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Module 1:
Driving Forces and Global trends

Workpackage 1.1:
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PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

D1.1.2 Calculation of land use price and land use claims for agriculture, transport and urban land use at national level

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SIXTH FRAMEWORK PROGRAMME

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Abstract

Objectives

The current deliverable report has been prepared in the framework of PLUREL Work Package 1.1 (Economic Scenarios) by Paris 1 Université – Lab. ERASME.

Methodology

The implementation of four scenarios for the PLUREL project allows the description of a range of possible futures in order to evaluate peri-urban land-use development. In this context the economic model NEMESIS provides, at a national level, a general overview of the impacts of such scenarios on different land-use types : agriculture, transport infrastructures and urban. The model uses a land-use module which takes into account the scarcity of land and implements a hierarchy between different land-use categories. Moreover, the module is based on economic mechanisms *i.e.* on the interaction between demand and supply which leads to land price. This evaluation of land-use by the NEMESIS model gives a starting point to other PLUREL partners. For instance Module 2 develops a downscaling approach of the results. This document presents the NEMESIS land-use module, its implementation in the core-model and provides simulation results for PLUREL scenarios explaining differences between scenarios as well as between countries.

Results

Scenarios with R&D investments (mainly for A1 “Hyper-tech” and to a smaller extent for A2 “Extreme water”) have important economic performance that pushes up demand for land from the industry and service sectors, and from households. Therefore, urban expansion is high in those scenarios. Nevertheless, the productivity gains allow a weak increase of agricultural needs for which the evolution is very similar between scenarios because there is either strong land intensification or a weak one in the agriculture sector.

% change between 2008 and 2025	Agricultural Production			Land-Use Farms size			Agricultural land use			Urban land use		
	EU	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**	**EU**	**EU-15**	**NMS**
A1 - "Hyper tech"	14.1%	13.4%	20.9%	58.6%	37.2%	81.2%	1.0%	1.1%	0.9%	9.9%	7.0%	18.6%
A2 - "Extreme water"	7.0%	6.4%	12.8%	71.4%	46.4%	98.4%	0.6%	0.7%	0.6%	9.7%	6.8%	18.4%
B1 - "Peak oil"	3.7%	3.2%	7.8%	55.8%	39.0%	72.5%	0.5%	0.6%	0.5%	7.9%	5.5%	15.2%
B2 - "Fragmentation"	2.6%	2.5%	4.0%	56.5%	38.8%	74.0%	0.3%	0.4%	0.3%	8.1%	5.8%	15.0%

Table 1: Land use change in PLUREL scenarios at EU level (summary results)

Finally, despite the difference in the drivers of B1 “peak Oil” and B2 “fragmentation”, we observe important similarities in land use results as was the case for economic results. Nevertheless, the dynamic between the both scenarios is not similar and some country results also differ.

Keywords

Economic modelling, Land use, agriculture and scenarios

Classification of results/outputs

Spatial scale for results:	EU-27 (excluding Bulgaria and Cyprus) EU countries (excluding Bulgaria and Cyprus)
DPSIR framework:	Drivers
Land use issues covered:	Agriculture Transport and urban land use
Scenario sensitivity:	Yes
Output indicators:	Land use structure
Knowledge type:	Detailed applied economic model (using a land use module)

How many fact sheets will be derived from this deliverable:	**1**

Introduction

In this document we present the results for land-use price and land-use claims for agriculture, forestry and urban. These results come from the macro-sectoral econometric model NEMESIS, which includes a land-use module computing the land use price and the allocation of different land use categories.

The land use market is characterized by land demand for agricultural production (vegetable production or animal production), which have priority over other land use types with respect to the available area. Land change priority leads to a constraint on total land available for agriculture. The land availability constraint is then represented as an asymptote for land supply. The initial situation of each country for the land asymptote determines the land price elasticity of land supply. An elasticity close to zero is present in countries with weak "unused" land.

The NEMESIS' land use module is used for the four PLUREL scenarios which are

- A1 "Hyper-tech", economic growth is important in EU (3.1% in average) and in the rest of the World, and innovation and productivity is pushed by huge investment in R&D.
- A2 "Extreme water", World economic growth is very weak, the EU's economic growth (2.8%) is only driven by EU R&D policies.
- B1 "Peak oil", energy prices reach a peak in 2015 (130 $\$_{2000}$) which contracts economic growth (2.1%)
- B2 "Fragmentation", the World is fragmented, EU external demand is weak, and environmental policies such as carbon tax reduce strongly economic growth (2%)

So, NEMESIS simulations of PLUREL scenarios provide different land use categories as well as land prices for each country and each scenario. Land demand is influenced by economic results and the general context of each scenario (presented in detail in D.1.1.1, Boitier *et al.* 2008).

The document is organized as follows: after a short overview of the PLUREL scenarios, the first part is devoted to presenting the general mechanisms of the NEMESIS land use module, and the second part presents the results for each PLUREL scenario, focussing on agricultural, transport infrastructure and aggregated urban land-use.

PLUREL Scenarios short overview

A comprehensive scenario framework was developed and led by CURE:

- based on the concept of the IPCC 'SRES' scenarios, adapted for the PLUREL
- applied to model settings, in economic, demographic and land use modelling;
- further extended with a series of 'shocks' i.e. accelerated change;
- flexible and arranged as a scenario 'cascade' in order to provide links from M1 to other Modules.

These scenarios are outlined in the figure below. Each shock is intended to reflect one of the M1 work packages. The variants are as follows (including interim titles, and showing the lead Work Packages for each):

- ***A1-hyper-tech***, rapid development in ICT leading to reduced commuting and transport needs, with no constraints on the location of new build.
- ***A2-water world*** **-** climate change reaches a tipping point leading to impacts including rapid sea level rise, flooding and water resource constraints
- ***B1-peak oil***, an energy price shock occurs, leading to rapidly increasing energy and transport costs and consequent changes in mobility and trade flows.
- ***B2-fragmentation***, a pandemic disease leading to major population declines and behavioural shifts within society.

This broad framework is summarized in Figure 1, and further detailed in Figure 1. For more details on PLUREL scenarios see the deliverable 1.3.1 (Ravetz *et al.* 2008).

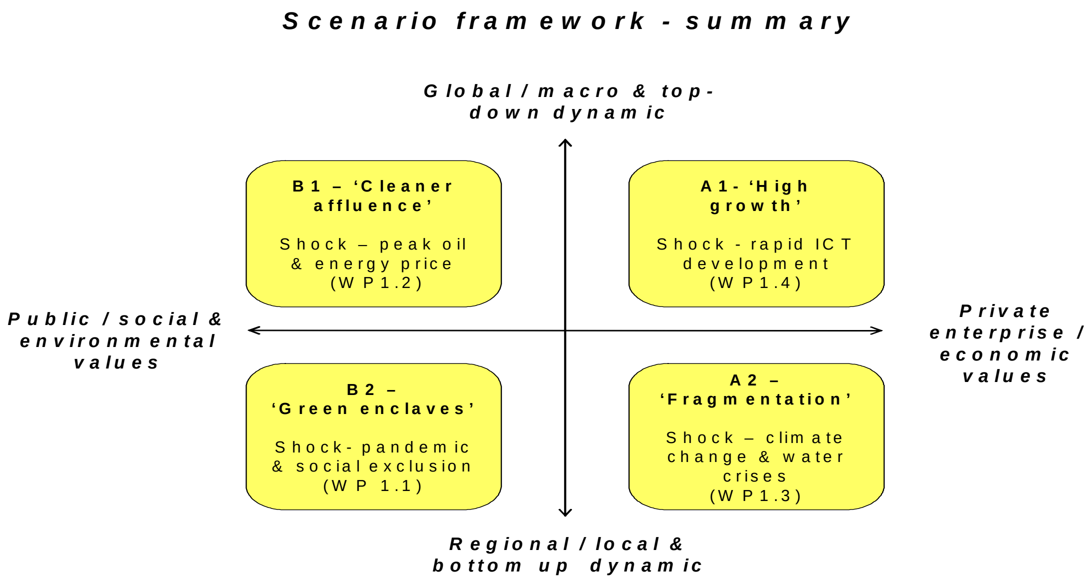


Figure 1: PLUREL scenarios framework

1 NEMESIS' Land-Use Module

1.1 General Overview

The NEMESIS model is a macro-econometric model for Europe (EU-27+Norway expect Cyprus and Bulgaria) which details the economic activity for each Member States (MS) in thirty production sector and twenty-seven consumption goods.

Box 1.1 : Short overview of the NEMESIS model[1]

The NEMESIS model (New Econometric Model of Evaluation by Sectoral Interdependency and Supply), has been funded under the fifth and sixth RTD Framework Programs of European Commission General Directorate of Research. It is a system of economic models for European countries (EU-27), devoted to study issues that link economic development, competitiveness, employment and public accounts to economic policies, and notably all structural policies that involve long term effects: RTD, environment and energy regulation, general fiscal reform, etc. The essential purpose of the model is to provide 'Business As Usual' (BAU) scenarios or counter-factual scenarios, up to 10 to 30 years. NEMESIS uses as main data source EUROSTAT, and specific databases for external trade (OECD, New CRONOS), technology (OECD and EPO) and land use (CORINE 2000). NEMESIS is recursive dynamic model, with annual steps, and includes more than 160,000 equations.

The main mechanisms of the model are founded on the behaviour of representative agents: Firms, Households, Government and Outside. These mechanisms are based on econometric works.

The main originality of the model lies in the belief that the medium and long term of the macroeconomic path is the result of strong interdependencies between sectoral activities that are very heterogeneous from a dynamic point of view, with leading activities grounded on Research and Development, and from environment and sustainable development with a huge concentration of pollutants on few activities. These interdependencies are exchanges of goods and services in markets but also external effects, such as positive technological spillovers and negative environmental externalities.

Main mechanisms

On the supply side, NEMESIS distinguishes 32 production sectors, including Agriculture, Forestry, Fisheries, Transportations (4), Energy (6), Intermediate Goods, (5) Capital goods (5), Final Consumption Goods (3), Private (5) and Public Services. Each sector is modelled with a representative firm that takes its production decisions given its expectations on production capacity expansion and input prices. Firms' behaviour includes very innovative features grounded on new growth theories, principally endogenous R&D decisions that allow firms to improve their process productivity and product quality. Production in sectors is in this way represented with CES production functions (with the exception of Agriculture which uses Translog functions, and Forestry and Fisheries where technology is represented with Leontief functions) with 4 production factors: capital, labour, energy and intermediate consumption, where also endogenous

[1] Please see www.erasme-team.eu for a detailed description of the NEMESIS model and other information related to the model. For publication with the NEMESIS model see *e.g.* Brécard *et al.* (2006) or Chevallier *et al.* (2006).

innovations of firms modify the efficiency of the different inputs (biased technical change) and the quality of output (Hicks neutral technical change). The production function was estimated by the dual approach and estimation and calibration of links between R&D expenditures, innovations and economic performance were picked up from the abundant literature on the subject. Interdependencies between sectors and countries are finally caught up by a collection of convert matrices describing the exchanges of intermediary goods, of capital goods and of knowledge in terms of technological spillovers, and the description of substitutions between consumption goods by a very detailed consumption module enhance these interdependencies.

On the demand side, representative household aggregate consumption is dependent on expectations of lifetime earnings but with a slow adjustment to changes in current income. Total earnings are a function of regional disposable income, a measure of wealth for the households, interest rates and inflation. Variables covering child and old-age dependency rates are also included in an attempt to capture any change in consumption patterns caused by an ageing population. The disaggregated consumption module is based on the assumption that there exists a long-run equilibrium but rigidities are present which prevent immediate adjustment to that long-term solution. Altogether, the total households' aggregated consumption is indirectly affected by 27 different consumption sub-functions through their impact on relative prices and total income, to which demographic changes are added. Government public final consumption and its repartition between Education, Health, Defence and Other Expenditures, are also influenced by demographic changes.

For external trade, it is treated in NEMESIS as if it takes place through two channels: intra-EU, and trade with the rest of the world. The intra- and extra-EU export equations can be separated into two components, income and prices. The income effect is captured by a variable representing economic activity in the rest of the EU for intra-EU trade, and a variable representing economic activity in the rest of the world for extra-EU trade. Prices are split into two sources of impacts in each of the two equations (intra- and extra-EU trade). For intra-EU trade, they are the price of exports for the exporting country and the price of exports in other EU countries. For extra-EU trade, price impacts come through the price of exports for the exporting country, and a rest-of-the-world price variable.

Main uses

With its original characteristics and great detail in its results, NEMESIS can be used for many purposes as medium/long-term economic and industrial "forecasts" for business, government and local authorities; analysing various scenarios and economic long-term structural change, energy supply and demand, environment, land-use and more generally sustainable development; revealing the long term challenges of Europe and identifying issues of central importance for all European, national, regional scale structural policies; assessing for most of the Lisbon agenda related policies and especially knowledge (RTD and human capital) policies; emphasizing the RTD aspect of structural policies that allows new assessments (founded on endogenous technical change) for policies, and new policy design based on knowledge: Education, Skill and Human Capital and RTD.

NEMESIS has notably been used to study various scenarios for the economic future of the EU and reveal the implication for European growth, competitiveness and sustainable development of the Barcelona 3% GDP RTD objective, of the 7th Research Framework Program of European Commission, of National RTD Action Plans of European countries, of European Kyoto and post-Kyoto policies, etc. NEMESIS is currently used to assess the European Action plan for Environmental and energy technologies, for European financial perspective and for the Lisbon agenda.

Furthermore, NEMESIS, in addition to its economic-core, includes several modules *i.e.* parts of the model that can be used or not used according to the requirements. There are different modules for energy/environment[2], for the agriculture sector, for downscaling economic indicators to NUTS-2, and for land use. The last module is in the centre of this chapter and is presented in detail below.

The NEMESIS land use module[3] distinguishes 3 main land-use categories which are divided into sub-categories:

- agricultural land: arable land and grassland
- built-up areas: housing, commercial and industrial buildings, road areas and railways areas
- natural areas: forest, nature conservation and wetlands

Agricultural land use gives priority of available land to built areas. But built areas cannot be transformed into agricultural land. So natural areas and built-up areas make up an asymptote to agricultural land supply (Le Mouël *et al.* 2008, Jansson *et al.* 2008). The asymptote allows building a functional form for agriculture land supply, which is represented in the module through the price function *i.e* the inverse supply function.

Regardless of the demand side, agriculture land claims are divided into two types: arable and grassland. These land categories are related to agricultural production, arable land following vegetal production whereas grassland is driven by animal production. Nevertheless, land is considered like an input for agriculture and then land demand results from farmers' optimization behaviour which allows these inputs to take into account technology and input prices. The farmer's behaviour is represented in the NEMESIS model by a translog cost function.

Forest, nature conservation and wetland are constant in the module. Forest could evolve in line with forestry activities but the need of expertise for Forest areas is huge and we prefer to keep it constant. Indeed, forest area "forecasts" and especially for protected ones, requires important knowledge of forestry practices, national forest maintenance policies for aforestation and deforestation and detailed information on trees (age, species, soil types, etc). But these pieces of information are not easily available and their proper implementation in the NEMESIS land use module is not possible in this state-of-the-art model as it would require a substantial amount of time. But as forestry is not the main PLUREL focus, it is supposed that forest land is constant.
In the NEMESIS model, forestry is an independent sector for which the projection of its activities were based on FAO forecasts (F.A.O. 2005) and are corrected by taking into account differences in national general

[2] The energy/environment module was under development when the PLUREL scenarios were realised.
[3] See Boitier (2010) for detailed on the NEMESIS land use module.

economic activities[4]. In other words, we took the FAO projections for the case of a business-as-usual scenario and we corrected those projections taking into account the change in GDP between this business-as-usual scenario and the PLUREL ones.

The aggregation of forest, nature conservation, wetland and built-up areas permits establishing the asymptote for available land which is presented in the next section.

1.2 Asymptote and inverse supply function

As presented in the former section, each land sector poses different land claims which are dealt with in a hierarchical manner. Thus, available area (*i.e.* unused agricultural lands and unprotected forest) is allocated uppermost to agricultural land claims *i.e.* for agricultural production. Therefore, agricultural land has priority over built-up areas for the use of available land. But after land conversion, the order of land priority changes; built-up areas can not be converted to other land-use types. Forest, nature conservation and wetlands are supposed to be protected and therefore stay constant. So after land conversion, land available for agriculture is constrained by other land-use categories which drive the position of the asymptote for agriculture land supply (Le Mouël *et al.* 2008, Jansson *et al.* 2008). Figure 2 portrays the land market with the asymptote.

[4] For instance, there is also the EFORWOOD (http://87.192.2.62/eforwood/default.aspx) European project that could be used for forestry projection, but studies were not available when we realised the PLUREL scenarios.

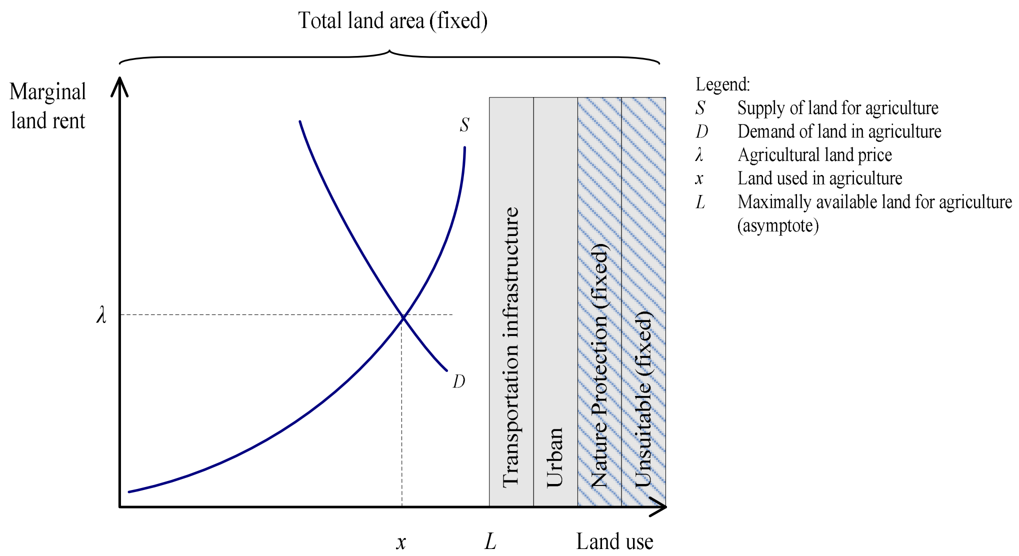


Figure 2: Land-use market in NEMESIS land-use module (Jansson *et al.* 2008)

Therefore, we construct land supply for each EU country *i* with the following functional form:

Equation 1: Land supply functional form

$$Q^S_{ag,i} = A_i - \frac{B_i}{\lambda^{\alpha}{}_{L,i}}$$

$$\text{with, } A_i > 0,\ B_i > 0,\ \alpha > 0,$$

$$Q \in [0; A_i],\ \lambda \in \left[\left(\frac{B_i}{A_i}\right)^{1/\alpha}; +\infty\right]$$

Where, $Q^S_{ag,i}$ represents the land used by agriculture[5], A_i and B_i are positive parameters, α is also a positive parameter and $\lambda_{L,i}$ is defined as land price.
The parameter A_i can also be interpreted as total land available for agriculture *i.e.* $\lim_{\lambda \to +\infty} Q^S_{ag,i}(\lambda_{L,i}) = A_i$. Consequently A_i represents the asymptote in Figure 2.
Whereas, if $\lambda = 1$, then $B_i = A_i - Q_{Ag,i}$. When land price is normalised to 1 for the base year, B_i is then equal to available area or unused lands.

This functional form for the land supply is inspired by Tabeau *et al.* (2006). Tabeau *et al.* use biophysical data for the IMAGE model (Bouwman *et al.* 2006), displaying that this functional form represented

[5] We use *i* as an index for country, we keep this notation in this document without specify it every time.

above can be justified by a graphical representation of a land productivity inverse curve.

For illustration, Figure 3 shows the inverse supply function for Austria, with a land price normalized to 1 in 2000. In 2000, Austrian land available for agricultural was about 50,000 km², whereas only 34,000 km² is used. Thus the initial position (the red point on figure 2) for Austria is relatively far from the asymptote and land price sensitivity to land supply (land price elasticity of land supply) is relatively weak (see next section).

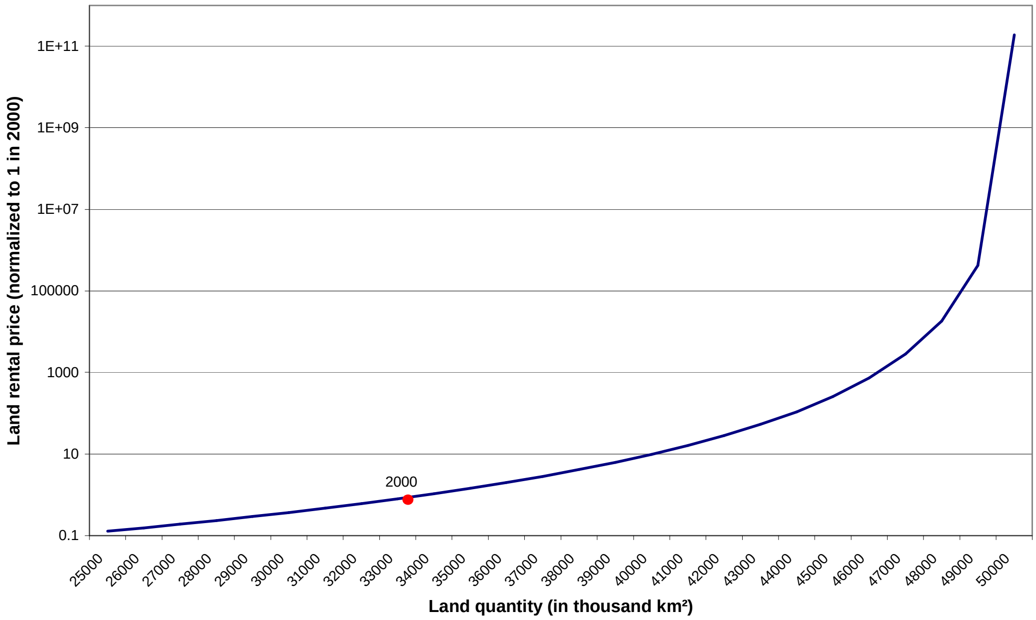


Figure 3: Inverse land supply curve (Austria, logarithmic scale)

1.3 Elasticity of land supply to land price

As presented in Figure 3, land supply elasticity depends on the initial situation of each country and so can be very changeable. Figure 4 shows the percentage of agricultural land used to total available agricultural land. There are important differences between countries, for instance Estonia uses relatively little land for agriculture compared to the available quantity (around 25%) whereas Malta uses almost all available land for agriculture (96%). On average for the Member States plus Norway, 35% of the land available for agriculture was not used by agriculture in 2000.

For the estimation of the α parameters in the land supply equation[6], we used different data sources: Eurostat (Structure of Agricultural Holdings, Selling prices of agricultural products (absolute prices), land prices and rents and Annual National Account) and the FADN (Farm Accounting Data Network) database. Thus we have a data set covering 13 EU countries with data starting from 1990 for the longest and finishing in 2007. We have then estimated each available country, and we used the panel estimation results for the unavailable countries[7]. The estimates of α range from 0.28 for Czech Republic to 3.1 for France whereas the panel estimate gives 0.71.

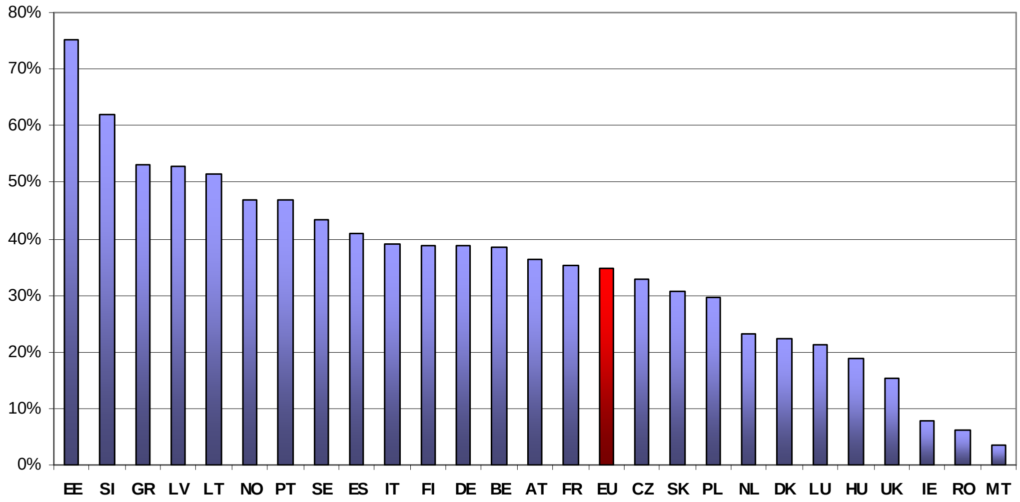


Figure 4: Agricultural land used in percentage of total agricultural land usable, in 2000

Taking into account the functional form presented in the last section, the estimates of the α parameters and the country's initial situation, the elasticity of land supply to land price is equal to:

Equation 2: Land supply elasticity to land rental price

$$\varepsilon_{Q/\lambda} = \frac{\partial Q(\lambda)}{\partial \lambda}\frac{\lambda}{Q(\lambda)} = \frac{\alpha B}{A\lambda^{\alpha} - B}$$

So, we can compute elasticities for each country[8]. Table 2 shows land supply elasticities to land price for European countries in 2008, we suppose that land price is normalized to one in 2008.

[6] See Boitier (2010) for details on land supply estimates.
[7] Available countries are: Belgium, Czech Republic, Germany, Denmark, Spain, Finland, France, Ireland, Italy, Lithuania, Luxembourg, Latvia, Sweden and United Kingdom.
[8] The Equation 2 does not include the country index i, by simplicity, but the elasticity is individualised by country.

AT	1.19	**LT**	0.17
BE	0.23	**LU**	1.29
CZ	0.16	**LV**	0.42
DE	1.09	**MT**	0.10
DK	0.06	**NL**	0.12
EE	1.21	**NO**	0.19
ES	0.36	**PL**	0.41
FI	4.65	**PT**	0.30
FR	1.42	**RO**	0.01
GR	0.36	**SE**	2.45
HU	0.24	**SI**	1.32
IE	0.07	**SK**	0.51
IT	0.32	**UK**	0.10

Table 2: Land supply elasticity to land price, in 2008

Land supply is relatively heterogeneous among European countries[9]. For instance, an increase of 1% in the land rental price in Italy leads to an increase in land supply of about 0.32% whereas in Estonia it leads to an increase of about 1.21%.

The range of elasticities between 0.1-4.6 is difficult to compare with other values in the literature. Indeed, to our knowledge, there are few estimates of land supply elasticity with respect to land price. Abler (2003) finds elasticities in line with some of our estimates *i.e.* between 0 and 0.2 but Abler only gives the range of estimates for EU without additional details. The work of Tabeau *et al.* (2006), on which our modeling is based, supposed that alpha is equal to 1[10], thereby the elasticity will be defined by the initial condition and the elasticity would be about 0.51 for Europe whereas in our estimates, it gives around 0.7. We can also speak about the LINKAGE model (van der Mensbrugghe 2005) which uses a logistic functional form for the land supply, but the parameters of the function are not given.

Therefore it is relatively difficult to compare our elasticity estimates to others, but according to the value presented above, it seems that there are no unrealistic values. Furthermore, land price elasticity with respect to land supply (*i.e.* the inverse of Equation 1) is an increasing function of land scarcity that seems to be logical. In other words, the closer land quantity is to the asymptote, the more the price change will be important for the same change in land supply. We observe low land supply elasticity in Romania (0.01), Ireland (0.07) and the United Kingdom (0.1) and high ones for Estonia (1.21), Sweden (2.45) and Slovenia (1.32).

[9] Countries nomenclature is available in appendix.
[10] In reality, the functional form for Tabeau *et al.* (2006) is much more complex but we do not go in detail to simplify.

1.4 Land-Use module linkage with NEMESIS model

After having shown how we determine land supply, we explain in this section how land demand is computed. Land demand comes from the agricultural sector of the NEMESIS model and thus makes the link with the "core model". Farmers take land as a production factor for vegetal and animal agricultural production. Grassland is an input for animal production whereas vegetal production uses arable land as a production factor.

In NEMESIS' agriculture sector, inputs are determined by a production factor demand system which is modelled through a transcendental logarithmic (translog) functional form (Christensen *et al.* 1973 and Berndt and Christensen 1973). The translog functional form allows the estimates of numerous elasticities of substitution between flexible inputs and quasi-fixed inputs (see Ngwa Zang and Le Mouël 2007).

Agricultural land is assumed to be a fixed production factor in the medium term but variable in the long term. Thus, land demand from a representative farmer, at the optimal equilibrium condition, is defined by the equality between the cost reduction implied by a change in land and the cost of this land, that leads with the translog function developed by Ngwa Zang and Le Mouël (2007) to :

Equation 3: Agricultural land demand

$$Q_{ag,i}^{D} = -\frac{\partial \log(CV_i)}{\partial \log(Q_{ag,i}^{D})} \cdot \frac{CV_i \cdot \left(1+\sum_{u=1}^{4} SK_{u,i}\right)}{UC_i(\lambda_i)}$$

$$\Leftrightarrow Q_{ag,i}^{D} = -\varepsilon_{CV_i/Q_{ag,i}^{D}} \cdot \frac{CV_i \cdot \left(1+\sum_{u=1}^{4} SK_{u,i}\right)}{UC_i(\lambda_i)}$$

where $Q_{ag,i}^{D}$ is the land demand, $UC_i(\lambda_i)$ is the user cost which is a function of land price λ_i, CV_i is the variable cost or short term cost where $\log(\lambda_i)$ is characterized by a translog functional form and $SK_{u,i} = \frac{PK_{u,i} . K_{u,i}}{CV_i}$ is the "pseudo-share" of capital u in the short term cost[11]. The translog short term cost function differentiated with respect to the logarithm of land

[11] Theoretical aspects of a system of production factor with flexible, quasi-fixed and fixed factors are not developed in this document. Interested reader can refer to Nadiri and Schankerman (1980) and more precisely for NEMESIS agriculture module: Ngwa Zang and Le Mouël (2007).

demand is equal to the short term cost elasticity with respect to land demand ($\varepsilon_{CV_i/Q^D_{ag,i}}$).

The land demand function is homogeneous of degree zero relative to input prices and is decreasing in land price. Thus this demand respects theoretical properties of production factor demand. Other noteworthy properties can be established in this input demand system. Notably that there is a "scale effect" on variable cost (CV_i) with respect to land by farm unit and production *i.e* that if agricultural production and land used by farm units increases by 1% the variable cost increases by less than 1%, around 0.65%[12]. Whereas if only agricultural production increases by 1% and land used by farm units stays constant then variable cost increases by about 1%. So an important stabilisation for land demand will be the farmer incomes. That is to say that when farmer incomes decrease, some of them drop agricultural activities in favour of other sectors. The decease in farm numbers increases land yield and thus reduces land demand for the same national agricultural production.

The interaction of agricultural land demand and land supply lead to equilibrium in the agricultural land price as well as land quantity. This land is then split between arable land and grassland using the evolution of the share of vegetable production and animal production respectively whereas land price is passed on by the construction sector production price *i.e* investment price. So with aggregation of land requirements for commercial and industrial buildings, housing and transport infrastructures, we can establish urban land used. A description of urban sub-categories demand is detailed in deliverable D.1.1.3. In this document we only present the aggregation of these urban land sub-categories.

But briefly, urban land use is modelled with economic criteria. We calculated the stock of buildings (for housing or commercial and industrial buildings) in monetary units (*i.e.* in €$_{2000}$) for each member state by using the perpetual inventory method and with the help of the household investment function in housing and with the help of the firms capital investment addressed to the construction sector for commercial and industrial buildings. With those stocks of buildings, we compute density coefficients (*i.e.* number of km² by €$_{2000}$ of buildings stocks) for each member state and for commercial and industrial buildings and for housing. For transport infrastructure, we apply a similar methodology but with the investment in roads and in railways.

[12] Please refer to Ngwa Zang (2008) for justification.

2 Land Price and main land-use results[13]

2.1 *Agricultural land use*

Figure 5 shows European agricultural output for the PLUREL scenarios. One can see that European agricultural production grows more slowly than other economic sectors[14] (average annual growth of European GDP is about 3%, 2.6%, 2.2% and 2% respectively in A1 “Hyper-tech”, A2 “Water World”, B1 “Peak Oil” and B2 “Fragmentation”).

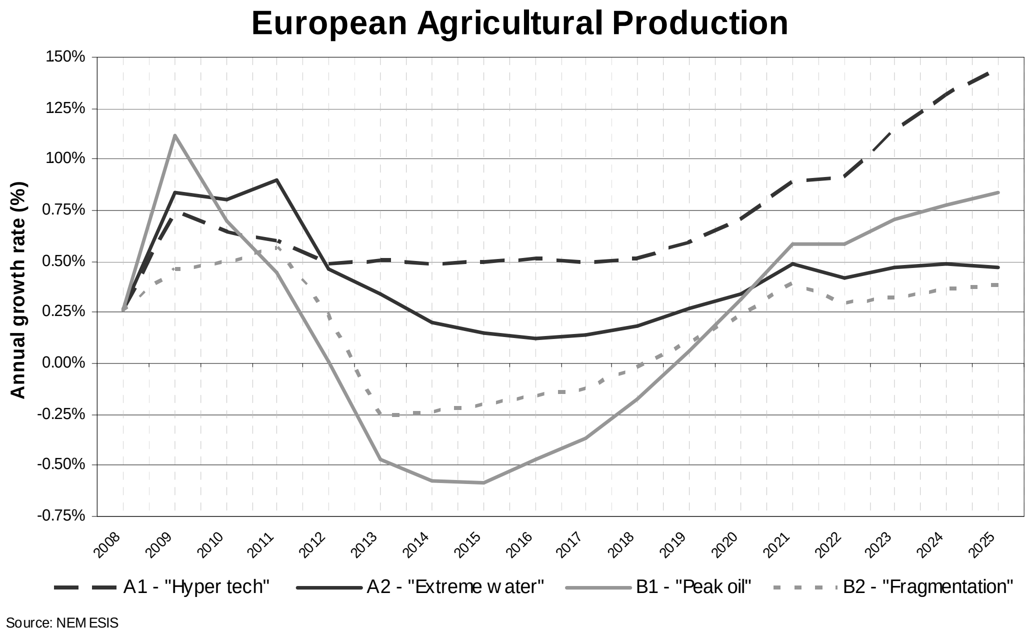


Figure 5: Annual growth rate of European Agricultural Production (2008-2025)

It reflects past trends and the fact that agricultural goods are generally inferior goods *i.e.* share of these goods in spending decreases when income increases. In addition to internal demand which is then weakly sensitive to price, the difference between scenarios comes from the external demand (weak in A2 “Water World” and B2 “Fragmentation”) and EU agricultural competitiveness which is very high in A1 “Hyper-tech” and relatively high

[13] We will present only European results in this section, expect when it is necessary for understanding, but all the national results are available in appendix. Furthermore some results are available on PLUREL Dataware House. If interested reader or partners have specific requests on results, please contact corresponding author: baptiste.boitier@ecp.fr

[14] Please refer to deliverable Ravetz *et al.* (2008) for scenarios definition and Boitier (2008) for detailed economic results.

in A2 “Water World” due to the effects of R&D investments. Finally production costs also influence agricultural goods demand and notably in the B1 “Peak Oil” scenario where the oil price pushes up inputs costs. We can also see that the agricultural production growth rate follows general economic activity with less amplitude as explained above. Agricultural production is strongly linked with farm size as explained in section 1.4. We use non-salaried workers as a proxy for number of farms.

Figure 6 shows European farms land-use size. Scenario A2 “Extreme Water,” with an average annual growth rate of 3.2%, demonstrates a strong agricultural concentration especially in eastern member states where increases in farm size reaches 6% in Latvia or 4% in Romania (see Figure 18 in appendix).
A2 “Extreme Water” is confronted by relatively weak external demand from the rest of the World and incorporates R&D policy, so incomes in agriculture are not held up by external trade as in A1 “hyper-tech”, but R&D investments, occurring in the whole economy, favour services or high technological industry at the expense of other “traditional activities” such as agricultural production. So farmers withdraw from agriculture for more lucrative activities. This explains why after 2017, when the economic effects of R&D policies start to take place, scenarios A1 “Hyper-tech” and B2 “Extreme Water”, in which R&D policies take place, European farms’ average size continues to increase at the same growth rates as before.

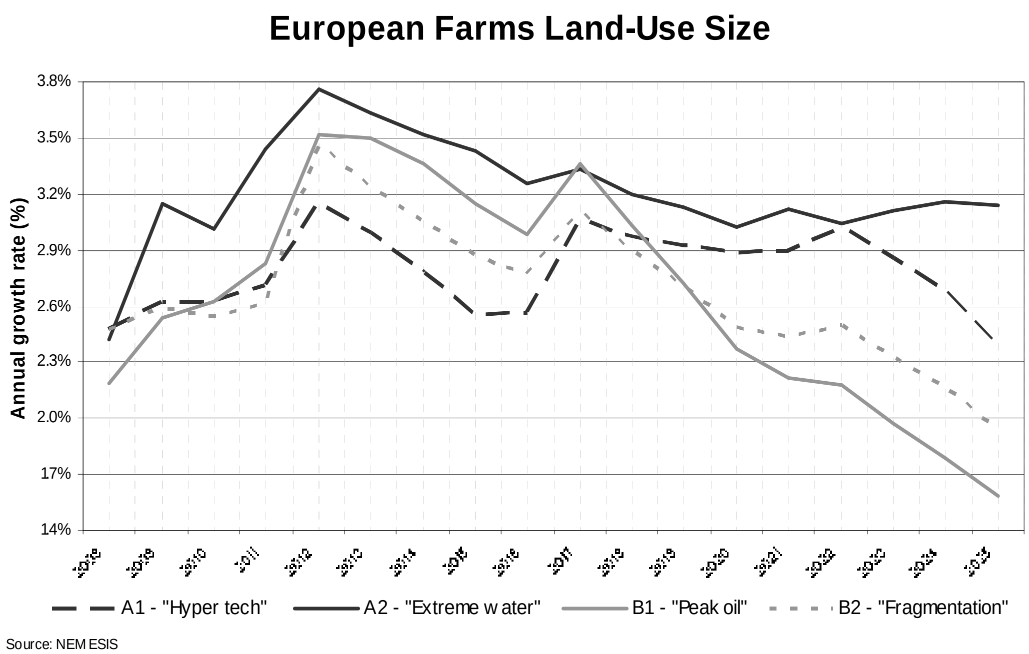


Figure 6: Annual growth rate of European Farms Land-Use size for PLUREL scenarios (2008-2025)

Whereas in both B1 “Peak Oil” and B2 “Fragmentation” scenarios, where farmers’ incomes begin to stabilize after 2017 compared to the rest of the economy, the growth rate of average farm size in terms of land-use starts to decrease to reach that of B1 "Peak Oil": 1.5%.

Therefore, on average, the land-use size of European farms changes from 30 ha per farm in 2007 to 54 ha in 2025 in A2 "Extreme Water", 50 in A1 "Hyper-tech" and 48 for B1 "Peak Oil" and B2 "Fragmentation". Nevertheless, at MS level (see Table 6 in Appendix) the changes are more contrasted, for instance, in Romania, the farm size starts at 10 ha per farm in 2007 and reaches 21 in A2 "Extreme Water" whereas it is about 16 in B1 "Peak Oil" and B2 "Fragmentation".

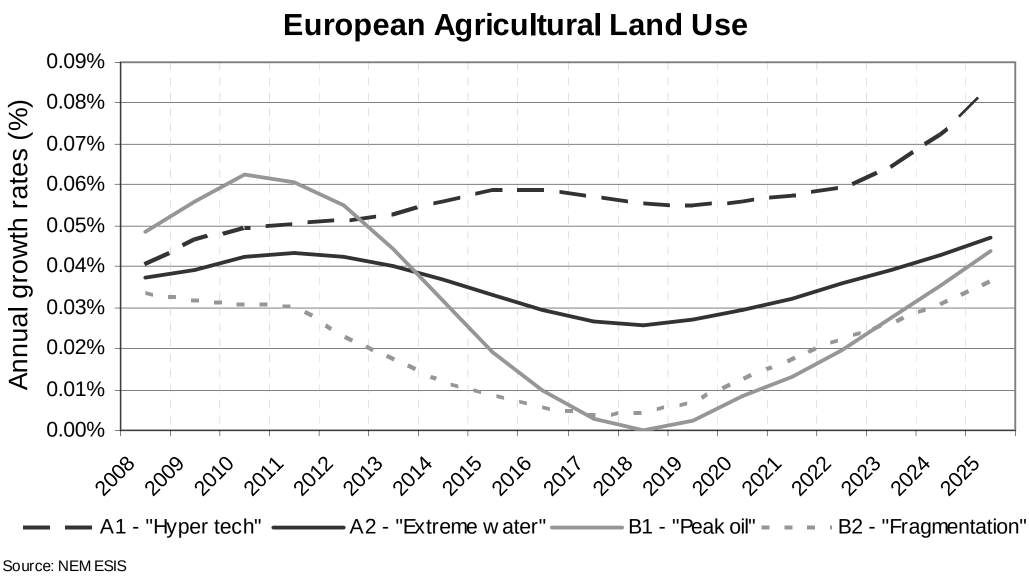


Figure 7: Annual growth rate of European Agricultural Land-Use for PLUREL scenarios (2008-2025)

European agricultural land use is relatively stable in the four PLUREL scenarios. Between 2008 and 2025, it increases by 1.1% (19 500 km²), 0.73% (12 900 km²), 0.61% (10 900 km²) and 0.43% (7 500 km²) respectively for A1 "Hyper-tech", A2 "Extreme water", B1 "Peak oil" and B2 "Fragmentation". Disparity between countries is huge; for instance Estonia displays an agricultural land-use increase of about 18% to 25% depending on the scenario (Figure 20 in Appendix) whereas it decreases about 0.25% and 1% in Slovakia. The disparity exists also between scenarios, for example in A1 "hyper-tech" Portugal faces an increase of agricultural land-use, between 2008 and 2025, of about 0.2% whereas it decreases by about 1% in B1 "peak oil" scenario where Portugal's economic growth rate is strongly affected by high oil prices.

So, agricultural land-use follows agricultural production with a weaker range. This moderated agricultural land-use reaction is firstly due to a long process of land adjustment to its optimal level (around 10 years) and secondly to agricultural land yields which generally follow farms' land-use

size (as explained in section 1.4). In Europe, the agricultural land yields[15] that are also influenced by global productivity and then by R&D investments, are relatively important in A1 "hyper-tech" with a raise of 13% between 2008 and 2025. They are moderate for A2 "Extreme water" with +6% and weak for B1 "Peak oil" and B2 "Fragmentation" with around 2.5% (see Table 7 in Appendix for more details).
Finally another factor that influences land demand is land price which is presented in following section.

2.2 Agricultural Land price

Agricultural land price results from the interaction of land demand and supply. Land demand is decreasing with respect to land price insomuch as it is a quasi-fixed input for agriculture production. Whereas land rental price (on the supply side) depends on the inverse supply function limited by the asymptote.

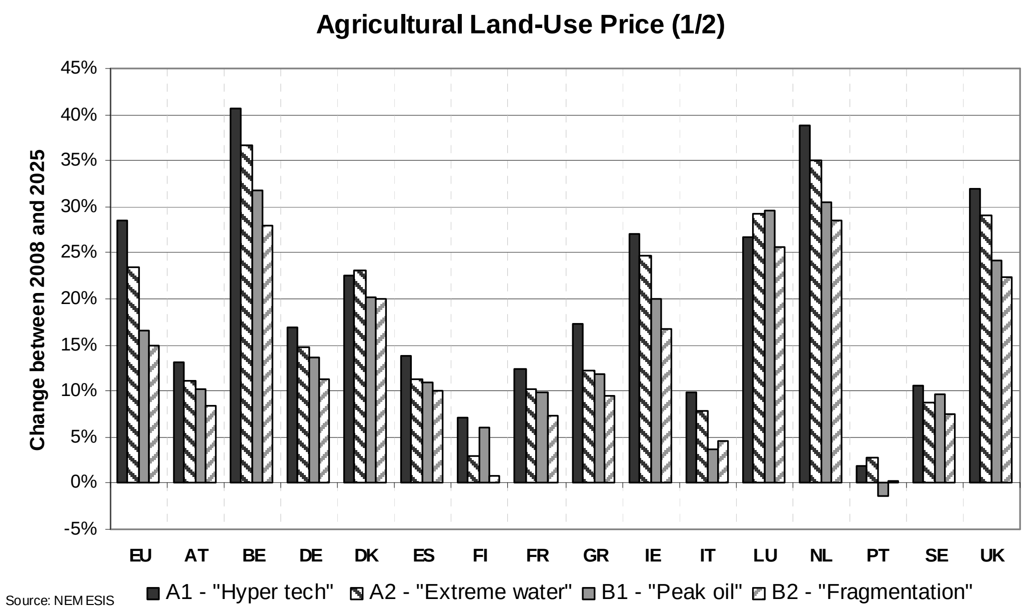


Figure 8: Agricultural Land-Use Price change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 1

So, in a case where a country is very close to its land asymptote, an increase in agricultural land use leads to a strong increase in land price reducing land demand for agricultural production. This can be witnessed

[15] Please note that, here, when we speak about agricultural land yields, it is the seeming land productivity, *i.e.* we divided the agricultural production in volume through the land used for its production. But, in addition to the productivity measure, there exist substitution effects due to relative input prices changes.

in Romania (see Figure 9), where available land for agriculture is very weak: 93% of available land for agriculture is already used in 2000. Then, Romania's agricultural land price increases strongly (more than 150% between 2008 and 2025 in A1 "Hyper-tech") under the pressure of agriculture production development despite a huge consolidation of the agricultural sector *i.e* a rise in farms land-use size (between 4% and 2.5% of growth per year according to the scenarios, see Figure 18).

At the opposite end of the scale is Latvia where unused land for agriculture is relatively important (52%, Figure 4) which can increase its agricultural production (from 1.5% to 0.75% per year in average according to scenarios, Figure 16) without facing a strong increase in its land price (between 6% and 8% more in 2025 compared to 2008 according to scenarios, Figure 9).

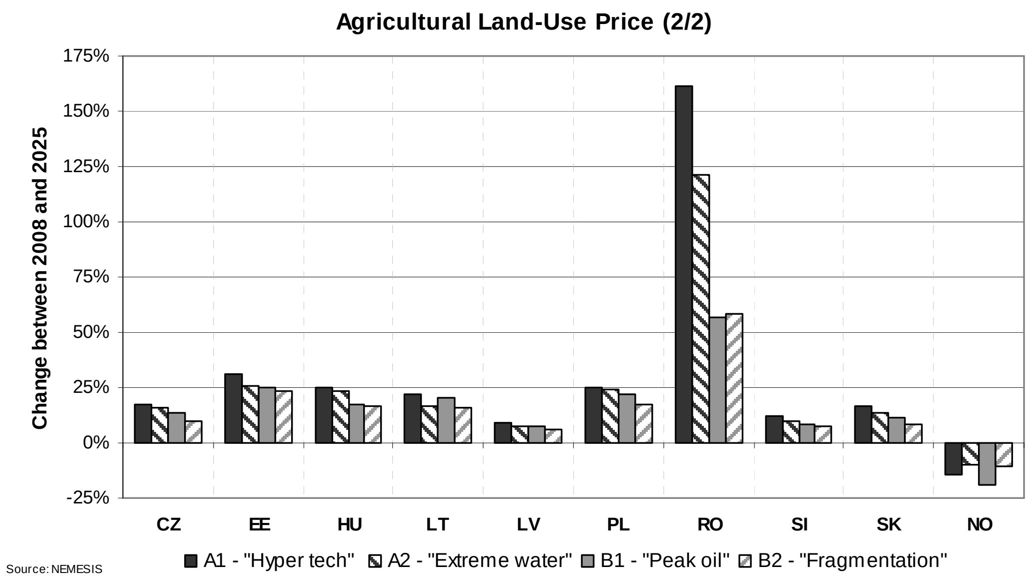


Figure 9: Agricultural Land-Use Price change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 2

Agricultural land-use price generally follows agricultural land-use and agricultural production. In fact, A1 "Hyper-tech" scenario where the average GDP growth rate (3.1% in EU plus Norway) and where demand from outside the EU as well as inside the EU is the highest, faces the highest agricultural goods demand. In order to satisfy this demand, agricultural inputs increase leading to a rise in agricultural land-use. This increase of land use in agriculture raises land price by an amount which depends on the country's position on the land supply curve.

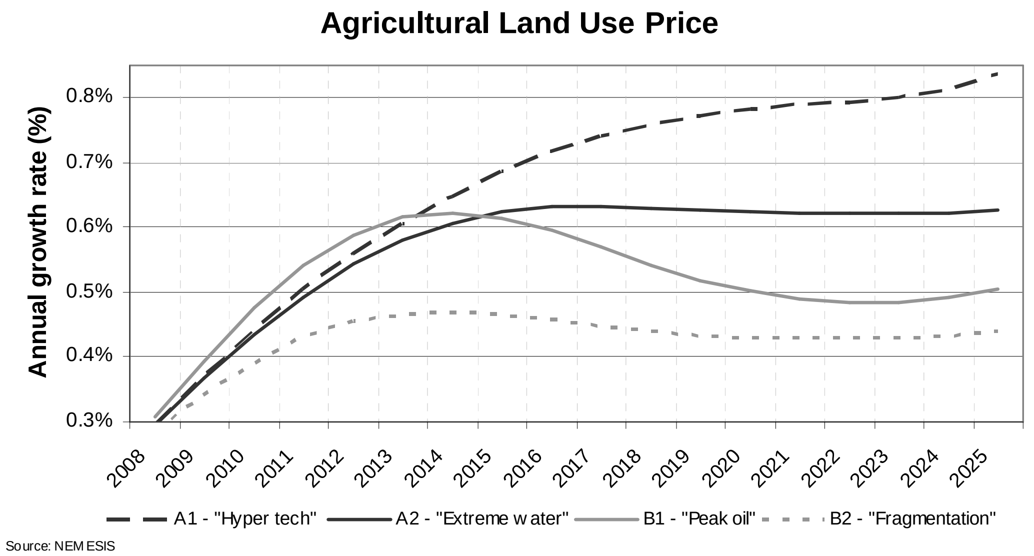


Figure 10: Annual growth rate of European Agricultural Land-Use Price for PLUREL Scenarios (2008-2025)

We can see in Figure 10 that before policy effects take place the growth rate of agricultural land-use price is similar in PLUREL scenarios, except for B2 “Fragmentation” with a lower growth rate due to weak external demand. But after 2015, the increase in economic growth due to R&D investment raises demand for agricultural goods and then increases the land price.

Finally another factor that impacts land price is the asymptote shifting. In fact, a change in built-up areas or transport infrastructures shifts the land asymptote and then acts upon land price. Section 2.3 presents NEMESIS’ results for urban and transport infrastructures land-use for PLUREL scenarios.

2.3 Urban and transport infrastructures land-use

This section presents built-up area and transport infrastructures evolution in the context of PLUREL scenarios. More detailed results on sub-categories of these land-uses as well as economic mechanisms which are implemented in the NEMESIS model which determine their evolution are available in D.1.1.3 (Boitier, 2008).

2.3.1 Transport Infrastructure land-use

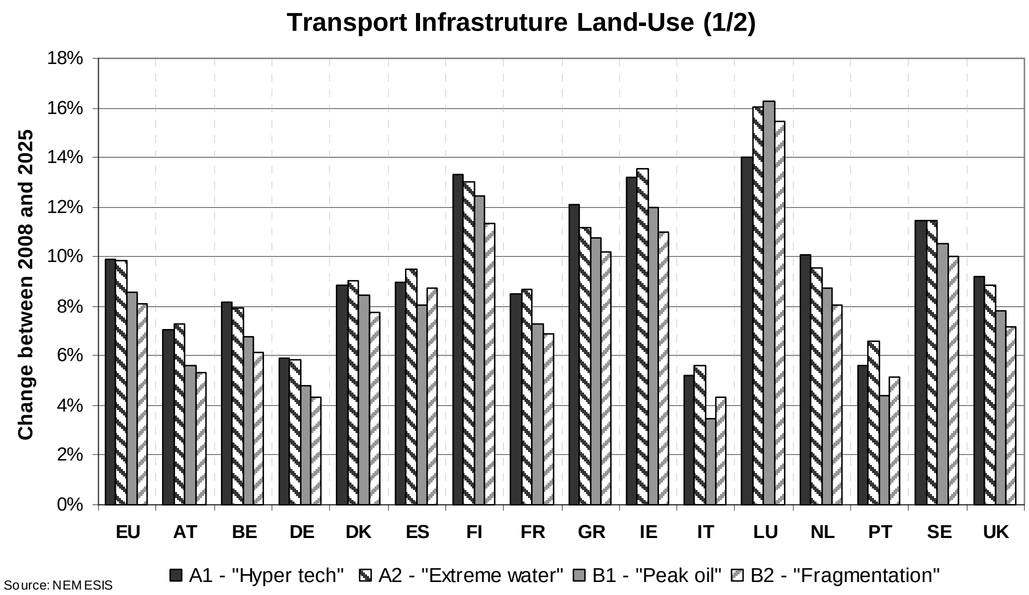


Figure 11: Transport Infrastructures Land-Use change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 1

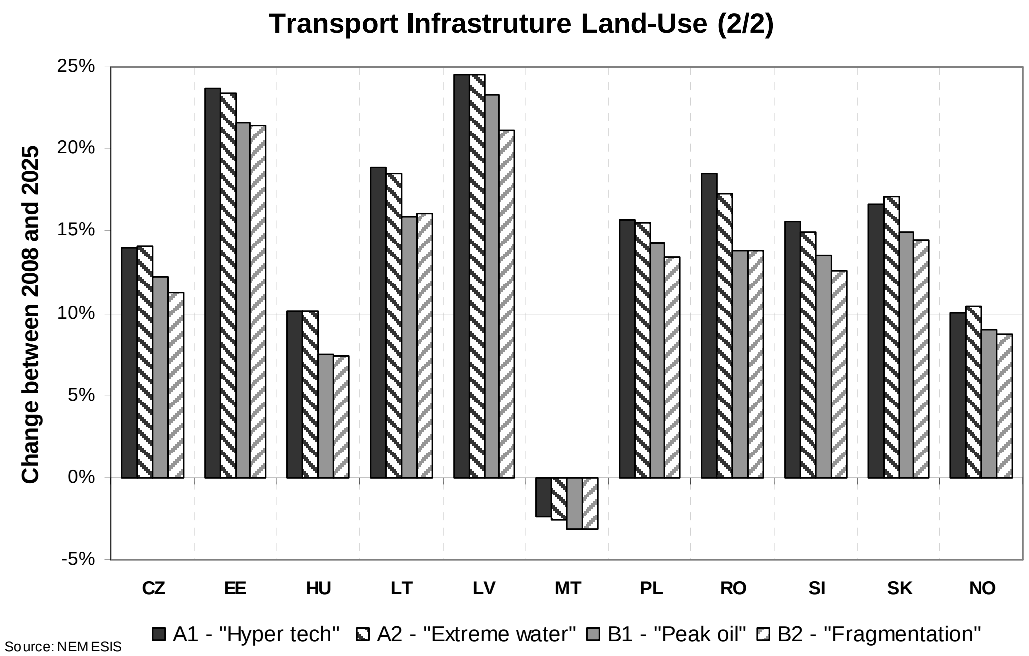


Figure 12: Transport Infrastructures Land-Use change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 2

As we can see in Figure 11 and Figure 12, scenarios with high economic growth (A1 "Hyper-tech" and A2 "Extreme Water") display the highest increase in Transport Infrastructures land-use (around 12% more in 2025 compared to 2008 for the EU). Infrastructural needs when economies grow rapidly are important but we can see that differences between scenarios are relatively small, less than 2% between the highest and the lowest one for the EU (10% growth for A1 "Hyper-tech" and 8% for B2"fragmentation"). In fact in A1 "Hyper-tech", economic development comes from development of new technologies which permit reducing needs for transport by increasing ICT technologies for instance.

Furthermore, Figure 13 shows the impact of the oil price on transport infrastructures development[16]. Between 2010 and 2020, the scenario assumptions for A2 "Extreme water" and B1 "Peak oil" are relatively close, except for the oil price and we can see that there is a rapid fall in the transport infrastructures land-use growth rate from 2010 to 2020 *i.e.* when there is a strong rise in the oil price. In B1 "Peak oil", the growth rate decreases progressively to reach that of B2 "Fragmentation" whereas A2 "Extreme Water" stays between 0.55% and 0.45%. But after the oil price shock *i.e.* after 2020, the annual growth rate of transport infrastructure land-use catches up with that in A2 "extreme water" under the influence of the oil price decrease (B1 "Peak oil") and technological development (A2 "Extreme water").

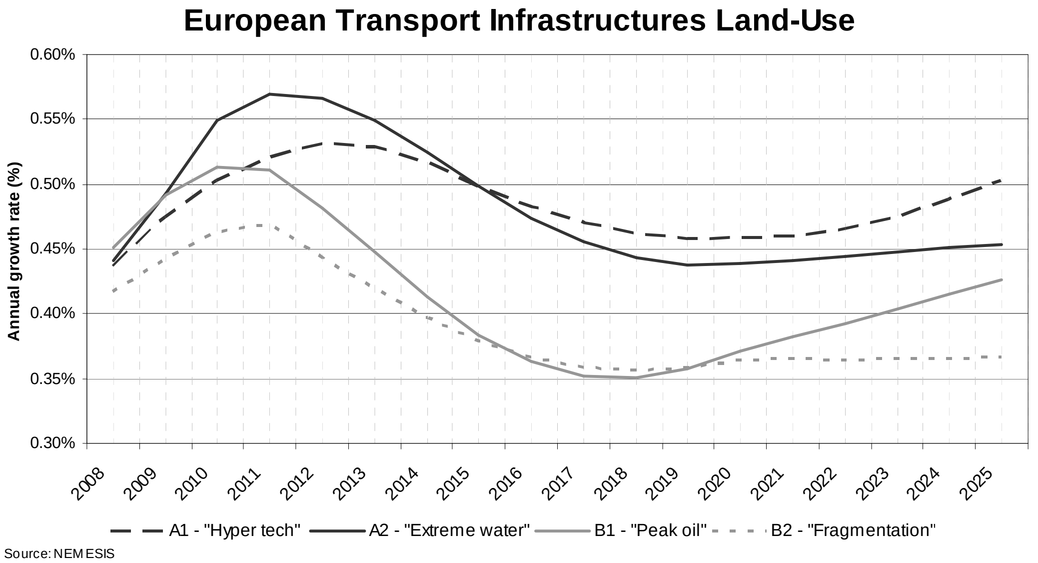


Figure 13: Annual growth rate of European Transport Infrastructures Land-Use for PLUREL scenarios

2.3.2 Urban land-use

Table 3 shows that urban land-use development is more important in new Member States (between 19% and 15%) than in the EU15 (between 7% and 5%). The economic catch up of new MS is also characterized by an increase in commercial and industrial building as well as housing. For urban land use, the major driver in the NEMESIS model is economic development

[16] Note that transport infrastructures land-use not only included transport using thermal engine but also electric engine like some trains.

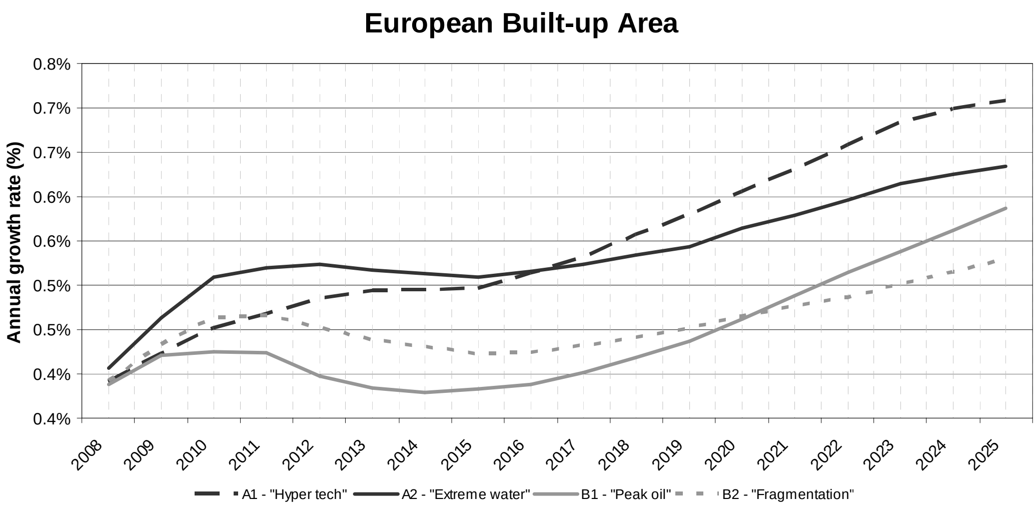
inducing a land requirement in order to implement these new activities. In addition, economic development induces an increase in households' real disposable income, allowing for investment in new houses. Consequently it is logical that in all PLUREL scenarios, new MS have a higher urban land-use development than that of EU15 states.

	Urban Land-use (change between 2008-2025 in %)			
	A1 - "Hyper tech"	A2 - "Extreme water"	B1 - "Peak oil"	B2 - "Fragmentation"
EU	9.9%	9.7%	7.9%	8.1%
EU15	7.0%	6.8%	5.5%	5.8%
EU10	18.6%	18.4%	15.2%	15.0%

Source: NEMESIS

Table 3: Urban Land-use change between 2008 - 2025 In EU, EU15 and EU10 for PLUREL scenarios (in %)

But there are other factors which influence urban land-use. In fact, the energy price is also not negligible. Scenario B2 "fragmentation" and more specifically B1 "Peak oil", where the energy price is high due to energy policies or high oil prices, display (Figure 14) a weak annual growth rate of urban land-use development. That results from three different effects: firstly, a high energy price reduces economic development for countries that are net importers of energy, which is the case for the majority of MS. Secondly, complementarity between energy and investment in most sectoral production functions reduces firms' investment and then reduces development of buildings and commercial units. Finally, a high energy price reduces households' real disposable income and increases commuting price, which cuts down households' housing expenditures.



Source: NEMESIS

Figure 14: Annual growth rate of European Urban Land-Use for PLUREL scenarios

To conclude, we can see that the productivity increase due to investment in R&D has a weak impact on urban land-use. In fact, scenarios A1 “Hyper-tech” and A2 “extreme water” include R&D policy and their urban land-use development is not moderate. After 2015, the growth in built-up areas increases (0.5% in 2015 to 0.7% in 2025 for A1 “Hyper-tech”). The productivity induced by R&D investment impacts all production factors: labour, energy and investment but does not diminish the need for buildings and commercial units as well as for housing.

Conclusion

The NEMESIS model simulations provide an overview of the economic consequences of PLUREL scenarios on national land-use change. As described, in addition to other economic mechanisms, the other important driver for land-use change is general economic activity (the GDP growth rate). In fact, faster economic development of Eastern countries results in more land requirement for agriculture, business or housing. Therefore, agricultural land use is expected to rise at 2025, by between 4,700 km² and 1,400 km² in the New Members States and between 13,900 km² and 5,000 km² in the EU-15. On the other hand, agricultural production is expected to grow by between 21% and 4% in New Members States and between 13% and 2.5% in EU-15. Furthermore, the economic growth rate is the main driver of urban development with urban area sprawling reaching about 8,300 km² in New Member States (*i.e.* +19% between 2008 and 2025) for the A1 "Hyper-tech" scenario whereas urban expansion is about 7% in EU-15 for this scenario.

Nevertheless these land needs are confronted by land availability in each country and we developed a model that takes into account land scarcity and leads to land price change. For instance, countries like Romania which has little "unused" land but a high economic growth rate faces a strong increase in their land price whereas other Eastern countries like Estonia, with strong economic growth and agricultural land-use has a moderate increase in land price because of the existence of important available land.

There are also other drivers which influence land-use change. R&D policy, which raises productivity and income in services or highly technological sectors, has an impact on agricultural land use through scale and productivity effects. For instance, in A1 "Hyper-tech" and A2 "Extreme water", agricultural land in Poland stays relatively stable, as in the two other scenarios, despite a strong increase in agricultural production.
Furthermore energy policy, through high energy prices, reduces demand for individual transports and therefore diminishes land demand for transport infrastructures but also increases the inflation rate and reduces demand for houses.

Finally, Table 4 summarises the main results for each scenario for the EU-15, New Member States and the EU, and displays the importance of the drivers identified above. Scenarios with R&D investment (mainly for A1 "Hyper-tech" and in a smaller extent for A2 "Extreme water") have important impacts on economic performance that pushes up demand for land from industry and the service economic and from households. Therefore urban expansion is high in those scenarios. Nevertheless, the productivity gains allow a weak increase of agricultural land needs for which the evolution is very similar between scenarios because there is either strong land intensification or a weak one in the agriculture sector. Finally, despite the difference in the drivers of B1 “peak Oil” and B2 “fragmentation”, we observe important similarities in the land use results as was the case for the economic results. Nevertheless, the dynamic between both scenarios is not similar and some country results also differ.

	Agricultural Production			Land-Use Farms size			Agricultural land use			Urban land use		
% change between 2008 and 2025	EU	EU-15	NMS	EU	EU-15	NMS	EU	EU-15	NMS	EU	EU-15	NMS
A1 - "Hyper tech"	14.1%	13.4%	20.9%	58.6%	37.2%	81.2%	1.0%	1.1%	0.9%	9.9%	7.0%	18.6%
A2 - "Extreme water"	7.0%	6.4%	12.8%	71.4%	46.4%	98.4%	0.6%	0.7%	0.6%	9.7%	6.8%	18.4%
B1 - "Peak oil"	3.7%	3.2%	7.8%	55.8%	39.0%	72.5%	0.5%	0.6%	0.5%	7.9%	5.5%	15.2%
B2 - "Fragmentation"	2.6%	2.5%	4.0%	56.5%	38.8%	74.0%	0.3%	0.4%	0.3%	8.1%	5.8%	15.0%

Table 4: Summary of main results for EU, EU-15 and NMS (% change between 2008 and 2025)

NEMESIS results can be viewed as a starting point for PLUREL’s quantitative results. The results provide the general overview of land-use evolution due to economic mechanisms in the context of PLUREL scenarios. Other PLUREL partners can then build-up their work onto NEMESIS results, as it is done by Module 2.

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Appendix

Country nomenclature:

Country	Abbreviation
France	FR
Belgium	BE
Germany	DE
Italy	IT
United-Kingdom	UK
Netherlands	NL
Ireland	IE
Denmark	DK
Finland	FI
Norway	NO
Sweden	SE
Austria	AT
Spain	ES
Greece	GR
Portugal	PT
Slovenia	SI
Estonia	EE
Latvia	LV
Lithuania	LT
Bulgaria	BG
Czech Republic	CZ
Slovakia	SK
Hungary	HU
Poland	PL
Romania	RO
Luxembourg	LU

Table 5: Members States Nomenclature

National Results:

- ***Agricultural Production***

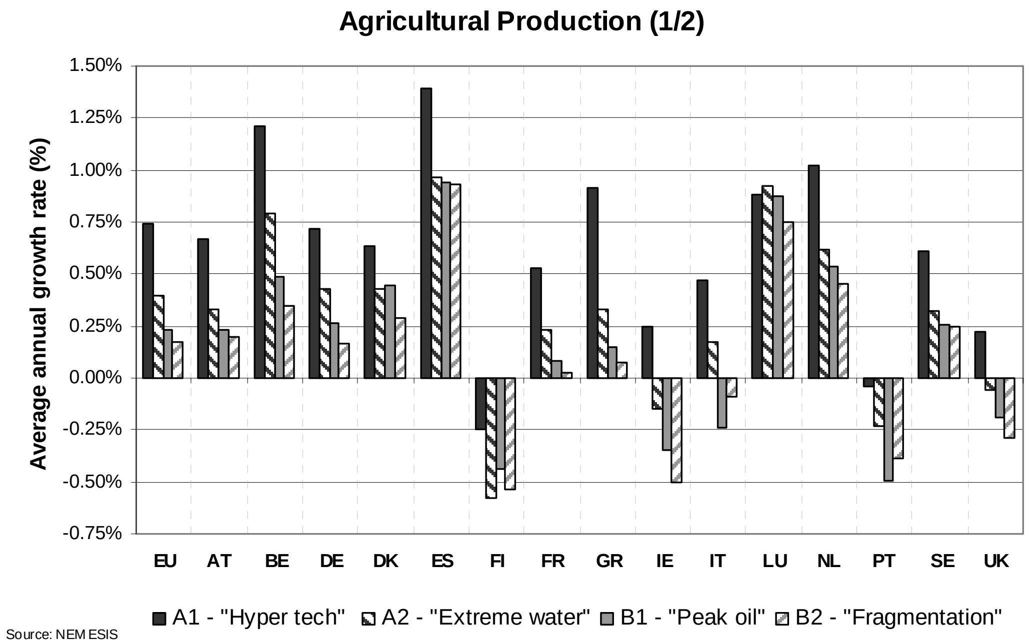

Figure 15: Average annual growth rate of Agricultural Production in MS + Norway for PLUREL Scenarios (2008-2025) part 1

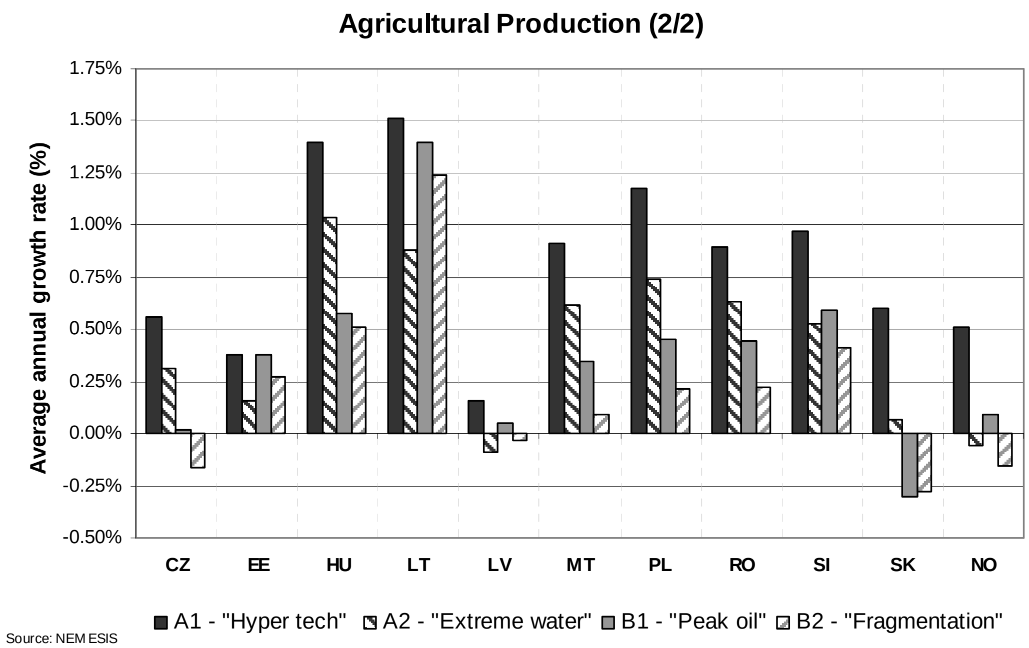

Figure 16: Average annual growth rate of Agricultural Production in MS + Norway for PLUREL Scenarios (2008-2025) part 2

- ***Farms Land-Use Size***

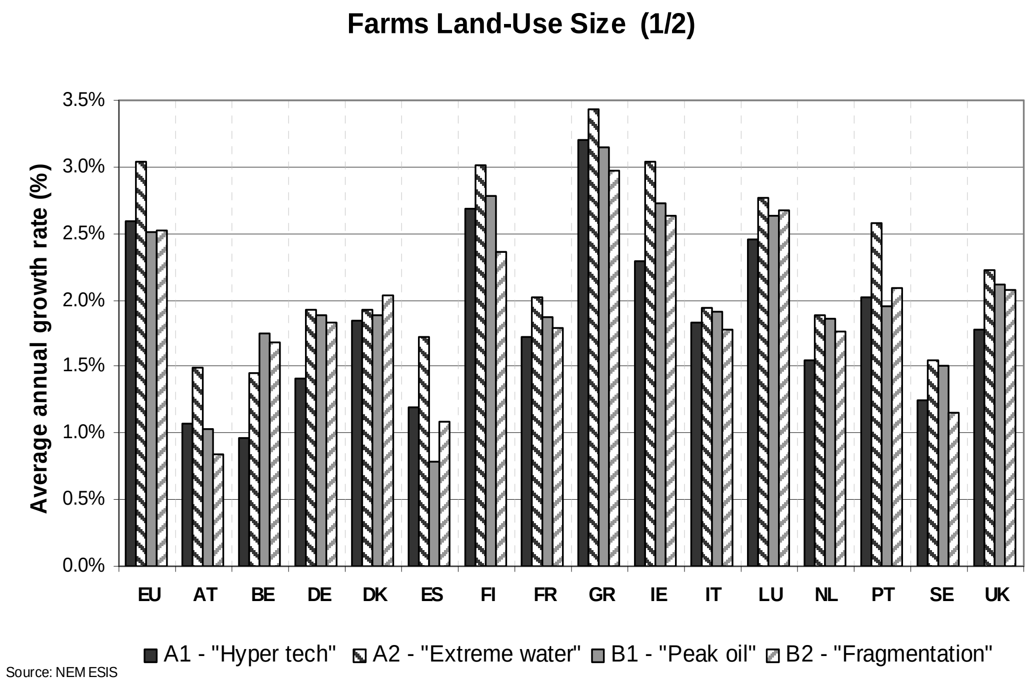

Figure 17: Annual average growth rate of Farms Land-Use Size for MS + Norway for PLUREL scenarios (2008-2025) part 1

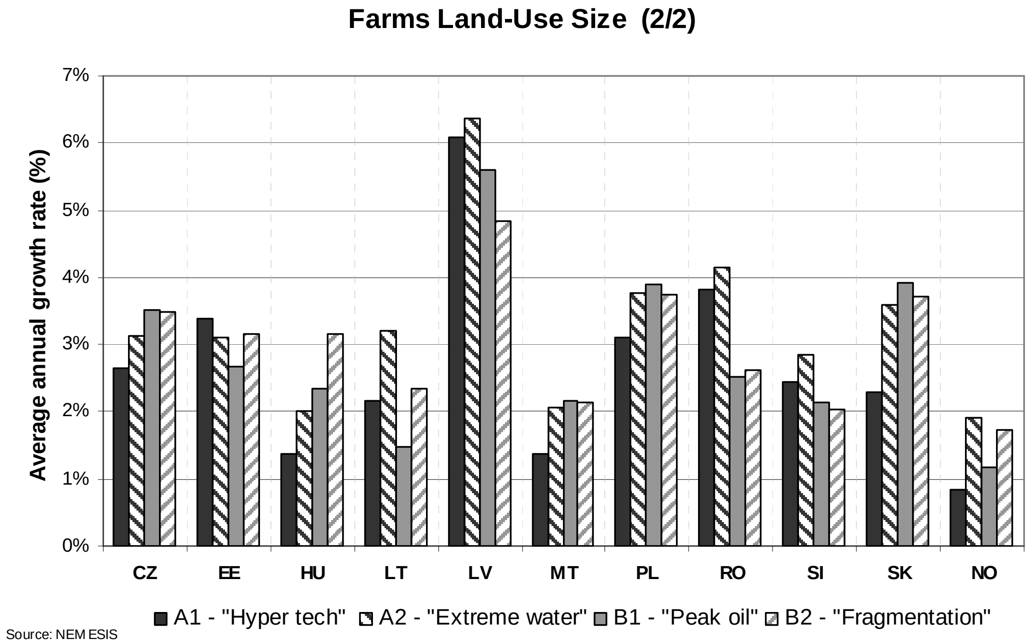

Figure 18: Annual average growth rate of Farms Land-Use Size for MS + Norway for PLUREL scenarios (2008-2025) part 2

ha per farm in 2025	2007	A1 - "Hyper tech"*	A2 - "Extreme water"	B1 - "Peak oil"	B2 - "Fragmentation"
AT	33.6	40.7	43.8	40.4	39.1
BE	43.9	52.1	56.8	60.0	59.1
CZ	236.9	378.6	411.9	440.8	439.4
DE	84.4	108.4	118.9	117.9	116.9
DK	80.6	112.1	113.8	113.0	115.8
EE	126.1	229.4	218.5	202.7	220.3
ES	28.7	35.5	39.1	33.1	34.9
EU	30.5	48.4	52.4	47.7	47.8
FI	51.9	83.6	88.5	85.0	79.0
FR	77.3	105.2	110.8	108.0	106.5
GR	7.0	12.4	12.9	12.3	11.9
HU	54.1	69.1	77.3	82.2	94.7
IE	45.1	67.8	77.3	73.1	71.9
IT	16.8	23.3	23.8	23.7	23.1
LT	51.5	75.8	91.0	67.0	78.2
LU	80.2	124.3	131.0	128.0	129.0
LV	62.5	181.3	189.6	166.8	146.2
MT	3.3	4.2	4.8	4.8	4.8
NL	32.6	43.0	45.7	45.4	44.7
NO	-	-	-	-	-
PL	17.3	29.9	33.7	34.4	33.4
PT	26.1	37.5	41.3	37.0	37.9
RO	10.2	20.0	21.2	15.9	16.2
SE	97.6	122.2	128.8	127.9	120.1
SI	11.6	17.9	19.2	17.0	16.6
SK	582.3	875.1	1100.1	1160.9	1121.8
UK	158.9	218.1	236.1	231.6	230.1

Table 6: Farms land Use Size for MS + Norway for PLUREL scenario (in ha per farms, Source 2007: FADN)

% change between 2008 and 2025	A1 - "Hyper tech"	A2 - "Extreme water"	B1 - "Peak oil"	B2 - "Fragmentation"
AT	11.8%	5.0%	2.9%	3.3%
BE	23.7%	14.7%	7.7%	6.3%
CZ	9.7%	5.0%	-1.0%	-3.3%
DE	12.1%	6.4%	2.8%	2.0%
DK	11.6%	7.5%	7.4%	5.2%
EE	-14.2%	-14.6%	-10.8%	-11.7%
ES	25.1%	16.1%	15.3%	16.0%
EU	13.0%	6.3%	2.8%	2.6%
FI	-5.0%	-10.2%	-8.9%	-8.5%
FR	8.9%	3.3%	0.1%	-0.1%
GR	13.6%	3.5%	0.0%	-0.3%
HU	27.3%	19.1%	8.9%	8.4%
IE	4.7%	-2.8%	-6.7%	-8.5%
IT	6.9%	1.5%	-5.6%	-2.5%
LT	26.6%	13.9%	23.5%	21.9%
LU	16.2%	17.1%	15.4%	13.9%
LV	1.8%	-2.3%	-0.4%	-1.0%
MT	18.1%	11.6%	5.8%	1.2%
NL	19.3%	10.7%	8.8%	8.2%
NO	13.3%	0.6%	6.5%	-0.6%
PL	22.8%	13.0%	7.2%	3.1%
PT	-0.7%	-4.3%	-8.1%	-6.4%
RO	18.3%	12.2%	8.2%	4.1%
SE	10.7%	4.9%	3.1%	4.2%
SI	15.3%	7.3%	8.6%	6.4%
SK	11.8%	1.4%	-5.8%	-4.4%
UK	4.5%	-0.9%	-3.7%	-4.8%

Table 7: Agricultural land productivity for MS + Norway for PLUREL scenario (% change between 2008 and 2025)

- ***Agricultural land Use change***

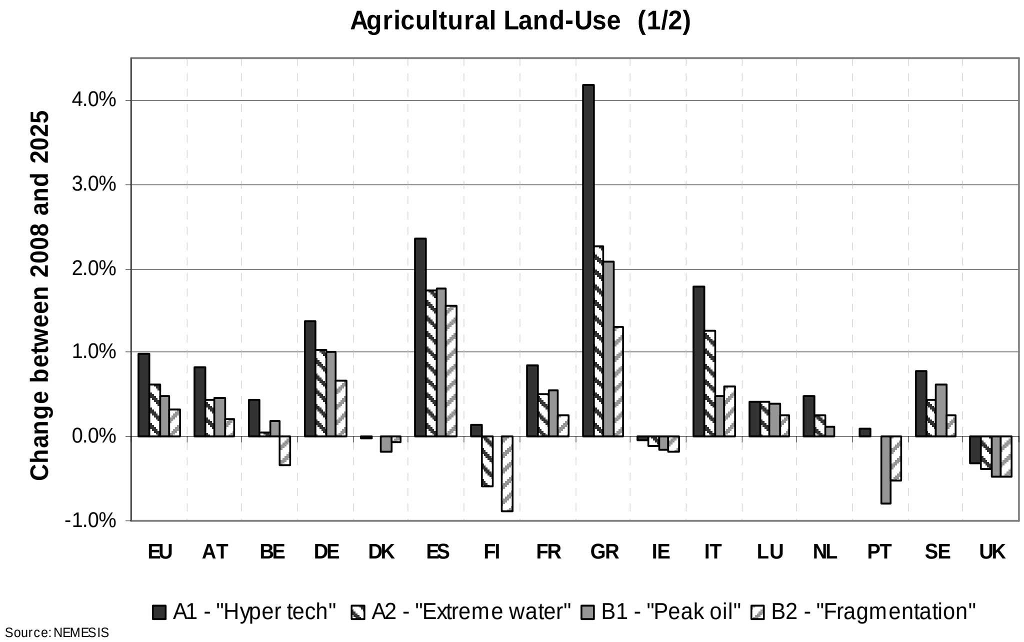

Figure 19: Agricultural Land-Use change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 1

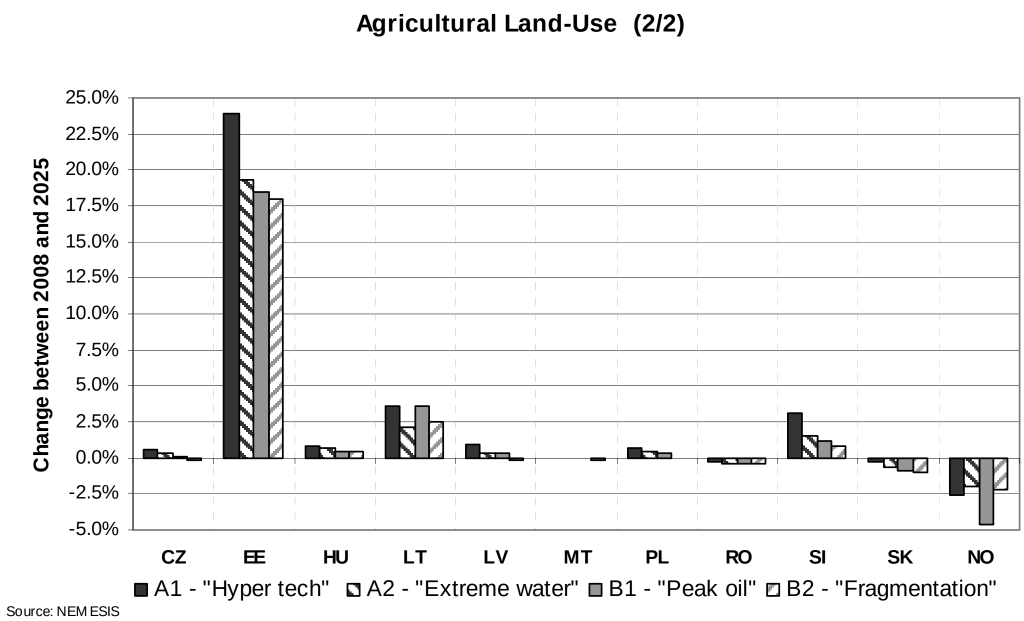

Figure 20: Agricultural Land-Use change between 2008-2025 in % in MS + Norway for PLUREL scenarios part 2

- ***Agricultural Land-Use Price***

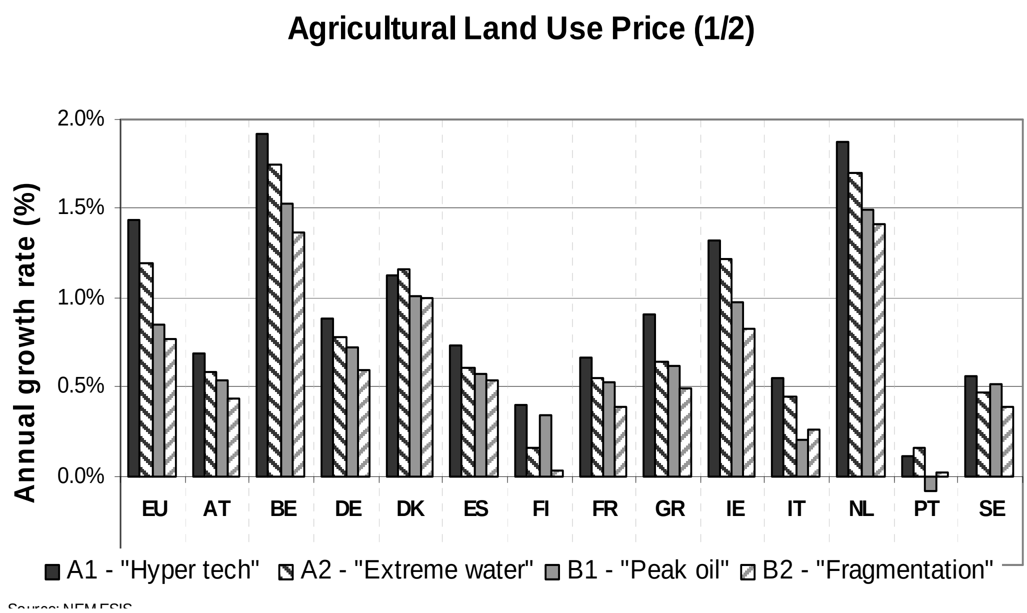

Figure 21: Average annual growth rate of Agricultural Land-Use Price for MS + Norway for PLUREL scenarios (2008-2025) part 1

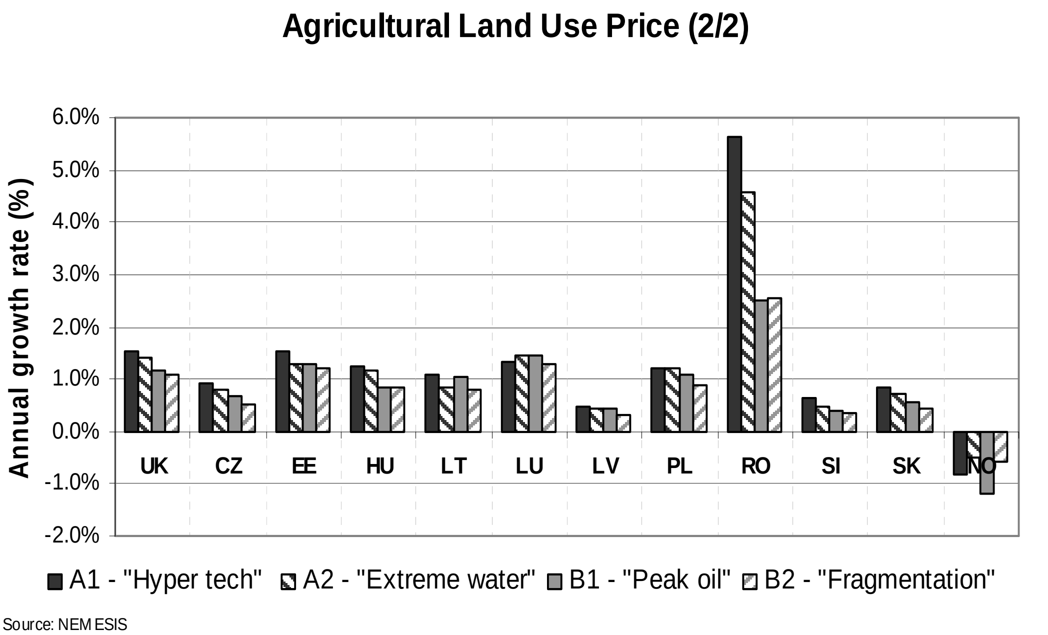

Figure 22: Average annual growth rate of Agricultural Land-Use Price for MS + Norway for PLUREL scenarios (2008-2025) part 2

- ***Urban Land-Use***

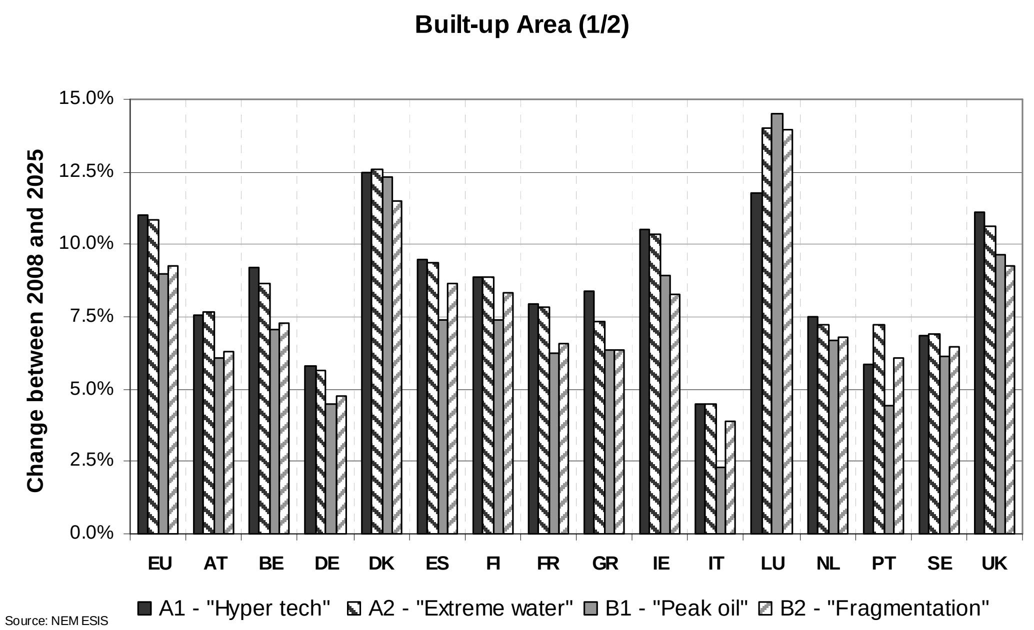

Figure 23: Growth rate of Urban Land-Use Price between 2008-2025 for MS + Norway for PLUREL scenarios (part 1)

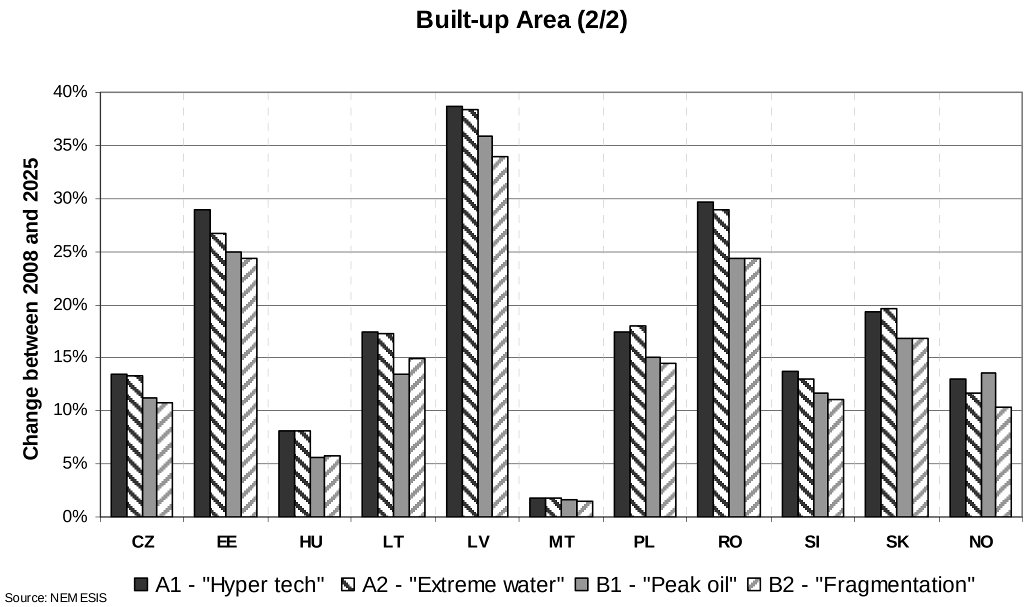

Figure 24: Growth rate of Urban Land-Use Price between 2008-2025 for MS + Norway for PLUREL scenarios (part 2)