LIAISE

Linking
Impact
Assessment
Instruments to
Sustainability
Expertise

Discussion Paper

Improvement of the use and contents of tools for policy relevant test cases

Tools related to the test cases of climate change adaptation and EU soil strategy improvement

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SEVENTH FRAMEWORK PROGRAMME

Project n. 243826

Preamble

One of the key activities of LIAISE is to develop a process through which Impact Assessment (IA) researchers can interact more effectively with IA practitioners by using improved IA tools.

In practice this turned out to be a very tedious task, which led to delay of activities in LIAISE and in WP3 in particular. One of the goals within WP3 was to collect user requirements from tool users. These requirements should then be translated in concrete specifications, modifications etc. which should result in improved tools.

However, as it turned out, it was difficult to identify our users. Were the policy makers our users who we should consult to identify how tools could be improved? We certainly did thought so when we started the LIAISE project. Or should we more focus on scientists and consultants, who would do model runs based on specific requirements of an IA by policy makers?

The second and maybe even more important insight we got in WP3 (and throughout the whole of the LIAISE project), was that having tools better used by the anticipated users, was not merely a matter of technical improvement of tools. Much more important was to get a better understanding on how tools were used in the process of doing an IA. If we could make ourselves part of this process and the tool selection, much more could be gained.

These insights, fed and confirmed by the outcomes of Policy Board Meetings in 2010 and 2011, and simultaneously, based on remarks made by Mr. Leen Hordijk (at the time director of JRC) led to the definition of the Agri test case, constructed around the reform of the CAP. For this test case, it was very important to get in contact with DG Agri en DG Clima, to be able to define a policy relevant test case in which we could learn more on how the DGs where doing their work, and how LIAISE could support them.

However, it was not possible to meet with DG Agri and DG Clima, since the update of the CAP was pending, and would only be made public in the second half of 2011. The Agri test case team started with technical preparations which needed to be done anyhow for this test case, and we couldn't wait any longer to really get started. In March 2012 we finally had our meeting with the DGs in Brussels, where we presented the outline of the test case and where we got directions on how to proceed, based on a number of questions we had prepared beforehand.

The slow start made it not possible to submit the first version of D3.4 in M18. However, the Agri test case is now well underway. This Deliverable reports on the outcome of Phase 1 of the Agri test case and combines the versions M18 and M30. In addition D3.4 includes a section on the newly defined Soil strategy test case.

Because of the changed understanding that improving the use and/or selection of tools is more important than improving tools from a technical/scientific perspective, the title of this deliverable has been changed from "Improved tools (software delivery and deployment) including documentation and manual" to "Improvement of the use and contents of tools for policy relevant test cases".

This deliverable describes the approach and set up in two policy-relevant test cases respectively, and the use of IA tools in these test cases:

1. the *approach* of a so called 'Agri test case' where we linked IA tools to assess the adaptation of European agriculture to changes in climate under different policy environments towards 2050
2. the *set-up* of a 'Soil strategy test case' that aims to use IA tools for a revised impact assessment of the soil thematic strategy in terms of the geographic variation, extent and whenever possible the economic consequences of various soil degradation threats.

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December, 2012

Executive Summary

Outcomes of Impact Assessment (IA) tools, which are meant to analyse consequences of complex changes, are not very often used for policy support by IA practitioners (Nilsson et al., 2008), such as officials at DG-Agriculture and Rural development due to limitations in their outcomes and a knowledge gap between developers and practitioners of IA tools. LIAISE is set up to bridge such gaps between developers of IA tools and practitioners of those tools in a way that leads to an enhanced use of IA tools in policy making. We are doing this by applying IA tools in a number of concrete and policy relevant 'Test Cases' in which, in interaction with policy makers, (i) the relevance of available tools is demonstrated for policymaking, (ii) tools are linked to produce model outcomes that are interesting for policy makers and (iii) available tools are improved to increase the accuracy, adequacy and transparency of model outcomes. This deliverable describes the approach and set up respectively of two of such policy-relevant test cases:

1. the *approach* of a so called 'Agri-Test Case' where we linked IA tools to assess the adaptation of European agriculture to changes in climate under different policy environments towards 2050: Focus on linkage of tools to produce model outcomes that are interesting for policy makers and future tool improvement (not yet described in this deliverable).
1. the *set-up* of a 'Soil strategy test case' that aims to use IA tools for a revised impact assessment of the soil thematic strategy in terms of the geographic variation, extent and whenever possible the economic consequences of various soil degradation threats: Focus on demonstration of the relevance of available tools for policymaking.

Agri-test case: adaptation of European agriculture to changes in climate under different policy environments
Before starting the AgriTest case, we had a meeting with various stakeholders from DG Agriculture (in total eight people, further denoted as DG Agri) in which the Agri-Test case was discussed in terms of its aim, focusing on the scenarios to be evaluated and the relevant results to be produced with the required time horizon, geographical extent, temporal and spatial resolution.

<u>Linkage of tools to produce model outcomes interesting for policy makers</u>
The aim of the 'Agri-Test Case' described in this deliverable is to supply answers to questions on the consequences of changes in climate and other drivers on agriculture and possibilities of different policy environments to support European agriculture under such changes. We linked a number of existing models (CAPRI, FSSIM, INTEGRATOR, and SIMPLACE) to explore the potential impacts and adaptation strategies at the farm and regional scale over Europe with the more general aim to enhance the usefulness of the coupled models in policy making. Details on various aspects of this model linkage including: (i) Data flow between models, (ii) use of common databases at EU scale, (iii) common story lines in terms of climate change scenario's, technological change etc. and (iv) linkage of input-output coefficients in the market model CAPRI with technology/management

changes are given in Annex I to IV respectively. The four linked models are being applied to analyse the effect of climate change only (CLIM) for a most likely Base line (i.e. B1) scenario for 2050 and next, for two alternative scenarios with respectively, strong (i.e. A1-b1) and weak economic growth (B2) for three regions/countries over Europe (i.e. Denmark, Flevoland, and Midi Pyrenées).

Future model improvement

In the current study, the models have been used as they were available, focusing on model harmonization and integration in view of coherent simulation of crop yields under climate and technology change for the coming decades and coherent inclusion of scenario runs. In the second phase of the project, tool improvements are foreseen including

- prices for inputs will be more differentiated between different types of input and between scenarios.
- harmonizing of N applications in agriculture by SIMPLACE, CAPRI, INTEGRATOR and FSSIM.
- improvements in the use-efficiency of inputs depending on the future socio-economic conditions and related technological development.
- Simulation of impacts of extreme events, such as drought/heat stress and extreme rainfall events on probabilities of yield loss and yield failure for the EU regions

Furthermore, in the next project phase, the effectiveness of a number of possible CAP policy instruments to support adaptation to changed conditions in 2050 will be analysed for some regions, as asked for by DG Agriculture.

EU soil strategy test case: Review of the "impact assessment of the thematic strategy on soil protection" of 2006

In 2002, the Commission presented its approach to soil protection in a Communication "Towards a Thematic Strategy on soil protection". The main threats to soil were described, including erosion, decline in organic matter and biodiversity, contamination, sealing, compaction, salinization and landslides. In 2006, the European Commission wrote down their "Thematic strategy for soil protection", including a proposal for a "Soil framework directive" with an accompanying document on an "Impact assessment of the thematic strategy on soil protection". However, the proposal for a "Soil framework directive" has not been adopted in 2006, amongst others with the arguments of excessive administrative burden and because the scientific evidence was not convincing to decision makers at that time.

The EU soil strategy test case, which has been set up in interaction with JRC, aims to revisit the 2006 impact assessment of the soil thematic strategy. The aim is to better assess the "Need of and options for a European wide soil protection strategy" in view of a new focus on (soil) ecosystem services in relation to Societal Challenges, particularly food security and sustainable agriculture, climate change mitigation and increased resource efficiency and new models and tools that have been developed since 2006 which may more properly assess: (i) (soil) ecosystem services and soil threats, (ii) impacts of management in relation to policies on these services and threats and (iii) the costs and benefits of measures based on new monetary insights. The study will be carried out in 2013 and the beginning of 2014.

Table of Contents

Tools related to the test cases of climate change adaptation and EU soil strategy improvement

Impact Assessment (IA) tools are meant to analyse consequences of complex changes, but there appears often a problem in their application and in the use of their outcomes for policy support by IA practitioners (Nilsson et al., 2008), such as officials at DG-Agriculture and Rural development. There is a large variation in IA tools and in their possible applications. Hence, to improve the use of IA tools and to solve the knowledge gap between developers and practitioners of IA tools, De Ridder et al. (2007) have made a framework for finding potentially appropriate IA tools for different types of applications and for justifying their use. LIAISE is set up to bridge such gaps between developers of IA tools and practitioners of those tools in a way that leads to an enhanced use of IA tools in policy making. One of the key activities of LIAISE (Linking Impact Assessment Instruments to Sustainability Expertise) is to develop a process through which Impact Assessment (IA) researchers can interact more effectively with IA practitioners. We are doing this by applying IA tools in a number of concrete and policy relevant 'Test Cases' Cases' in which, in interaction with policy makers, (i) the relevance of available tools is demonstrated for policymaking, (ii) tools are linked to produce model outcomes that are interesting for policy makers and (iii) available tools are improved to increase the accuracy, adequacy and transparency of model outcomes.

This deliverable describes the approach and set up respectively of two of such policy-relevant test cases, i.e.

2. the *approach* of a so called ‘Agri-Test Case’ where we linked IA tools to assess the adaptation of European agriculture to changes in climate under different policy environments towards 2050: Focus on linkage of tools to produce model outcomes that are interesting for policy makers and future tool improvement (not yet described in this deliverable).
3. the *set-up* of a ‘Soil strategy test case’ that aims to use IA tools for a revised impact assessment of the soil thematic strategy in terms of the geographic variation, extent and whenever possible the economic consequences of various soil degradation threats: Focus on demonstration of the relevance of available tools for policymaking.

PART A Agri-test case: adaptation of European agriculture to changes in climate under different policy environments

1 Introduction

1.1 Background

Conditions for farming over Europe are rapidly changing and hence, it is important to analyse the risks and resiliencies for agriculture under changes in climatic conditions (Parry et al., 1999, 2004) but also under changes of other drivers (market, technology, policy, etc.). For example, climate change may induce more frequent extreme weather events and/or the reduction of water availability, both of which may result in lower yields and/or lower yield quality, and may require adaptation measures at the farm level and policy changes. Hence, it is crucial to gain more insight in the consequences of changes in climate and other drivers on agriculture (Wolf et al., 2012) and in the possibilities of different policy environments to support European agriculture under such changes.

A number of relevant policy questions in this context are:

- what are the impacts of climate change and other drivers in 2050 on agricultural systems over Europe, in terms of crop yields, cropping patterns and farm net income?
- what are the resulting consequences for the environment?
- which adaptations at farm level to changed climate conditions are most effective depending on farming structure, bio-physical conditions and region?
- which are the most effective policy changes to support adaptation to changed conditions in 2050?
- which differences in the impacts of climate and other drivers at various scales (from farm level to region to Europe) do occur?

1.2 Aim

The aim of the 'Agri-Test Case' described here is to supply information related to the above mentioned questions by linking IA tools and their databases in the policy-relevant area of the adaptation of European agriculture to changes in climate and other drivers towards 2050. In interaction with stakeholders (DG Agriculture) we linked a number of existing models (CAPRI, FSSIM, INTEGRATOR, and SIMPLACE) to explore the potential impacts and adaptation strategies at the farm and regional scale over Europe with the more general aim to

- Enhance the usefulness of the coupled models in future policy making
- Gain more insight in the process of researcher-practitioner interaction for successful tool development and application.

In the following the Agri-Test case the methodological aspects will be presented in terms of its interaction with stakeholders (DG Agri) and its approach (Section 2) and preliminary results for a Base year (2003-2005) and for future scenarios (2050) for three regions (Denmark, Flevoland, and Midi Pyrenées) in Europe (Section 3) for the models FSSIM, INTEGRATOR and SIMPLACE, who have used each other input and output. The next version of this Deliverable will report on model results from all four linked models for an EU wide application.

2 Methodology

2.1 Interaction with DG Agriculture

Before starting the AgriTest case, we had a meeting with various stakeholders from DG Agriculture (in total eight people, further denoted as DG Agri) in which the Agri-Test case was discussed in terms of its aim, focusing on the scenarios to be evaluated and the relevant results to be produced with the required time horizon, geographical extent, temporal and spatial resolution.

DG Agri mentioned the AVEMAC study by JRC that shows similarities with the Agri Test Case, as future crop yields and productions are calculated for the main crop types over Europe (Donatelli et al., 2012) (see http://mars.jrc.ec.europa.eu/mars/Projects/AVEMAC). The interaction made clear that the 'Agri-Test Case' has to go beyond the AVEMAC project in several aspects. DG Agri was interested in how changing technology will affect results in addition to climate change. Regarding results, there was an interest in both macro (EU) and micro (farm) financial impacts (income) and in environmental impacts, especially in effect on biodiversity. We thus decided that we (i) will assess the impacts of future climatic change on crop production also in the context of technological, socio-economic and policy changes and (ii) will look at both economic and environmental consequences of climatic change on different farming system, both at the farm level and over the whole Europe. Both aspects are considered in this study.

There was also an interest at DG Agri which policy instruments could help farmers adapt to climate change for which agricultural sectors. Consequently, it was decided that the Agri Test case will analyse (iii) the effectiveness of adaptation measures in agriculture at the farm level and (iv) evaluate the effectiveness of a number of CAP policy instruments which support the most promising adaptation measures. These aspects were, however, not considered in this preliminary study. Finally, there was a discussion on suitable time horizons, and DG Agri expressed interest in both long term (2050) and medium term (2020) results in response to differing storylines/scenarios. In this study, results are limited to the year 2050 but in a later study, results will also be presented for 2020.

2.2 Modelling approach

No single model can currently assess all the effects of climate change on farming systems over Europe, within the context of technological, socio-economic (markets) and policy changes towards 2050. Hence, we have linked a number of existing models (i.e. CAPRI, FSSIM, INTEGRATOR and SIMPLACE) and used the linked models to assess the impacts of foreseen changes in climate, agricultural policies and management on the environment and the farm productivity and incomes.

To enable this linkage, four subgroups were formed that worked on relevant aspects of this model linkage including:

- Data flow between models in terms of inputs, models and outputs and its inter linkages, such that the flow of information is transparent and the assumptions that are made are explicitly mentioned,
- Common databases at EU scale in terms of data used by models and a suggestion for the common database to be used.
- Common story lines in terms of climate change scenario's, technological change etc.
- Linkage of input-output coefficients in the market model CAPRI with technology/management changes.

Details on the various aspects are given in Annex I to IV respectively. Based on the results of those discussions, Figure 1 gives a summary overview of (a) how the four models are linked, (b) the main data sets that are used, (c) the main input data that are used by the four models, and (d) the main outputs (e.g. farm net income, environmental impacts) from the integrated analyses done with the linked models. The various aspects are discussed in some detail below.

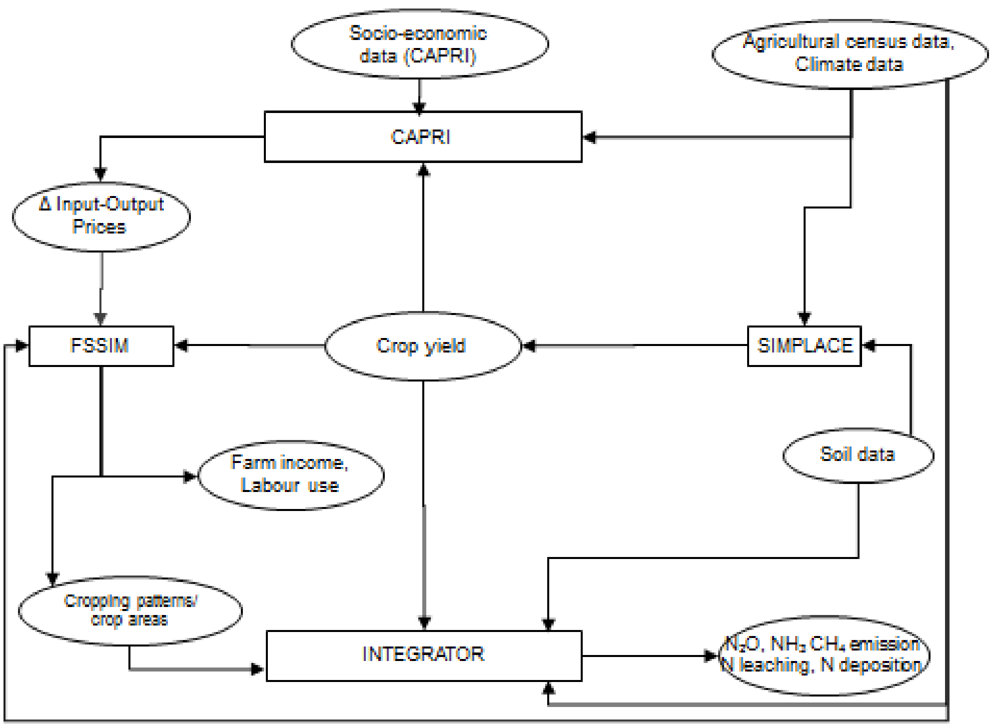

Figure 1 Main flows of inputs and outputs to and from the four models that are linked for the Agri-Test case in the LIAISE network

2.2.1 Data flow between models and model overviews

Results of SIMPLACE on future yield changes (Wolf et al., 2012) and of CAPRI on future price changes are used by FSSIM, which then calculates future changes in farm net income, farm labour demand and cropping patterns for different future scenarios. SIMPLACE results on future yield changes are also used by INTEGRATOR, which calculates N applications and N uptake and N losses to air and water for the main crop types per region for the scenarios. The N applications and emissions per crop type from INTEGRATOR are finally linked to the computed future cropping patterns from FSSIM, which results in the following main outputs from the linked models: future changes in cropping patterns, farm net income, labour demand, N applications and N emissions at the farm and regional level.

The four linked models can be shortly described as follows:

- SIMPLACE is a crop growth model that is suited to do yield calculations at large scales. Its modelling approach is based on the LINTUL-2 model (Spitters and Schapendonk, 1990; Van Oijen and Leffelaar, 2008). SIMPLACE can be applied to assess the impacts of changes in CO_2, temperature, rainfall and technological development on crop yields and can be run for Europe at NUTS-2 level (Wolf et al., 2012, Section 2.2).
- CAPRI (http://www.capri-model.org/dokuwiki/doku.php) is a comparative static partial equilibrium model for the agricultural sector developed for policy impact assessment of the Common Agricultural Policy (CAP) and trade policies from global to regional and farm type scale, focusing on EU27 level (Britz et al., 2007; Britz and Witzke, 2008). CAPRI has the capacity to assess economic consequences at the regional level over Europe. In this study CAPRI results on future price changes are used in FSSIM to assess impacts on cropping patterns and thereby on farm gross income, farm net income and farm labour demand .
- FSSIM is a generic bio-economic farm model that has been developed to quantify the integrated agricultural, environmental and economic responses of major farm types across the EU to new policies and agro-technologies (Janssen et al., 2010; Louhichi et al., 2010). FSSIM has the capability to assess effects of policies and product prices on agricultural actors and their decisions regarding land use and management at farm level. These decisions in turn affect cropping patterns and thereby farm gross income, total costs per farm, farm net income and farm labour demand per farm, which are the main direct outputs from FSSIM.
- INTEGRATOR is an environmental agricultural model which can calculate N and greenhouse gas emissions from housing and manure storage systems, agricultural soils, non-agricultural soils and surface waters at EU 27 level (De Vries et al., 2011; Kros et al., 2011; Velthof et al., 2009). INTEGRATOR is strong in assessing nitrogen flows and GHG emissions in landscapes in response to changes in land use and land

management. In this study, INTEGRATOR calculates total N application, total N uptake, total N leaching to both ground and surface water, NH_3 emission and N_2O emission to the air, based on changes in crop yields from SIMPLACE and in cropping patterns from FSSIM. The latter three N losses contribute, respectively to eutrophication, decrease in biodiversity and greenhouse gas accumulation.

Bio-economic farm models such as FSSIM, can answer at farm level what will be the optimal agricultural adaptation strategies to changes in climate and policies in terms of farm net income and farm labour demand. FSSIM can be run for representative farm types in a region, and the results can be aggregated to the regional level. However, inter-linkages between farms and landscapes are not simulated. Hence, FSSIM is not suited to up-scale the resulting impacts on the environment and the farm productivity and incomes at landscape level. Environmental agricultural models such as INTEGRATOR, can answer questions related to the impacts of changes in agricultural structure on the environment, but they cannot make a linkage to actual policies, such as quotas, income support, taxes, subsidies, cross-compliance policies, nor can derive possible trade-offs between economic and environmental objectives. This linkage is possible with CAPRI. Linking INTEGRATOR with FSSIM (for farm and regional analyses) and with CAPRI (for regional and EU-scale analyses), combined with SIMPLACE to do yield estimates for future scenario conditions, will thus strengthen the usability of the different models and will help to answer policy questions, such as the impacts of changes in climate and other drivers on farming systems and the environment in different regions over Europe towards 2050.

2.2.2 Evaluated scenarios for agriculture in 2050

We have applied the linked models first to the Base year, in particular for calibrating FSSIM to the observed cropping patterns, and next, to three socio-economic scenarios including a Baseline scenario for 2050 (B1, as described by the trend projections given in In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

- Changes in climate conditions (as based on IPCC scenarios); climate data are derived from the Intergovernmental panel on Climate Change (IPCC) Data Distribution Centre (DDC IPPCC, 2010) and clearly differ between the scenarios, as described in Wolf et al. (2012, p. 16).

Table 1), a strong economic growth scenario (A1-b1) and a weak-economic growth scenario (B2) for 2050 (In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

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Table 1). The A1-b1 scenario assumes for 2050 rapid economic growth, global free trade and a strong increase in wealth and thus food demand, whereas the B2 scenario assumes more limited economic growth, more trade blocks and environmental taxes, and more limited increase in wealth and thus in food demand. The B1 scenario represents the most likely future development with an economic growth and other future changes, assumed to be roughly in between those for the A1-b1 and B2 scenarios.

In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

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Table 1 Description of the scenarios as based on the Agri-Adapt project outcomes (Source: Wolf et al., 2012). Note that for these scenarios all the different types of changes towards 2050 (i.e. changes in climate, technology, management, prices and policies) are indicated.

	Base year [2004]	**B1 (Baseline) [2050]**	**B2 [2050]**	**A1_b1 [2050]**
Exogenous assumptions	Observed data (average 2003 -2005) taken from EuroStat, FAO, OECD etc.	Inflation rate of 1.9% per year		
		constant exchange rates		
		Projection of GDP	Derived from IMPACT scenarios (decreasing demand for agricultural products)	Derived from IMPACT scenarios (leading to increasing demand for agricultural products compared to B2)
		Projection of population (growth)		
Commodity Prices	Observed prices (average 2003 -2005)	Extrapolated from market outlooks (European Commisssion and IFPRI)	Simulation results	
Input Prices	Observed prices (average 2003 -2005)	Extrapolated from market outlooks (constant in all simulations)		

Yield	Observed yields (average 2003 -2005)	Trend projection combined with SIMPLACE simulation (BCCR_BCM2_0/SRES B1 - less warming consistent across all European regions and seasons)	SIMPLACE simulation (Pattern-scaled SRES B2 15-model ensemble mean)	SIMPLACE simulation ·(SRES A1B 15-model ensemble mean)
Set-aside and quota policies	With obligatory set-aside and quota (milk and sugar)	Abolishing obligatory set-aside, expiry of milk quota, continuation of sugar quota		
Premium scheme	2003 CAP reform (decoupled + partially coupled payment) [1]	2009 Health Check (decoupled payment, increased modulation) [2]		
WTO trade policy	Tariffs and TRQ as in 2004	Tariffs and TRQ as in 2004		Reduction of tariffs and expansion of TRQ (sensitive products) as proposed by Falconer (2009)

[1] Since 1992, the common agricultural policy (CAP) has been reformed, aimed at moving away from a policy of price and production support to a more comprehensive policy of farmer income support. The last step in this process was the introduction of the Single farm payment scheme. For more information about the CAP reform 2003, decoupling, modulation, etc., see http://ec.europa.eu/agriculture/mtr/sum_en.pdf

[2] On 20 November 2008 the EU agriculture ministers reached a political agreement on the Health Check of the CAP (EC, 2008). The agreement abolishes arable set-aside. Ministers also agreed to increase modulation, whereby direct payments to farmers are reduced. For more information see http://ec.europa.eu/agriculture/healthcheck/index_en.htm

- Increases in atmospheric CO_2 that affect future crop yields (i.e. 369 µmol CO_2/mol for Base year and respectively 488, 532 and 478 µmol CO_2/mol for B1, A1-b1 and B2 scenarios).
- The degree of technological improvement in crop varieties and management leading to higher yields in the future; these improvements are assumed to be related to the different IPCC socio-economic and emission scenarios (Ewert et al., 2005) (being dependent on future changes in global demand of agricultural commodities and in investments to improve crop varieties and management).
- Changes in the prices of the inputs for agricultural production and the agricultural products; these price changes will generally be determined by economic changes at the global scale but are also affected by European policies such as CAP regulations and the EU agricultural border protection. Relationships between the different socio-economic and emission scenarios (e.g. A1-b1 versus B2 scenario) for the future (as described by IPCC (2007)) and the resulting changes in supply and demand of the different agricultural products are used to derive these future price changes.

To be able to distinguish the effects on arable farming of these different factors, we have done four types of analysis (being indicated by the term:

variations) of the impacts of and adaptations to changes in climate and other drivers in 2050:
Projecting climate change of 2050 on present farming systems over Europe Europe (with CAPRI model) and in EU27 administrative NUTS-2 http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction) tion) regions in more detail (with FSSIM model), with their present layout, layout, agro-management and productivity, markets and policies – 2050 2050 climate change only analysis (**CLIM**). We use data from the Base year year (In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

- Changes in climate conditions (as based on IPCC scenarios); climate data are derived from the Intergovernmental panel on Climate Change (IPCC) Data Distribution Centre (DDC IPPCC, 2010) and clearly differ between the scenarios, as described in Wolf et al. (2012, p. 16).

Table 1) and only change the yields due to climate and CO_2 change for three scenarios for 2050 (see In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

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1. Table 1 with Baseline B1 scenario, Strong economic growth A1-b1 and Weak-economic growth B2) and their related N applications.
2. Projecting climate change of 2050 on images of future arable farms over Europe (with CAPRI) and in few NUTS-2 regions in more detail (with FSSIM), in alternative future scenarios (2050) of agro-management and productivity, markets and policy environment, which include respectively, the effects of improved crop cultivars and management on crop yields (i.e. improved Technology --> **CLIMT**), the effects of changes in policies and in the prices for inputs and agricultural products (**CLIMP**), and the effects of all factors together (i.e. 2050 integrated analysis --> **CLIMTP**).

The assessments are carried out for the Base year (2003-2005) and for 12 different combinations of three scenarios (Base line B1, A1-b1 and B2), and four variations (CLIM, CLIMT, CLIMP and CLIMTP) for 2050, as shown in

Table 2. They are performed for three different (from North to South) regions/countries over Europe, i.e. Denmark, Flevoland/The Netherlands and Midi Pyrenées/France.

*Table 2 Overview of the applied scenarios and types of analysis (as indicated by the term: **variations**) with respectively, inclusion of the effects of increased atmospheric CO_2 and climate change on crop yields only (CLIM), additional inclusion of the effects of improved technology and management on crop yields (CLIMT), both CLIM and the effects of changes in policies and prices (CLIMP), and both CLIM and the effects of all factors together (CLIMTP) for 2050*

Scenarios	Variations	Climate change (change in CO_2 and climatic parameters)	Technological change (e.g. improved cultivars)	Price changes for both inputs and products
B1, A1-b1, B2	CLIM	Yes	No	No
B1, A1-b1, B2	CLIMT	Yes	Yes	No
B1, A1-b1, B2	CLIMP	Yes	No	Yes
B1, A1-b1, B2	CLIMTP	Yes	Yes	Yes

2.2.3 Input data

The main input data used in this study, the main flows of data between the models, and the main results from the linked modelling approach are presented in Figure 1. The main input data for INTEGRATOR and FSSIM, and the data linkage to SIMPLACE (i.e. yield changes) CAPRI (i.e. price changes for inputs and products to FSSIM) and between INTEGRATOR and FSSIM (crop-soil area fractions) are listed in Table 3 and Table 4, receptively.

Table 3 Main input data for INTEGRATOR model and the applied data links to SIMPLACE and FSSIM

N excretion, emission and uptake factors Data depend amongst others on N source, soil type, land use and precipitation		Changes per crop type, in cropping pattern and data link Relative changes based on input data from SIMPLACE (S) or FSSIM (F)	
Input data	Unit	Input data	Unit
N excretion rate	kg N/animal	Relative change in crop yield (S)	-
N uptake factor[1]	-	Change in cropping patterns (F)	ha
N content in crops	-	Other input data Based mainly on FAO data	
NH_3 emission factor	-	Input data	Unit
N_2O emission factor	-	Land cover	ha
NO_x emission factor	-	Land use (crops in arable land)	ha
N leaching factors	-	Crop yields	kg/ha
N surface runoff factor	-	N fertilizer application	kg/ha
N subsurface runoff factor	-	Animal livestock numbers	-
		Total N deposition levels	kg/ha
		Soil properties	

[1] Efficiency factor of the effective N applied

The main types of data used by INTEGRATOR are (i) N process factors, (ii) data on land cover, land use, and animal numbers which all change over time, and on soil properties which remain constant and (iii) changes in crop yield and cropping pattern which are based on SIMPLACE and FSSIM output, respectively.

N process factors include N excretion, N uptake, N emission, N leaching and N runoff fractions (Table 3), which factors depend on e.g. animal categories, land use, crop type, soil type and climatic factors. For example, N_2O emission factor is a function of N source, application technique, soil type, land use and amount of precipitation, as based on Lesschen et al. (2011). NH_3 emission factor is a function of housing and manure storage systems and of manure and fertilizer types and the sum of the N leaching and subsurface runoff factors is related to soil type, land use, soil organic content, precipitation surplus, temperature and rooting depth (Velthof et al., 2009). We assume that the N use efficiency in INTEGRATOR increases by 20% towards 2050 (i.e. increase in N uptake factor in Table 3) and also that the housing systems and manure application techniques improve over time, leading to reduced NH_3 emissions.

Table 4 Main input data for FSSIM modelling of arable farms and the applied data links to SIMPLACE, CAPRI and INTEGRATOR

Management per crop type Data are given for the main crop activities in the region for the Base year, as collected by local experts		**Changes per crop type and data link** Relative changes based on input data from CAPRI (C) and SIMPLACE (S); data link to INTEGRATOR (I) for N emission calculations	
Input data	**Unit**	**Input data**	**N emissions, in kg N/ha**
Yield	ton/ha	Relative change in crop yield (S)	NH3 emission (I)
By product	ton/ha	Relative change in by-product (S)	N2O emission (I)
Price of yield	euro/ton	Relative change in price of yield (C)	NOx emission (I)[a]
Price of by-products	euro/ton	Relative change in price of by-product (C)	N2 emission (I)[a]
Amounts of active biocides applied	kg/ha	Relative change in costs (C)	N leaching to ground and surface water (I)
Amounts of fertilizer N, P and K applied[b]	kg/ha	**Constraints and Other input data per farm type** Base year data mainly based on FADN; Subsidies are the same for Base year, CLIM and CLIMT and become nil for CLIMP and CLIMTP with price changes; resources (i.e. available land, water and labour) per farm type are similar for Base year (data from FADN) and the three scenarios and four variations	
Costs of biocides applied	euro/ha	**Input data**	**Unit**
Costs of fertilizer nutrients applied	euro/ha	Total labour available	hours
Other variable costs	euro/ha	Total land area	ha
Irrigation water applied	m3/ha	Total irrigable land area	ha
Labour demand	hour/ha	Water available	m3
		Subsidies	euro
		Actual cropping pattern	ha
		Available crop rotations	-

[a] This N emission is not shown in the reported outcomes

[b] These N applications are not used in this study but N applications are calculated in the INTEGRATOR model on the basis of the yields

Regional cropland area data in INTEGRATOR are based on CORINE 2000 (ETC,2000), whereas the land share data per crop type are based on CAPRI-SPAT (Leip et al., 2008). We have assumed here that there are no changes in total cropland area towards 2050, but only in the cropping patterns, to be able to interpret the results. Current data on N fertilizer use and animal livestock numbers in INTEGRATOR are based on the FAO database (FAO, 2007), whereas results from IMAGE modelling exercises for the different scenarios are used to scale these current data towards the future. These changes have affected the ratio between N fertilizer and manure inputs. CAPRI-SPAT data were used for the downscaling of the output data. Used soil type, texture class, C content and C/N ratio data were derived from the up-scaled SPADE/WISE database (Heuvelink et al., 2009).

The main types of data used by FSSIM are the current agricultural management data, the available resource endowments for each farm type, and the changes for the different scenarios towards 2050 (Table 4). The management information consists of the crop activities (i.e. main crop rotations) in a region with their yields and required inputs and their costs for average management. These data refer to the Base year (2003-2005), are collected for each crop-soil combination in a region, and were derived from a survey (Zander et al., 2009). FADN data (Farm Accountancy Data Network, see http://ec.europa.eu/agriculture/rica/) were used to define the available resource endowments per farm type. Changes towards the future according to the three scenarios and the policy environment are described in In the integrated analyses we aim at assessing climate change in the context of technological, socio-economic (markets) and policy changes towards 2050. This is relevant as climate change is only one of the drivers of agricultural systems in 2050. The main factors that influence future agricultural systems and their development and that differ between the three scenarios for 2050 (as specified in **Error! Not a valid bookmark self-reference.**), are the following:

- Changes in climate conditions (as based on IPCC scenarios); climate data are derived from the Intergovernmental panel on Climate Change (IPCC) Data Distribution Centre (DDC IPPCC, 2010) and clearly differ between the scenarios, as described in Wolf et al. (2012, p. 16).

Table 1 and in Section 2.3.

3 Results for three selected NUTS regions for models FSSIM, INTEGRATOR and SIMPLACE

In the following, results are presented in terms of change ratios in (i) agronomic indicators, i.e. cropping patterns and crop yields, (ii) socio-economic indicators, i.e. farm gross income, farm net income, and farm labour demand, and (iii) environmental indicators, i.e. N losses to air and water, for each scenario and variation. These change ratios are the results from dividing the model results for 2050 by those for the Base year (2003-2005).

Cropping patterns are given as they partly explain the economic and environmental results. For example, changes in production and thereby in farm net income are not only influenced by changes in crop yields due to changes in climate, CO_2 concentration and technology change, but also by changes in cropping patterns (e.g. shift from grain crops to a high value crop as seed potato). The same holds for changes in N inputs, needed to obtain the yields of the different crops, which in turn largely affects the N emissions to air and water.

3.1 Changes in agronomic indicators

3.1.1 Cropping patterns

Cropping patterns change for each combination of scenario and variation. To give insight in those changes, Figure 2 presents the cropping patterns on mean farms in Flevoland, Midi Pyrenées and Denmark for the Base year, whereas the cropping patterns in 2050 for the four variations of the B1 scenario are given in Table 5. Finally, Figure 3 presents the cropping patterns for the three scenarios and four variations in 2050 for Flevoland as an example.

Table 5 Relative crop area fractions (-) for Base year (2003-2005) and Baseline (B1) scenario for 2050 in the regions Denmark as a whole, Flevoland, and Midi-Pyrenées with respectively CLIM, CLIMT, CLIMP and CLIMTP variations. Note that the cropping patterns are based on aggregating the results from the different farm types in that region weighted according to the number of represented farms

Region (no. of farm types)	Base year	B1 scenario CLIM	B1 scenario CLIMT	B1 scenario CLIMP	B1 scenario CLIMTP
Flevoland (2)					
Maize fodder	0.02	0.00	0.00	0.01	0.00
Maize grain	0.00	0.00	0.00	0.00	0.00
Onion	0.16	0.09	0.06	0.14	0.06
Peas	0.01	0.00	0.00	0.00	0.00
Potato seed	0.37	0.61	0.64	0.08	0.42
Potato ware	0.01	0.00	0.00	0.16	0.02
Rape seed	0.00	0.00	0.00	0.00	0.00
Spring barley	0.06	0.07	0.07	0.09	0.08
Spring wheat	0.07	0.03	0.00	0.08	0.04
Sugar beet	0.15	0.13	0.10	0.15	0.10
Tulip	0.00	0.00	0.00	0.00	0.00
Winter wheat	0.13	0.04	0.10	0.24	0.24
Fallow	0.02	0.02	0.02	0.03	0.02
Total area (ha)	60.7	60.7	60.7	60.7	60.7
Midi-Pyrenées (3)					
Maize fodder	0.01	0.00	0.00	0.00	0.00
Maize grain	0.21	0.00	0.02	0.00	0.00
Oats	0.00	0.00	0.00	0.00	0.00
Peas	0.04	0.04	0.03	0.03	0.02
Rape seed	0.02	0.02	0.02	0.04	0.04
Soya bean	0.03	0.04	0.10	0.00	0.01
Sunflower	0.20	0.15	0.13	0.03	0.00

Winter barley	0.03	0.03	0.03	0.02	0.01
Winter durum wheat	0.22	0.44	0.37	0.51	0.51
Winter soft wheat	0.12	0.16	0.18	0.26	0.30
Fallow	0.11	0.11	0.11	0.11	0.11
Total area (ha)	102.0	102.0	102.0	102.0	102.0
Denmark (8)					
Alfalfa fodder	0.01	0.00	0.00	0.00	0.00
Grass seed	0.03	0.03	0.02	0.02	0.01
Grass fodder	0.04	0.05	0.08	0.04	0.02
Maize fodder	0.02	0.08	0.08	0.06	0.07
Oats fodder	0.03	0.02	0.01	0.02	0.01
Peas fodder	0.01	0.01	0.01	0.00	0.00
Potato ware	0.02	0.03	0.06	0.01	0.03
Rape seed	0.05	0.03	0.02	0.06	0.06
Rye	0.03	0.02	0.00	0.01	0.00
Spring barley	0.30	0.22	0.28	0.10	0.12
Sugar beet	0.02	0.05	0.13	0.01	0.03
Triticale fodder	0.00	0.00	0.00	0.08	0.00
Winter barley	0.07	0.04	0.03	0.04	0.06
Winter soft wheat	0.32	0.37	0.23	0.48	0.52
Fallow	0.06	0.06	0.06	0.06	0.06
Total area (ha)	64.6	64.6	64.6	64.6	64.6

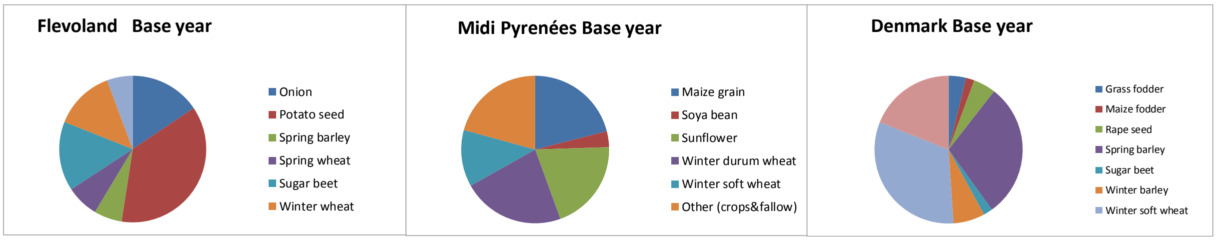
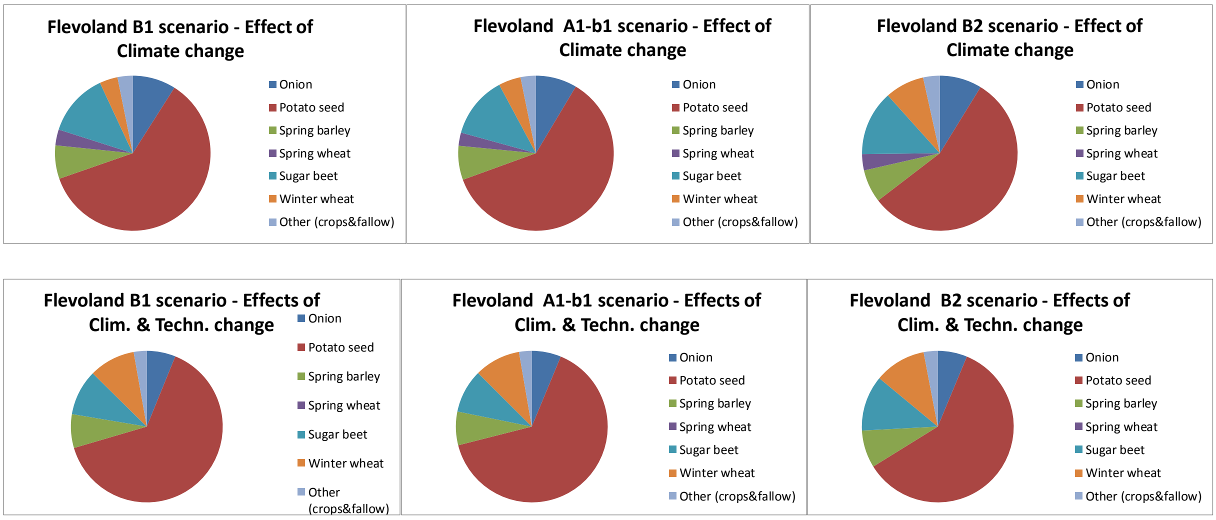


Figure 2 Cropping patterns on mean farms in Flevoland, Midi Pyrenées and Denmark for the Base year (2003-2005)



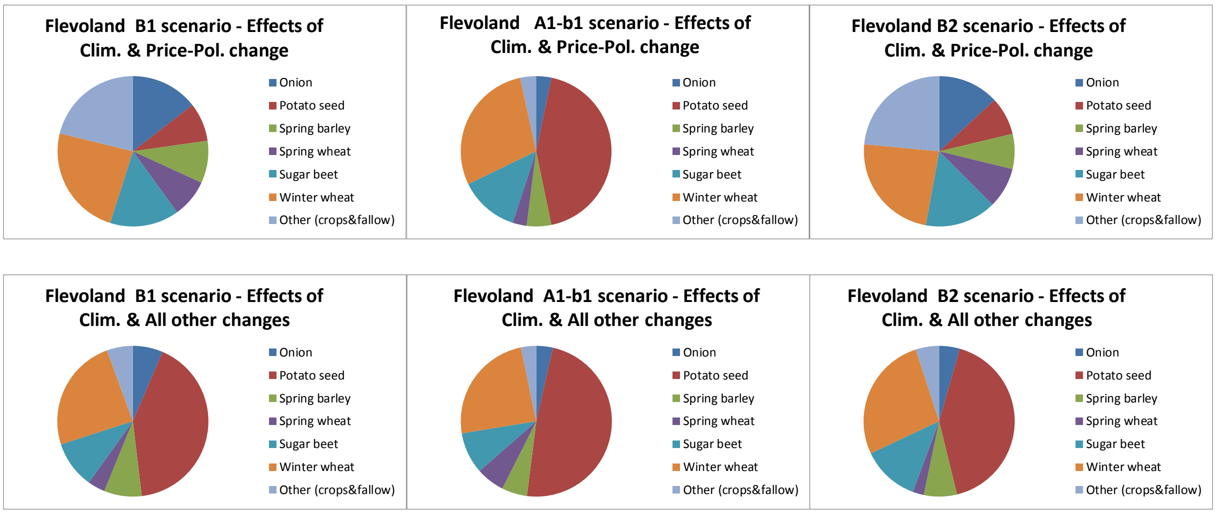


Figure 3 Cropping patterns on mean farms in Flevoland for respectively the Base line (i.e. B1), the A1-b1 and the B2 scenarios for 2050, considering the effects of (i) changes in climate and atmospheric CO_2 on crop yields only (CLIM; top figure), (ii) CLIM and changes in technology and management on crop yields (CLIMT; second figure), (iii) CLIM and changes in product and input prices and in policies (CLIMP; third figure) and (iv) CLIM and changes in all other factors (CLIMTP; bottom figure)

In Flevoland, the main crops in the Base year are seed potato (37%), onion (16%), sugar beet (15%) and winter wheat (13%), with smaller area fractions for spring wheat and spring barley. In Midi-Pyrenées, the main crops are winter durum wheat (22%), grain maize (21%) and sunflower (20%), with smaller area fractions for winter soft wheat, fallow land and peas. In Denmark the main crops in the Base year are winter soft wheat (32%) and spring barley (30%) with smaller area fractions for winter barley, fallow land, rape seed (See Figure 2 and Table 5).

In Flevoland the B1 scenario for 2050 results in a strong increase in the area fraction with seed potato (i.e. 61%) compared to that in the Base year (Figure 2), at the cost of the area fractions for onion, spring and winter wheat in case of climate and CO_2 change only (Figure 3; top graph). The A1-b1 scenario results in the same cropping pattern in 2050 as that for the B1-scenario, whereas the B2 scenario results in less specialization in seed potato. The changes in the cropping pattern per scenario due to technology and management effects on crop yields changes, compared to those from CLIM, appear to be very small for the three scenarios (i.e. slight increase in area fraction for both seed potato and winter wheat; Figure 3; second graph). The price changes for 2050, as included in CLIMP result for the B1 and the B2 scenarios in a very strong decrease in seed potato area (from respectively 61% and 56% for CLIM to 8% for both scenarios), and in moderately increasing areas for onion and spring wheat and strongly increasing areas for winter wheat and ware potato (Figure 3; third graph). For the A1-b1 scenario the seed potato area also decreases but to less extent (from 61% for CLIM to 43%) and this result in a very strong increase in the winter wheat area. The changes in both prices and technology and management for 2050 result for the B1 and the B2 scenarios also in a strong decrease in seed potato area (from respectively 61% and 56% for CLIM to 42% for both scenarios), and in a strong increase in winter wheat area. However, this decrease in seed potato area is much smaller than that in case only price changes are applied For the A1-b1 scenario the seed potato area also decreases but to a less extent (from 61% for CLIM to 48%) and this also results in a strongly increasing winter wheat area (Figure 3; bottom graph).

In Midi Pyrenées the area fractions of durum and soft wheat increase strongly and moderately, respectively, for the B1 scenario compared to those in the Base year, which results in a nil grain maize area and in a lower area fraction for sunflower in case of climate and CO_2 change only (Table 5). The area distributions for CLIMT are about similar to those from the CLIM. For the A1-b1 and B2 scenarios the changes in cropping pattern appear to be practically similar to those for the B1 scenario (not shown). The price change for 2050 (i.e. CLIMP versus CLIM) results for the three scenarios in increasing areas with winter soft wheat and winter durum wheat and in decreasing areas with soya bean and sunflower (see Table 5 for B1 scenario). The price and technology changes for 2050 (i.e. CLIMTP versus CLIM) result for the three scenarios in increasing areas for mainly winter soft wheat and in decreasing areas for mainly soya bean and sunflower (see Table 5 for B1 scenario).

In Denmark the B1 scenario results in moderate to considerable increases in area fractions for winter soft wheat, sugar beet and fodder maize compared to those for the Base year, at the cost of the spring and winter barley area fractions in case of climate and CO_2 change only (Table 5). For the A1-b1 and B2 scenarios the changes in cropping pattern are similar to those for the B1 scenario (not shown). The area distributions for CLIMT differ from CLIM with respect to strong increases in area with spring barley and sugar beet, a moderate increase in potato area, and a strong decrease in area with winter soft wheat for both the B1 and A1-b1 scenarios. However, for the weak economic growth B2 scenario, there are practically no changes in cropping pattern. The price changes for 2050 (i.e. CLIMP versus CLIM) result for the B1 and the A1-b1 scenarios in increasing areas with mainly winter soft wheat, for the B2 scenario in increasing areas with winter barley and rapeseed, and in decreasing areas with spring barley and sugar beet (see Table 5 for B1 scenario). The price and technology changes for 2050 (i.e. CLIMTP versus CLIM) result for the B1 and the A1-b1 scenarios in increasing areas with mainly winter soft wheat and decreasing areas with spring barley, and for the B2 scenario in increasing areas with rape seed and winter barley and in decreasing areas with spring barley and sugar beet (see Table 5 for B1 scenario).

3.1.2 Crop yields

Crop yields increase due to climate change towards 2050, mainly due to the increase in atmospheric CO_2. SIMPLACE has also calculated yields if both climate and farm technology (e.g. improved crop varieties) and management change over time, resulting in even stronger yield increases (Wolf et al., 2012). Only for a C4 crop as maize, this positive climate change effect is roughly nil. These yield increases are important, as they result in a higher farm income in the FSSIM modelling and in higher N demands and N fertiliser applications in the INTEGRATOR modelling. Crop yields are, of course, not influenced by price changes towards 2050. These yield changes by changes in climate only and in climate and technology together towards 2050 are specific per crop type but, in general, they are respectively positive and strongly positive. As an example, crop yield changes are presented in Figure 4 for the most representative crop type per region, i.e. seed potato in Flevoland, winter durum wheat in Midi-Pyrenées and winter soft wheat in Denmark. Yield increases by improved varieties are apparently stronger for grain crops than for potato. These results also show that the yield increases are stronger for the strong-economic growth A1-b1scenario than for particularly the low economic growth B2 scenario, assuming strongest food demand and highest investment in improved crop varieties for the A1-b1 scenario.

3.2 Changes in socio-economic indicators

The socio economic indicators used in our analysis are farm gross income (i.e. yields times product prices for the cultivated crops), farm net income (i.e. farm gross income minus variable costs, both in Euro/farm), and farm labour demand (in working hours).

3.2.1 Farm gross income

In both Flevoland and Denmark, climate change according to the ***B1 scenario*** results in a moderate increase in farm gross income and in even a strong increase in farm gross income, when also the effects of improved technology and management (CLIMT) on crop yields in 2050 are considered (Figure 5).

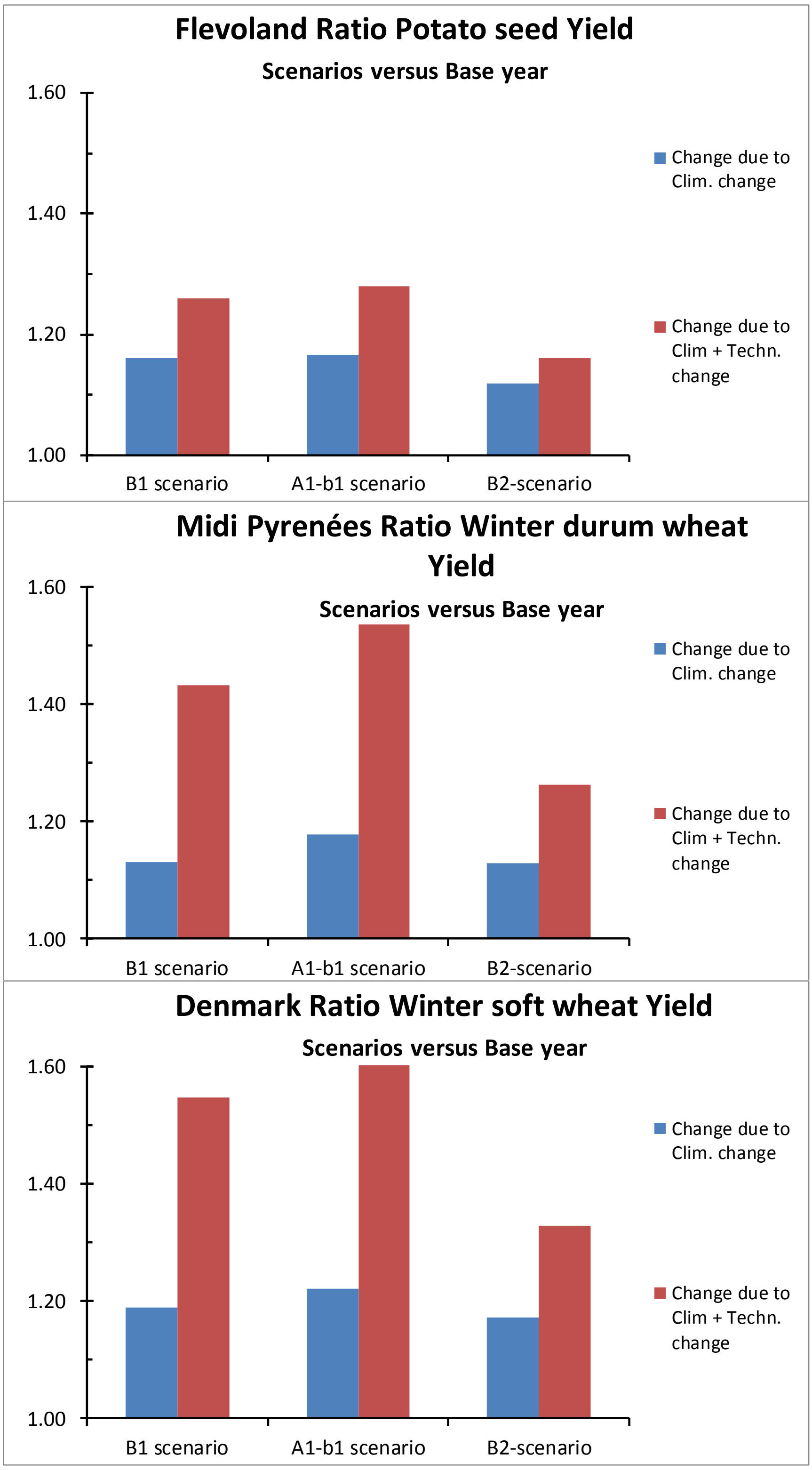


Figure 4 Relative changes in crop yields of potato seed in Flevoland, winter durum wheat in Midi Pyrenées and winter soft wheat in Denmark for respectively, the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering first, the effects of climate change and increased atmospheric CO_2 on crop yields only (CLIM) and next, the effects of both CLIM and technology and management changes on crop yields (CLIMT)

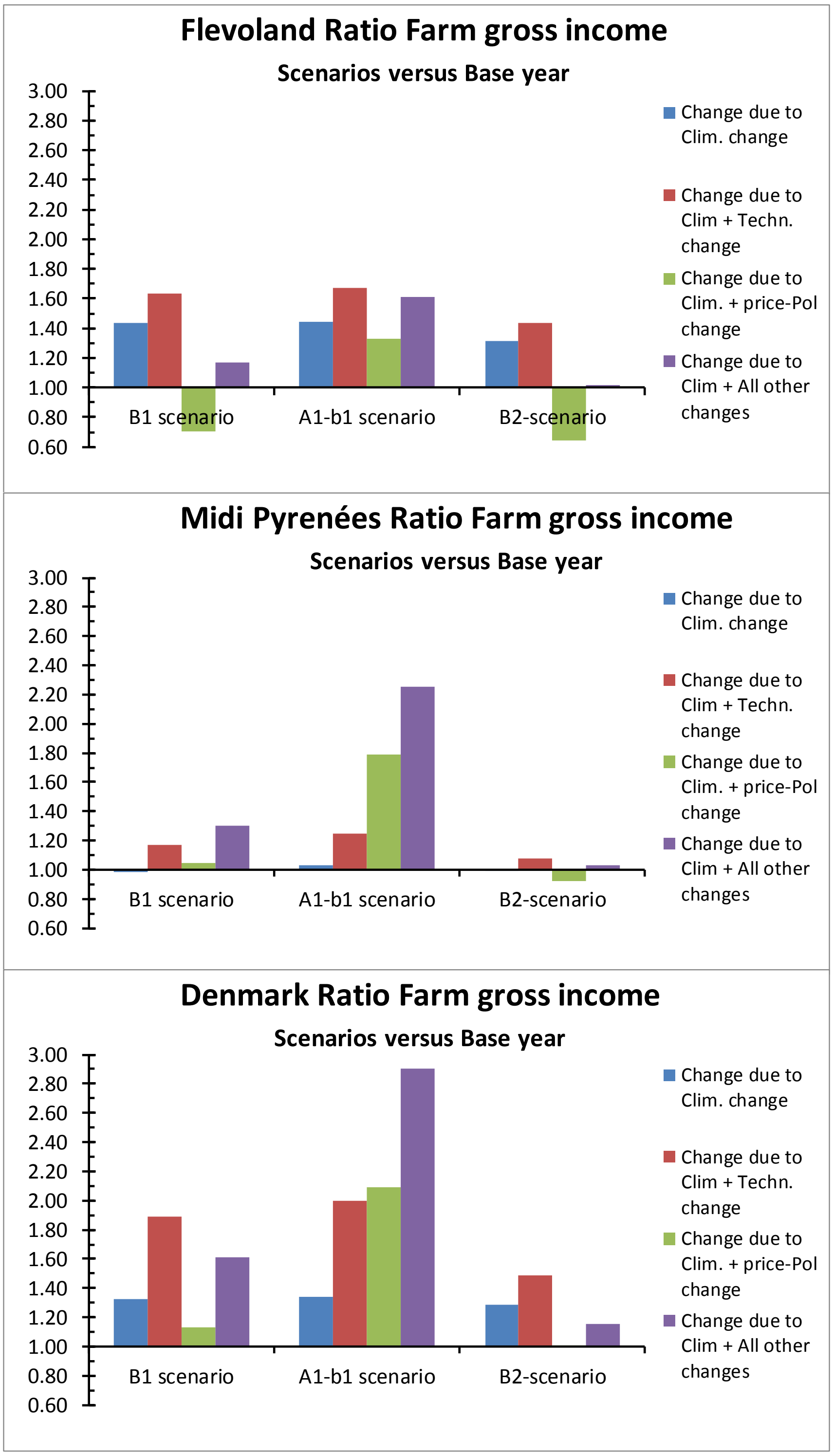


Figure 5 Relative changes in farm gross income on mean farms in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering effects of (i) climate change and increased atmospheric CO_2 only (CLIM), (ii) both CLIM and technology and management changes (CLIMT), (iii) both CLIM and changes in prices and policies (CLIMP), and (iv) CLIM and all changes in technology/management and prices/policies (CLIMTP)

The expected changes in prices towards 2050 have respectively, a strong and moderate negative effect on farm gross income in Flevoland and Denmark. In Midi Pyrenées climate change according to the B1 scenario has no effect on farm gross income, whereas a slightly positive effect on is predicted when improved technology and management in 2050 are considered. In the ***A1-b1 and B2 scenarios*** the farm gross incomes in the three regions become respectively, much higher and moderately lower than the farm gross incomes for the B1 scenario in both CLIMP and the overall CLIMTP for 2050 (Figure 5). This is mainly due to the price changes towards 2050.

3.2.2 Farm net income

In both Flevoland and Denmark climate change according to the ***B1 scenario*** results in a moderate increase in farm net income and in a very strong increase in farm net income, when also the effects of improved technology and management (CLIMT) on crop yields in 2050 are considered (Figure 6). The expected changes in prices towards 2050 have a strongly and a moderately negative effect on farm net income in respectively, Flevoland and Denmark. In Denmark this can be compensated by the increased yields due to climate change and improved technology (Figure 4). However, in Flevoland this results in a lower farm net income also with the overall CLIMTP variation. In Midi Pyrenées climate change according to the B1 scenario has practically no effect on farm net income and has a moderately positive effect on farm net income, if improved technology and management in 2050 are considered.

In the ***A1-b1 and B2 scenarios*** the farm net incomes in the three regions become respectively, much higher and moderately lower than the farm net incomes for the B1 scenario in both CLIMP and the overall CLIMTP for 2050 (Figure 6). This is mainly due to the price changes towards 2050. These increases in farm net income for the A1-b1 scenario are clearly higher in Denmark and Midi Pyrenées than in Flevoland. This can be explained from the fact that the price changes towards 2050 for seed potato as mainly grown in Flevoland, are less favourable compared to the price changes for grain and oil crops, mainly grown in Denmark and Midi Pyrenees.

3.2.3 Farm labour demand

In Flevoland climate change according to the ***B1 scenario*** results in a moderate increase in farm labour demand due to the increasing area with seed potato at the cost of the areas of most other crops (Table 5), both without and with the effects of improved technology and management (CLIMT) on crop yields in 2050 included (Figure 7). The expected changes in prices towards 2050 have a strongly negative effect on farm labour demand due to the decrease in seed potato area. In Midi Pyrenées climate change according to the B1 scenario results in a lower farm labour demand in 2050 compared to that in the Base year in three of the four variations (Figure 7), which is due to the fact that an irrigated and intensively cultivated crop as grain maize is replaced by winter durum and soft wheat (Table 5). Only with the CLIMT variation the labour demand is similar to that in the Base year, as grain maize is replaced by another irrigated and intensively cultivated crop (i.e. soya bean). In Denmark climate change according to the B1 scenario results in nil to slight increases in farm labour demand in 2050 for all four variations (Figure 7)

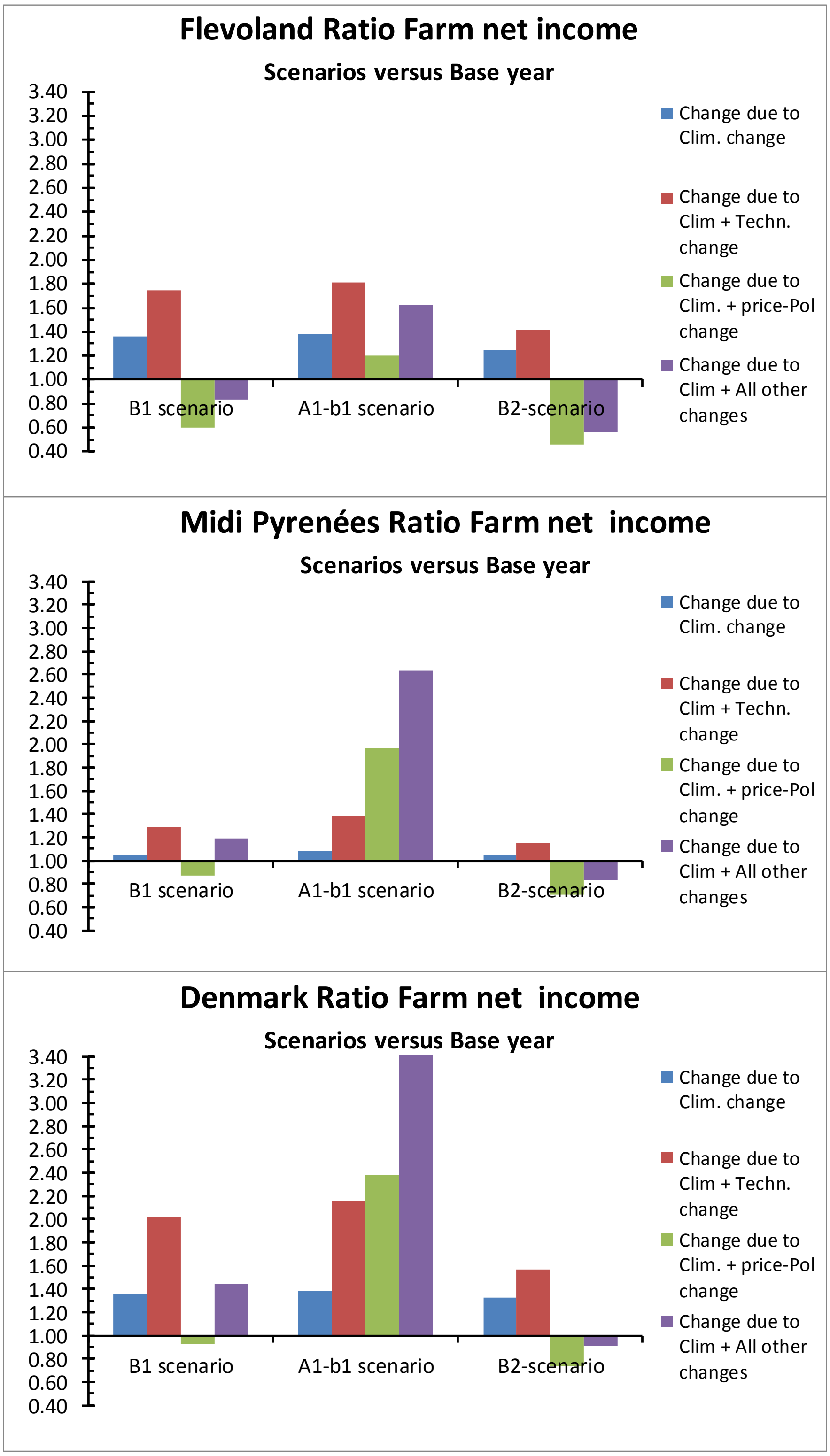


Figure 6 Relative changes in farm net income on mean farms in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering the variations CLIM, CLIMT, CLIMP and CLIMTP (see Table 2)

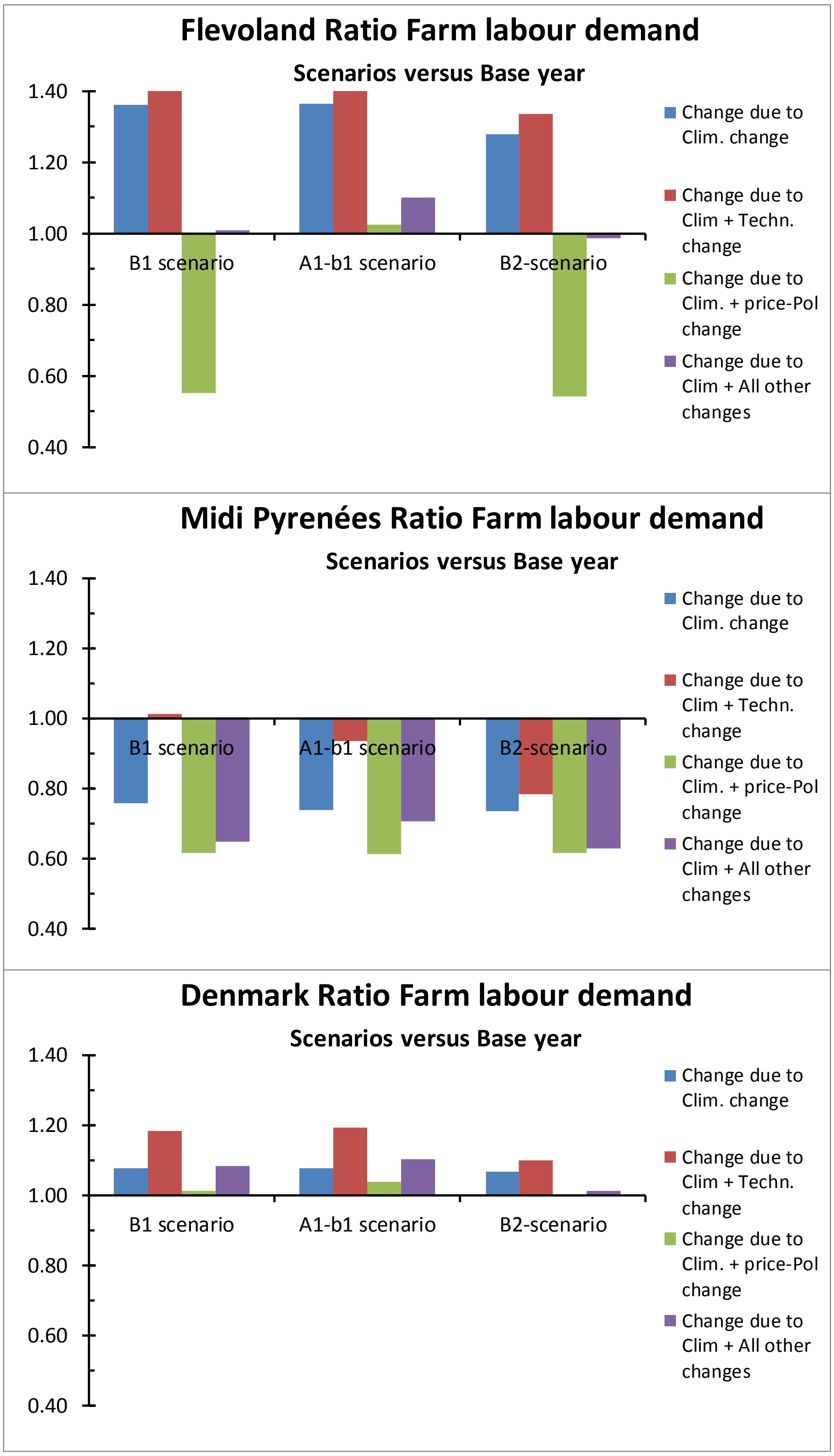


Figure 7 Relative changes in farm labour on mean farms in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering the variations CLIM, CLIMT, CLIMP and CLIMTP (see Table 2)

This is related to the slight changes in cropping pattern (and if so, mainly changes within the same sort of crops, namely grain crops).

In the ***A1-b1 and B2 scenarios*** the changes in labour demands for 2050 in the three regions compared to those in the Base year, are similar to those for B1 scenario (Figure 7). These results show that the changes in labour demand, as caused by the changes in cropping pattern, are mainly due to the differences between the four variations and much less so due to the differences between the three scenarios. An exception is the nil decrease in seed potato area and thus in farm labour demand in Flevoland for the A1-b1-scenario with CLIMP compared to the strong decreases in seed potato area and farm labour demand for the B1 and B2 scenarios.

3.3 Changes in environmental indicators

The environmental indicators used in our analysis are NH_3 and N_2O emissions to the air and the sum of N leaching and N runoff to ground and surface water (all in kg N $ha^{-1}yr^{-1}$).

3.3.1 Ammonia emissions

Changes in ammonia (NH_3) emissions are determined by changes in both NH_3 emission factors and the total N inputs from applied fertilizers and animal manure. Since we assume that NH_3 emission fractions will decrease towards 2050 due to improved housing systems and application techniques, an emission decrease is to be expected unless increased N inputs compensate for this. With respect to the total N inputs (not shown) in both Flevoland and Denmark, slight increases are modelled in response to climate change according to the ***B1 and A1-b1 scenario*** and respectively, moderate and strong increases, when also the effects of improved technology and management (CLIMT) in 2050 are considered. This is due to the increased N demand, as determined by changes in crop yields and cropping patterns. Price changes towards 2050 (i.e. CLIMTP vs. CLIMT and CLIMP vs. CLIM) lead in both Flevoland and Denmark to practically no changes in the applied N inputs. In the ***B2 scenario*** the increases in N inputs are nil to slight in both regions for all variations. In Midi Pyrenées climate change according to the ***B1 and A1-b1 scenario*** leads to a strong decrease in applied N inputs and CLIMT (with effects of improved technology included) results in a moderate increase. These changes in applied N inputs are practically similar, if also the effects of price changes towards 2050 (i.e. CLIMP and CLIMTP) are considered. In the ***B2 scenario*** there is a strong decrease in N inputs for all variations.

The relative changes in NH_3 emissions (Figure 8) compared to those in the Base year show similar patterns as those described above for the N inputs in Midi Pyrenées. However, in Flevoland and Denmark the relative changes are reversed, becoming generally negative, except for the variations CLIMT and CLIMTP for the B1 and A1-b1 scenarios in Flevoland. Apparently in these two regions, the reductions in NH_3 emission factors are in general larger than the modelled increases in N inputs. This is due to increases in applied N inputs, which consist mainly of inorganic N fertilizers with a low NH_3 emission factor.

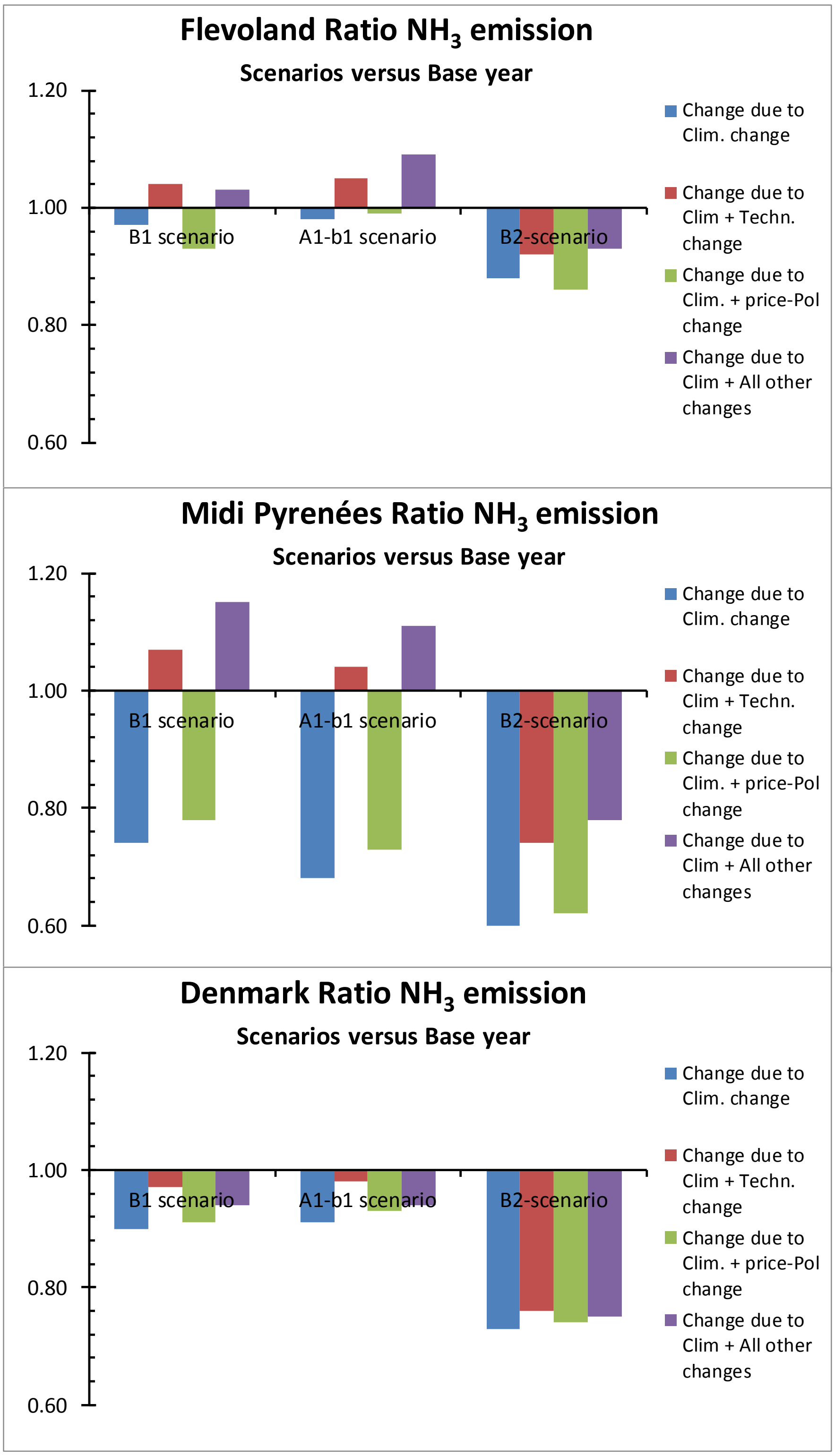


Figure 8 Relative changes in ammonia emissions in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering the variations CLIM, CLIMT, CLIMP and CLIMTP (see Table 2)

3.3.2 Nitrous oxide emissions

Changes in nitrous oxide (N_2O) emissions are determined by changes in both N_2O emission factors and the total N inputs from applied fertilizers and animal manure. Unlike NH_3, the N_2O emission fractions hardly change towards 2050, as they are mainly determined by relatively constant environmental factors, such as N source, soil type and land cover. Consequently, the changes in N_2O emissions (Figure 9) strongly follow the changes in N inputs, as described in Section 3.3.1.

3.3.3 N leaching and runoff

Changes in the sum of N leaching and runoff are determined by changes in both the summarized factor for N leaching and subsurface runoff (Table 3) and the N surplus (i.e. N inputs from applied fertilizers and animal manure minus the total crop N uptake). As with N_2O, the changes in the N leaching and runoff factors towards 2050 are limited, as they are mainly determined by relatively constant environmental factors, such as soil type, land use, soil organic content and rooting depth. These factors also depend on precipitation surplus and temperature, which change over time, however, their assumed impact is limited. As described in Section 3.3.1, the N inputs increase slightly to moderately and slightly to strongly towards 2050 in respectively, Flevoland and Denmark, and both increase and decrease (depending on scenario and variation) in Midi Pyrenées. However, due to the assumed increase in N use efficiency by 20% up to 2050, the N surpluses do not completely change in the same way as the N inputs. Consequently, the sum of N leaching and runoff to ground water and surface water (Figure 10) shows a nil to slight decrease in Flevoland for the B1 and A1-b1 scenarios and a moderate to strong decrease in the Midi Pyrenées for all scenarios. However, in Denmark there is almost always an increase in the sum of N leaching and runoff towards 2050, with the differences between scenarios and variations (Figure 10) being practically similar to those for the N inputs (see Section 3.3.1).

4. Discussion and main outcomes

4.1 Influences on changes in socio-economic, agronomic and environmental indicators

The effects of the three scenarios and the four variations on all socio-economic and agronomic indicators are clearly different in the three regions. For example, climate change according to the B1 scenario results in moderate increases in farm net income in both Flevoland and Denmark and in very strong increases, if improved technology is applied. However, climate change has practically no effect on farm net income in Midi Pyrenées.

Changes in farm income are caused by changes in crop yields, cropping pattern and prices for inputs and outputs. Changes in farm labour demand are mainly caused by changes in cropping pattern, which in turn are influenced by the different yield and price changes. Changes in N emissions and N leaching are mainly caused by changes in total N inputs from the applied fertilizers and animal manure.

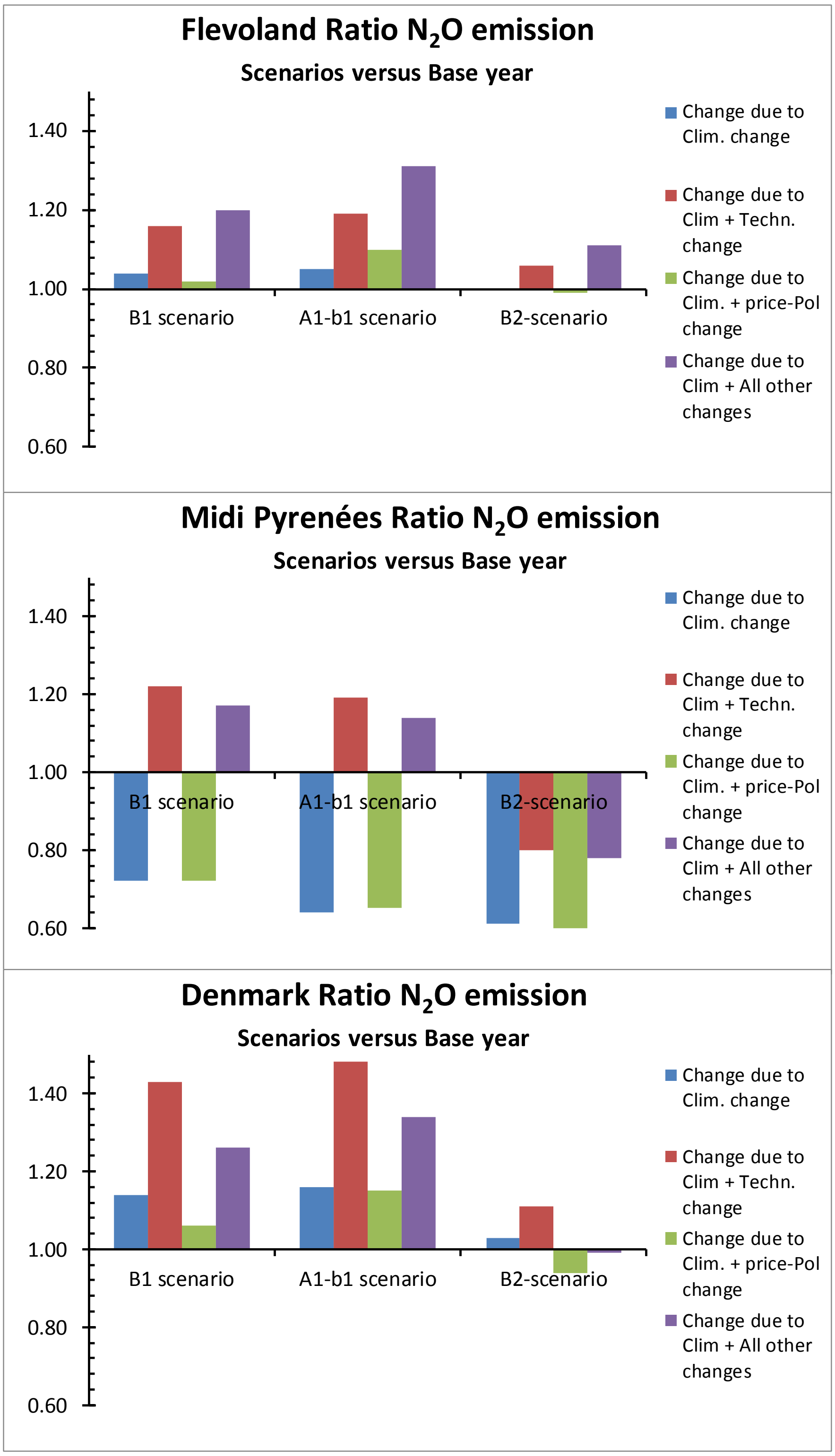


Figure 9 Relative changes in nitrous oxide emissions in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering the variations CLIM, CLIMT, CLIMP and CLIMTP (see Table 2)

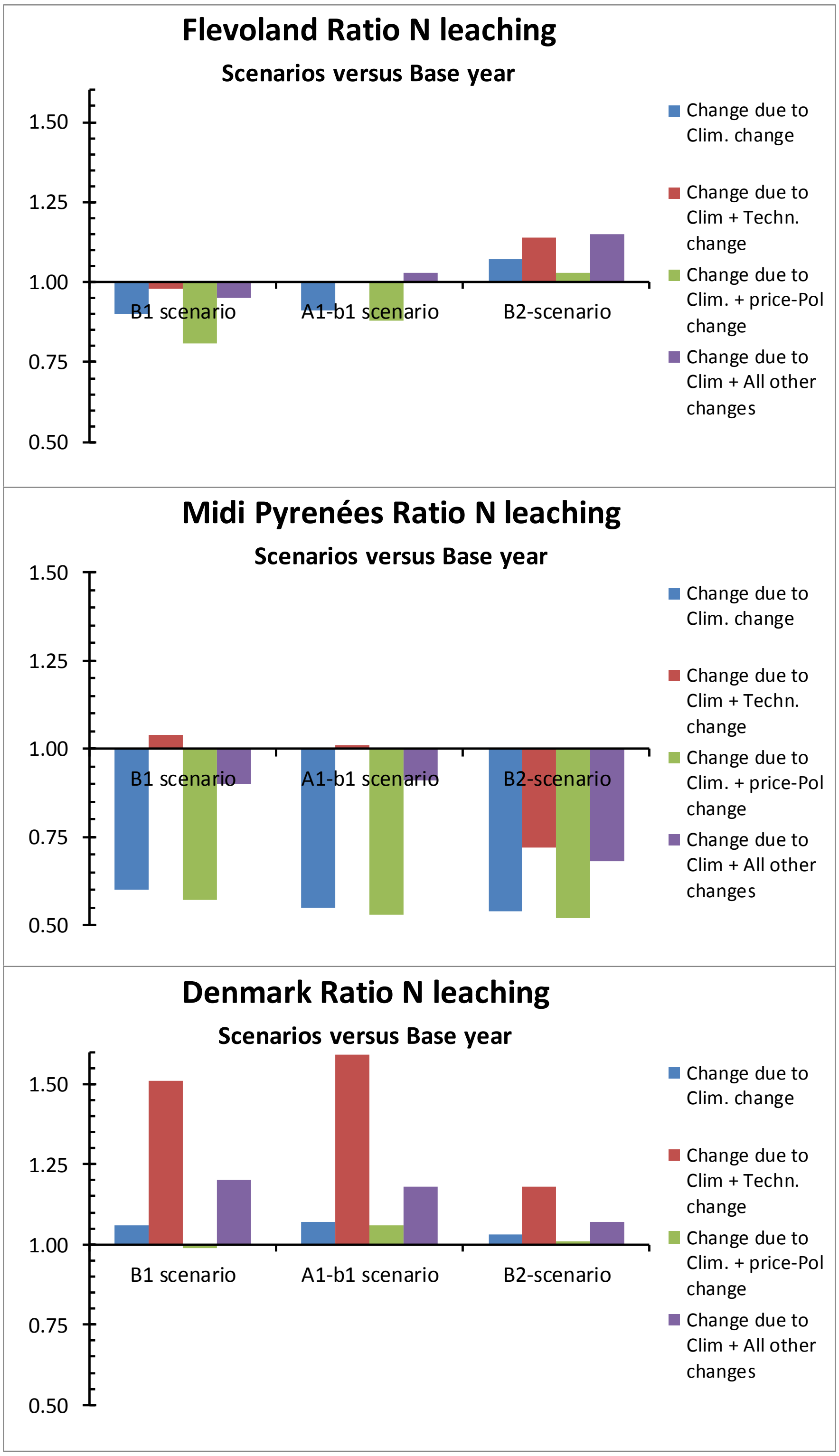


Figure 10 Relative changes in the sum of N leaching and runoff to ground water and surface water in Flevoland, Midi Pyrenées and Denmark for respectively the Base line (i.e. B1), A1-b1 and B2 scenarios for 2050 compared to the Base year (i.e. 2003-2005), considering the variations CLIM, CLIMT, CLIMP and CLIMTP (see Table 2)

These are in turn determined by changes in N demand, which depend on the changes in crop yields and cropping patterns. Considering these different influencing variables, it is understandable that the modelled results are highly variable between scenarios, variations and regions. This indicates the importance of considering all possible future changes in climate, technology, management, prices and policies in scenario analyses. This is only possible by applying an integrated approach, as presented.

4.2 Strong aspects of the present approach

The added value of the final Agri-Test Case compared to the previous Agri-Adapt study (Wolf et al., 2012), which focused on the same topic, is a considerable improvement in the modelling approach. The main improvements are as follows: a) assessment of climatic change impacts on agriculture in the context of technological, socio-economic and policy changes towards 2050 for EU-27 and not only for Flevoland, the Netherlands, b) impacts on the environment will be simulated with the INTEGRATOR model and not based on environmental indicator calculations, c) coherent linking of the four applied models. This will lead to a strongly improved usability of the linked models for doing impact assessments for future conditions over Europe and for answering questions about climatic change impacts on agriculture and the environment in the future.

Strong points of the presented integrated approach which in a next step of the Agri-Test case will be further improved and integrated (see Section 4.3), are as follows:

- Price changes of the major agricultural products and inputs for the different future scenarios, as calculated by the market model in CAPRI, are essential, as these price changes determine the future changes in cropping patterns on the different farm types (as modelled in FSSIM).
- Changes in yields of the main crop types under the different future scenarios have been calculated with the crop growth model SIMPLACE for different climate change scenarios (Wolf et al., 2012).
- N emissions have calculated with the INTEGRATOR model for regions over Europe for the different future scenarios, using the future cropping patterns per farm type as based on the FSSIM modelling and the future yields as based on SIMPLACE modelling.
- Responses of farming systems to changes in climate, input and product prices, and in technology, farm management and policies are modelled at the farm level (i.e. the actual decision level in farming) and for representative farm types, and in a next step they are up-scaled to the regional scale; this provides integrated information about the responses of farming systems to all these different changes.

FSSIM calculations have been done at the level of individual farms, of which the outcomes have next been up-scaled to a mean farm at the regional level. Results for Flevoland, not presented in this paper, show that the responses of different farm types in this region to changes in climate, technology and prices are related to their farm structure (e.g. specialization in seed potato or in grain crops), and that it is important to analyse the effects of changes in climate, technology, prices and policies on farming at the farm level for representative farm types and not at the regional level (as often done in market models).

4.3 Next steps in the Agri-Test case: Tool improvement

In the current study, the models have been used as they were available, focusing on model harmonization and integration in view of

1 Coherent simulation of crop yields under climate and technology change for the coming decades:

- Plausible yield developments for major crops for different zones in Europe
- Integration of technology factors into crop growth models
- Integration into software infrastructure of CAPRI
- Development of a long term baseline for Europe in CAPRI (B2 scenario)

2 Inclusion of scenario runs

The AVEMAC study mentions on page 141: “The socio-economic assessment of climate change adaptation measures require building a comprehensive economic modelling framework which considers economic and environmental interlinkages and feedbacks present in the agricultural sector as well as the complexity of the farming systems and adaptive agro-technological processes”. This is included in our approach in here: by application of CAPRI-FARM including the global market model, driven by simulated yield changes from SIMPLACE, in combination with FSSIM

In the next phase of this study:

- the future changes in prices, yields and agricultural systems will be analysed for the different scenarios in a more integrated way and over the whole of Europe (EU27). Furthermore,
- the effectiveness of a number of adaptation measures in agriculture to climatic change impacts will be evaluated and
- a set of Common Agricultural Policy (CAP) instruments which may support the application of most promising adaptation measures, will be developed and tested in the model simulations.

We intend to apply in the next phase of the project the linked models in a more integrated way for the three scenarios for 2050. For example, SIMPLACE has calculated yields for future climate change conditions over Europe with and without technological change. In the next phase these potential yields will be translated into actual yields for 2050, for which in the CAPRI simulations the future socio-economic conditions and technological development will be taken into account. This more integrated approach will replace the simple approach for calculating crop yields for different future scenarios from Ewert et al. (2005). This approach consists mainly of changing the coefficient in the historical yield trend differently per scenario.

A second improvement is that the prices for inputs will be more differentiated between different types of input and between scenarios. Third, the linkage between the models and the harmonization of data will be improved by harmonizing N applications in agriculture by SIMPLACE, CAPRI, INTEGRATOR and FSSIM. Fourth, future input-output relationships in farming will be included in FSSIM and CAPRI, which will consider possible improvements in the use-efficiency of inputs depending on the future socio-economic conditions and related technological development. In the next project phase, also the effectiveness of a range of adaptation measures to climate change at the farm level will be tested with FSSIM. Fifth, the impacts of extreme events on crop growth will be simulated including the implementation of droughts/heat stress and extreme rainfall events on probabilities of yield loss and yield failure for the EU regions to be included in model chain. Finally, the effectiveness of a number of possible CAP policy instruments to support adaptation to changed conditions in 2050 will be analysed for some regions with both CAPRI and FSSIM.

5. Conclusions

The presented modelling approach as based on the linkage of the SIMPLACE, FSSIM, INTEGRATOR and CAPRI models, allows to compute the effects of climate change, improved technology and farm management, and changes in prices and policies towards 2050 on (a) future cropping patterns and crop yields for representative farm types per region, (b) future economic outcomes per farm, such as farm net income and labour demand, and (c) future main N emissions (e.g. N leaching to ground and surface water, and NH_3 and N_2O emissions to the air).

Model assessments which have been carried out for three scenarios for 2050 (i.e. Baseline (B1) scenario, a strong economic growth A1-b1 and a weak economic growth B2 scenario) and have considered the effects of respectively, climate change only (CLIM), CLIM plus technology and management change (CLIMT), CLIM plus price and policy change (CLIMP), and CLIM plus all changes (CLIMTP), show the following main results:

1. Farm income

- Climate change and particularly with improved technology and farm management towards 2050 result in higher farm net incomes compared to those in the Base year.
- Price changes towards 2050 result for the B1 and B2 scenarios in lower farm net incomes compared to those in the Base year.
- With the all including CLIMTP variation the farm net income increases for the A1-b1 scenario, decreases for the B2 scenario, and may increase or decrease depending on the region and its cropping pattern for the B1 scenario.
- Differences in farm gross income and farm net income between the A1-b1 and B2 scenarios and the B1 scenario are mainly caused by differences in prices and to a less extent by different yield changes due to different changes in climate, technology and management between the scenarios.

2. Farm labour demand

- Farm labour demand may increase or decrease towards 2050 as related to the changes in cropping pattern, which depend on the scenario, variation and region. Labour demands mostly increase in Flevoland and Denmark and decrease in Midi Pyrenées.
- Differences in the changes in farm labour demand towards 2050 are mainly due to the differences between the four variations and much less so due to the differences between the three scenarios.

3. N losses to air and water

- Changes in N emissions and N leaching towards 2050 are mainly caused by the changes in total N inputs from the applied fertilizers and animal manure, which in turn are influenced by changes in crop yields and cropping patterns.
- N emissions and N leaching appear to increase or decrease towards 2050 depending on the scenario, variation and region. They mostly increase in Denmark, nil to slightly change in Flevoland, and mostly decrease in Midi Pyrenées, except for NH_3 emissions which also decrease in Denmark.

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PART B EU soil strategy case: Review of the "impact assessment of the thematic strategy on soil protection" of 2006

1 Background

1.1 Background on the thematic strategy on soil protection

Soil quality and resources are relevant for sustainable development, because of its role for food security, climate change mitigation, and resource efficiency. Over the past decade, Member States and stakeholders have thus been disputing if and how the European Union should contribute to the conservation of soils. An impressive wealth of knowledge and information systems about soil properties and processes in Europe have been compiled not at least in the frame of the proposed European soil thematic strategy, of which an overview is given below.

In 2002, the Commission presented its approach to soil protection in a Communication "Towards a Thematic Strategy on soil protection" (COM (2002) 179.3). The main threats to soil were described, including erosion, decline in organic matter and biodiversity, contamination, sealing, compaction, salinization and landslides and flooding (later, flooding has been addressed in a separate Communication on flood risk management prevention, protection and mitigation (COM (2004) 472) and has therefore been excluded from the Thematic Strategy on soil protection). The Commission stressed the importance of integrating soil aspects into other policies, but also indicated the need for legislation focussing exclusively on soil.

In 2006, following a comprehensive stakeholder consultation, the European Commission wrote down their "Thematic strategy for soil protection" [SEC(2006)620] , including a proposal for a "Soil framework directive". The 2006 Thematic strategy for soil protection" also had an accompanying document on an "Impact assessment of the thematic strategy on soil protection" ({COM(2006)231 final}; {SEC(2006)1165}, providing(i) a qualitative and quantitative analysis of the extent and costs of soil degradation in the EU, divided in the differing threats and (ii) qualitative assessment of the impacts of possible measures to be taken by Member States. The focus of the impact assessment was about costs of implementation (reporting, monitoring) versus costs of inaction. However, the proposal for a "Soil framework directive" has not been adopted in 2006 because a qualified minority of EU member states opposed it with the arguments of excessive administrative burden and alleged violation of the subsidiarity principles. Furthermore, the scientific evidence was not convincing to decision makers at that time. Quantitative data, particularly monetary information related to soil degradation where not sufficiently available.

In February 2012, the European Commission published a report on the implementation of the soil thematic strategy (COM(2012)46final) and ongoing activities, namely awareness raising, research, policy integration and legislation. The report argues that despite considerable efforts in awareness raising, research and integration, the state of soil degradation is still alarming. Further legislative action is therefore not obsolete, particularly because safeguarding important soil functionalities at European level is a necessary precondition for meeting upcoming grand societal challenges including food security and sustainable agriculture; energy security; climate action and resource efficiency.

1.2 Joint workshop JRC – LIAISE on mainstreaming soil conservation into policy impact assessment

This above given background on the thematic strategy on soil protection was the reason why LIAISE researchers in Work Package 2 ('Science for IA tools and procedures') invited experts from soil sciences to a workshop in JRC, Ispra, which was held on 24-25 April, 2012. The purpose of the workshop was to establish the status quo and to elaborate a research roadmap towards improved uptake on soil evidence in impact assessment. This was done by inviting experts with complementary expertise on soil science and related policy support on the following topics:

1. Soil related policies – state of play and recent developments
2. Policy Impact Assessment – an instrument to fuel scientific evidence into the policy process
3. Soil related evidence for policy support - stocks and research needs

Status quo on soil conservation and policy impact assessment
The main conclusions of this workshop, which was attended by 18 experts from eight European countries, and hosted and supported by JRC staff, namely Luca Montarella, in view of the above given aims are as follows (see minutes for all information):

1. *Soil is now more prominent on the awareness list than it was in 2006* because of its crucial role for coping with the Grand Societal Challenges, particularly food security and sustainable agriculture, secure, clean and efficient energy, climate change mitigation and increased resource efficiency. The topic soil has gained attention during the last 3-4 years in many policy areas (e.g. food security and food safety, climate change, energy policy, biodiversity, CAP, environment). In Section 3, we elaborate in detail on this renewed interest.
2. Even though soil scientists are aware of the need to communicate and transfer knowledge on soil issues to policy-makers, the *models and tools used in decision making are not always state-of-the-art*. There is also a need to reinforce the information flow between basic research, applied research and policy decision support.
3. It is important to *consider not only direct effects but also indirect effects of human activities* (business, agriculture, industry, settlement, policies) *on soil functioning*. While some relations are well known (agriculture – soil degradation), others are less well known or less prominent on the policy agenda (e.g. relation between urban sprawl and soil compaction; between bio-energy promotion and indirect land use change with related biodiversity impacts).

Research roadmap towards improved uptake on soil evidence in impact assessment

Most relevant items mentioned for a research agenda aiming at an improved uptake on soil evidence in impact assessments included

Define soil benefits and threats in view of property rights: Since soil is at the same time a common good as well as a private good, there is a need to understand and the legal relationships of those who own and those who manage soil as well as of those who benefit from soil functions and services and/or are affected by soil degradation. There is a large motivation to use a functional approach in order to specify further strategies (soil = private good; soil function = common good)

Develop a soil suitability classification: In international soil reference systems soils are generally classified in terms of genesis and textural, physic/chemical properties, while some systems also classify soils in terms of capability for food production. To acknowledge the full range of soil functions there is a need to develop a classification system for all different qualities related to the soil multi-functionality (soil quality classes for production; filtering & buffering; habitat; settlement; raw material sources; carbon storage; geological and archaeological archive) following a common conceptual framework.

Develop practical instruments to integrate soil issues in land planning: As yet, planners do not have enough guidance on how to deal with soil values and there are no criteria applicable in a planning process. Thus, there is a need to develop practical instruments for political and planning processes as well as for implementation of strategies. Instruments need to visualize choices and consequences ("what-if") and provide support in the valuation and categorization of land area and land use.

Integrate social, economic and environmental consequences in sustainable soil use and management: There is a need to explore other options than only regulation when considering a sustainable soil management approach. More research is needed on the integration of the social, economic and environmental consequences (i.e. people, profit planet, being the three pillars of sustainability) of soil use and management.

Provide policy sensitive information: In order to be relevant and useful for policy support, models, maps and monitoring systems need to consider variables that are sensitive to policy decisions for a broad variety of policy areas need to be served, including agriculture, environment, energy, climate, infrastructure, and mobility. In this context, the need for harmonisation of information was mentioned, including harmonization of:

1. data and tools used for foresight and ex-ante analysis on one side and those used for monitoring and reporting on the other side, i.e. static data (maps), trend data (monitoring) and dynamic data (modeling & simulation)
2. indicator systems used for different purposes (foresight, assessment, monitoring)
3. networks of experimental data (field sites) to increase congruency.

Further steps

Further steps suggested at the workshop were that members of the LIAISE project in collaboration with the workshop participants will further process the results of the workshop by:

1. Consolidating the research agenda by identifying items for impact assessment and use the material as a basis for a joint paper on soil research for policy support in e.g. Environmental Science and Policy.
2. Further developing the LIAISE tools box for improved update of scientific evidence for policy making and sharpening of the functionality with regards to different user groups and attach practical examples of tool applications to the tools in the box.
3. Revisiting the 2006 impact assessment of the soil thematic strategy in view of: (i) new tools and knowledge that have come available that could cover questions which had to be left open in the earlier assessment and (ii) progress that has been made since 2006 with regards to the methodology and the conceptual framework of impact assessment, allowing for new insights through different integration of existing knowledge.

1.3 Need for a renewed impact assessment in view of global interest in soil degradation

An important reason for a renewed impact assessment of the thematic strategy on soil protection, including an assessment of the possible need for as soil framework directive, is that soil degradation is now much more prominent on the awareness list than it was in 2006. It has been stressed in many policy related documents in the last decade that soils are fundamental pillars of sustainable development. They are essential for food security, support human well-being, and provide further ecosystem services, such as carbon storage.

Global Soil Partnership for Food Security

In September 2011, the Global Soil Partnership for Food security and Climate Change Adaptation and Mitigation was launched at FAO (http://www.fao.org/globalsoilpartnership/home/en/), being a new effort to assure soils for future generations. Within the framework of the "Global Soil Partnership. The vision of this partnership is to “Improve global governance of the limited soil resources of the planet in order to guarantee healthy and productive soils for a food secure world, as well as sustain other essential ecosystem services”. The key issues that lead to the launch of the Global Soil Partnership is the link of soil management to food security and climate change.

Soil resources across the globe are subject to increased pressure from competing land uses and are affected by extensive degradation processes that rapidly deplete the limited amounts of soils and water available for food production. According to FAO, in Africa alone 6.3 million hectares of degraded farmland have lost their fertility and water-holding capacity and need to be regenerated to meet the demand for food of a population set to more than double in the next 40 years. The global problem of land degradation and associated phenomena of desertification, increasing drought and soil erosion are thus threatening global food security and increase livelihood vulnerability to disasters.

The FAO stresses that adequate soil and water management policies and practices are needed in order to build greater resilience to degradation, drought and climate change and reduce human vulnerability to disasters. In 1982 FAO adopted a World Soil Charter spelling out the basic principles and guidelines for sustainable soil management and soil protection to be followed by governments and international organizations. However, there have been long delays in applying the Charter in many countries and regions of the world. Besides helping implement the provisions of the World Soil Charter, the Global Soil Partnership is intended to raise awareness and motivate action by decision-makers on the importance of soils for food security and climate change adaptation and mitigation and at helping mobilize resources and expertise for joint activities and programmes. The Global Soil Partnership will complement the 15-year-old Global Water Partnership initiated by the United Nations Development Programme and the World Bank in 1996.

World Soil Day, Global Soil Week and Global Soil Policy

Another sign of the interest in soil is that FAO with full support of its country members (as expressed during the 144th FAO Council, 11-15 June 2012) has decided to celebrate the World Soil Day at 5 December in 2012 with the theme "Securing healthy soils for a food secure world" http://www.fao.org/globalsoilpartnership/news/detail/en/?dyna_fef%5Buid%5D=161398. Until 2012 the the celebrations of the World Soil Day have mainly taken place at national levels with little international awareness. And yet another sign is the first Global Soil Week (http://www.globalsoilweek.org/) that takes places from 18-22 November in Berlin and that will provide a platform to initiate follow-up actions on land and soil-related decisions made at the Rio+20 Sustainable Development Conference . One Dialogue Session at the Global Soil Week's is a "Global Soil Policy" that aims to analyse and discuss policies and legal frameworks for soil management and conservation at the international level, mainly in the frame of UNCCD, UNCBD, UNFCC. It will take a look at existing legislations, conventions and declarations and identify their achievements and gaps. The session will address the question of how to strengthen and better coordinate soil conservation at an international level including proposals for international soil protection instruments.

Even though all these initiatives have a global character, it is clear that it also puts pressure on the EU to take proper care of soils and re-evaluate the possible need for a soil frame directive in view of a renewed assessment of the thematic strategy on soil protection

2 Aim of the study

This study aim to revisit the 2006 impact assessment of the soil thematic strategy. The major components of this impact assessment in 2006 were an overview of (i) extent and costs of soil degradation in the EU, (ii) analysis of impacts of obligations specified in the suggested Soil Framework Directive and (iii) monitoring and evaluation, including identification of risk areas, assessment of drivers of change and evaluation of measures to combat the soil threats and their efficiency. The aim is to better assess the "Need of and options for a European wide soil protection strategy" in view of new insights since 2006 in terms of:

- context: a new focus on (soil) ecosystem services in relation to Societal Challenges, particularly food security and sustainable agriculture, climate change mitigation and increased resource efficiency. Soil functionalities and soil threats thus need to be assessed in view of those challenges.
- models and tools: new models and tools that have been developed since 2006 need to be identified and evaluated in view of their potential and actual use in assessing: (i) (soil) ecosystem services and soil threats, (ii) impacts of management in relation to policies on these services and threats and (iii) the costs and benefits of measures based on new monetary insights.
- policies: since 2006, new information on the impacts of policies is available, including an analysis of policy measures for agricultural soil conservation in the European Union and its member states in 2009 and an evaluation of cross compliance measures using models available within LIAISE in the same year.

The revision of the impact assessment will also include a further identification of: (i) research items for impact assessment to consolidate a research agenda (step 1) and (ii) tools for inclusion in the LIAISE tools box to enable the continuous update of scientific evidence for policy making (step 2).

The renewed assessment is highly appreciated by the JRC to improve the science basis for a soil framework directive. In 2006, the soil framework directive was not accepted because the scientific evidence, particularly monetary information related to soil degradation, was not sufficient to decision makers at that time. It will not only consider the impact of strategies that explicitly protect the soil itself, but also those policies that only indirectly affect soil properties and functionalities. We aim not only for publication of the material in a short report but also in a joint paper on "Need of and options for a European wide soil protection strategy". Finally, two workshops are foreseen: one near the start to fine tune objectives and approach of the study with JRC and researchers to guarantee JRC interaction from the beginning and one near the end to discuss the results at the end with interested scientists and policy makers.

3 Approach to the study

A. Workshop to specify study objectives.

In interaction with JRC, a workshop with the involved scientists at Alterra and Zalf and some crucial other scientists, will be scheduled at the start of the project to (i) specify objectives of the study, (ii) explore in how far we can improve the impact assessment of 2006,.

B. Revisiting the 2006 impact assessment of the soil thematic strategy.
Based on the results of the workshop, a revised impact assessment of the soil thematic strategy will be made, including an overview of the:

- Analysis of soil functions, based on a soil functional framework (e.g. Bouma, 2010).in the light of grand societal challenges and what that means for soil conservation strategies.
- Availability of methods and tools/ approaches to quantify: (i) soil degradation and its extent including where possible the causal relationship between land use/land management and soil degradation, (ii) the environmental impacts in terms of food security, water retention, water quality, emission of greenhouses etc. and (iii) economic impacts.
- Geographic variation and extent of the environmental impacts of various soil degradation threats (Soil erosion, Soil compaction, Decline of soil organic matter, Soil salinization and Soil contamination) in terms of current status, the likely impacts on food production, soil fertility, water retention, water quality, emission of greenhouse etc. and the anticipated impacts of non- action (no soil policy) by considering the economic consequences of those impacts whenever possible.

C Communication and publication of results and final workshop.
Results of the study will be reported in a joint Institute report and a peer reviewed paper and presented at a final workshop in Brussels.

Annex I: Transparent flow of data to and from models

The crucial question with respect to model linkage is: how much consistency and coverage is required?. Optimally, a link between SIMPLACE, CAPRI, FSSIM and INTEGRATOR requires complete harmonization of the model behaviour such as similar reactions to price changes regarding hectares, herds, yield changes, fertilizer and manure N application rates, emission factors, etc. and updating of excretion or emission factors of certain models based on other models. Full harmonization is however impossible and we neglected this problem by soft linking the models and just neglecting the differences, apart from using common centralised databases where ever possible and making use of systematic data transfer.

The approach to the work was thus a soft link between SIMPLACE, CAPRI, FSSIM and INTEGRATOR with a linkage for regional assessments, without harmonizing all aspects in the models apart from (i) use of common input data and (ii) a (see below).

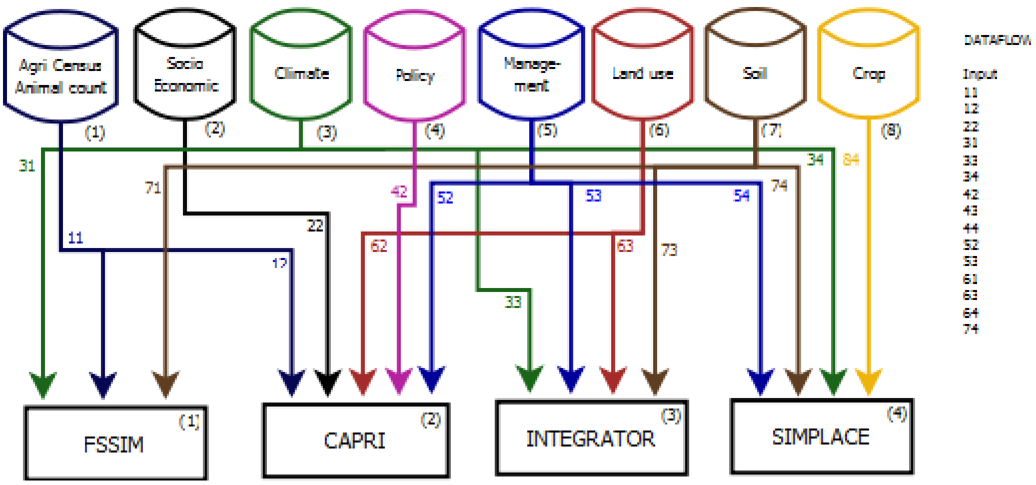
There are many linkages between the scenarios and models such as:

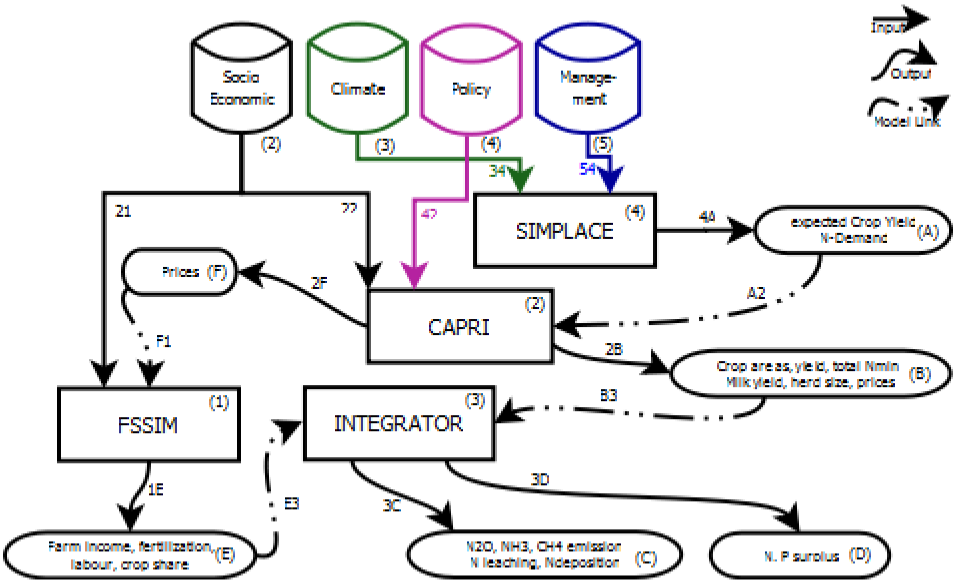
- Technological changes related to plant breeding and management affect input-output prices
- Crop yield is affected by climate change, plant breeding and management
- Crop yield affects N uptake.
- N uptake affects N losses to air and water

Links that will be included are e.g. trends in:

- Crop yields from SIMPLACE to CAPRI, FSSIM and INTEGRATOR
- prices from CAPRI to FSSIM
- cropping patterns from FSSIM to INTEGRATOR.

The linkages used are shown in the figures below and the attached excel sheets





Input
Output
Model Link
Socio Economic
Climate
Policy
Manage-ment
(2)
(3)
(4)
(5)
34
54
21
22
42
SIMPLACE (4)
4A
expected Crop Yield N-Demand (A)
Prices (F)
2F
CAPRI (2)
A2
F1
2B
Crop areas, yield, total Nmin Milk yield, herd size, prices (B)
FSSIM (1)
INTEGRATOR (3)
B3
1E
E3
3C
3D
Farm income, fertilization, labour, crop share (E)
N2O, NH3, CH4 emission N leaching, Ndeposition (C)
N, P surplus (D)

Annex II: Set up of a database for intercomparison of LIAISE models

An aspect that we need to reconcile when comparing the models include the area involved (spatial extent), geographic resolution , temporal resolution and temporal extent. An overview of the situation for the four models is given in Table 1.

Common database
Whenever possible, we need to have and use a common database on

- Socio-economic data (from CAPRI)
- Land use and land management data, such as (all these data are part of the CAPRI data base with time series starting at least in 1990; while similarly data are available in INTEGRATOR since 1970, partly based on different sources):

1. Land cover/ land use (grass and crops in arable land) and crop yields
2. Animal livestock numbers, carcass weights, milk yield etc.
3. N fertilizer application

- Climate
- Soil properties

When different, we need to know that this is the case and make intercomparisons between datasets. Apart from basic data, we need to describe outputs, i.e. crop yields and N demand from ACE and crop areas and milk yield from CAPRI. An overview of the situation for the four models is given in Table 2.

CAPRI data and CAPRI model
Regarding the CAPRI data it is important to mention that the CAPRI model does not use the raw data on socio-economic inputs, land cover/ land use, crop yields etc. directly. Instead, quite some manpower is used to check for gaps and errors, and rather complex Bayesian based estimators are applied to render the raw data consistent. To give an example of consistency requirements:

- Total soft wheat production in the EU is the sum of the Member States, and in each Member State, over the NUTS2, and inside the NUTS2, over the farm types. And in each region or farm type, production is equal to yield x area.
- At the same time, at Member State level, production + imports = exports + human consumption + feed … etc.
- At global scale, each ton of wheat produced must be consumed somewhere, the import of the EU must match import flows from other destination, and each destination, the export flows must match total export and these export quantities fit in the market balance.

Table 1 Characteristics of the four models used in the LIAISE test case on climate adaptation European land N budgets at various geographic resolutions

Model	Method	Sectors considered	Area involved	Geographic resolution	Temporal resolution	Temporal extent
INTE-GRATOR	Adapted MITERRA approach for agricultural systems. Statistical model for terrestrial systems	Agriculture, (semi)-natural terrestrial systems	EU 27+3	NCU[1]	Year	1970-2030
CAPRI-Spat	Spatial downscaling component; post model module to CAPRI-farm; linked to mechanistic model (DNDC) to simulate soil N and water budgets;	Agriculture; Focus is arable land	EU 27	HSMU[1]	3-Year average Ex-ante	2004 (other years possible) 2020[2]
CAPRI-Farm	Economic model (bio-economic programming models) with emission factor based indicator calculators for GHGs, N and P budgets, LCA energy; used in conjunction with CAPRI-Trade; delivers input to CAPRI-SPat	Agriculture (ca. 60 production processes/products)	EU 27, Norway, Turkay, Western Balkans	NUTS2, farm type group inside NUTS2 (EU27)	Year	1985-2010 (expost data base) 2020 exante[2]
CAPRI-Trade	Economic model (multi-commodity model with representation of bi-lateral trade flows) emission factor based indicator calculator for GHGs – used in conjunction with CAPRI-Farm; land use component in alpha version	Agriculture (ca. 50 agricultural products including tropical ones)	Globe	Countries or country blocks (75 world-wide)	Year	1990-2005 (data base) 2020[2]
SIMPLACE	Crop growth model for agricultural systems Dynamic Model Framework with components: Potential growth, water- and nitrogen-limitation	Arable land, 8 Crops, Grassland*, Trees*	EU 27	NUTS2	Biomass: Day Yield: Year	1980-2050
FSSIM	A bio-economic farm model that assesses farm income and environmental impacts in response to farm resource management	Arable and dairy farming	NUTS-2 region, Farm	Specific farm type	Mean year	Management info from around 2005

[1] HSMU=Homogeneous Spatial Mapping Units; NCU=NitroEurope Calculation Units. Units refer to clusters of 1 km^2 grid cells that are characterized by similar environmental and/or agronomic conditions. [2] (a) CAPRI has also been used for long-term studies (2030, 2040,2050). (b) For interactions in model runs, the ex-post data bases of CAPRI are not necessary – the simulation modules of CAPRI are comparative-static, i.e. do not produce time series.

There are further consistency requirements which relate to values, volumes and prices, land balances etc.. These consistency requirements are naturally quite valuable also for environment accounting as mass flows are respected.

Table 2 Data sources for the various model inputs in the four models

Model inputs	INTEGRATOR	CAPRI (region is always NUTS2)	SIMPLACE	FSSIM
Land cover/ land use (grass and crops in arable land)	CLUE model predictions, based on CORINE 2000 data for grassland and cropland. CAPRI-SPAT disaggregated data on crops.	CAPRI regional data based on EUROSTAT, disaggregated in CAPRI-SPAT on the basis of about 100,000 observational plots	Not included	From statistics per farm type
Crop yields	FAO database at country level, the same data are also used at NUTS and NCU level	CAPRI regional data, based on EUROSTAT production statistics disaggregated in CAPRI-SPAT on the basis of irrigated/rainfed potential yield	To be simulated! For calibration purpose available data from Destatis/Eurostat (Yield) weres used	From crop growth simulation or statistics (LEI, EUROSTAT)
Animal livestock numbers	FAO database at country level (FAO, 2007) and CAPRI data for distribution at NUTS 2 level.	CAPRI regional data, based on EUROSTAT production statistics, disaggregated in CAPR-SPAT	Not included	From statistics per farm type
Milk yield	Included as input to calculate N excretion from dairy cattle. Basis is FAO (past) and IMAGE predictions (future)	Calculated in CAPRI, matches market bilance for raw milk	Not included	Related to dairy management system or derived from statistics
N fertilizer application	FAO stat data at country level, downscaled to NCUs	CAPRI regional data, based on FAO (FAO/IFA/IFDC/IPI/PPI, 2002), disaggregated in CAPRI-SPAT (Leip *et al.*, 2008)	Can be included from CAPRI Results	From region specific management data, like KWIN for the Netherlands
Climate	Time series of temperature, precipitation and cloudiness from a high resolution European data base containing monthly values for the years 1901-2100 and projections for 2001-2100 for land-based grid-cells of 10' x 10' (approx. 15 x18 km in central Europe) ((Mitchell et al., 2004)	Climate data are not used in the regional CAPRI model, but only in the 1 km x 1km downscaling component CAPRI-Spat. Climate data used there are meteorological data used in Crop Growth Monitoring Sysems (CGMS) as described in Orlandi and Van Goot (2003).	SEAMLESS database for the period 1983-2006 for climate zones. Data include daily rainfall (mm/ d-1), maximum air temperature (°C), minimum air temperature (°C), global solar radiation (MJ/ m2-2 d-1), wind speed (m/ s-1), vapour pressure (hPa) and evapotranspiration (mm/ day-1), calculated with Penman formula	Not directly used; yield level may be related to climate
Soil properties	Soil type, texture class, C content and C/N ratio based on upscaled SPADE/WISE database (Heuvelink et al., 2009).	Texture class, C content, bulk density and pH based on the European Soil Database v.2.0. and a related organic C map (Jones et al., 2005).	SEAMLESS database for Agri-Environmental-Zones, main soil types	Not directly used; management data related to soil type

Crop phenology	Not included	Not included	For calibration purpose available data from JRC was used	Not included

Raw data typically do not fulfil these requirements, thus requiring approaches to render the raw data consistent. Part of the balancing algorithm line up animal nutrient requirements (energy, protein, lysine, dry matter max/min, fibre, max/min shares of different feeding stuff) with the feed mix while exhausting available feed quantities. Another part ensures that mineral fertilizer and manure are distributed to crops while crop nutrient for N, P, K are covered. There is no doubt that the data base could be improved, but it provides a unique closed, consistent and harmonized data set for the EU, Norway, Western Balkans and Turkey which is linked to matching global data set with market balances, land use and import and export flows. As the model code, the data base is open source and available on request for anybody. The consistent data base at Member States and regional level (NUTS2) are available as time series. For the three-year averages around the base year, each NUTS2 is broken down to up nine farm types (by specialization and economic size). The types are selected according to agricultural area and livestock units. All other farms are aggregated into a residual type. That farm type resolution is now the typical level for production runs.

CAPRI simulation modules are available on the global scale (CAPRI-Trade) and European scale, distinguishing a bio-economic supply nodule (CAPRI_FARM) with a regional resolution at NUTS2 or farm types insides NUTS 2 regions and statistical down-scaling module (CAPRI-SPAT) which takes the CAPRI-FARM results as inputs and dis-aggregates them to HSMUs (multiples of 1km x1 km). For simulation runs, the global part of CAPRI and the European supply part (NUTS2 or farm types in NUTS2) are solved iteratively until convergence. They are hence not independent models, but integrated modules of the same modelling system and used in conjunction. Convergence of both modules means that at current prices, each regional market (e.g. the beef market in the US) is cleared, including bil-lateral export and import flows. Price and quantities have both to adjust to find that equilibrium point. For the European supply part (NUTS2 or farm types), it means that acreages, herd size, yield, feed use etc are profit-maximal at current prices, and after aggregation to country level, match the results of the global part. The global part has not only a much lower regional resolution compared to the European one, but is also based on a different methodology with far less technological detail. The regional respectively farm type results can be used to calculate N,P,K balances, GHG emission inventories for agriculture according to IPCC guidelines or to source a life-cycle assessment for energy use at the level of individual activities. As we do not (yet) model input use (fertilizer, energy etc.) beyond Europe, environmental assessment at global scale is restricted to land use (in development) and emission factor based GHGs inventories for the regions in the market model.Once the simulation model is solved, key NUTS2 results (crop acreages, herds, yields, fertilizer application rates) can be down-scaled based on statistical methods to HSMUs, being clusters of 1x1 km grid cells.

The normal use of CAPRI is ex-ante, combining the global trade model and currently for the year 2020. In order to do so, market outlooks from

OECD/FAO/EU Commission are combined with other expert data and trend analysis to construct a complete and consistent set of data for the future. A relatively new feature is "now-casting" where those parts of statistics already released are combined with outlooks, trends and expert data to generate a data set for the near past. The simulation model is then calibrated to replicate that future points or the near part. Thanks to harmonized definitions and an identical structure, ex-ante results –for the outlook and for counterfactual runs - can be compared to ex-post data.

In LIASE we use in conjunction the global and the regional (European) scale modules of the CAPRI model. Socio-economic drivers (agricultural policies, population, taste shifts, gross domestic product, crude oil prices, exchange rates, change in built up areas) and climate change impacts on land use change/land abandonment and on crop yield are included as an exogenous model input (e.g. IMAGE outcomes for land use and LPJ outcomes as done in the AgriAdapt project for crop yield).

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Annex III: Storylines for the Test case "Agricultural Adaption to Climate Change under different Policy environments"

1 Scenarios as storylines

The main factors that will influence future agricultural systems and that will be included in the test case, are:

- Changes in climate conditions, such as a more frequent occurrence of extreme events, which may result in lower yields and/or lower yield quality, and may require adaptation measures to prevent such yield reduction
- Increases in atmospheric CO2 that will affect future crop yields
- The degree that technological improvement of crop varieties and management
- Changes in the CAP regulations and the EU agricultural border protection
- Prices of the inputs for agricultural production and the agricultural product prices

Based on these factors, we can compile a number of future and coherent scenarios. We will start with a number of IPCC scenarios. These IPCC scenarios are both socio-economic scenarios which are based on assumptions with respect to (a) population growth, income growth and technological changes (Table 1) and (b) policies impacting especially on energy use, and the related emission scenarios. For these emission scenarios the related climate changes and atmospheric CO_2 concentrations in the future have been computed (IPCC) and will be used for, in particular, modeling future crop yields with SIMPLACE.

We assume that the long-term vision for the CAP should match the selected IPCC scenarios. For example, the B2 scenario describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. For agricultural policies, we assume that no global agreements on tariff reduction for agricultural products will then be reached and the CAP in its current format (single farm premium, Pilar II) will continue. However, given that EU agriculture is a very small economic sector and the impact of agricultural policies on the long-term development of EU agriculture is restricted, one might alternatively argue that assumptions about the future CAP need not to be harmonized with the IPCC scenarios.

Anyway, the IPCC scenarios need to be related to a set of quantitative assumptions about population and GDP growth, etc. This has been done in the AGRI-ADAPT project (Table 1). In order to save working time and let the Test case concentrate on its main goals, being (a) to contribute to better tools and (b) to contribute to a better understanding of Integrated Assessments, it is proposed to use the scenarios and their quantitative assumptions, as developed within the AGRI-ADAPT project (Ewert et al., 2011; Wolf et al., 2011), and to complement them with policy scenarios (i.e. future changes in CAP).

We will do the analyses for three strongly differing scenarios for year 2050 (and possibly also for an earlier year like 2020), i.e. the Baseline scenario B1 with likely changes in climate, technology and markets, and the A1_b1 and the B2 scenarios, which are associated with different estimates for each scenario with respect to (a) climate change (changes in rainfall and temperature) and technological improvement in crop varieties and management, (b) changes in the future CAP regulations, (c) frequency of extreme events under climate change and (d) global oil and energy price changes. Note that we intend (as mentioned at the beginning) to do the analyses for first, the climatic change impacts only and second, the climatic change impacts plus the related effects on technology, prices and policies per scenario, to be able to sub-distinguish the direct climate change impacts from the effects of the other changes in 2050 (as show in the example in Annex 1). Table 1 gives an overview of the scenarios proposed for LIAISE based on the AGRI-ADAPT project with the applied assumptions about prices, yields, trade policies, etc.

2 Comparison with existing studies on adaptation of agriculture to climatic change over Europe

The recent AVEMAC study (Donatelli et al., 2012) by JRC (see http://mars.jrc.ec.europa.eu/mars/Projects/AVEMAC) shows some similarities with this study, as future crop yields and productions are calculated for the main crop types over Europe. Our study, however, goes beyond the AVEMAC project in several aspects. First, we will also take the global perspective into account. Second, we will assess the impacts of future climatic change on crop production also in the context of technological, socio-economic and policy changes. Third, we will analyse the effectiveness of adaptation measures in agriculture at the farm level. Fourth, we will look at economic and environmental consequences of climatic change on different farming system, both at the farm level and over whole Europe. Fifth, we will evaluate the effectiveness of a number of CAP policy instruments which support the most promising adaptation measures.

In comparison to the AGRI-ADAPT study (Wolf et al., 2011) which was focused on the same topic, we will considerably improve the modelling approaches. The main improvements are: a) assessment of climatic change impacts on agriculture in the context of technological, socio-economic and policy changes towards 2050 will be done for EU-27 and not only for Flevoland, the Netherlands, b) impacts on the environment will be simulated with the INTEGRATOR model and not based on environmental indicator calculations, c) coherent linking of the four applied models. This will lead to a strongly improved usability of the linked models for doing impact assessments over Europe and for answering questions about climatic change impacts on agriculture in the future.

3 Adaption measures in agriculture

In addition to the story lines, a number of adaption measures in agriculture will be evaluated. These measures which may limit the negative effects on future productivity and income from changed climate conditions and may allow to make full use of the positive effects of these changed conditions, will be included to analyze their effectiveness. They are the following:

- Adjustment of the cropping pattern to the changed climate (e.g. earlier sowing date; different crop rotation) and cultivation of more 'southern' crops (e.g. sunflower) and cultivars
- Changing the intensity of crop production (e.g. more intensive by applying irrigation water and more fertilizer; less intensive to reduce the production risk in drought years)
- Adaptation measures to handle increased risks under future climate conditions (e.g. improve soil drainage; develop a heat-resistant and/or a disease resistant crop variety)
- Changes in grassland management, herd size, livestock density and feeding practices
- Not-agricultural ways to handle the higher production risk: crop insurance, diversification including off-farm work

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Table 1. Description of the scenarios for the LIAISE simulations based on the Agri-Adapt project (Source: Ewert et., 2011)

	Base year [2004]	**B1 (Baseline) [2050]**	**B2 [2050]**	**A1_b1 [2050]**
Exogenous assumptions	Observed data (average 2003 -2005) taken from EuroStat, FAO, OECD etc.	Inflation rate of 1.9% per year		
		constant exchange rates		
		Projection of GDP	Derived from IMPACT scenarios (decreasing demand for agricultural products)	Derived from IMPACT scenarios (leading to increasing demand for agricultural products compared to B2)
		Projection of population (growth)		
Commodity Prices	Observed prices (average 2003 -2005)	Extrapolated from market outlooks (European Commisssion and IFPRI)	Simulation results	
Input Prices	Observed prices (average 2003 -2005)	Extrapolated from market outlooks (constant in all simulations)		
Yield	Observed yields (average 2003 -2005)	Trend projection combined with ACE-FAST simulation (BCCR_BCM2_0/SRES B1 less warming consistent across all European regions and seasons)	ACE-FAST simulation (Pattern-scaled SRES B2 15-model ensemble mean)	ACE-FAST simulation (SRES A1B 15-model ensemble mean)
Set-aside and quota policies	With obligatory set-aside and quota (milk and sugar)	Abolishing obligatory set-aside, expiry of milk quota, continuation of sugar quota		
Premium scheme	2003 CAP reform (decoupled + partially coupled payment)	2009 Health Check (decoupled payment, increased modulation)		
WTO trade policy	Tariffs and TRQ as in 2004	Tariffs and TRQ as in 2004		Reduction of tariffs and expansion of TRQ (sensitive products) as proposed by Falconer (2010)

Annex IV: Identifying and quantifying future-oriented agricultural production activities and their input-output coefficients

1 Background and rationale

Agricultural activities (i.e. the growth of a crop or crop rotation in a particular agri-environmental zone as characterised by climate, topography and soil), their management and hence their input-output coefficients change in time. Currently, agricultural sector models and CGE models generally use agricultural activities and input-output coefficients based on datasets of observed (current) activities. Future activities are usually the same in terms of crops/rotations, but outputs (yields) are linearly extrapolated into the future, or in scenario analysis trends may be adjusted (increased or decreased). Sometime inputs are adjusted accordingly (also using a trend function).

Agricultural activities and their inputs and outputs are defined by GxExM interactions (genotype, environment and management interactions). So a current agricultural activity is fully defined by its genotypes (cultivar/variety), environment (climate, soil, topography) and management (production technique and used inputs). Future agricultural activities are defined by the same interactions. Linear extrapolations may violate production ecological principles that dictate the production of agricultural crops and their required inputs (Van Ittersum and Rabbinge, 1997). Some examples why linear extrapolations may not be valid:

- Part of the historical yield increases were due to new genotypes with improved harvest index or phenology. In particular for major crops with major investments in breeding in the past, biological or production ecological limits of harvest index or phenological improvements may have been reached, whereas for other crops this is not (yet) the case.
- The environment may change due to CO_2, climate change and soil degradation or restoration. Generally these are not linear processes.
- Management of the farmer determines yield levels of activities (low input versus high input systems). From a production ecological point of view, management determines the degree of yield gap closure, i.e. the difference between the actual yield of farmers and the theoretical potential or water-limited production level that could be achieved with a defined genotype and environment, while the crop is free of water and nutrient stress and free yield reduction due to weeds, pests, diseases and pollutants. Changes in management may include the selection of different crops. Linear yield (or input) extrapolations may violate production ecological limits such as potential or water-limited production levels.

There seems to be a growing awareness that some of these points are important when it comes to studies with a long time horizon, including climate change studies. A number of groups (IFPRI, AgMIP, AgriAdapt project, Harvest Choice) seems to work on this issue, though hitherto partial and pragmatic solutions dominate. Even though we will have to become pragmatic within the LIAISE test case as well, the subject deserves a more fundamental approach, before we come to a pragmatic proposal. Note, that the focus of this note is on continental and global level. In studies at farm and regional level, a rich number of publications is available on identifying and quantifying alternative agricultural activities. These are a source of inspiration and will be summarized below as well.

*The aims of this note are to (i) d*escribe the principles of identifying and quantifying future-oriented production activities that can be used in agricultural sector or CGE models with a time horizon of 10-40 years and (ii) propose a method for identifying and quantifying future-oriented production activities to be used in the LIAISE test case 'CAP reform'

2 Principles of quantifying future-oriented production activities in economic models

Approaches to update input coefficients differ between model families (bio-economic, partial market model and economy wide models). It must be first understood that economist attribute yield changes to different factors.

Firstly, there is technical progress which allows producing more from the same amount of inputs: the production frontier is shifted. If we talk about yield increases in the context of technical progress, we would refer mostly to land saving technical progress, .e.g. new variants with a higher yield potential. The land saving character is often accompanied by other changes in input use (e.g. more fertilizer used per unit as loss rates of e.g. nitrogen increase). GMO crops often save land (i.e. allow higher yields) and might save also plant protection. Precision farming might save land, but also save fertilizers. Manure injection saves manure etc. Climate change (or other changes in land productivity e.g., stemming from salinisation, change in carbon content, nutrient depletion, groundwater table changes) could be understood as positive or negative technical progress in that sense.

Secondly, yield changes can be triggered by price changes. A higher output price or lower input prices will render it economically attractive to spend more inputs as the economic return per unit of input increases (e.g. the value of the wheat produced from a kg of nitrogen). Such a yield change is hence not related to new production possibilities, but rather reflects an adjustment inside the given production possibilities. If land becomes are scarce, e.g. by land demand for buildings or for production of biomass for energy production, farmers will adopt land saving management options such as using more fertilizer per ha. Relative land scarcity can explain why countries with otherwise similar economic characteristics as e.g. the Netherlands and the US show very high differences in yields (and hence yield gaps).

And thirdly, yields might change due a composition effect, e.g. if acreages in marginal areas are reduced, the average yield in the aggregate goes up if no single farmer changes the yield. The same might happen in product aggregates (cereals, different type of potatoes ...).

As mentioned above, the problem with historic trends in yields is that the development reflects a mix of these three effects, i.e. changes in the production possibility set, adjustments to price / factor scarcity changes and composition effects. Only the later can easily be identified if e.g. single farm observations are available.

In Computable General Equilibrium (CGE) models, a widely used economy wide model type, input coefficients for variable production factors (fertilizer, diesel, plant protection) are conventionally expressed per unit of output and measured not in physical units, but constant dollars. In such models, fertilizer rates per unit of output are hence fixed. A yield changes occurs if less land compared to labour and capital is used in a simulation. But there are also variants of these models where input coefficient themselves are variable, so that e.g. land can be substituted against fertilizers. Technical progress can be integrated here as “factor neutral”, i.e. more wheat is produced from the very same factor mix which implies that e.g. also the fertilizer need per unit of wheat produced drops, or in a more complex way such that e.g. only the land needed per unit of output drops.

Partial market models either do not distinguish between yields and outputs (e.g. the CAPRI global market part until summer 2011) or break up output into yield and acreage. They do typically however not model explicitly input use.

(Bio)-economic programming models typically describe in some detail the relation between output and inputs, and, often express input and output use per ha. One can roughly distinguish three variants. The first one offers the model a wide palette of different production possibilities for each crops, e.g. different yield levels for wheat along with matching input coefficients. These variants are calculated by coefficient generators which can also draw on crop growth model simulations. The relation between … and FFSIM in SEAMLESS offers an example. Non-current relations between inputs and outputs can be offered to the model which will pick the economically best one. A challenge provides the calibration of the variant choice. The second possibility updates the input/output coefficient outside the programming model depending on prices and/or shift factors. That is the solution chosen in CAPRI. And thirdly, instead of offering variants, a yield curve can be offered to the model, which brings the solution close to the way CGEs work

3 Proposed preliminary method for identifying and quantifying future-oriented production activities in the LIAISE Agri test case

In the preliminary LIAISE approach, we decided to apply the AgriAdapt approach in CAPRI at EU 27 scale and the FSSIM regional approach at selected NUTS2 regions, as described below.

AgriAdapt approach (Ewert et al., 2011): this approach accounts for changes in climate, [CO2] and technology, with a focus on EU25 level (though CAPRI runs for the entire world). Only effects on outputs (yields) were accounted for; associated effects on inputs (e.g. amounts of water or nitrogen) were not considered. Also, changes in crops or crop rotations were not considered, nor changes in management options (e.g. adaptation or switching from low to high input or vice versa). In short, the relative effects of changes in climate, [CO2] and technology on crop growth simulation results with the SIMPLACE model were used to correct statistical yields (‘current yields’) as used in the agricultural sector model CAPRI.

In the crop growth simulations with SIMPLACE, changes in climate and [CO2] were derived from different Global Circulation Models (GCMs) and IPCC, respectively. Changes in technology stand, in this study, for a combination of progress in yields due to breeding ('gene') and management. In this study the technology parameters to correct the historic yield trends were taken from Ewert et al. (2005). Technology changes were imposed on top of climate change and [CO2] effects. Hence interactions (e.g. through adaptation] were not considered. In general, alternative management options were not considered and progress in breeding and management was lumped into one factor 'technology'.

FSSIM regional approach; in various farm and regional level studies a fairly high degree of detail was applied to the identification of alternative agricultural activities for farms, farm types or a defined region (Van Ittersum and Rabbinge, 1997; Bouman et al., 1999; Hengsdijk and Van Ittersum, 2002; 2003; Dogliotti et al., 2004). The approach generally consists of three steps: (i) goal-driven design of cropping systems, i.e. given the societal goals that play a role, which type of cropping systems and their management must be considered; (ii) quantification of biophysical production targets, i.e. what are target yield (or emission) levels of different crops/rotations; these targets are within the range of biophysical options (usually between current levels and potential or water-limited levels; and (iii) definition of the optimal mix of inputs required to realize production targets; this is done through the so-called target-oriented approach (Van Ittersum and Rabbinge, 1997).

The emphasis in these studies was on changes in management. Changes in climate and genetic progress received little attention. Recently, climate change, adaptation options and technology were considered in a farm level study for Flevoland (NL) (Wolf et al., 2011). Climate change (incl. [CO2]) was estimated using the WOFOST crop growth simulation model and technological progress (genetic and yield gap closure) was based on Ewert et al. (2005) but with amendments. This approach is used in the tests case for three different study areas

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Annex V: Contributors to the report

This report is the result of discussions between all partners in the LIAISE consortium. It has been edited by XX. The different chapters were written by the following persons:

Part 1 Agri-test case: adaptation of European agriculture to changes in climate under different policy environments : Joost Wolf and Wim de Vries

Part 2: EU soil strategy case: Review of the 2006 "impact assessment of the thematic strategy on soil protection": Wim de Vries and Katharina Helming

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Annex 2 Wim de Vries, Wolfgang Britz, Hans Kros and Andreas Enders
Annex 3 Joost Wolf and Wim de Vries
Annex 4 Martin van Ittersum, Joost Wolf, and Wolfgang Britz

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LIAISE - Linking Impact Assessment Instruments to Sustainability Expertise has received funding under the European Community's Seventh Framework Programme (FP7/2007-2013) THEME 6 Environment (including Climate Change). Grant agreement n° 243826.