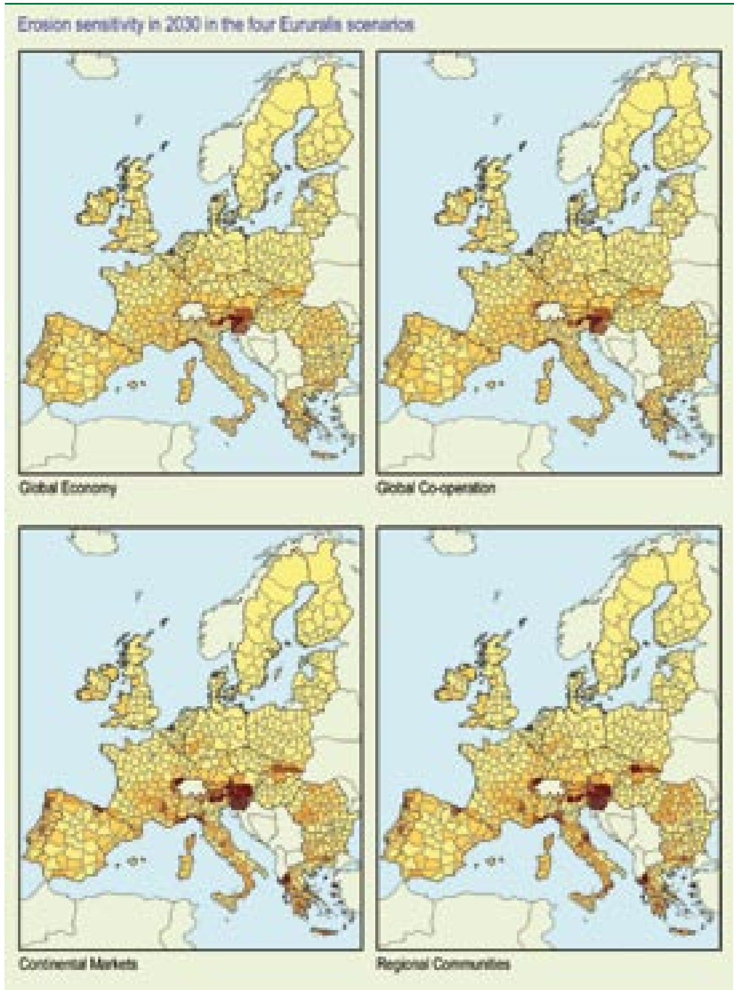


Figure 40. Erosion sensivity in 2030 in the four Eururalis scenarios.

6. DISCUSSION AND CONCLUSIONS

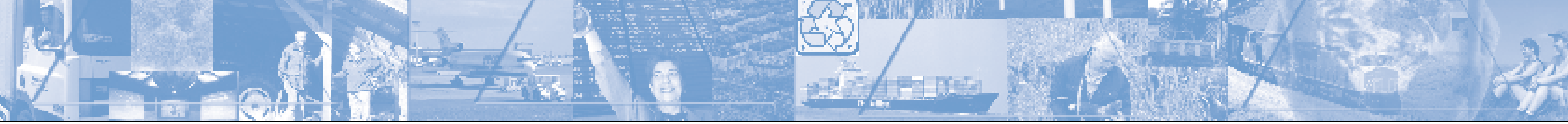
In this report a comprehensive overview of Eururalis 2.0 has been given. Eururalis 2.0 is characterized by the combination of three different land-use models at different geographical scales. This enables drawing conclusions on the future of Europe's agriculture in the context of global developments. Moreover, Eururalis 2.0 is a discussion-support tool for political and societal questions on the longer term (2030). Therefore, different narratives and corresponding scenarios are constructed to take future uncertainties into consideration. However, to be able to address specific features of policies, four policy options have been developed on top of the four baseline scenarios. This enables Eururalis users to deal with future uncertainties and, at the same time, assess the potential impact of specific policies on impact indicators for people, planet and profit.

Substantial improvements have been made in the linkage between the different models within the Eururalis 2.0 project. The use of land supply curves in LEITAP linked to the IMAGE model returns more realistic production potentials: in land scarce regions LEITAP simulates lower production levels than standard general equilibrium models, whereas in land abundant regions more food and feed is produced for the export (Tabeau et al., 2007). This feature of the Eururalis modeling train is crucial for results on commodity prices, agricultural income and the trade balance in Europe. The connection of Europe with the global developments is one of the most crucial assets of Eururalis.

The link from LEITAP/IMAGE to CLUE-s is, however, one-directional: CLUE-s gets the size of arable land, pastureland and land for biofuels on a European country level and needs to perform the complete land allocation on basis of that input. Therefore, within Eururalis most of the impact indicators at the end of the modeling chain are determined by areas from LEITAP/IMAGE and the allocation scheme of CLUE-s. This crucial link between the three models needs to be strengthened in next versions of Eururalis. Especially, local allocation decisions by CLUE-s need to be fed back to the economic optimization of LEITAP to be able to address the land-use consequences of EU environmental policies. For example, current biodiversity and N-surplus impacts of land-use change in CLUE-s are end points within Eururalis and those end points are not affecting the volumes that need to be produced in the specific countries. In next versions of Eururalis this feedback needs to be included. First, a European country version of IMAGE is essential to establish such a feedback. This country-version will also render redundant up- and downscaling between LEITAP and IMAGE that is currently undertaken in the iteration between both models. And second, the impact of other environmental stress factors on crop productivity besides climate change, need to be included in IMAGE as well. Especially, nutrient shortage and exceedance will have to have an impact on crop productivity to assess the full impacts of EU's policies on water quality and nutrient loading.

Besides the biophysical jump from world regions and EU countries to grid scale results, the socio-economic downscaling as performed in Eururalis needs to be elaborated upon as well. In the current version of Eururalis this downscaling is performed rather straightforward (Section 2.2): current characteristics of regions in each EU country and the country-level rate of change is determining all socio-economic conclusions on leading and lag-

ging regions. Although such a downscaling is transparent, a better socio-economic representation of the EU regions is crucial to make Eururalis applicable for analyses on the wider rural agenda of EU policies.
Eururalis 2.0 is currently able to address analyses on impacts of policies on CAP in combination with new energy policies regarding first generation biofuels. Therefore, the incorporation of biofuels within the Eururalis modeling tool is another crucial step in the project. This required adjustment of the economic part to define prices and imports of biofuels in Europe as well as extension of the land allocation part to allocate biofuel production within Europe. Although the use of second generation biofuels is of importance to sketch the longer term impact of the Biofuel Directive, the adaptations in the Eururalis modeling tool have been limited to only first generation biomass crops. Incorporating second generation biomass crops requires more radical changes of the modeling structure and therefore more effort. Besides, historical data on production, consumption, trade and allocation are unavailable, which makes it difficult to calibrate the several models. However, to support future discussions concerning rural Europe, extension to the second generation biofuels is necessary. Moreover, in future versions of Eururalis consistency between IMAGE's energy model and LEITAP needs to be guaranteed as well to simulate climate change and land-use change because of biofuels in a coherent way.
The Eururalis 2.0 visualization tool is currently filled with results for 4 baseline scenarios and 33 variations to them (Section 3.4). Logically, Eururalis analyses are not restricted to these results only. Other policy options or even new baselines can be analyzed with the Eururalis modeling chain as well. These opportunities of Eururalis need to be seized in the near future. Only in that case, Eururalis can really be regarded as the discussion-support tool as it was designed for. This technical background report is meant to help all users of Eururalis results in understanding the flow of information between models. Although potential new Eururalis simulations are not retrievable from the current Eururalis 2.0 visualization tool (Rienks, 2007), this technical report will help in tracing the causes of all results. Nevertheless, this report focuses the explanation of results on the four baselines as defined in Westhoek et al. (2006). In combination with the CD-ROM (WUR/MNP, 2007) and the policy booklet (Rienks, 2007), this technical report completes the documentation of Eururalis 2.0. Scientific publications of Eururalis and potential new applications are being updated on the website: http://www.eururalis.eu.



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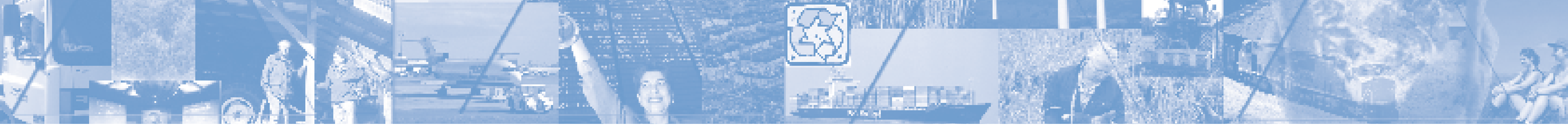

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ABBREVIATIONS AND GLOSSARY

CAP	Common Agricultural Policy; Agricultural policy of the European Union.
CLUE-s	Conversion of Land Use and its Effects at Small regional extent. CLUE-S is specifically developed for the spatially explicit simulation of land-use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems.
Driving force	Development influencing the results of a model to a large extent. This development could be exogenous, i.e. used as input to the model, or endogenous (calculated within the model itself). Within Eururalis important driving forces are for example economic growth, demographic developments and technological developments.
U12	Member states of the European Union accessed in 2004 or 2007, i.e. Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.
EU15	Member states of the European Union accessed before 2004, i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and United Kingdom.
U2	Member states of the European Union accessed in 2007, i.e. Bulgaria and Romania.
EU27	European Union as from 2007 (comprising EU15 and EU12).
Eururalis visualization tool	The Eururalis tool, which visualizes the results of Eururalis 2.0. The tool is available on CD-ROM or can be downloaded from internet (http://www.eururalis.eu).
Eururalis modeling tool	The framework of several models delivering the Eururalis results, i.e. LEITAP, IMAGE, CLUE-s and the meta models delivering impact indicators.
First generation biofuels	Current generation of crops containing sugar or starch for the production of bioethanol (sugar cane or maize) or oil seeds to produce biodiesel (palm oil).
GDP	Gross Domestic Product.
High nature value farmland	Farmland areas hosting habitats with high biodiversity values often accompanied by extensive management.
IMAGE	Integrated Model to Assess the Global Environment, developed to explore the long-term dynamics of global change as the result of interacting demographic, technological, economic, social, cultural and political factors.
Income support	Subsidies provided to farmers, such as single farm payments.
LEITAP	Version of GTAP (Global Trade Analysis Project) developed by the Agricultural Economics Research Institute (LEI).
LFA	Less Favored Area: areas with less favored farming conditions.
Market support	Export subsidies and import tariffs.
MSA	Mean Species Abundance: index calculating the trend in species abundance of a representative cross section of the species per biome.
Narrative	A storyline based on plausible future developments. Within Eururalis the future developments are related to the way policy approaches problems (global versus regional and low regulation versus high regulation).
PPP	Purchasing Power Parity: exchange rate used to compare the standarts of living between countries.
Scenario	Quantification of a narrative resulting in a coherent set of driving forces.
Second generation biofuels	Next generation of biomass products consisting of ligno-cellulosic crops that need more advanced technologies to produce bioethanol. These biofuels are not commercially available yet and are not considered in Eururalis 2.0.
WTO	World Trade Organization.

ANNEX I GROWTH IN GROSS DOMESTIC PRODUCT IN EURURALIS 2.0

Growth in GDP per inhabitant in the four Eururalis 2.0 scenarios							
		Global Economy			**Global Co-operation**		
	Purchasing Power Standard US $ (2000)	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Austria	25400	2.60	2.93	2.31	1.54	1.72	1.27
Belgium	24000	2.38	2.68	2.55	1.33	1.49	1.38
Bulgaria	5300	7.39	7.82	4.46	8.92	8.91	4.24
Cyprus	16900	2.60	2.93	2.31	1.54	1.72	1.27
Czech Republic	13000	3.60	4.06	2.96	3.25	3.61	2.26
Denmark	25100	2.60	2.93	2.31	1.54	1.72	1.27
Estonia	8500	4.86	5.09	3.57	4.86	5.09	3.05
Finland	22300	2.60	2.93	2.31	1.54	1.72	1.27
France	22000	2.38	2.68	2.55	1.23	1.38	1.16
Germany	22600	2.06	2.31	2.19	1.13	1.27	1.16
Greece	16000	2.60	2.93	2.31	1.54	1.72	1.27
Hungary	10700	3.75	4.25	3.05	3.48	3.91	2.41
Ireland	24900	2.60	2.93	2.31	1.54	1.72	1.27
Italy	22300	2.16	2.43	2.31	1.13	1.27	1.16
Latvia	7000	4.86	5.09	3.57	4.86	5.09	3.05
Lithuania	7500	4.86	5.09	3.57	4.86	5.09	3.05
Luxembourg	46400	2.38	2.68	2.55	1.33	1.49	1.38
Malta	15900	2.60	2.93	2.31	1.54	1.72	1.27
Netherlands	25600	2.16	2.43	2.19	1.33	1.49	1.27
Poland	9200	3.93	4.47	3.16	3.74	4.25	2.58
Portugal	14900	2.60	2.93	2.31	1.54	1.72	1.27
Romania	4900	7.39	7.82	4.46	8.92	8.91	4.24
Slovakia	9500	4.26	4.87	3.34	4.24	4.86	2.85
Slovenia	15000	2.70	2.82	2.27	1.90	1.53	0.99
Spain	18500	3.28	3.70	2.93	2.16	2.43	1.49
Sweden	24100	2.60	2.93	2.31	1.54	1.72	1.27

Growth in GDP per inhabitant in the four Eururalis 2.0 scenarios							
		Continental Markets			Regional Communities		
	Purchasing Power Standard US $ (2000)	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Austria	25400	2.16	2.43	1.84	1.23	1.38	0.62
Belgium	24000	1.95	2.19	1.84	1.03	1.16	0.62
Bulgaria	5300	4.87	5.15	2.74	3.75	3.88	1.66
Cyprus	16900	2.16	2.43	1.84	1.23	1.38	0.62
Czech Republic	13000	2.84	3.24	1.95	1.87	2.13	0.94
Denmark	25100	2.16	2.43	1.84	1.23	1.38	0.62
Estonia	8500	3.75	3.84	2.43	2.71	2.68	1.49
Finland	22300	2.16	2.43	1.84	1.23	1.38	0.62
France	22000	1.85	2.07	1.84	0.84	0.94	0.51
Germany	22600	1.85	2.07	1.72	0.84	0.94	0.62
Greece	16000	2.16	2.43	1.84	1.23	1.38	0.62
Hungary	10700	2.92	3.33	1.99	1.94	2.21	0.97
Ireland	24900	2.16	2.43	1.84	1.23	1.38	0.62
Italy	22300	1.64	1.84	1.61	0.74	0.83	0.30
Latvia	7000	3.75	3.84	2.43	2.71	2.68	1.49
Lithuania	7500	3.75	3.84	2.43	2.71	2.68	1.49
Luxembourg	46400	1.95	2.19	1.84	1.03	1.16	0.62
Malta	15900	2.16	2.43	1.84	1.23	1.38	0.62
Netherlands	25600	1.74	1.95	1.72	0.94	1.05	0.72
Poland	9200	3.00	3.41	2.03	2.01	2.29	1.01
Portugal	14900	2.16	2.43	1.84	1.23	1.38	0.62
Romania	4900	4.87	5.15	2.74	3.75	3.88	1.66
Slovakia	9500	3.26	3.68	2.15	2.25	2.53	1.12
Slovenia	15000	2.43	2.78	1.72	1.49	1.70	0.73
Spain	18500	2.71	3.05	2.19	1.43	1.61	0.51
Sweden	24100	2.16	2.43	1.84	1.23	1.38	0.62
United Kingdom	22300	1.95	2.19	1.61	1.03	1.16	0.51

ANNEX II EU MEMBER STATE POPULATION IN EURURALIS 2.0

Trends in population in the four Eururalis 2.0 scenarios							
	Global Economy				Global Co-operation		
x 1000	**2000**	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Austria	8024	7968	8071	8254	7951	7988	8064
Belgium	10059	10094	10269	10557	10074	10166	10318
Bulgaria	7799	7088	6648	6420	7071	6576	6261
Cyprus	787	853	918	985	851	909	964
Czech Republic	10249	10154	10230	10397	10134	10124	10156
Denmark	5289	5375	5518	5749	5365	5464	5621
Estonia	1394	1260	1179	1135	1257	1166	1107
Finland	5022	5072	5181	5327	5061	5128	5205
France	59314	61352	63739	66396	61232	63116	64934
Germany	82170	82505	83626	84968	82343	82791	83036
Greece	10634	10850	11058	11336	10829	10949	11083
Hungary	9972	9519	9326	9363	9499	9227	9141
Ireland	4010	4382	4757	5151	4374	4712	5042
Italy	57910	57149	56865	57487	57037	56291	56159
Latvia	2434	2328	2281	2268	2324	2258	2215
Lithuania	3719	3721	3799	3915	3714	3761	3827
Luxembourg	440	487	531	575	486	526	563
Malta	387	408	429	455	407	425	445
Netherlands	15802	16374	17038	17746	16342	16868	17347
Poland	37557	37809	38645	39831	37733	38260	38936
Portugal	10041	10137	10337	10697	10118	10235	10459
Romania	22276	21958	22038	22534	21914	21815	22021
Slovakia	5312	5418	5604	5821	5407	5548	5691
Slovenia	1990	1995	2015	2057	1991	1995	2010
Spain	39769	39971	40351	41029	39878	39933	40079
Sweden	8818	8889	9158	9476	8871	9064	9261
United Kingdom	58785	59699	61670	64256	59582	61057	62821
EU27	**479964**	**482815**	**491282**	**504187**	**481843**	**486352**	**492764**

Trends in population in the four Eururalis 2.0 scenarios						
	Continental Market			**Regional Communities**		
x 1000	2010	2020	2030	2010	2020	2030
Austria	7916	7841	7739	7910	7747	7486
Belgium	10029	9977	9894	10020	9855	9569
Bulgaria	6951	6042	5118	6952	6026	5074
Cyprus	841	862	857	842	859	848
Czech Republic	10000	9520	8820	10009	9498	8742
Denmark	5347	5396	5463	5344	5334	5285
Estonia	1241	1096	956	1242	1095	949
Finland	5045	5064	5058	5042	5004	4891
France	60977	61956	62326	60902	61199	60293
Germany	82005	81289	79703	81902	80262	77038
Greece	10767	10682	10507	10753	10549	10165
Hungary	9375	8670	7907	9384	8656	7842
Ireland	4354	4623	4838	4350	4568	4686
Italy	56713	54945	53195	56656	54287	51467
Latvia	2290	2117	1915	2294	2116	1901
Lithuania	3663	3532	3323	3668	3528	3296
Luxembourg	483	515	540	483	509	522
Malta	405	415	421	404	410	408
Netherlands	16276	16570	16661	16255	16366	16111
Poland	37222	35964	33856	37253	35883	33545
Portugal	10055	9971	9898	10048	9862	9591
Romania	21524	20039	18128	21525	19983	17968
Slovakia	5335	5215	4950	5342	5207	4910
Slovenia	1964	1876	1747	1966	1873	1732
Spain	39642	38960	38006	39600	38501	36803
Sweden	8846	8959	9004	8835	8845	8702
United Kingdom	59321	59936	60284	59263	59187	58291
EU27	**478589**	**472032**	**461117**	**478245**	**467210**	**448113**

ANNEX III SCENARIO SPECIFICATIONS FOR LIVESTOCK DISTRIBUTION

Scenario	Global economy (A1)	Continental Markets (A2)	Global co-operation (B1)	Regional communities (B2)
Type of change	Proportional to current livestock distribution	Proportional to current livestock distribution	Resource capacity is leading, current livestock distribution is very important	Resource capacity is leading, more tendency for regionalized production
Land-based systems				
Carrying capacity [lu]*	1600 for non-irrigated arable land and pasture 10 for (semi-) natural vegetation, recently abandoned arable land, heather and moorlands, and recently abandoned pasture land	800 for non-irrigated arable land and pasture 10 for (semi-) natural vegetation, recently abandoned arable land, heather and moorlands, and recently abandoned pasture land	300 for non-irrigated arable land and pasture 10 for (semi-) natural vegetation, recently abandoned arable land, heather and moorlands, and recently abandoned pasture land	200 for non-irrigated arable land and pasture 10 for (semi-) natural vegetation, recently abandoned arable land, heather and moorlands, and recently abandoned pasture land
Producer preferences	High preference for large-scale grassland areas Moderate preference for current concentrations of land-based animal husbandry	Low preference for large-scale grassland areas High preference for current concentrations of land-based animal husbandry	Moderate preference for large-scale grassland areas Moderate preference for current concentrations of land-based animal husbandry	High preference for current concentrations of land-based animal husbandry
Land-less system				
Carrying capacity [lu]*	4000 for irrigated and non-irrigated arable land, pasture, permanent crops, arable land devoted to the cultivation of biofuel crops, and biofuel crops	3000 for irrigated and non-irrigated arable land, pasture, permanent crops, arable land devoted to the cultivation of biofuel crops, and biofuel crops	In NVZ**: 700 (2010), 600 (2020/30) and 1000 outside NVZ for irrigated and non-irrigated arable land, pasture, permanent crops, arable land devoted to the cultivation of biofuel crops, and biofuel crops	In NVZ**: 400 (2010), 300 (2020/30) and 700 outside NVZ for irrigated and non-irrigated arable land, pasture, permanent crops, arable land devoted to the cultivation of biofuel crops, and biofuel crops
Producer preferences	High preference near large harbours, towns, and current concentrations of land-less animal husbandry	High preference near towns and current concentrations of land-less animal husbandry	High preference near large harbours, towns, and current concentrations of land-less animal husbandry Some more spread compared to A1	Preference based on local production conditions, high preferences near towns, and current concentrations of animal husbandry High spread

* lu-livestock unit. Given values are maximum values that can be expected in this scenario.
** NVZ- Nitrate Vulnerable Zones. Carrying capacities are assumed to decrease over time because of full policy implementation.
Not listed land use types are assumed to have a carrying capacity of zero.

ANNEX IV N UPTAKE RATES

Country	N Uptake (kg N/ha)	
	upland crops	grass
Austria	88	37
Belgium	102	246
Bulgaria	30	30
Cyprus	55	148
Czech Republic	70	56
Denmark	137	206
Estonia	12	29
Finland	42	144
France	91	43
Germany	125	150
Greece	61	19
Hungary	59	32
Ireland	36	218
Italy	94	48
Latvia	10	17
Lithuania	19	95
Malta	1322*	68
Netherlands	232	363
Poland	57	72
Portugal	68	54
Romania	33	35
Slovakia	45	28
Slovenia	52	68
Spain	22	28
Sweden	58	101
United Kingdom	177	123

*Uncertain statistics

ANNEX V MEAN SPECIES ABUNDANCE VALUE PER LAND-USE TYPE

Land use Class	Mean Species Abundance
Built-up area	5
Arable land (non-irrigated) Intensive and extensive	10
Pasture intensive (>50 LSU/km^2)	10
(semi-) Natural vegetation (including natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes)	70
Inland wetlands	100
Glaciers and snow	100
Irrigated arable land	5
Recently abandoned arable land (i.e. 'long fallow'; includes very extensive farmland not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30 cm)	30
Permanent crops	20
Biofuel crops (Intensive)	10
Forest (natural/plantation – average forest age in region between 50 and 80 years)	70
Sparsely vegetated areas	100
Beaches, dunes and sands	100
Salines	100
Water and coastal flats	100
Heather and moorlands	100
Recently abandoned pasture land (includes very extensive pasture land not reported in agricultural statistics, grasses and shrubs below 30 cm)	30
Woody Biofuel crops	30
Pasture extensive(<50 LSU/km^2)	40
Forest (plantation when average forest age in region is under 50 years)	60
Forest (plantation when average forest age in region is under 40 years)	45
Forest (plantation when average forest age in region is under 30 years)	35
Forest (plantation when average forest age in region is under 20 years)	25
Forest (plantation when average forest age in region is under 10 years)	15
Forest (natural – average forest age in region older than 80 years)	100

ANNEX VI CARBON EMISSION FACTORS

Country	Emission factors (ton C/km²/year)				Forest biomass carbon stock[2] (ton C/km²)
	Grassland[1]	Cropland[1]	Wetlands[1]	Forest/ nature[2]	
Austria	25.5	-16.2	0.1	127	8210
Belgium +Luxembourg	15.8	-9.1	-9.1	127	6977
Bulgaria	6.8	-19.8	-0.3	54	3630
Cyprus	2.8	-10.1	-0.5	42	3818
Czech Republic	6.6	-35.8	-0.7	23	6830
Denmark	2.6	-39.9	-6.0	119	4110
Estonia	2.2	-39.7	-26.2	87	3500
Finland	5.6	-5.5	-12.8	43	2970
France	12.0	-19.1	-0.7	43	5520
Germany	13.6	-28.3	-6.4	134	7190
Greece	2.8	-10.1	-0.5	42	3818
Hungary	6.3	-44.8	-6.4	111	6180
Ireland	21.2	-12.3	-52.7	192	2910
Italy	12.7	-19.5	-2.8	67	5390
Latvia	2.9	-44.1	-7.9	87	3500
Lithuania	3.2	-60.8	-2.4	87	3500
Netherlands	18.4	-25.4	-47.1	111	4950
Poland	8.5	-36.6	-26.2	87	5410
Portugal	-4.5	-28.1	-2.0	92	2080
Romania	11.1	-30.7	-0.2	166	6640
Slovakia	12.2	-24.7	-0.7	91	6460
Slovenia	3.7	-8.2	0.5	65	7330
Spain	20.7	-4.7	-0.4	33	1330
Sweden	1.2	-6.5	0.4	68	4070
United Kingdom	24.2	-13.7	-27.5	165	3990

[1] Janssens et al., 2005
[2] Karjalainen et al., 2003

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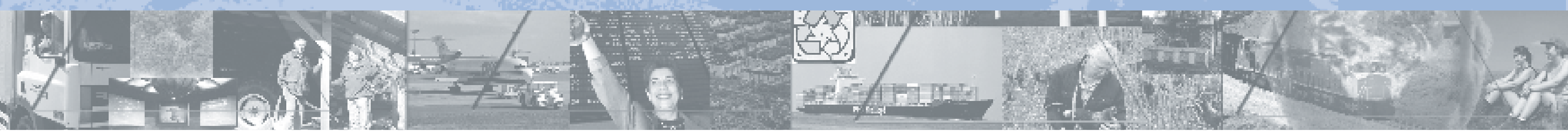

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