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Genedec

A quantitative and qualitative assessment of the socio-economic and environmental impacts of decoupling of direct payments on agricultural production, markets and land use in the EU

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Report on results concerning models linking farm, markets and the environment

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1 Executive summary

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1.1 General introduction

This document is related to a part of the work realized inside the workpackage 3 (WP3) of the programme GENEDEC. The deliverables D4 and D5 are expected by the Commission as contractual outputs from GENEDEC. The present document is the deliverable D4. The D5, devoted to theoretical topics related to non point source problems, was delivered on January 2006.

1.2 Objective

The GENEDEC project is aimed at providing insights into the workability, the efficiency and the impacts of various scenarios of decoupling, for the whole EU, so as to provide the Commission with recommendations and alternative options to improve such a system. This study will be useful for future negotiations with current and new Member States, as well as in the perspective of the on-going WTO negotiations.

Scenarios will be based on MTR proposal and existing decoupling schemes, first analysed through expert interviews, ex post statistical analysis and literature review. Specifically, the project addresses quantitative assessments of the impacts of decoupled support schemes on production, land use and land prices and their implications for farm incomes and the future structural development of farms. Special attention is also paid to efficiency, welfare effects and administrative and implementation issues, including environmental and social concerns. *These points are documented in the Deliverable 1*

The modelling used has recourse to linear programming and positive mathematical programming, through the use of a set of micro-oriented farm-level models, implemented with European databases such as FADN. Existing models are further developed to tackle quotas, premium entitlements and land markets and are connected to each other thanks to shadow prices. This requires the harmonisation of models and software, which enables results aggregation at a sector level and at different scales (region, state, EU). *General overview of the models involved in GENEDEC is provided by the Deliverables 2 and 3.*

Extending the analysis towards the new Member States seems to be necessary with regard to: a) the impacts of direct payments on supply and structural change; b) the assessment of the impacts of the principal de-coupling scheme based on unified premia for land for the new MS compared to the single payment scheme for EU-15, i.e. supply effects, rental value for land, income distribution etc. Models could be adapted to address new Member States and candidate countries, on condition that representative and reliable data under the FADN format are provided by the Commission sufficiently early in the project second year. Access to these data will be under the control and the authority of the Commission. If the data pre-requisite is fulfilled, the project could benefit from FAL experience in project EDIM, which consists in applying an existing farm model to Hungary, to model other new Member States. These already existing resources assure at least a limited coverage of the new Member States for the quantitative analyses.

Interdependencies with world markets can be dealt with by coupling farm level and partial equilibrium models in a recursive manner. As for environmental aspects and structural changes, they will be addressed both quantitatively and qualitatively. Finally, the quantitative ex ante assessment will be validated by experts and sociological studies.

More precisely, the Workpackage 3 was initially designed to cover the following points :

- To develop a set of models that would describe the interaction between EU and world markets (the "small country" assumption is irrelevant for the EU).
- To improve the assessment provided by farm-type models (in WP2) by sharpening land opportunity cost thanks to land market modelling.
- To examine the effects of decoupling on structural change in farming (farms number and size, full or part-time farming, entry-exit Ě).
- To determine of the relationship between EU agricultural production and its physical environment.

It was decided during the kick-off meeting of GENEDEC (March 2004) that the second point had to be modified and concentrated on the analysis of the shadow prices of the agricultural land provided by the farm-level models.

The figure 1.1 provides an overview of the WP3 location in the GENEDEC architecture.

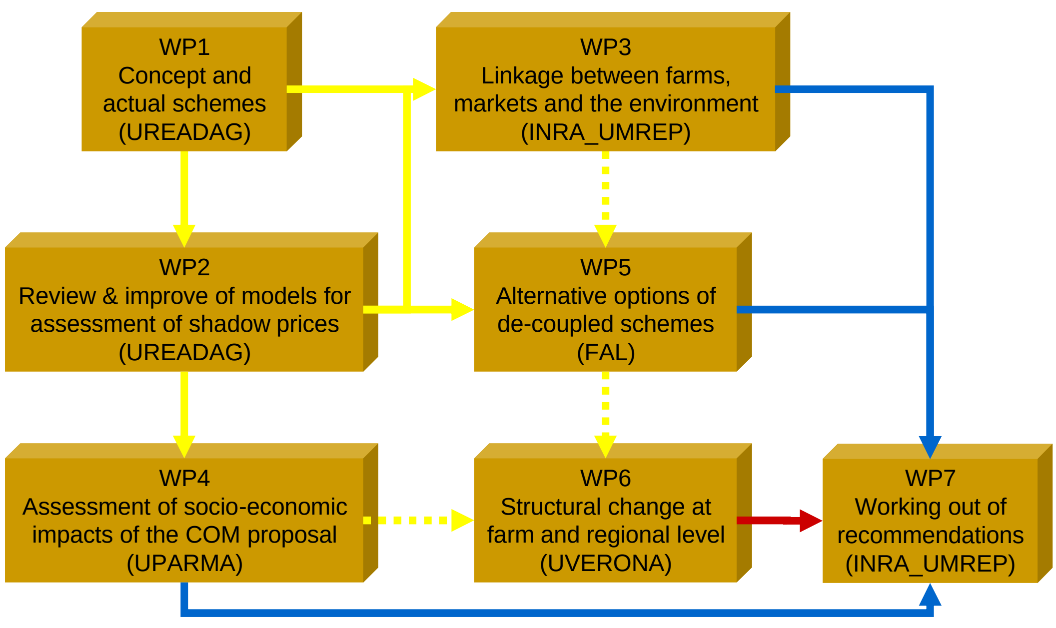

Figure 1.1: The simplified GENEDEC structure

1.3 Resources employment

The WP3 is highly driven by the use of human resource and computing tools. The table 1.1 provides the human resource assessed by the technical annex describing the GENEDEC programme.

Table 1.1: WP3 : persons months (see the technical annex of the contract)

Deliverable	Partner		Person-months
D4	INRA	(1)	33
D4	FAL	(2)	5
D4	PARMA	(3)	2
D4	UREADAG	(4)	2
D4	TEAGASC	(5)	16
D4	CIRED	(8)	3
D4	JRC	(10)	12
D5	FORTH	(6)	3

The INRA team hired persons through short-term contracts specifically for the accomplishment of a large part of its work : Bineta Niang, Nathalie Novello, Sophie Durandeau, Paul Zakharov. PhD students are strongly involved in this work : Caroline Godard, Elodie Debove (INRA), Marta Piniés (UPM). Other persons involved in this WP3 are permanent researchers and ingeneers : Raja Chakir, Stéphane De Cara, Pierre-Alain Jayet, Benoît Gabrielle, Christine Le Bas (INRA) ;

1.4 Goals achieved and results expected

Operational models exist thanks to the WP2. Some improvements have been realized thanks to the WP3, mainly concerning the coupling of AROPAj with a crop model on one hand and with a partial equilibrium model on the other hand. The impacts of these two kinds of coupling are assessed either at the regional scale (when a crop model is coupled to the economic model AROPAj) or at the EU scale (when a partial equilibrium model is coupled to AROPAj). It is possible to assess the direct impact of change in CAP and the indirect impact taking account the "rest of the world" on the change of the agricultural gross margin. Change in land use and change in land shadow price are also provided.

Shadows prices of the land are provided by farm-level models covering the EU-15. Change of these prices is assessed when the CAP changes. A preliminary work compares the change related to the respective implementation of the Luxembourg agreement on one hand and to a "full decoupling" scheme on the orther hand.

Mapping and down scaling of model ouputs are now realized through the location of agricultural activities thank to the data provided by the Join Research Center, Ispra. Methodology is now operational and it should be extended during the activity period devoted to the WP7.

We begin to include environmental indicators in the economic models, partly using the coupling between the AROPAj model and N-response biphysical models (STICS and CERES). We focus on environmental criteria related to the consumption of nitrogen fertilzers. New results related to greenhouse gas emissions aare provided, allowing to estimate the change in emissions related to the change in agricultural policies.

1.5 Linkage with other workpackages

A large part of results provided by the WP3 are directly based on pre-existing models improved by the work realized in the WP2.

The policy scenarios were defined and prepared by the WP1.

Outputs of WP3 should feed the analysis developed in WP4, WP5, and WP6. This will be particularly checked in WP5. All methodological and operational results provided by the WP3 will feed the synthetic WP7 devoted to working out of recommendations for policy making.

1.6 Structure of the Deliverable 4

The first part presents the last improvement of the core model designed to cover the European Union. It assesses the impact of the implementation of the Luxembourg agreement seen as close as possible to the real agreement signed by all member States of the EU in 2003. Additional impact due to the coupling wetween the agricultural supply model and the partial equilibrium model (PEATSim) is presented and assessed.

The second part is devoted to the structural change expected after the CAP changes. A specific dynamic approach is used to estimate the amplification of change observed in the past in Ireland.

The third part focuses on the valuation of the quasi-fix factors -mainly the land- through the dual analysis of results provided by mathematical programming models. Shadow prices of the land should strongly change when the degree of coupling between agricultural activities and public support decreases.

The fourth part covers the linkage between farming systems and the environment through modelling. Methodological investment is realized by softly linking the AROPAj model and the crop models STICS (for yields) and CERES (for nitrous oxyde emissions).

The fifth part is twofold. First It provides an overview of the management of the data involved in the MIRAjE system developed around the AROPAj model. Second it delivers the different steps of the methodological work devoted to spatial analysis and to down scaling useful for mapping the economic model outputs.

Part I

The impacts of decoupling on the agricultural supply and incomes taking account the feedback from the rest of the agricultural world through change in prices

Introduction of the part I

This part is devoted to results covering the European Union (EU-15) at different scales, from the regional level to the European level. These results are provided by runs of the AROPAj model, chosen like the "core model" by the GENEDEC consortium. They focus on the impacts of the implementation of the Luxembourg agreeement. In addition, the first results delivered by the coupling of the agriculutural supply model (AROPAj) and a partial equilibrium model (PEM) assess what could be yhe additional impacts of taking account the rest of the economy in the rest of the world.

A more complete set of results will be reported in the last scientific deliverable of the Genedec programme (i.e. the D10 related to the workpackage 7). Runs of the model based on the coupling of the economic models (AROPAj and the PEM one) will be analysed and presented in the Deliverable D7, while they focus on different scenarios of de-coupling in the CAP. This part of modelling results is liable to the work realized through the workpackage 2 (D2 and D3), especially when the AROPAj carries a new version based on the FADN-2002 and the consecutive steps of farm group clustering, res-estimating of parameters, and re-calibrating of all farm group models.

2 The Luxembourg agreement seen through the core model

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Abstract

New World Trade Organization (WTO) rules involving subsidies compel adhering countries to modify their agricultural policy. To this end and to internal budget consideration, in the European Union (EU), the 2003 Luxembourg agreement introduced a major change in the Common Agricultural Policy. This agreement is driving the striking increase in the scope of direct payment decoupling across the EU.

In the field of agricultural economics, mathematical programming models, and more precisely linear programming ones, are particularly efficient tools for assessing change in agricultural land use arising from shifts in policy. The aim of this article is to highlight the main impacts on land use and agricultural gross margins through the implementation of the Luxembourg reform in linear programming models representing of a large part of European farming systems.

In agreement with the literature on theoretical decoupling simulations, our study shows that the farmers' gross margins increase when the decoupled support is maintained equal to the amount of direct aids previously devoted to agricultural production. The other major result concerns change in land use and in marketed productions. Land devoted to pastures significantly increases at the expense of land devoted to cereals and protein crops. These differences depend on the choice made by Member States when implementing the Luxembourg agreement. Some maps showing the regional impact of decoupling are presented.

Simulation results showing what would happen if full decoupling were implemented are compared to the 2003 Luxembourg reform. When the European agricultural budget is taken to be constant, the difference in producers' profits according to three scenarios (reference, Luxembourg, full decoupling) makes it possible to estimate changes in social welfare at regional, national, and European levels, involving the producers' as well as the taxpayers' surpluses. When coupling the European agricultural supply model with a partial equilibrium world model, we can reasonably expect favourable additional impact for producers related to higher agricultural prices.

Introduction

The WTO Agriculture Agreement was negotiated during the Uruguay Round, and it is a significant first step towards fairer competition. It includes specific commitments by WTO member governments to improve market access and reduce trade-distorting subsidies in agriculture.

The main complaint about policies which financially back domestic prices, or subsidize production in some other way, is that they encourage over-production. Consequently, they squeeze out imports or induce subsidized exports. They can also lead to price dumping on world markets. This induces trade distorsions.

The Agriculture Agreement distinguishes between support programmes that stimulate production directly, and those that are considered to have no direct effect. A color code is in use to facilitate the distinction between domestic policies that have a strong or direct effect on production and trade from those with a weak effect. Policies with strong, direct effects have been allocated to an "amber box" (derived from the amber traffic light that means "slow down"). Policies with a weak effect have been allocated to the "green box". They include payments made directly to farmers that do not stimulate production, such as certain forms of direct income support, assistance to help farmers restructure agriculture, and direct payments under environmental and regional assistance programmes. Policies in which subsidies that are tied to programmes limit production have been allocated to a blue box. One of the major features of the WTO Agreement is that domestic policies that are in the "amber box" have to be cut back.

This international framework drove the reformation of the European Common Agricultural Policy (CAP). Priorly, most of the CAP supports belonged in the amber box. In a first wave of reforms (1992 McSharry reform), new policies were designed to fit into the blue box. Then, the Luxembourg agreement (the "decoupling reform") induced a shift in policy towards the green box.

This article focuses on the implementation of the CAP reform in a European scale model as well as on the practical consequences of the reform from the regional to European scales. In section 1, we examine the concept of decoupling and the expected theoretical outcomes. We also examine what has been done to evaluate practical consequences at the regional level in the broad sense of that term. In section 2, we look very precisely at the Luxembourg reform and how to implement it in a European scale model (AROPAj) to evaluate the reform at the different geographic scales the model allows for. This implementation implies some hypothesis on CAP reform options which are set out. In section 3, we present the main results of simulation at the European scale but also at the regional scale (i.e. the "Farm Accountancy Data Network (FADN) Regions"), and more specifically, results reflecting changes in land use, livestock, sold plant production, GHG emissions, and gross margin. We also confront the 2003 Luxembourg agreement with results generated from a hypothetical full decoupling reform not yet envisaged by most Member States (MS).

2.1 Decoupling in theory and in modelling

2.1.1 The concepts of decoupling

Supporting farmers creates distortions in markets and in the economy as a whole, as well as distortions between economic agents within and between countries. Considering that policy makers would like to maintain transfers between agents which indeed differ from neutral lump-sum transfers, the relevant question remains the minimizing of their social costs. In this sense, the CAP offers to economists an interesting field for the design of second best policies.

Decoupling appears to be the final outcome of the CAP with the aim of minimizing the loss of welfare supported by consumers and taxpayers. It has been under study for some time now. The

OECD (2000) has summed up the different contributions in the literature in order to specify the concept of decoupling.

The OECD (2000) distinguishes between two kinds of decoupling policies: a totally decoupled policy or an effectively decoupled policy according to whether or not there is an effect in case of a shock. According to the OECD (2000), the demand and supply functions remain unchanged when any new package of policy measures is introduced. A new package does not change the equilibrium in prices and quantities, and it does not change the nature of the market's response of the market to any exogenous shock arising on the demand or the supply side.

However, the definition of decoupling drawn up during the Uruguay Round is less restrictive. Some minimal effects on trade and production are to be felt. The measurement of the effects of a decoupled policy depends on the theoretical framework under consideration: dynamic or static, deterministic or uncertain. In fact, it seems to be difficult to design a policy that does not have some effect on production or trade. According to the OECD (2000), the decoupling as defined by the Luxembourg agreement induces impacts on trade and markets through the wealth and insurance effect. Even if no recoupling was included in this agreement – which is not the case in reality because National implementation by several Member States does include partial recoupling – the minimum income guarranteed by the decoupled payment would lead to a modification in the producers' behaviour.

The important question is if a reform toward a more decoupled support is beneficiary. All theoretical studies say yes, it is. The rest of this paper aims at estimating the expected outcome as well as the spatial and farm distribution of the producers' benefits.

2.1.2 Assessment of the CAP reform impact

The European Commission needs a precise assessment of the impacts of policy reforms. This assessment should have been carried out before designing the Luxembourg agreement. Even if the Commission based its decision on positive theoretical impact statements, that would not prevent it from assessing more precisely what would happen once the National scheme is implemented. With this in mind, two European programmes, GENEDEC and IDEMA, have been financed by the European Commission's Sixth Framework Programme to inform policy makers about the potential impacts of the real implementation of the CAP on producers' income and public support.

GENEDEC has been created to assess the socio-economic and environmental impacts of the decoupling of direct payments which was decided in the framework of the Luxembourg agreement. It is aimed at providing insights into the workability, the efficiency, and the impacts of various decoupling scenarios, so as to provide the European Commission with recommendations and alternative options for further improvement of the CAP.

One of the guidelines related to GENEDEC is to design modelling tools providing impact assessment of land allocation, production and other economic information at different scales – from the farming system to the European scale, to cover homogeneously the entire EU-15 (the EU-25 analysis is restricted by the FADN availability).

Kuepker and Kleinhanss (2006) have analysed the impact of the Luxembourg decoupling scheme on farming systems in France, Germany and the United Kingdom. The analysis was carried out with the EU-FARMIS model that is based on positive mathematical programming. One of the features of this modelling approach is to take into account conditions introduced by the CAP concerning good practices necessary to maintain the quality of the land. Accounting for land use and budget allocation, their results show significant constrasts between the 3 countries, due to the national implementation schemes. Their results differ from results using AROPAj, partly due to the way the sugarbeet "C quota" is handled in EU-FARMIS.

Judez et al. (2005) have studied the impact of decoupling in Spain, for farming identified as "specialist cereals (other than rice), oilseeds and protein crops" with the PROMAPA.G model that is based on positive mathematical programming. Their results are in accordance with a decoupling reform which penalizes COP (Cereals, Oleo-Proteins) crops: the area of COP crops declines and is given over to non-COP crops, particularly fodder. This trend is not a marked one because of a lack of alternatives in the farm types studied. For other types of farming, the reduction of COP crops could be greater. They also observed a small decline in farmer gross margin, primarily due to the implementation of the modulation reduction (see section 2.2).

IDEMA was created to develop methods and tools to provide a comprehensive socio-economic assessment of the impact of decoupling on the EU farm sector, especially in New Members States. One of the models of the project is ESIM, a partial equilibrium model. According to ESIM results (Balkhausen and Banse 2006) decoupling leads to a shift in allocated farmlands from "grandes cultures" towards grass and arable fodder. The policy option of keeping meat payments partly coupled to production can lead to an increase in meat production.

2.1.3 Expected outcome of the AROPAj model

One of the major purposes of the GENEDEC programme is to provide an assessment as comprehensible as possible of the decoupling reform. One of the major concerns is the ability to insert the Luxembourg Agreement into a model, taking into account the national implementation rules which offer a large set of possibilities. To do so, it is necessary to render the model outputs sensitive to new policy tools.

A preliminary task was to identify the models suitable to the estimation of impacts of changes of the CAP. GENEDEC brought them together into a single programm according to this criterion. Mathematical programming models are highly suitable to new policy tools. This is particularly true when commitments and thresholds have to be included in the modelling, made possible by algorithms devoted to problems including continuous and integer variables.

The AROPAj model was initially developped in order to take into account any geographical extension of the EU (as long as the FADN is available), as well as the continuously changing CAP. These characteristics – genericity and adaptability – make it relevant for the estimation of the new CAP impacts throughout the EU.

From a practical point of view, the improvement of the model involves a two-step process. The first step is devoted to the identification of the parameters of the policy support relative to the Agreement and consistent with the design of the model. That could require some "stylization" of the various national specifications the CAP implementation allows for. The second step is to let the model run with the reference values of the parameters so that the past-dependent parameters of the CAP (land set-aside, subsidies) are estimated. In our approach, the "past" refers to the reference year from which the model is calibrated thanks to the FADN.

The improvement allows us to provide policy makers with the change in land allocation of the major agricultural productions (crops, forage), the on-farm consumptions and the marketed productions, as well as the shadow prices of quasi-fix factors (land, livestock, quota of milk and sugar). Moreover, we are able to assess indirect consequences like environmental impacts. Falling into line with De Cara et al. (2005) and De Cara and Jayet (2006), change in emissions of greenhouse gas by farming systems can be estimated.

In this paper, we focus on impacts of policy change in production, land use, and opportunity cost of the land as well as gross-margin. For added value, an assessment of the Luxembourg impacts at the broad European scale (UE-15) is provided. Our work makes it possible to pinpoint regional disparities brought about by the CAP reform. In effect, decoupling can give more or less of an advantage to some regions.

2.2 The Luxembourg agreement in the AROPAj model

2.2.1 Short description of the AROPAj model

The general structure of the AROPAj model and last developments are presented in several papers. A detailed presentation of the constraints is given by De Cara et al. (2005) and the web-page "miraje". A short presentation is given by Bamière et al. (2005). Other elements are delivered in De Cara and Jayet (2000) and Chakir et al. (2005). The model is based on farm-groups. It consists of a set of independent, mixed integer and linear-programming models. Each model describes the annual supply choice of a given 'farm-group' (denoted by k), representative of the behaviour of "real" farmers. The farm-group representation makes it possible to account for the wide diversity of technical constraints faced by European farmers. Each farm-group k is assumed to choose the supply level and the input demand (x_k) in order to maximize total gross margin (Π_k). In its most general expression, the generic model for farm-group k can be written as follows:

$$\begin{aligned} \max \quad & \Pi_k(x_k) = \max \ g_k.x_k \\ s.t. \quad & A_k.x_k \leq z_k \\ & x_k \geq 0 \end{aligned}$$

where x_k is the n-vector of producing activities for farm type k, and g_k is the n-vector of gross margins. A_k is the m x n-matrix of input-output coefficients and z_k is the m-vector of the right-hand side parameters (capacities). Together, A_k and z_k define the m constraints faced by farm type k.

The components of x_k include the area of each crop, animal numbers in each animal category, milk and meat production as well as the quantity of purchased animal feeding. The gross margin g_k contains series of elements corresponding to each producing activity, which, for crops, gives: per-hectare revenue (yield times price) plus, when relevant, support received, minus per-hectare variable costs. As the emphasis is put on the farm-type level, each farm-group is assumed to be price-taker. Thirty-two crop producing activities are allowed for in the model and represent most of the European agricultural land use related to arable land and pasture. Crop production can be sold at the market price or used for animal feeding purposes (feed grains, forage, and pastures). As for livestock, thirty-one animal categories are represented in the model (27 for cattle plus one each for sheep, goats, swine, and poultry).

The technically feasible production set is bounded by the constraints defined by A_k and z_k. For a fast understanding of the results given in the third section of this paper, it should be noted that the quasi-fix animal numbers are allowed to vary by ± 15% of the initial animal numbers in the corresponding animal categories.

The last important set of constraints regards the restrictions imposed by the CAP measures. Set-aside requirements as well as milk and sugar beet quotas fall into this category. Mandatory and voluntary set-asides are accounted for, each type of set-aside being treated as a producing activity associated with the corresponding payments. The different types of sugar beet quotas (A, B, and C) are also included. Many of the CAP policy instruments included in the model involve the use of binary or integer variables whenever producers have to face mutually exclusive "discrete" choices.

The primary source of data is the Farm Accountancy Data Network (FADN). The 2002 FADN provides accounting data (revenues, variable costs, prices, yields, crop areas, animal numbers, support received, types of farming and economic sizes) for a sample of slightly less than 60,000 surveyed farmers. Approximately 50,000 sample farms are included in the model, which represent a total of more than 2.0 million European (full-time) farmers. Data are available at a regional level (101 regions in the EU-15). The FADN regions are represented on the website `http://europa.eu.int/comm/agriculture/rica/` and differ slightly from the NUTS 2 level regions (the details of which are given on the website `http://europa.eu.int/comm/eurostat/ramon/nuts/`).

Due to the annual nature of the model, sample farms defined as "Specialist horticulture" and "Specialist permanent crops" are excluded (types of farming 2 and 3 -permanent productions like horticulture, olives, fruit, vineyards- in the FADN classification). The analysis is thus restricted to the remaining population of farmers representing annual crop and livestock farmers. This restriction is important to keep in mind when analyzing the results as the excluded farms may represent a significant share of total agricultural land area for some regions.

2.2.2 The CAP reviewed by the Luxembourg agreement

The aim of the CAP introduced in 1962 was to render Europe self sufficiency food wise. It was so within ten years. Then some difficulties arose. The European production had a surplus and the policy was too costly. Some measures were proposed in the 80s to limit the financial commitments. In 1992, the McSharry reform transformed the CAP from a policy which supported production to a policy which ensured farmer income. In an international framework, the WTO negociations focused on distorsions. In 1999, the Berlin agreement set up the Agenda 2000 reform. To improve price competitiveness, Agenda 2000 introduced reductions in market support prices. It also introduced a comprehensive rural development policy which recognised the multifunctional nature of agriculture and which promoted measures to support the broader rural economy. Agenda 2000 sought to strengthen the environmental provisions of the CAP and to integrate them, in a more systematic way, into a broader policy for rural development. The Agenda 2000 agreement gave Member States the opportunity to modulate direct payments made to farmers under the CAP based on criteria that could include the workforce on the holding, the overall prosperity of the holding or the total amount of payments granted under support schemes.

The Luxembourg agreement has introduced the implementation of a system of single farm payment to farmers, without any link between support and the act of production. The aid is conditionned upon whether or not European rules are followed in the realms of the environment, food security, health, animal welfare, land management, and preservation of set-aside. It has also introduced the implementation of a compulsory modulation of support to redirect a share of the support towards rural development.

The CAP reform provides MS with two options for decoupling: a historic individual scheme or a regional scheme. For both options, the basis for decoupled payments is the average of subsidy receipts for the 3–year period, 2000, 2001 and 2002, for crops, beef and sheep payments. However, the method of computation depends on the scheme.

For the historic scheme, the acreage for this reference period determines the number of entitlements. The value of the single farm payment (SFP) is computed as the average of subsidy receipts divided by the number of entitlements (SPE). The acreages taken into account during the reference period are cereals, oil crops, protein crops, linseed, rice, grain legumes, starch potatoes, dry fodder, seeds and animal forage land. For set aside land, entitlements are computed on the average acreage.

The other option for decoupling is the regional scheme. In this case, the value of the entitlement is the same by hectare, computed as an average by region. The MSs having chosen this option have adopted a hybrid model for a transition period to mitigate revenue reductions for farmers. The hybrid models are either static or dynamic, and in both cases they combine SFP payments with a purely regionalisation model. The static models never modify the given combination over time,

		Full decoupling	Partial decoupling
Historic		Greece, Ireland, Italy, Scotland, Wales	Austria, Belgium, France, Netherlands, Portugal, Spain, Sweden
Hybrid	Static	Luxembourg	Denmark, Northern Ireland
	Dynamic	Germany, England	Finland

Table 2.1: Member State Choices of decoupling scheme

whereas the dynamic ones evolve towards a purely regionalisation model. Table 2.1 describes the choices of MSs.

2.2.3 The Luxembourg agreement in the model

Mathematical programming models theoretically suit modellers' needs for new parameters, new linear constraints and new activities to represent the phenomenon under study. The Luxembourg agreement has lead to defining modified ways for delivering subsidies offered to farmers. Therefore, the core of the AROPAj model needed to be slightly modified. Member States keep the right to (partially) recouple some supports. Table 2.3 sets out the recoupling choice of each MS as it has been implemented in AROPAj.

Full decoupling of beef production is one of a number of options that are available at the Member State level. The other two options are either 1) to retain up to 100% of the suckler cow premium, 100% of the slaughter premium for calves and 40% of the slaughter premium for other animals (the choice of Belgium, Spain, France, Netherlands, Austria and Portugal), or 2) to retain up to 75% of the special beef premium and 100% of the slaughter premium (the choice of Denmark and Sweden).

For crops, the intervention price remains unchanged. Apart from full decoupling, the options are to either retain up to 25% of the arable crop payments in the coupled form (apart from set aside payment, the choice of France and Spain), or retain up to 40% of the durum wheat payment in coupled form.

For sheep, apart from full decoupling, the available option is to continue up to 50% of the ewe premium (the choice of Denmark, Spain and France).

As of 2005 (2007 at the latest), the new milk premia can be part of the single farm payment.

Mathematical programming models make it possible to compute SFP and SPE as well as compare farmers' gross margins before and after the reform.

The computation of individual or regional decoupled payments in the AROPAj model is based on the results obtained using the Agenda 2000 policy as input. In the model, the single year of simulation is representative of the 3–year reference period. The prior AROPAj supports have been broken up according to different items related to possible decoupling combinations:

1. basic support for cereals, oilseeds and proteins;
2. specific support for durum wheat;
3. specific support for proteins;
4. set-aside support;
5. extensification support related to livestock;
6. support for milk;
7. support for ovine, caprine, and generally for “small” herd;

8. support for suckler cows;
9. support for male bovine;
10. support for slaughter calves;
11. other slaughter supports; and,
12. other supports, possibly excluded from decoupling (taxes, sugar regimes, etc.).

The decoupling reform as modelled with AROPAj is subject to the general structure of the model, based on FADN regions and farm groups. Thus, it is possible to compute single farm payment for each farm group or a unique regional entitlement.

Some supports from the Agenda 2000 policy are currently not in the model. The main reason is due to the general lack of data. For example, the FADN does not supply information about product destination, and it does not distinguish between some types of crops, e.g., starch and food potatoes. Consequently, neither does the model. Nevertheless, the total European budget devoted to agricultural policy is well represented in AROPAj.

The regionalisation option can be implemented without any difficulty in the AROPAj model when the regions covered by this option correspond to FADN regions upon which the AROPAj model is based (this is the case for Germany). Otherwise, some hypotheses are necessary about which part of a FADN region a farm group belongs to (the case for England).

In order to implement decoupling reform in the AROPAj model, we introduced a matrix (Table 2.2) into the code, with new parameters ($refarea$, $psngl$, $reffin$), new activities (X_{nsa}, X_{sgdl}, X_{pgdl}, X_{rgdl}, I_{gdlg}, I_{gdlh}), and new constraints (GDL_i with $1 \leq i \leq 6$, GDU) as described below.

The variable X_{nsa} corresponds to the set-aside area which is supported as of the first ha and which can vary from 0 to $refarea$. $refarea$ corresponds to the set-aside area of the reference period. If X_{nsa} is less than the $refarea$, the remaining area receives no support, and is labelled X_{sgdl}. If X_{nsa} is equal to the $refarea$, the remaining area receives $psngl$ by ha. $psngl$ is the premium by hectare computed in the first run of the model as SFP. The set-aside supported can not be larger than $reffin$. $reffin$ corresponds to the amount of support received fo set-aside during the reference period. However, Germany is a specific case. It distinguishes between pasture and arable land which do not receive the same support per hectare over the first years. X_{pas} and X_{pgdl} represent the pasture activity in the model. The activity X_{pas} is implicated for agricultural costs and all constraints related to technical modules (i.e. the “agronomic” module and the module related to feed). The activity X_{pgdl} is only implicated for the de-coupled payment. The line “GDU” represents the “exclusion” constraint on binary variables I_{gdlg} and I_{gdlh}. If $I_{gdlg} = 1$, farmers receive payments for their whole surface, whereas if $I_{gdlh} = 1$ they do not receive payments for their whole surface. The lines “GDL” are the 6 other constraints requested by the implementation of the Luxembourg reform in the model. The farmer receives payments for set-aside ($psgel$). This payment can not exceed a historic amount (see the constraint GDL_4 and the amount $reffin$). If the set-aside area is at least as great as the historic set-aside, the farmers receive payments for other surfaces ($I_{gdlg} = 1$). The GDL_5 constraint holds the whole surface (SAU) to be shared between variables X_{nsa}, X_{sgdl}, X_{rgdl}, and X_{pgdl}. In the case of Germany, there are 3 kinds of payments per hectare so that land should be split into 3 kinds of activities: set-aside, arable land, and pasture. The payments by hectare are respectivly $psgel$, $psrta$, and $psrpa$. For other member States, we have $psrpa = psrta = 0$.

Other parts of the Luxembourg agreement could have been introduced in the model, but they tend to obscure findings and to render the reform impacts less clearly distinguishable. In this sense we did not still implement the modulation of support.

	X_{nsa}	X_{pas}	X_{sgdl}	X_{rgdl}	X_{pgdl}	I_{gdlg}	I_{gdlh}	ZF	
OBJ	psgel			psngl+psrta	psngl+psrpa				
GDL_1	-1					refarea			≤ 0
GDL_2			1				-99999		≤ 0
GDL_3				1	1	-99999			≤ 0
GDL_4	1							-reffin	≤ 0
GDL_5	1		1	1	1			-SAU	≤ 0
GDL_6		-1			1				≤ 0
GDU						1	1		$= 1$

Table 2.2: Technical introduction of the decoupling scheme and related set-aside in the AROPAj model (ZF should be seen as the "right hand side column")

2.3 Results

2.3.1 Scenarios

Two kinds of runs of the model are necessary to take into account decoupling. The first one leads to the "reference" position, which is the "Agenda 2000" situation (Agenda 2000 scenario). It replaces the reference period situation which characterized the historical amount of subsidies allocated to producers. In other words, the first run allows us to compute individual and regional payments as the future decoupled payments. The following runs deliver the assessment of the CAP reform effects on productions and revenues when decoupling is implemented.

Three scenarios are implemented in the model. First of all, decoupling is designed as close as possible to the Luxembourg agreement, taking into account the national implementation of partial decoupling (Luxembourg scenario).

Second of all, decoupling is viewed as a premium which is "unique" at the farm scale, no matter how farmers allocate their land (Full Decoupling scenario). This unique premium can be defined at the farm group scale, the regional scale, the national scale, and the European scale. The level of the premium is computed so that the agricultural budget does not change, considering the given scale. As regards this unique premium, results based on the regional scale are presented. The EAGGF (European Agricultural Guidance and Guarantee Fund) budget is maintained constant for each FADN region (Labonne and Jayet 2005).

A third scenario results from the coupling of AROPAj and PEATSIM, a partial equilibrium model. This coupling makes it possible to account for the impact of the Luxembourg reform on European prices. The impact is presented as variation in price as seen in Table 2.4.

Likewise, each scenario can be differentiated according to the level of livestock adjustment which is allowed. Two different levels have been implemented : 0% and 15%.

Three effects will be assessed thereby: the livestock adjustment effect, the policy change effect and the price variation effect. To measure these different effects the scenarios are compared as in Table 2.5.

In order to make easier the link between the scenario and the tables, we denote respectively by AG, LX, FD and PS the scenarios "Agenda 2000", "Luxembourg agreement", "Full decoupling" and "Luxembourg agreement coupled with the partial equilibrium model PEATSim". The label is augmented respectively by 00 or 15 according to the unchanged livestock or to the adjustment of livestock within a given interval ($\pm$ 15% around the initial livestock).

MS	arable land	dur. wheat	protein	sheep	suckler cows	special beef premia	slaughter (calves)	slaughter (others)
belg	0	0	0	0	1	0	1	0
dani	0	0	0	0.5	0	0.75	0	0
deut	0	0	0	0	0	0	0	0
ella	0	0	0	0	0	0	0	0
espa	0.25	1	0	0.5	1	0	1	0.4
fran	0.25	1	1	0.5	1	0	1	0.4
gbre	0	0	0	0	0	0	0	0
irla	0	0	0	0	0	0	0	0
ital	0	0	0	0	0	0	0	0
luxe	0	0	0	0	0	0	0	0
nede	0	0	0	0	0	0	1	1
osto	0	0	0	0	1	0	1	0.4
port	0	1	0	0.5	1	0	1	0.4
suom	0	0	0	0.5	0	0.75	0	0
sver	0	0	0	0	0	0.75	0	0

Table 2.3: Rate of recoupling according to subsidy type (AROPAj)

Product	Price variation (in %)
rice	2.59
durum and soft wheat	3.49
corn	2.72
other cereals (barley, ...)	2.25
soya	1.26
sunflower	4.97
rapeseed	6.80

Table 2.4: Variation in European prices from the coupling of AROPAj and PEATSIM

Effect to measure	Scenarios to compare
Adjustment effect	AG00 and AG15
Policy effect (Luxembourg reform)	LX15 and AG15
	LX00 and AG00
Policy effect (Full decoupling)	FD15 and AG15
Price effect	PS15 and LX15

Table 2.5: Effect assessment and scenarios to compare

2.3.2 Change in gross margins

By focussing on gross margins, a major impact of the reform is revealed. In accordance with theoretical approaches, our model shows that a decoupling policy induces gross margin increase. However, the reader should note that the European budget is slightly altered when the Luxembourg agreement is implemented. This is due to regional elements related to incentives toward pasture, especially in Germany. Net total change in gross margin and the public budget need to be taken into consideration to obtain the more accurate evaluation of the impacts of the CAP reform. The real social net benefit estimated by the model – all other aspects of the economy taken as stable – comes from the possible addition of the positive change in the gross margin to the change in the total support. This means the social benefit should be respectively 943 million € and 2,024 million € according to the CAP scenario (respectively the Luxembourg agreement and the full decoupling scenario, with livestock adjustment).

Different effects can be ranked according to scenarios. Table 2.6 shows us the most important effect arises from the livestock adjustment (+5,609 million €), followed by policy choice (between + 866 and +2,024 million €), and then price effect (+680 million €).

Concerning the policy effect, as expected after theoretical analysis, the computed gross margin of farms increases when decoupling is implemented. One of the objectives of the CAP reform was to be more economically efficient by increasing farmers' income while taxpayers pay the same amount of euros. It is interesting to notice that the market effect emphasizes this results. When AROPAj is coupled with PEATSIM, European prices change and in turn change AROPAj's results. Concerning gross margins, the market effect as measured by the use of PEATSIM enhances the increase in gross margin. We also compared the impacts of the Luxembourg reform to those of a full decoupling reform with a regional prime. A full decoupling reform would induce more benefits for farmers and less expenditures fo the European budget, very much in line with theoretical views.

Table 2.7 shows not surprisingly that Member States where animal production plays an important role (e.g., Belgium, Denmark) are particularly sensitive to livestock adjustment. Some countries seems to lose with the implementation of the Luxembourg reform. This is due to a decrease in the amount of subsidies they receive. In Germany, the regionalisation scheme associated to a special

policy option	Gross margin	EAGGF	Net Gain
AG00	85093	27249	-
AG15 - AG00	+5704	+95	+5609
LX00 - AG00	+1350	+484	+866
LX15 - AG15	+1223	+280	+943
FD15 - AG15	+1929	-95	+2024
PS15 - LX15	+679	-1	+680

Table 2.6: Gross margin and FEOGA variations (in million €)

	gross margin			subsidies		
	AG15-AG00	LX15-AG15	FD15-AG15	AG15-AG00	LX15-AG15	FD15-AG15
belg	32.2%	1.1%	4.3%	-3.5%	0.0%	3.7%
dani	12.7%	0.6%	2.7%	-0.4%	0.4%	0.4%
deut	3.5%	5.4%	1.9%	0.3%	15.6%	-0.3%
ella	6.7%	-1.3%	-1.2%	7.1%	-6.7%	-6.7%
espa	9.9%	-0.3%	2.1%	1.2%	-2.3%	-1.1%
fran	6.2%	0.1%	4.0%	-0.8%	-3.3%	0.8%
gbre	7.0%	1.7%	2.7%	0.1%	-0.1%	-0.1%
irla	9.0%	0.5%	0.9%	3.6%	-3.4%	-3.4%
ital	8.9%	0.4%	0.9%	0.6%	-0.6%	-0.6%
luxe	4.8%	2.8%	4.3%	-0.9%	0.9%	0.9%
nede	4.4%	0.4%	0.5%	-0.1%	-0.1%	0.2%
osto	4.2%	1.0%	2.3%	-0.2%	-0.6%	0.2%
port	4.3%	1.6%	4.1%	0.4%	-1.5%	-0.4%
suom	2.0%	0.1%	0.6%	2.3%	-2.1%	-2.2%
sver	4.1%	1.6%	2.9%	1.9%	-1.6%	-1.9%
Europe	6.7%	1.3%	2.1%	0.3%	1.0%	-0.3%

Table 2.7: Gross margin and subsidy variations, by hectare according to MS

premium for pastures induces a higher amount of subsidies which in turn induces a large increase in gross margin. Greece is a special case, indeed in the model, this MS receives an important subsidy by hectare (636€ to compare to 311€ in average for EU15).

2.3.3 Change in land allocation

One of the most expected results concerns land use change. Table 2.8 presents land use variation for the EU-15 on the whole. In the Luxembourg scenario, set-aside remains constant as was expected. This is due to CAP incentives to keep the amount of set-aside area stable. Farmers are interested in maintaining set-aside area in order to obtain subsidies. The major impact across Europe can be seen in the marked shift from arable land toward pasture. This is in line with other studies devoted to the assessment of the impacts of the CAP reform. However, in our study, fodder land is also to be seen shifting toward pasture.

	cereals	oil & protein	indus. crops	set aside	fodder	pasture	fallow
AG00	36598	4303	4876	6440	10867	22367	2082
AG15 - AG00	-50	+6	+33	+36	-37	-30	+41
LX00 - AG00	-3105	-518	+216	-133	-1295	+4001	+833
LX15 - AG15	-3092	-506	+216	-169	-1301	+4070	+782
FD15 - AG15	-2969	-89	+309	-6306	-1944	+5464	+5536
PS15 - LX15	+72	+75	-28	0	-121	-105	+107

Table 2.8: Land use and land use change according to CAP option (in thousands of ha)

Due to the reform, the relative interest farmers have in crops decreases. It is more profitable to have pasture and fodder. However, it can be seen that because the direct support of animal production decreases, fodder use is less profitable. Consequently, animals pasture graze which is less expensive than feeding them fodder. The full decoupling scenario reinforces the tendancies observed in the Luxembourg scenario, but with a shift from set-aside towards abandonment.

Globally speaking, in the PEATSIM scenario, these tendancies are slightly counterbalanced. This is due to the price effect. Indeed when European productions increase, market prices decreases and in turn European productions decrease. When the number of livestock is allowed to fluctuate by a given interval ($\pm$ 15%), these tendancies are once again slightly reinforced (less arable land, less fodder, and more pasture).

It is also possible to compare each scenario with others by the way of a criterion to measure the disparity in land use induced by the scenarios. We estimate this disparity through the following index I computed as explained in the equation 2.1.

$$I(CAP1/CAP2) = \sum_{MS} \sum_{a \in land\ uses} \left(\frac{S_{aCAP2} - S_{aCAP1}}{UAA_{MS}} \right) \tag{2.1}$$

where MS represents each Member States, a represents a type of land use (among cereals, oil and protein crops, industrial crops, set aside, fodder, pasture or fallow), S_{aCAPi} represents the area devoted to land use a within the CAP i and UAA_{MS} represents the total agricultural area of the Member State MS. Table 2.9 shows the changes are more important with a full decoupling scenario than with the Luxembourg reform.

	I
AG15-AG00	16
LX15-AG15	1830
FD15-AG15	4103

Table 2.9: Index values to measure the disparity in land use induced by policy change

2.3.4 Productions

At the very beginning, the main objective of the CAP was to ensure the food self reliance within Europe. This aim may be no longer a concern. Nevertheless, some politicians are still arguing that this aim must drive the first pillar of the CAP. In our Luxembourg scenario, only first pillar aspects of the Luxembourg reform have been taken into consideration. From this point of view, Table 2.10 presents marketed production variations for the EU-15 on the whole. Globally speaking, marketed production does decrease and it could be regarded as an unsettling prospect by some politicians. However, when the market role is accounted for, these tendancies are mitigated.

	cereals	oilseeds	potatoes	beet	protein
AG00	156643	11112	80570	122909	645
AG15 - AG00	+2443	+17	+572	+604	-1
LX00 - AG00	-5688	-1412	+547	+15473	+185
LX15 - AG15	-5413	-1371	+585	+15354	+186
FD15 - AG15	-1491	-550	+113	+22278	+209
PS15 - LX15	+838	+214	-831	-410	-12

Table 2.10: Marketed productions in thousand metric tons

More in particular, in the Luxembourg scenario, cereal production decreases whereas oil seed production increases. The increase in sugar beet production is mainly due to an increase in the C-beet land allocation.

In this case, when we compare effects, the policy effect is preponderant compared to the livestock adjustment effect.

	durum wheat	soft wheat	barley	other cereals
AG00	1033	14683	10244	2521
AG15 - AG00	24	-1322	-515	-239
LX00 - AG00	-331	-2396	-2455	-588
LX15 - AG15	-372	-2162	-2655	-556
FD15 - AG15	-479	-2869	-2872	-566
PS15 - LX15	-42	-281	139	3

Table 2.11: On-farm consumption variation according to the scenario in thousand metric tons

The implementation of the Luxembourg reform induces a decrease in the on-farm consumption compared to the Agenda 2000 scenario (Table 2.11). This decrease is slightly reinforced when the number of livestock is allowed to fluctuate within a given interval (± 15%). This result is made possible by the increase in pasture area. Animals indeed graze instead of being fed on-farm production.

2.3.5 Downscaling approach at the regional scale

The AROPAj model is based on farm groups defined at the regional level, when the region unit is the FADN one. This allows us to analyse the diversity of impacts seen through a geographical criterion. In this subsection, we focus on the effect of the livestock adjustment on one hand, and on the effect of the CAP option on the other hand.

The livestock effect is mainly sensitive regarding the gross margin variation (see the maps on Figure 2.1). The expected increase in gross margin (in accordance with maximisation with respect to an enlarged feasible set) is obviously higher in regions mainly dedicated to animal production. This increase is mitigated when change occur in CAP option. The implementation of the Luxembourg agreement leads several regions to lose a part of the previous gain in France, Spain and Greece. The increase is more significant in Germany, in accordance with particular incitatives devoted to pastures. The decrease estimated in a few French and Spanish regions seems to be correlated with change in durum wheat subsidy. The full decoupling would supply an additional advantage in almost all regions but in Greece.

The impact of CAP change is more significant regarding land use (see the maps on figures 2.2-2.8). Globally speaking, decoupling induces a decrease in areas devoted to cereals. Figure 2.2 shows that the livestock adjustment induces nearly no changes in cereals area whereas the policy effects are strong. More the decoupling is important, greater is the decrease in cereal area. We can see that by comparing the FD15 scenario to the LX15 one, but also by comparing MS between themselves in the LX15 scenario. In Spain and France, where the coupled subsidies are the most important, the decrease in cereal area is smaller than in other MS. However, in some very productive regions (i.e. "Ile de France" and "Picardie"), the model leads to an increase in area devoted to cereals.

Figures 2.3 and 2.4 show that areas devoted to oil and protein crops or industrial crops don't change very much at the regional level.

As seen in Figure 2.5, fodder area mainly decreases, and in greater proportions when the decoupling is full. In regions where cereal area also decreases, it is replaced by pasture (Figure 2.6).

Set aside disappears in the full decoupling scenario, whereas it remains unchanged in the Luxembourg scenario (Figures 2.7 and 2.8). In the Luxembourg scenario, set-aside is partly replaced by fallow but we have to pay attention to the disparity in this kind of replacement. In a large number of productive regions, set-aside previously existing due to the subsidy access could be replaced by crops, whereas set-aside could be replaced by fallow in less productive regions.

2.3.6 Change in environmental indicators

We can expect some strong impacts of the reform on a large set of environmental indicators. Change in net producer prices leads farmers to change in land use and factor demand. Consequently, environment in the broadest sense -through local and global phenomena- could be strongly affected by the reform. We have chosen to focus on greenhouse gas (GHG) emissions which have been previously explored (De Cara et al. 2005).

It needs to be noted that previous CAP and past agricultural evolution led to an abatement in GHG emissions (ECCP 2006). The Luxembourg agreement as implemented in the AROPAj model slightly increases this abatement.

Concerning GHG emissions, the livestock adjustment effect is the most important one. This is essentially due to a decrease in livestock number (we estimate the decrease to be 7%). When policy reform is implemented, the decrease in total GHG emissions is mitigated and fully due to changes in crop activity (N_2O emissions). The price effect (Peatsim scenario) seems to have only a slight effect on GHG emissions.

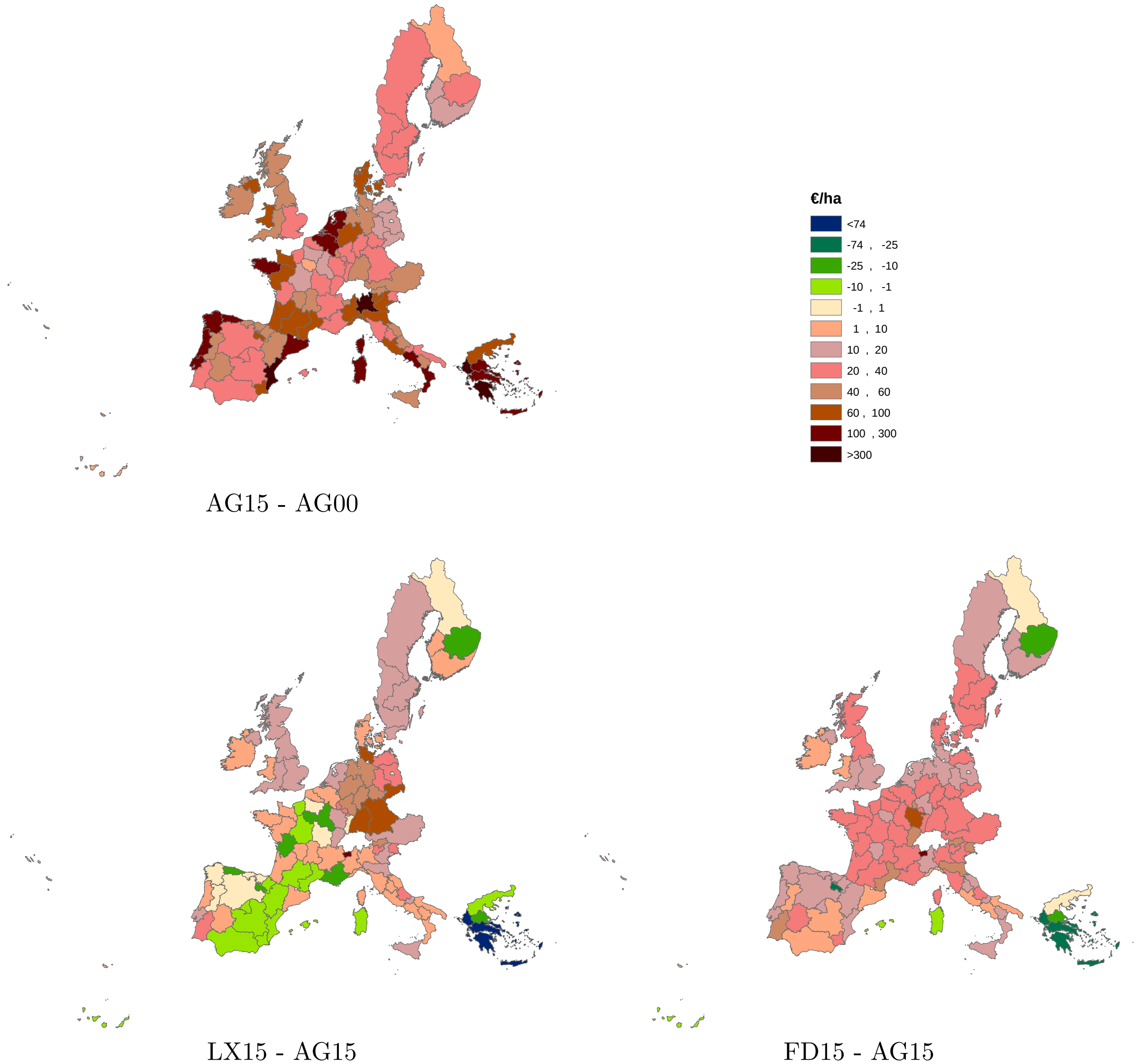

Figure 2.1: Variation in gross margins by hectare between the scenarios AG00, AG15, LX15 and FD15.

	N_2O	CH_4	GHG
AG00	187747	165827	352344
AG15 - AG00	-3113	-8247	-10130
LX00 - AG00	-6090	1083	-3776
LX15 - AG15	-7042	1735	-5307
FD15 - AG15	-6040	3255	-2784
PS15 - LX15	102	-164	-62

Table 2.12: GHG emissions and variations in thousand tCO_2eq

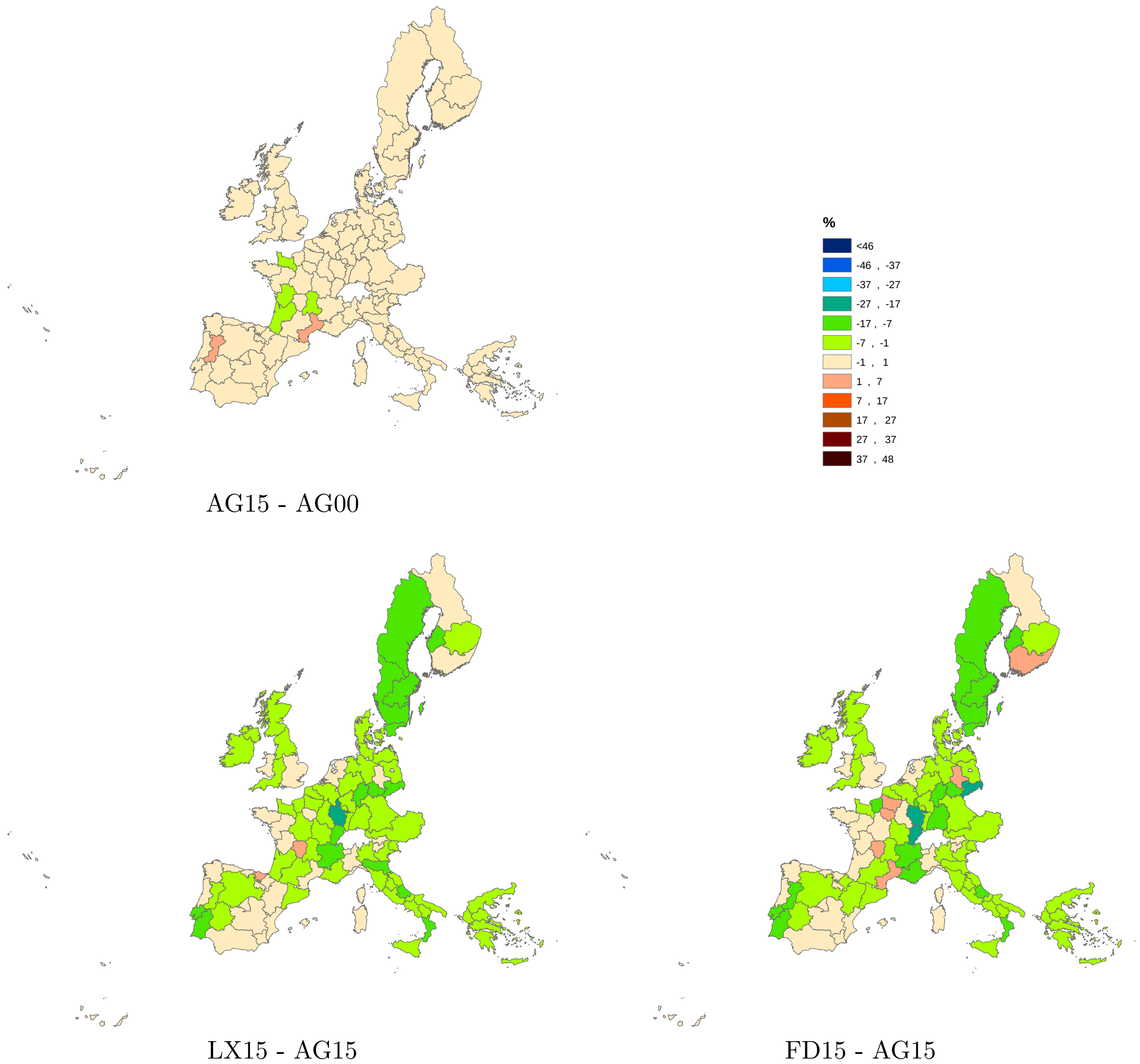

Figure 2.2: Variation in area devoted to cereals between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

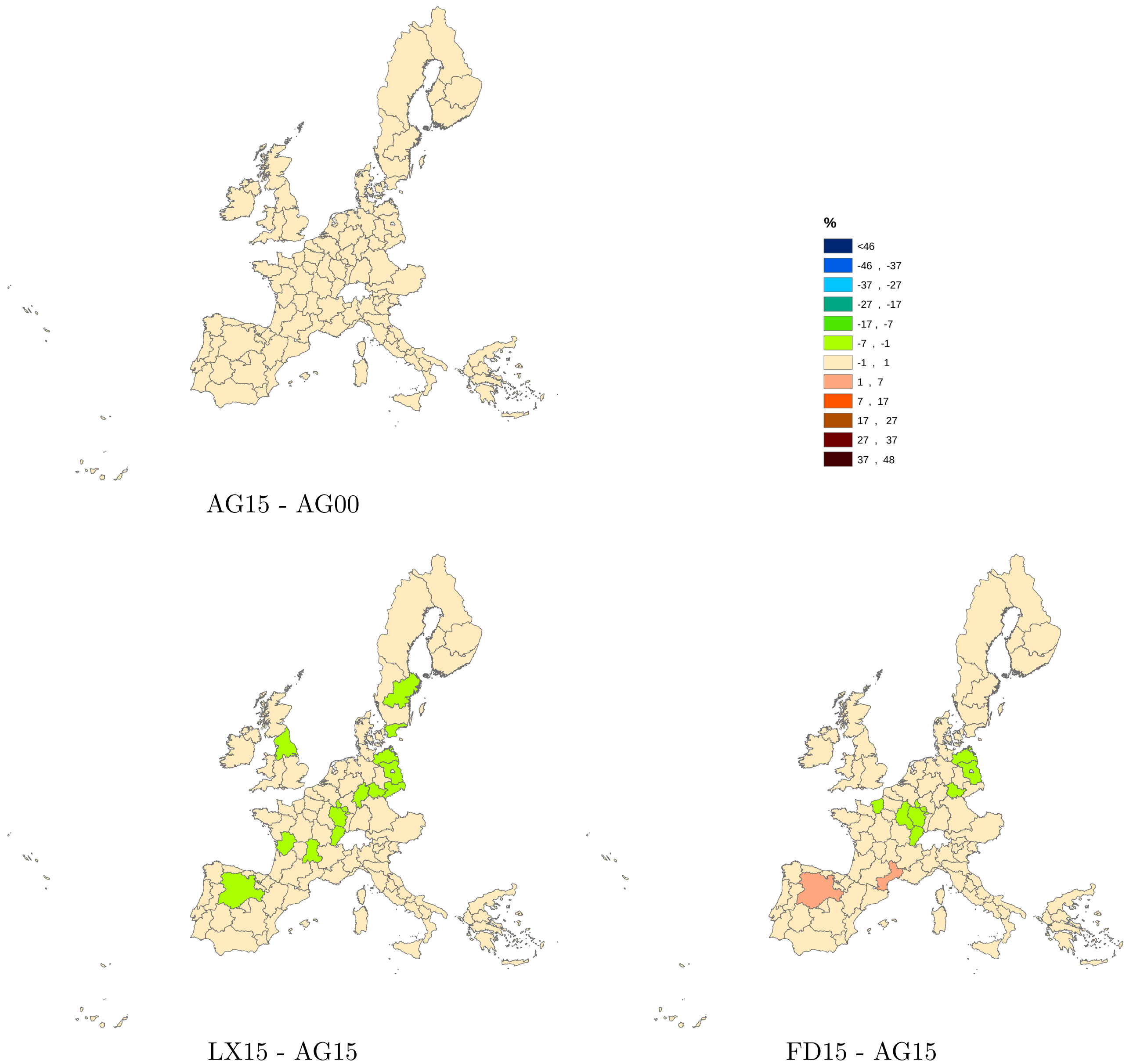

Figure 2.3: Variation in area devoted to oilseeds and proteins between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

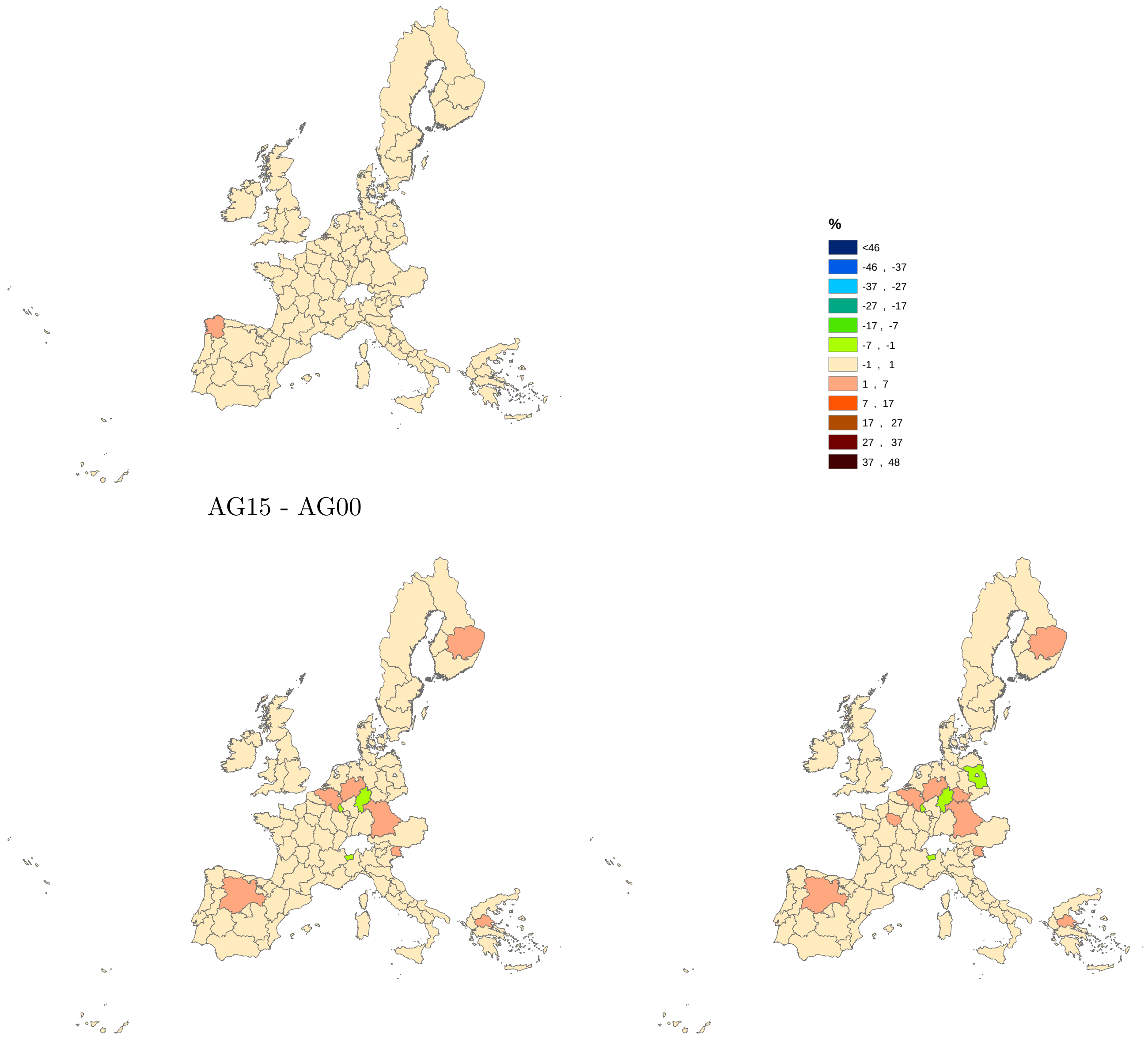

Figure 2.4: Variation in area devoted to potatoes and sugarbeet between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

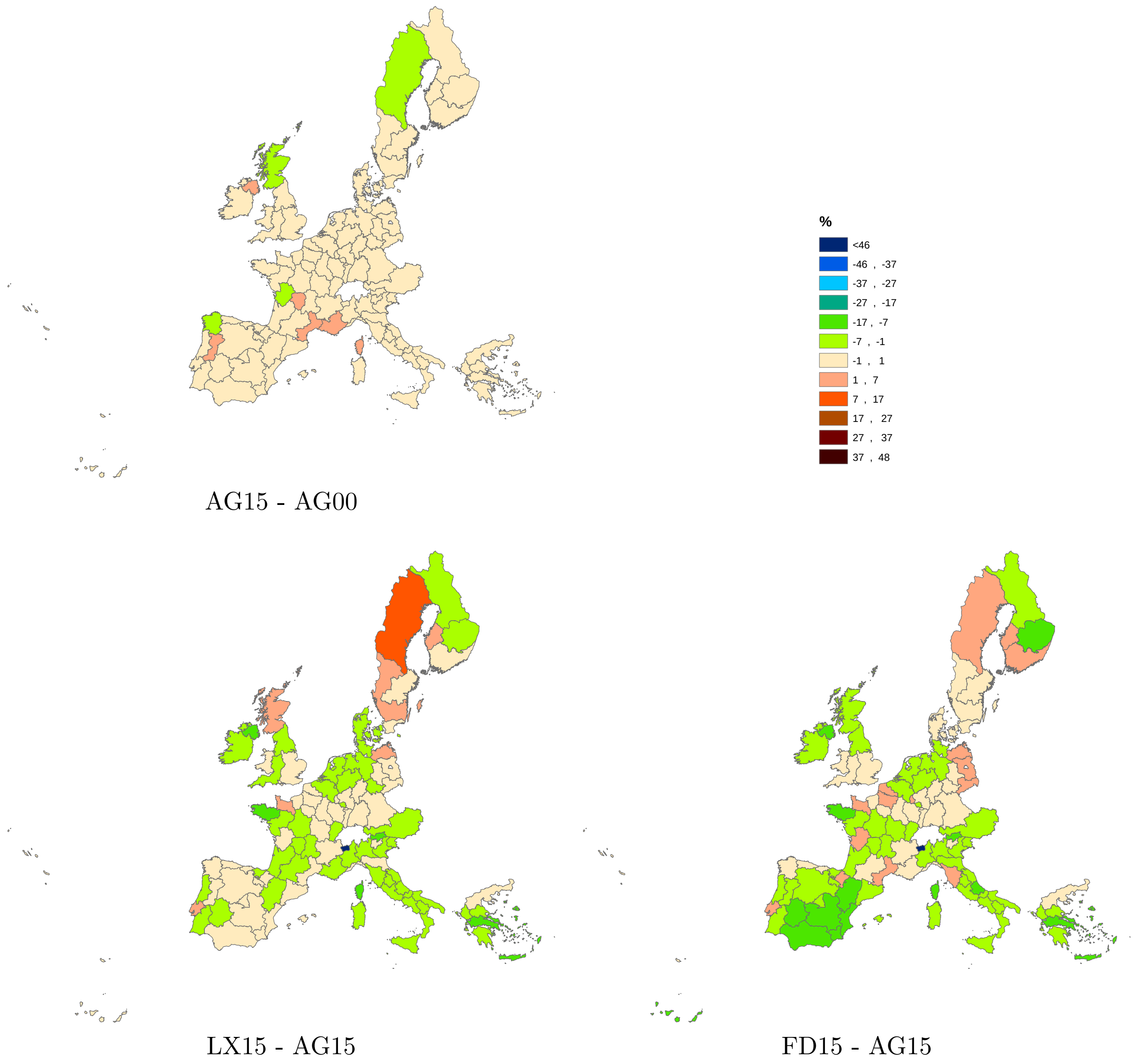

Figure 2.5: Variation in area devoted to fodder between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

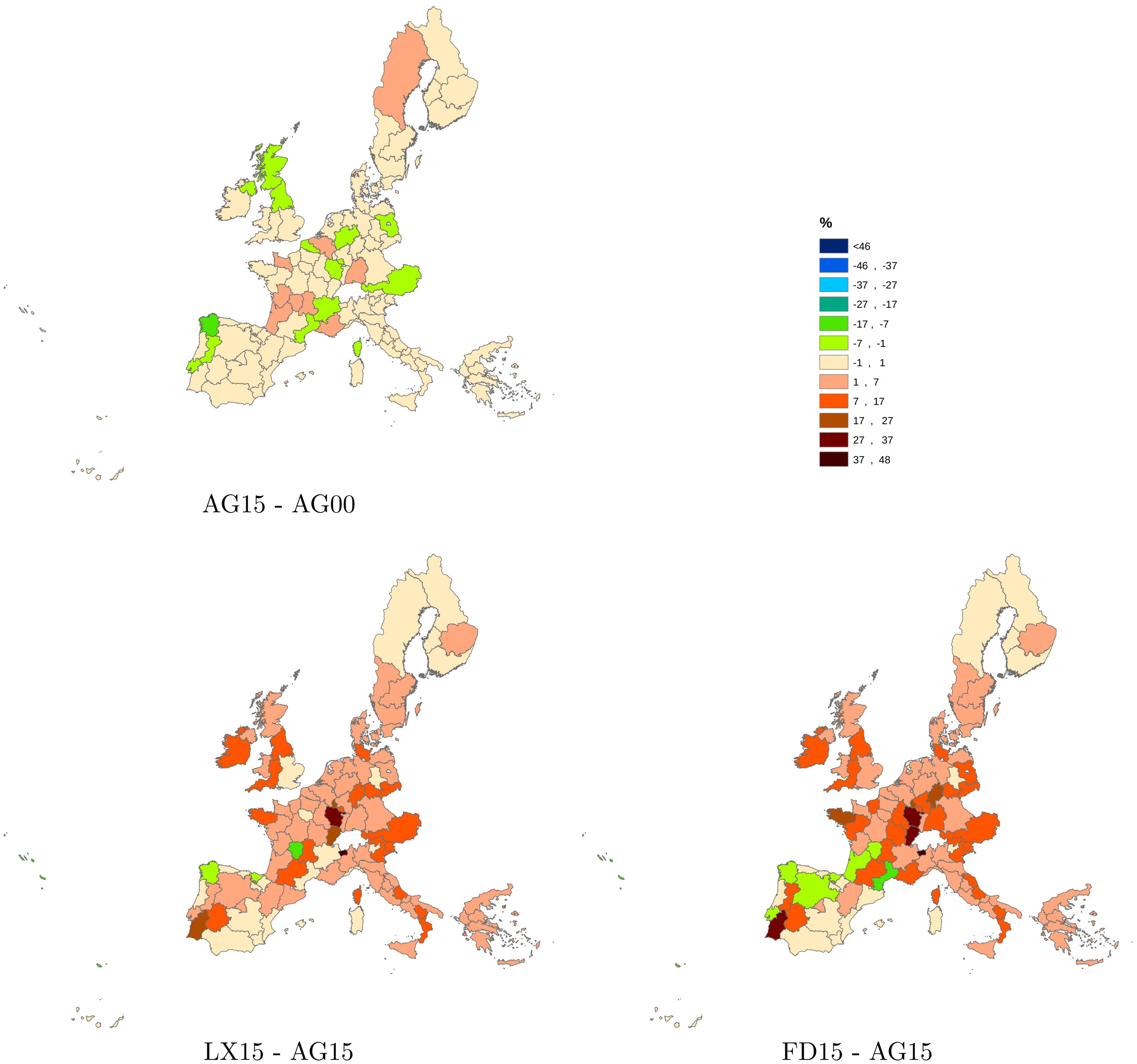

Figure 2.6: Variation in area devoted to pastures between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

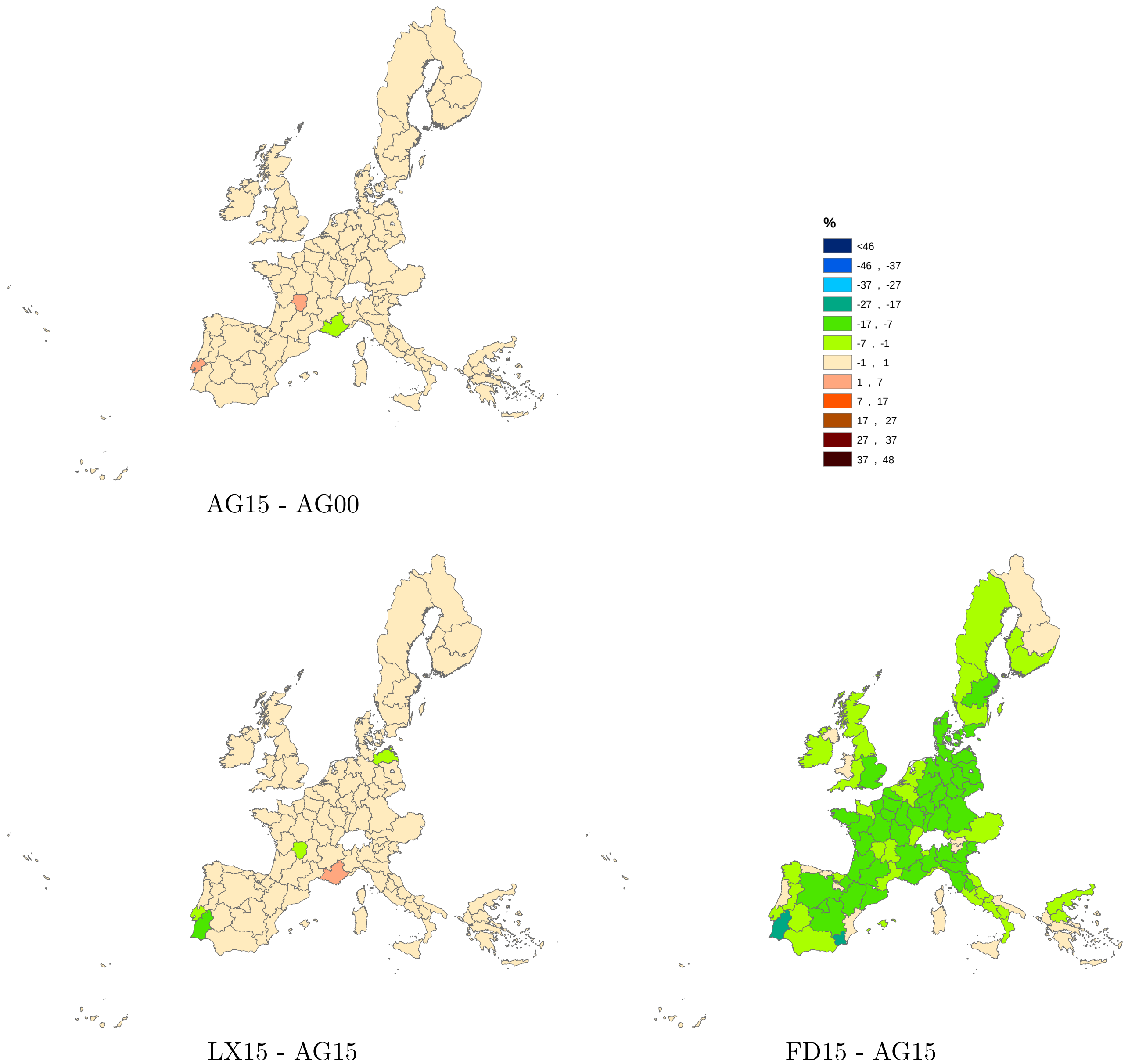

Figure 2.7: Variation in area devoted to set-aside between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

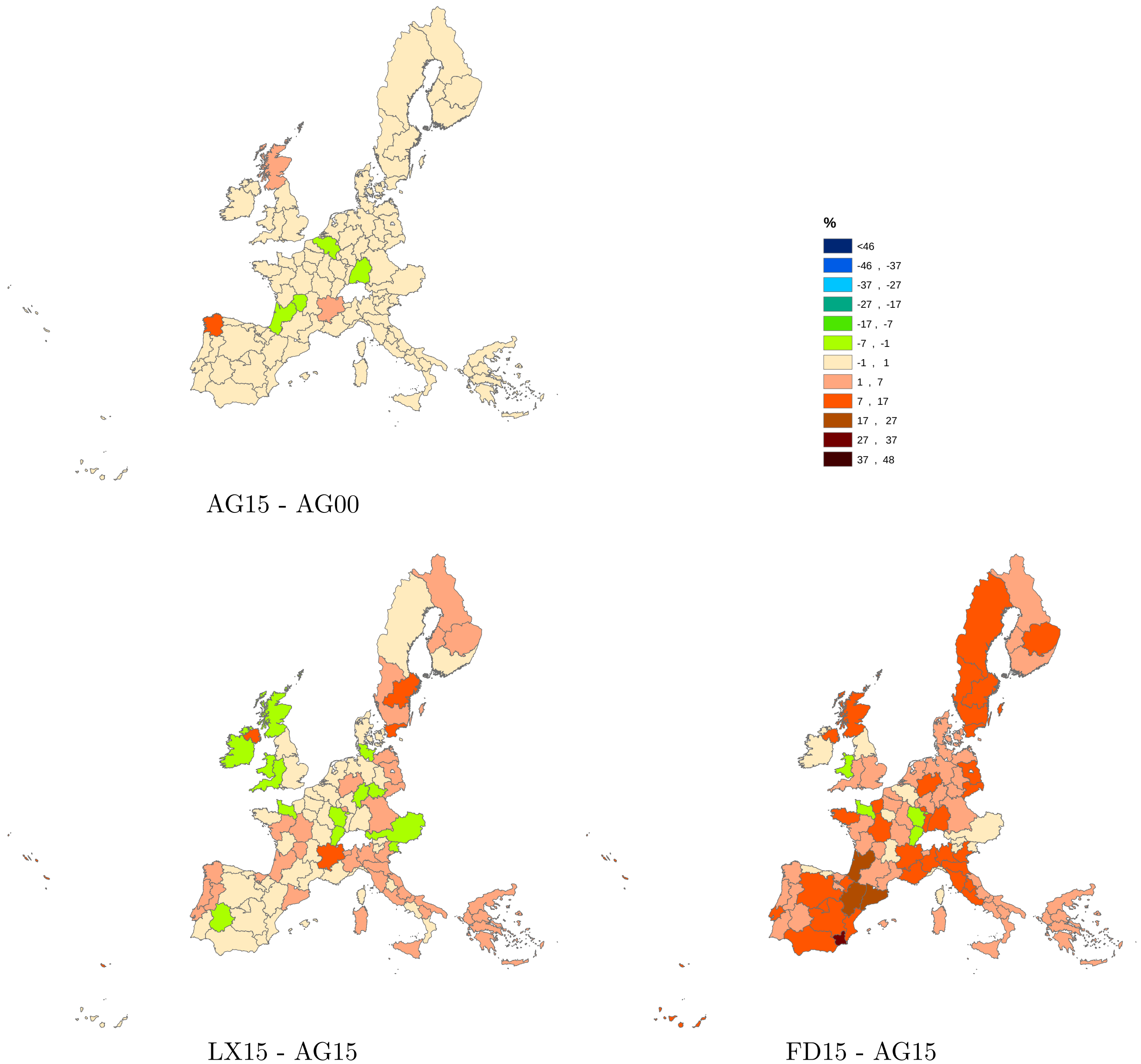

Figure 2.8: Variation in area devoted to fallows between the scenarios AG00, AG15, LX15 and FD15 (in % of the regional agricultural area).

Conclusion

Our results are in accordance with those of other models (ESIM, PROMAPA.G, EU-FARMIS) even if positive mathematical programming models mitigate some effects provided by AROPAj. Concerning gross margins, our model as well as others are in accordance with theoretical approaches. As regard this, when the total amount of subsisdy is kept unchanged, full decoupling should ameliorate social welfare and could maintain or increase farmers' gross margins.

Full decoupling results will be more precisely presented and analyzed in workpackage 5 of GENEDEC. Likewise, in workpackage 3.1, as a means to bring GENEDEC and IDEMA together, the coupling of AROPAj with the partial equilibrium model ESIM is to be implemented. The aim is to account for the changes in EU and world prices resulting from changes in EU agricultural policy. At the moment, a coupling of AROPAj is being carried out with PEATSim, whose code and data were available. Once this step is finished, it will be possible to assess the impacts of decoupling on world prices. In turn, AROPAj will then assess the reform impacts with the related prices. Lastly, it would be interesting to take modulation into account.

Obviously, results depend of the model used for estimation, as far as they depend of the upstream data. The quality of data is under the responsability of national statistical services, and disparity in quality and representativity should not to be excluded from modelling concerns.

Our study shows that set aside due to CAP commitments is maintained by the Luxembourg reform but disappears in the full decoupling scenario whereas the fallow area slightly increases in the Luxembourg scenario and strongly increases in the full decoupling scenario. At the European scale, it seems one activity is replaced by the other. But when we focus on a more precise scale, we highlight numerous disparities among regions. The full decoupling reform would imply some land being abandoned for fallow in regions where productivity is weak. Likewise, in regions where productivity is high, previously set aside land would be cultivated. It would induce a higher production so far as weak yield land is replaced by high yield land at the European level. Considering arable crops, the two policy options lead to a decrease in cereals and oilseed and protein grains. Fodder slightly decrease and pasture area significantly increases. Again, disparities occur among different Member States and different regions.

The AROPAj model would lead us to provide spatial results at a more precise scale. The infra-regional analysis has to be conducted by coupling the economic model with a geographical information system itself linked to databases on observed land use (LUCAS and CORINELandcover), soil, climate, digital elevation model. Statistical methods are used for lacting of the AROPAj crops and farm groups. [citer Ckakir, et un papier de Heckelei par exemple si possible publié dans ERAE]

Then the local variations in land use should be analysed more precisely in accordance with strong geographical diversity occuring in several regions. We have examples in the French regions Auvergne and Basse-Normandie, when respectively the Limagne and the Plaine de Caen appear as arable lands dedicated to crops in farms surrounded by livestock farming systems. Down scaling approaches realized inside the GENEDEC programme supply us the expected result of local contrasted change in land use (Chapter 10, 16 and 15).

Regarding the environmental issue, the Luxembourg reform could be presented as providing a double dividend. Stabilized subsidies could be accompanied by a gross margin increase and a GHG emissions abatement. Two concerns arise when considering the GHG emission abatement due to the CAP reform. First, the EU would like to take advantage of an abatement not specifically due to environmental regulation policies, but to CAP reform which respects budget and WTO obligations. Even if examples of advantage taking can be found among other countries and in other context (e.g., the Russian "hot air"), signatories of the Kyoto protocol might not find any additional abatement compared to business as usual for the European Union. Another problem might occur if the decline of European agricultural production encourages the same production elsewhere in the world under worse conditions. This leakage effect should be taken into account by policy makers once they are convinced by the importance of impacts of anthropogenic climatic change.

Impacts of the reform on land prices will be analysed in the chapter 5.

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3 Coupling of the AROPAj model and the partial equilibrium PEATSim model

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Abstract

In this paper, we present the method used and assumptions made in implementing the coupling between a supply-side mathematical programming model (AROPAj) and a partial equilibrium model of agricultural markets (PEATSim), as well as some results regarding the changes in area and prices for crop products upon implementation of the Luxembourg Agreement. Despite substantial differences in the modelling approach, data sources, and formulation of the two models, the iterative process implemented converges, with price increase ranging from 2.2% to 3.5% for grains, and from 1.2% to 6.8% for oilseeds.

3.1 Introduction

Several assessments of the impacts of EU agricultural and environmental policy reforms on farmers' income, production and resource allocation have relied on mathematical programming models of agricultural supply (Judez et al. 2005, Labonne and Jayet 2005, Küpker 2006, Küpker and Kleinhanss 2006). One of the main interests of this modelling approach is to allow for a detailed description of the various constraints faced by farmers when making their economic decisions. This approach thus ensures that economic impacts are consistent with technological and policy requirements that prevail at the farm level. Based on microeconomic data, these models usually operate at a high level of disaggregation. As a large number of farms (or farm-types) is generally modelled, assessments based on such an approach account for a wide diversity of conditions of production, hence making possible the analysis of how policy impacts vary across space and/or types of farming. Such a level of disaggregation is generally not available in partial or general equilibrium models, as the typical basic modelling unit in the latter approach is the country or group of countries.

However, the level of disaggregation prevailing in mathematical programming models is generally obtained at the expense of some simplifying assumptions. In particular, demand aspects and market responses to policy-induced changes in crop and animal production are generally not endogenously accounted for[1]. As the approach is focused on the supply of agricultural products, input and output prices are taken as exogenous parameters. Consequently, simulated economic impacts obtained from this modelling approach pertain to a given structure of prices, which is generally assumed to be fixed. This assumption—in line with a price-taker behaviour at the microeconomic level—makes sense at the farm level. In addition, assuming constant prices could be partially supported by the existence of policy instruments aimed at insulating internal prices from world prices and mitigating price fluctuations, at least to a certain degree and for some products. Yet, given the current context of international agricultural trade negotiations and the nature of the recent nature of CAP reforms, accounting for market impacts of agricultural policy reforms—that is, not only considering supply-side effects, but also impacts of policy reforms on the demand side and on market equilibrium prices—has gained considerable importance.

This text describes an attempt to relax the constant price assumption that often prevails in mathematical programming approaches. This is done though the coupling of a supply-side oriented model (AROPAj) and a partial equilibrium model (PEATSim). This approach is aimed at making possible the discussion of the policy impacts on agricultural supply at a disaggregated level, while at the same time accounting for the resulting changes in equilibrium prices. In this paper, we present the method used and assumptions made in implementing the coupling, as well as some results regarding the changes in area, output, and prices for crop products upon implementation of the Luxembourg Agreement.

The remainder of the text is structured as follows. Section 3.2 briefly presents the two models used in the coupling. The way the two models are coupled in order to obtain price impacts of a policy reform is exposed in Section 3.3. This section also summarizes the assumptions made in implementing the coupling and the way the Luxembourg Agreement is modelled in the supply-side model. Section 3.4 presents the results.

[1]Some agricultural sector models, operating at a regional resolution include endogenous equilibrium prices mechanisms, for instance through a quadratic programming formulation (McCarl and Spreen 1980). Given the resolution of the agricultural supply model, which involves several farm-types'models in each region, the use of this method was not possible.

3.2 Supply-side and partial equilibrium models

3.2.1 Supply-side agricultural model

The mathematical programming model of European agricultural supply used in this paper is the AROPAj model. The model describes the behaviour a set of "farm-types". The farm-types results from a typology of the surveyed farms available in the FADN dataset (by region, main technical and economic orientation, altitude class, and economic size. Each farm-type thus encompasses a group of FADN sample farms, which are representative of European agriculture at the regional level[2]. The current version of the model includes 1,074 farm-types spread over 101 FADN regions covering the EU-15. The model is calibrated against 2002 FADN data.

Each farm-type is associated with a mixed integer linear programming model, which determines optimal farmers' choices in terms of area, output for each crop (distinguishing between on-farm consumption and marketed production), animal numbers in each animal category, milk and meat production, and the quantity of purchased animal feeding. Each farm-type is assumed to maximize total gross margin subject to farm-type dependent agronomic, technological, and CAP-related constraints. Individual results are scaled up at the regional and European levels using the weights reported by the FADN. For a further description of (a previous version of) the model—including a presentation of the overall modelling approach, typology, data sources and some modelled policy instruments—, the reader is referred to De Cara et al. (2005). Additional features, revisions and data updates are documented elsewhere in this report.

The modelling approach thus puts the emphasis on the technical conditions of production and on the availability of (quasi-)fixed factors. To some extent, this approach is of short/medium-term nature, as the feasible production set—which is described in details by the matrix defining the relationships between producing activities—is held constant when examining alternative policy scenarios in the model. Therefore, the simulated impacts pertain to a given and fixed technology. Likewise, the distribution of farm-types within each region as well as variable costs and prices for each producing activities are also generally assumed not to be modified by the introduction of the new policy provisions. The simulated policy impacts correspond to first-order changes on the supply-side only, not accounting for further adjustments that can occur in input or output markets, nor for changes in the structure of the industry (entry/exit, changes in the distribution of farm-types).

3.2.2 Partial equilibrium model of agricultural markets

A number of partial equilibrium models provide projections of agricultural prices, supply, demand and trade and/or to assess impacts of policy reforms (Fabiosa et al. 2005, Fuller et al. 2003, Balkhausen and Banse 2006).

By definition, partial equilibrium models describe simultaneously the demand and the supply side of agricultural markets. By contrast with mathematical programming models, the emphasis is thus less on the description of the availability of (quasi-)fixed factors of production than on price adjustments on agricultural markets. In this sense, simulated impacts of a policy reform pertain to longer-term analysis, as they include effects of the changes in equilibrium prices of agricultural products.

The level of aggregation used in those models is higher than for supply-side mathematical programming models. Typically, the basic modelling unit is the country or group of countries. Supply and demand equations are defined at this level of aggregation. Each country or region is modelled

[2] It should be noted that, as the main focus in the subsequent analysis is on main annual crops and livestock activities, farms predominantly oriented toward the production of perennial crops and horticulture are excluded from the analysis

as one single farm, defined as one single set of behavioural supply (area, yields, livestock numbers, etc.) and demand (food, feed, variation of stocks) equations.

Key to this approach is the set of elasticities defining demand and supply equations, which can be either calibrated or econometrically estimated. Supply and demand equations also account for the effect of macro-economic, policy, or technological parameters, which are usually assumed to be exogenous. Equilibrium prices are endogenously obtained through market clearing mechanisms, usually at the world market level. World prices are then converted into producer or consumer prices for each country or region through price transmission equations that are meant to capture the impacts of, for instance, tariffs, transportation costs, and quality differentials.

The partial equilibrium model used in the subsequent analysis is the PEATSim model (Stout and Abler 2004). The choice of this model was motivated by the availability of the code, the compatibility with supply-side model in terms of modelling platform (GAMS), and accessibility to the raw data sources, especially for price elasticities, tariffs and tariff rate quotas (TRQs). This model has been jointly developed by the Economic Research Service of the USDA and the Department of Agricultural Economics and Rural Sociology at Penn State University. The version used (2.1.1) covers twelve (groups of) countries, namely the United States, European Union (EU-25), Japan, Canada, Mexico, Brazil, Argentina, China, Australia, New Zealand, South Korea, and the rest of the world (modelled as one region). The model covers 35 commodities (grains and oilseeds, oilseed products, livestock products, and processed dairy products)[3].

Equilibrium prices and quantities are endogenously determined on the world markets in a non-spatial manner, meaning that net exports are not distinguished according to the country of origin/destination on the world markets. The model includes a number of built-in policy instruments such as tariffs, TRQs, specific and ad valorem import and export taxes/subsidies, as well as specific instruments corresponding to the CAP (compensatory payments, intervention prices, set-aside, sugar and milk quotas). Given its dynamic nature, the model can be used as a comparative static analysis tool or for analyses in which dynamics and adjustment paths are of interest. Data sources include USDA's PS&D database and AMAD (for applied tariffs and TRQs).

One of the main interest of this model for the present exercise lies the accessibility of the elasticities database to the user. These elasticities underly the behavioral equations. The use of constant-elasticity formulation also eases the coupling and ensures—together with standard economic restrictions on the value of the elasticities (symmetry, homogeneity)—the economic consistency of supply and demand responses to a change in prices.

3.3 Description of the coupling

The coupling of the supply-side model and the partial equilibrium model is aimed at relaxing the assumption of constant prices often made in supply-side models. The objective is thus to account for the effects of agricultural market adjustments at the aggregate level, while maintaining the possibility of analyzing the diversity of farm-types' responses within the European agriculture. The coupling relies on an iterative process (see also Figure 3.1):

1. The policy provisions pertaining to the policy reform are included in the supply-side model, which provides the corresponding optimal farm-types' changes in crop area allocation;

2. EU-aggregated changes in crop area are passed on to the partial equilibrium model as an exogenous supply shock in the EU area equation; PEATSim returns the corresponding new

[3] The detailed commodity coverage of the model, together with the full GAMS code and further documentation of the model, can be found in the PEATSim documentation at the following address: `http://trade.aers.psu.edu/`

equilibrium prices for each product;

3. The vector of the relative changes in producer prices are passed back to the supply-side model;
4. A new iteration starts as the resulting changes in the vector of optimal crop area changes are passed on to the partial equilibrium model.

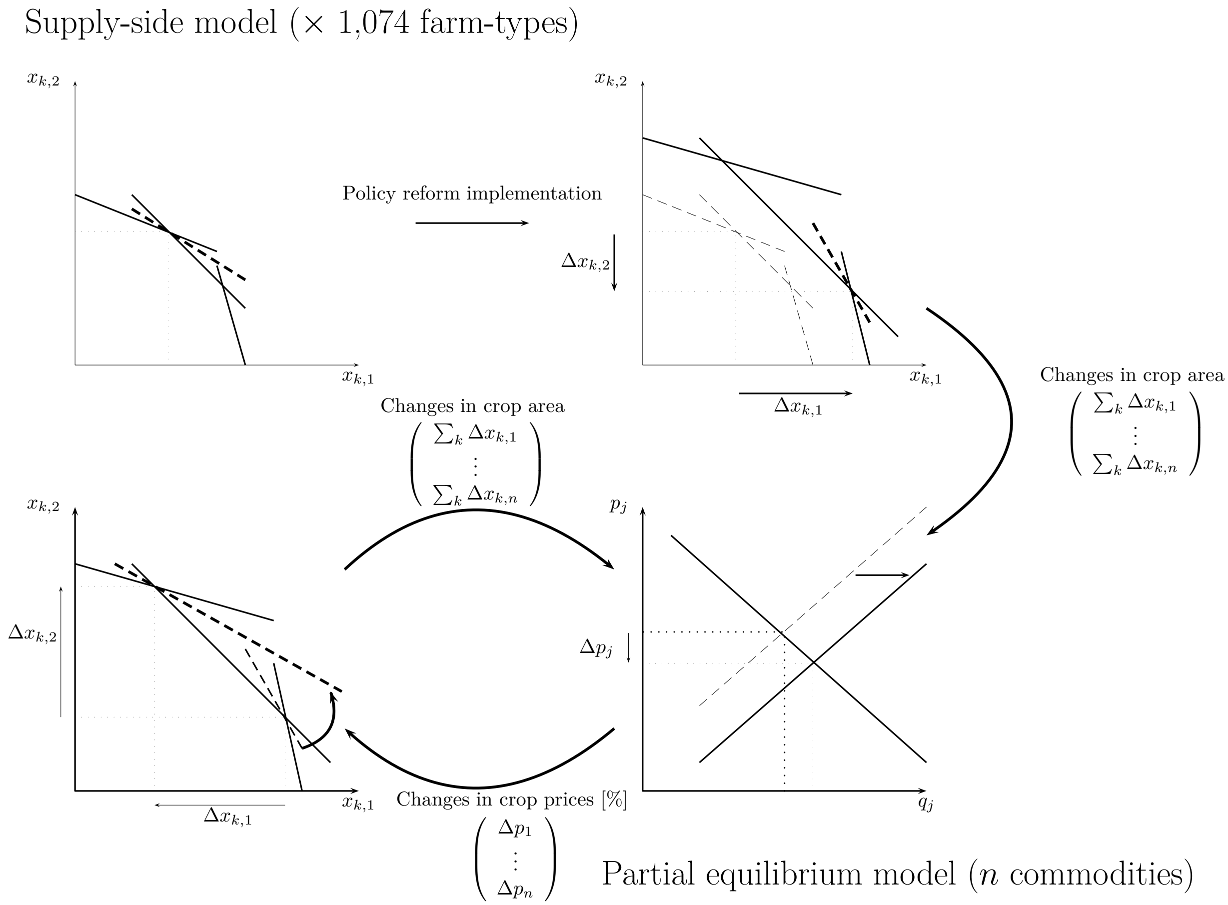


Figure 3.1: Coupling of the supply-side and partial equilibrium models

The process is stopped when the changes between two successive steps in area in the supply side model (for all products) are small enough to ensure convergence. This iterative process thus relies on a "soft"-coupling of the two models. This allows for more flexibility and easier control over both models than would have been permitted by the hard-coding of one model into the other. However, this requires more computing time, as both models are independently run at each iteration. The coupling has been implemented on a UNIX server through a set of script programs handling the exchange files between the two models and automatizing both models' runs.

The initial changes in crop area (step 1) results from the introduction of new policy instruments in the supply-side model, which lead to modifications of the structure of the constraints at the farm-type level, to changes in the relative gross margins, and to new optimal resource allocation and output levels. The first-order impact on area thus pertains to the structure of agricultural prices prevailing prior to the policy scenario. In the following steps of the iterative process, prices are adjusted until the excess supply generated by the change in area is equal (or sufficiently close) to zero.

As the two models significantly differ in their conception, data sources, product coverage, and spatial resolution, a number of assumptions are necessary in the implementation of the coupling. First, the changes in prices that are accounted for in the coupling process only include crop products[4]. The list of crop products considered in the subsequent analysis are defined according to the commodity coverage prevailing in PEATSim. It includes wheat, corn, rice, other coarse grains, sunflower, rapeseed, and soybean. In AROPAj, soft and durum wheat are considered as two distinct commodities, and "other coarse grains" (one single aggregate in PEATSim) is further decomposed into barley, oats, rye and other cereals. At each iteration of the coupling process, the relative changes in prices of crops that are grouped together in PEATSim is thus assumed to be the same for all AROPAj crops belonging to the same group.

Second, changes in crop area are passed from AROPAj to PEATSim as absolute changes in step 2 of the coupling process and are expressed in million hectares. In the PEATSim model, the EU-25 is considered as one single player on the world agricultural markets, while AROPAj regions only cover the EU-15. By expressing the changes in area in absolute terms, it is assumed that the initial shock on crop area upon implementation of the reform only occur in the EU-15 so that area in the ten new Member States is not impacted in the first iteration. In the subsequent steps, EU-25 demand and supply in PEATSim respond to the changes in equilibrium prices.

Third, changes in prices that are passed from PEATSim to AROPAj (step 3) are expressed as relative changes from baseline producer prices in PEATSim. Producer prices are farm-type dependent in AROPAj in order to account for the differences between the two models with respect to baseline prices. The relative changes in producer prices determined by PEATSim are applied to each farm-type's producer prices. It is thus assumed that the variability in crop producer prices among farm-types reported in the FADN data set is preserved on the supply side.

Fourth, the changes in prices computed by PEATSim pertain to the first-year price impacts. As a dynamic recursive model, PEATSim computes the price path over time up to a user-defined time horizon. In order to stay in line with the modelling structure of the supply-side model—which relies on a *static* structure and distribution of the individual feasible production sets—, further adjustments of the price over time through partial adjustments in supply and demand equations and variations of stock are not taken into account. Moreover, the policy parameters included in PEATSim are held constant, so that the price impacts correspond to a fixed structure of policy instruments affecting trade flows and equilibrium prices (tariffs, TRQs, policy instruments in other countries).

As mentioned above, area equations in the PEATSim model involve constant elasticities formulations, meaning that relative area responses to a 1%-change in the price of any crop are constant along the supply curve. This is ensured by log-linear formulations. By contrast, mathematical programming models, crop area responses to price changes are implicit as price elasticities are not hard-coded in the model. At the farm-type level, a change in any crop price results in a modification of the slope of the objective function, which—if large enough—leads to a new optimal area allocation (see Figure 3.1). The area response to a change in prices thus depends on the feasible

[4] Admittedly, livestock and animal products prices are also important, but the differences in the definition of animal categories and in the way animal feeding is modelled in both model did not permit to include them in the iterative process at this stage. Nevertheless, as on-farm animal feeding is accounted for in AROPAj and as some flexibility is allowed in adjusting livestock numbers on the supply-side, changes in crop prices do have an influence on farmers' optimal choices regarding animal activities.

production set for each farm-type. At the farm-type level, the area responds to price changes in a stepwise manner. By making the price of one crop vary in a given range, and summing up the resulting changes in area over the 1,074 farm-types, one can obtain the apparent aggregate own- and cross-price elasticities.

Although it is not necessary that price elasticities in both models perfectly match, similar magnitudes in area responses are likely to facilitate convergence in the coupling process. The comparison of price elasticities in AROPAj and PEATSim is illustrated in the case of wheat. We make the wheat price vary from 50% to 150% of the baseline price for each farm-type. The apparent elasticities are then computed by regressing the total area in different crops against the wheat price (log-linear formulation). The results—presented in Table 3.1—suggest that area responses to changes in the wheat price are of similar magnitude in both models if averaged over the examined price range and over all farm-types[5]

Crop	AROPAj	PEATSim
Wheat area$^{(*)}$	0.479	0.475
Barley area$^{(**)}$	-0.337	-0.326
Corn area	-0.019	-0.028
Rice area	-0.001	0.001

**Soft wheat in AROPAj, wheat aggregate in PEATSim*

***"Other coarse grains" in PEATSim*

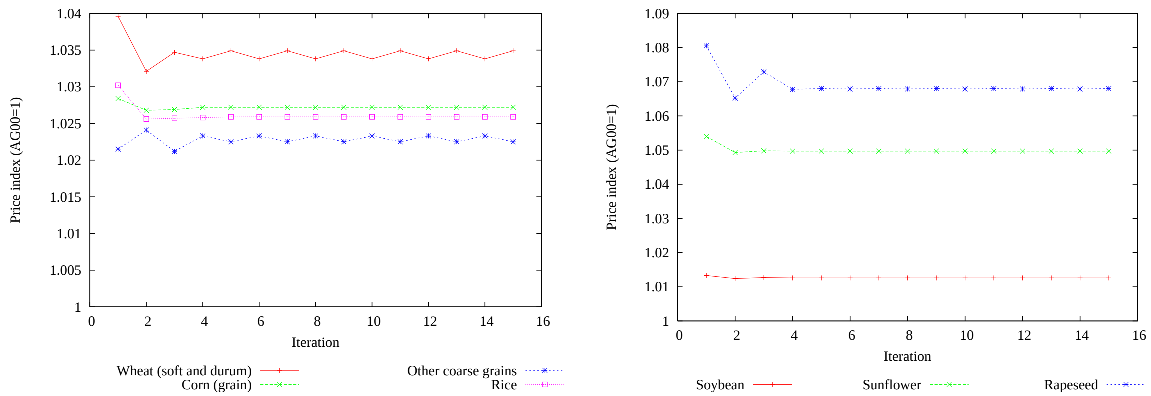
Table 3.1: Comparison of wheat area price elasticities in AROPAj and in PEATSim

The simulations presented hereafter correspond to the introduction of the Luxembourg Agreement in the supply-side model (Scenario "LX15"), which accounts for the introduction of the Single Farm Payment and for country-dependent implementation of the decoupling scheme by the Member States. The impacts are compared against the continuation of the Agenda 2000 policy (Scenario "AG00"). In the subsequent simulations, it is assumed that farmers have the possibility to adjust their animal numbers in response to policy and price changes. In order to reflect the quasi-fixed nature of animal numbers, such adjustments are however limited to ±15% of the calibrated value. The changes in area are passed to PEATSim additevely in the corresponding area equations, without modifying the general structure of the model. In particular, demand and supply elasticities, price transmission equations, as well as policy parameters such as tariffs and TRQs are maintained at their values in the PEATsim "base scenario".

3.4 Results

Figure 3.2 shows how the EU producer prices for the crops considered change during the iterative process described above. The price effect resulting from the initial reduction in crop area leads to an initial increase in prices ranging from 1.3% (soybean) to 8.0% (rapeseed). The initial price effect is mitigated as adjustments occur on the demand side. Prices are stabilized in a few iterations, with prices of the crops that occupy a larger share in land use (wheat, other coarse grains) converging slightly more slowly.

[5]The proximity in the estimates presented in Table 3.1 should not hide the important differences that exist between the two models with respect the area-price relationship. As mentioned above, crop area in AROPAj responds to price changes in a stepwise manner, whereas supply curves in PEATSim are smooth. The estimation of apparent elasticity in AROPAj and is also dependent on the examined price range.

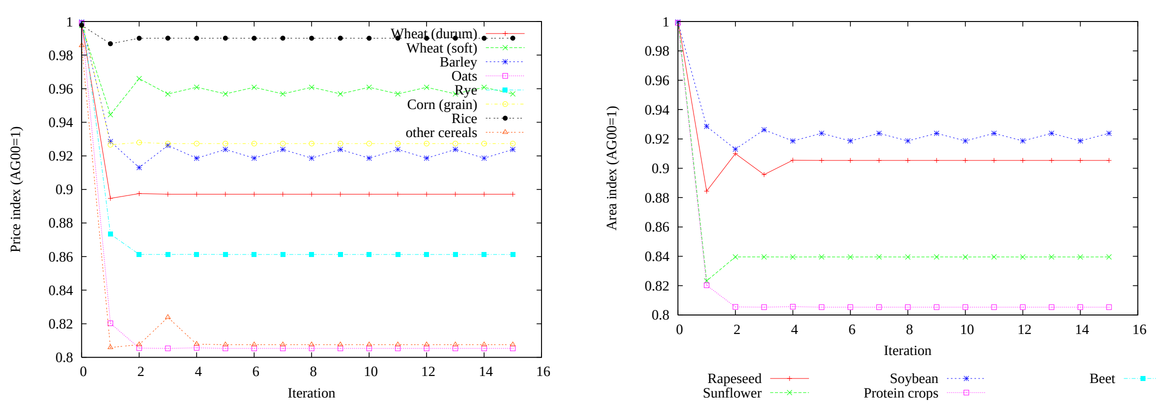


Grains Oilseeds

Figure 3.2: Price path during the iterative coupling process

The cycle in the price path is noticeable for wheat and other coarse grains. This is explained by the stepwise nature of area response characteristic of mathematical programming models and is caused by a few farm-types switching back and forth between those two crops as prices vary. The amplitude of these oscillations is however limited (up to 0.1 percentage point).

The corresponding area changes are shown in Figure 3.3. They are expressed relatively to their levels in scenario "AG00". The first-order impact of the implementation of the "LX15" scenario (with constant price, step 1) on crop area allocation is much larger than the changes caused by the price adjustments in the subsequent steps of the coupling process. The increase in prices caused by the initial decrease in supply following implementation leads to an increase in area for most crops, which offsets only partially the initial area change. The initial decrease in wheat area, for instance, is found to total 0.7 Mha hectares upon implementation of the Luxembourg Agreement, down from 12.7 to 12 Mha when prices are held constant. When accounting for the resulting adjustments in crop prices, the decrease in wheat area is limited to 0.5 Mha. The overall effect of the price adjustment on total gross margin remains small compared to the direct effect of the implementation of the Luxembourg agreement (see Figure 3.4).



Grains Oilseeds

Figure 3.3: Area path during the iterative coupling process

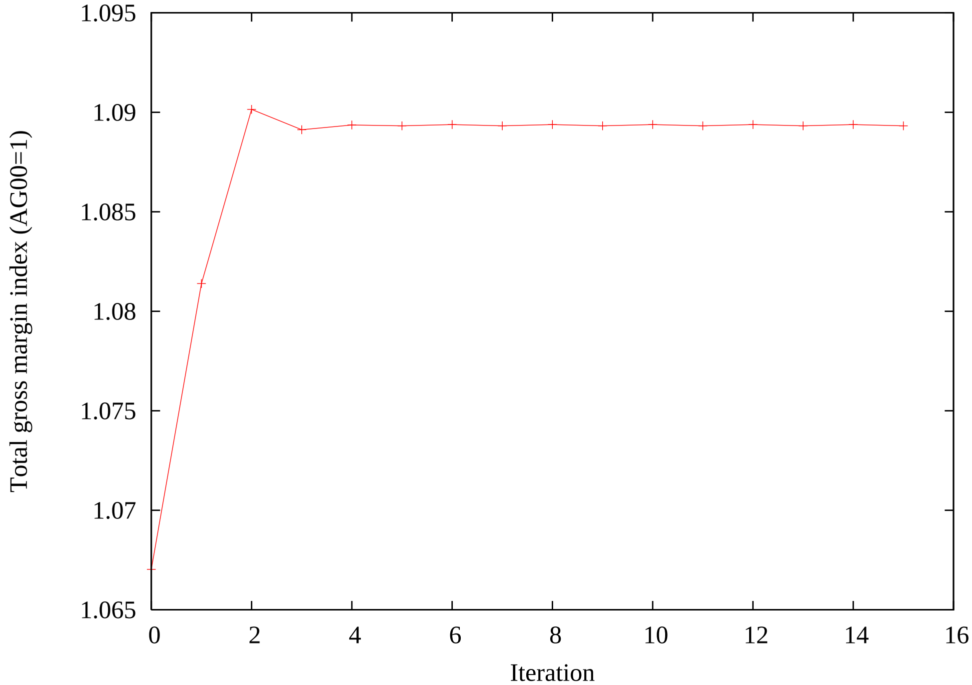


Figure 3.4: Total gross margin path during the iterative coupling process

3.5 Concluding remarks

One challenge in assessing the impacts of an agricultural policy reform is to account simultaneously for the induced changes on agricultural markets and the conditions of production that prevail at the farm level. The results suggest that these two dimensions can be addressed simultaneously, by coupling between a mathematical programming model of the agricultural European supply and a partial equilibrium model. Despite substantial differences in the modelling approach, data sources, and formulation of the two models, the iterative process implemented converges, with price increase ranging from 2.2% to 3.5% for grains, and from 1.2% to 6.8% for oilseeds.

The impacts on equilibrium prices of the implementation of the Luxembourg Agreement tend to mitigate the initial area decrease obtained from the supply side model. The first-order impacts on total gross margin are marginally modified by the adjustment of prices.

The scope of the price adjustment process has been restricted to the main crop products. It would be necessary in further work to account for the impacts of price changes on livestock products and feeding.

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Part II

Some lights from structural change analysis

Introduction of the part II

Farms move from one farming system to another along years. This change in capital and productions is not easily taken into account in usual one-period mathematical programming models. Nevertheless, it is useful to assess this change on order to better know the limiting value of these models. Structural change is seen through the Irish example.

4 Effect of Decoupling on Structural Change in Farming within the EU

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Abstract

This paper examines the effect of decoupling on structural change in farming. The paper begins with a literature review of the forces causing structural change and in particular focuses on the role of policy. Historical changes in farm numbers in selected EU member states are presented. Following this, the most commonly implemented methodologies for modelling structural change are reviewed. Markov Chain models are discussed in depth and stationary Markov Chain models are developed for a number of member states to project farm numbers. It is argued that a stationary model is incapable of modelling policy change and the suitability of non-stationary models is evaluated. It is concluded that they are not suitable for the assessment of an unprecedented policy change such as decoupling that may result in new structural states. A time series model is also estimated and the historical relationship between subsidies that are unrelated to production and farm numbers is established. Using these coefficients derived from historical data, future farm numbers are projected. For Ireland a case study approach is implemented and a more detailed analysis is possible. The Irish model integrates both mathematical programming and econometric modelling. Programming models are used to simulate production decisions and the profit maximisation assumption is invoked. Econometric models are used to simulate household decisions such as to continue in farming or not, succession of a new farmer, changing of enterprise specialisation and participating in off-farm employment. The conclusions from the Irish case study are that decoupling will not accelerate the historical rate of exit from farming but will result in restructuring within the population. In particular, a number farmers are likely to allow their land to go fallow, not engage in production but retain their land to claim their decoupled payment. There is likely to be an increase in the number of part-time farmers and a reduction in the number of hired workers due to the declining returns to farm labour. There is also likely to be a decrease in the number of active dairy farmers resulting in a restructuring of milk quota. The results of the farm level models developed in WP2 for the GENEDEC project are examined to ascertain if these results are also applicable for the other EU member states.

4.1 Background

This section of the paper provides a theoretical background to the empirical investigations presented later in the paper. The section begins by providing a definition of structural change and in particular defines the measures of structural change considered in this study. Following on from that, a review of the factors that cause structural change is presented and the likely effects of decoupling are outlined. The next section of the paper addresses the methods of modelling structural change, describing the most commonly used tools and evaluation their suitability to the task at hand in this paper.

4.1.1 Definition of Structural Change

Structural change in farming is a broad concept, encompassing everything from a change in farm numbers to a change in the volume of purchased inputs. For example, Boehlje (1993) purports that industrial structure is defined as (1) the size distribution of firms, (2) the technology and production characteristics of those firms including type of activity and level of specialisation, (3) the characterisation of the work force including age, education, experience, skill level, part-time versus full-time status, (4) the resource ownership and financing pattern including tenancy, leasing and debt/equity sources, (5) the inter and intra sector linkages including contract production and vertical and horizontal integration. A change to any one of these factors, according to Boehlje, constitutes a structural change. Structural change is a continual process of normal evolution; it is usually a 'lasting' change to the structure of an industry and not just a temporary reversible alteration. Schumpeter (1943) noted that the stable structure of an industry is interrupted by new innovations, which recombine existing resources to create new and more valuable products and services. Schumpeter called this 'interruption' a process of 'creative destruction', which he defined as "the process of industrial mutation that incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one."

Agriculture is a large and diverse sector and its structure is multi-dimensional and multi-sectoral. The agricultural sector extends across several linked sectors, restaurants and grocery stores at one end, and firms specialising in the development of production technologies at the other, Sonka (2001). A change in any one of these sectors may be considered a structural change in agriculture. This study is specifically concerned with structural changes in the farming sector only. Even within the context of farming structural change is a vast concept which can refer to changes in the numbers and size distribution of farms, age distribution and ownership status of farm operators and the numbers of hired farm workers, (Buckwell and Shucksmith 1979). Structural change in farming has been the subject of many diverse publications. For example, studies on changes in farm numbers, (Krenz 1964) farm size, (Hallberg 1969, Chavas and Magand 1988) herd size, (Coleman 1967 and Keane 1976) age structure, (Gale 1993), technical progress (Zepeda 1995) and the ownership status of farmers (Lowenberg-DeBoer and Boehlje 1986), to mention just a few.

One may ask why study structural change in farming, if it is a normal evolution that occurs in all industries? As outlined in the ensuing text, structural change in farming is an important process that has implications for the performance of the sector, the management of natural resources and the environment, the structure and performance of related industries and the socioeconomic welfare of rural areas. Mason's seminal Structure-Conduct–Performance paradigm (1939) was predicated on the theory that the structure of an industry influences the conduct of the agents in the industry and therefore the performance of the industry as a whole. To apply the paradigm to farming, it follows that the performance of the farming sector, at least on the supply side, depends on the conduct of farmers, that is what they produce and where, how much of it they produce and so forth. In turn, their conduct is influenced by the structure of farming, that is the number and location of farms, the age structure, ownership status and the many other factors that determine structure. Mason defined performance as the difference between the economic results of an industry and the best possible contribution that industry could make to achieve socio-economic goals. Economic performance measures include, efficiency in pricing and production, allocative efficiency, equity, technological progressiveness and responsiveness, and employment creation, while the social measures include environmental and product safety concerns and the responsiveness of the firms to societal needs, (Allen, Reeves and Muuma 1999).

Based on Mason's paradigm, the structure of farming is important because it influences the economic performance of the agricultural sector, in terms of how efficiently the resources are allocated, how production is managed and how the output is priced.[1] On the social side, the structure influences how the sector responds to the needs of society, such as their concerns for food safety, animal welfare, the countryside, environmental considerations and implications for rural populations. Therefore it can be concluded that structure affects the dynamism, viability and future of the sector, while also influencing economic efficiency, income stability, resource use and conservation, food security and safety, and the survival of the farm family; (Goddard *et al* 1993).

In addition to Mason's paradigm, studies specific to structural change in farming have shown its influence on rural areas. The family farm has been long considered the central unit of rural society, (Brinkman and Warley 1983). As farms become fewer and larger, rural populations tend to decline and this has adverse impacts on the sustainability of some rural communities. The negative relationship between the concentration of farming and the well being of rural communities was first studied by Goldschmidt (1944). Studies have shown that a decline in farm numbers adversely affects the demand for goods and services in rural areas.[2] Tweeten (1984) stated that the exit of each one or two farm families from a rural area will result in another non-farm family also exiting the area. The structure of farming also influences the structure of related industries; (Goddard *et al* 1993). The number, size and location of farms is significant to the industries that support farming as well as the industries that purchase and process the output of farms. Fewer but larger farms may result in a decline in demand for some farm inputs, as farmers may produce some of their own inputs such as animal feed. A change in the number of full-time and part-time farmers can also impact on the suppliers of inputs and services to farmers. For example, it has been noted in Ireland that agricultural service providers, such as farm advisers and animal markets, have extended their traditional business hours in order to cater for farmers that work off farm during normal business hours; (Hennerbry 2003). The structure of farming influences how natural resources are organised and managed, hence structural change may have implications for the environment. Norris and Batie (1987) found that the negative externalities associated with waste from livestock farms increased with farm size.

Structural change in farming has implications for many aspects of agriculture and rural society. It is important to study structural change in farming because once the factors that influence and drive structural change are understood; those factors can be manipulated in order to achieve a desired structure depending on the prevailing goals of government and society. Studies on the structure of farming are of interest to policy makers and the farm lobby as they provide an indication of the future prosperity of the sector, highlighting the likelihood of survival both in terms of enterprise type and size class of certain farms. The future number of farms is of interest to government as they will need to know the number, size and location of farms if they are to provide infrastructure to rural areas, if they are involved in providing services to farmers, if they are to design agricultural

[1] In the agricultural sector, structure does not necessarily influence product price due to the intervention of governments through agricultural policies.

[2] For a review of such studies see Goddard et al (1993).

policies and if they wish to prevent market failure.

4.1.2 Causes of Structural Change and Role of Policy

The process of structural change can be best explained by the neo-classical microeconomic theory of the firm. This theory states that, ceteris paribus, the number of firms in an industry depends on the optimal size of the firm and on aggregate demand. The optimal firm size, for a profit maximising firm, is the point on the production function where marginal revenue equals marginal cost, if the firm grows any larger than this then the cost of producing the marginal product exceeds the revenue earned from that product. If in the long run, relative input and output prices change, or if there are technological advances, this affects optimal firm size. Firms quick to exploit these changes experience increasing economies of scale, or a declining long run average cost curve, this increases optimal firm size as profit can be increased as production increases. As new technologies become more widely adopted, the minimum firm size at which increasing economies of scale can be realised increases and this places smaller firms at a disadvantage. Eventually, the more efficient firms will gradually take over the less efficient, growing in size in the process. Hallem (1991) reviewed studies on the returns to economies of scale in farming and secured evidence that the long run average cost curve in farming is a sagging L shape as represented by Figure 4.1.

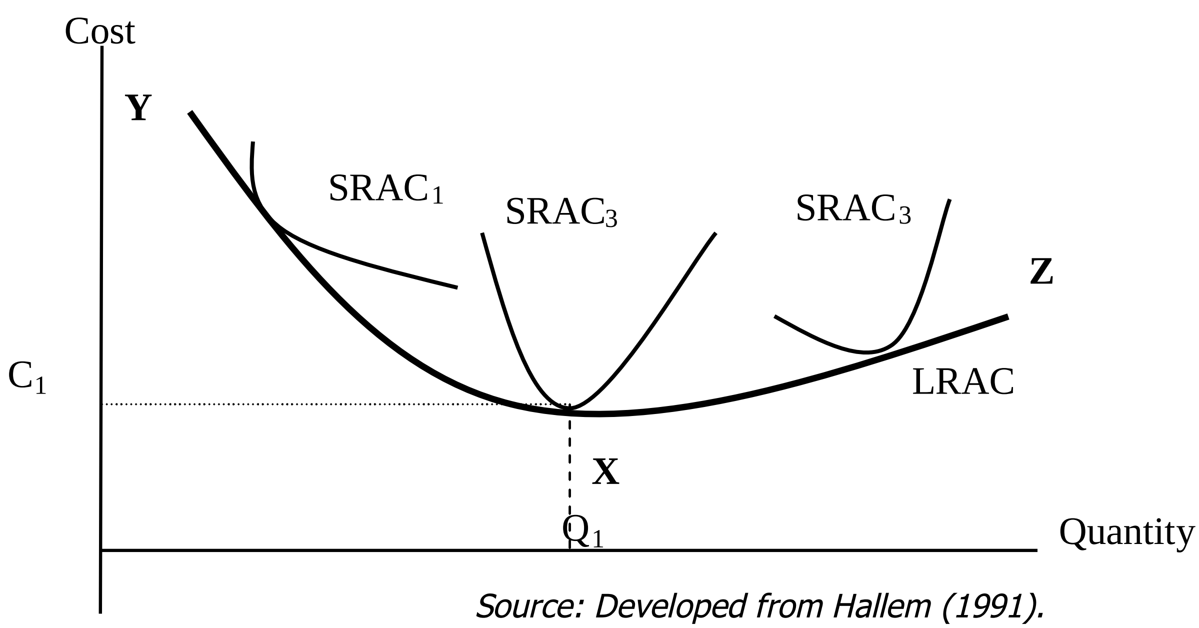


Figure 4.1: Long-Run Average Cost Curve in Farming

Figure 4.1 displays a series of short run average cost (SRAC) curves for a number of farms operating in the industry and the long run average cost (LRAC) curve. The SRAC curves assume at least one of the resources is fixed, for example land or labour but the LRAC traces the relationship between the lowest attainable average total cost and output when capital, land and labour can be varied. The SRAC curves are U-shaped as initially average costs fall as output increases but eventually start to increase, as increasing proportions of variable inputs must be added to the fixed resources to increase output. Economies of scale exist when an increase in output results in a drop in the lowest point of the SRAC. In Figure 4.1, there are increasing returns to scale for farms up to point X and therefore the optimal level of production is at Q_1 and this is the optimal size of the firm in the neo-classical sense of optimality. From points X to point Z the LRAC curve begins to increase implying that there are decreasing returns to scale. As Hallem observed, the shape of the LRAC curve means that farms with increasing economies of scale should grow in size that is consistent with X, that is the minimum LRAC, to maximise their profits or else they are no longer competitive.

Neo-classical economic theory is the key explanatory factor for structural change within an industry. Policy however, also plays a role in the neo-classical economic theory. A change in agricultural policies, such as changes to intervention prices or direct payments can affect the marginal revenue and marginal cost on farms, thus affecting the optimal size of the farm and the number of farms. Many factors play a role in the neo-classical theory and affect the structure of farming. Goddard et alia (1993) identified a number of factors that can change the shape of the cost curves. One of the main driving forces of structural change in agriculture is technological development. In the first instance, it reduces and possibly changes the shape of the LRAC curve thus affecting the optimal size of the firm. Furthermore, there tends to be a bias in the rate of adoption of new technology. Lu (1985) noted that larger farms adopt new technologies faster as they have better access to information and financing, hence larger farms experience declines in cost first and have an advantage over their smaller counterparts. Cochrane (1958) described the effect of technological forces on structure as the 'technological treadmill'. He showed that improvements in technology cause productivity driven increases in food supply, he noted that as food has an inelastic demand, an increase in supply causes prices to fall and farmers to exit the industry. He described this force as a treadmill where farmers are constantly 'running faster to standstill.' Technological change has also resulted in labour saving mechanisms and therefore the substitution of capital for labour. This has resulted in a reduction in the number employed on farms, an increase in the size of farm that can be efficiently operated by one labour unit and a reduction in the total number of farms, (Albretch, 1997).

Changes in relative prices of inputs can induce structural adjustment through substitution effects. Changes in the relative price of capital and labour have resulted in structural adjustment in industry all over the world. See Goddard et alia (1993) for a review of a number of studies relating to farming. Hayami and Ruttan (1985) contend that relative prices and technological progress are not independent driving forces. A change to the relative price of inputs may lead to the creation of new technology, for example the innovations in labour saving technologies when labour became a relatively expensive input was not incidental. Improvements in human capital over the years have effectively reduced the LRAC curve (Boehlje, 1993). Accumulation of human capital means that farmers can more effectively process information, allocate resources and adopt new technologies and therefore the size of farm that can be operated by one farmer has increased. Improvements in human capital have also resulted in an increase in the opportunity cost of labour, which in turn affects the relative pricing of labour and capital. Once again, this is not an independent driving force, as human capital influences relative prices, a change in relative prices promotes technological innovation and improvements in human capital accelerate the adoption of new technologies. All of these drivers of structural change are interdependent.

Macroeconomic changes can influence structure from both the demand and supply sides in terms of the demand for food, the relative price of inputs, the rate of innovation of new technology and possible employment opportunities outside of agriculture. Income growth increases the opportunity cost of labour, thereby altering the relative price of labour and capital. An increase in the opportunity cost of labour will most probably result in a decline in the number of people employed in farming. Gardner (1993) has labelled this effect 'the invisible hand of non-farm opportunity' while he has called technological advances 'the invisible foot of farm labour saving technology'. The demographic structure of the general population, in addition to its knowledge, earnings and location influences the demand for food. The demographic structure of the farming population also influences structure, declining birth rates have resulted in a shrinking number of young people raised on farms and therefore a decline in the number of potential entrants into farming. This may lead to a shift away from the traditional arrangements of family farming to more non-traditional entrants such as business entities, farm corporations and so on, (Gale, 1993).

The effect of improved off-farm employment opportunities on farm structure is two-fold and in conflict. On the one hand, the existence of off-farm employment opportunities for farmers has served to counter the trend of exit from farming as farmers supplement declining farm incomes with off farm employment (Goddard *et al* 1993). While on the other hand, it has contributed towards the exit of farmers and the decline in new entrants. Hallem (1991) stated that given the shape of the LRAC curve, small firms must grow to a size that is consistent with the minimum LRAC or else they must exit the industry. However, small farms can now supplement their farm profit with off-farm income and can continue to operate at sizes not consistent with minimum cost. Hence, the availability of off-farm employment has alleviated some of the pressure to expand farm size. Tweeten (1984) agrees that the range of firm size in which increasing returns to scale exist has increased creating continual impetus for larger farms but small farms can still exist under such a scenario provided that they are willing to use income from outside the sector to pay for the way of life enjoyed within agriculture just as they would for any other consumption good.

Goddard (1993) identified public policy as one of the major causes of structural change. In the EU, public policy has played a significant role in the promotion and prevention of structural change depending on the objectives of the era. Marsh (1991) commented that throughout the history of the European Union, conflict has existed in relation to structural policy. On one hand, economic theory suggests that competitiveness and economic efficiency are created by the more efficient allocation of resources. However, social and structural policies have posed barriers to this more efficient allocation of resources, as the resources of the small farm have become protected. Marsh says, “there is conflict in relation to structural policy with which the policy maker must grapple”.

In 1968, the first policy specifically tackling structural problems in farming was established. The Mansholt plan was designed to deal with the problems of over production. The programme aimed ”at extricating agriculture from its present position, where it is handicapped both economically and socially.” The plan proposed to deliver substantial reductions in the numbers involved in farming through retirement programmes, retraining and the consolidation of agricultural activity into larger units. The plan was somewhat successful in its early years as people moved out of agriculture and found employment in other sectors. However, after the oil shocks of 1973 and 1979 economic growth slowed and hence employment opportunities outside agriculture began to wane. By the late 1970s, structural change in agriculture had occurred but not at the pace which policymakers had hoped for and the problems of over production still continued. The late 1960s and the 1970s can be considered an era of policy conflict as noted by Marsh. On the one hand, the Mansholt plan was in operation with the objective of encouraging exit from farming and increased concentration in farm numbers and size. However, market and price support polices were also in operation. These policies were keeping small and inefficient operations in business, that is they were enabling farms that were not operating at the minimum point in their long run average cost curve to remain in business. Therefore, one policy was inhibiting the process of structural change while another policy was trying to stimulate it.

The development of the CAP from the time of Ireland’s accession in 1973 to the present day has been broadly outlined in the previous chapter. Here the implications for structural change are discussed. In the early 1980s, the EU responded to the problem of overproduction with a new policy of supply control for dairy products, sugar, and some cereals. These control mechanisms, which are still in place at time of writing, could be considered the greatest barriers to structural change in European farming. Quotas for production were offered to those in business at the time of the policy's inception. Before long, quotas had developed a market value and were traded freely between farmers. In some States, such as Ireland, the government intervened in the market for production quotas. In Ireland, the trade of milk quota is managed by the State. The Minister for agriculture fixes the price of milk quota and all exiting farmers must sell their quota to the State. The Minister for agriculture then resells that quota at a fixed price to farmers who wish to expand their businesses. However, the resale of quota is on a priority basis and smaller farmers get priority on the purchase of milk quota.

Production quotas impede structural change in farming in a number of ways.

First, production quotas limit total production and fix price. As the name implies, quotas put a limit on the total output of the sector to which they apply and limit the price by ensuring undersupply, or in this case, government purchase of any over supply. Neo-classical economic theory states that the structure of an industry is determined by the demand for the industry's products and the optimal number of firms. The demand for the product is irrelevant in sectors where quotas are applied and there is an institutional customer, e.g. intervention, as the output is fixed regardless of the demand and it is always consumed. When the volume and value of output is fixed there is very little scope for structural change.

Second, production quotas act as a barrier to expansion of production. Progressive and efficient farmers that have increasing returns to scale can only increase output if they can purchase additional quota. In the Irish example, it is very difficult for larger farmers to acquire additional milk quota as sale of milk quota is operated by the State and priority of allocation is given to smaller producers and producers in disadvantaged areas. Hence, it is difficult for larger farmers to exploit increasing economies of scale and the natural process of change that leads to fewer and larger farms is impeded.

Third, production quotas act as a disincentive to exit production. As the production quota limits supply of the product, it maintains price at an artificially high level. The higher price for output reduces the optimal size of the firm, that is the point where profit is maximised. Therefore, production quotas allow smaller farms to exist. In Ireland where the State manages the milk quota market, quota is typically undervalued so as to make it affordable to less efficient producers. However this lower institutional price for quota acts as a disincentive to exit the sector. If there were a free market for milk quota, then the sale price of milk quota would reflect its true economic value. This higher price would *pull* far more producers out of the industry, quota would automatically move to the more efficient producers and the natural process of structural change and more efficient allocation of resources would occur.

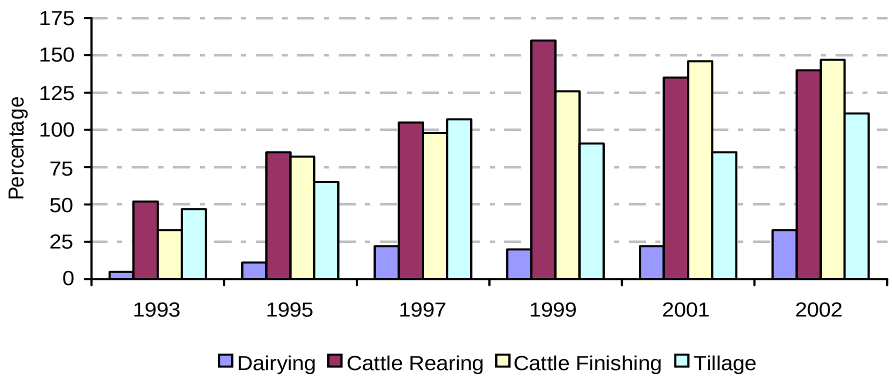
Fourth, production quotas act as a barrier to entry. In States where the trade of production quotas is managed, it is extremely difficult for new entrants to acquire quota. Where quota is secured it is usually in small, incremental quantities that would make the creation of a new operation unviable. In States where there is a free market for milk quota, the cost of entry is prohibitively high.

The MacSharry reforms of the CAP in 1992 promoted some structural change under the auspices of the early retirement programme. However, the Mac Sharry and Agenda 2000 reforms were responsible for further impediments to structural change. The introduction of direct payments isolated farmers even further from market forces. In some cases, over 100 per cent of farmers' income came in the form of direct payments, (Hennessy 2000). Farmers' production decisions were not influenced by prices of inputs or the market value of outputs but by the receipt of direct payments. With a negative market profit on most beef animals there was no incentive to expand production beyond the direct payment limit. Once, again EU agricultural policy encumbered the natural pace of structural change, to encourage inefficiency and the misallocation of resources.

It is clear government policy significantly influences the structural change process in farming through its influence on the farm's long and short run average costs curves and the demand, including institutional, for the sector's products. The decoupling on the structural change process is the principal concern of this paper and the next section of the paper reviews a number of studies of the impact of decoupling.

4.1.3 Decoupling and Structural Change

The Mid Term Review (MTR) of the Common Agricultural Policy (CAP) has allowed for the decoupling of all direct payments from production from 2005 onwards; until then, most direct payments were coupled to production, requiring farmers to produce specific products in order to claim support. After decoupling, farmers will receive a payment regardless of production as long as their farm land is maintained in accordance with good agricultural practices. Direct payments to farmers have been an integral part of the CAP since the 1992 Mac Sharry reforms. Throughout the 1990s, market prices for farm produce have declined generally in line with policy while costs of production have continued to increase. Meanwhile, direct payments increased in value, increasing farmers' reliance on this source of income. Furthermore, farmers adapted farming practices to maximise their receipt of direct payments, leading to the culture of 'farming the subsidy'. By 1997, on cattle and tillage farms in Ireland 100 per cent of family farm income was derived from direct payments, meaning that on average the market-based revenue was insufficient to cover total costs. Farmers engaged in production only to receive the payments, see Figure 4.2.



Source: Irish National Farm Survey, Teagasc.

Figure 4.2: Direct Payments as a Percentage of Family Farm Income on Irish farms (*Source: Irish National Farm Survey, Teagasc.*)

The decoupling of direct payments is expected to have major ramifications for aggregate agricultural production, farm practices and the structure of farming in Ireland. It will significantly reduce the actual 'coupled' return to production; and, in some cases, the return to coupled production will be negative. Economic theory suggests that if coupled subsidies are replaced with decoupled payments, then production falls to a level that would exist without any subsidies. If such a situation transpires, then production on farms making a market-based loss should fall substantially post decoupling unless significant cost management or efficiency gains can be achieved thus resulting in major structural change effects. These structural effects however are still somewhat of an enigma. Burfisher and Hopkins (2003) reviewed research on the topic to show that even fully decoupled payments have a 'production inducing effect' as they affect farmers' exposure to economic risk, their access to capital and their future expectations. Whilst direct payments may be decoupled from production there may still be an 'incentive effect', which can occur if some residual production or resource use is still required to qualify for the decoupled payment (Swinbank 2004). Although production is not necessary after the MTR, the direct payment remains tied to land. Even if payments were not to be linked to production at all, supply will not be so price sensitive so as to immediately fall to the free trade levels, which is especially the case for multi-period activities such as livestock.

With or without a link to production, payment is a source of revenue for the farm household and thus it may indirectly affect exit decisions through what is referred to as a 'wealth effect'. The decoupled payment is a source of wealth that may induce the farmer to stay in production for longer than the market suggests he should. Decoupled payments also relax the household's capital constraint, lowering the cost of capital to the household. According to Andersson (2004) the resulting effect is that farm investment is likely to be greater after decoupling than in the absence of such payments. Revell and Oglethorpe (2003) have recently explored the expectations effect, claiming that producers may adopt a 'safety first' strategy and make only minimal changes to their farm and production plans in case future payments are reassessed and again related to production or an agricultural activity. It is clear then that the replacement of decoupled subsidies with decoupled ones changes the economics of production and for many farms makes production unprofitable. However there are a number of other effects at play such as the wealth effect and the expectations effect that might encourage farmers to stay in business even if it is no longer profitable to do so. This paper explores some of these issues empirically.

4.1.4 Modelling Structural Change

Despite the long-standing interest in structural change in farming, modelling such change still remains notoriously difficult (Garvey and Steele 1999). The processes of structural change play a powerful role in the analysis of competitive industries in standard microeconomic text books, but as noted by Gale (2002), there has been relatively little empirical study of the process in farming. The available empirical models of structural change in agriculture mostly focus on the aggregate by examining changes in the total number of farms using time-series econometric models or changes in the numbers in various sub-sections of the population using, for example, Markov Chain models. Such aggregate modelling approaches are often criticised for overlooking the micro dynamics of change (Jackson-Smith 1999). Furthermore, such models do not lend themselves conveniently to policy analysis as it is difficult to quantify the relationship between policy instruments and changes in farm numbers.

The Markov Chain is probably the most frequently used model for analysing structural change. The theory is that many processes, ecological and economic, exhibit a degree of variability, but are nevertheless, influenced, if not controlled, by the events that have gone before (Jeffers 1988). Markov developed the theory and proved that, the probability of an observation being in a given state at a certain point in time is related to the immediately preceding state of that observation. An MC model is a series of mutually exclusive and exhaustive states with a given population at each point in time, accompanied with probabilities of transition for each observation from one state to another. First the series of states must be defined, for example, if the research is concerned with the trend towards fewer and larger farms, then the states will be based on farm size. Once the states are defined, the transition probabilities must be estimated. If, for example, the Chain has three states S_1, S_2 and S_3 representing small, medium and large farms then the transition from one state to another in any point in time can be described by a single transition $n * n$ matrix, as represented by Figure 4.3 below. So for example, $\boldsymbol{P}_{13}$shows the probability of moving from the small state to the large state.

		Future States		
		Small	Medium	Large
	Small	$\boldsymbol{P}_{11}$	$\boldsymbol{P}_{12}$	$\boldsymbol{P}_{13}$
Present States	Medium	$\boldsymbol{P}_{21}$	$\boldsymbol{P}_{22}$	P_{23}
	Large	P_{31}	P_{32}	P_{33}

Figure 4.3: Example of Transition Matrix for Markov Chain Model

If the chain is a first order stationary one, then each transition probability in the matrix can be calculates as follows;

$$P_{13}(t) = P_{13}(t-1)$$

In other words, the probability of moving from the small state to the large state is equal to the movement between these states in the previous period. Since the states S_1 to S_3 are mutually exclusive and exhaustive the rows of the probabilities in the matrix must always sum to one, i.e. $p_{11} + p_{12} + p_{13} = 1$.

The data demands for Markov Chain modelling makes its application difficult. Where micro level balanced panel data is available it is possible to trace particular observations through time. However, the availability of micro level balanced panel data is limited and furthermore if a matched panel is used, there is no record of entry or exit and therefore it cannot be accounted for in the model. The alternative is census data which will only provide the total number of farms at a point in time and therefore the results yielded are not as rich as the results emanating from a model using micro data. It is often necessary to constrain models with further assumptions due to the unavailability of data. Krenz (1964) was the first to develop such a constrained model in response to data limitations, this has since become known as the Krenz-modified MC model. The Krenz-modified MC model involves constraining the pace of structural change so that a farm can only move from the small state to the medium state and not any larger states. In the Krenz-modified model there are only three potential moves, the first is to remain in the same size state, the second is to increase one size state while the third is to exit farming, (Tonini and Jongeneel 2002).

In this paper stationary Markov Chain models are developed to examine structural change in farming in various EU member states. Following this attempts are made to develop non-stationary Markov Chain models but a number of problems are encountered this work is detailed in the ensuing text.

4.2 Review of Structural Changes in Selected EU Member States

As a first general fact the total number of farms in the EU is falling in nearly all EU-member countries for several decades. Nevertheless, the extent of this reduction is very different from country to country. While total farm numbers in Ireland in 2003 were just about 80 per cent of the 1990 figure the reduction of farm numbers in Germany was even stronger. Compared to 1990 it was just a little higher than 60 per cent, while France and Spain lost just a little less during that period. An exceptional development can be seen in the UK, where farm numbers increased over the considered period. Figure 4.4 illustrates the development of farm numbers in each of the five countries. Taking 1990 as base year the changes in farm numbers is evident with France and

Germany experiencing the largest declines while numbers in the UK actually increased.

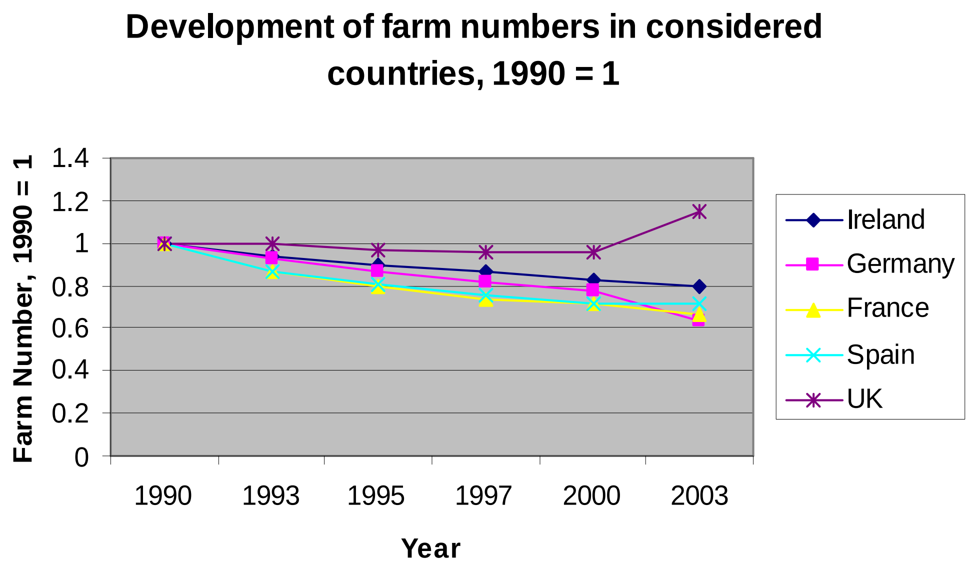


Figure 4.4: Index of Changes in Farm Numbers 1990-2003 (*Source: Eurostat Data - Own illustration*)

The reduction in farm numbers in four of the five countries coincides with a considerable loss of labour force in the agricultural sector of each country. Compared to the base year of 1990 Ireland lost about 20 per cent of its agricultural work force, while in France and Spain there was a reduction of more than 30 percent in the workforce from 1990 to 2003. Germany had greater reductions and fell to just 57 per cent of the 1990 level by 2003. These changes can be seen in Figure 4.5.

4.2.1 Stationary Markov Chain Models of Structural Change

In this section of the paper a series of stationary Markov Chain models are constructed for a number of EU member states. A stationary Markov Chain model assumes that transition probabilities estimated using historical data can be used to project future structural movements, in other words it assumes the continuation of a trend. It can therefore be interpreted as a baseline analysis. The details of the Markov Chain model for Ireland are outlined first below. Table 4.1 demonstrates the development of farm numbers per size group in Ireland from 1975 to 2003. Over the period total farm numbers declined from approximately 228,000 farms to 135,000. A trend of land concentration is evident where there has been a significant decline in the number of small farms while the number of large farms increased.

Figure 4.6, shows the data presented in Table 4.1 as an index with 1975 as base year. What is really evident is the strong increase in farm numbers in the larger categories.

Using this data it is possible to develop a stationary Markov Chain model whereby the probability of farms exiting or remaining in the same size class can be estimated. This analysis is only conducted for the period 1990 to 2003, as these are the only years for which data are available for the other EU states. Due to the limitations associated with using macro data it is not possible to develop a model that allows movement between all states of structural change; that is, a matrix of transition probabilities for all n*n cells cannot be estimated. A Krenz-Modified Chain must be used. This assumes that farms either stays in the same size class, move to the next largest class or exit farming

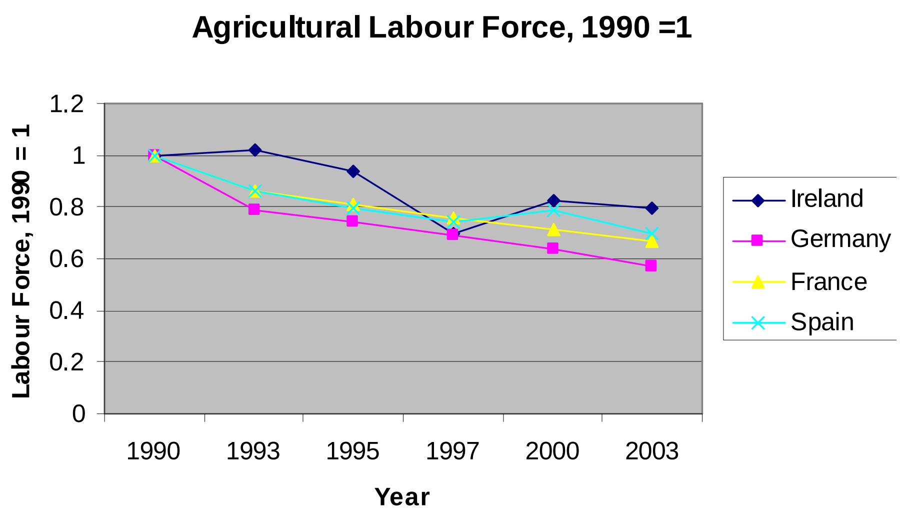
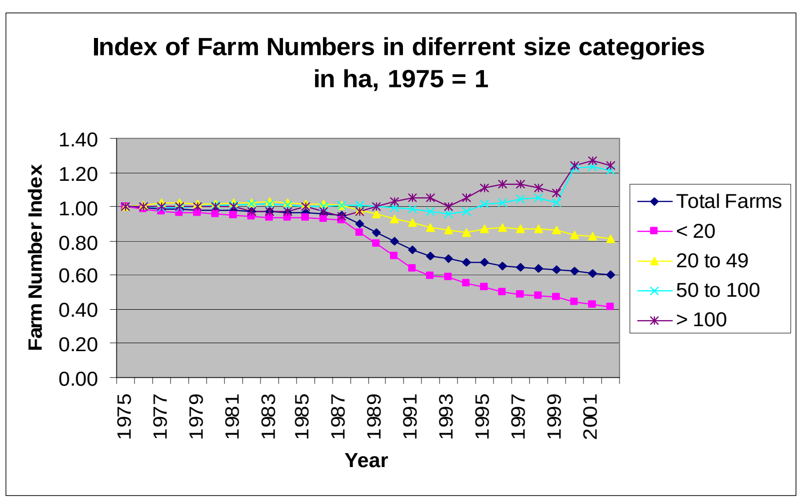


Figure 4.5: Index of Changes in the Agricultural Labour Force 1990-2003 (*Source: Eurostat Data - Own illustration*)

Size - Hectare	**1975**	**1980**	**1987**	**1990**	**1993**	**1995**	**2000**	**2003**
0 to 19	143	137	131	91	83	75	63	59
20 to 49	66	67	66	59	57	57	55	52
50 to 99	16	16	16	16	15	16	20	19
more than 100	4	4	3	4	4	4	5	5
Total	228	223	217	170	159	153	141	135

Table 4.1: Thousands of farms by size category in Ireland from 1975 to 2003 (** - Figures are rounded – may not sum exactly - Sources: Central Statistics Office of Ireland*)



Sources: Central Statistics Office of Ireland - Own illustration

Figure 4.6: Index of farm numbers by size categories 1975 = 1 (*Sources: Central Statistics Office of Ireland - Own illustration*)

completely. One of the major disadvantages of this methodology is the limiting effect of these assumptions. The transition probability matrix is estimated by examining the changes in farm numbers from one period to next. Table 4.2 below provides an example of one such probability matrix.

	New	< 20	20 to 49	50 to 99	> 100	Exit
New	1	0	-	-	-	-
< 20	-	0.91	-	-	-	0.09
20 to 49	-	-	0.96	-	-	0.04
50 to 99	-	-	-	0.97	-	0.03
> 100	-	-	-	-	0.96	0.04
Exit	-	-	-	-	-	1

Table 4.2: Transition Probability Matrix for Irish Farms 1990 to 1993

The Chain is split up into states defined by the farm size categories presented in Table 4.1 a New state and an Exit state are also included to allow for new entrants and exits from the population. In the period 1990 to 1993 total farm numbers declined and therefore the probability of all potential new exits staying in the new pool rather than entering the population is equal to 1. In the period 1990 to 1993 the total number of farms in the less than 20 hectares category decreased. In the Krenz Modified Chain there are only two states these farms could have moved to (i) the 20 to 49 hectares size category or (ii) the exit pool. The population of the 20 to 49 hectares size category decreased over the same period and therefore it is assumed that the farms leaving the less than 20 hectares group exited production. The consequent transition probability is a 0.91 probability of staying in the same size class and a 0.09 probability of exiting. Transition probability matrices can be developed for each time period and the stability of trends can be examined. Figure 4.7 presents the transition probability matrices for the less than 20 hectare category from 1990 to 2003. The graph shows that the probabilities remain more or less static over time implying a steady trend with a slight increase in the probability of small farms exiting production over the time period analysed.

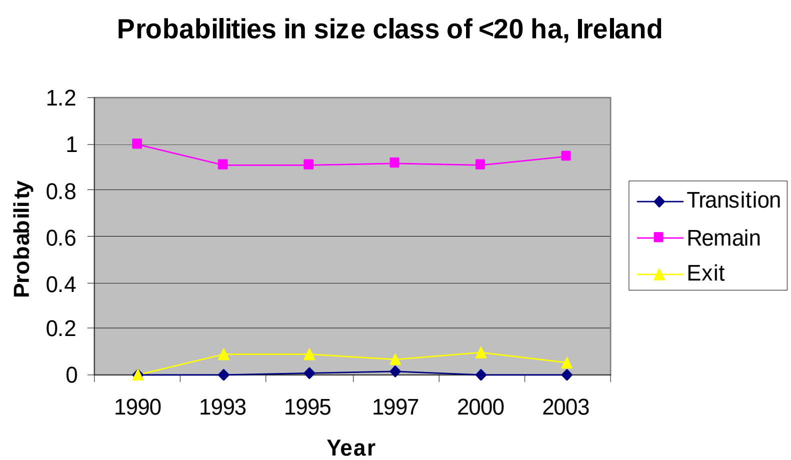


Figure 4.7: Transition Probabilities for the < 20 ha in Ireland 1990-2003 (*Source: Author's Own Calculation.*)

A time series of transition probabilities is estimated so that the probability of a farm of 20 hectares or less exiting production is a function of the probabilities of such a farm exiting production over the 13 year period for which data are available. By applying the trend based transition probability estimates to the 2003 farm numbers data then future changes in farm numbers can be projected. Figure 4.8 presents the actual 2003 Irish farm population and the estimated population for 2013. The results show that total farm numbers are projected to fall from 135,000 in 2003 to less than 110,000 in 2013 in a baseline situation i.e. that assumes that past trends continue. The two smaller farm size categories lose farm numbers while the two larger categories retain broadly the same number of farms.

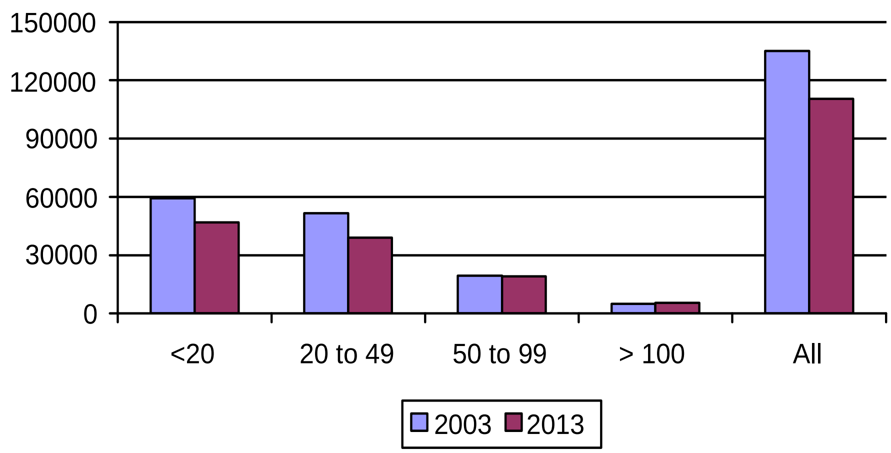


Figure 4.8: Estimated Change to Farm Numbers in Ireland 2003-2013

A similar exercise can be conducted for each of the selected member states. Table 4.3 demonstrates the development of farm numbers per size group in Germany from 1990 to 2003. Over the period total farm numbers declined from approximately 629,000 farms to 420,000 farms. A trend of land concentration is evident where there has been a significant decline in the number of small farms while the number of large farms increased. The numbers of farms sized less than ten hectares declined from approximately 296,000 to 165,000 in the thirteen year period.

Size - Hectare	**1990**	**1993**	**1995**	**1997**	**2000**	**2003**
0 to 10	296	272	250	235	186	165
10 to 29	210	183	164	150	133	117
30 to 49	76	73	69	65	59	55
more than 50	48	65	72	75	80	93
Total	630	593	555	545	458	421

Table 4.3: Thousands of farms by size category in Germany from 1990 to 2003 (*Figures are rounded – may not sum exactly* - *Sources: Eurostat*)

Using the farm numbers data it is possible to generate transition probability matrices for the German farming population. Table 4.4 presents the transition probability matrix for the period 2000 to 2003. The matrix shows that the small farm groups are in net decline with the probability of exiting being high at 0.11 and 0.12 for the less than 10 hectares and the 10 to 29 hectare groups respectively.

	New	< 10	10 to 29	30 to 49	> 50	Exit
New	1	0	-	-	-	-
< 10	-	0.89	-	-	-	0.11
10 to 29	-	-	0.88	-	-	0.12
30 to 49	-	-	-	0.92	0.08	-
> 50	-	-	-	-	1	-
Exit	-	-	-	-	-	1

Table 4.4: Transition Probability Matrix for German Farms 2000 to 2003

The stability of movements in the German population can be viewed graphically by looking at the transition probability for one size group through time. Figure 4.9 graphs the probability matrix for the 10 to 29 hectare group from 1990 to 2003.

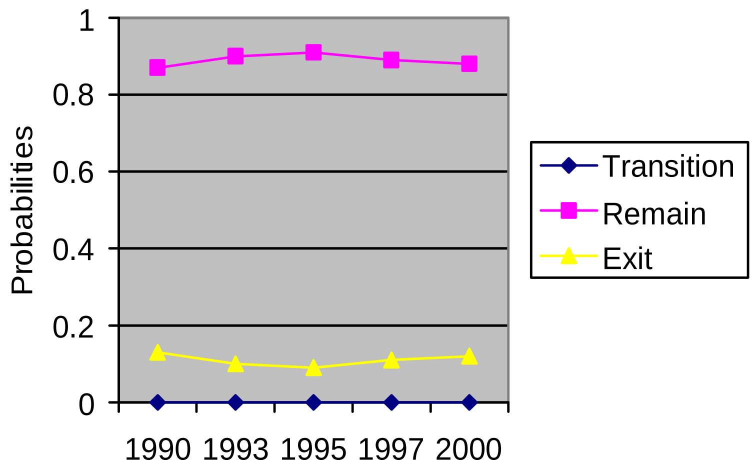


Figure 4.9: Transition Probabilities for the 10-29 ha group in Germany 1990-2003 (*Source: Author's Own Calculation.*)

Using the estimated transition probabilities a Markov Chain model is developed for the German data and estimates of the 2013 population are made these are presented in Figure 4.10 below. The actual 2003 German population of farms is presented as well as the estimated population for 2013. The results show that total farm numbers are projected to fall from approximately 400,000 in 2003 to almost 300,000 in 2013 in a baseline situation, i.e. that assumes that past trends continue. All size categories apart from the largest that is greater than 50 hectares lose farm numbers.

In relation to France total changes in farm numbers from 1990 to 2003 are presented in Table 4.5. As like the other countries reviewed total farm numbers have been declining, with small farms declining fastest, medium sized farms remaining more or less static in population and large farms growing in numbers. Total farm numbers declined from approximately 900,000 farms in 1990 to about 600,000 in 2003.

Again a stationary Markov Chain model is developed for the French data and estimates of the 2013 population are made, these are presented in Figure 4.11 below. The actual 2003 French population of farms is presented as well as the estimated population for 2013. The results show that total farm numbers are projected to fall from approximately 600,000 in 2003 to about 450,000 in 2013 in a baseline situation, i.e. that assumes that past trends continue. All size categories apart

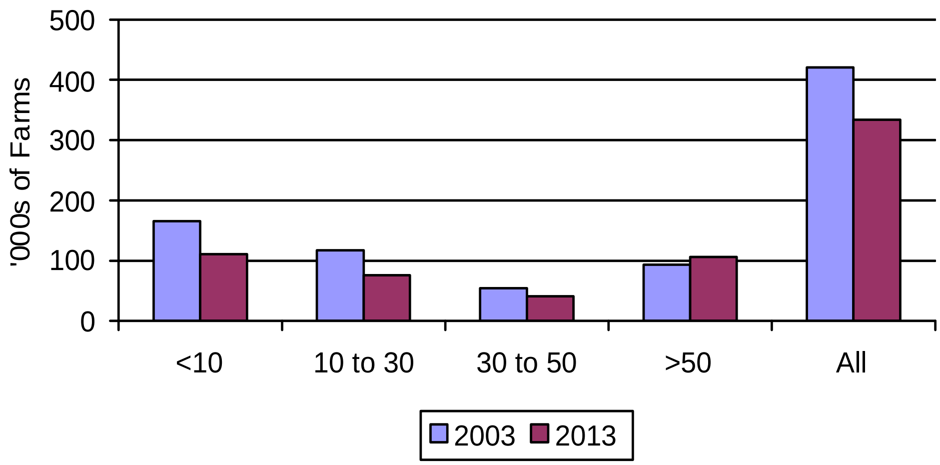


Figure 4.10: Figure 10: Estimated Change to Farm Numbers in Germany 2003-2013

Size - Hectare	**1990**	**1993**	**1995**	**1997**	**2000**	**2003**
0 to 20	480	400	360	300	300	280
20-50	250	200	180	180	150	120
50-100	150	150	150	150	140	120
more than 100	40	50	55	60	65	70
Total	900	800	720	680	620	600

Table 4.5: Thousands of farms by size category in France from 1990 to 2003 (*Figures are rounded – may not sum exactly* - *Sources: Eurostat*)

from the largest, which is greater than 100 hectares, lose farm numbers.

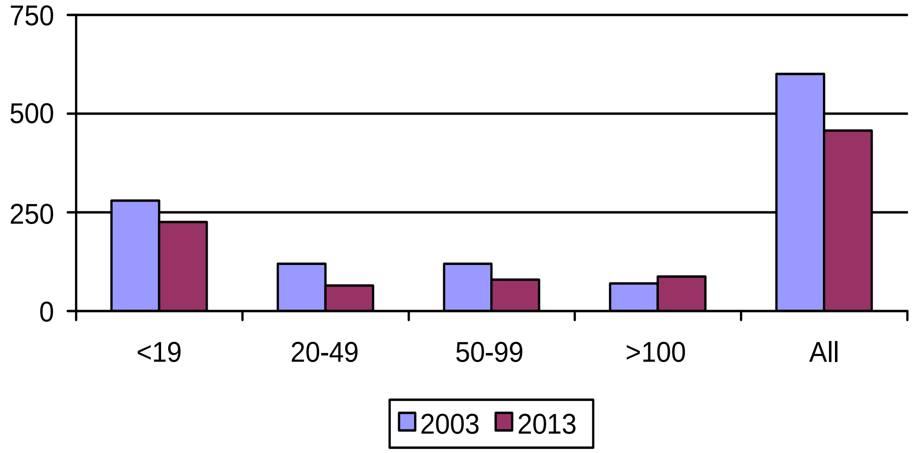


Figure 4.11: Estimated Change to Farm Numbers in France 2003-2013

Changes in farm numbers in Spain from 1990 to 2003 are presented in Table 4.6 below. The data shows that generally farm numbers are in decline but that from 1997 to 2000 farm numbers increased possibly due to a change in the size definition of a farm as the number of farms in the smallest size category increased during that period.

Size - Hectare	**1990**	**1993**	**1995**	**1997**	**2000**	**2003**
0 to 20	1382	1176	1065	994	1073	927
20-50	125	115	115	115	114	114
50-100	49	50	52	52	51	49
more than 100	38	43	45	47	49	50
Total	1594	1384	1278	1208	1287	1141

Table 4.6: Thousands of farms by size category in Spain from 1990 to 2003 (** - Figures are rounded – may not sum exactly* - *Sources: Eurostat*)

Using a transition probability matrix derived across all time periods farm numbers in 2013 are projected for Spain. The results presented in Figure 4.12 show that farm numbers are projected to decline from 1.1 million to 950,000 from 2003 to 2013 with the majority of exits coming from the smallest size structure. The number of farms in the smallest size category is projected to fall by 200,000 over the time period. Despite the large exit of small farms it is projected that by 2013 over three quarters of Spain's farms will still be in the less than 20 hectares category.

4.2.2 Limitations of the Stationary Markov Chain Model

The stationarity assumption is a major disadvantage of the model outlined above. In some situations the stationary model has provided accurate projections of future structure, Keane (1991) and Edwards et alia (1985). For cases, where structure is inert and does not respond to changing exogenous forces then the stationary MC is a suitable modelling technique, as it will project forward historical trends. Similarly, if the economic and political conditions that applied during the derivation of the transition matrix still prevail during the projection period then the model should also produce reasonably accurate results. However, the aim of this research is to analyse the effect of

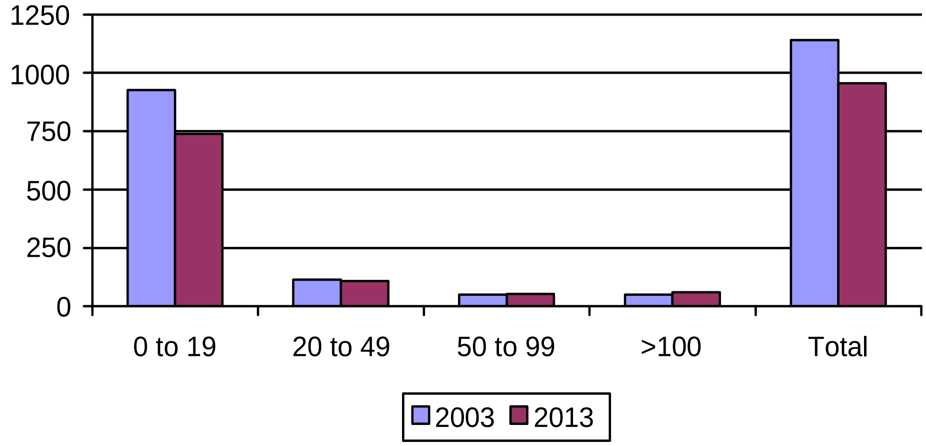


Figure 4.12: Estimated Change to Farm Numbers in Spain 2003-2013

decoupling on structural change in farming; with a stationary Markov Chain model it is necessary to assume that the past trend will continue and that the transition probabilities will not be affected by the policy change. Therefore, it is not possible to analyse the effect of decoupling on structural change in farming with a stationary Markov Chain.

4.2.3 Non-Stationary Markov Chain Analysis

Recently, non-stationary Markov Chain models have been used to project changes in the structure of farming in response to exogenous shocks, see (Zepeda 1995; Karantininis 2001; and. Jongeneel 2002). Theoretically, the non-stationary Markov Chain model would analyse the effect of a policy reform and likewise, regression techniques could be used to estimate the effect of the new policy on the probability of farms moving from one structural state to another. There are however two main reasons why a Markov Chain model is not appropriate for the research questions addressed in this paper. First, the limited details available in the Irish macro data it is not possible to develop a model that allows movement between all states of structural change; that is, a matrix of transition probabilities for all n*n cells cannot be estimated. It is therefore necessary to use a Krenz-modified Markov Chain, which assumes that an identifiable pattern of structural change is evident; for example, farms getting bigger, only small farms exiting and entry only through one size class. This assumption is not tenable for Ireland, as exits from farming occur from all sizes and systems and farms of all sizes and systems choose to transfer into part-time farming. Furthermore, given the major policy reform under investigation, new structural states may evolve, for example the existence of the "sofa farmer", and the Krenz-modified Markov Chain model cannot predict unprecedented structural states.[3]

The second problem in using non-stationary Markov Chains is the estimation of the transition probabilities; the model assumes that the historical relationships between the various exogenous variables and the transition probabilities remain constant into the future. This assumption is not sustainable in analysing the effect of a change in intervention prices or export subsidies, that is the policy instruments are the same and there is simply a marginal adjustment to their value. Decoupling is an unprecedented change to policy and hence the coefficients estimated from regression

[3]A sofa farmer is one who uses the farm land only to claim the decoupled payment but not to produce any tangible agricultural output.

analysis on data from an Agenda 2000 type policy regime would not be appropriate for decoupling.[4] Furthermore, with decoupling new policy instruments emerge, most notably the SFP. To analyse the effect of the SFP in a non-stationary model, it is necessary to identify a proxy for the SFP. Identification of a suitable proxy variable, that is a source of revenue to the household that is linked to land but not to production, is problematic. Given these difficulties, it was decided to move away from a Markov Chain type methodology and instead to develop a farm level model of structural change.

4.2.4 Time Series Analysis of Changes in Farm Numbers

In the absence of any other appropriate methodologies a simplified multiple regression analysis using time series data on farm numbers can be employed to explore the effect of decoupling on future farm numbers. A number of factors that are hypothesised to influence future farm numbers can be included in a regression analysis and the statistical significance of each factor can be calculated. This approach is somewhat similar to a non-stationary Markov Chain analysis but the advantage is that the Krenz-modified assumptions do not have to be invoked. The disadvantage of this time series approach is that while the historical effect of total agricultural sector income can be estimated using a time series analysis, there is no historical variable measuring the effect of a decoupled payment on structural change.

The effect of both macroeconomic and agricultural variables on historical changes in farm numbers can be estimated and the estimated co-efficients can be used to project future farm numbers. Total agriculture sector income can be included in the regression analysis as a measure of the buoyancy of the sector over the period. Following decoupling total agriculture sector income may follow a similar trend as it did historically and so the future farm numbers may also follow a similar trend. However, while decoupling may not induce any significant changes in total sector income it will result in changes in the sources of agricultural income which may result in some structural change. Since the Mac Sharry reforms the proportion of income emanating from subsidies has increased while income from the market place has decreased. The majority of these subsidies were subsidies on products. Subsidies on products, such as the special beef premium, are only paid when the product is produced and therefore they are coupled subsidies. Over the last number of years subsidies on production were also paid, these are payments that were made on the type of production process rather than the volumes of production examples of such payments include Rural Environmental Protection Payments and Disadvantaged Area Payments. These payments may be considered to be already decoupled from production as the value of the individual payment is unrelated to volumes of production. To test the potential future effects of decoupling the historical effect of both coupled and decoupled subsidies can be included in the multiple regression analysis.

The multiple regression analysis of changes in farm numbers is based on the following equation;

$\mathrm{F}_t = \alpha + \beta \mathrm{X}$

Where $\mathrm{X} = \mathrm{F}_{t-1} + \mathrm{GDPpc} + \mathrm{UNEMP} + \mathrm{AGINC} + \mathrm{SUBpd} + \mathrm{SUBpdtn}$

The equation states that the number of farms in period t is a function of the number of farms in the previous period, real GDP per capita, unemployment rates, real agriculture sector income, total subsidies on products and subsidies on production. The analysis is somewhat limited however, due to the availability of data. Only six time points of data are available 1990, 1993, 1995, 1997, 2000 and 2003 with the exception of Ireland for which a full series is available from 1990 to 1993. Therefore the analysis is conducted for Ireland first to determine whether the relationship between

[4] This criticism is due to Lucas (1976) who, in his seminal paper, argued that empirical models estimated under a specific policy regime are not applicable for economic analysis under another policy regime because the parameters of an estimated model embody the policy under which the data were generated.

farm numbers and decoupled payments can be quantified. Figure 4.13 below presents the data for Ireland, the data is presented as an index so that all series can be interpreted at once.

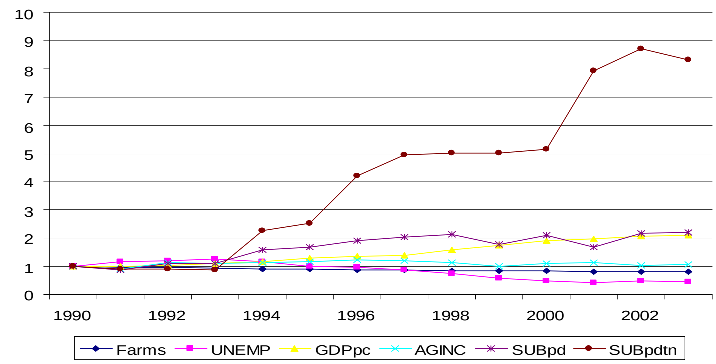


Figure 4.13: Macroeconomic and Agricultural Data for Ireland 1990 to 2003

The data in Figure 4.13 show that farm numbers decreased by over 20 percent between 1990 and 2003. Over the same period unemployment in Ireland halved and GDP per capita doubled in nominal terms. This suggests that there is a negative relationship between the health of the macro-economy and farm numbers; as GDP and employment improve farm numbers decline. In relation to the agricultural variables agricultural sector income was more or less maintained in nominal terms over the period while subsidies increased. Subsidies on products doubled but more significantly subsidies on production that is decoupled subsidies increased almost nine fold in nominal terms over the period. This suggests that as agricultural sector income declines and as more income comes from subsidies farm numbers decline. Table 4.7 below presents the correlation co-efficient between farm number and various explanatory variables.

	GDPpc	UNEMP	AGINC	SUBpd	SUBpdtn
Correlation with farm Numbers	-0.95	0.87	-0.22	-0.90	-0.94

Table 4.7: Correlation Co-efficients -Farm Numbers in Ireland and Various Variables

The correlation coefficient measures the degree to which the two series of data vary together or oppositely, a negative relationship implies that they vary in opposite directions while a positive relationship suggests that they vary together. Normally a correlation co-efficient greater than 0.8 is seen to indicate a significant relationship. The data presented in Table 4.7 suggest agricultural sector income has very little statistical relationship with farm numbers. The correlation co-efficient only measures the relationship between one set of variables at a time. A multiple regression analysis can include all variables simultaneously. The results of the initial regression run including all of the above variables are presented in Table 4.8. There are 13 observations, 14 years of data with one dropped for a missing lagged variable. The F test shows that the model is highly significant at the 99 percent level. The R-Squared is also very high at 0.9995, stating that over 99 percent of the variation in farm numbers is explained by the variables included in the model. The t-statistics show the statistical significance of the variables included in the model. The number of farms in the previous time period is statistically the most significant variable in the model and this variable dominates the results. The only other variable showing a statistical significance of 95 percent or greater is the national rate of unemployment. Interestingly, none of the variables pertaining to the agricultural sector are significant, suggesting that the macroeconomic environment and past trends are a greater determinant of change in farm numbers than the economic welfare of the agricultural sector. There is a possibility that some multicollinearity may exist between each of the macro-economic and agricultural variables. To test for this a stepwise regression approach is used and the autoregressive lagged dependent variable was excluded from the analysis to gain more understanding of the dynamics between farm numbers and agricultural subsidies.

Number of obs = 13		F(6, 6) = 1337.34		
Prob > F = 0.0000		R-squared = 0.9993		
Farms	Coef.	Std. Err.	t	P> |t|
AGINC	1.576394	1.111055	1.42	0.206
GDPpc	-.3282003	.3072821	-1.07	0.327
UNEMP	-2881.404	1050.005	-2.74	0.034
SUBpdtn	-1.444185	1.867138	-0.77	0.469
SUBpd	.1630511	1.848691	0.09	0.933
Farmlag	.9593265	.0948689	10.11	0.000
CONS	8636.306	19515.28	0.44	0.674

Table 4.8: Results of Multiple Regression Analysis for Ireland

The data in Table 4.9 presents a similar analysis excluding the autoregressive independent variable from the analysis. The results show that the statistical significance of some of the variables increase when the lagged dependent variable is excluded. Particularly the macroeconomic variables are very significant, but agricultural sector income and subsidies on production are still not significant. This suggests that even if decoupling results in large changes in agricultural sector income and decoupled compensation that this will have no effect on future farm numbers.

Number of obs = 13		F(5, 8) = 84.68		
Prob > F = 0.0000		R-squared = 0.9815		
Farms	Coef.	Std. Err.	t	P> |t|
AGINC	-5.590007	4.597055	-1.22	0.259
GDPpc	-3.842173	.8853729	-4.34	0.002
UNEMP	-8127.72	3871.788	-2.10	0.069
SUBpdtn	.3557657	9.176612	0.04	0.970
SUBpd	-14.90502	6.327973	-2.36	0.046
CONS	230939.7	14880.29	15.52	0.000

Table 4.9: Results of Stepwise Multiple Regression Analysis for Ireland

The exploratory analysis conducted using time series data on farm numbers, macroeconomic variables and agricultural variables suggest that changes in farm numbers are mostly driven by changes in the macro economy and not the economics of agriculture. However it is difficult to model structural changes in farm numbers from a macro economic perspective. Aggregate modelling approaches are often the subject of criticism because the micro dynamics of change are often ignored. Jackson-Smith (1999) argues that while aggregate census data provide reasonable information about the population as a whole, they provide little information about the nature of changes in individual farms or sub-groups of farms, which may run counter to overall trends. For the purpose of policy analysis, an aggregate model that produces projections of change but fails to explain the link between the policy and the change is not particularly useful. Given that decoupling is a farm specific micro-level policy, techniques that can examine the decision making process at the farm household level are more favourable for this study. It is argued here that farm specific policies are more effectively analysed at the micro level using farm level models rather than the traditionally more popular aggregate models. The case study for Ireland outlines a micro modelling approach.

4.3 Case Study Analysis - Ireland

Econometric and optimisation models are integrated to analyse the effect of decoupling on structural change in Irish agriculture. The modelling framework uses a profit maximising LP framework to simulate production decisions. The advantage of LP is it does not rely on time-series data and it does not extrapolate future relationships from historical ones, and therefore it can go beyond the realm of past observations and analyse unprecedented changes. The disadvantages of using LP however are its normative nature and its limited scope to project population change. To overcome these weaknesses, the LP model is supplemented with a number of exogenously estimated models of farmer behaviour that can quantify the effects of non-pecuniary factors on farmers' decision-making. Three exogenous models were estimated: first, entry to and exit from farming; second, labour allocation; and third, land and milk quota distribution. The first model simulates the Irish farming population. The second model estimates the number of part-time farmers and the amount of farm labour to provide the right hand side parameters for the labour constraint in the LP models. The third model simulated the allocation of land and milk quota; again, to provide the right hand side parameters for the land and quota constraints in the LP models.

4.3.1 Modelling Entry and Exit Decisions

An age cohort analysis of the Irish data reveals that farm numbers in Ireland are in net decline as older farmers leaving the sector exceed the young new entrants. Hence entry and exit from farming are modelled in the context of succession and retirement decisions. Several empirical models of retirement were developed, including early retirement scheme and heir identification models. Due to the lack of verifiable empirical data and in the absence of a statistically significant model, it was necessary to assume that the retirement process is independent of the agricultural policy environment and that retirement occurs on average at 70 years of age, as suggested by previous qualitative research (Gasson, Errington and Trantrer 1998). Better empirical data are available on the succession decisions and it is therefore possible to quantify the factors affecting a young person's decision to enter farming.

The decision to enter farming is modelled in the context of the nominated farm heir's occupational choice between farm and non-farm work (Hennessy and Rehman 2007). Drawing on the seminal contribution by Schmidt and Strauss (1975), a model of occupational choice is developed. Theoretically, an individual chooses his/her eventual occupation by comparing the discounted utilities derived from all alternative occupations over the entire expected life-span of a career and, then chooses the occupation that maximises life-time utility (Barkley 1990). The individual i is assumed to have a subjective evaluation of each occupation type and to choose the occupation with the highest utility index. Thus for the individual i faced with j choices, the utility of choice j is

$$Uij = \alpha + \beta' xij \ + \ \varepsilon\mathrm{ij} \tag{4.1}$$

where $\beta' xij$ is a function of the observed attributes of the alternative, the occupational choice and the observed characteristics of the decision-maker and εij, the random component, represents the unobserved attributes of the occupations and the decision-maker. If the individual makes the choice $j = 1$ then U_{ij} is maximised from among the j utilities. The empirical model is driven by the probability that choice j is made, that is:

$$\text{Prob}(Uij > \ Uik)\ \forall \text{ k } \neq \text{j} \tag{4.2}$$

The above probability is estimated using the multinomial logit model (MNL). In the MNL x_{ij}denotes the vector of variables that influence the utility associated with each occupational choice j as perceived by each individual heir i. The probability that individual i will choose occupation $j$is

$$\text{Prob}(i \text{ chooses } j) = \frac{\exp\ (\beta' xij)}{\sum_{k=1}^{m} \exp(\beta\text{'xik})} \tag{4.3}$$

where m equals the number of occupations in the choice set. It is assumed that the nominated farm heir is faced with three choices; full-time farming, a non-farming occupation and part-time farming; that is, combining both farm and non-farm work.[5]

Using data collected by the Irish National Farm Survey (NFS) on farmers' succession plans and their heirs' occupational choices the above MNL model can be estimated. Farmers participating in the survey were questioned about their succession plans and their nominated farm heirs' future plans. Farmers were asked first if they had nominated an heir and subsequently about what they expected their heir to do in future, i.e. continue the farm or not.[6] The nominated heirs' occupational choice is represented by the categorical variable CHOICE. The empirical data suggest that part-time farming is the most common occupational choice as reported by 48 per cent of respondents, whereas just 21 percent of farms are likely to continue on a full-time basis. Using the MNL framework, the farm and personal characteristics that are hypothesised to affect the succession are tested empirically. Table 4.10 presents the variables included in the MNL model.

The results of the MNL model show that an heir's educational achievements influence all occupational choices significantly (appendix 4.4). Interpreting the effect of education on the occupational choice is problematic. The third level education is a self-selecting process and thus participation in education may not vary autonomously from other factors that influence the occupational decision; that is, the occupational and educational decisions are joint decisions and should be modelled thus by using a bivariate probit specification. This specification is a simultaneous equation model which tests and controls for the endogeneity of the two choices that are related. The results of this bivariate probit model (appendix 4.4) suggest that the educational and succession decisions are indeed determined jointly, showing that heirs with third level education are significantly less likely to enter full-time farming and that education participation is negatively influenced by farm income. Thus, if decoupling results in a decrease in farm incomes then the probability of farm heirs entering third level education will increase, thereby reducing the probability of their participation in full-time farming.

4.3.2 Modelling Labour Allocation Decisions

It is hypothesised that decoupling will lead to a significant decline in the return to farm labour resulting in a shift of labour out of agriculture. The allocation of labour cannot be modelled effectively in a profit maximising LP model as the model will reallocate labour to the most profitable activity regardless of preferences, the stickiness of labour and the hidden costs associated with

[5]Whilst there may be many non-farming occupations, they have been combined to one occupational category here as our interest is specifically in the probability of entering farming.

[6]The data on the nominated farm heirs' occupational choices suffers from generational bias in that it reflects the current generations' opinions of what their heirs will do rather than the heirs' actions or plans. However, it is the only such data available for this study.

Variable	Description	Unit	Mean	Std Dev
FFI	Family Farm Income	Ă'000	22.876	22.8
FFI2	Family Farm Income Squared	Ă0'000	1.04e+09	1.95e+09
UAA	Utilised Agricultural Area	Acres*	53.3	54.9
UAA2	Area Squared	Acres	5844	27157
LUS	Livestock Units	Unit	73.8	60.3
LUS2	Livestock Units Squared	Unit	9081.1	17416.76
FJOB	Dummy=1 if current farm operator has an off farm job	Yes/No	0.23	0.42
SJOB	Dummy=1 if operator's spouse has an off farm job	Yes/No	0.30	0.46
DAIRY	Dairy=1 if farm is in dairying	Yes/No	0.42	0.49
HED3	Dummy=1 if heir has third level education	Yes/No	0.22	0.41

Table 4.10: Independent variables for the occupational choice model - (*N=514, * An acre equals 0.404 of a hectare.)*

reallocating labour. The allocation of labour is modelled exogenously so as to quantify the effect of decoupling on (i) the number of part-time farmers and (ii) the amount of labour available for farm work.

Theoretically, farmers' labour allocation can be explained using the agricultural household model (Singh, Squire and Strauss 1986). The essence of the model is that farmers maximise a utility function which is a function of consumption and leisure, subject to time and budget constraints. An individual optimises his/her utility by choosing those levels of hours of farm labour, off-farm labour and leisure so as to equate the respective marginal utilities of time spent on each alternative use. Consumption and leisure are restricted by a budget constraint. Income is derived from farm profit depending upon the amount of labour allocated to farm work, from off-farm wages obtained from the amount of labour allocated to such work and also, from non-labour income, that is, income generated without any labour input, for example, investments. The shift from coupled to decoupled subsidies is likely to affect labour allocation within the household too. Coupled subsidies are attached to production and are, therefore, equivalent to an increase in the marginal value product of farm labour. The decoupled subsidy is not attached to production but it is nonetheless a source of revenue for the household and is thus 'non-labour' income. It follows then that decoupling is likely to affect the relative return to farm work in two conflicting ways. First, the return to farm labour will decline significantly and, other things being equal, farmers will substitute off-farm employment for farm labour; that is the substitution effect. An increase in non-labour income however relaxes the budget constraint, allowing the farmer to work less and maintain consumption; the so called wealth effect.

The above theoretical analysis can be tested empirically using econometric labour participation and labour supply models (Hennessy and Rehman 2005). The participation model is a binary probit which estimates the effect of a vector of exogenous variables on the farmers' probability of participation in the off-farm labour market. The labour supply model is an OLS (ordinary least squares) model where the dependent variable is the number of hours a farmer devotes to off-farm employment. The dependent variable is incidentally truncated, as for some farmers who do not work off-farm the number of hours recorded is zero; thus raising the possible problem of sample selection bias as some of the unobserved factors affecting the participation decision may also affect the supply decision. The Heckman two-step procedure is used to test for sample selection bias in the labour supply model (Heckman 1979).[7] The results show that no sample selection bias is present, and therefore the OLS model of labour supply is an appropriate one to estimate.

[7] For further details see Hennessy and Rehman (2005)

The Irish National Farm Survey (NFS) data for 2002, consisting of 937 observations, are used to estimate these models. Most of the factors that were identified as affecting labour allocation decisions significantly in previous studies are recorded by the NFS. The system and size of farm as well as the number of livestock units are included as explanatory variables. Demographics of the farm household are also included in the model. To explore the effect of decoupling, the substitution and wealth effects have to be measured and therefore variables representing the return to farm labour and total household wealth are specified in the model. Returns to on-farm labour are estimated by dividing total farm income by total labour employed on the farm.[8] To explore the effect of wealth, a variable representing non-labour income should be included in the model. The identification of such a variable is however problematic as the NFS does not collect any non-farm data; therefore in common with Mishra and Goodwin (1997) and Ahituv and Kimhi (2002) a farmer's net worth is used as a proxy for household wealth.[9] The variables used in the model are presented in Table 4.11.

Variable	**Definition**	**Sample Mean** (N=937)	**Standard Deviation** (N=937)
Dependent Variables			
WORK	Dummy variable=1 if operator engages in off-farm employment	0.26	0.44
HOURS*	Number of hours supplied off-farm	1481	678
Independent Variables			
SYSTEM	Dummy variable=1 if farm is in dairy production	0.52	0.49
SIZE	Total agricultural area in hectares	46	39
SIZE2	Agricultural Area Squared in hectares	3571	17938
FFI	Family Farm Income Ă000	22.8	22.05
FWAGE	Family farm income per hour of total labour Ă	11.38	10
FWAGE 2	Family farm income per hour of total labour squared Ă	231	438
LUS	Number of livestock units	70	55
LUS2	Number of livestock units squared	7928	14302
AGE	Farmer's age in years	55	12
AGE2	Farmer's age squared	3148	1243
SPJ	Dummy variable=1 if spouse engages in off-farm employment	0.30	.45
NO	Number living in farm household	3.9	1.8
LAB	Number of unpaid labour units on the farm	1.09	0.43
UNEMP	Local unemployment rate in percentage	4.6	0.86
OWAGE*	Estimated Off-farm work wage per hour Ă	14.34	11.89
NW	Net Worth Ă000	434.25	348
NW2	Net Worth Squared Ă000	309564	872610

Table 4.11: Data for Labour Allocation Models (** Sample mean and standard deviation provided only for sample of 247, i.e. where HOURS>0*)

The results of the labour participation and supply models are presented in Appendix 4.4. The effect of on-farm wage is as expected, negative but non-linear, suggesting that as the farm wage increases the probability of working off-farm declines but at a declining rate. The effect of farm size is also negative suggesting that operators of larger farms are less likely to participate in the off-farm labour market. The effect of the farming system is significant and negative suggesting that the presence of a dairy enterprise reduces the probability of working off farm by 0.31. Again, this is as expected as dairy farming is very labour intensive and is one of the more profitable farm enterprises in Ireland. The effect of the age variable is counter-intuitive in that as farmers get

[8]In some cases the return was negative due to negative farm income; to avoid negative farm wages the variable was constrained to a lower limit of zero.

[9]Some have argued that this is not an appropriate measure of wealth as many farmers tend to be asset rich but income poor; however, in the absence of any more appropriate verifiable data, there is no realistic alternative to using net worth.

older the probability of off-farm employment increases, albeit at a declining rate. The effect of the labour variable is negative indicating that farms with more unpaid family labour units have a lower probability of the farmer engaging in off-farm employment. Finally, the non-labour income variable, net worth, is significant at the 1 percent level and is negative as expected, suggesting that an increase in non-labour income reduces the probability of off-farm employment.

The results of this labour supply model show that the on-farm wage, the farmers' net worth, the amount of unpaid labour on the farm and the number living in the farm household all affect the number of hours supplied to off-farm employment significantly. The effect of the farm wage and wealth variables are both negative as expected. It follows, therefore, that other things being equal, a decline in the on-farm wage - as is likely to occur following decoupling - increases the numbers working off-farm and the amount of time allocated to off-farm employment. Any increase in non-labour income, which is likely to occur, decreases the number of part-time farmers and hence the amount of time spent working off-farm. The effect of decoupling, therefore, depends on the extent of the decline in the on-farm wage and the increase in non-labour income. The initial estimates suggest that the probability of labour participation increases for 58 percent of the observations, while at the same time the number of hours spent on off-farm employment also increase for the majority of part-time farmers, with the average number of hours increasing from 1481 hours in the baseline situation to 1550 hours for a decoupled scenario.

4.3.3 Modelling the Distribution of Milk Quotas

The allocation of milk quota as distributed amongst different types of farms is modelled outside the LP framework because of the existence of institutional barriers as well as non-profit related factors influencing production decisions. Modelling the reallocation of milk quota is particularly important, as milk quota is one of the few factors over which the Irish government has complete control. The milk quota market is managed as the price at which quota is traded is set administratively and the redistribution of the existing quota is also state managed through spatial ring-fencing. Milk quota therefore, is of great interest to policy makers in Ireland as they can manipulate this policy instrument to achieve desired economic, social and political goals.

The farm level milk price will decline by approximately 10 percent from 2005 to 2012 as a result of the agreed reductions in the intervention prices for dairy products (Binfield et al 2003). The associated compensation will be decoupled from production meaning that producers giving up milk production in 2005 will still receive Ă0.04 per litre compensation in 2006 and onwards. Furthermore, producers remaining in production should no longer factor the Ă0.04/litre into the returns to their output as this payment is received regardless of production. The effect of the policy reform, therefore, is the erosion of the actual (coupled) returns to production and to milk quota. This erosion of the returns to production is likely to render dairy production unprofitable on many farms and, as a result, will have negative consequences for the number of producers. Previous studies of decoupling in the dairy sector suggest that the implications for farm numbers would be negative. Harvey and Colman (2003) concluded that milk producer numbers in the UK would fall by 21 percent in the period from 2002 to 2010 as a result of decoupling.

A model of dairy farmers' production decisions was estimated where farmers could make one of a discrete number of production decisions, maintain, increase, contract or cease milk production. Historical data from a panel of farms was used with the objective of estimating the types of farms that are most likely to change their production decisions. The objective was to simulate the demand for and supply of milk quota in the various regional quota markets. The lack of historical data that exist on farm however posed some problems; so, some additional data on farmers' future plans were collected. Again, problems were encountered as it was not possible to identify any factors that would affect farmers' future production plans significantly. The data collected could not be used to project what may happen in the future. Instead, it was necessary to resort to a farm profitability analysis to extrapolate future production decisions.

The number of farms exiting milk production was estimated as the numbers retiring without a successor and as well as those operating below the critical level of profitability below which exits from farming have occurred in the past. From these estimates the regional supply of milk quota was estimated. It was assumed that farmers with a marginal revenue exceeding marginal cost would demand additional milk quota. From these estimates the milk quota market was simulated and new quantities of milk quota per farm were projected. These milk quota estimates provide the right hand side parameters for the milk quota constraint in the LP models.

4.3.4 Modelling the Reallocation of Land

Structural change may result in the re-allocation of land as the resources of exiting farmers are redistributed among those who remain in farming. The retirement and succession models produce annual estimates of the number of farmers exiting production each year. The estimates of exiting farmers are used to develop regional land banks. The land left by each departing farmer enters a regional land bank and that land is then redistributed amongst expanding farms within the same region. The redistribution of such land banks is achieved by the LP models, which reallocate newly available land on a rental basis to the farms with the highest shadow values for land; that is, to those farms that can afford to pay the most. This transfer of land is a rental, rather than a permanent, transfer because of the complexities of annualising the cost of a permanent acquisition of land within a multi-period model.

It is assumed that land is reallocated only when a farm ceases production; further, all active farmers continue to farm the same land area as in the base period, with the exception of those acquiring the land that becomes available. It is a tenuous assumption, which may limit the final findings of this modelling exercise. It can however be argued that there may not be any significant change in the allocation of land as after decoupling. Under the MTR the decoupled payment is still linked to the land and, therefore, the farmer must keep 'farming' the land to qualify for the payment. Even the most inefficient farmer would have to be offered, at the minimum, the value of the decoupled payment less the compliance costs to induce him to lease out their land. The land rental prices in a decoupled scenario are therefore likely to reflect the value of the associated decoupled payment rather than the productive capacity of land. Farmers wishing to expand production beyond what they produced in the reference period will have to do so without any direct payments or financial support; therefore, the market based margins, after excluding the decoupled payment, that may be earned on rental land, in many cases may not be worthwhile.

4.3.5 The Integrated Modelling Approach

To recapitulate: in order to assess the impact of the MTR reform of the CAP, the above econometric models are integrated with individual farm level optimisation models. Figure 4.2 presents a schematic outline of how these models link together to form the integrated modelling system. The 'entry and exit' model estimates the number of active farms in any one year. The lands of farms that are estimated to exit production during the year enter the land simulation model and are reallocated to exiting farms wishing to expand. Following on from this, the econometric labour model is run in order to estimate the number of part-time farms and the amount of labour available on each farm. When labour estimates are available, the milk production decision model, this model, as explained above, is used to estimate the number of farmers exiting milk production and the amount of milk quota being reallocated to existing farms. In the final stage of the integrated modelling system, a generic multi-period LP model is specified for each farm in the dataset and production plans and farm incomes are simulated for each year covering a period over 2005 to 2010 for two scenarios: a baseline situation, which is the continuation of the Agenda 2000 reform, and the MTR scenario. Projections of prices and costs for the baseline and the decoupling scenarios are taken from the FAPRI-Ireland model (Binfield et al 2003). The input-output coefficients in the LP model are 'mean values' for the base year and remain constant throughout the projection period. In the MTR scenario direct payments are removed from the objective function and the Single Farm Payment (SFP) is the new source of revenue, due to decoupling, which is attached to land use. The choice set for this scenario includes the option of entitlement farming, which is the activity of using land to claim the SFP but not to produce any tangible products (Breen et al 2005).

4.3.6 Results of the Two Scenario Runs

Figure 4.14 shows the proportion of beef farmers participating in the off-farm labour market. Given inter-generational changes and a positive macroeconomic outlook, the number of farmers participating in off-farm employment will increase in both scenarios. The pace of structural change, however, is faster under the MTR scenario as the substitution effect dominates the wealth effect for the majority of farmers and therefore the numbers participating in off-farm employment increases when the payments are decoupled from production.

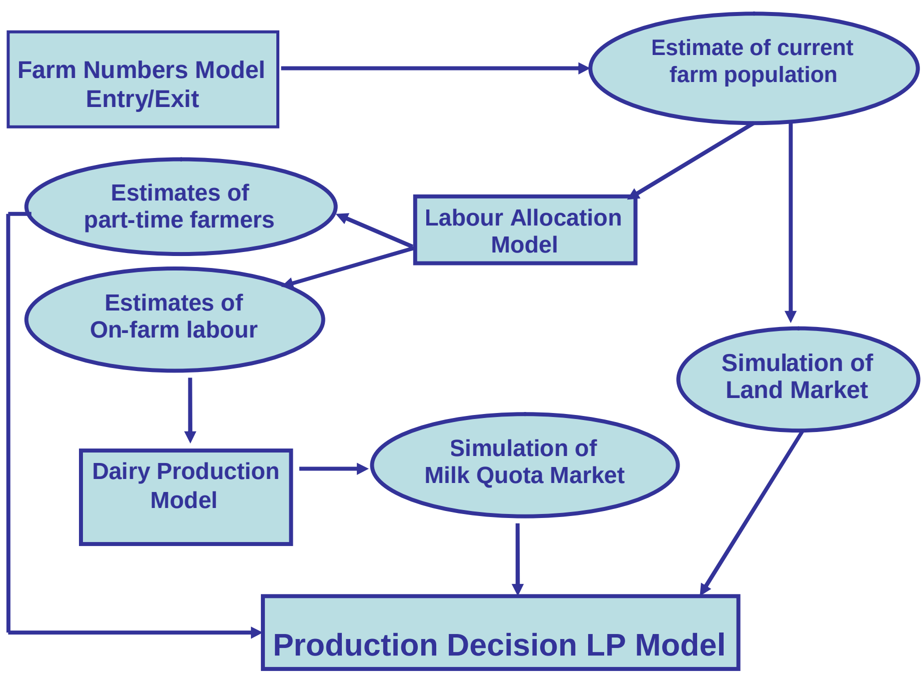


Figure 4.14: Schematic Outline of Integrated Modelling System

A mass de-stocking of animals and a proliferation of entitlement farming is predicted after decoupling. A closer analysis however suggests that such a change is not likely transpire. A large number of Irish beef farmers have been farming at a market loss and it was thought that they could maximise profits by de-stocking. But if overhead costs are still incurred, then most of such farmers would be acting rationally by continuing with some level of farm activity. A vast majority of them can obtain a gross profit from at least one enterprise and, post-coupling they would specialise in their most profitable enterprise. Figure 4.16 presents the projected number of entitlement farmers who would let their land go fallow and choose not produce any tangible agricultural output.

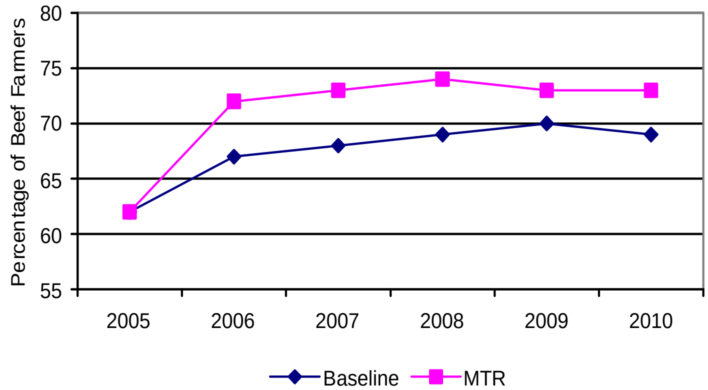


Figure 4.15: Projections of the Proportion of Beef Farmers with Off-farm Employment in Ireland

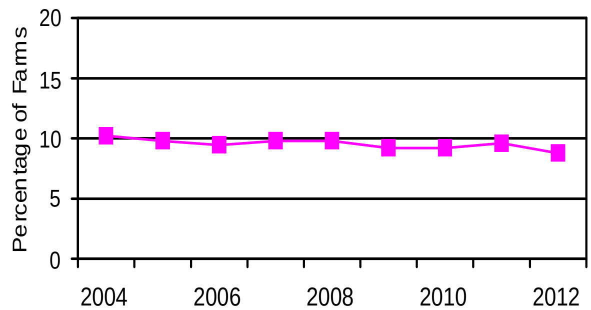


Figure 4.16: Projections of Entitlement Beef Farmers in Ireland

The impact of the MTR is likely to be inequitable and differentiated with some farmers benefiting and others losing, by adapting stratagems such as off-farm employment, enterprise substitution and/or specialisation, for example. It is important, therefore, to consider the full impact of decoupling on both the viability of the farm business and the sustainability of the household. Such effects are assessed using a framework developed by Hennessy (2004), where an economically viable farm business is classified as one having (a) the capacity to remunerate family labour at the average agricultural wage, and (b) the capacity to provide an additional 5 per cent return on non-land assets (Frawley and Commins 1996). Farms that are not economically viable but where the farmer participates in off-farm employment are classified as nonviable but sustainable, as off-farm income contributes to the long-term sustainability of the household. Farmers that do not work off-farm and operate an economically nonviable business are considered vulnerable.

Table 4.12 shows the 2002 population of Irish beef farmers as projected population for 2010 for a baseline (continuation of Agenda 2000) and the MTR scenario. In 2002 just 17 percent of beef farms were economically viable; this number is projected to grow after decoupling as farmers benefit from higher beef prices and less market distortion. The number of viable farmers relying on outside income is also projected to increase. The number of nonviable but sustainable farms will almost double after decoupling, due to the declining importance of farm income to many farm households. Finally, the number of vulnerable farms would decline faster under decoupling than the baseline scenario because of the improved economic outlook for beef and the increased attraction of off-farm employment.

Farm Group	**2002**	**Baseline 2010**	**MTR 2010**
All Viable Farms (percentage)	10,363 (17)	7,265 (12)	11,500 (20)
Of which are part-time *(percentage)*	5,104 (8)	2,700 (5)	7,152 (12)
Non-Viable Sustainable (percentage)	22,635 (38)	38,355 (64)	35,500 (61)
Vulnerable (percentage)	25,829 (43)	12,920 (23)	11,500 (19)
All Farms	58,828	58,600	58,002

Table 4.12: Viability of Beef Farming in Ireland

Table 4.13 presents similar results for the dairy farming sector, where the effect of the MTR is less positive. The reduction in the intervention prices for dairy products means a considerable price/ cost squeeze, accelerating the rate of exit from this sector after the MTR relative to the baseline situation. The average level of milk production on dairy farms in 2002 was 230,000 litres, increasing to 34,000 litres by 2010 under the MTR scenario. Despite these increases in output, the number of economically viable dairy farmers will decline.

Farm Group	**2002**	**Baseline 2010**	**MTR 2010**
Viable Farms (percentage)	16,110 (57)	15,200 (66)	12,250 (66)
Viable Part-time (percentage)	700 (2)	500 (2)	-
Non-Viable Sustainable (percentage)	2,000 (6)	1,500 (7)	-
Transitional (percentage)	10,700 (37)	6,300 (27)	6,500 (34)
All Farms	28,800	23,000	18,750

Table 4.13: Viability of Dairy Farming in Ireland

The objective of the research presented in this paper was to model the effects of decoupling on structural change in Irish farming. Undertaking this research has proved challenging from a number of perspectives. First, modelling the effect of policy change on structural change in farming remains difficult methodologically. Aggregate models based on trend analysis provide little information about the interaction between policy instruments and structural change, while the more advanced econometrically estimated Markov Chain models are data intensive and are based on some very restrictive assumptions. Apart from the methodological difficulties associated with capturing the essence of structural change, modelling decoupling is problematic because of it being an unprecedented policy instrument and evidently it is too early to expect any empirical evidence on supply inducing effects of its implementation. The traditional partial equilibrium models based on historically estimated supply elasticities are of limited value in analysing the effects of decoupling. This paper has addressed the research questions posed at the beginning of the paper by using a farm level modelling approach. Linear programming is used as the analytical technique because of its ability to analyse unprecedented changes; but it is of little use in projecting structural changes, unless it is supplemented with a number of exogenously estimated models. The integrated modelling approach, using optimisation and econometric estimation, allows us to simulate changes in the farming population, the proportion of full and part-time farms, the number of dairy farms and the number of economically viable farm businesses under different policy scenarios. The approach developed shows the effect of decoupling on the number of economically viable businesses, on the sustainability of farm households and on the number of vulnerable households. Undoubtedly, there is still considerable scope for improvement within the modelling approach and capacity for future research: in particular, the lack of verifiable empirical data on the number of farmers who leave farming mid-career, that is, for reasons other than retirement, makes it difficult to simulate exits from farming other than those that are caused by retirement and non-succession. Further, data on factors that influence dairy farmers' decisions to exit the industry are scare, rendering the simulation of the milk quota market a very difficult task.

4.3.7 Applicability of Irish Methodology to Other Member States

The methodology developed for the Irish case study provides a comprehensive framework for analysing the effect of decoupling on structural change in farming. The methodology facilitates the estimation of the effect of decoupling on (i) the rate of retirement from farming, (ii) the number of new entrants into farming, (iii) the redistribution of land and quota due to farmers exiting farming, (iv) the allocation of farmers' labour, (v) systems of production, (vi) trade of milk quota, (vii) volume of production and (viii) farm incomes and the associated viability of farming. The methodology has a number of limitations as outlined above, however given the complexity of the research question and the lack of an appropriate alternative methodology the framework applied above seems to be the most appropriate approach.

The extension of the Irish case study for the analysis of structural change in the other member states has posed a number of problems. The first is the lack of comparable data. Within the Irish framework, the estimation of future farm numbers emanates from the succession model. The data available on succession in Ireland was collected by the operators of the Irish FADN database but because it was an additional survey, comparable data is not available for other member states. Where data on succession is available for example see Glauben et al. (2002) for the German situation, Stiglbauer and Weiss (2000) for the Austrian situation and Kimhi and Nachlieli (2001) for details on Israel it is not collected through the FADN framework and therefore the succession data cannot be linked back to the data in the FADN dataset meaning that the estimation of the rest of the modelling framework would not be possible. In relation to the modelling of labour allocation, the data collected by the Irish FADN on farm labour seems to be somewhat superior to that collected in other countries. In Ireland the off-farm job status of the farmer and spouse is recorded, where one or the other works off farm the type of employment is recorded, the number of hours spent working off-farm is recorded as is the off-farm income. These variables are necessary for the estimation of the two-step labour model outlined above. In the absence of this data, as is the case with other member states, it is not possible to develop similar models. Finally the last problem of replicating the Irish modelling system for other member states is the development of the quota trade module of the modelling framework. In the Irish situation, the quota trade model is simulated to replicate exactly the workings of domestic policy on milk quota trade in Ireland. To develop a similar model for each member state would be most onerous as the modeller would need to familiarise themselves with the details of milk quota trade in each member state and then develop a model that can simulate that trade. It was concluded that due to the availability and quality of data and the sheer size of the task that it was beyond the scope of this project to replicate the Irish modelling system for the other EU member states. Notwithstanding this, a number of lessons can be learnt from the Irish case study and some of the main conclusions may be applicable to other EU member states. The applicability of these conclusions can also be tested by the results of the farm level models developed for the other member states.

4.3.8 Lessons to be drawn from Irish Study

The results of the Irish case study seem to suggest that the MTR of the CAP may have created a disincentive to exit farming, particularly the fact that the linking of the SFP to land area farmed. Under previous agricultural policies, farmers were obliged to grow crops, produce milk or rear animals to qualify for financial support in the form of direct payments. Typically when the returns to these activities declined, farmers exited the sector or retiring farmers were not replaced. With the MTR, farmers can continue to receive direct payments without engaging in agricultural activity and without allocating substantial amounts of labour to farm work. Additionally, farmers can stack their payment entitlements on a portion of their land and plant forestry on the remainder, thereby benefiting from both decoupled payments and forestry premium. Farmers can also participate in the REPS scheme, which has recently become financially more attractive, without forfeiting their decoupled payment. Furthermore, the retirement and succession analysis conducted on Irish data suggests that the decisions to retire from farming and to enter farming are more influenced by demographic and macroeconomic forces than the economics of farming. Due to these factors, the results of the Irish case study suggest that the MTR will not result in any acceleration of the trend of farm exits. In other words the baseline situation of the historical trend will continue but that some restructuring within the sector, in terms of the systems of farming and the number of part-time farmers, will occur. Whether this conclusion also applies to other member states is questionable especially given that some countries have opted to partially decouple rather than fully decouple. However, examination of the results of the farm level models may provide some insight into the applicability of this conclusion.

The Irish case study suggests that decoupling is likely to induce restructuring within the sector. Principally, the types of restructuring projected are (i) an increase in the number of part-time farmers, (ii) a reduction in the number of dairy farms, (iii) a reduction in the land area under cereal production with cereal producers shifting into grass based systems and (iv) the emergence of the entitlement farmer. For Ireland the data and the empirical analysis support the likelihood of these changes occurring post decoupling. By reviewing the results of the farm level models for each of the other EU countries under investigation it is possible to ascertain whether similar structural changes will occur in each country.

4.4 Main Conclusions

The objective of this research was to analyse the effect of decoupling on structural change in farming in the EU. Undertaking this research has proved challenging from a number of perspectives. First, modelling the effect of policy change on structural change in farming remains difficult methodologically. Aggregate models based on trend analysis provide little information about the interaction between policy instruments and structural change, while the more advanced econometrically estimated Markov Chain models are data intensive and are based on some very restrictive assumptions. Apart from the methodological difficulties associated with capturing the essence of structural change, modelling decoupling is problematic because of it being an unprecedented policy instrument and evidently it is too early to expect any empirical evidence on supply inducing effects of its implementation. A number of methodologies were explored and static projections of farm numbers were produced but tt was not possible, within the remit of this project, to identify a methodology that could comprehensively model structural change in all member states. Instead, a more detailed micro analysis of structural change in Ireland was conducted. The results of this analysis and of the exploratory time series analysis suggests that macroeconomic developments are likely to continue to be the main driving force of structural change in agriculture in terms of total farm numbers but that decoupling is likely to engender some changes within the farming population. Specifically, the Irish case study points to the emergence of a new structural state, entitlement farming, a decline in the number of dairy farms and an increase in the proportion of part-time farms.

While it was not possible to extend the Irish methodology to other member states, the output of the farm level models developed under the GENEDEC project can be evaluated to determine whether the conclusions from the Irish case study are applicable to other member states. The AROPAj model has been used in the GENEDEC project to look at the effect of decoupling on the EU 15. The results on the effect of land use change support the theory that decoupling will cause a change in the system of farming. According to 2001 data approximately 41 percent of the land area in the EU15 was used to grow cereals. The model projects that when the MTR is fully implemented that this will cause the area of land under cereal production to decline to 38 percent. Furthermore the model projects that grassland will increase from 29 percent of total land area to 33 percent and most interestingly the AROPAj model supports that theory that a new class of farmers, entitlement farmers will emerge, with the amount of land remaining fallow increasing from 1 percent in the baseline to 7 percent post decoupling. The results of the AROPAj model of the EU 15 support the conclusion from the Irish study that decoupling is likely to result in a new structural state in European farming, namely the entitlement farmer. The FAL model also projects an increase in “mulched area” that is land area farmed by entitlement farmers, i.e. not used to produce any tangible products. This land area is projected to almost triple when decoupling is implemented as per the national implementation plan (Kuepker and Kleinhanss 2006). The FAL and Spanish PROMAPA.G models both project declines in the income of dairy farms in Germany and Spain which is consistent with the results for Ireland and therefore may be indicative of a decline in dairy farm numbers in these member states also. It was not possible to interpret the shadow values of labour from the GENEDEC models and therefore it is difficult to infer whether the projection of an increase in part-time farming is applicable across the EU.

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Appendix 1

Independent Variables	**Part-time CHOICE=2**		**Non Farming CHOICE = 3**		**Don't Know CHOICE = 4**	
	Param.	z ratios	Param.	z ratios	Param.	z ratios
Intercept	2.23**	7.29	-.668	-1.15	.7790*	2.49
UAA	-.0056	-1.57	-.0027	-0.32	-0.006*	-1.79
LUS	-.0178**	- -4.64	-.0215**	-2.66	-0.0015	-0.53
FJOB	1.399**	2.88	.5718	0.77	.9002	1.70
SJOB	.9046**	.9046	1.616**	3.30	0.389	1.24
DAIRY	-.9913**	-3.17	.3430	0.63	-0.4616	1.51
HED3	1.163**	2.91	1.561**	2.81	0.7733*	1.90
* Significant at 5%; ** Significant at 1% N= 514 Pseudo R2 =0.178 Log Likelihood =-499.19 Unrestricted Log Likelihood = -607.7 Correct predictions: CHOICE=1 (65%) CHOICE=2 (89%) CHOICE=3 (0) CHOICE=4 (31%) Total Correct Predictions (65%)						

Table 4.14: Results of the Multinomial Logit Model of Occupational Choice

Independent Variables	**Full-time CHOICE=1**	**Part-time CHOICE=2**	**Non-Farming CHOICE=3**	**Don't Know CHOICE=4**
UAA	.0007	-.0003	.00009	-.00049
LUS	.0016	-.0037	-.00052	.0026
FJOB	-.133	.1904	-.0182	-.0387
SJOB	-.0962	.1212	.0534	-.0784
DAIRY	.1010	-.1850	.0459	.0380
HED3	-.1194	.1257	.03532	-.0416

Table 4.15: Marginal effects of Selected Explanatory Variables

Appendix 2

Independent Variables	FULLTIME		HED3	
	Parameter	(t ratios)	Parameter	(t ratios)
Intercept	-.2333**	-4.09	-.4464**	-5.02
SJOB	-	-	.1947*	2.19
FFI	-	-	-.0177**	-6.68
HED3	-1.809**	-13.70		
Rho (ρ) 0 .99** * ($p \leq 0.05$) ** ($p \leq 0.01$)				
Number of Observations = 514 Log Likelihood = -484.80				

Table 4.16: Results of the reduced bivariate probit model

Variable	Coefficient (Z-Values)	Marginal Effect
Intercept	-1.136783 (-1.11)	
FWAGE***	-.0284262 (-2.57)	-.007
FWAGE2*	.0003971 (1.63)	.0001
SIZE**	-.0060623 (-2.15)	-.0015
SYSTEM***	-1.210383 (-9.03)	-.3158
AGE***	.1234819 (3.08)	.0318
AGE2***	-.001633 (-4.26)	-.0004
NO***	.0849544 (2.78)	.0219
NW***	-.0008696 (-2.62)	-.00022
NW2***	3.95e-07 (3.11)	1.02e-07
LAB**	-.3207875 (-1.92)	-.0828
Pseudo R^2= 0.324 Correct Predictions = 80%		
Likelihood Ratio Statistic χ^2_{10}= 349.40***		

Table 4.17: Results of the Probit Model of Labour Participation (N = 937; * Significant at 10%. ** Significant at 5%. *** Significant at 1%.)

Variable	Coefficient (T-Values)
Intercept***	2169.69 (19.86)
FWAGE**	-12.3749 (-2.02)
NW***	-.6025994 (-2.53)
LAB***	434.0715 (-3.68)
R^2= 0.199 F= 15.61***	

Table 4.18: Results of the Ordinary Least Squares Model of Labour Supply (N = 247; * (p < 0.1);** (p < 0.05);*** (p < 0.01))

Part III

Potential change of land prices

Introduction of the part III

Major change in CAP should have strong impact on the value of quasi-fixed factors related to farming systems. The linkage between de-coupling susbsidy on one hand and land or farm or farmer on the other hand, in addition to the question of tranferability of right to subsidy, should have strong importance for the price of the land.

Mathematical programming models are able to provide estimates of the shadow prices of land. These prices could be compared to yearly rental prices. We deliver some lights about the impact of different CAP options. The analysis takes account of the different modelling -and real policy-constraints related to land and land use.

Results should differ from one model to another. This is possibly due to each particular model structure, to productions and farming systems covered by the models, to inputs and especially fixed factors taken into account, to the way in which CAP is stylized and integrated. For instance FARMIS and AROPAj differ in what concerns the sugarbeet production related to "C" exports, and in the split (in FARMIS) between the arable land and meadows. Another strong structural difference appears when AROPAj turns towards linear mixed programming, and when other mathematical programming models turn toward "positive mathematical programming".

5 Impact of the Luxembourg agreement on the shadow prices of the land through the use of the AROPAj model

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Abstract

The first consideration accompanying any reform of the CAP is generally its impact on the farmers' income. Little consideration has been given to the distribution effect of such a policy among the production factors that farmers use. Considering this income like the result of the optimal use of limited factors, we provide estimate of the impact of CAP change on the value of the agricultural land. In the field of agricultural economics, mathematical programming models, and more precisely linear programming ones, are particularly efficient tools for assessing change in agricultural land use arising from shifts in policy. As a double benefit from these model are the dual values linked to the constraints characterizing the production sets. The AROPAj model allows to estimate average regional shadow prices of the land for the EU-15. Two options of decoupling are analysed. The intermediate decoupling scheme related to the Luxembourg agreement could imply a significant increase of these prices due to the transfer of subsidies toward the land. We show how this increase involves the set-aside constraint included in the Luxembourg agreement. When all historical payments move toward an entitlement entirely related to the land, the shadow price of the land increases again.

Introduction

One of the aims of the last Common Agricultural Policy (CAP) reform designed by the Luxembourg agreement (2003) is to maintain farmers' income. Doing that policy makers should expect change in value of fixed factors such as land devoted to agricultural production. High consideration should be given to the distribution effect of such a reform among the production factors that farmers use, and among farmers.

In the field of agricultural economics, mathematical programming models, and more precisely linear programming ones, are particularly efficient tools for assessing change arising from shifts in policy. As a double benefit from these model in addition to estimates of land use, productions and income, are the dual values linked to the production set constraints. Concerning land constraints, associated dual values give an assessment of the rent value of land.

This article focuses on the land rental prices assessed by a European scale model as well as their change when the CAP reform follows different options. In section 5.1, we revisit briefly the relationship between land price, agricultural support and entitlement possibly dedicated to the land use. In section 5.2, we present the main results of simulations at the European scale focusing on land price effect when different CAP reform options occur. Results are delivered with consideration of the scale, from the European scale to regional scale viewed through the "Farm Accountancy Data Network (FADN) Regions". We confront the 2003 Luxembourg agreement with results generated from a hypothetical full decoupling reform not yet envisaged by most Member States (MS). We estimate the additional impact related to the taking into consideration of feedback from the rest of the economy through prices got from partial equilibrium models.

5.1 Land prices, land market, entitlements and agricultural support

5.1.1 Agricultural support and land prices

Land price and land rental price

Ricardo's theory of rent defined rent as "that portion of the produce of the earth which is paid to the landlord [by the tenant farmer] for the use of the original and indestructible powers of the soil." Rent, Ricardo (1817) argued, is what remains from gross farm revenue after all the farmer's production costs have been paid, including remuneration for the capital and labor he had expended on the land. It is an unearned surplus (now referred to as an economic rent) in that its payment is not necessary to ensure a supply of farmland. For Ricardo, rent arises from the advantages that one site has over another due to differing degrees of soil fertility: rent per acre is highest on the most fertile land, and declines to zero on the worst quality soil.

In the simplest case, with no taxes, no collection of the rent by a community beyond the title holder, no price appreciation, and no inflation, the sale price p tends to equal to the rent r divided by the interest rate i. This comes from the seminal formulation $r = p * i$ (rent equals the principal or price of land times the interest rate), since the same funds (p) if loaned out at interest rate i would yield the annual amount r. If the money is inflating, then we need to subtract out inflation from the interest rates being paid in order to get the "real" interest rate i. If there is a tax on the land, or the collection of the land rent by a community, then the collection rate is added to the interest rate, since the rent must pay for both the collection and the net yield to the title holder : $r = p * (i + c)$, where c is the collection rate, the percentage of land value being collected. Hence, as i or c or both increase, the price of land decreases. If rent increases, then the price increases.

Several econometric studies have tried to explain land prices from some land features, such as land quality, geographical position, risk aversion and transaction costs.

Lussier et al. (2001) have expressed land price as a function of land quality in an econometric model in Quebec. According to their study, the market provides a positive price incentive to install drainage (soil conservation). However quality characteristics of agricultural land while undeniably beneficial to agricultural productivity, produced ambiguous results with regard to positive price signals.

Cavailhès and Wavresky (2003) shows that land prices fall with distances from cities. In peri-urban belts, parcels can indeed be converted to urban use and their prices reflect potential capital gain from such future development.

Chavas and Thomas (1999) study land prices in the US between 1950 and 1996 in a dynamic analysis with risk aversion and transaction costs. The econometric findings indicate that both risk aversion and transaction costs have significant effects on land prices.

Those studies are all in accordance with Ricardo's theory: land prices reflect potential future rents or gain.

Land prices and agricultural support

Among potential economic advantages associated to land is the agricultural support. In many developed countries, agricultural policies are indeed a quite important source of farmers' income. Tangerman (2006) recalls that direct subsidies contribute by 18%, 35% and 80% of the net agricultural income, respectively for USA, EU, and Japan on the last five years.

The way the support is delivered to farmers may have different impacts on land prices. The former article on this subject was maybe by Floyd (1965). In his paper, he studied three price-support programs (where output is alternatively not controlled, controlled by acreage restrictions, or controlled by restrictions on the quantity of produce that farmers can market) and assessed their effects through the elasticities. He showed that the type of support may influence the land price, and has different impacts according to the farmer is the owner of the land or not. Most of the benefits take the form of a windfall gain, either an increase in the value of land or the receipt of marketing certificates issued by the government and having a commercial value, and the gain is once and for all. There is little advantage in these policies for the landless or young person who would like to enter the industry.

One of the main concern for econometric studies is the lack of data. Data are indeed an determining factor to study a phenomenon such as policy impact on land prices. However, land prices have to deal with structural change in time for long period or structural change in location for vast areas. Average avalailable data are often quite irrelevant for the assessment of policy impacts when these changes are not kept in mind. In the reverse order analysts should take advantage of impacts of policy changes on income and land use to assess impacts on land prices. Among agricultural policies, the Common Agricultural Policy has evolved several times since the 1990s and supplied examples of strong structural change.

Cavailhès and Degoud (1995) develop models which are assessed econometrically on French data. They show how strong is the inertia of anticipations and how high is the long-term elasticity of land prices to production factor prices. They conclude that the 1992 CAP reform has an effect on land prices through an expected decrease of the land rent.

By raising returns to fixed factors, agricultural policies increase the market price of land and capital. Bourdon (1999) states that the theoretical point of view does not coincide with the observed values in the case of the 1992 CAP reform. The gap between observed prices and simulated prices is due to the lack of instantaneous rationality in the behavior of land market actors, which could be seen as an inertia effect.

However, unlike the common idea that a farm support induces an increase in land price through capitalisation, Mèze (2003) shows that the effects are more complex and that the interactions between arable land and permanent grassland play an important role in the capitalisation of agricultural support. Concerning rents, the capitalisation of agricultural support is also small. The owner has no means to capt a part of the support. This is due to the legislation which protects more the farmer than the owner. Following this approach, land rent could even decrease with the introduction of modulation of support.

Decoupling and land prices through mathematical programming models

Different mathematical programing models have been used for estimate of the impact of CAP reforms on land prices.

Küpker (2006) studies the impact of the 2003 Luxembourg reform on shadow prices for land within the model EU-FARMIS for Germany. He distinguishes between two decoupling scenarios, a regional scheme and an individual historical scheme. He shows that the regional implementation yields an increase of shadow prices for land whereas the historical implementation leads to a sharp decrease of dual values for land. The author argues that these findings are in line with Courleux (2006) and due to the fact that, in their model, only a relatively small part of direct payments is captured in the dual value for land in the historic scheme.

Judez et al. (2006) study the effect of the 2003 CAP reform on shadow prices for land in Spain. They show a substantial decline due to the drop in coupled payments. We have to notice their shadow prices don't take into account the payment entitlements per ha appearing with decoupling.

It should be noticed that the two previously cited models (FARMIS and PROMAPA) are based on positive mathematical programming (PMP). We can suspect that the implementation of the de-coupled subsidies in the objective cost function could play an important role.

In the context of a CAP reform, mathematical programming models make us able to give information of the impacts of the reform on land shadow values, and so maybe on land rent. To well understand the links between land shadow values and rents it is necessary to better know the land market rules and how the new payment entitlement, introduced by the 2003 Luxembourg reform is linked to the land or the farmer.

5.1.2 Land market and entitlements

European land tenure

Land tenure is the relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land. In simple terms, land tenure systems determine who can use what resources for how long, and under what conditions (FAO 2002).

In much of northern Europe for example, term lengths are imposed. They tend to reflect minimum terms that can be both extended to longer periods, and renewed prior to termination. In all these cases the minimum terms are long (in the order of 10 years), while agreed terms of 18 to 25 years are not uncommon (FAO 2001).

European land tenure encourages family farming. Some jurisdictions encourage family farming by restricting the amount of land that can be farmed as an individual holding. One example is Denmark where the maximum farm size is currently set at 125 ha.

A number of countries, including France, use systems of "guided" or "preferred" ownership controls to ensure the continuity of family farming. In controlling local land markets, the French

SAFER committee system ensures, for example, that the purchase of agricultural land for investment purposes or speculation (on any scale) is discouraged. This effectively favours ownership by farming families. Although expensive to operate and often uneven in their practices (largely due to regional variations in farming practices and conditions), the SAFER system has underpinned the continuation of family farming throughout France. The SAFER may buy agricultural land, should it come on the market. Since 1962, they have a legal option to purchase. They are to sell this land to young and new farmers or to sustainable family owned units; since enactment of a new law in January 1990, they may lease the land. The SAFER are very active and effectively control the farmland market.

Often, the sale prices are controlled and enclosed. For example, the Land Transfer Act in Germany limits the sale price of agricultural land to 150% of the average sale price of land of comparable quality.

Examples can be found of a number of measures designed to achieve this, relating to controlling the disposal of land, either by prohibitions on sales, limiting the sale price of agricultural land, or restricting its conversion to non-agricultural uses. In Ireland, for example, farmers have only been subject to income tax since 1974, and then at rates far below non-farmers. Similarly, those leasing out land on long leases (over 18 years) in France can gain advantageous tax benefits, while there are tax concessions on the purchase of agricultural land in Italy.

The transfer of entitlements in the Luxembourg reform

According to the article 46 of the *Council Regulation (EC) N 1782/2003 of 29 septembre 2003* (n.d.), payment entitlements may only be transferred to another farmer established within the same Member State except in case of transfer by actual or anticipated inheritance. A Member State may decide that payment entitlements may only be transferred or used within one and the same region. Payment entitlements may be transferred by sale or any other definitive transfer with or without land. In contrast, lease or similar types of transactions shall be allowed only if the payment entitlements transferred are accompanied by the transfer of an equivalent number of eligible hectares.

Except in case of force majeure or exceptional circumstances, a farmer may transfer his payment entitlements without land only after he has used at least 80 % of his payment entitlements during at least one calendar year or, after he has given up voluntarily to the national reserve all the payment entitlements he has not used in the first year of application of the single payment scheme.

In case of sale of payment entitlements, with or without land, Member States may, acting in compliance with the general principle of Community law, decide that part of the payment entitlements sold revert to the national reserve or that their unit value is reduced in favour of the national reserve, according to criteria to be fixed by the Commission in accordance with the procedure referred to in Article 144(2).

The article 9 of *Commission Regulation (EC) N 795/2004 of 21 april 2004* (n.d.) describes the possibilities of retention on sales of payment entitlements. Each Member State may decide that it shall revert to the national reserve: (a) in case of sale of payment entitlements without land, up to 30% of the value of each payment entitlement or the equivalent amount expressed in number of payment entitlements. However during the first 3 years of application of the single payment scheme, the percentage of 30% may be replaced by 50%; and/or (b) in case of sale of payment entitlements with land, up to 10% of the value of each payment entitlement or the equivalent amount expressed in number of payment entitlements; and/or (c) in case of sale of set-aside entitlements without land, up to 30% of the value of each payment entitlement. However during the first 3 years of application of the single payment scheme, the percentage of 30% may be replaced by 50%; and/or (d) in case of sale of payment entitlements with an entire holding, up to 5% of the value of each payment entitlement and/or the equivalent amount expressed in number of payment entitlements; and/or (e) in case of sale of payment entitlements in the regional scheme, up to 10% of the value of each payment entitlement. In case of sale of payment entitlements with or without land to a farmer commencing an agricultural activity and in case of actual or anticipated inheritance of payment entitlements no retention shall apply.

Payment entitlements may be transferred at any time of the year. Member States shall define the region at the appropriate territorial level in accordance with objective criteria and in such a way as to ensure equal treatment between farmers and to avoid market and competition distortion.

In UK transfers can be made by sale or gift with land, by lease with land, by sale or gift without land, or through inheritance. Unless "force majeure" events, UK farmers can only transfer entitlements without land if they have already claimed payment against 80% of their total number of entitlements in one year, or voluntarily given up to the National Reserve all the entitlements they have not used in the first year of the SPS. About geographical restrictions applied to the transfer of entitlements, UK based farmers can own or lease entitlements anywhere in the UK, but entitlements established in Northern Ireland, Scotland, Wales or in any of the three English areas can only be used to claim a payment in that region or area. Transfers between farmers established in different Member States can only take through inheritance, but the entitlements concerned may only be used in the originating Member State. In UK, the action of transferring an entitlement does not alter its value. No deduction will be made from the value of entitlements that are transferred. The UK has decided not to apply the so-called "siphon" provisions for supplying the National Reserve, at least for the first year of the scheme.

In France the basic geographical limitation is the "departement" (subregional level). Transfers are allowed between farmers in a same "departement" and entitlements can only be used in that "departement". No retention on transfers is allowed for new farmers, or developing farmers, or familial transfers. The retention limit is 3% when transfer takes place with land, even in the case of a transfer with the totality of a farm. This limit becomes 10% when the transfer induces the creation a big farm (according to "departement" rules), and 50% when the transfer takes place without land.

Expected effects of decoupling on the land market

Decoupling could induce either an increase or a decrease of the shadow prices of the land according to the decoupling scheme implemented in the CAP. The basic point is the link between the payment entitlement and the concerned amount of area.

We can expect an increase when all previous subsidies -including the ones devoted to animal production- are equally shared among hectares of the land used for farming. In this case, the value provided by subsidies is entirely linked to the land factor. This should be the case when the decoupled subsidy turns into a single area payment, and consecutively the total payment is proportional to the land at disposal of the farmer.

We can expect a decrease when decoupled subsidies take a form close to a lumpsum transfer to the farmers. In this case, the factor value is shared between the land and the entitlement. The payment turns into a single farm payment which could not depend on the land at disposal of the farmer.

Globally speaking, the European regulation examination makes quite strong the link between the land and the decoupled subsidies. Without land, farmers can not obtain their payments. That was not the case before for animal producers, who could intensify their production by selling some land and receiving the same amount of money. From this point of view, less agricultural land should be abandoned to non agricultural use.

For crop farmers, selling of land should meet the same kind of constraints as before the reform, when access to entitlement means restrictive conditions to the land market access.

So the possible global results should be that the reform induces a decrease in the liquidity of the agricultural land market, because it is a kind of new constraint to exchange. And definitely this reform should involve a decrease in the exchanges from agricultural land toward non agricultural land.

But after years, the CAP should go on changing, and policy makers have to anticipate the possible impacts of the implementation of other decoupling schemes. We include in our analysis the estimate of impact of a CAP option which should reinforce the decoupling. In the light of what it comes before, we can now study the results concerning shadow prices for land from a European scale model, AROPAj.

5.2 Contribution of a European scale model (AROPAj)

The AROPAj model delivers a major role to land among quasi fixed factors, in addition to the role devoted to livestock capacities. Anyone of the farm groups cannot use area more than what it holds as resource. In other words, the amount of land at the disposal of a farm group is an upper limit under which land allocation is optimized by the model. The "individual" land resources are parameters of the model. The dual value related to the land availability provides the shadow price of the land when no other constraint involves the land resource. Land involvement in other constraints should lead to revisit the shadow price, and this occurs for the CAP reform designed by the Luxembourg agreement. The design of entitlements related to the land use would also interfere with the shadow price problem.

5.2.1 The shadow price of land

An important outcome provided by mathematical programming models is the sharing of the optimal value of the objective between the different quasi-fix factors. In the case of the AROPAj model, these factors are land and livestock. We focus on land, which could lead to interesting development when this factor intervents in different constraints depending on CAP reform options. Two kinds of results should be analyzed, separately when the Luxembourg agreement and the unique premium are implemented.

The theoretical base of the analysis comes with the envelope theorem. Let us consider the following maximization programme *(P)* :

$$\begin{aligned} max_x \quad & f(x,\alpha) \\ s.t. \quad & g(x,\alpha) \leq 0 \end{aligned}$$

Let us associate the multiplier vector λ to the m-dimension constraint $g(x,\alpha) \leq 0$. Let us denote by $\pi(\alpha)$ the function defined at the optimum which depends on α when it exists. This is the case when the functions f and g respect the "good" conditions of regularity. Let us denote by $x^*(\alpha)$ and $\lambda^*(\alpha)$ one solution of the programme when it exists. Let us consider a value of α for which the solution of the programme is not degenerated. The variation of the optimum can be estimated by the following expression :

$$\frac{\partial \pi}{\partial \alpha} = \frac{\partial f}{\alpha}(x^*(\alpha),\alpha) + \lambda^*(\alpha) \cdot \frac{\partial g}{\alpha}(x^*(\alpha),\alpha)$$

Practically this expression can be used for linear programming, keeping care of local problem of uniqueness of solutions which could arise particularly when the maximization programme includes integer variables.

Les us consider now the land resource S devoted to a farm group of the AROPAj model. When this parameter enters one CAP option through one or more added constraints included in the model, the estimate of the marginal variation of the optimal gross margin should take account of the associated multipliers. The de-coupling reform belongs to this category, when the land has to be split between crops and permanent area devoted to set-aside, with set-aside area greater than a threshold part of the land as a condition for payment of subsidy.

With the implementation of the Luxembourg agreement, land appears through different constraints (see table 2.2), namely the limit due to the total amount of land and a constraint related to subsidies granted only with respect to set-aside threshold. So the shadow price of the land becomes a two parts one. The first part is associated to the land use constraint. The second part delivers information about the relative importance of the political constraint.

Finally let us consider the full de-coupling option for CAP. We re-write the previous maximization programme *(P)* when splitting the variable vector x in two sub-sets y and s. The sub-vector s denotes the areas allocated to the different uses of the land S. We introduce the parameters μ and ν which respectively denote a vector of subsidies per hectare and a total amount of fixed subsidy. The set of constraints is split so that the limitation constraint on land is now explicit. The set of multipliers is now denoted by $\lambda = (\sigma, \tau)$ with σ is the multiplier related to the upper limit on land used for farming. The parameter vector α is re-written as (S, β). The programme *(P)* is re-written such as :

$$\begin{aligned} max_{s,y} \quad & f(s, y, \beta) + \mu \cdot s + \nu \\ s.t. \quad & \sum_j s_j \leq S \quad (\sigma) \\ & h(s, y, \beta) \leq 0 \quad (\tau) \end{aligned}$$

Let us consider the two options *(P_1)* and *(P_2)* in which first $\mu_j = d$ for any j and $\nu = 0$, second $\mu_j = 0$ for any j and $\nu > 0$. Let us consider the general case of a solution such as the limitation constraint on land holds (i.e. $\sum_j s_j = S$). Then the solutions of the two programmes *(P_1)* and *(P_2)* are identical. Following the envelope theorem, the estimates of the marginal variation of the objective function differ :

$$\frac{\partial \pi_1}{\partial S} = d + \sigma$$
$$\frac{\partial \pi_2}{\partial S} = \sigma$$

Let us consider the specific case of $\nu = d\ S$ leading us to the same value of the objective function at the optimum. We have now two equivalent options of full de-coupling. The first one is related to a single area payment proportional to the area but not depending on the land use. The second one could be related to a single farm payment, not depending on the land resource S.

5.2.2 Contribution of the land factor to the gross margin at the member state scale

As previously analyzed the gross margin delivered by the solution of the maximisation problem leads us to the estimate of the quasi-fixed factor pricing. Land value appears generally as strictly positive for all farm group models.[1]

[1]The search for optimal solutions does not completely succeed for a few farm groups, and the solver does not provide the dual solution even when we know that the optimal solution exists. Consecutively the solver delivers a

This dual value could be greater than the gross margin per hectare, when other resource constraints lead to negative value. This case occurs for some animal production –mainly the pig production– in several regions.

Table 5.1 provides average estimates of the gross margin per hectare, the subsidy per hectare, and the shadow price of the land, for member States of the EU-15 and for three CAP options which are the Agenda 2000, the Luxembourg agreement, and a full decoupling option. In these 3 options, livestock can move in a range of +/-15% of its initial value. The three CAP options are respectively denoted by $AG15$, $LX15$, $FD15$. In the two last CAP options, the premiums are based on the Agenda 2000 options when livestock remains equal to its initial value. In the Luxembourg agreement option, the estimate of the land shadow price takes account of the two dual values related to the land resource and to the set-aside constraint.

It is to be noticed that results delivered for the LX15 scenario are provided by the model with possible adjustment of the subsidies. That means, compared to the AG15 scenario, gross margins and correlatively land shadow prices related to the LX15 scenario could decrease. This is due to the fact that the LX15 option is based on historical subsidies (referred as the "AG00" scenario).

MS	Gross margin			Subsidies			Shadow price of land		
	AG15	LX15	FD15	AG15	LX15	FD15	AG15	LX15	FD15
belg	641	648	670	288	288	299	932	1011	1060
dani	810	813	833	320	320	322	782	868	859
deut	1126	1189	1148	321	373	320	762	922	852
ella	2136	2111	2113	655	614	614	1180	1526	1538
espa	615	613	628	306	299	303	632	672	734
fran	801	801	833	324	313	326	621	673	752
gbre	781	794	802	265	265	265	569	748	734
irla	647	651	653	294	284	284	554	656	637
ital	2349	2359	2370	357	355	355	792	883	884
luxe	958	985	999	270	272	272	492	623	628
nede	3748	3764	3768	297	296	297	3677	3805	3606
osto	1001	1012	1025	324	323	325	741	782	856
port	890	905	927	249	245	248	735	817	854
suom	840	840	845	204	199	199	398	480	493
sver	766	778	789	225	222	221	479	551	557
EU15	1025	1039	1047	311	315	310	712	811	827

Table 5.1: Comparison by MS between gross margin per ha, subsidy per ha and shadow price of land for the 3 CAP scenarios : "Agenda2000" (AG15), "Luxembourg agreement" (LX15) and "full decoupling" (FD15) - in the 3 scenarios, livestock adjustment is allowed and limited by the range of +/-15%.

The average European contribution of subsidy to the gross margin is on line with what is generally delivered by other authors (Tangerman 2006). The AROPAj model shows that this contribution

wrong null value of the land shadow price. Specific runs of the model were realized for slight change of one parameter –namely the adjustment rate of livestock on the range +/- 10^6 around the initial value of this parameter. In any case the model provides a dual solution and a positive shadow price of the land. Nevertheless it was too run-time costly to take into account of these additional runs. Tables and maps are based on estimates related to farm groups for which the land dual value is strictly positive, excluding farm groups for which the optimization software do not deliver the dual solution. This software problem occurs for 28 farm groups upon a total of 1074 farm groups for the 3 CAP scenarios.

	LX15		FD15	
MS	land	set-aside	land	subsidy
belg	812	198	761	299
dani	545	323	537	322
deut	540	382	532	320
ella	902	623	924	614
espa	489	184	431	303
fran	470	203	426	326
gbre	482	265	469	265
irla	373	283	353	284
ital	521	362	529	355
luxe	351	272	356	272
nede	3522	283	3309	297
osto	533	249	531	325
port	657	160	606	248
suom	261	203	294	199
sver	328	223	336	221
UE15	548	267	517	310

Table 5.2: Contribution of the land allocation constraint and of the set-aside constraint (Luxembourg agreement) or of the single area payment (full decoupling) to the shadow price of the land (€/ha).

is around 30%. In the same time, the net contribution of the land resource is about 70% considering the $AG15$ option. The variability of the last contribution is high, and some member States supply the case of high negative contribution provided by other limited factor like livestock. This is especially the case with Belgium, Netherland and Spain. [2]

When the CAP changes towards the $LX15$ option, the increase of the total shadow price of the land is checked for any member States, as a consequence of the fundamental change of the subsidy. Even if some re-coupled subsidies remain for animal production, a large part of subsidies move from the animal production to the land. Table 5.2 provides (two columns left) the respective contribution of the land disposal and of the set-aside constraint relative to the Luxembourg agreement implementation. The first term could be compared to the shadow price of the land in the $AG15$ option (in this option, set-aside is related to arable land but not to the total land resource). The increase of the shadow price of the land is clearly due to the set-aside implementation in the CAP reform designed by the Luxembourg agreement.

When the CAP turns into the FD15 option, the estimate of the shadow price related to the farmer's land resource strongly decreases compared to the estimates delivered by the AG15 and LX15 options when the subsidy is not linked to area. The entitlement based on historic subsidies devoted to area leads the land value to increase (as shown through the mathematical programme (P_2) of the section 5.2.1). When this entitlement is equal to the historical payment –the average individual payment or the regional payment are here equivalent– the total dual value of the land is higher than it is when the two other CAP option are taken into consideration (see the two columns right of table 5.2).

All these results are summarized at the European scale on figure 5.1.

[2] We can suspect problems of underestimation of production prices for pig and poultry.

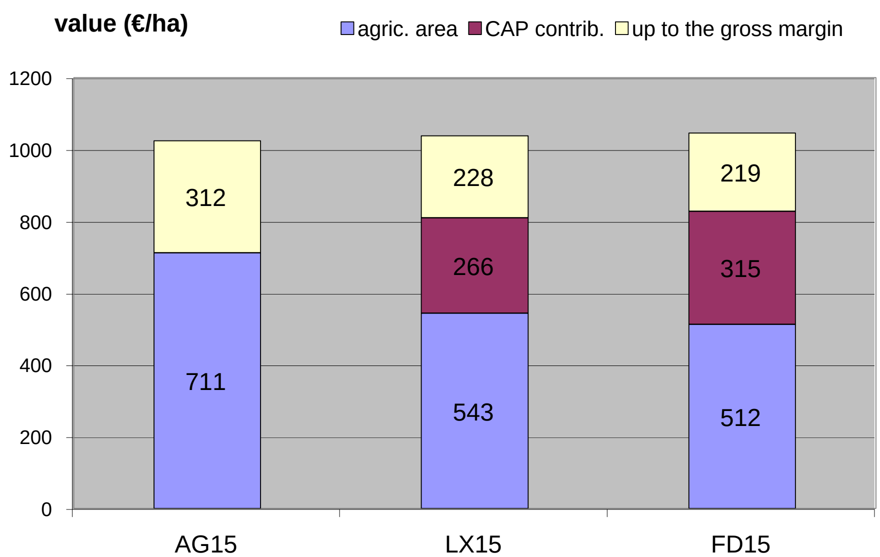


Figure 5.1: Contribution of the surface constraint and of the CAP rules explicitly linked with the total land at farmer's disposal, to the gross margin (results provided by the AROPAj model for 3 CAP options; 28 farm groups for which GAMS does not provide the dual solution are excluded in the estimate.)

5.2.3 Regional change in the shadow prices of land

The estimates provided at the member State scale could hide some strong local disparities. We previously show that the change of land shadow price could strongly depend on the specialization (crops or livestock). This specialization appears better at the regional scale than at the national scale. So the region scale is more appropriate for the analysis when we intend to correlate the impacts of change in CAP and the agricultural specialization.

Figures 5.2 and 5.3 show the gross margin by hectare and the shadow price of land by region within 3 scenarios: AG15, LX15 and FD15.

Map "No support" on Figure 5.3 shows that, not surprisingly, the shadow price of land is decreasing everywhere, compared to other scenarios. This result highlights the fact that subsidies contribute to the modification of land price. Direct subsidies clearly have a strong effect not only on the directly concerned productions but also on the production factors.

When the policy involves a unique regional premium (so called the full decoupling scheme in this paper) for which the amount is determined so that the EAFFG budget is kept unchanged, the shadow price of the land is higher compared to the one arising from the Agenda 2000 scenario (Figure 5.3). Here the subsidy is entirely devoted to the land factor whereas a part of the support is devoted to animals and milk in the Agenda 2000 scenario. The Luxembourg case is an intermediate one between the Agenda 2000 and the "full decoupling" scenario. The reform has different impacts according to Member States. When some animal aids are recoupled (e.g., in France or Spain), the shadow price of the land is lower than in the "full decoupling" scenario and higher than in the Agenda 2000 scenario. When the totality of the aids is decoupled (e.g., in Germany or Italy), the shadow price is also lower because some constraints remain on land use (set-aside, and in Germany especially pasture) in the Luxembourg reform compared to the "full decoupling" scenario. However in Germany, Figure 5.3 shows the shadow price is higher in the Luxembourg scenario than in the "full decoupling" scenario (FD15). This is due to the specific scheme chosen by Germany concerning

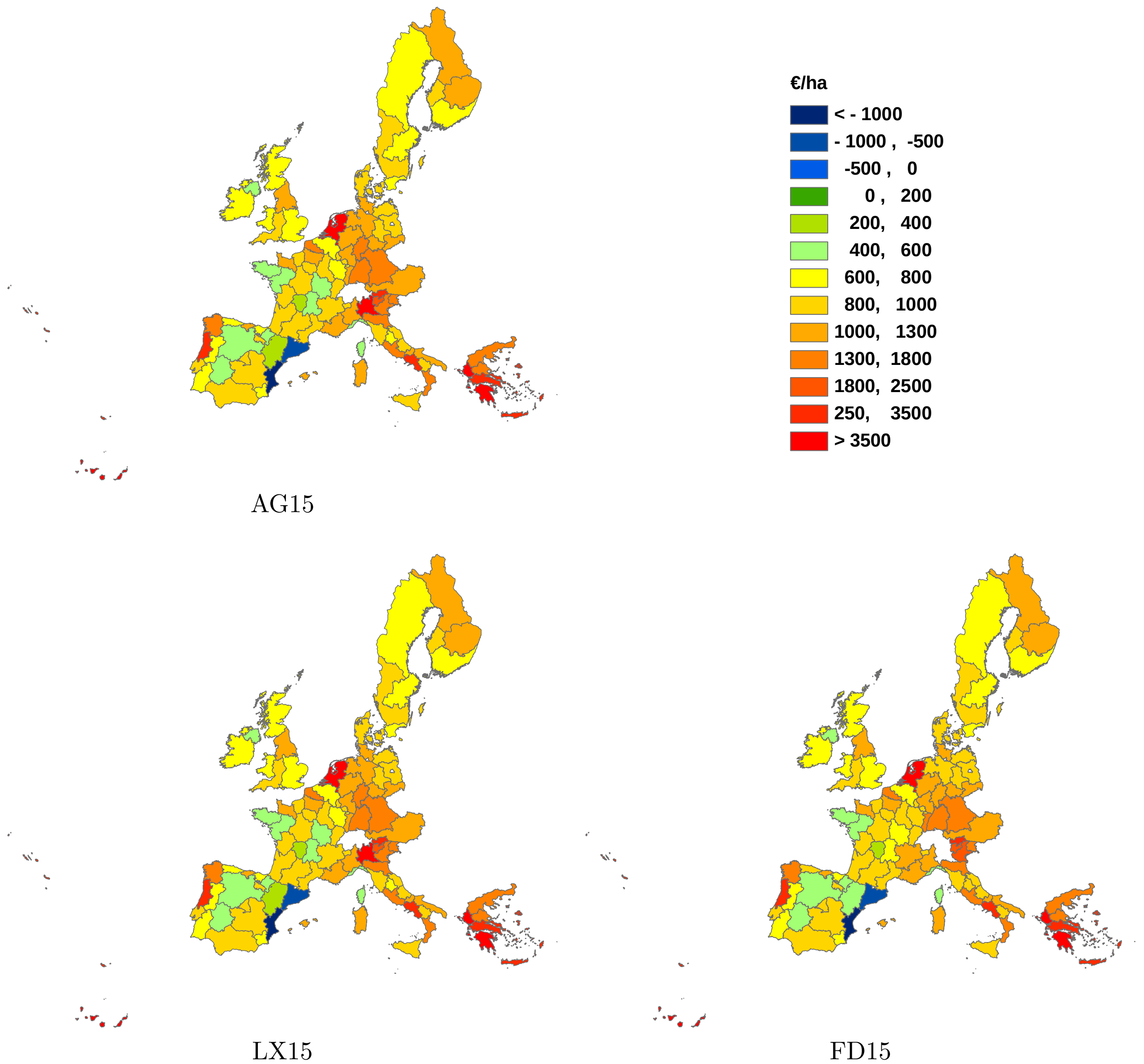


Figure 5.2: Gross margins by hectare with the scenarios AG15, LX15 and FD15, for land and activities covered by the AROPAj model.

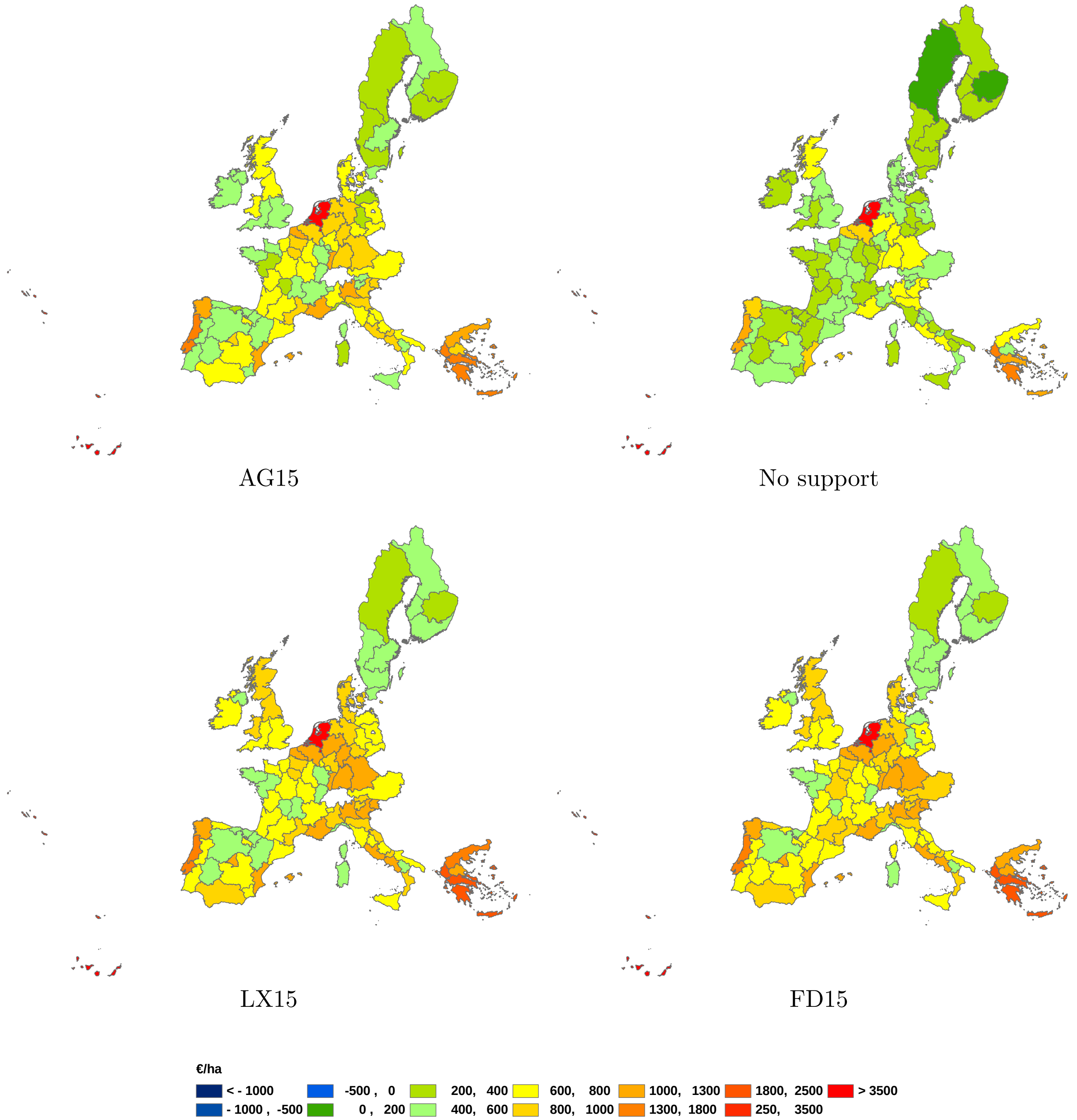


Figure 5.3: Shadow prices of land within the scenarios AG15, LX15, FD15, and in the case of a "no support" policy, for land and activities covered by the AROPAj model.

pastures. This activity receives a payment by hectare which differs from the arable land payment. It induces an increase in the European budget for Germany (+743 millions €, +15.6%) which induces in turn an increase in shadow price of land.

When the agricultural policy includes a single area payment and coupled subsidies, only the single area payment and a part of the coupled subsidies devoted to crop area contribute to the land value.

Consequently, land value is higher when the farm production is based on crops, and lower when the farm production is based on livestock. Map "LX15" shows clearly this point for instance in France and Spain. In those both MS, some animal and crop subsidies remain indeed partly coupled, and the subsidy remaining coupled to the animal production does not induce any increase of land value. When animal subsidies remain partly coupled, the increase of the land value compared to the AG15 scenario is lower in the LX15 scenario than in the FD15 scenario in which the totality of the entitlement is transfered to the land value.

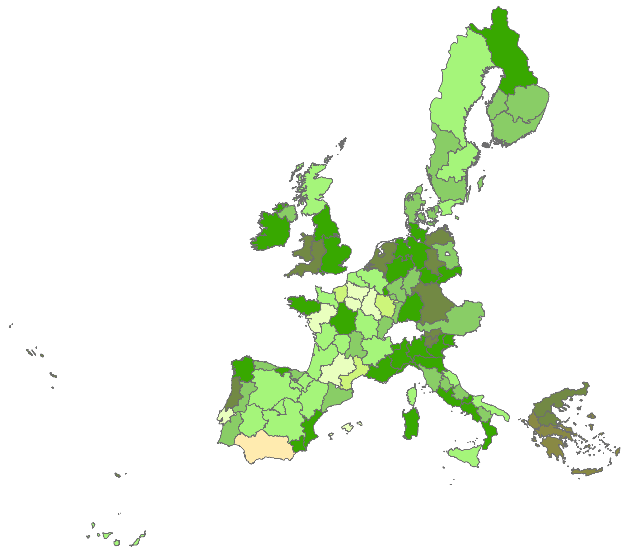
The maps 5.4 and 5.5 describe the variation of the shadow price of the land at the regional scale when the CAP respectively turns from the reference scenario (AG00) into the Luxembourg agreement implmentation (LX15) and into a single area payment keeping unchanged the regional amount of subsidy (FD15). The combined impact of the livestock adjustment and of the new CAP option leads to strong differentials of the shadow price from one region to another, locally much more important than the average European differentials which are respectively around 13% and 15.5% of the AG00 shadow price.

Conclusion

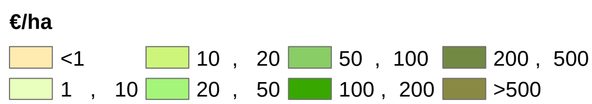
To conclude, we have shown in what extent agricultural policies may induce changes on land value provided by farming. The results should be considered taking account the partial covering of the European agriculture by the AROPAj model used in the analysis. Not all agricultural activities are taken into account, excluding permanent crops. And the farm accounting data network (FADN) on which the model is based does imperfectly cover all the European farmers, partly excluding the part-time farming systems in several member States. The last general consideration comes with the fact that the AROPAj model focuses on a few fixed factors –land and livestock– and other farming system constraints are related to limitations introduced by the CAP (i.e. set-aside).

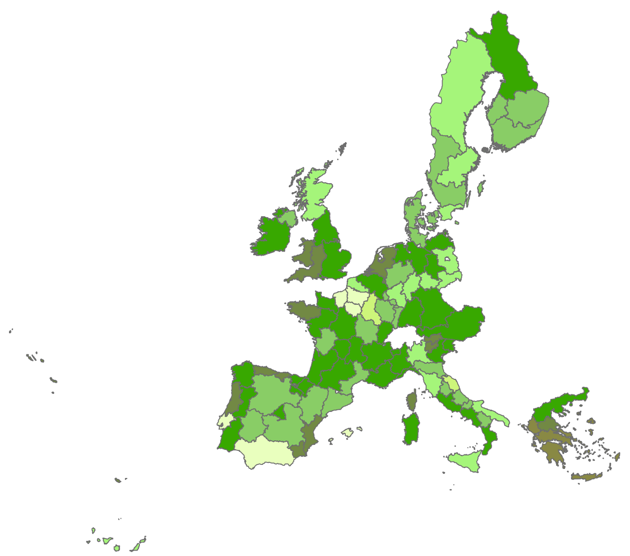
Our analysis aims to deliver an estimate of the change of land shadow price at the regional scale. It should be noticed that the structural change in subsidy payment would be of high consideration for the evolution of agricultural land price. In our modelling approach, we implement a payment seen like a single area payment. That means initial subsidies devoted to animal productions and now decoupled are linked to the land. The implementation of the Luxembourg agreement takes account of partial re-coupling of some subsidies (devoted to crops or animal productions) depending of the choice from member States. We take account of contraints involving set-aside (for all member States) and of incentives in favour of pasture (in Germany). We take account of the individual or regional design of the entitlement. This "Luxembourg agreement" option is denoted by LX15. The other option analysed in the paper is a generalized single area payment scheme in which the historical amount of subsidy is transformed in one unique payment per hectare (this option so-called "full decoupling" is denoted by FD15). In this last case, the optimal solution of the linear programming models does not depend of the level of the entitlement (except the gross margin –obviously– and the shadow price of the land).

In order to estimate the impacts of livstock adjustment and to deliver more realistic results, we let the farming systems adpating animal production when the "animal capital" is allowed to change



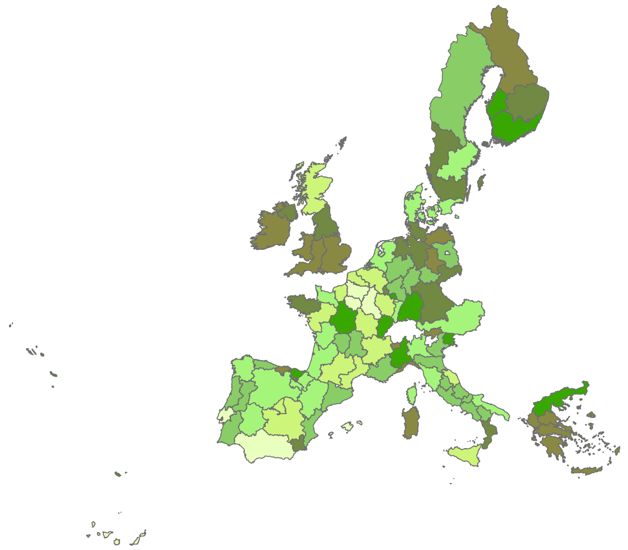
LX15 compared to AG00



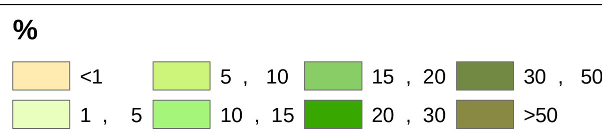


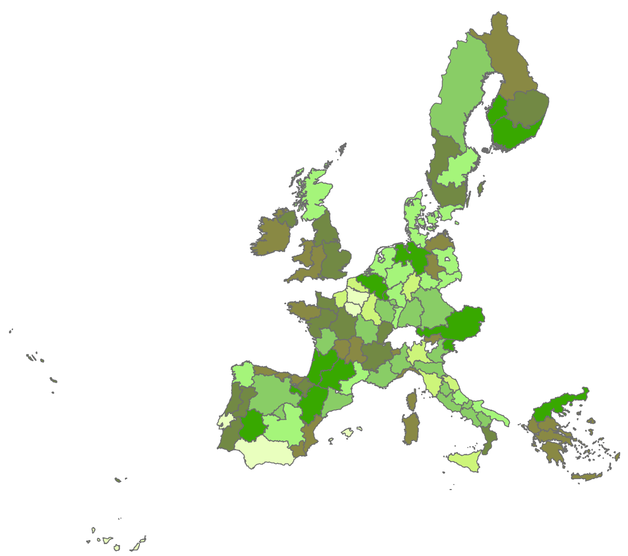
FD15 compared to AG00

Figure 5.4: Regional gap of the shadow price of land when CAP turns into the Luxembourg agreement option or into a full decoupling option (€/ha).



LX15 compared to AG00





FD15 compared to AG00

Figure 5.5: Regional gap of the shadow price of land when CAP turns into the Luxembourg agreement option or into a full decoupling option (% of the AG00 regional shadow price).

inside a range of +/-15% of the reference level estimated from the FADN.

Inside this framework, we show that the land shadow price should significantly increase with an average European gap of around 100 €per hectare (12%). But variation should highly differ from one member State to another, and more highly from one region to another. Maps and figures are provided in the paper. When the FD15 option replaces the LX15 option, the gap is slighly higher at the European scale, with some more significant variations at the national and regional scales.

In this static analysis, the LX15 and FD15 options lead to entitlements transfered to land value. However, from the study on rules devoted to the transferability of land and entitlements in the Luxembourg agreement, entitlements seem not often being fully transfered with land. When there is a transfer of land, the buyer will not receive the total amount of the entitlements linked to that land, a more or less great part will be cut off. However the land value estimated in this paper should be considered by the seller as far as it is the value the land brings him.

In any case, it is complicated to use these results in order to assess the impacts on land market. Land market first is very controlled by Member States. Second pedo-climatic and soil quality characteristics make very large the range of values of the land. Third farmers could meet convex costs related to transport due to plots a long way from the farm center. On this point the contribution of the paper could be summarized by the permanence and likely the reinforcement of the distorsion brought by the CAP on the land market. This is due to the fact that all payments would be more and more only related to the land. The key point should be now the real implementation of transferability rules.

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6 Single farm payment, modulation and dual values of land: a theoretical approach

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Abstract

This paper introduces the theoretical grounds for interpreting the dual values of land obtained when the PROMAPA.G model is applied to analyze the impact of decoupling on Spanish agriculture.

6.1 Introduction

PROMAPA.G model results associate steep declines in the dual values of land with the decoupling of direct crop payments implemented under the new CAP reform. The present paper discusses a theoretical analysis of the reasons underlying such declines to provide a rigorous interpretation of how new dual values of land are generated in payment decoupling scenarios.

The sections below describe, first, the formulation of single payments and modulation under PROMAPA.G for the various farm types, and then the dual formulation for analyzing land dual values.

6.2 Single farm payment and modulation modelling

Let **X** be a vector with 2n components having variables X_{hi} representing the hectares of crop i on land type h in a given farm type. The following variables are likewise defined:

XES = ha of land eligible for the single payment in the simulated scenario.

XE = area of eligible land, in ha, generating the single farm payment.

XP1 = sum in €in the first payment bracket, exempt from modulation measures (regarded to be less than or equal to 5000 €).

XP2 = sum in €in the second payment bracket, subject to a modulation discount, assumed to be 5%.

The right hand side and coefficients are defined as follows:

A_h= ha of land type h (h=1: non-irrigated; h=2: irrigated) on the farm

AER = ha of land on the holding eligible for the single payment in the reference period.

a_{hi}= coupled payment per ha in €for crop i on land type h.

d = payment entitlement per ha in €.

Taking M_{hi} (**X**) as the average gross margin of crop i on land type h, and distinguishing between eligible (i = 1,2, . . . , n_1) and non-eligible (i = n_1+1, n_1+2, . . . , n) crops, the model that incorporates the specific characteristics of the single farm payment and modulation can be summarized in the following expressions[1]:

(1)	$\max : \sum_{h=1}^{2} \sum_{i=1}^{n} M_{hi}(X)X_{hi} + XP1 + 0,95 * XP2$	subject to:	
(2)	$\sum_{i=1}^{n} X_{hi}$	$\leq$ A_h(h = 1, 2)	(λ_h)
(3)	$\sum_{h=1}^{2} \sum_{i=n_1+1}^{n} X_{hi} + XES$	$\leq$ A_1 + A_2	(λ_{12})
(4)	XE	$\leq$ AER	(λ_{ER})
(5)	$XE - XES$	$\leq$ 0	(λ_{ES})
(6)	$-\sum_{h=1}^{2} \sum_{i=1}^{n_1} a_{hi} * X_{hi} - d * XE + XP1 + XP2$	$\leq$ 0	(λ_{TP})
(7)	$XP1$	$\leq$ 5000	(λ_{MP})
	$X_{hi}, XES, XE, XP1 > 0, XP2 \geq 0$		

The function to be maximized (equation (1)) is the gross margin, including coupled and decoupled payments, where the terms M_{hi}(**X**)are quadratic functions.

[1]While not exactly the same, this formulation is based on that described by Henry de Frahan et al. (2006).

Equation (2) limits the cultivated area on land type h to the area of this land type on the holding. Dual values of land are associated with this equation.

Equation (3), which defines the eligible area under the simulated scenario, is formulated in such a way that land that is not farmed is included in the eligible area.

Equations (4) and (5) define the eligible area that serves as a basis for computing the single payment in the simulated year. This area is the lesser of the eligible area in the reference period (AER) and the eligible area in the simulated year (XES).

Equation (6) defines the total sum of (coupled and decoupled) payments, XP1+XP2, in the simulated year.

Finally, equation (7) limits the sum of payments not subject to modulation measures.

6.3 Dual relationships

The notation used for the dual of restrictions (2) to (7), shown at the right of each expression, are defined , at the optimum solution, as follows:

λ_h= dual value of land type h.

λ_{12} = decline in single farm payment per ha less of eligible land in the simulated year.

λ_{ER}= decline in single farm payment per ha less of eligible land in the reference period.

λ_{ES}= same meaning as λ_{12}.

λ_{TP}= earnings per additional euro of (coupled or decoupled) payment.

λ_{MP}= earnings per euro of increase in the sum of payments exempt from modulation measures.

Taking $m_{hi}\left(\bar{X}\right)$, in turn, to be the marginal gross margin for crop i on land type h under optimal solution $\bar{X}$, the dual system of equations associated with model (1)-(7) is:

(8)	$m_{hi}\left(\bar{X}\right) + a_{hi} * \lambda_{TP} - \lambda_h$	$= 0$	$\forall\left(i, h/i = 1, 2, ...n_1\right)$
(9)	$m_{hi}\left(\bar{X}\right) - \lambda_h - \lambda_{12}$	$= 0$	$\forall\left(i, h/i = n_1 + 1, n_1 + 2, ..., n\right)$
(10)	$\lambda_{12} - \lambda_{ES}$	$= 0$	
(11)	$\lambda_{ER} + \lambda_{ES} - d * \lambda_{TP}$	$= 0$	
(12)	$\lambda_{TP} + \lambda_{MP}$	$= 1$	
(13)	λ_{TP}	$\geq$ 0.95	
	$\lambda_h, \lambda_{MP}, \lambda_{12}, \lambda_{ER}, \lambda_{ES}, \geq 0, \lambda_{TP} > 0$		

The four cases that can be deduced from system (1)-(7) and the above equations generate different dual values of land, summarized in Table 6.1.

Since in most farm types the dual value of land is established on the basis of the expressions in equation (8), the decline is due to the drop in coupled payments. Where the dual value of land is generated from the expressions in equation (9), the decline is due to λ_{12}, associated with the payment entitlement per ha and likewise an outcome of lower coupled payments.

6.4 Conclusions

The new CAP reform occasions a substantial decline in the dual values of land. This decrease is due to the steep drop in coupled payments, which may affect the decline in different ways depending on the farm. In all cases, any comparison of the dual values of land obtained after the new reform to those obtained in the context of Agenda 2000 must take account of the payment entitlements

	$\lambda_{ES} = 0, \quad \lambda_{ER} \neq 0$ Elegible area for the reference period smaller than for simulation year	$\lambda_{ES} \neq 0, \quad \lambda_{ER} = 0$ Elegible area for the reference period greater than for simulation year
Total Payments < 5000 € $\lambda_{MP} = 0$	$\lambda_{MP} = 0$ $\lambda_{TP} = 1$ $\lambda_{ES} = 0$ $\lambda_{ER} = d$ $\lambda_{12} = 0$ λ_h does not depend on SFP and neither on modulation.	$\lambda_{MP} = 0$ $\lambda_{TP} = 1$ $\lambda_{ES} = d$ $\lambda_{ER} = 0$ $\lambda_{12} = d$ λ_h depends on the payment entitlement per ha (d) if the dual value of land is established on the basis of non-eligible crops.
Total Payments > 5000 € $\lambda_{MP} \neq 0$	$\lambda_{MP} = 0.05$ $\lambda_{TP} = 0.95$ $\lambda_{ES} = 0$ $\lambda_{ER} = 0.95d$ $\lambda_{12} = 0$ λ_h depends on λ_{TP} if the dual value of land is established on the basis of eligible crops.	$\lambda_{MP} = 0.05$ $\lambda_{TP} = 0.95$ $\lambda_{ES} = 0.95d$ $\lambda_{ER} = 0$ $\lambda_{12} = 0.95d$ λ_h depends on λ_{TP} or λ_{12} if the dual value of land is established on the basis of eligible or non-eligible crops

Table 6.1: Generation of dual values of land. Possible cases

per ha appearing with decoupled payments, although such entitlements may have a market without necessarily being associated with the land.

The analysis of the impact of different decoupling options on Spanish agriculture conducted by Júdez et al. (2006) for WP5 delivery D7 shows that both nation-wide and for all regions: when the degree of decoupling increases, the dual value of land (associated with the revenues per hectare deriving from land use in farming) declines, while the entitlement payment per hectare (linked to decoupled payments) rises.

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7 Quantitative assessment of the impacts of agricultural policy on the shadow prices for land and land trade

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Abstract

In this paper, the impacts of two implementation options of the 2003 CAP Reform on the shadow prices for land and the land market are analysed : the National Implementation in Germany and the historical model. The analysis is conducted with the farm group model EU-FARMIS. It is shown that the National Implementation in Germany yields an increase of dual values for land, especially for grassland while the implementation of a scheme based on historical, farm individual entitlements leads to a sharp decrease of the dual values for land. Interpreting these dual values as land rents, the National Implementation leads to significantly higher land rents than the scheme based on farm individual entitlement levels. It was found that compared to Agenda 2000, in both scenarios grazing livestock farms tend to rent in more land while arable cropping and pig and poultry farms rent out land.

7.1 Introduction

In this paper, the impacts of the 2003 CAP Reform in Germany on the shadow prices for land and the land market are analysed. The results are obtained using the farm group model EU-FARMIS. The results of the impact assessment of the National Implementation are compared to a scenario based on the continuation of Agenda 2000. First, general model characteristics and the modelling approach concerning the land market are sketched. More details are given in the model description in Delivery 2. Afterwards, scenarios and respective results are described.

7.2 Implementation of the land market in EU-FARMIS

The transfer of land is implemented in the form of a rental market. All farm groups in each trading region are optimised simultaneously. Each farm group can rent in or rent out both arable and grassland. Grassland and arable land are treated as homogeneous goods. Transaction costs resulting from transport distances are not considered. As trading regions are quite large this seems to be problematic. However, it has to be kept in mind that not single farms, but farm groups are analysed. Assuming that farms are distributed in space, the size of the trading regions is less problematic. The land market is controlled by four equations.

The first three guarantee that in each farm land use does not exceed the sum of own land and rented land [1]. In the forth equation it is ensured that the sum of all rental activities in each region equals zero.· Additionally, a variable was introduced to allow for the conversion of arable land to grassland, but not vice versa. The dual values for the equations restricting the use of arable and grassland are interpreted as regional rental prices. The model does not distinguish between land and entitlement value. It is assumed that entitlements are transferred together with land.

The model is calibrated to the observed average rental prices of both arable and grassland in each region. Marginal values for land in the base year, therefore, cannot be used for interpretation. In the scenarios however, marginal values develop depending on policy and price changes.

It has to be emphasised that land trade in EU-FARMIS is a stylised way of modelling the land market, based on the changes of the marginal rate of return of land under different policy options. Further extensions to account for different soil qualities and the farm-field distances can improve the modelling, but it should be acknowledged that the land market is very complex and not all aspects can be implemented in this type of model. Therefore, the results should not be take literally but contribute to the understanding of cause and effect

7.3 Scenarios

Three scenarios are analysed: the continuation of Agenda 2000 policies till the year 2013, the National Implementation of the 2003 CAP Reform in Germany and a scheme where entitlements are determined based on historical farm individual references. Scenarios are chosen from those analysed in Delivery 7.

7.3.1 Reference scenario: Agenda 2000 (2013)

This scenario represents the situation in the year 2013 that would have been realised if no changes had been made to the Agenda 2000 package. Compared to the base year 2002, this implies constant

[1] Total land use and use of both arable land and grassland is controlled in one equation each. See Bertelsmeier (2005).

agricultural policies, with the exception of the milk market reform, starting in 2004. Direct payments continue to stay coupled to production. Part of the milk price reduction is compensated by milk premiums. Milk quota is extended by 1.5%.

7.3.2 SFP_nat: National Implementation of decoupling in Germany (2013)

Germany introduced a so-called dynamic hybrid model. In a transition period from 2005 until 2012, farms receive a regional area-based payment and a farm individual top-up payment. The payments will be fully decoupled and entitlements will be transferable. In the analysis only the final step of the implementation scheme (2013), where unified regional area-based payments are granted, is considered.

7.3.3 SFP_hist: SFP based on historical references

Direct payments are fully decoupled. Entitlement levels vary among farms as they are determined based on the historic references of individual farms. Target year is 2013.

7.3.4 Price scenarios

Price projections were realised in cooperation with IDEMA, another project of the 6^{th} Framework Programme. They are based on ESIM estimates - a partial equilibrium model developed by the University of Goettingen (Balkhausen and Banse 2006). Price projections for sugar beets are based on own calculations. Projections are given in Table 7.1.

	Change to Agenda 2000 (2013)	
	SFP_nat	SFP_hist
	%	%
Wheat	4.0	4.4
Rye	0.0	0.0
Barley	6.5	7.0
Oats	7.2	8.0
Grainmaize	7.1	7.7
Rape	2.7	2.9
Other oilseeds	2.4	2.6
Potatoes	10.7	11.2
Sugarbeets[1]	-39.7	-39.7
Milk	-4.7	-4.2
Beef	11.8	16.9
Pork	2.0	2.3
Sheep meat	25.9	32.3
Eggs	2.2	2.4
Poultry meat	2.0	2.2

1) Average price reduction for A/B sugar beets (16% sugar content)
Price projections for sugarbeets are not based on ESIM projections
Source: ESIM/IDEMA

Table 7.1: Price scenario

7.4 Impact on the shadow prices for land and on the land market

7.4.1 National Implementation

In Tables 7.2 and 7.3, the assessed impacts of the National Implementation on the shadow prices for grassland and arable land are given. The CAP reform in Germany has a significant impact on the shadow prices for land. In comparison to the reference, the shadow prices for grassland increase dramatically while the increases for arable land are less pronounced. As the assumptions about the development of yields and technical progress are the same in both scenarios, the discrepancies are caused by differences of the policy framework and in the price projections. The increase of shadow values can be explained by looking at the German implementation scheme. Germany opted for the regional implementation, and correspondingly farmers in each region receive uniform entitlements for the entire agricultural area. As the entire available agricultural land is needed for the activation of entitlements; direct payments are captured in the dual values of land. In the case of arable land this does not make a major difference compared to Agenda 2000 because most arable crops were eligible for coupled area payments as well. However, in the case of grassland it does, because grassland was not favoured by direct payments before.

	Shadow costs of arable land		
	Agenda	SFP_nat	Change (abs)
	€/ha	€/ha	€/ha
States (German names)			
Schleswig-Holstein	382.6	430.5	47.8
Niedersachsen	313.6	367.5	53.9
Nordrhein-Westfalen	364.4	429.8	65.4
Hessen	219.7	243.9	24.1
Rheinland-Pfalz	176.5	237.1	60.6
Baden-Wurttemberg	184.1	238.2	54.1
Bayern	208.2	258.4	50.1
Brandenburg	82.5	149.9	67.4
Mecklenburg-Vorpommern	157.4	217.0	59.6
Sachsen	122.7	197.2	74.5
Sachsen-Anhalt	169.0	205.8	36.9
Thueringen	135.2	216.4	81.3

Source: FARMIS-EU, 2006 INLB-EU-DG-AGRI/G.3

Table 7.2: Impact of the National Implementation in Germany on the shadow values of arable land

7.4.2 SFP based on historical references

In the case of a historical implementation, shadow prices for both grassland and arable land drop dramatically (see Table 7.4 and 7.5). In most German Federal States, the dual values even become zero. The reason is the following: in the historical implementation the number of entitlements is slightly lower than the amount of eligible land[2] and the level of entitlements differs among farms. As high level entitlements are activated first; for marginal land only low level entitlements will be

[2] In the historical implementation entitlements are not granted for land where in the reference period starch potatoes were grown but the land will be eligible for the activation of entitlements. However, over time, the amount of agricultural land will decrease because some of the land will be used for non-agricultural purposes. Therefore, in the long run, the number of entitlements will be at least equal to the amount of eligible land.

	Shadow costs of grassland		
	Agenda	SFP_nat	Change (abs)
	€/ha	€/ha	€/ha
States (German names)			
Schleswig-Holstein	194.8	378.5	183.6
Niedersachsen	207.4	367.5	160.1
Nordrhein-Westfalen	253.8	429.8	176.0
Hessen	60.0	243.9	183.8
Rheinland-Pfalz	67.1	237.1	170.0
Baden-Wurttemberg	64.2	238.2	174.0
Bayern	31.4	258.4	226.9
Brandenburg	36.6	149.9	113.3
Mecklenburg-Vorpommern	48.8	217.0	168.2
Sachsen	30.3	197.2	166.9
Sachsen-Anhalt	43.2	205.8	162.6
Thueringen	41.7	216.4	174.7

Source: FARMIS-EU, 2006 INLB-EU-DG-AGRI/G.3

Table 7.3: Impact of the National Implementation in Germany of the shadow values of grassland

available and consequently only a relatively small part of direct payments is captured in the dual values for land. As dual values are an indicator for land rents, we conclude that the National Implementation in Germany will induce much higher land rental prices than a scheme based on the historical implementation. This is supported by the findings of Courleux (2006).

However, it has to be emphasised that the results represent extreme outcomes. Due to factors like the reduction of total eligible land over time and the possibility of tenants to retain their entitlements when the tenancy agreement ends, it is unlikely that negotiations between tenants and land owners will lead to such extreme price changes. However, it is still convincing that a flat rate payment leads, in comparison to farm individual entitlement levels, to higher rental values for land.

Looking at the dual values for grassland and arable land it is striking that in the decoupling scenarios these are often equal. This effect is caused by the possibility to convert arable land into grassland. Due to decoupling, the dual values for grassland increase more than those of arable land. This leads to a conversion of arable land to grassland till duals are equal.

The assessment of the reform's impact on the land market is very difficult because factors important in the context of the land market, such as structural change, soil quality and transaction costs are not considered in the model. Land trade is only driven by the impact of the reform on farm individual competitiveness. Therefore, only a comparatively low amount of land trade takes place. In Figure 7.1 the reform's impact on land rental activities of farm types is shown. Grazing livestock farms tend to rent in more land while arable cropping and pig and poultry farms rent out land. The reason for this development is that the CAP reform improves the attractiveness of extensive grassland and extensive fodder production and both are realized, especially in grazing livestock farms. The attractiveness increases because on the one hand grassland is now eligible for direct payments and on the other hand the need for roughage fodder decreased due to a drop of animal production. Hence, farms tend to increase low input activities, which meet the cross-compliance restrictions.

	Shadow costs of arable land		
	Agenda	SFP_hist	Change (abs)
	€/ha	€/ha	€/ha
States (German names)			
Schleswig-Holstein	382.6	171.3	-211.3
Niedersachsen	313.6	56.0	-257.6
Nordrhein-Westfalen	364.4	116.3	-248.1
Hessen	219.7	0.0	-219.7
Rheinland-Pfalz	176.5	0.0	-176.5
Baden-Wurttemberg	184.1	0.0	-184.1
Bayern	208.2	0.0	-208.2
Brandenburg	82.5	0.0	-82.5
Mecklenburg-Vorpommern	157.4	0.0	-157.4
Sachsen	122.7	0.0	-122.7
Sachsen-Anhalt	169.0	0.0	-169.0
Thueringen	135.2	0.0	-135.2

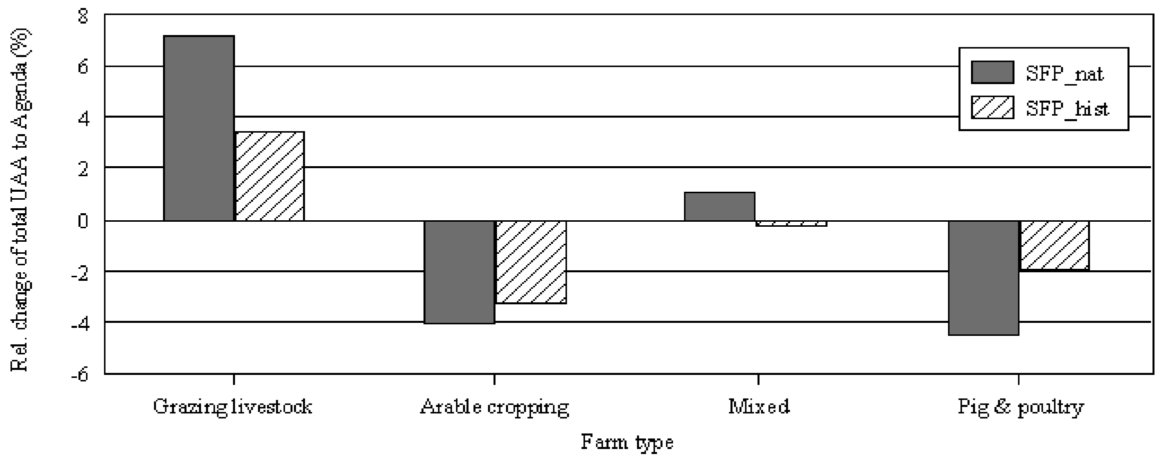
Source: FARMIS-EU, 2006 INLB-EU-DG-AGRI/G.3

Table 7.4: Impact of the historical implementation on the shadow values of arable land

	Shadow costs of grassland		
	Agenda	SFP_hist	Change (abs)
	€/ha	€/ha	€/ha
States (German names)			
Schleswig-Holstein	194.8	101.4	-93.4
Niedersachsen	207.4	56.0	-151.4
Nordrhein-Westfalen	253.8	116.3	-137.5
Hessen	60.0	0.0	-60.0
Rheinland-Pfalz	67.1	0.0	-67.1
Baden-Wurttemberg	64.2	0.0	-64.2
Bayern	31.4	0.0	-31.4
Brandenburg	36.6	0.0	-36.6
Mecklenburg-Vorpommern	48.8	0.0	-48.8
Sachsen	30.3	0.0	-30.3
Sachsen-Anhalt	43.2	0.0	-43.2
Thueringen	41.7	0.0	-41.7

Source: FARMIS-EU, 2006 INLB-EU-DG-AGRI/G.3

Table 7.5: Impact of the historical implementation on the shadow values of grassland



Source: FARMIS-EU, 2006 INLB-EU-DG-AGRI/G.3.

Figure 7.1: Relative change of the total amount of land on farm type level

7.5 Summary and conclusions

In this paper two alternative schemes for the implementation of the 2003 CAP Reform are analysed with respect to their impact on the shadow prices for land and the land market: the National Implementation of 2003 CAP Reform in Germany and a scenario based on historical farm individual references. Reference is the continuation of Agenda 2000.

It is shown that the National Implementation in Germany yields an increase of dual values for land, especially for grassland. In contrast, the implementation scheme based on historical, farm individual entitlement leads to a sharp decrease of land dual values. Interpreting dual values for land as land rents, the National Implementation leads to significantly higher land rents than the scheme based on farm individual entitlement levels.

Concerning the impact on land trade, it was found that compared to Agenda 2000, in both scenarios grazing livestock farms tend to rent in more land while arable cropping and pig and poultry farms rent out land. This is mainly caused by the increase of economic attractiveness of extensive activities like extensive grassland and other arable fodder crops which are mainly realized by grazing livestock farms.

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8 The single farm payment and the value of the land in Italy

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Abstract

The Italian agriculture is characterized by different specialized sectors (i.e. milk production, grazing cattle, arable crops, horticulture, vineyards, orchards) concentrated in homogenous areas of each region. The different use of the soil produces different market value of the land. In a situation characterized by a jeopardized agricultural specialization and by a relevant variability of the land values, the question that arises is the following: in which measure can the decoupling affect the value of the land changing the modalities of the public intervention and the farmer production plan? This study aims to assess the impact of the Fishler's reform on the marginal value of the land with respect the prospected new productive organization of the Italian agriculture. The evaluation is carried out by adopting a Positive Mathematical Programming (PMP) model merging the FADN information with the administrative information of the Italian IACS database. The results achieved show a generalized strong reduction in the marginal value of the land in consequence to the subsidies decoupling. The explanation of such result is twofold. First, the decoupling reduces the part of the land value incorporated in the crop production before the application of the Reg. EU 1782/2003. The value of the aid is transferred from the specific productions to the entitlements owned by farmers. Secondary, the new allocation of the farm activities that increases the number of hectares harvested with fodder crops and the "good practice area" reduces the average specific profitability of the land, reflecting it inside the marginal value of the land.

8.1 The land value determinants in Italy

The value of the land in Italy is characterised by a high difference at territorial level according to the quality of the land and the agricultural vocation of the different rural areas. In general, the plain zones, more agriculture-oriented, have values of the land higher than the other zones of mountain. This affirmation is true in general, but if we look at the specificity of the agriculture in the different geographical areas of Italy, we will find mountain zones, like Trentino-Alto Adige region, where the value of the land is very high due to the quality of the land particularly convenient for cultivating vineyard and to the scarce availability of agricultural areas for such production. The value of the land varies, area by area, in relation to the following elements:

1. the quality of soil;
2. the structural asset on the agricultural area;
3. the different agricultural production options;
4. the intensiveextensive use of technology;
5. the presence of public regulation constraints.

The quality of soil is a crucial variable that influences the price of the land in a certain area. The quality of the land is composed by the level of fertility, the chemical and physical components of the soil. All this elements are important to define the main agricultural vocation of the soil and the different agricultural possibilities in harvesting it. The degree of fertility has important effects both in term of crop options and in term of production costs. A land with high degree of fertility requires less intensive use of fertilizers and, in certain cases, of water. The bio-physical properties of the soil defines also the main vocation of the land, leading to constitute homogeneous agrarian regions where one type of production is generally produced in (wine in Trentino, fruits in Romagna, ...).

The structural assets are associated to all the investments executed on an agricultural soil in order to allow a better workability and a more efficient use of the land. The canals of irrigation are an example of investment adopted to transfer water from a basin to the various agricultural parcels. To ameliorate the use of the land by removing stones on the surfaces of the soil is another example of structural investment on the agricultural soil. Furthermore, the smoothing of the soil in order to permit a better irrigation of the soil is a third possible investment. All the cost sustained for improving the workability of the agricultural soil are incorporated in the value of the land. There is another kind of investment that influences the price of the land: the permanent crop. An agricultural area planted by olives, fruits or vineyard will integrate in its price the actual value of the investment supported in growing and maintaining the plants.

The plain area of Pianura-Padana, that includes the west part of the Emilia-Romagna region and the southern area of Veneto and Lombardia, is characterized by the cultivation of fodder crops in relation to the feeding needs of the milk cows breaded in such zones. The value of the land in that areas doesn't consider only the revenue provided by selling fodder production to the market, but this value incorporate the revenue generated by the entire agriculture system linked to milk cows breading. So, the price of the land is linked to the prevalent farm activity of each area.

More specifically, the value of the land is related with the profitability of the prevalent farm type in a certain area. The level of intensity in using the agricultural soil is another elements that should keep in account when one analyzes the value of the land. The technology that can be used in a certain area defines the level of productivity and efficiency of the agricultural system adopted.

The economic performances of the farms depends in greatest part on the methods used to lead the agricultural activity and the value of the land reflects the efficiency can be reach adopting the prevalent technology adopted by farms.

The public regulation can widely influence the value of the land with respect three main directions: in constraining the use of the land for certain crops, in limiting the use of the land for environmental issues and affecting the land by payment entitlements. The CAP regulation foresees for certain crops a quota system in order to limit the expansion of the crop that can lead to an increasing in the level of production depressing the market prices and demanding more financial resources to the Community budget. This is the case of olive-oil, wine-yards, for which the rights can be sold with the land. Another case of public regulation influence in the value of land is represented by the limitation in using agricultural soil in order to protect the environment and natural resources. The nitrate directive is an example very representative. In Italy, the directive was implemented at regional level and it is applied on the basis of different criteria according to the municipality. The degree of constraint is, thus, related to the area of application. Where the prescriptions are less strict, the demand for land and for rent land is very high, increasing the value of the land in such areas. The CAP contribution to variation of the value of the land is strictly related to the decoupling mechanism. The separation between the subsidies and the specific production should lead to a reduction of the value of the land due that doesn't consider the value of the coupled aid. By the decoupling, farmers can choose to sell or rent the land with or without the entitlements and in this last case the could show a value reduced with respect to the period before the enter into force of the Fischler's reform.

Probably, in this list, it can be considered other land value components, like the proximity of the agricultural soil to an urbanized area, but this kind of elements are external to the mere agricultural land property and, for this reason, it was not included in the list above.

8.2 The market of the land in Italy

The National Institute of Agricultural Economics (INEA) records each year by a survey in all the Italian regions the value of the agricultural land. In 2004, the average value of the land was equal to 16.000 euro per hectare. This value has showed a relevant increasing during the last decade, but it the same information is evaluated in term of real prices, the trend observed during the period presents a very small increasing. Indeed, the augmentation of the value of the land has been important in few agricultural area of the country (i.e. Pianura Padana), but in the greatest part of Italy the increase in value of the land could not overcome the inflation level.

At geographical level, the price of the land is very differentiated: in South Italy the prices are not higher than 10.000 euro/ha, while in the Center of Italy the prices are around 20.000 euro/ha. In the richest areas of North Italy the value of the land is higher than 20.000 euro/ha, arriving until 36.000 euro/ha in North-East regions. It's quite obvious, but the highest prices and the most dynamic market of the land can be found in the agricultural areas more fertile and with high profitable activities. The table 8.1 shows how the land prices in the plain area of North are, generally, higher than the prices observed in other areas of the countries and in particular for the mountain, where the prices are structurally smaller. The value of the land are particularly small in the Appennini mountains, where the difficulty to work, the high cost of production and the weak agricultural alternatives don't help to create the conditions for a dynamic market of the land as in other zones. Some exceptions to the previous situation can be found in some area with land particularly vocated to certain type of productions. In Trentino-Alto Adige the land for vineyard is very appreciated and present average values higher than the prices observed in the North plain. In this case, the land

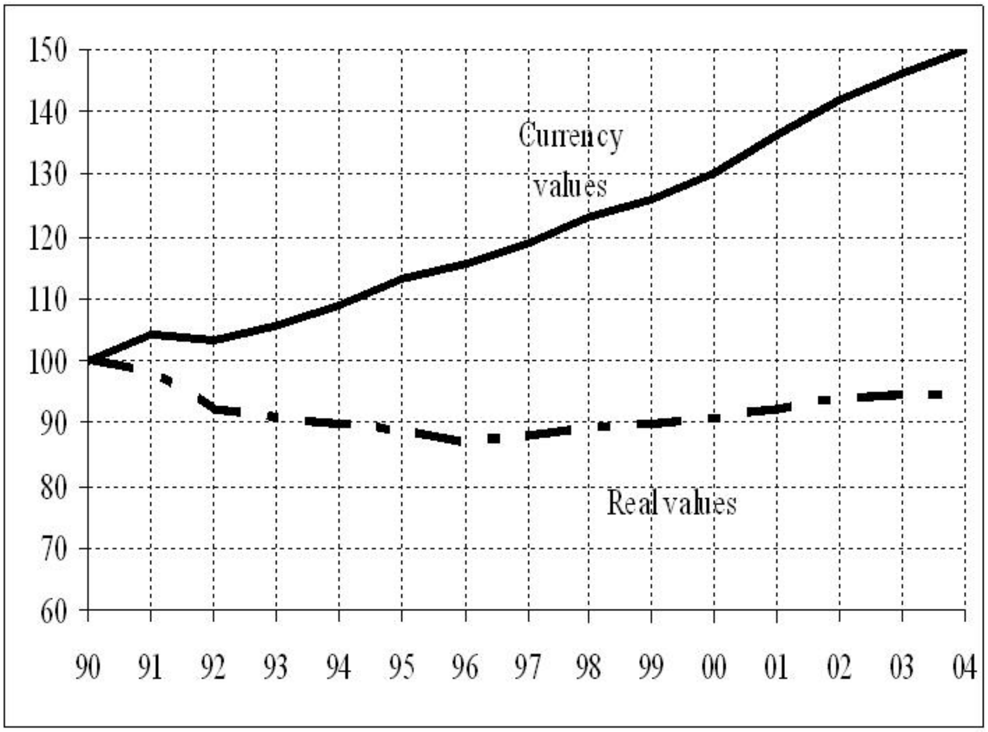

Figure 8.1: Index values of the land prices in Italy (1990=100).

shows specific characteristics of great value for producing some specific agricultural products.

Geographical area	Altitude					Total
	inner mountain	coast mountain	inner hill	coast hill	plain	
North-West	5,6	13,9	17,9	35,6	31,8	21,5
North-East	18,3	-	27,7	26,1	36,5	30,2
Center	6,9	11,0	10,7	15,5	19,6	11,6
South	6,3	9,9	10,0	15,0	14,1	10,8
Islands	5,7	9,3	7,2	9,1	12,4	8,3
ITALY	8,7	9,9	11,8	13,3	26,8	15,8

Table 8.1: Prices of the land by geographical area (Italy, 2004), .000 euro/ha. *(Source: INEA, 2005).*

The higher prices observed for Padana valley is in part to attribute to the high level of urbanization of this region, but much more to the very intensive agriculture carried out by farmers. According to the distribution by class of value, about 21% of the entire agricultural surface shows a land price higher than 21.000 euroha, while around the 60% of the surface doesn't exceed 15.000 euro/ha.

If one observes the information organised with respect to the market operator that have exchanged land, it can be possible to highlight that the major contribution to the land demand came from the big producers and, in certain areas, by off-farmers. The strategy of these big farmers is to enlarge their farm in order to achieve relevant return to scale. The land purchase is frequently carried out incorporating land by neighbours. According to the survey developed by INEA, the objective followed by farmers in purchasing land is not only attributable to the enlargement of the farm activity, but also to invest family money in a financial asset much more stable and less risky than others financial investments.

The supply is prevalently generated by the part-time farmers and old owners. Part-time farmers find in the farm activity an complement to the income. When the revenue generated by the agricultural activity is not sufficient to compensate the production costs and this situation continue for a many years (agricultural cycles) and the land price is convenient, the part-time farmers can decide to sell the land in order to generate liquidity to use in other investment. The last decade was characterised by a very relevant abandonment by old farmers without a intergeneration substitution and generally with small farms. The phenomena of selection in the agricultural field continues to operate and the less efficient farms placed in marginal areas or conducted by old farms loss land in favour to bigger efficient farmers that enlarge their farms.

The effects of agricultural policies in sustaining the farm income are mainly due to the new reform that has introduced the single farm payment calculated for each farmers on the basis of the average of what they had received in the period 2000-2002. The impact of this reform on the is not yet very clear, but one can attend a reduction in the dynamic of the market due to the linkage between the land (the eligible hectares) and the farmer entitlements. Indeed, to obtain the decoupled payments, farmers have to demonstrate that the number of entitlements for which they claim the payments can be associated to a identical number of eligible hectares of their farm. This regulation contained in the Reg. UE 17822003 doesn't favour farmers to sell and on the market, otherwise they could loss the value of their entitlements. Although, it can happen that marginal land that exceed the maximum amount of eligible hectares to obtain the payment could be exchanged on the market.

Moreover, the decoupling system introducing the separation between crop profitability and public sustain can reduce the value of the land. The possible implication of the decoupling measure could be evaluated by using the quantitative model used in this part of the work.

In some regions (Valle d'Aosta) the rural development plans have supported farmers in buying agricultural surface, with the specific objective to improve the efficiency and the level of competitivity of farms in the lagging regions.

The figure 8.2 shows the value of the land according to the different types of production harvested on the agricultural surface. The orchards and vineyards show the highest value of the land, due to the high investment costs operated for these productions. For orchard the value exceed 30 euros/ha, while for vineyards the value reach 28 euros/ha. The land cultivate by arable crops costs around 18 euros/ha. The statistics for olives shows value of the land lower than the arable crops, due in part to the low market price of the olive-oil. It is important to highlight, that this data presntes average values at national level. At territorial level, the price is very differenciated. For example, the land value cultivate by olive near the Garda lake has a value much higher than the average price recorded at national level for orchard. The meadows and pasture present the lowest values, because in general this land is localized in the marginal rural areas (mountain and lagging regions) where the agricultural economic alternatives are very scarce.

8.3 The land rent

The Eurostat data provides information about the agricultural surface rented in EU and according to this data it is possible to portrayed the market of the rent of land in Italy. In 2003, the surface ranted in Italy was equal to 3,7 million hectares, more than 700.000 hectares with respect to the

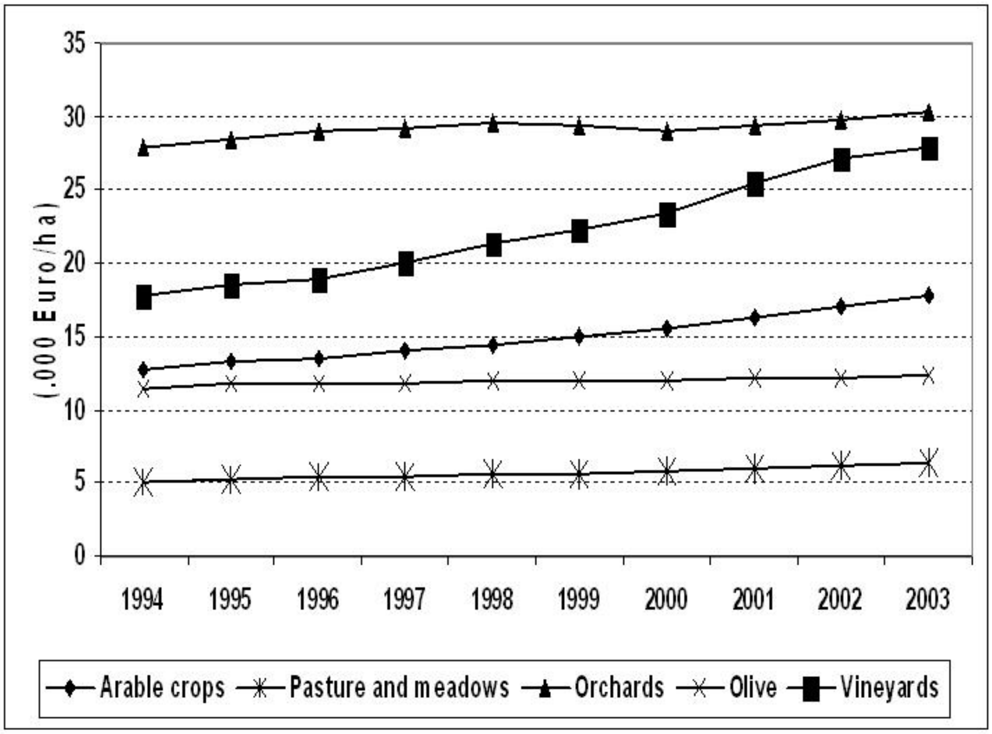

Figure 8.2: Land value for type of production (Italy).

situation presented in 2000. The incidence of the agricultural surface rented on the total agricultural surface is equal to 28%, while 10 years before this weight reached about 18,4%. The deep evolution encounter by the agricultural sector during the last decade justifies this result. Indeed, the Census data says us that the agricultural surface reduced of 30%, whit a high reduction in the number of farmers (-40%). The modification of the agricultural sector during this period has lead to feed the market of rented land increasing the incidence of this form of land purchase on the total utilization of agricultural surface.

The increase of the percentage incidence has contributed to reduce the divergence between the Italian situation and the European average. In the EU-15, the rented surface is equal to 55 million of hectares and the incidence of this land on the total agricultural acreage is equal to 48%. The countries where the rent of land is most relevant are France (70%), Belgium (67%), Germany (64%), Sweden (45%) and United Kingdom (35%).

According to the Eurostat data, in '90s, the greatest diffusion of the rent of land has been recorded in the Centre of Italy (+51%) and in North Italy (+21%), the areas where the dynamics in the structures of farms has been much more intense. While in South Italy, the low dynamics observed (in ten years, only 3% of farms exits from the sector), the market of land rents is very stable, without important variations during the period. The situation at regional level is very differentiated. In almost all the regions in the North Italy present a incidence of the land rents on the total agricultural acreage higher than the national average. The highest diffusion of this form of land purchase is showed by Valle d'Aosta region with a percentage on the UAA equal to 75%, Lombardia (50%) and Piemonte (45%). In Centre and South Italy the diffusion of the land rents is not so diffused as in the North. Only in Marche region and in Sardegna it can be possible observe incidences higher than 30%.

The demand of land rents is prevalent in the plain of North regions, where the value of the agricultural land reaches the highest level of the entire country. In a situation where the value of land is very high and the perspective of agricultural revenue very uncertainty, farmers prefer form of purchase different to the land-buy. In contrast to this situation, the marginal areas of the mountains showed levels of supply higher that the demand of land rents. In the area of Lombardia, it is particularly important the rent of the land in order to respond to the criteria of minimization of the environmental impact of animal breading required by the regional regulations. Indeed, decisions concerning the enlargement of the animal activities should keep in account an enlargement not only the augmentation of the stable capacity but also the increasing of the agricultural surface on which to throw the zootechnical wastes.

	2003	**Var. %**	**Incidence % on UAA**		
Regions	**(ha)**	**2003/00**	**2003**	**2000**	**1990**
Piemonte	488.010	20, 4	45, 4	37, 9	29, 7
Valle d'Aosta	40.460	*-14,2*	74, 6	66, 3	54, 3
Liguria	13.680	1, 4	27, 2	22, 2	12, 8
Lombardia	492.850	6, 0	50, 2	44, 7	38, 7
P.A. Bolzano	56.150	104, 3	20, 2	10, 3	6, 8
P.A. Trento	27.520	45, 9	18, 3	12, 8	14, 1
Veneto	248.020	17, 4	29, 8	24, 9	18, 0
Friuli-Venezia Giulia	75.910	3, 1	34, 7	31, 0	20, 8
Emilia-Romagna	399.840	13, 8	37, 2	31, 5	21, 2
Toscana	221.420	18, 9	27, 4	21, 9	12, 0
Umbria	102.790	32, 3	28, 5	21, 4	14, 0
Marche	163.220	24, 8	31, 9	25, 9	12, 6
Lazio	139.450	33, 3	19, 2	14, 8	11, 0
Abruzzo	98.520	44, 5	23, 6	16, 0	10, 0
Molise	52.740	9, 4	24, 7	22, 6	15, 6
Campania	138.390	33, 9	24, 6	17, 9	16, 1
Puglia	164.970	11, 1	12, 9	12, 1	10, 8
Basilicata	115.470	38, 2	20, 8	15, 7	15, 6
Calabria	93.830	53, 3	17, 2	11, 3	11, 6
Sicilia	214.520	25, 7	16, 9	13, 6	11, 5
Sardegna	383.850	51, 2	33, 3	25, 1	28, 6
North	1.842.440	14, 2	39, 1	33, 2	25, 7
Centre	725.400	27, 8	25, 7	19, 9	11, 7
South	1.163.770	33, 8	20, 9	16, 2	15, 9
Italy	**3.731.610**	22, 0	28, 5	23, 4	18, 4

Table 8.2: Agricultural surface rented in Italy. *(Source: Eurostat, 2005).*

The market of land rents varies according to the regions and is regulated by traditional instruments of negotiations not necessary formalized, like the contract on word in South Italy. In Southern regions is typical the rent contract without obligations to pay the rent, the so-called free-use of the land. This case occurs generally when farmers transfer land to young components of his family in order to capture the financial provisions of the measures of rural development plan finalised to encourage young farmers.

The length of the rent contract is very dependent to the type of production to cultivate on. For arable crops, like fodder crops and cereals, the rent contract generally is not higher than 10 years, while for pasture the contract can exceed 10 years. In the case of tomatoes, the contract generally doesn't exceed 3 years, because after this period the rotations needs cannot permit to achieve the same economic results provided by the tomato crop. For the permanent crops, the duration of the contract can reach ten years. For the vineyards, this contracts can foreseen an obligation to ameliorate the quality of the production (by changing the variety) and for this reason the first four years are generally free of payment.

8.4 FADN rental prices

EUROSTAT statistics provide important information on the surface rented for a given year, but avoid any information about the market prices of the agricultural land rents. To dispose this kind of information, it needs to turn the attention towards the most important source of information in the agricultural domain: the FADN databank. FADN provides data on the surface rented by each farms composing the sample and the information about the value of the rents. This last kind of economic information cannot distinguish the rent price paid by farmers to use idle land from the rental price to dispose buildings and plants. In any case, the strong linkage between the land and the agriculture structures is sufficient in order to consider that inside the rental value declared by farmers is included both the agricultural inputs.

In order to calculate the unit value of the rent paid by farmers included in the FADN, we have considered the archive for the year 2001 (the last complete year available) and only the farms with land rented. As the statistics about land values said us that the variation between 2001 and 2004 is equal to +10%, we can said that the unit rent values obtained on the basis of year 2001 are not far from the actual values.

The analysis of the rental prices calculated by the FADN shows an interesting differentiation in relation to the type of activity lead and the rural area concerned.

The table 8.3 shows the unit rental prices for the agricultural land at farm type level. In Italy, the highest value of rental prices concerns the horticulture productions. The horticulture products in this case don't consider the industrial crops, like the industrial tomatoes, but only the fresh vegetables usually produced on small parcels. The high rental value for this kind of production is motivated by the intensive use of the surface dedicated to those products (one parcel can be utilized up to three times by year). The rent values for the permanent crops is lower than the previous farm typology. The land harvested permanent crop, constituted by olives, orchard and vineyards, is generally sold and not rented in reason of the high investments costs sustained to install the plants. The land harvested in farms specialized in field crops has a rental price of 516 euro/ha, while the farms specialized in grazing livestock (included milk cows) the rent prices reach 350 euro/ha. For this last farm type the rent price consider the rents of meadows and pasture in mountain areas, where the land value for this kind of activity is very low. For the farm type oriented in granivore breading, the rental value is higher than for the specialist grazing livestock and for the specialist field crop. This high value is due to small land generally owned by this kind of breading and, so, to the incidence of the rental value associated to the agricultural buildings.

The analysis at territorial level (see table 8.4) shows a high difference in rental values between the Northern areas and South Areas. The Northern regions present, in average, rent prices higher

Farm type	**Rent price (Euro/ha)**
Specialist field crops	516
Specialist horticulture	2,804
Specialist permanent crops	737
Specialist grazing livestock	350
Specialist granivore	851
Mixed croping	468
Mixed livestock	305
Mixed crops-livestock	315
ITALY	597

Table 8.3: Rent prices by farm type. *(Source: our elaborations on Italian FADN, 2001).*

than the rent prices observed for the Southern regions. Indeed, the highest prices are identified in Trentino (one of the two independent provinces of Trentino Alto-Adige region), where the quality vineyards push up the land value and in consequence the rental prices, and Liguria region characterized by a very small acreage (1% of the entire Italian UAA) and a very high specialisation in horticulture and flowers. The others important Northern agricultural regions, Lombardia, Veneto and Emilia-Romagna are characterized by an agriculture diversified in many agriculture activities (milk, beef, arable crops, horticulture, olives, orchards, vineyards). The sum of this different production frameworks produce the average value showed in table 8.3. the Only Valle d'Aosta region present a rental prices lower than the other North regions. This mountain region has a agriculture oriented on animal breading on grassland and meadows.

The agriculture of Southern regions of Italy is in average poor in all sectors, with some exceptions in Campania and Puglia where the industrial crops and olive oil maintain the farm income at satisfying level, and in Sicilia where some localized agri-food systems based on vineyards (in particular for producing table grapes) can sustain the agriculture in such zones. Although, the generalized low economic performance of the South agriculture is reflected in the prices of land rents.

8.5 The impact of the decoupling on the land marginal value

8.5.1 The implemented approach

The evaluation of consequences of the new CAP reform on the land prices and, more specifically, on the shadow prices of the land can be achieved by using models that describe the relationship among the different technical and economic variables governing the decision process of farmers. The model developed for the present CAP evaluation is a model able to simulate possible agricultural policy scenarios at regional level guaranteeing methodological correctness in describing the behaviour of the farmers. The model is based on the Positive Mathematical Programming (PMP) methodology and uses farm information collected by the FADN archives and IACS data. The PMP methodology consists of three steps:

1. The first step has the objective to recover marginal cost related to crops and animal production present in the observed farm.

2. The second steps of the PMP approach deals with the reconstruction of the marginal cost function using a specification that is linear in the parameters. The linearity aspect of the

Regions	**Rent price (Euro/ha)**
Valle d'Aosta	291
Piemonte	461
Lombardia	690
Trentino	1,537
Alto-Adige	422
Veneto	733
Friuli-Venezia Giulia	600
Liguria	2,559
Emilia-Romagna	973
Toscana	1,110
Marche	374
Umbria	345
Lazio	644
Abruzzo	412
Molise	229
Campania	563
Calabria	305
Puglia	529
Basilicata	270
Sicilia	428
Sardegna	297
ITALY	**597**

Table 8.4: Rent prices by region. *(Source: our elaborations on Italian FADN, 2001).*

model becomes important when the number of farms is large. The integration of the marginal cost function with respect to the output variables within the admissible domain will produce the desired total variable cost function.

3. Third step is the calibration phase where model exactly reproduces the base period allocation and output decision of the observed farm and of the entire sample. That is, the primal and dual solutions of this quadratic programming models is exactly equal to the primal and dual solution of the initial LP model which, in turn, reproduces the realized results of the base period. This is the meaning of calibration within the PMP methodology.

The prediction step of PMP exploits the calibrated model to generate responses in the exogenous variables induced by the variation of some relevant parameters, as various scenarios of agricultural policy like changes in amount of subsidies or different payments system (as decoupling). Even if the model deal with the behaviour of a single observed farm, and in this sense con be consider as a micro economic tools, adopting "self selection" techniques and by aggregation process it is possible move from "farm dimension" to a "regional dimension", providing a precise measure of the effects of specific agriculture policy for each specific region.

The information used by the model to map and estimate the variation of the marginal value of the agricultural land is collected by two different sources of data: the IACS databank and the FADN archive. The first one collects all the administrative information about land allocation for those farms that receive a subsidy from the EU; the second one is the timely and reliable source of information on the accountancy of a representative sample of EU farms.

The following phase of agricultural policy evaluation is done by gathering together every calibrated farm model into a single regional model, where the objective function is the sum of the objective function of every single farms, linked to the connected farm technical matrices. The maximization process of the aggregated objective function provides us with an "optimal" solution for the entire model, which is also "local optimal" for each farm. Organized in this way, in the policy scenario analysis phase, the PMP model will lead to an overall representation of the behaviour of the farms present in the concerned regions.

8.5.2 The policy scenarios

In the Scenario S1 the hypothesis adopted for evaluating the Fischler's reform concerns the implementation of the total decoupling scheme without any coupled aids for processes. This Scenario have been analysed by introducing price influences according to the results from the model ESIM. More specifically:

1. a baseline is developed in order to establish a scenario of reference on the basis of which it is possible to compare the base situation with the modification in policy measures. The baseline is formulated keeping in account the CAP rules in force in 2003, that is the last year of application of AGENDA 2000.

2. S1: the hypothesis formulated for this scenario concerns the application of the Reg. EU 1782/2003 in the option of total decoupling for all the agricultural product, milk included, according to the annex VI of the horizontal regulation. This Scenario considers also the variation in product prices as presented in table 8.1 in the column "Single farm Payment".

3. S1p: S1 + variation in product prices as presented in table 8.1 in the column "Single farm Payment".

Processes	**Scenario**
	Single Farm Payment (%)
SOFT WHEAT	2.3
DURUM WHEAT	3.7
BARLEY	-5.7
CORN	-14.8
RYE	-14.0
OTHER GRAIN	-15.5
RICE	-48.4
SUGAR	-24.9
POTATO	-37.7
SOYBEAN	0.3
RAPSEED	-3.8
SUNSEED	-5.0
MANIOC	12.2
SMAIZE	-32.9
FODDER	-46.2
GRAS	-42.5
CGF	10.5
MILK	-22.4
BEEF	-4.6
SHEEP	37.6
PORK	0.5
POULTRY	-2.1
EGGS	-4.0

Table 8.5: Real price change (%), 2013 in comparison to baseyear (2002), deflated with 1,5% p.a. *(Source: FAL-ESIM model).*

8.5.3 Impact on production plans

In order to better understand the effect of the Fischler's reform on the marginal value of the land, it is important to indicate the main reactions of the farm decisions in term of allocation of the land to various agricultural processes.

The table 8.5 highlights that the decoupling reform seems to have a relevant impacts on the land allocation, in particular for cereals, oilseeds and protein crops. For these crops the harvested area is interested by strong modifications in the scenarios considered. Cereals sustain the widest reduction equal at national level to 13% in S1, with a curb in durum wheat about 20% and more light variations for maize and other cereals. The decoupling of the base aids and of the supplementary premiums was responsible for the negative results in durum wheat area. Between the first scenario and the baseline, durum wheat leave on the field about 300.000 hectares even if the horizontal regulation introduces 40Ă/ha for quality grain.

The influence of prices doesn't change very much the situation that continues to remain quite negative for cereals. In particular, the increase in prices for durum and soft wheat (+2,3% and +3,7%) allows a moderated restoring for those crops. For the others cereals, the effect of decoupling is reinforced by a strong reduction in market prices so that the price scenario shows an accentuated decrease of harvested surfaces.

Activities	Baseline	No price changes S1	Price influence S1p
	(Ha)	(Var. %)	
Cereals	3.942.959	-13,0	-14,0
Oilseeds	377.976	9,3	2,0
Fodder plants	2.548.187	12,3	11,2
Other crops	635.849	-0,4	-8,6
Set-aside	282.505	0,0	0,0
Good practice area (ha)	0	163.535	305.848
Total surface	**7.787.476**	**0**	**0.0**

Table 8.6: Variations in crop acreage, Italy.

The total decoupling scheme portrayed in the first scenario leads to an increase of oilseeds and in particular in sunflower in the southern areas of Italy. The market scenarios for oilseeds are foreseen in drop that leads an augmentation for sunflower in S1p not so high as in the first scenario S1. The outcomes for oilseeds read with the results about the other crops lead to say that the decoupling induces a substitution of the crops with high production cost with crops less expensive in term of variable input use. Relevant cases of substitution among crops are related to cereals and fodder crops, but also the substitution between cereals and the good practice area. In certain areas, like in South Italy, the more evident substitution is detected for the durum wheat which is substituted by the sunflower. The fodder crops benefit of their relative profitability due to the eligibility to the single payment and the low costs of production. The good practice area is eligible to the single payment as well and it is characterized by low cost for maintenance, estimated to 250 Ă/ha.

The market price variations, which are very negative for the most crops and quite positive only for few activities, reduce the process of substitution among crops increasing the transfer of land to the good practice area. This area reaches more than 300 thousand hectares in S1p (4% of the total surface). It is interesting to note that the good practice area is concentrated in the zone with the highest agricultural productivity and the highest (region padano-veneta).

The analysis of the model results for the animal sector shows dynamics completely divergent according to the type of scenario. Indeed, the net result of the decoupling system portrayed by scenario S1 shows an increase in the animal capital, in particular for beef and milk cows, while for slaughter cows the trend is negative. The reason of this positive dynamic for milk cows and beef is due to the strict linkage between fodder crops and animal processes. This kind of relation allows to considers the two activities like one activity that participates to the process of maximization of the gross margin.

The reduction in milk price proposed by scenarios S1p (-22%) produces an important decrease in the number of milk cows (-11%). In this second series of scenarios, the decoupling is not sufficient to develop the fodder crops used in animal breeding. Beef, even if it encounters a decrease in market prices of -4,6%, doesn't have significant reduction in the number of livestock. The foreseen important increase in prices for sheep and goat productions leads to a relevant augmentation of goats (+15%), while sheep livestock is substantially stable.

Activities	**Baseline**	**No price changes S1**	**Price influence S1p**
	(UBA)	**(Var. %)**	
Beef	1.537.147	6,6	1,9
Milk cows	751.676	3,1	-10,9
Slaughter cows	372.834	-4,8	-5,9
Sheep	538.755	7,8	2,1
Goats	126.569	-4,8	15,3

Table 8.7: Dynamics for animal productions, Italy.

It is important to remark that the zootechnical component of the model is related to the animals breaded by farms with arable crops. For this reason, all the farm specialized in beef processing without use of own land is not considered in the present analysis.

8.5.4 Impact on marginal value of the land

The shadow prices of the land calculated by the regional model implemented in this study are presented in table 8.8. One of the first element to note is the low level of the marginal values of the land in all the Italian regions. This result is explained by two main reasons. The first one is related to the type of model that is a regional model and the values of the land reflects the average values of all harvested surface - also the different way of cultivation and the quality of the soil - in the entire agricultural area of each region. This consideration leads to add that the model's results may be considered as the results of one big farm characterized by wide heterogeneity inside. The responses of the model for the shadow prices of the land has also be attributed to the structure of the model characterized by different constraints (milk quota, tomato and sugarbeet quotas, etc.) by which it is possible to have other shadow prices. By this perspective, it would be useful to consider the shadow prices of the land as a part of information of the dual value of the farm agricultural system.

Secondary, the sample on which the simulations are developed includes information about farms having requested the CAP payment for the arable crops regime. This means that the farms that we have considered are not specialized in any particular agricultural sector, but they can be considered as farm type "mixed crops-livestock". Actually, the sample doesn't consider explicitly the farms oriented in animal productions or in horticulture, even if the processes characterizing those sectors are integrated among the activities composing the farmers production plan. In this sense, the shadow prices are influenced by this mixed crop composition, where the sustained arable crops (cereals, oilseeds and protein crops) prevail.

	Baseline	S1	S1p	S1	S1p
Regions	(Euro/HA)			(Var.%)	
Abruzzo	77	20	21	-73,8	-72,6
Basilicata	104	64	61	-38,3	-41,1
Calabria	185	175	141	-5,5	-23,9
Campania	85	64	57	-24,7	-32,9
Emilia-Romagna	147	86	78	-41,0	-46,8
Friuli	78	21	18	-73,1	-76,9
Lazio	151	101	96	-33,0	-36,4
Lombardia	231	148	136	-36,0	-41,0
Marche	121	102	82	-15,5	-32,2
Molise	91	44	36	-52,0	-60,4
Piemonte	232	113	96	-51,1	-58,5
Puglia	83	62	55	-25,5	-33,9
Sardegna	50	41	34	-18,4	-31,9
Sicilia	167	47	34	-71,6	-79,6
Toscana	67	46	31	-31,0	-53,4
Umbria	105	34	25	-67,6	-76,1
Veneto	216	82	74	-62,1	-65,7

Table 8.8: Variation of shadow prices of the land per region.

The dynamics in the shadow prices reflect the dynamics of the coupled payments. Actually, the decoupling intervention breaks the link between the agricultural products and level of aid received by farmers and, in some way, separates the relation between the aids and the land. It is known that the horizontal regulation of the CAP reform keep a link between the land and the right through the eligibility area for which farmers request each year the subsidy. This is the reason by which the decoupled aids from the processes lost a direct linkage with the land and the shadow prices of the land decrease respect to the baseline.

Both policy and market scenarios portrayed a strong reduction in the value of the land, highlighting the role of the coupled payment in defining the market price of the land or, better, the market price of the land rents. According to the results of the model, the most intensive decrease arise in the agricultural richest regions of the North Italy (i.e. Lombardia and Emilia-Romagna), where the amount of the coupled payments was higher. While, the Southern regions, where the farm single payment amount (included milk premiums) is not comparable to the farms in North Italy, the decrease is much lower.

8.6 Conclusions

The high diversity of the Italian agriculture in term of activity specialization and the concentration of such activities in homogeneous areas determines a relevant differentiation in the land values. So, one can find rural areas characterized by quality vineyards, like Trentino, where the value of the land reach the highest level in the entire country and areas characterized by poor arable crops, with scarce differentiation possibilities, where the value of the land is very low (i.e. Sardegna). The picture portrayed is reflected also by the level of land rental prices.

In a situation characterized by a geopardised agricultural specialization and by a relevant variability of the land values, it is important to know the reaction of the land market after the application of the Fischler's reform. To do that, this study proposes to evaluate the variation of the land value by the assessment of the marginal values obtained by simulating the decoupling by a positive mathematical programming model. The model is applied on all the Italian regions keeping in account the information related to the farms with arable crops. Vineyards and the other permanent crops (excluded pasture and grassland) are not considered.

The results show a generalized strong reduction in the marginal value of the land in consequence to the payment decoupling. This result is, although, almost intuitive: the decoupling reduces the part of the land value incorporated in the crop production. Although, the value of the entitlements for obtaining the single farm payment can be used only if farmers demonstrate a linkage between those rights and the eligible farm acreage, so that it remains a strict connection between the land and the value of the rights. For this reason, the value of the land should consider not only the idle value of the land but also the value of the entitlements owned by the farmers. Furthermore, the market value of the land reflects the agricultural profitability of rural areas and for this reason it can be useful to consider with the analysis of the information about the land shadow prices the unitary gross margin by hectare for each region.

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Part IV

Linkage between the farms and the environment through the core farm model

Introduction of the part IV

Environment and coupling between economic models and biophysical models take a part of the work more important than it was initially thought during the process of GENEDEC proposal generating. A large part of this work is devoted to "response functions" when yields and N-pollutants depend on N inputs.

This was made possible thanks to effort realized in database and software or modelling improvement (see also V). The chapters of this part are methodology oriented, but application are presented to assess the feasibility and the operational capability of this approach.

The economic model involved in this part is mainly AROPAj. The biophysical models involved here are mainly STICS and -more lightly- CERES.

9 Interface between agriculture and the environment: integrating yield response functions in an economic model of EU agriculture

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Abstract

To address the environmental impacts of agricultural production, economic models have to better take into account the relationship between inputs (fertiliser, animal feeding), outputs and the environment. We present an integrated approach which introduces yield response functions to nitrogen in the economic model AROPAj. The farm-group approach for each EU region, relying on an agro-pedo-climatic database, and the linking of a crop model (STICS) to the economic model are an innovation. The methodology is applied to a French region and focuses here on GHG emissions. The results show that variables are more sensitive to crop price variation.

9.1 Introduction

Agricultural activities have been widely recognized as affecting the environment, be it their positive impacts, such as landscape conservation, or their negative impacts, such as pollution. The recent CAP reform agreed in Luxembourg (2003) clearly emphasizes the importance of accounting for and monitoring the environmental impacts of agricultural production. Cross-compliance is a key feature of the reform. On a more global level, the agricultural sector may play a central role in helping the EU countries respect the greenhouse gas (GHG) levels set by international agreements, such as the Kyoto Protocol.

In order to address the issues, economic models have to better take into account the relationships between inputs, such as nitrogen use and animal feeding, agricultural outputs, and the environment. From a policymaking standpoint, there is strong need for new modelling tools that enable integrated assessment of environmental and economic impacts in order to design appropriate economic instruments decisions can be based on. Moreover, the changing policy and environmental context argues for the development and use of generic models which can be easily re-defined and improved when data and/or policy change. This text focuses on the theoretical and numerical aspects related to the inclusion of yield response functions in the micro-economic model AROPAj. Integrated approaches, as this one, are particularly relevant when addressing the relationships between climate change and agriculture: not only does agriculture contribute to the accumulation of GHGs leading to climate change, but climate in turn will impact the agricultural production possibilities. Indeed, the main biological and biophysical processes governing plant relationships with its environment affect crop production and yields. Those effects can extend to the evolution of farming systems, through emergence and re-location of new cultivars, new species, and new management practices.

Such an integrated approach has already been implemented in various contexts. Schneider (2000) uses the ASM (Agricultural Sector Model) linked to the EPIC model to analyse the reduction of agricultural GHG emissions in US regions. Angenendt et al. (2004) provide a survey at the regional scale, for a typology of farming systems. As the latter, we propose a farm type approach, for each region in the EU, however, instead of a single region, all the EU regions are taken in consideration. In comparison to those two studies, the innovative factors in our study are the geographical scope, the number of regions and the ability to scale down to a single farm type. Such a scale of analysis, which enables aggregated and disaggregated reading of the CAP impacts for the whole EU was used in CAPRI (Meudt and Britz 1997). Nevertheless, that method, relying on a very complete statistical data base, does not use any crop model nor does it integrate physical and management practice characteristics of the studied farm types. We chose to both use a crop model and integrate characteristics which permit the obtention of continuous yield in response to nitrogen rate for each crop and farm-type, and differing from Schneider who opted for a discrete set of fertilizer application rate.

In this text, we first present the modelling approach prior to the integration of nitrogen response curves. The second section deals with what the link between the crop model STICS and the economic model AROPAj is based on. In the third section, implementation of nitrogen response curves is illustrated through two examples. The fourth section presents our first results with the new tool. At last, needs for further research and perspectives are discussed.

9.2 Current modelling approach

9.2.1 The model

The AROPAj model consists of a set of independent, mixed integer and linear-programming models. Each model describes the annual supply choice of a given 'farm-type' (denoted by k), representative of the behaviour of , 'real' farmers. The farm-type representation makes it possible to account for the wide diversity of technical constraints faced by European farmers. Each farm-type k is assumed to choose the supply level and the input demand ( ) in order to maximize total gross margin ( ). In its most general expression, the generic model for farm-type k can be written as follows:

$$\max_{x_k} \Pi_k(x_k) = g_k.x_k$$
$$s.t. A_k.x_k \leq z_k$$
$$x_k \geq 0$$

where x_k is the n-vector of producing activities for farm type k, and g_k is the n-vector of gross-margins. A_k is the m $\times$ n-matrix of input-output coefficients and z_k is the m-vector of the right-hand side parameters (capacities). Together, A_k and z_k define the m-constraints faced by farm type k.

The components of x_k include the area in each crop (distinguishing between on-farm and marketed production), animal numbers in each animal category, milk and meat production, as well as the quantity of purchased animal feeding. The gross margin g_k contains series of elements corresponding to each producing activity, which, for crops gives: per-hectare revenue (yield times price) plus, when relevant, support received, minus per-hectare variable costs. As the emphasis is put on the farm-type level, each farm-type is assumed to be price-taker. Thirty-two crop producing activities are allowed for in the model and represent most of the European agricultural land use related to arable land and pasture. Crop production can be sold at the market price or used for animal feeding purposes (feed grains, forage, and pastures). As for livestock, thirty-one animal categories are represented in the model (27 for cattle plus sheep, goats, swine, and poultry).

9.2.2 Constraints presentation

The technically feasible production set is bounded by the constraints defined by and . As the total number of non-trivial constraints is fairly large, the present description focuses on constraints that are directly relevant for GHG emissions and abatement costs. For a more detailed presentation of some of the constraints see Cara et al. (2005) and Cara and Jayet (2000).

Total crop and grassland area is constrained by the availability of land area, defined as total farm-type k's land endowment (see appendix). In addition, crop rotation constraints are formulated as maximum area shares of individual (or groups of) crops in total area. Maximum area shares are derived from historic observations at the regional level and reflect actual agricultural practices. The corresponding constraints summarize the dynamic nature of crop rotations in a static framework.

Animal numbers are also limited by the availability of stalls, which are allowed to vary by $\pm$ of the initial animal numbers in the corresponding animal categories. This limitation concerns animal categories related to final production (i.e. mainly older males and females). In addition, cattle numbers are constrained by relationships that reflect demographic equilibrium in the distribution by age and sex classes. This approach thus corresponds to a comparative static, and is very akin to that used for crop rotation.

To feed their animals, farmers can use their own crop and forage production, or purchase concentrates and/or roughage. Four kinds of purchased concentrates and one kind or purchased roughage are considered in the model. This makes it possible to distinguish between energy- and protein-rich concentrates, as well as between straight and compound feedstuff. Farmers have to meet the minimal digestible protein and energy needs of each animal category. In addition, each cattle category is associated with a maximal quantity of ingested matter. The characteristics of feedstuff with respect to energy and protein content, dry matter fraction and digestibility, as well as the energy/protein requirements and maximal quantity of ingested matter for each animal category have been taken from Jarrige (1988). In addition, energy and protein needs are further differentiated to account for the differences of per-animal milk and meat yields.

The last important set of constraints regards the restrictions imposed by CAP measures. Set-aside requirements as well as milk and sugar beet quotas fall in this category. Mandatory and voluntary set-asides are accounted for, each type of set-aside being treated as a producing activity associated with the corresponding payments. The different types of sugar beet quotas (A, B, and C) are also included. Many of the CAP policy instruments included in the model involve the use of binary or integer variables whenever producers have to face mutually exclusive 'discrete' choices.

9.2.3 Data sources

The computation of the components of A_k and g_k , and the baseline levels of producing activities (x_k^0) proceeds in three major steps: (i) selection, typology, and grouping of sample farms into farm types, (ii) estimation of the parameters, and (iii) calibration. The primary source of data is the Farm Accounting Data Network (FADN). The 1997 FADN provides accounting data (revenues, variable costs, prices, yields, crop areas, animal numbers, support received, types of farming) for a sample of slightly less than 60,000 surveyed farmers. Approximately 50,000 sample farms are included in the model, which represent a total of more than 2.5 million European (full-time) farmers. Data are available at a regional level (101 regions in the EU-15). Because of the annual nature of the model, sample farms defined as "Specialist horticulture" and "Specialist permanent crops" are excluded (types of farming 2 and 3 in the FADN classification). The analysis is thus restricted to the remaining population of the farmers, representing annual crop and livestock farmers. This restriction is important to keep in mind when analyzing the results, as the excluded farms may represent a significant share of total agricultural area for some regions.

9.2.4 Farm-types

The selected sample farms are then grouped into 'farm-types' (or 'farm-groups') according to three main variables: (i) region (101 regions in the EU-15); (ii) average elevation (3 elevation classes: 0 to 300 m, 300 to 600 m, and above 600 m); and (iii) main type of farming (14 types of farming in the FADN classification). The typology results from the following trade-off. On the one hand, the number of sample farms grouped in any farm-type has to be large enough to comply with confidentiality restrictions (at least 15 sample farms for each farm-type) as well as to ensure the robustness of the estimations. On the other hand, the total number of farm types has to be as large as possible to reduce the aggregation bias at the regional level. Each farm-type thus results from the aggregation of sample farms that are located in the same region, are characterized by similar type(s) of farming and belong to the same elevation class(es). Farm-types may actually encompass more than one FADN type of farming and/or more than one elevation class depending on the number of sample farms and on their heterogeneity in a given region. Likewise, the grouping of sample farms may differ from one region to another: e.g. sample farms labelled in FADN as 'Specialist crops' may be aggregated with 'Mixed cropping systems' in one region and modelled separately in another, again depending on the number of sample farms and their heterogeneity. The number of farm-types by region thus varies from 1 to 15 farm-types. The farm-type approach is important in several respects. First, it takes into account the diversity of farming systems at the infra-regional level better than models that rely on regional aggregates. Farm-type results can still be aggregated at the regional level, but the region itself is not modelled as one single 'big' farm. Consequently, models based on farm-type approach are less subject to aggregation bias ((Perez et al. 2003), (Commission 2002)). Second, mixed farming systems being explicitly modelled, the farm-type approach better reflects the existence of a fairly diversified agriculture. Each individual farm in the FADN sample is associated with a FADN weight indicating its representativity in the regional population. The individual weights of sample farms that are grouped into farm-type k are aggregated (ν_k) and used to extrapolate the results at the regional level. Following this procedure, 734 farm-types were obtained, each associated with a specific supply model.

9.2.5 Parameters estimation

Parameters and baseline levels of variables that are systematically estimated using FADN data include: variable costs and output prices, area and area shares for each crop, animal numbers, and support received. The estimation procedure is conducted at the farm-type level and uses the extrapolation factors provided by the FADN. As for variable costs, the model distinguishes between two categories of costs: 'fertilizer use' and 'other inputs' (seeds, fuel consumption, pesticides, etc.). Because of the accountancy nature of the FADN data, only total expenditure is available. Per-crop variable costs are therefore inferred from linear covariance analysis, using area crops and including a specific additive farm-type effect. Alternative sources of information are also used whenever relevant data is lacking in the FADN. An important alternative source of information is the Intergovernmental Panel on Climate Change (on Climate Change 2001), from which emission factors are taken. Likewise, characteristics of feeding products and animal feeding requirements are obtained from technical workbooks ((Jarrige 1988)). Expert knowledge is used when no other statistical or technical source is available. This is the case for the types of fertiliser used for each crop and each country or region and some feeding parameters. Other sources of economic data include Eurostat and FAOstat databases for fertilizer prices, as well as technical references for animal feeding characteristics and greenhouse gas accounting (IPCC).

9.2.6 Calibration

The last step entails the calibration of a subset of the parameters. Calibration is used when information is lacking or is insufficiently reliable. The subset of calibrating parameters includes: some of the parameters defining animal feeding requirements, lifetime of certain cattle categories, grassland yields, and maximal crop area shares. The calibration uses a combination of Monte-Carlo and gradient methods in order to minimize the distance between the observation data for each farm-type k, x_k^0, and the optimal solution x_k^* (Cara and Jayet (2000)).

9.3 Improvements

9.3.1 Relaxing the fixed yields assumption

As aforementioned, many parameters are estimated from FADN data for a given year (1997). Among others, for each farm-type k and crop j, we estimate the reference yield and the total expenditure for fertilizers. The AROPAj model determines the area allocated to a crop according to these fixed reference yields and fertilization levels/costs. As the model stands, it cannot take into account price variations for fertilizer or crop, to determine the optimal level of fertilization and yield which would maximize the crop gross margin. Thus the model misestimates the impacts of a change in guaranteed prices, for instance.

The first step in our analysis entails relaxing the fixed-yields assumptions. To do so we need to estimate the yield-response function to nitrogen $y_{jk}(N_{jk})$, supposed to be concave. This is done thanks to the crop model STICS. Then we calculate the nitrogen fertilization N_{jk} and the corresponding yield y_{jk} which maximize the gross-margin per unit of area π_{jk} for a given crop j, considering the crop selling price (p_j), fertilizer f price (p_f) and the share of nitrogen in fertilizer f (ν_f) as given. Let us write the theoretical program maximizing g_{jk} per hectare (the k-index is omitted here):

$$\max_{N_j} \pi_j = p_j \times y_j(N_j) - \frac{p_f}{\nu_f} \times N_j \qquad (st.N_j \geq 0)$$

The first order condition associated to fertilizer consumption is then $\frac{\partial y_j(N_j)}{\partial N_j} = \frac{p_f}{\nu_f p_j}$

9.3.2 The choice of the response function type

We keep as baselines a set of usual assumptions formulated in the various disciplines where modelling is used. For instance, the usual rationality principle for guidance of the economic behaviour is kept in action. Likewise, the decreasing marginal productivity, accepted by both agronomists and economists, applies to the curves relating fertilizers and yields. This is why we refer to the Von Liebig hypothesis of the minimum (" crop yields are limited by the deficiency or lack of one nutrient necessary to crop growth ") and Mitscherlich's law ("when raising amounts of nutrients are brought to a plant, yield increases are lower the higher the amounts get"), which are commonly admitted as basic rules of fertilisation at the frontier of economics and agronomy. They convey the notions of non-substitutability between nutrients and yield plateau (or limit). Nevertheless, they do not necessarily imply the linearity between yield and nutrient ((Paris 1992)). Exponential production functions such as Mitscherlich-Baule's type show several advantages in our case study. Such functions are defined by $y = y_{max} - (y_{max} - y_{min}) \times \exp(-tN)$, where y is yield, N is the nitrogen fertilizer amount, y_{min}, y_{max}, and t standing respectively for the minimal yield, maximal yield and rate of increase. This type of function has been shown as fitting properly the pseudo-experimental data, and offering good properties to estimate economic optimum fertiliser rates ((Neeteson and Wadman 1987), (Oger 1994)). From an economic point of view, it was important that the chosen curve be concave, strictly increasing, and with a finite limit in the infinite. From an agronomic point of view, the curve also had to be increasing, with a finite positive value in zero and a finite positive limit in the infinite. Hence, we have selected the exponential production function which enabled us to meet both agronomic and economic requirements.

9.3.3 The choice of the STICS crop model to be linked to the economic model

Our modelling approach relies on a "soft" coupling of a micro-economic, supply-side oriented model of the EU agriculture (AROPAj), and a crop model (STICS). It thus differs from a "fully" integrated approach.

Yield-response functions vary in a large extent with soil, climate and crop management practices: those parameters need to be taken into account at any scale of analysis, from farming system to regions and countries. The required model had to be able to reflect such diversity and to be adaptable to specific modalities of nitrogen fertilisation at the European scale (for example fertilisation calendar).

The generic STICS model had been selected for its adaptability and its ability to simulate the wide range of crops and cropping systems corresponding to crop production situations of the economic model. For various examples of applications, the reader is referred to Brisson et al. (2003).

9.3.4 An overview of the crop model STICS

STICS is a crop model that has been developed at INRA since 1996 ((Brisson et al. 1998)). It simulates crop growth as well as water and nitrogen soil balances all dynamically driven by daily weather data. It uses information about soil and management practices as inputs. It estimates both agricultural variables (such as yield, input consumption) and environmental indicators (such as nitrogen and water losses). Figure 9.1 synthesises the relationships and exchanges of information and matter between the plant and the atmosphere within the model. The underlying relationships are well-known and presented in Brisson et al. (1998) Brisson et al. (2003). The plant also interacts with soil through its root system and soil management practices.

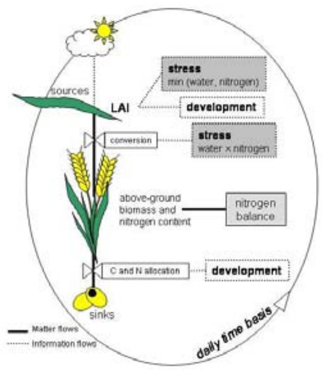

Figure 9.1: The plant-atmosphere system in the STICS model.

9.4 Implementation of endogenous yields

9.4.1 The generation of response functions

The basic process relies on the STICS model running apart from the economic model using specific inputs, and thus providing pseudo-experimental data to which response curves are fitted.

To do so, farm types had to be given an agronomic, pedological and climatic context to enable crop simulations. Specific constraints were forced in the agronomic model: as we only focus on nitrogen as nutrient affecting crop yield (neither available economic data nor the agronomic model dealt with phosphorus and potash), we assume there is no lack of those nutrients for the plants. So we made the hypothesis of proportional amount of potassium and phosphorus with nitrogen rate. Fertiliser combination and types were based on expert knowledge.

STICS input parameters are derived from : (i) FADN and AROPAj for organic supplies and irrigations; (ii) regional experts for other crop management data; (iii) the MARS (Monitoring Agriculture with Remote Sensing) database for soil and climate parameters.

STICS inputs are either pre-determined or fitted to the economic data. Within a given region, climate inputs are related to farm-types according to their altitude class; the sowing date, fertilizer type and calendar are imposed for each crop. For one crop in one farm-type, the following set of inputs are selected so that yield and fertilizer supply meet economic data: soil type (one out of five), preceding crop (a legume or a cereal), and variety, characterized by precocity group, (one out of three). The Artix database related software combines all the inputs and launches the corresponding STICS simulation set. A non-linear fitting procedure (SAS NLIN) provides the estimation of the parameters of the response curve, $y = y_{max} - (y_{max} - y_{min}) \times \exp(-tN)$. Then, STICS inputs are chosen according to those which optimize the two following criteria (ranked by increasing importance): 1) the actual reference yield y_j^0 (AROPAj calibration step based on FADN) is obtained, 2) the difference is minimal between the price ratio $\frac{p_j^0}{\nu_f p_f^0}$ (fertilizer purchasing price over crop selling price) and the derivative value of the function where yields equals the reference yield, $\frac{\partial y_j}{\partial N_j}(y^{-1}(y_j^0))$. An example is presented on Figure 9.2.

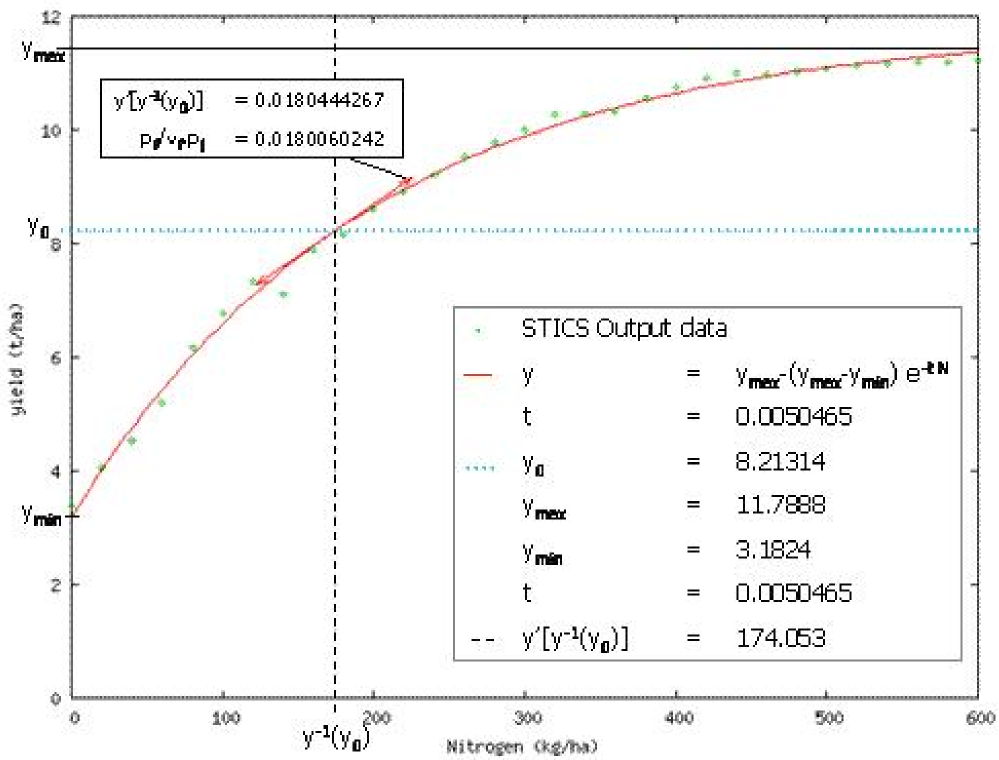

Figure 9.2: An example of nitrogen response curve for soft wheat from a farm-type of cereal growers in Picardie (Northern France)

9.4.2 Adjustment of the response curve to the calibrated basic parameters

There is no reason that the curves produced by STICS precisely fit the point defined by (N_j^0, y_j^0) . Likewise the slope at this point, while close, is seldom equal to the price ratio mentioned in theoretical analysis. Because of this deviation, we need to adjust the agronomic curve in order to fit the economic information upon which the economic model is calibrated. Using FADN, yields and fertilizer expenditure are computed for each farm type and for each crop. These estimations are assumed not to change during the calibration process. The assumption is that reference yield y^0 and reference expenditures for fertiliser c_f^0 represent well the baseline situation. However, an uncertainty remains on the total amount of nitrogen brought to the crop, due to the uncertainty regarding organic-nitrogen input during the reference year and regarding the type and price of market fertilizers. To ensure consistency between the yield response function and economic data, the parameters defining the curve need to be calibrated. The assumption – supported by agronomic considerations – is that the intercept yield and the asymptotic yield of the curve adjusted to STICS outputs remain unchanged. As a consequence, the only calibrating parameter is t, which defines the curvature of the response function.

Let us consider $y(N) = y_{max} - (y_{max} - y_{min})\ times \exp(-tN)$, the response function provided by STICS, and $y_a(N)$ the adjusted response function. Let us consider the price ratio $\frac{p_f^0}{\nu_f p_j^0}$ is derived from estimated cost c_f^0 . We define $y_a(N)$ such that:

$$y_a(N) = y_{max} - (y_{max} - y_{min}) \times \exp(-tN)$$
$$y_a(N_a^0) = y^0$$
$$y_a^{'}(N_a^0) = \frac{p_f^0}{\nu_f p_j^0}$$

Given $y_{min} \leq y_0 \leq y_{max}$, $t \geq 0$ and the equations above, we deduce the value of the adjusted growth rate t_a :

$$t_a = \frac{p_f^0}{\nu_f p_f^0} \frac{1}{y_{max} - y^0}$$

The difference between the reference expenditure and the adjusted one should be defined as:

$$\Delta c_f^0 = c_f^0 - c_{af}^0 = c_f^0 - \frac{p_f}{\nu_f}(y_{max} - y^0) \ln(\frac{y_{max} - y_{min}}{y_{max} - y^0})$$

Figure 9.3 shows how the original STICS curve is modified through this adjustment procedure.

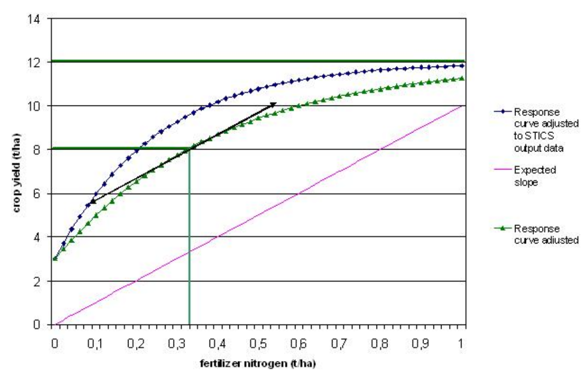

Figure 9.3: Adjustment of the STICS curve with respect to the calibration of the economic model based on the reference yield and the reference variable cost.

9.4.3 Introducing yield response functions in AROPAj

The first step is dedicated to the optimization of the gross margin of each crop. As seen in a previous section, the optimal level of fertilization N_j^* and yield y_j^* related to the crop j are achieved when the marginal cost equals the marginal benefit. As the concavity assumption is fulfilled by construction, the function $y_j(N_j)$ is sufficient to determine the optimum (N_j^* , y_j^*). Then, knowing the gross-margin per hectare, we thus only have to determine the optimal area allocated to each crop to maximize the farm gross margin through the usual version of the economic model. With this two-step process, we avoid non-linear programming in the main model.

9.5 First results analysis

In this section, the impacts of the introduction of endogenous yield response function on the results of the economic model are tested. We first examine how the optimal solution is modified consecutively to a change in the output (wheat) price. Secondly, we address the issue of a change in the input price through the introduction of GHG emission tax.

9.5.1 Sensitivity analysis at the farm level

Using a sensitivity analysis, the contribution effects of yield response function within the economic model are our first concern. This step entails the analysis of change in land allocation, marketed crop output, and gross margin when one yield response curve is introduced in the model. Soft wheat is focused on due to the importance of this crop in the European agricultural sector. No ex-ante preference between farm types leads us to introduce this yield curve for the first farm type on the list, namely FT1 from Belgium. Simulations are based on change in crop price, keeping constant the nitrogen price. Considering 101.3 €/t as the reference price of soft wheat, we change this price from -10 to +10 €around this reference price by increments of 1€. The adjustment process is implemented with this reference price. Figure 9.4 shows the sensitivity analysis results for the three variables mentioned above without and with the introduction of the adjusted yield function. As expected, the gross margin ”with” is greater than the gross margin ”without” yield-response function. The difference is zero only when the price is equal to the reference price. Change in land allocation is weak. Finally, again as expected, change in the marketed part of the soft wheat production is the most significant. Moreover, and consistently with the economic intuition, the marketed output is smoother with endogenous yield response than without. The difference is monotically increasing with respect to the output price.

9.5.2 Endogenous yields and GHG abatement costs at the regional level

First, yield response curves were elaborated for soft wheat, maize, and sunflower and for several groups concerning the Picardie region (Northern France). This region was selected for its variability in term of crops, soils, climate and management practices; it includes crop grower, dairy and cattle raiser farm types, with different types of manure and slurry management as well as fertilizer types and fertilization calendars. The baseline scenario corresponds to the 1997 CAP. Without tax, results with endogenous yields are the same as results with exogenous yields. The tested scenario corresponds to the introduction of a tax on GHG emissions. This is a first rank instrument which supposes GHG emissions are known. With a new CAP or environmental policy, and consequently new prices, the model results differ according to whether the yields are endogenous or not. Total GHG emissions are endogenously computed in the model through equality constraints, and are included in x_k. The corresponding component of g_k represents the per-tCO2eq tax. In the baseline scenario, the tax is assumed to be zero. First, the model optimizes the crop yield according to nitrogen price, GHG emissions tax, and crop price. Then the model optimizes the gross margin of the farm-type.

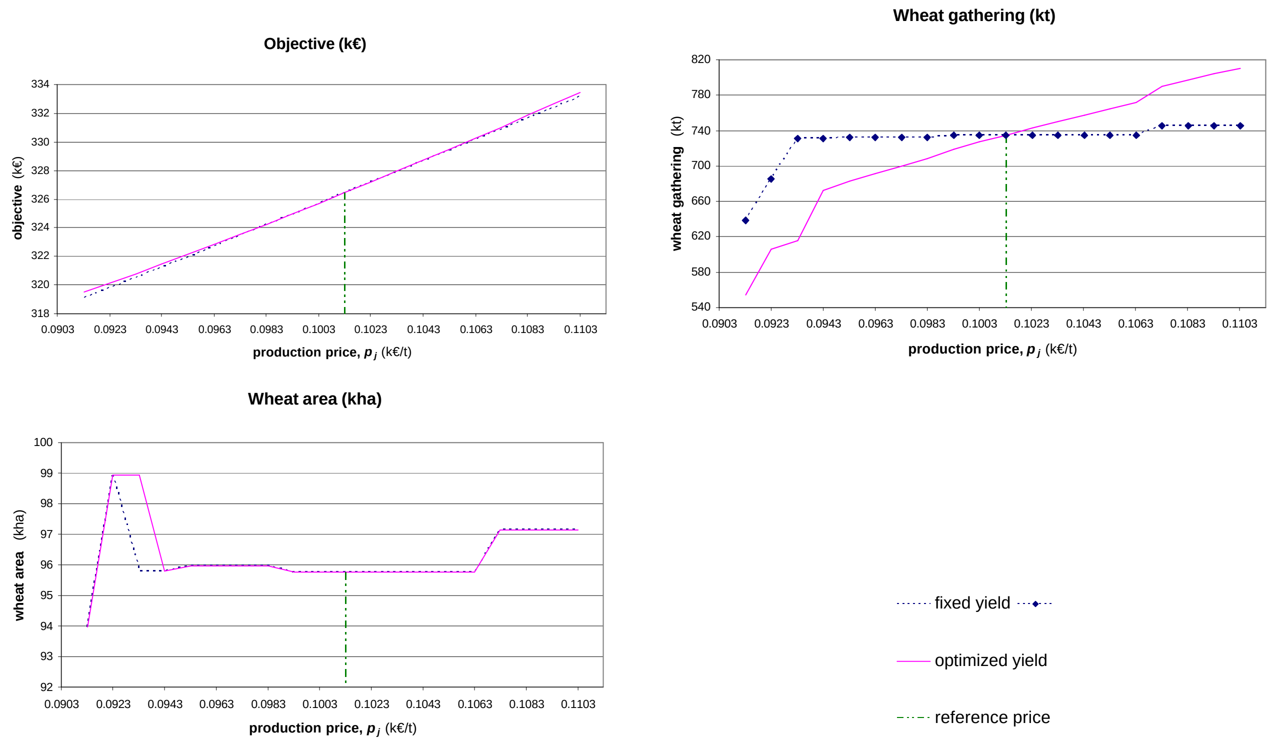

Figure 9.4: Sensitivity analysis of 3 variables to crop prices ranging +/- 10 euros around reference, by 1 euro increments

For Picardie, with exogenous yields, a tax of 30 €/t CO2eq involves an abatement of about 160 ktCO2eq compared to 2000 total emissions. With endogenous yields, the same level of tax involves an abatement of about 380 ktCO2 (Figure 9.5). With endogenous yields, the model takes into account a wider range of production choices. Not only can the crop area be adjusted, but also the fertiliser expense directly affecting crop yield. Marginal abatement costs are consequently reduced.

Figure 9.5 shows the evolution of emissions (agenda 2000 situation) with and without endogenous yields. If the emission tax is zero, endogenous yields make it possible for farmers to maximize their profit by adjusting the quantity of nitrogen used to new prices (Agenda 2000), thus involving a reduction in GHG emissions. As the tax increases, farmers are encouraged to reduce all activities which are a source of GHG emissions. One important limitation is in this adjustment is the necessity to feed animal. Recall that farmers can only reduce their animal number by up to 15%. As purchased animal feed is less GHG producing than domestic feed, with a very high level of tax, farmers are encouraged to stop all crop activity. Or at least, they have to drop drastically their nitrogen input requirements which are responsible for GHG emissions.

9.5.3 Qualifying the results

To qualify the results, we have to remember that, currently, the module of endogenous crop yields does not take into account the cereal opportunity cost linked to on-farm consumption. The price ratio used in the second section, leading to the computation of the optimal yield and the input, holds when the production related to this crop is not entirely on-farm consumed (see appendix). When the crop is not marketed, we theoretically need to use the dual price of the positivity constraint related to the marketable output, which is strictly greater than the crop selling price. Therefore one may

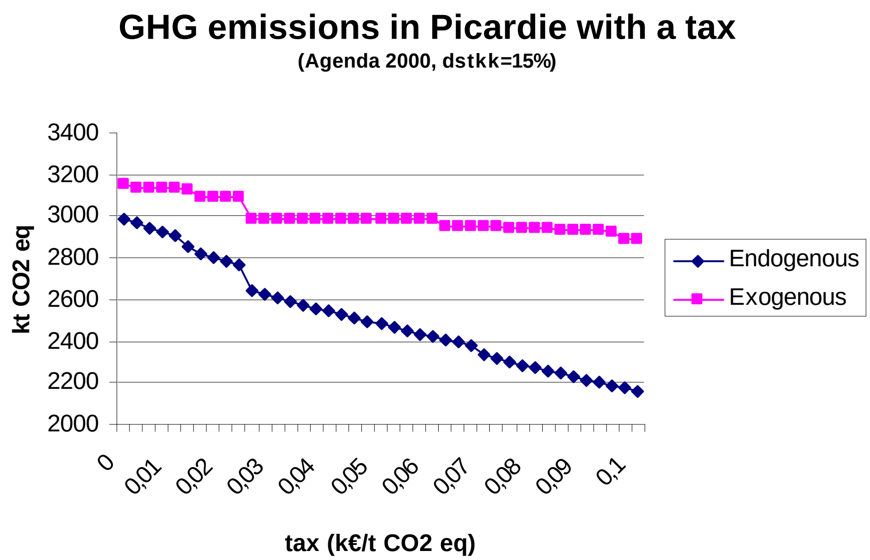

Figure 9.5: GHG Emissions Reductions in Picardie, with or without endogenous yields.

expect the per-hectare crop gross margin to be under-estimated. In this case, an iterative procedure is needed: the model is run a first time to compute initial values of the shadow prices; these prices are then used as proxy for crop price, and then the model runs again until a stable solution is reached. This calculation would be time consuming if applied to all crops of all farm types. So we set out to find an expression of this shadow price (μ_j) that would enable the calculation of its value beforehand.

The resolution of the theoretical model provides no general expression for μ_j that can be directly derived from the model parameters. However, an upper bound which applies to all situations can be computed:

$$p_j \leq \mu_j \leq \sum_{n=1}^{N} \frac{p_m t_{nj}}{u_{mn}}$$

where p_m stands for the price of feedstuff m, t_{nj} is the dietary value of crop j in nutrient n and u_{mn} is the dietary value of feedstuff m in nutrient n.

9.6 Conclusion and perspectives for further research

The introduction of crop yield response function to nitrogen fertilisation in the AROPAj enables to relax strong assumptions regarding fixed reference yields and fixed fertilisation levels. Therefore, this provides more flexibility in the model as both fertilisation level and land allocation can be adjusted.

Exponential response functions chosen in this study fit both agronomic and economic criteria and offer interesting properties with regard to optimisation, namely concavity, positivity and finite limit. The approach was implemented for one region chosen for its diversity of productions and for which all data were available. Changes in crop production, crop area, gross margin and GHG emissions prompted by changes in crop selling price were discussed. The results are more sensitive to price variations when yields and fertilisation are optimised. As expected, the supply elasticity with respect to a GHG emission tax increases. This is particularly true for N2O. Indeed, the adjustment of the gross margin is not only made for land allocation but for the level of nitrogen fertilisation, which is directly linked to N2O emissions. Impacts on CH4 emissions are less pronounced. All these results are valid only when the production for a crop is not entirely on-farm consumed. In such a case, the dual price for this crop should be substituted for the domestic price.

An important issue for further research will be a proper account of the possibility to substitute manure for purchased fertiliser in order to reach the optimal level of nitrogen. Indeed, a similar methodology can be used to define manure nitrogen response curve using the STICS crop model. Once the crop model has all its input determined for each crop of each farm type, a batch of runs leads to several response curves: one for fertilizer nitrogen only, others corresponding to each identified manure category (manure, slurry and poultry manure). The last response curves enable us to pinpoint the equivalent coefficients in terms of yield of nitrogen from fertilizer and nitrogen from various manure categories. These parameters will be introduced into the economic model. This way, nitrogen input not only provided by the market but partly by on-farm effluents from livestock could be included in the model.

Another field of investigations is to apply the methodology used in this article to meat and milk production. The generic yield curves related to animal production are not as well defined, but our first efforts in this field seem to be fruitful. We also need further research to properly deal with crops concerned by one or a series of quotas, as the sugar-beet is.

Further research will also be needed regarding the assessment of climate change impacts on agricultural supply. First, the weight of potential reduction in net GHG emissions, including the carbon sequestration, offered by the agricultural sector will re-inforce the interest in the interface between agriculture and the environment. Second, climate change can be considered as a major direct or indirect cause of change in land use and crop yields. While yields and related costs vary in a given territory, land cover is expected to change with the relative net price of the eligible productions. Indeed eligible crop productions are the profitable ones consistent with climate and soil conditions. Actually, climate change could deeply modify the range of such potentially grown crops (species and cultivars) on a territory by excluding the most unadapted ones, and offering favourable growing conditions for new ones. The prospective analysis of such interactions between crop production and its environment requires a step further in modelling. Indeed, it would be necessary to consider the location of productions and the feed-back effects of climate change in our economic modelling approach. The technical context currently brought to the farm types constitutes a first step towards a modelling tool integrating more complex interactions. It would enable us to deal with potential agricultural changes in land cover and production allocations, apart from other factors such as demography and global economic context. Those perspectives will necessitate new collaborations between research teams implicated in climatology and environmental sciences among others.

9.7 APPENDIX

9.7.1 Theoretical model

With :

We solve the programme, considering the number of animals fixed:

$$p_j - \mu_j + \varphi_j = 0$$

$$-\frac{p_f}{\nu_f} s_j + \mu_j \frac{\partial y_j}{\partial N_j} s_j + \varepsilon_j = 0$$

$$\max_{Y_j, C_{ji}, N_j, s_j, q_{mi}, a_i} \sum_{j=1}^{J} \left(p_j \times Y_j - \frac{p_f}{\nu_f} N_j \times s_j \right) - \sum_{m=1}^{M} \sum_{i=1}^{I} p_m q_{mi} + \sum_{i=1}^{I} v_i a_i$$

s.t.	$\sum_{j=1}^{J} s_j$	$\leq$	s		(λ)
	$Y_j + \sum_{i=1}^{I} c_{ji}$	$\leq$	$y_j(N_j) \times s_j$	$\forall j$	(μ_j)
	$\sum_{m=1}^{M} (u_{nim} \times q_{mi})$	$\geq$	$b_{ni} \times a_i$	$\forall n, i$	(κ_{ni})
	Y_j	$\geq$	0	$\forall j$	(ϕ_j)
	s_j	$\geq$	0	$\forall j$	(σ_j)
	N_j	$\geq$	0	$\forall j$	(ε_j)
	C_{ji}	$\geq$	0	$\forall j, i$	(γ_{ji})
	a_i	$\geq$	0	$\forall i$	(α_i)
	q_{mi}	$\geq$	0	$\forall m, i$	(ξ_{mi})

Y_j :	marketed crop j (t)
C_{ji} :	on-farm consumption of crop j by animal type I (t/head)
s_j :	area in crop j (ha)
N_j :	nitrogen fertilization level per hectare of crop j (tN/ha)
p_j :	selling price crop j (€/t)
p_f :	purchase price for fertilizer f (€/t)
ν_f :	nitrogen share in fertiliser f (tN/t)
p_m :	purchase price of feedstuff m (€/t)
v_i :	gross product associated to animal type I (€/head)
a_i :	animal number, type I (head)
$q_{m\ i}$:	quantity of feedstuff m bought for cattle type i (t)
$b_{n\ i}$:	need of animal i for nutrient n (unit of n/head)
t_{nij} :	dietary value of crop j in nutrient n for animal I (unit of n/t)
u_{nim} :	dietary value of feedstuff m in nutrient n for animal I (unit of n/t)

$$-\frac{p_f}{\nu_f}N - \lambda_j + \mu_j y_j(N_j) + \sigma_j = 0$$

$$-p_m + \sum_{n=1}^{N} \kappa_{ni} u_{nim} + \xi_{mi} = 0$$

$$-\mu_j + \sum_{n=1}^{N} \kappa_{ni} t_{nij} + \gamma_{ji} = 0$$

$$\lambda \times \left(s - \sum_{j=1}^{J} s_j \right) = 0$$

$$\mu_j \times \left(y_j(N_j)s_j - Y_j - \sum_{i=1}^{I} C_{ji} \right) = 0$$

$$\kappa_{ni} \times \left(\sum_{m=1}^{M} (u_{nim} \times q_{mi}) + \sum_{j=1}^{J} (t_{nij} \times C_{ji}) - b_{ni} a_i \right) = 0$$

$$\varphi_j \times Y_j = 0$$

$$\sigma_j \times s_j = 0$$

$$\varepsilon_j \times N_j = 0$$

$$\gamma_{ji} \times C_{ji} = 0$$

$$\xi_{mi} \times q_{mi} = 0$$

We deduce from the expressions above (with the positivity of dual activities):

$$\mu_j \geq p_j$$

$$\mu_j \geq \sum_{n=1}^{N} \kappa_{ni} t_{nij}$$

$\sum_{n=1}^{N} \kappa_{ni} u_{nim} \leq p_m$, which implies $\kappa_{ni} \leq \frac{p_m}{u_{nim}}$ (due to positivity constraints)

When the entire output in crop j is on-farm consumed we have:

$$\mu_j > p_j$$

$$\mu_j = \sum_{n=1}^{N} \kappa_{ni} t_{nij} \qquad (\text{as } \gamma_{ji} = 0)$$

$$\kappa_{ni} \leq \frac{p_m}{u_{nim}}$$

So we have a lower and upper bounds forμ_j, which applies to every situation:

$$p_j \leq \mu_j \leq \sum_{n=1}^{N} \frac{p_m t_{nij}}{u_{nim}}$$

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10 Impacts of coupling a crop model and the AROPAj model on gross margins and on greenhouse gas emissions

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Abstract

Agricultural activities are partly responsible for the increase of the nitrous oxide greenhouse gas in the atmosphere. Studying the N_2O emissions in agriculture is necessary to establish mitigation measures. IPCC guidelines promote a default method for the assessment of these emissions. However, interdisciplinary research appears as a promising route for an accurate global assessment of N_2O emissions from agricultural soils. Here, we report results from the coupling of biophysical crop-model, CERES-EGC, and the micro-economic model, AROPAj, at the regional level in northern France Picardie region for the year 1997. Response curves of the N_2O emissions to the nitrogen fertilizer input in relation to soil, climate and crop management characteristics are built with CERES-EGC. N_2O emissions depend on the nitrogen amount with a linear function varing from 0.10 to 2.25% according to crops and the environement conditions, whereas the default method define a constant 1.25% emission factor for N_2O emissions from synthetic fertilizers. The AROPAj makes its analysis at the scale of "farm-groups" representative of each regional agricultural production systems, hence producing results at various aggregated levels. New emissions factors assessed from CERES-EGC, specific to each crop and each farm group were input into AROPAj. The total N_2O emissions for Picardie are reduced with the new emission factors. The impact of the use of response function to nitrogen input (yield and N_2O) in AROPAj is tested against greenhouse gas mitigation measures : a first best tax on the GHG emissions and a second best tax on the assumed factors of the GHG emissions (animals and nitrogen input). The introduction of yield response function to nitrogen input brings more reactivity to the economic model. By then, the taxes appear to be more efficient. An 8% reduction of the greenhouse gas emissions correspon-d to a tax of about 50 €/ t-CO_2-eq with the "fixed" yields, and 11 €/ t-CO_2-eq with the yield response functions. The introduction of new emission factors for N_2O emissions also brings changes in the effects of the taxes : for equal mitigation target, taxes need to be slightly higher with the new emission factors from CERES-EGC.

10.1 Introduction

10.1.1 N_2O emissions in agriculture

The globally-averaged abundance of nitrous oxide (N_2O) in the atmosphere was 319.2 ppb in 2004, and has been increasing at a rate of 0.74 ppb per year during the last ten years WMO and WDCGG (2006). Nitrous oxide is a greenhouse gas : per kilogram, it has 296 times the effect of carbon dioxide for producing global warming. It is naturally emitted from soils and oceans, but human activity also contributes to significant release of this gas (one third of it WMO and WDCGG (2006)).

Therefore, N_2O is a subject of efforts to curb greenhouse gas emissions. In addition to carbon dioxide and methane, nitrous oxide is the third most important gas contributing to global warming.

Agriculture is generally responsible for a large part of N_2O emissions at the country level. In France, it was estimated to contribute 76% of the total emissions in 2004 CITEPA (2006), when compounding the cultivation of soils and the use of nitrogen fertilizers.

Agricultural N_2O emissions are known to depend on the nitrogen (N) input to a large extend Houghton et al. (1996). Besides, an excessive use of fertilizer N is also responsible for the increase of nitrate leaching Beaudoin et al. (2005), Schnebelen et al. (2004) and ammonia (NH_3) emissions Herrmann et al. (2001). Nitrate pollution of groundwater is a well-known environmental problem, harmful for aquatic ecosystems and human health. NH_3 is considered as an important atmospheric pollutant with major impacts on the atmospheric chemistry and on the stability and the biodiversity of terrestrial and aquatic ecosystems Asman et al. (1998).

But these N-pollutants are not solely related to the N input. N_2O, NH_3 and nitrate productions occur throughout the nitrogen cycle in the soil. Complex processes involving the soil microbiology affect nitrogen and nitrogen-containing compounds in the soil system. By then, they are strongly related to the environment conditions (climate, soil-type, etc.)

10.1.2 Coupling economic and biophysical models to assess N_2O emissions

The Kyoto protocol (1997) is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). It requires a national inventory for a list of greenhouse gases (GHG). It is thus necessary to assess the N_2O emissions annually for each country in order to study their variations over time. Guidelines were setup by the Intergovernmental Panel on Climate Change (IPCC) to help the countries involved in the Kyoto Protocol in their national greenhouse gas inventory Houghton et al. (1996). However, the methods provided by IPCC for the assessment of the various GHG emissions are default ones, and should not be considered as an exclusive standard. Caution is expressed in the guidelines regarding "the default assumptions and data which are not always appropriate for specific national contexts". The development of alternative methodology thus appears as a promising way to assess more accurately the GHG emissions.

The major shortcoming of the IPCC default method lies in its ignoring the complexity of the microbiological processes (nitrification and denitrification) responsible for N_2O emissions Firestone and Davidson (1989). Also, it is necessary to take into account the effects of the soils characteristics, the climate, the crop management and the land use in the assessment of the N_2O emissions Granli and Bockman (1995), Smith et al. (1998), Ruser et al. (2001), and their variability in both space and time Kaiser et al. (1998), Dobbie et al. (1999), Smith et al. (2004).

Contrary to the IPCC default method, biophysical soil-crop models have the potential to deal with these drivers, and may be used to assess more accurately the amounts of N_2O emitted from agricultural soils, in relation to crop management. As those models integrate the complexity of nitrogen cycles pathways in the soil-crop-atmosphere system, they are also expected to provide a rather fine assessment of other N losses (NO_3^-, NH_3 and NO).

However, while there exist spatially-explicit maps for the biophysical input parameters of these models (including soil properties and climatic data), the crop management data prove much more challenging to infer because of the variety of agricultural production systems present within a given geographical zone. However, crop management data may be approached with micro-economic models of farms combined with farm accountancy data, which have been made available at the EU level with the recent reforms of the Common Agricultural Policy (CAP) Jayet et al. (1997), De Cara and Jayet (2000a).

Fully taking advantage of the capacity of biophysical models for the assessment of N_2O emissions thus requires their linkage with economic models, which is the focus of this paper.

Thus, coupling economic and biophysical models is relevant to tackle the issue of scale variability and the sharpness of the assessment. Economist do their analysis at the level of a firm, a sector or a society. Agriculture scientists usually study cases where physical, and technical conditions are homogenous, namely, and so the field level appears as the most common working scale. These differences are caused both by variation in scope and by the time of processes studied Vatn et al. (1999). Nevertheless, the coupling of ecomonic and crop models first provides proper physical and technical characterization of cases studied by the economy (Godard, 2005). Thus, such a coupling allows finer studies on the effects of public policies because it allows the improvement of the economic analysis through the contribution of a crop model focusing on a finer scale.

10.1.3 Modelling the efficiency of mitigation measures for agricultural greenhouse gases emissions

Countries that ratify the Kyoto Protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases (methane, nitrous oxide, sulfur hexafluoride, HFCs, and PFCs), or engage in emissions trading if they maintain or increase emissions of these gases.

There is by then a need to study measures for the mitigation of the GHG emissions. Economic models can implement various economic environment such as agricultural policies. Using a biophysical model linked to an economic model permit to assess more accurately certain environmental issues as GHG emissions. Thus, the coupling of biophysical and economic model appears as an interesting method to study accurately such mitigation policies.

In order to mitigate environmental damage, the economic theory put forward two different type of taxing : a first best taxing using a tax on the direct damage (like the quantity of pollutant dumped in the environment) ; and a second best taxing using taxes on the assumed factors of the damage De Cara and Jayet (2000b). Theoretically, first best taxing allows a very tight linkage to the damage, and by then a better efficiency within the reduction of the environmental damage. But, it demands an important knowledge of the real damage which is very costly and so often unattainable. In practice, it is less wasteful to be interested in the assumed factors of the damage (which can be well-known and measurable) and to implement a second best taxing, but there are losses in the efficiency of the mitigation measure. This present paper focus on possible measures for the reduction of GHG emissions from agriculture with a first best tax on the GHG emissions and a second best tax on the assumed factors of the GHG emissions.

As certain GHG emissions like N_2O emissions are linked to other N-pollutants (such as nitrate leaching and NH_3 emissions), it could be interesting to study how mitigation measures of GHG emissions could affect the other harmful N-losses in the environnement. For example, introducing in the economic model a tax on the use of nitrogenous fertilizers in order to reduce their use, and subsequently restrict the harmful effects of nitrogen inputs on the environment could help predicting the effects of such taxation policy on N-losses to the environment, crop yields and farmers' income. However, it requires detailed knowledge of the response of these terms to fertilizer N use.

Godard Godard (2005), Godard et al. (2004) coupled the biophysical model crop-model STICS Brisson et al. (1998, 2002) and the economic farm-group model AROPAj, which is based on the European data of the Farm Accountancy Data Network. This linkage made it possible to simulate the response of crop yields to fertilizer nitrogen (Nf), in various EU regions, and thereby predict the effect of various GHG emissions taxation scenarios on farmers' management strategies. In this work, the consequences in terms of GHG emissions at the farm level were estimated using the optimized Nf doses and the IPCC default emission factor of 1.25% for N_2O (whereby 1.25% of applied Nf is evolved as N_2O). Here, we set out to further her analysis by using a biophysical crop model to predict the N_2O emissions, instead of the fixed emission factor. Because STICS does not simulate as yet the N_2O emissions, we had to use another biophysical model, more environmentally-orientated. We thus selected the CERES-EGC crop model Gabrielle, Laville, Hénault, Nicoullaud and Germon (2006) for the coupling, as it struck a good balance between process description level and ease of use.

The objectives of this work were to quantify the N_2O emission from cropland depending on the amount of N fertilizer applied in order to build response curves, and to input these results to the economic model AROPAj. We thus assessed the regional N_2O emissions from agriculture, and investigated the effects of mitigation measures. As co-results, we have also studied the evolution of NH_3 emissions and nitrate leaching in response to N input. In this first approach, we worked with data from the Picardie region (Northern France).

10.2 Materials and Methods

10.2.1 The biophysical model CERES-EGC.

CERES-EGC was adapted from the CERES family of soil-crop models with a focus of environmental outputs (nitrate leaching, gaseous emissions of N_2O, ammonia and nitrogen oxides). CERES-EGC runs with sub-models that mimic the major processes governing the cycles of water, carbon and nitrogen in soil-crop systems. Because it is a daily time step model, it requires as forcing variables daily climatic data (rain, mean air temperature, and Penmann Potential Evapo-Transpiration) Gabrielle, Laville, Hénault, Nicoullaud and Germon (2006), Gabrielle, Laville, Duval, Nicoullaud, Germon and Hénault (2006). The figure 10.1 presents a simplified schematic of the model.

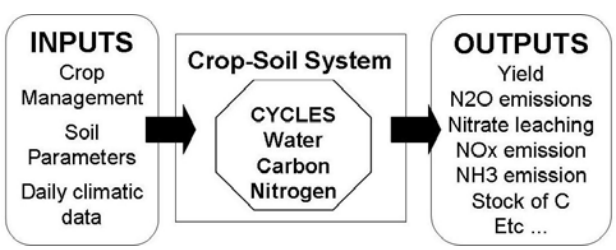


Figure 10.1: Schematic of the CERES-EGC model

NOE is the semi-empirical sub-model used in CERES-EGC to simulate the production and reduction of N_2O in agricultural soils Hénault et al. (2005). NOE imitates the denitrification and nitrification pathways. The total denitrification of soil NO_3^- is defined as the product of a potential rate with three unitless factors related to soil water content, nitrate content and temperature. The fraction of denitrified nitrate that evolves as N_2O is then considered as constant for a given soil type. Nitrification is modeled as a Michaëlis-Menten reaction, with NH_4^+ as substrate. The corresponding rate is multiplied by unitless modifiers related to soil water content and temperature. A soil-specific proportion of total nitrification evolves as N_2O.

As CERES-EGC biophysical model includes the major processes of the nitrogen cycle in soil-crop systems, it is also capable of predicting NH_3 emissions and nitrate leaching, in its current version.

10.2.2 The AROPAj economic farm-group model

AROPAj is a linear programming model which simulates the agricultural offer of the European Union regions De Cara and Jayet (2000a), Godard (2005). For a given economic situation, it provides an assessment of the type and amount of the agricultural products delivered on the markets. This model is mostly used to study the successive reforms of the CAP Jayet and Labonne (2005), but it has been used also to address global agri-environmental problems such as agricultural GHG emissions De Cara et al. (2005).

AROPAj is built up as a set of independent sub-models simulating each the behavior of a category of producers, as related to a "farm-group" Chakir et al. (2005). These farm-groups are representative of the behavior of real producers. The major assumption of the model is that each producer is supposed to optimize his or her total gross margin.

The figure 10.2 presents a schematic of the AROPAj model, showing the input parameters (the variable cost and the yield of the crop - specific for each farm-group, the prices); the constraints (technical, structural, and agricultural policy); and the outputs (the crop allocation, the optimal yield, the area of set-aside, the goal of the products - intra-consumption or markets, the livestock size, the farm's income, the GHG emissions). Among the variables taken into account in AROPAj there are the area of each crop (32 crop activities identified), the livestock size per animal type (31 identified animal classes), the quantity of meat, milk, grains or other crop production produced, the quantity of animal feed bought, and the land opportunity cost.

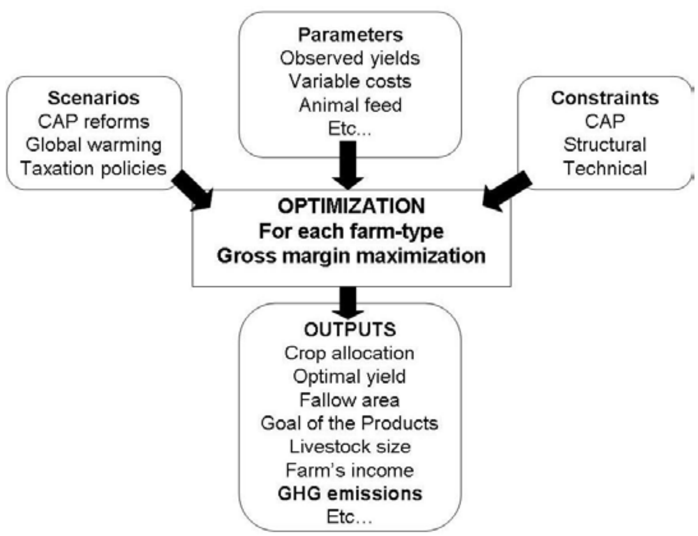


Figure 10.2: Schematic of the AROPAj model

By default, the GHG emission calculation is done with the IPCC Tier 1 methodology, whereby N_2O emissions are assumed proportional to fertilizer N inputs Bouwman (1996) (the background emissions are not taken into account in this assessment). By then, the N_2O emissions represent a fraction (emission factor) of the Nf input which has the value of 1.25% by defaut. However, the emission factor may be varied in AROPAj, in order to explore alternative estimation methods.

In the implementation of AROPAj we have used, it is important to note that the Utilized Agricultural Area for each farm-group is a constant (there is by then no possibility of land abandonment), and the animals breeders have the possibility to reduce their livestock solely down to 15% of the initial livestock.

There is a possibility to introduce different mitigation measures as taxes on the GHG emissions, on the animals or on the nitrogen input, and see its effects on the AROPAj outputs.

10.2.3 Data Sources

CERES-EGC requires the same type of inputs as STICS, and the typology of AROPAj used for thise study is based on 1997 typology. Since then, we have used the data base put together for the work on STICS and AROPAj Godard (2005). Table 10.1 presents the sources of the different types of data within this data base, at the EU level, including climatic and soil data, agricultural management data, and economic data. More information on the sources of the data and their attribution to the farm-groups may be found in Godard (2005). Only a few soil parameters specific to CERES-EGC, used in the nitrification and denitrification routines were added in the soil input files.

Type of Data	Sources	Data Attribution
Economic	Farm Accountancy Data Network (1997)	Creation of ”virtual” farm-group with real FADN farms
Climatic	MARS Project Database	1 farm-group = 1 climate
Soil	European Geographical Soil database Corine Land Cover 2000 Digital Elevation Model	1 farm-group = 5 different types of soils
Management practices	Phenological MARS project database Expert judgment	Defined for each crop and each farm-group

Table 10.1: Sources of the data used in the crop simulations.

10.2.4 Coupling CERES-EGC and AROPAj

The coupling is based on the introduction in AROPAj of mathematical relationships relating crop yields and N_2O emissions to fertilizer N input (Nf). Points of these curves are generated with the crop model by running simulations with increasing doses of Nf, against which a monotonous analytical equation is subsequently fitted.

The metholodology was first established by Godard (2005), regarding crop yields with the crop model STICS. For each combination of crop, cultivar, soil, and farm-group occurring in a given EU region, she ran simulations with Nf varying from 0 to 600 kg N ha^{-1}, and obtained a set of response curves as a result. Each curve was adjusted with the following equation :

$$Y(Nf) = B - (B - A) \cdot e^{-tNf}$$

where $Y(Nf)$ is the yield (in t ha^{-1}), and Nf in kg N ha^{-1}. For each farm-group, she thus selected the curve according to the associated economic data (FADN 1997) and properties, based on the following criteria. With the hypothesis made on the economic rationality of the farmer, the yield obtained in 1997 was assumed to be the economic optimal value for the yield, so that this optimal yield should belong to the curve chosen. Secondly, because of the maximization of the gross margin, at the intersection point of the curve and the optimal yield, the tangent should match as closely as possible the price ratio of the nitrogen fertilizer over the sold crop.

The resulting Nf dose was input to AROPAj for the baseline economic simulations (CAP agenda 2000 scenario). The model was also run under a set of taxation rules, in which case the farmers could be expected to adjust their fertilizer doses taking into account these new economic environment. Two calculations were made in that respect. In the first variant (referred to as EXOG in the following), the yields were considered constant and fixed at the values given in the FADN for each crop and farm-group. The total nitrogen fertilizer inputs were estimated based on the costs of each crop and farm-group, as extracted from the FADN data. In the second variant (noted ENDOG), the yields and fertilizer doses were calculated by the micro-economic model based on the yield response curves, following Godard (2005)'s method. Crop yields were subsequently deduced from Nf input using the yield response curves. Changes in fertilizer costs due to taxes on this commodity may alter the optimum Nf. This methodology thus allows a better linkage between the prices and the behavior of the farmers, and an accurate response of the model to policy changes.

The objective of this paper was to study the variation of the N-losses as Nf increased, ie to generate response curves similarly to Godard (2005). Accordingly, we ran simulations with the CERES-EGC model for the same cases as those of the yield curves, with yearly Nf doses varying from 0 to 400 kg N ha^{-1} in 20 kg N ha^{-1} increments. The Nf doses were split based on rules suggested by local experts, specifying for each type of crop the number and rates of Nf application. The application dates depend on the earliness of the crops, and thus on the selected cultivars (see section below). These fertilization rules match current farmers' practice in a majority of cases, and also maximize crop N use efficiency Godard (2005).

The resulting yearly N_2O emissions curves were regressed against Nf assuming a straight-line, following the "emission factor" approach of the default IPCC method. The resulting emissions factors were input to AROPAj. For comparison with the IPCC method, the GHG emissions of the farm-groups were assessed with AROPAj either with the default emission factor (noted IPCC) or with the CERES-EGC emission factors (noted CERES).

10.2.5 Crop simulations at the regional level

Since this work directly follows that by Godard Godard (2005), and involves comparison with her results, we chose the same simulation conditions as hers. Namely, we used the same typology of AROPAj farm-groups and same year (1997).

Here, we worked on the Picardie region (northern France), which is characterized by an important agricultural activity based on intensive cereal, sugar-beet, potato, oil and protein-producing crops. The harvest year of the simulations is the year 1997 because the economic data used by AROPAj are the ones of the FADN of 1997. As the altitude of the farm-groups are all in the same "AROPAj altitude class" (namely below 300 meters high), we considered only one climate for all the Picardie region Godard (2005). We have used climatic data of the years 1995 to 1997 (in order to take into account the preceding crop).

The various simulation cases are combinations of FADN farm-groups, soil type units, types of crop and crop management practices corresponding to the best-fit yield response curves obtained by Godard. The characteristics of the cases are presented in Table 10.2.

For soft wheat and maize we used two different cultivars with different "earliness" characteristics. The variation in the earliness implies a variation in the dates of the phenological stages of the crops,

Case	Crop	Farm-group	Soil	Precocity Group [1]	Sowing date	Preceding Crop [2]
Spring crops						
1	Maize	8, 10	1969	1	5 may 1997	Wheat
2	Maize	9	1974	2	5 may 1997	Pea
3	Sugar beet	8, 9, 10, 11	1974	RA*	2 april 1997	Wheat
4	Spring Barley	8	1042	RA	16 march 1997	Wheat
5	Spring Barley	11	1974	RA	2 feb 1997	Pea
Winter crops						
6	Soft wheat	8, 10, 11	1042	1	15 oct 1996	Pea
7	Soft wheat	9	1974	2	15 oct 1996	Pea
8	Rapeseed	8	1042	RA	30 august 1996	Pea
9	Rapeseed	9, 10	1974	RA	30 august 1996	Pea
10	Rapeseed	11	1974	RA	27 august 1996	Wheat
11	Winter Barley	9	1792	RA	31 oct 1996	Wheat
12	Winter Barley	10	1974	RA	31 oct 1996	Pea

* RA = Regional Average

Table 10.2: Characteristics of the different cases. See Tables below for the description of soil codes and farm-group classes.

Soil code	FAO Classification
1042	*Eutric Fluvisol*
1792	*Calcic Cambisol*
1969	*Orthic Luvisol*
1974	*Calcaric Eutric Cambisol*

Table a : Soils of the simulations.

Farm-group	Characteristics
Farm-group 8	Farms specialized in cereals, oil and protein-producing crops
Farm-group 9	Farms with general crops
Farm-group 10 and 11	Mixed farming and husbandry

Table b : Farm-groups of the simulations.

Table 10.3: Description of soil codes and farm-group classes.

and thus in the fertilizers application dates Godard (2005).

We started the simulations upon sowing of the preceding crop in order to smooth out the effects of initial soil conditions setting. The preceding crop was either a non-fertilized pea or a fertilized soft wheat. Since we focused on N-losses in relation to Nf application, and because the processes in the nitrogen cycle responsible for the various N-losses do not instantly respond to Nf inputs, it may be relevant to include the N losses occurring over the next few years of the crop rotation. However, as the economic model only takes into account the year of the FADN data (1997, in this case), we only used the N loss estimates for this year.

For the choice of the simulated crops, we were restricted by the capacity of the CERES-EGC model. Indeed, the cultivation of potato or sunflower are not input yet in the crop-model. However, as shown in the Table 10.4, we have worked with the most abundant crops of Picardie region. Wheat, barley, maize, rapeseed and sugar beet cultivation represented 74% of the total arable area of the region in 1997 AGRESTE (1997).

Crop	Area
Soft wheat	502 343 ha
Maize	35 100 ha
Sugar beet	166 855 ha
Rapeseed	37 839 ha
Spring barley	39 286 ha
Winter barley	91 183 ha
Sum	872 606 ha
Part of total arable area	74 %

Table 10.4: Area assigned to the different crops in Picardie. *Source : Agreste (1997)*

10.3 Results and discussion

10.3.1 Response curves to nitrogen fertilizer inputs.

Yield results : comparison with the STICS estimates.

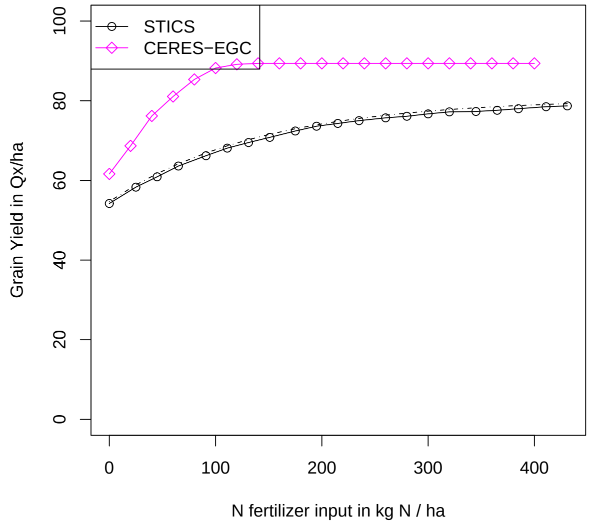
In order to test the consistency of CERES-EGC with the combinations of crop, cultivar, farm-group and soil defined by Godard (issued from STICS assessments), we needed to compare our results with those obtained with STICS.

Figure 10.3 (page 161) presents the yield comparison for four different cases. For the case 6, involving soft wheat, CERES-EGC and STICS provided similar results. On the other hand, the other cases evidenced some degree of discrepancy between the yields simulated by STICS and CERES-EGC. As we used the same input data with both models, the differences in the yield estimates should be ascribed to differences in the mechanisms or formalisms entailed by the models. For future work, it would be interesting to further the comparison and point out the differences in the mechanisms and performances.

In this preliminary stage of the work, we elected to proceed with the CERES-EGC model for all the Picardie cases even though the yield results did not exactly match the STICS results. It should

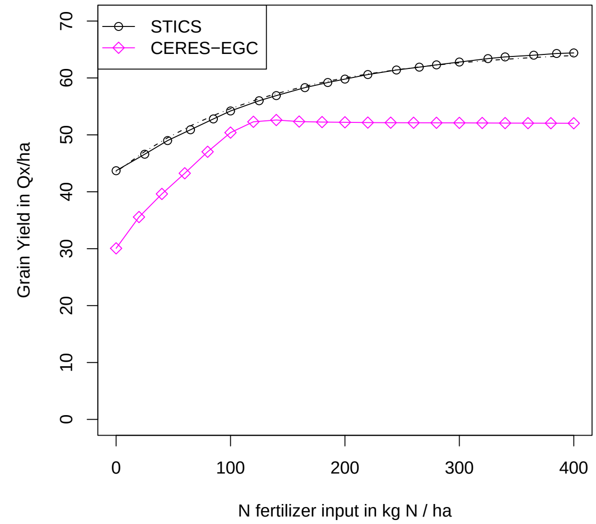
[1] The "precocity group" is a characteristic of a crop cultivar to define its maturity. It is a determining factor of the different dates of intervention during the cultivation of one crop.

[2] The preceding crop "Pea" is not fertilized whereas "Wheat" is fertilized with 200 kg N ha^{-1}.



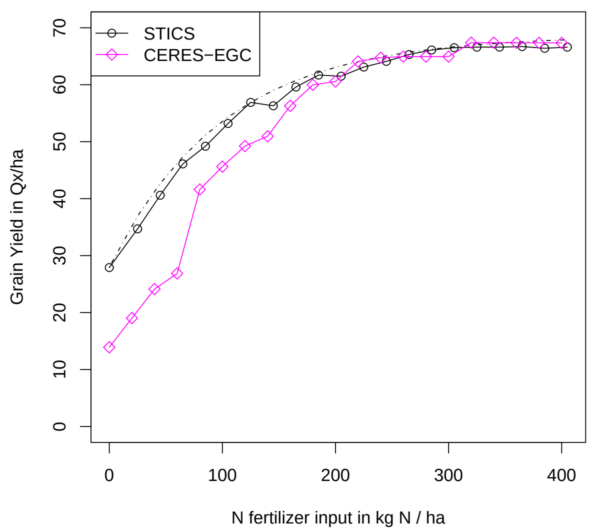
Case 2 : Maize

Calcaric eutric cambisol, Pea as previous crop.



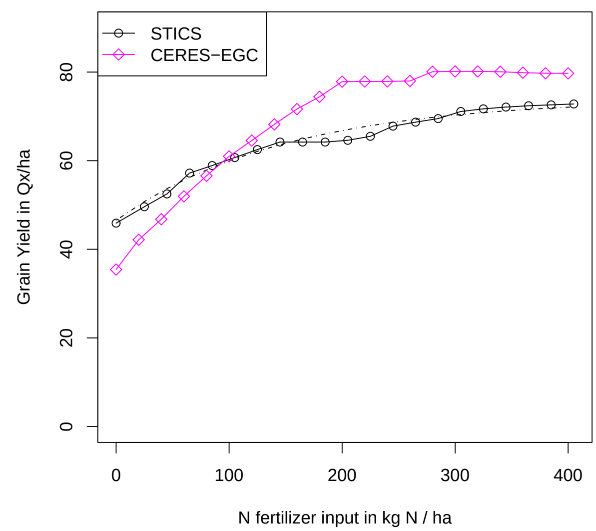
Case 5 : Spring barley

Calcaric eutric cambisol, Pea as previous crop.



Case 6 : Soft wheat

Eutric fluvisol, Pea as previous crop.



Case 12 : Winter barley

Calcaric eutric cambisol, Pea as previous crop.

Figure 10.3: Comparison of the Yield results : CERES-EGC / STICS

be kept in mind for the rest of the study that there is differences in the yield assessments between STICS and CERES-EGC.

Response curves of N_2O emissions to nitrogen inputs.

We studied the N_2O emissions for each case for Nf amount varying from 0 to 400 kg N ha^{-1}. Figure 10.4 (page 163) presents the N_2O emissions simulated with the CERES-EGC crop-model.

Generally, N_2O emissions increased as the Nf input increased. However differences are shown between the cases in the order of magnitude of the N_2O emissions. For a 400 kg N ha^{-1} fertilizer input, N_2O emissions may reach 3.5 kg N_2O-N ha^{-1} for wheat, and nearly 11 kg N_2O-N ha^{-1} for sugar-beet. Besides the response pattern to the Nf input can be significantly different between cases, to the extent that in some certain cases (wheat and rapeseed), a decrease of the N_2O emissions was observed when the Nf input increased. The variability of the response curves obtained with CERES-EGC for the different cases was due to the variability of one or several of the parameters of the cases (soil, crop, sowing date, previous crop).

The straight lines (noted *Bouwman assessment*) in the graphs of the figures 10.4 represent the N_2O emissions assessments according to the equation $E = 1 + 0.0125 * Nf$, with E the annual direct N_2O-N emission and Nf the nitrogen fertilizer applied (E and Nf in kg N ha^{-1}year^{-1}) Bouwman (1996). This linear model is used as the default IPCC methodology Houghton et al. (1996). It also represents the current calculation of the N_2O emissions in the AROPAj economic model with the difference that the background emissions (represented when there is no Nf input) are not taken into account in AROPAj. The comparison between Bouwman and CERES-EGC assessment clearly showed that the two models never matched. Depending on the cases, Bouwman equation either over- or under-estimates N_2O emissions. It proves the importance of a finer assessment of the N_2O emissions with biophysical model that can take into account the variations in soil, climate, and crop management.

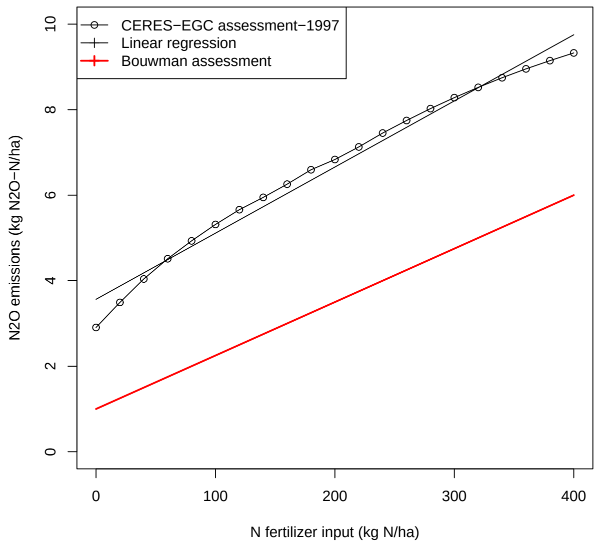
In its current implementation, the AROPAj economic model uses the Bouwman emission factor to estimate N_2O emissions but ignores the "natural" (or background) N_2O emissions represented by the intercept of the regression line. For this preliminary study, we elected to keep a linear response pattern of N_2O emissions to Nf. As a consequence, only the slope of the curves (emission factor) were modified in the economic model. Linear regressions were thus made on the CERES-EGC N_2O emissions results. Note that the rather variable levels of background emissions (going from 0.37 to 3.67 kg N_2O-N ha^{-1}) simulated by CERES-EGC in the various cases were not input to AROPAj.

Table 10.5 presents the characteristics (Coefficients, Residual Standard Error and Adjusted R-squared) of the linear regressions, the lines of which are depicted on the graphs of figure 10.4 (noted *Linear regression*).

Examination of the graphs and analysis of the regressions' residuals show that the linear regressions fitted the N_2O emission response curve quite well. However, for certain cases such as those involving rapeseed crops (e.g. cases 8 to 10), or soft wheat (e.g. case 6 and 7), the N_2O emissions curve presented an important dip (see figure 10.4). This particular pattern in the response curve was ignored by the linear regression.

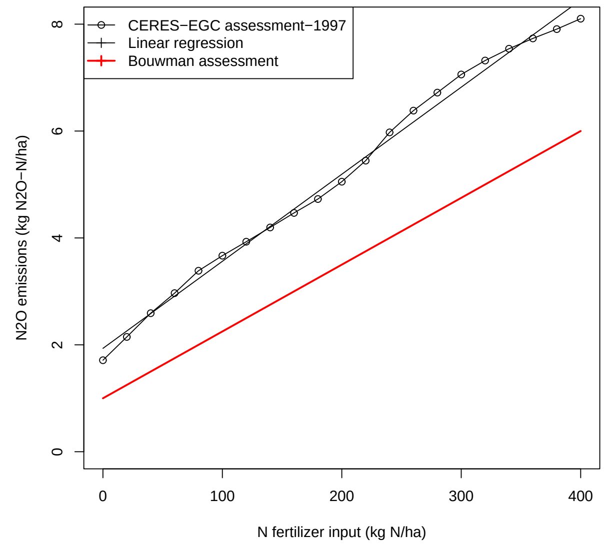
As shown on figure 10.5, a major difference in the N_2O emissions can be observed between spring crops and winter crops. The emissions were overall higher for spring crops than for winter crops. This can be easily explained by the difference in the lengths of the growing season. With spring crops, the soil is supposedly bare during winter, inorganic forms of nitrogen are not taken up by crop roots, and are available to be denitrified or nitrified.

As mentioned earlier, in some cases the linear regressions smoothed out particular pattern of the N_2O response curve. This implies that the linear model is not the most appropriate to describe



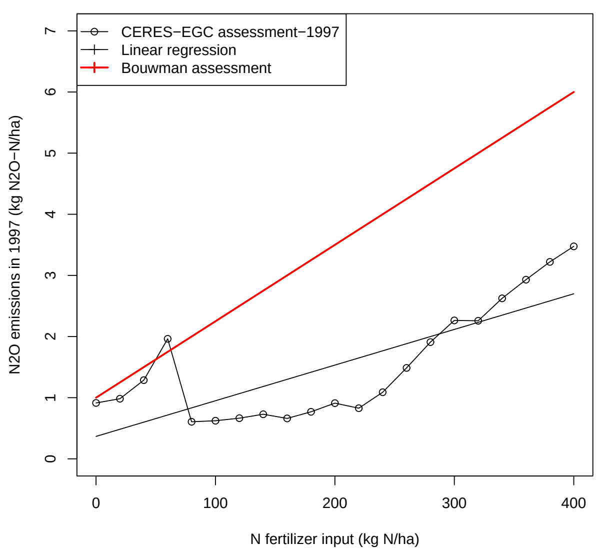
Case 2 : Maize

Calcaric eutric cambisol, Pea as previous crop.



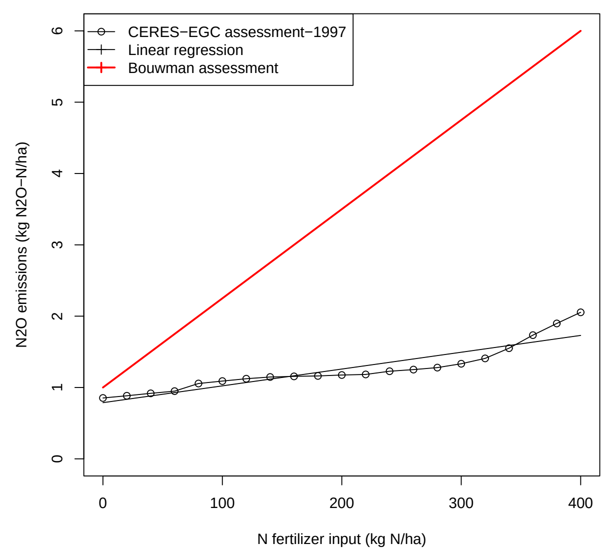
Case 5 : Spring barley

Calcaric eutric cambisol, Pea as previous crop.



Case 6 : Soft wheat

Eutric fluvisol, Pea as previous crop.



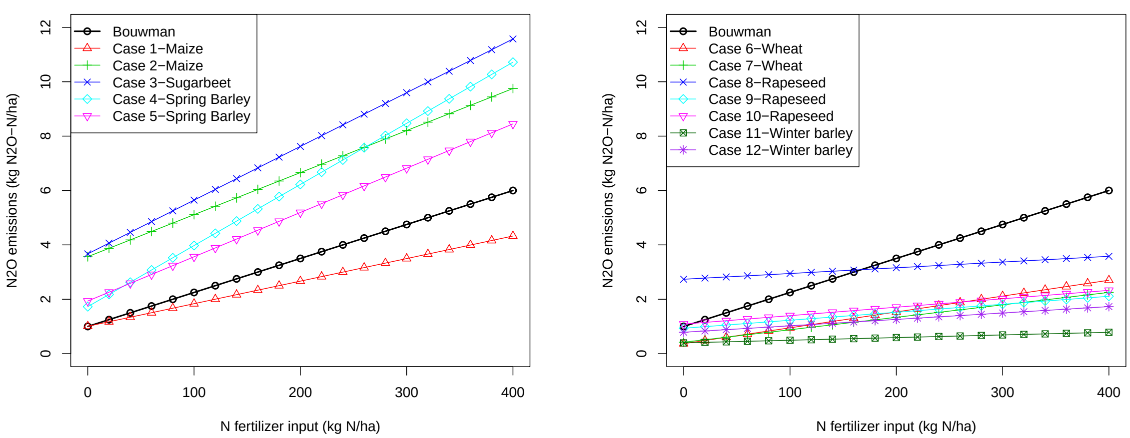
Case 12 : Winter barley

Calcaric eutric cambisol, Pea as previous crop.

Figure 10.4: N_2O emissions : response curves to Nf input, linear regression and IPCC assessment.

Case	Crop	a (%)	b	Residual standard error	Adjusted R-squared
1	Maize	0,83	1,01	0,36	0,89
2	Maize	1,55	3,56	0,26	0,98
3	Sugar beet	1,98	3,67	0,42	0,97
4	Spring Barley	2,25	1,73	0,61	0,95
5	Spring Barley	1,63	1,93	0,17	0,99
6	Wheat	0,58	0,37	0,60	0,58
7	Wheat	0,46	0,42	0,25	0,84
8	Rapeseed	0,21	2,74	0,71	0,08
9	Rapeseed	0,29	0,93	0,48	0,35
10	Rapeseed	0,31	1,09	0,51	0,34
11	Winter Barley	0,10	0,39	0,03	0,95
12	Winter Barley	0,24	0,79	0,13	0,83

Table 10.5: Coefficients of the linear regressions of N_2O emissions with Nf. The regression reads: $E_{N2O} = a \times Nf + b$.



Spring Crops Winter Crops

Figure 10.5: Comparison of the linear N_2O emissions between spring crops and winter crops

the response of N_2O emissions to the Nf inputs. Other non-linear model were tested (exponential model), they could fit the response function of N_2O emissions better (the residual standard error for the wheat cases were close to 0.13) but we needed a linear model to be compare to the IPCC methodology. For further work, we should go thoroughly into this study in order to find the best-fit model, and make it feasible in AROPAj to easily introduce non-linear functions.

Response curves of the other N-losses

Ammonia emissions and nitrate leaching also depend on Nf inputs. It is interesting to look at their relationship to Nf, to study how a taxation targeted at the mitigation of GHG emissions would impact other types of N losses. Figure 10.6 (page 166) presents the variations of NH_3 emissions and nitrate leaching with Nf for two cases : a winter crop (soft wheat) and a spring crop (spring barley).

Nitrate leaching had the same linear response pattern for both cases, with virtually no influence of Nf dose. However, it should be pointed out that the results given by CERES-EGC pertain to the year of cultivation (1997 in this case). As some processes of the nitrogen cycle depend on soil microflora, they do not respond instantly to Nf input. The following years of cultivation should be studied in order to see the influence of the amount of the Nf input on the nitrate leaching. Besides, it is noteworthy the magnitude of nitrate leaching was quite different between the two cases.

The NH_3 emissions had the same response pattern for both cases, increasing with increasing Nf. However, for the same Nf input, the cultivation of winter wheat produced less NH_3 than the cultivation of spring barley.

10.3.2 Impacts of response functions to nitrogen input in economic modelling.

Introduction of new N_2O emissions factors in the AROPAj model

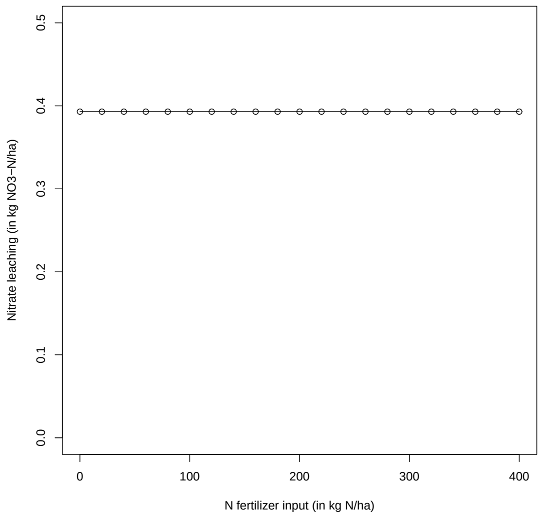
Since we kept the assumption that N_2O emissions respond linearly to Nf input, we used the linear regressions of the CERES-EGC results for the different cases (combining climate, soil characteristics and crop management for the 1997 climatic data of the Picardie region). We introduced in AROPAj several emission factors for direct N_2O emissions from agricultural soils depending on the crop and the farm-group. Indeed a large part of Godard work consisted in linking AROPAj farm-group with climate, soil and crop-management characteristics. These emission factors are the slopes of the linear regressions made on the N_2O emissions for the different cases. Indeed the intercept of the curves were considered as natural (or background) part of the N_2O emissions and they are not taken into account in AROPAj. When AROPAj had no information on the N_2O emission factor, the default emission factor were used (1.25% of the total Nf input).

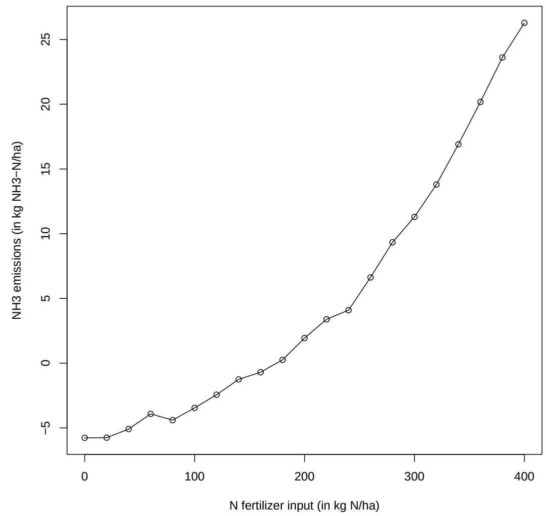
For the simulations made with AROPAj economic model, we used the CAP agenda 2000 scenario De Cara et al. (2005).

Table 10.6 summarize the four simulation cases done with the AROPAj micro-economic model. The yields were assessed either exogenously using the direct FADN data or endogenously thanks to the yield response curves to Nf input Godard (2005). The N_2O emissions were assessed either with the default emission factor (noted IPCC) or with the CERES-EGC emission factor (noted CERES).

Figure 10.7 presents the AROPAj results for the N_2O emissions and the global GHG emissions for all the Picardie region.

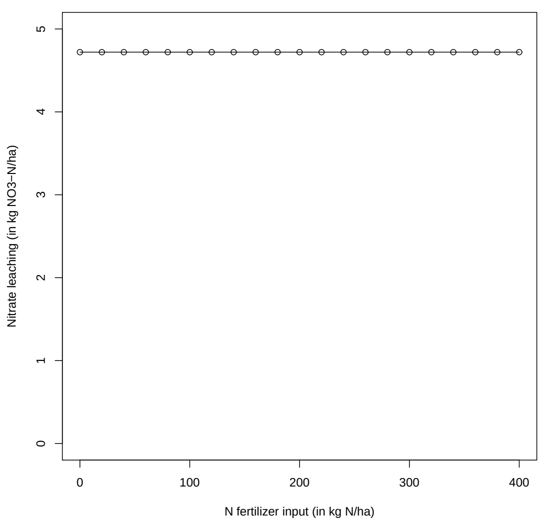
It clearly shows that with the new emission factors N_2O emissions are reduced (either with the exogenous or the endogenous yields) : there is a 20% reduction of the N_2O emission with the emission factors from CERES-EGC. The level of the N_2O emissions is as well reduced from the exogenous to the endogenous yield assessment : there is nearly 30% reduction of the N_2O emissions with the use of the yield response curves. With the endogenous yields, the model is more reactive to

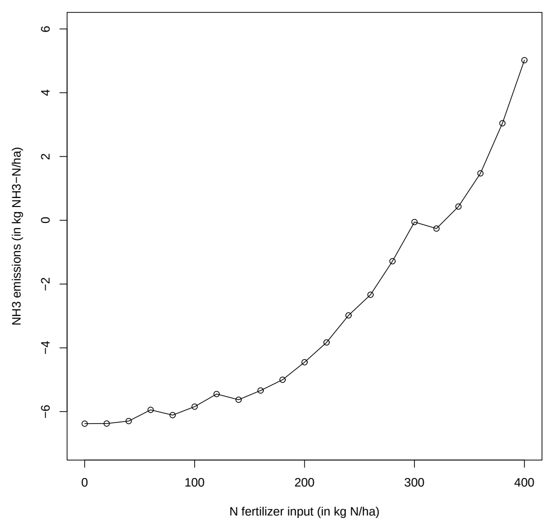




Nitrate leaching NH_3 emissions

Case 4 : Spring Barley, Calcaric eutric cambisol, Wheat as previous crop.





Nitrate leaching NH_3 emissions

Case 6 : Wheat, Eutric fluvisol, Pea as previous crop.

Figure 10.6: Variation of nitrate and ammonia losses as a function of N fertilizer input.

	Yield assessment	N_2O emissions assessment
IPCC-EXOG	Exogenous	1.25 % of the Nf input
CERES-EXOG	Exogenous	% of the Nf input depending on the crop and the farm-group
IPCC-ENDOG	Endogenous	1.25 % of the Nf input
CERES-ENDOG	Endogenous	% of the Nf input depending on the crop and the farm-group

Table 10.6: Characteristics of the AROPAj simulations.

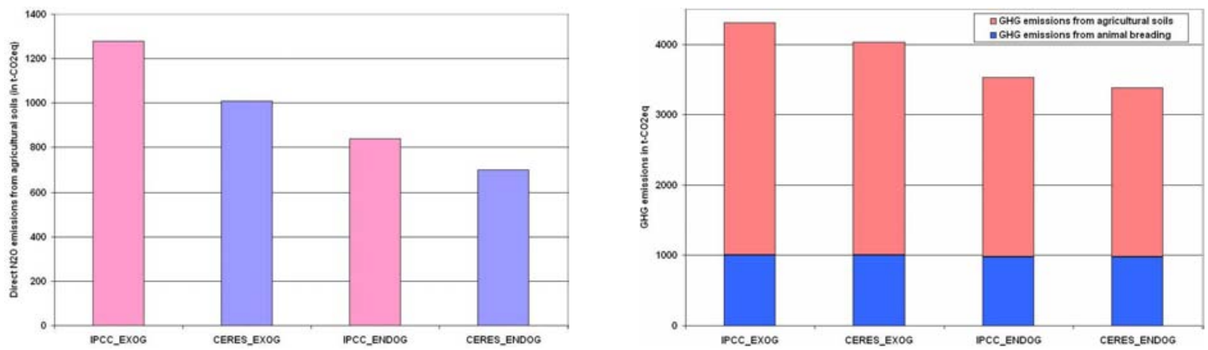


Figure a : N_2O emissions from synthetic fertilizers Figure b : Global GHG emissions

Figure 10.7: Results on GHG emissions for Picardie region.

the CAP agenda 2000 scenario, by then there are changes in the management of each farm-group : the areas allocated to each crop are slightly modified as well as yields, and so the GHG emissions.

As the N_2O emissions are reduced, the global GHG emissions (Figure 10.7b) were reduced when the simulation went from IPCC to CERES assessment of the N_2O emissions and from the exogenous to the endogenous yield assessment. Obviously, the GHG emissions from animals are not affected by the new emission factors.

Figure 10.8 presents the global gross margin results of AROPAj for the different cases of simulation. Coherently, the changes in the N_2O assessment brought no changes in the economic results : the gross margins remain the same. As well, the crop areas and the crop production levels were not affected by the changing in the N_2O emissions assessment.

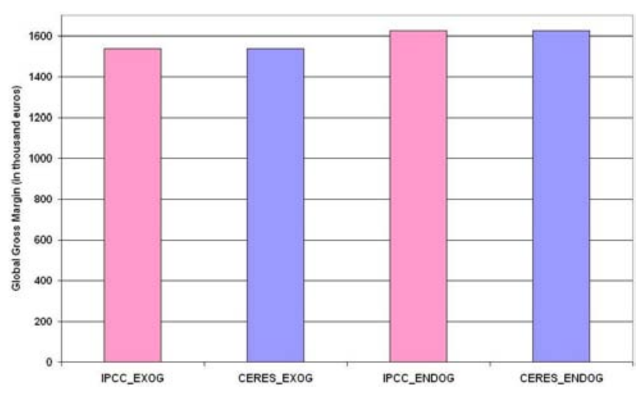


Figure 10.8: Global gross margin results for Picardie region.

However, with changes in the yield assessments the economic results were modified. All the production levels increased, as well as the gross margins. The total arable area was not modified because the AROPAj model considers the Utilized Agricultural Area for each farm-group as constant. Nevertheless, the cultivated area of each crop was modified.

Economic modeling to study mitigation measures of greenhouse gases emissions

Different tax policies may be implemented in AROPAj with different parameters. In order to mitigate the total GHG emissions, and by then the N_2O emissions, we enforced two different type of taxing : a first best taxing using a tax on the GHG emissions; and a second best taxing using taxes on the assumed factors of the GHG emissions.

Taxing the GHG emissions

We studied for each case of simulation (presented table 10.6) the effects of an increasing tax on the GHG emissions going from 0 to 100 € per t-CO_2-eq. Figure 10.9 presents the results for Picardie region regarding the total GHG emissions and the reduction of these emissions.

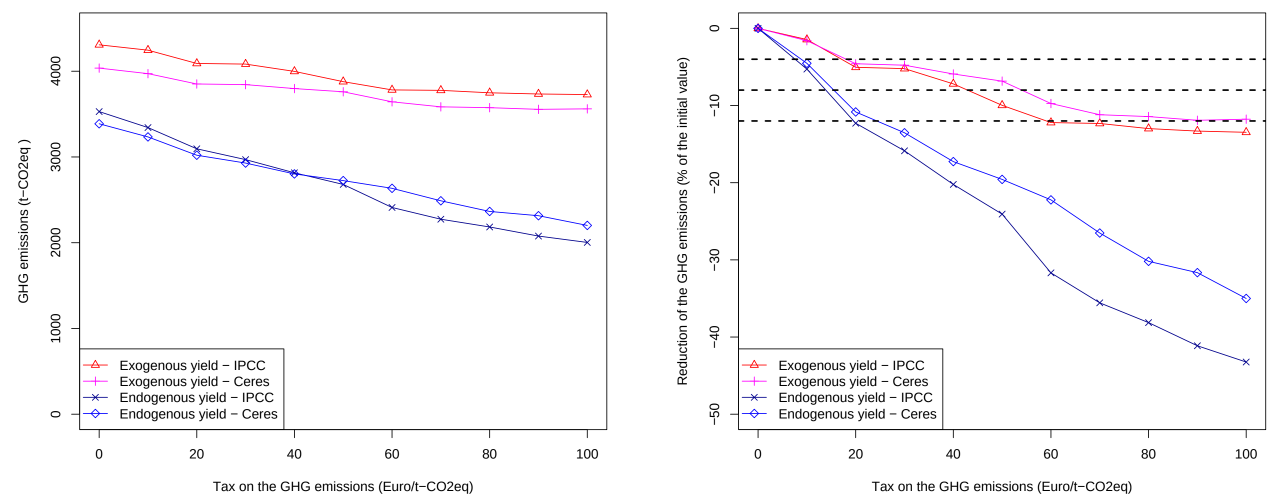


Figure a : Global GHG emissions Figure b : Reduction of the GHG emissions

Figure 10.9: Increasing tax on GHG emissions : Global results on GHG emissions for Picardie region.

As expected, for each case of simulation the GHG emissions were shown to decrease when the level of the tax increased. The major difference between the cases is due to the yield assessment : the GHG emissions with the exogenous method are significantly higher than the ones with the endogenous method. All the more, the response to the tax is different : with the endogenous yield assessment the reduction is more pronounced. However, the difference in the N_2O emissions assessment has also an impact : it brings changes in the level of the emissions, and also affects slightly the response to the tax increase.

The study of the level of the tax needed to achieve targets of GHG emissions mitigation corroborates this analysis. The three lines on the graph of figure 10.9b present three mitigation target (4, 8 and 12% reduction of the GHG emissions) and the curve presents the reduction of the GHG emissions with the increasing tax on the GHG emissions. Table 10.7 presents the level of the tax needed to achieve the mitigation targets for each case.

	Exogenous Yields		Endogenous Yields	
GHG emissions reduction	IPCC	CERES-EGC	IPCC	CERES-EGC
4%	14.5	14	6.9	8
8%	46	53	10.8	11
12%	59	85	19	24

Table 10.7: Tax on the GHG emissions (in euro/t-CO_2-eq) for each mitigation target.

In order to reach the same level of mitigation, cases using the exogenous yield assessment need a higher tax on GHG emissions. The stronger is the mitigation target, the higher is the gap between the taxes needed for the exogenous or the endogenous yield cases. In order to have a 4% reduction of the GHG emissions, the taxes of the exogenous yield cases are 2 times higher than the ones of the endogenous yield cases, whereas the tax is 3 to 4 times higher for an 8% mitigation.

In addition, the difference in the N_2O assessment is well described here. Generally, the tax needed to achieve a mitigation target needs to be slightly higher when the new emission factors are used, and for highly ambitious mitigation target, the gap between "CERES" and "IPCC" assessment methods is intensified.

We can observe the same tendencies through the analysis of the response of the total gross margin for the whole Picardie region to an increasing tax on GHG presented figure 10.10.

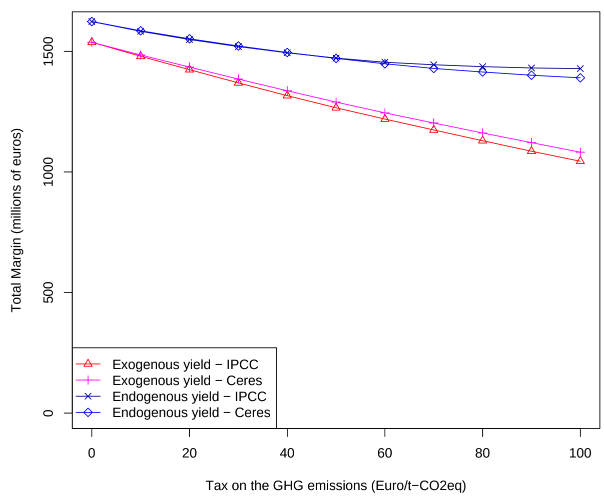


Figure 10.10: Total Gross Margin with an increasing tax on the GHG emissions.

The difference in the yield assessment is well marked : the total gross margin is higher with the endogenous than with the exogenous yield assessment. More, with the increasing tax, the reduction of the gross margin is significantly less important with the endogenous method than with the exogenous one. Indeed, the endogenous method allows a better reactivity of the farmer to the changes in prices, and by then to the political measures. In these gross margin results appear also small differences due to the use of CERES-EGC emissions factor, and the more important the level of the tax on GHG is, the more these differences are pronounced.

This tax on the GHG emissions allows the public regulator to reach ambitious target of environmental damage abatement. However, it is very costly to implement such taxing because one needs to be precisely aware of each farmer's level of GHG emissions. Economically and materially, it seems to be unfeasible to measure these GHG emissions on each cropland.

Taxing the assumed factors of the GHG emissions

The GHG emissions in AROPAj aggregates methane (CH_4) and N_2O emissions. Methane is produced by the enteric fermentation of the cattle, the manure management, and the rice cultivation. N_2O is largely produced by the agricultural soils with the nitrogen fertilizer use, the manure application, the crop residues, etc. By then, the most important factors of the GHG emissions can be assumed to be the animals (for CH_4 and N_2O), and the nitrogen fertilizer use (for N_2O) De Cara et al. (2005).

As the animals or the nitrogen fertilizer use are easily observable factors (through the CAP or the markets), a second best GHG mitigation policy focused on the assumed factors of the GHG emissions could be implemented. It would lead to tax the livestock population and the nitrogen fertilizer use for each farm. Thus, we have studied the effects of such taxing policy on the GHG emissions with the AROPAj model and the different cases of simulation presented table 10.6.

Figure 10.11 (page 170) presents the results of AROPAj simulations with a combination of two taxes : one on the animals (in €/LU[3]) and one on the nitrogen fertilizer input (in €/t of N). The curves present the combined tax needed to reach a certain level of reduction (2 to 12% reduction of the total GHG emissions - in relation to the initial level of emissions).

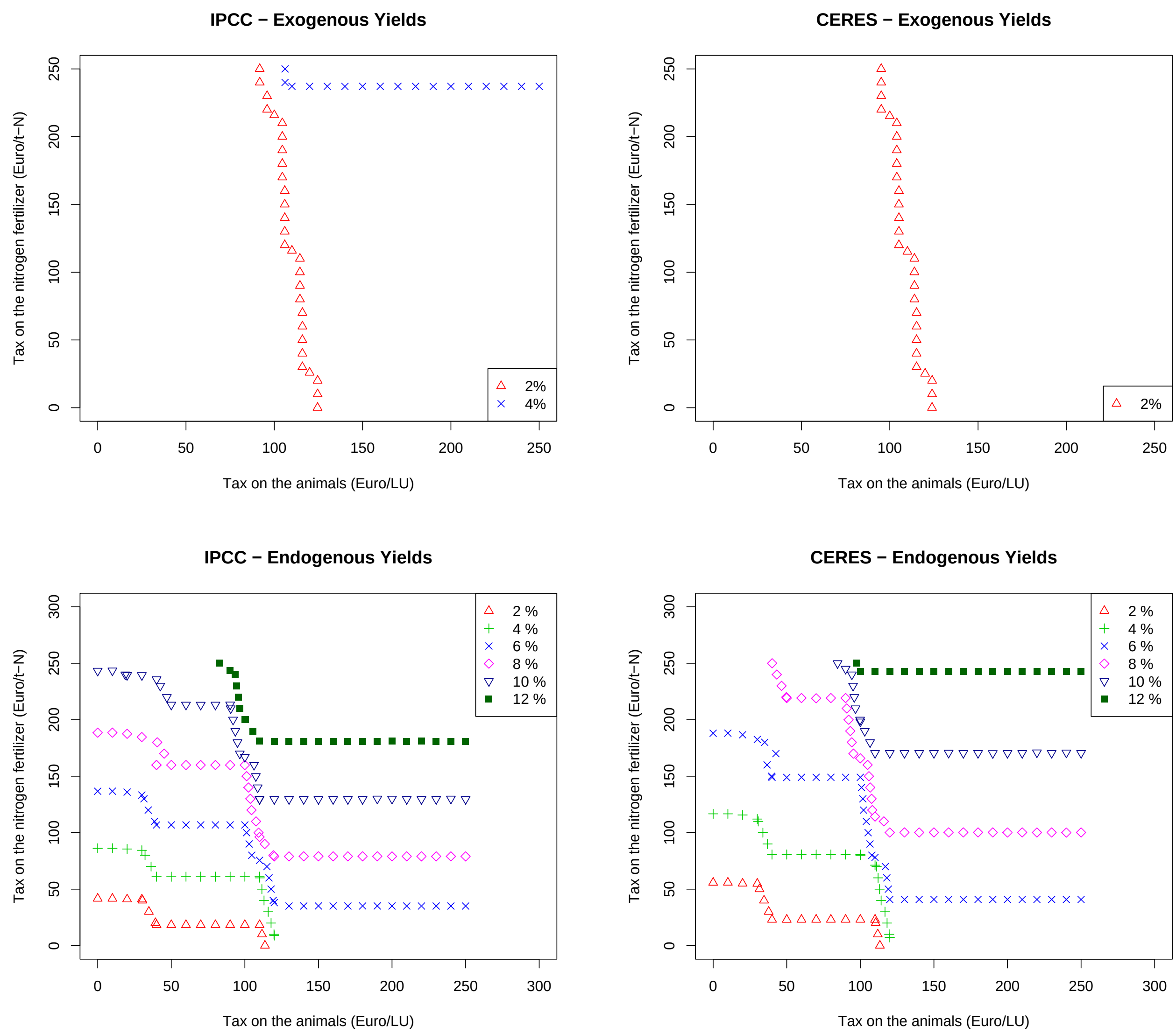


Figure 10.11: Achieving different mitigation targets with the coupled taxes on the animals and on the Nf input. *Results for Picardie region.*

The graphs clearly show the important difference between the use of the exogenous and endoge-

[3]LU (Livestock Unit) is a unit used in order to compare livestock size of different species or category of animals. It is based on the feeding demand of the animals.

nous yield assessment. With the exogenous yields, reasonable mitigation target are hardly reached : in order to have a reduction of the GHG emissions higher than 2%, the 2 taxes need to be higher than 200 €/ LU (or /t of N). Whereas, with the endogenous yields, for couples of taxes higher than 200 €/ LU (or /t of N), the reduction of the GHG emissions can reach more than 10%.

It is important to note that in the AROPAj present implementation, there is no possibility to have an endogenous assessment of the animal production. Namely, meat or milk producion levels are not related to animal feed supply levels. Obviously, such assessment should bring more reactivity to the model and the response to the second best taxing would be more linked to the reality.

The graphs also show an effect of the method used for N_2O emissions assessment. On the whole, for the same reduction target, the taxes needs to be higher with the new emission factors from CERES-EGC. With the endogenous yields, in order to have a 12% reduction of the GHG emissions, the tax on the nitrogen input needs to be between 180 and 250 €/t N with the 1.25 emission factor from the IPCC methodology and between 240 and 250 €/t N with the new emission factors.

In comparison with the first best tax, there is a loss in the efficiency with the second best taxing policy. Indeed, for the same reduction target, the second best taxes brought back to an equivalent in €/t-CO_2 eq are much higher than the first best tax. For an 8% reduction of the GHG emissions, the first best taxing ranges nearly 11 €/t-CO_2 eq whereas the second best taxing could be up to 125 €/t N and 110 €/LU. Considering that 1 t-N produce roughly 4 t-CO_2 eq and that 1 LU produce 3 t-CO_2 eq[4], the equivalent tax on the GHG emissions for the second best taxing is 68 €/t-CO_2 eq , 6 times higher than the first best taxing. However, an analysis of costs and profits of the taxation policies needs to be done in order to compare the efficiency of the 2 taxes.

10.4 Conclusion

Currently, the IPCC Tier 1 methodology is used to assess greenhouse gas emissions such as N_2O emissions, but this methodology presents certain lacks of precision. This paper studied an alternative methodology to assess the N_2O emissions at an aggregated level with the coupling of a biophysical crop-model and a micro-economic model. The biophysical crop-model CERES-EGC enabled a fine assessment of N_2O emissions related to the environment conditions, and the economic farm-group model AROPAj enabled the generalization of the N_2O results at the farm-group scale. All the more, the paper also studied possible mitigation measure of the GHG emissions.

For different cases combining soil, climate and crop management characteristics in the Picardie region, response curves of N_2O emissions to nitrogen fertilizer input were built. As co-results, response curves of the other N-losses (NH_3 and NO_3^-) to the amount of nitrogen applied were also built but these results were not used in the economic analysis.

A linear function was chosen to smooth the response curves obtained for the N_2O emissions. The slopes of the regressions ranged from 0.10 to 2.25% depending on the cases, whereas the IPCC default method considered a constant 1.25% emission factor. These slopes were introduced in the economic farm-group model AROPAj as new emission factors depending on the crop and the farm-group.

With AROPAj, we defined 4 different cases of simulations : using the exogenous yield assessment or the endogenous one (using yield response curves to nitrogen input), and using the 1.25% emission factor or the new emission factors from CERES-EGC. We first noticed that the global N_2O emissions for the Picardie region were less important with the new emission factors. All the more, we noticed

[4]Approximate calculation using the 1.25% emission factor from IPCC and a 300 Global Warming Potential for N_2O; and an approximate value of 150 kg of CH_4 per LU and a 21 Global Warming Potential for CH_4.

that taking into account the yield response functions to N-input appeared as very important for the economic modelling.

AROPAj allowed us to study two different greenhouse gas mitigation measures : a first best tax on GHG emissions and a second best tax on the assumed factors of the GHG emissions (the animals and the nitrogen input). It is interesting to remark that the differences in the modelling (exogenous or endogenous yields, IPCC or CERES-EGC N_2O emission factors) brought lots of differences in the response to the taxes and by then in the conclusions that could be taken on the efficiency of the mitigation policies.

For the first best tax, the discrepancy between the cases leads to taxes going from 11 to 53 €/t-CO_2 eq for an 8% reduction of the GHG emissions. The gap is firstly due to the yield assessment : with the endogenous yields when the tax increases, the reduction of the GHG emissions is more pronounced. For high level of taxes (up to 50 €), differences due to the N_2O emissions assessment appear.

For the second best taxing coupling a tax on the animals and a tax on the nitrogen input, the same differences between the cases could be observed. The endogenous yields brings a better reactivity of the model, and mitigation target are easily reached. However, in order to reach a reasonable level of 8% reduction the taxes need to be very high (more than 100 €/ LU or t-N).

In order to compare the 2 types of taxing and measure the loss of efficiency, a detailed analysis must be made on the cost and the profits of each tax. All the more, to improve the operational status of the method, we need to extend the building of response functions for yields and environmental impacts to other regions and other crops. The environmental impacts such as NH_3 and NO_3^- could be introduced in the economic analysis. Implementing response functions of animal production (meat and milk) to animal feed supply levels in AROPAj may also be an interesting issue to go through. This methodology should be applied to the last version of the AROPAj model (with FADN of 2002) using the database in progress.

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11 How the AROPAj model would deal with the nitrogen demand : a first modelling step

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Abstract

Nitrate leaching is one of the most important nitrogen born pollutions from agriculture apart from N_2O and NH_3 emissions. A quick review of both agricultural practices and political measures able to cope with such a pollution is exposed. Simple formulas of nitrate leaching calculation from the litterature are a first way to model such pollution phenomenon. To be able to integrate nitrate leaching in a modelling framework such as the one of AROPAj, an additionnal review of modelling approaches provides more detailed methodologies. This led to the study of the possibility to integrate alternative cropping techniques in the STICS-AROPAj modelling framework. As a first modeling step, AROPAj simulations (without link to the STICS model) are used to assess the effect of a tax on nitrogen on the gross margin of farmers and the volume of N-fertilizer they buy. Agregated EU15 farm groups show a decrease of both the gross margin and the quantity of bought fertilizer with the growth of the N-tax. A focus made on the Castilla-La Mancha region shows more detailed results, sometimes contradictory. Namely, the quantity of fertilizer bought does not depend on the N-tax level if the latter is below 20% ot over 30%. On the contrary, the amount of % fertilizer bought decreases for a N-tax in the interval from 20% to 30%. Those first results should be completed by other assessments from simulations of the AROPAj model linked to the STICS model and so integrating N-response curves.

11.1 Introduction

Although an adequate supply of Nitrogen (N) in soil is essential for crop growth, if soil is overloaded, N could cause major pollution problems. Pollution caused by the excess of N compounds affects surface water, leading to eutrophication; groundwater, altering the quality of the drinking water; and air, with the emission of nitrous oxide and ammonia (OECD 2001). The environmental effects coming from the soil N leakage, especially nitrate leaching and gaseous emissions, have received more attention than the others (Lewis et al. 2003).

The current agricultural practices in Europe are the main source of nitrates content in ground and surface water (Johnsson et al. 2002, Oenema et al. 1998, Watson and Atkinson 1999). Inputs of fertilizers and animal manures to agricultural soils have augmented much more than the output of N in harvested crops (Oenema et al. 1998). As a consequence of this, it has been detected an increase in N losses from agriculture and the growth of nitrate concentrations in groundwater. Nitrates are mainly leached from intensive agriculture lands, especially where livestock densities are higher (Jansen et al. 1999) such as in the Netherlands, the United Kingdom, Denmark or Germany. Thus, local authorities, national governments and the European Union have implemented several action plans to reduce these negative impacts (Johnsson et al. 2002). The Commission of the European Communities (1991) enacted the Nitrate Directive 91/676/1991 concerning the quality of water against pollution by nitrates from agriculture. This directive imposed a limit of 50 mg/l for nitrate content in potable water for all Member States.

The main purpose of this work is to determine the most important aspects to be considered in the nitrate leaching modelling, as well as to compare the methodologies that have been developed. Furthermore, it pretends to suggest some scenarios and some agricultural practices that MIRAjE modelling framework could include in order to simulate the pollution from nitrates.

11.2 Working plan

The working plan was divided into different phases:

1. Revision of those scientific papers related to the nitrate pollution issue that consider the measurement of nitrate leaching from arable land by means of experimentation or modelling simulations (see summarising tables in ANNEX)

2. Revision of the political measures implemented to reduce the nitrate pollution, in the last years, apart from the one proposed by the Commission of the European Communities (1991).

3. Finding out the agricultural practices that decrease or increase the risk of nitrate pollution

4. To determine the ways that different models take into account alternative agricultural practices to reduce N losses and to extract for each one the main aspects: data, the methodology, the scenarios and the kind of conclusions that can be obtained from their simulations

5. To discuss which agricultural practices and political measures could be modelled by using the integrated MIRAjE framework (Godard, Bamière, Debove, Cara, Jayet and Niang 2005), that links the economic model AROPAj (Jayet 2004) with the crop simulation model STICS (Brisson et al. 2003).

11.3 Methodology

1. The review has been done for the scientific articles whose publication date is after 1994. The keywords used for the search are the following: nitrogen, leaching, arable land and fertilizer. In addition, some bibliography available at the UMR Economie Publique INRA INA-PG has been reviewed.

2. A scheme has been made to summarize the information contained in the bibliography, in order to remark the data used in each research, the keywords included in the publication, the agricultural practices considered, the methodology applied (experimental or model), the region where the study takes place, the scale of the study and the kind of conclusions that could be obtained from the different approaches.

3. A deeper study has been done for those articles whose models have been implemented to calculate the nitrate content in the soil coming from the agricultural practices.

4. Revision of the bibliography related to the models AROPAj and STICS and its coupling to have a better understanding of their possibilities to incorporate the nitrate leaching issue.

5. Elaboration of a report that includes all the main findings of the review and that considers the possibilities of incorporating the nitrate leaching issue in both models, AROPAj and STICS.

11.4 Nitrogen cycle

The Nitrogen (N) cycle is characterised by a number of complex transformations and transports of N compounds. Thus, according to Vatn et al. (1996) the processes involved in the cycle are the following:

1. Assimilation process: Primary producers (plants and algae) assimilate N in mineral form, ammonium (NH_4^+) or else nitrate (NO_3^-), or from the atmosphere pool as N_2 through a symbiotic process, N fixation.

2. Mineralization process: The assimilated N is transformed into NH_4^+ through nutrient webs and decomposer communities.

3. Stabilization process of organic N in "humus N", which is an important transitional sink in soil and water. It provides the latter the capacity of changing their storage of organic N in response to the modifications of the climate and the agricultural management.

4. Nitrification is the oxidation of NH_4^+ into NO_3^-. NO_3^- is a more mobile compound and a more accessible N source than NH_4^+ for many plants. Additionally, during the oxidation process of NH_4^+, gaseous N_2O is released as side product.

5. Denitrification: Gateway of soil N compounds to the atmosphere (Vatn et al. 1996). It is an anaerobic bacterial process that reduces nitrate (NO_3^-) to nitrite (NO_2^-) and then to nitrous oxide (N_2O) or nitrogen gas (N_2). Both N_2O and N_2 are lost to the atmosphere (Benbi and Nieder 2003).

Figure 11.1 schematises the relationships that exist between the N compounds and their fluxes. The grey arrows represent N inputs while black arrows mean N outputs. The varied forms of N are represented in bold text and the processes of transformation are shown in italics.

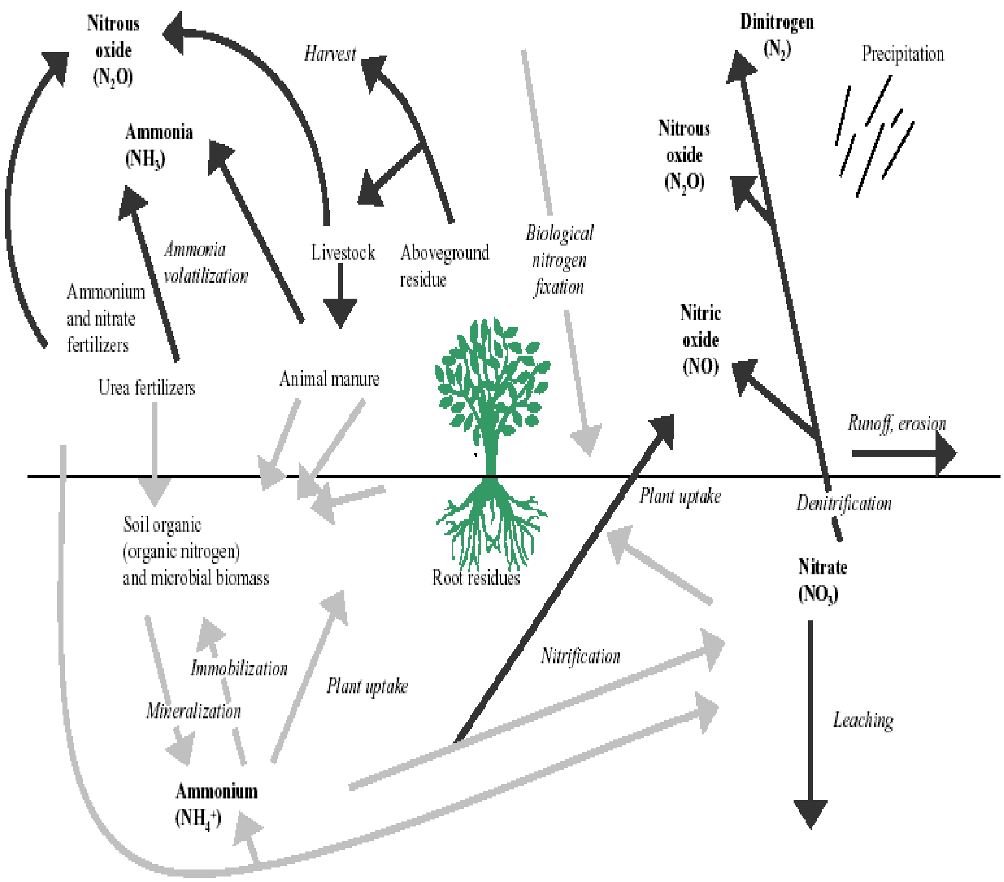

Figure 11.1: Nitrogen cycle. *(Source: OECD (2001)).*

11.4.1 Losses in the environment from agriculture sector

Nitrogen (N) surplus is the difference between inputs and outputs and it represents a potential N loss from any sector or process. Therefore, this is the maximum amount that could be leached in the environment unless accumulation processes occur, either in biomass or in N humus. The principal processes involved in the agricultural sector pollution from N compounds are nitrate leaching, ammonia volatilisation, nitrification and denitrification (Vatn et al. 1996).

- Ammonia volatilization: As soon as urea and ammonium forms of fertilizers are applied on moist soil surfaces they suffer a series of chemical conversions to ammonia gas (NH_3). The ammonia gas escapes to the atmosphere in a loss process called ammonia volatilization (Benbi and Nieder 2003).
- Nitrification and Denitrification: The N_2O is a side product in nitrification and denitrification proccesses. N_2O gas is released in the atmosphere causing a problem at global scale because it contributes to the global warming and to the destruction of ozone (Vatn et al. 1996).
- Nitrate leaching

11.4.2 Nitrate leaching

Leaching happens when water that moves through the soil can transport N down out of the rooting zone of the plants. This process affects the nitrogen in nitrate form (NO_3^-) since it moves freely with the soil water unless soils have significant anion exchange capacity (Benbi and Nieder 2003). It occurs when the deposition in terrestrial environments exceeds the system's capacity for N assimilation. The N surplus in nitrate form that escapes from the agricultural system causes the enrichment of surface and ground water in nitrates, and therefore their eutrophication (Vatn et al. 1996). Furthermore, leaching of N also reduces the N fertilization efficiency since N is no longer available for plant uptake (Benbi and Nieder 2003).

According to Benbi and Nieder (2003), the rate and the extent of nitrate leaching depend on climatic, soil, plant and management factors. Among the climatic factors, rainfall, evaporation and temperature are the most important. Considering the soil factors, soil texture and soil structure interaction have the highest influence. Generally, nitrate leaching is more important in sandy soils than in clayey soils. Among management factors, there is a linear relationship between leaching and N fertilization. Nitrate leaching is likely to be higher in agricultural systems based on organic fertilization than in those which are based on mineral fertilization, due to a lack of measurement of the N content in the manure and the slurry supplied.

The nitrate leaching generates non-point source pollution. Subsequently, in order to reduce its negative effects in the environment, specific technical agricultural measures have already been implemented at farm level.

11.5 Changes in agricultural practices to reduce nitrate leaching

Measures to reduce nitrate leaching below the root zone include the reduction of N-fertilization, the split of the fertilization, an appropriate crop rotation, inclusion of catch crops, the reduction or the delay of tillage, some changes in manure handling/spreading techniques, an adequate timing of manure application and some changes in feeding techniques (Vatn et al. 1996).

11.5.1 Appropriate cropping sequence

The choice of the most appropriate crop rotations along with the inclusion of winter crops or catch crops is a way of reducing nitrate leaching during wet seasons.

The suitability of different crop rotations in different agri-evironmental conditions is considered in the research developed by Kutra and Aksomaitiene (2003) , Kyllmar et al. (2005), Nevens and Reheul (2002) and Webster et al. (1999).

The growing of catch crops or cover crops during winter period may reduce the nitrate leaching and decrease the N concentration annual variability. The cover crop uptakes N from the soil in its mineral form. In addition, mineral N is the fraction with the highest risk for leaching. Thus, its effect is potentially larger when mineral N concentration throughout the autumn is high (Vatn et al. 1996). Several researchers (Gustafson et al. 2000, Wyland et al. 1996) have focused their attention on the outcomes of the introduction of winter crops or catch crops during the intercropping period.

11.5.2 Balanced fertilization

An additional measure is the calculation of the N balance before designing the year around fertilizing plan in order to avoid future nitrogen surplus. The improvement of fertilizer use efficiency is crucial to increase crop yield and to reduce the environmental damage. The fertilizers should be applied to make N available only when the crop needs it. Hence, the optimum fertilizer management system should be selected considering many factors (Malhi et al. 2001):

- the balance between rate of application, cost and availability of equipment;
- soil disturbance;
- seedbed quality;
- moisture conservation;
- time and labour constraints;
- and finally, fertilizer use efficiency.

Moreover, fertilization limitations can be established for each crop. There are some studies that were focused only in the effects of organic N fertilizing (Dauden and Quilez 2004, Maticic 1999) but many other researchers considered the behaviour of both mineral and organic fertilizers (Grignani and Zavattaro 2000, Oenema et al. 1998).

11.5.3 Buffer zones

The *Code of Good Practices* recommends the incorporation of non-fertilized grass strips and hedges along watercourses and ditches. Furthermore, when lands have steeply sloping soils specific practices are suggested as well as some restrictions for cultivation procedures. According to Kruijne (1996), the buffer strips in arable crops and pastures gave good results in reducing nitrate leaching.

11.5.4 Soil Acidity

Nitrification is sensitive to low pH, therefore allowing a natural acidification or lowering intentionally the soil pH might lead to a decrease in nitrate leaching. Even though this management practice may reduce crop yields, it could be an effective tool for decreasing nitrate leaching, and hence, maintaining the quality of drinking water (Kemmitt et al. 2005).

11.5.5 Tillage

Tillage operations also have an influence in nitrate leaching. According to Stenberg et al. (1999) nitrate leaching was greater in the fields where there had been early tillage than in those where there had been a late tillage. This was probably caused by an increase of N mineralization. On the other hand, the same authors showed that when tillage was delayed until late autumn or spring, there was a substantial growth of weeds during autumn that affected crop yields. The results presented by Catt et al. (2000) showed that, in the long term, more nitrate was leached from land subjected to minimal or zero tillage and ploughing than from land ploughed every year.

11.6 Political measures to reduce nitrate losses

The management practices at farm level, mentioned above, can be framed in European, national or regional political measures. Subsequently, there is a brief description of some European political measures, such as the *Agri-environmental measures* and the *Nitrate Directive (91/676/EEC)*, and national political measures, for example *MINAS* Nutrient Accounting System and *Danish Action Plan*. Moreover, the two mentioned measures, Nmineral and N fertilizer tax could be included in a political framework at any level.

11.6.1 Agri-environmental measures

To reduce agricultural nutrient losses, the Finnish and the French governments implemented *Agri-environmental Support Schemes* (Granlund et al. 2000, Lacroix et al. 2004) under the Common Agriculture Policy (Communities 1992). The goal of these Schemes was to develop agricultural practices towards higher sustainability than the conventional practices. According to the *Support Schemes*, farmers are paid for reducing the use of nitrogen fertilizers below the limits established for each crop by the *Code of Good Practices*.

11.6.2 Nitrates Directive (91/676/EEC)

The aims of the Nitrate Directive (91/676/EEC) are to preserve the human health, the living resources and aquatic resources and to prevent from the eutrophication. The Nitrate Directive process has five steps, which start after its transposition in each Member State. The first step is the detection of polluted or threatened polluted waters with N, to preserve the human health and the living resources and aquatic ecosystems and to prevent the eutrophication. Afterwards, the *Nitrate Vulnerable Zones* (NVZs) are designated, selecting the agricultural land areas which contribute significantly to N pollution at a watershed level. Then, a *Code of Good Practices*, with a voluntary character, is defined for all Member State territories. After that, an *Action Plan* is defined within the NVZs and the *Code of Good Practices* becomes mandatory. Finally, every four years each Member State has to submit a report with information related to the *Code of Good Practices*, the designated NVZs, the results of the water monitoring and a summary of the most relevant aspects of the *Action Plan* (Council of the European Communities 2002).

The annexe II *Code of Good Practices of the Nitrate Directive* (Commission of the European Communities 1991) includes the main types of measures to reduce nitrate losses that were previously mentioned. Farmers that belong to a NVZ are forced to follow all the indications of the code, while for the other farmers it is a voluntary commitment.

11.6.3 Nutrient Accounting system (MINAS)

Dutch agricultural policies, since 1998, have included action plans to reduce N and P surplus like MINerals Accounting System (MINAS). This system consists on quantifying all controllable inputs at the farm level, as manure, fertilizer, feed and seeds, and all controllable outputs at the same level, e.g. manure, milk, crop products, ammonia losses from stables. Atmospheric deposition and net mineralization of soil organic N are excluded from the budget calculations. Then, a levy is imposed on N and P surpluses that are above a tolerated level. This levy is used to "stimulate" farmers to reduce the surplus (Jansen et al. 1999). The levy-free surpluses in 1998 were based on the surpluses admitted by the *Code of Good Practices.* The levy-free surpluses for the following years were determined by the relationship between what was economically, practically feasible and environmentally required (Oenema et al. 1998).

11.6.4 Danish Action Plan

The *Danish Action Plan* on the aquatic environment was first implemented to reduce N leaching from rural areas by 100,000 t N·year^{-1} (equivalent to 36 kg N·ha^{-1}·year^{-1}), in 1987. The legislation has been gradually implemented from 1987 until 1997 to reach the goal of the action plan. For land use, it stipulates the rate of winter crops and crops that could be harvested and ploughed in late autumn. The normative on N fertilization schedules allows the spreading of slurry and liquid manure only during the spring. The percentage of organic N in slurry has to be under 60% for pig slurry and 55% for cattle slurry (Borgesen et al. 2001).

11.6.5 N mineral

The *N mineral* (N_{min}) is an official recommendation system implemented in European countries to calculate N fertilization requirements taking into account the soil mineral N. The system consists on the measurement of the soil mineral N in the upper soil layer (0.60 cm) at the planting or sowing time. Farmers would find its implementation difficult because they are not used to have their soils analysed (Ramos et al. 2002).

11.6.6 Nitrogen fertilizer tax

Vatn et al. (1996) proposed the taxation of the N fertilizer inputs to incentive the farmers to reduce N fertilizer consumption and, as a result, to reduce the environmental damages. In relation to the effects of the N fertilizer tax, Vatn et al. (1996) made the following observations:

- A tax may motivate the farmers to use manure N content and change to spreading techniques with less losses in the environment.
- A tax may also induce the increase in the use of legume crops due to their capacity of atmospheric N fixation
- Finally, a tax may encourage farmers to use cover crops or nitrogen catch crops.

Even though the political frameworks that have been implemented have a wide area of action, the nitrate issue demands for a local assessment. There is a need of methods, either the calculation of nitrate leaching or simulation models, to provide an insight of the effects of the political measures on different local environments.

11.7 Calculating nitrate leaching

N nutrient budgets have become an indicator of the possible contamination from nitrates (Houlès et al. 2004, Oenema et al. 1998). Different equations have been used to calculate those budgets and to estimate the possible nitrate leaching. Some of them are the following:

- A simple model was described by Jansen et al. (1999) and implemented in the Netherlands where nitrate leaching is assumed to be strongly related to the amount of N applied and the dynamics of the ground water:

$$NL_h = \lambda_h \cdot \frac{62}{14} \cdot N_h$$

where NL_h, is the nitrate leaching at an homogenous unit; λ_h, is the fraction that actually is leached, depends on the ground water dynamics at the homogenous unit; 64/12 is the conversion factor of N to nitrate; and N_h, is the N surplus at soil level (kg·ha^{-}1·year^{-1})

- Calculation of nitrate concentration in the groundwater at a depth of the average lowest groundwater level, as proposed by Oenema et al. (1998)

$$[NO_3] = \frac{62}{14} \cdot F_{NO_3} \cdot \left\{ \frac{(N_{surpl} + N_{depos} + N_{biol.fix} - N_{NH_3volat} - N_{denit} - N_{runoff} - N_{inmob})}{V_{groundwater}} \right\}$$

where *[NO_3^-]* is the concentration of NO_3^- in groundwater in mg/l; 62/14 is the conversion factor of N to nitrate; F_{NO3} is the fraction nitrate of the N recharge; N_{surpl} is the levy free N surplus following MINAS (kg/ha); N_{depos} is the N input from atmospheric deposition (kg/ha); $N_{biol.fix}$ is the N input through biological N_2 fixation (kg/ha); $N_{NH3volat}$ are the N losses through ammonia volatilisation (kg/ha); N_{denit} are the N losses through denitrification (kg/ha); N_{runoff} are the N losses through runoff and drainage (kg/ha); N_{immob} is the net N storage in the soil (kg/ha); $V_{groundwater}$ is the groundwater recharge (1000m^3·ha^{-1}·year^{-1}).

- Borgesen et al. (2001) used a simple linear model in which N leaching is written as a linear function of number of livestock units

$$Y_j = \alpha + \beta_{liscf} X + A_s + B_i + C_f + D_c + \varepsilon_j$$

where Y_j, is N leaching (kg·ha^{-1}·year^{-1}); α, is an intercept; β_{liscf}, is a parameter that describes the increase of N leaching depending on legislation (l), irrigation (i), soil type (s), climate (c), and farm type (f); X, is the average number of livestock units; A_s, B_i, C_f, D_c: are class variables for soil type, irrigation, climate and farm type; ε_j, is the statistical error, N(0,σ^2). β_{liscf} , has to be calculated for each combination of class variables. Input data for the equation were available in the national statistical farm data sets.

11.8 Methodologies for modelling agricultural alternatives that influence nitrate leaching

Different simulation models have been developed in a number of countries to determine the dynamic processes of the nitrogen compounds in the soil when agricultural or political measures are implemented to reduce nitrate leaching. Those models have demonstrated their suitability as tools to evaluate the implementation of certain agricultural or political measures at local level.

Some reviews and comparisons can be found in the bibliography (Addiscott and Mirza 1998, Benbi and Nieder 2003, Wu and McGechan 1998). Hence, they can be used to asses the effect of agricultural alternatives on the nitrate losses. Some of the different applications of these models to determine nitrate leaching are the subsequent. Indeed, they are tools able to take into account physical, biological and technical aspects as well as political or economical points.

11.8.1 Nitrogen fertilization

Many simulation models are applied to assess the effects of the N fertilizer on nitrate leaching. Although methodology approaches may vary, many of them precise soil hydrological characteristics and texture. Moreover, they demand from ten to thirty weather records. Models are constructed by linking modules (N cycle module, hydrological module, crop growth module. . .) and can be used at farm or at regional level. Furthermore, the N cycle module is constructed by adding up N input processes, N output processes and N transformations. The main N transformations simulated are mineralization, denitrification and nitrification. The ammonia volatilisation, despite of its importance as N transformation, it is not always considered. On the other hand, the effect of N fertilizer management is generally studied in combination with different crop rotations.

One of the objectives of these studies is to assess European and national measures to reduce water pollution by nitrate leaching. In addition, they could also give support to farmers to improve their N fertilizing efficiency. Some models have been developed to evaluate the effect of implementing different agro-environmental policies coming from the European Union such as the *Code of Good Agricultural Practices* (Lewis et al. 2003), *Agri-environmental Support Schemes* (Granlund et al. 2000) or *Nitrate Vulnerable Zones* (Brown et al. in press, de Paz and Ramos 2004).

Otherwise, models can analyse the consequences from the implementation of MINerals Accounting System (MINAS) (Jansen et al. 1999, Oenema et al. 1998), a measure that establishes a control on N and phosphorus surplus in the Netherlands, or the Danish Action Plan (Borgesen et al. 2001). Among the revised models, the implementation on taxation policies are also considered as tools to reduce nitrate leaching (Berntsen et al. 2003).

Berntsen et al. (2003) used an integrated framework that linked an economic model, implemented as a linear programming planning module, with a dynamic farm simulation model for crop simulations. The cropping sequences recommended by the Code of Good Agricultural Practices are considered in both modules. The cost and the effectiveness of the environmental regulation were illustrated by selecting three scenarios to reduce nitrate leaching. The first scenario included a tax of 100% of N commercial price on imported mineral N. The second one established a tax of 100% of N commercial price on imported mineral N and feedstuff. Finally, the third scenario simulated a tax of 100% of N commercial price on N surplus, defined as imported N minus exported N. Each scenario was run for a 30 years period. The first 10 years were run to determine the crop rotations and soil pools. During the second 10 years, the taxes were introduced in the simulations. The last period of ten years made the determination of the economic and the environmental results possible.

According to Berntsen et al. (2003), farming sustainability should be determined at farm level. This way the effects of management decisions on the environment could be integrated. The framework they implemented has demonstrated its ability to simulate socio-economic and environmental aspects. The results of simulations suggested that the effectiveness of taxes depended on the farm type. It was also shown that the degree of control of environmental pollution with taxation depended on the market price of the underlying product.

A soil profile framework SOIL/SOILN that linked SOIL and SOILN models, was used to estimate nitrate leaching. The SOIL model (Jansson and Halldin 1979) is a one-dimensional model for heat and water, while SOILN (Johnsson et al. 1987) model is a N model to calculate nitrate leaching.

Both models have been used for field level assessments (Granlund et al. 2000, Lewis et al. 2003).

Granlund et al. (2000) collected data by interviewing farmers in different study areas. They calculated the potential impacts of the changes in nitrate losses due to the implementation of an *Agri-enviromental* measure that subsidies the adoption of sound agricultural management practices. Field results were obtained from the simulation with SOIL/SOILN, whose up-scaling provided regional results. Moreover, a specific GIS software was used to combine field results in a digital map. The application of N fertilizers had decreased in all the study areas to meet the requirements from the *Support Scheme*. Hence, the Agri-environmental Support Scheme had led to more environmentally sustainable agriculture. The adjustment of fertilizing to crop requirements had been proved to be the most important single measure to reduce nitrate leaching.

Lewis et al. (2003) implemented SOIL/SOILN model to simulate the long-term effects of N fertilizer and slurry management. The aim of their work was to supply a decision system for selecting the best management practices for fertilizer and slurry applications. A module to measure the ammonia volatilisation from the slurry has been linked to the SOIL/SOILN framework. The simulated scenarios were derived from the *Code of Good Practice* "Prevention of Environmental Pollution from Agricultural Activity". The scenarios covered three different rates of slurry applications and ten possible spreading dates. In addition, the three mineral rates of mineral fertilizer, that were considered, reflected the typical average rates. The results of their study showed that spreading date was the most important decision so, if the applications were made in autumn the risk of nitrate losses was higher. Moreover, they found out that significant variations related to the type of soil and climate variation also produced noticeable and significant differences in both N leached and total crop harvest.

Brown et al. (in press) describes a new decision support system for fertilizer management in grassland to improve N fertilizer efficiency. The decision support system is based on an empirical model that measures annual N cycling in grassland soils. The new approach developed by Brown et al. (in press) includes sub-models to calculate the N cycle on a monthly basis. This tool provides the link between production and the environmental impact so it can be used in NVZs. The relationship between inorganic N flux and plant N flux comes from multi-site trials at different rates of N fertilizer, different soil types and land-use histories. The N fertilization efficiency relies on site characteristics and the farm management. The best results are obtained in sandy-texture soils where moderate N inputs are applied. Brown et al. (in press) show that it is possible to reduce N leaching without compromising herbage yield.

de Paz and Ramos (2004) used GIS software to divide the regional study area into homogeneous units, according to soil characteristics, crop rotation, climate and N concentration in irrigation water. They used the GLEAMS (Knisel 1993) framework with two modules that considered hydrological and N cycles and it was linked to a GIS software. Simulations were made for different crop rotations and management practices to analyse their effects at a regional scale. In this study, four N fertilization rates were considered: base fertilization rate, 20% reduction of base fertilization rate, 50% reduction of fertilization rate as well as a rate calculated by N mineral recommendation system. The last scenario was found to be the most efficient management system and the one that increased farmers' economic benefits. de Paz and Ramos (2004) noticed that if irrigation groundwater has high nitrate concentration it has to be considered as a source of N.

Jansen et al. (1999) and Oenema et al. (1998) studied the effects of the implementation of MINAS in the Netherlands on nitrate leaching. Jansen et al. (1999) developed a procedure for ex-ante evaluation of a regional plan. The region selected by these authors was schematised into homogenous units by using GIS software (ARCVIEW). Then, the alternative land-use options for each unit were described. Finally, a linear programming model, that minimised costs keeping nitrate concentration under a certain value, optimised the spatial allocation of variants. It has to be underlined that the costs that corresponded to the measures beyond MINAS were obtained from literature.

Jansen et al. (1999) reported that nitrate concentration in upper groundwater level could be estimated from N surplus at soil, via a simple model considering site specific conditions. Three groups of scenarios were analysed: the first two ones allowed two different regional average nitrate concentrations: 37,5 mg/l and 50 mg/l. Finally, the third one imposed to each socio-economic unit a limitation of nitrate concentration of 50 mg/l (EC Nitrate Directive). Jansen et al. (1999) warned that forcing all farms to comply with a maximum level concentration was more costly than setting a regional maximum and allowing a regional average level.

Oenema et al. (1998) applied a statistical approach at farm level to predict the effects of MINAS on soil N content in the Netherlands. The Netherlands were divided into units that had different land-use, soil type and hydrology. In this research, the ammonia volatilisation process was also considered. The N and P surplus in soil were measured assuming that farmers would meet the levy-free surplus. The predictions of this model suggested, after the implementation of MINAS, that the mean nitrate concentration in groundwater would decrease. Hence, it also would decrease the area of land with more than 50 mg of nitrate per litre. However, there would remain problems in dry and medium dry soils. Oenema et al. (1998) reported that additional policies and measures were required for areas with specific problems.

Borgesen et al. (2001) presented an approach to estimate N leaching at a regional scale. This model had three parts: point-field scale simulations of leaching for different scenarios; a general statistical model that described the N leaching in the point-field simulation; and, finally, an up-scaling procedure which simulates N leaching at a municipality level. The DAISY model (Hansen et al. 1991) is the one dimensional mechanistic and a deterministic model for soil, water and N that was used to make point-field simulations. Moreover, the movement of water and N was supposed to be vertical. The up-scaling procedure required to know the soil types at municipality levels and farm data. Therefore two types of crop rotations were considered: dairy crop rotation with different levels of livestock density; and pig crop rotation with two livestock densities. The representation of crops in both rotations came from statistical farm data within the climate zones. The simulations carried out included two scenarios for the N fertilization considering the reduction of N leaching in rural areas by the Danish Action Plan. The first one assumed a fertilization schedule from the eighties meanwhile the second one assumed the full implementation of the legislation in 1997. It was concluded that the N leaching/livestock units ratio was lower in dairy crop rotations than in pig crop rotations. In addition, the highest levels of N leaching took place when sandy soils were combined with high livestock density. Otherwise, it is important to point out that regional results included a degree of uncertainty due to the uncertainty of parameters and the up-scaling procedure.

11.8.2 Catch crops

Simulation models are useful to study the effects of changes on agricultural management practices to reduce nitrate leaching. Johnsson et al. (2002) and Wyland et al. (1996) studied the effect of including catch crops in crop rotations, while Korsaeth et al. (2002) measured the N dynamics after the incorporation of green manure. As in other simulation models mentioned before, crop, soil and meteorological data were necessary. The results from different simulation models demonstrated that the inclusion of catch crops reduced nitrate leaching (Johnsson et al. 2002, Wyland et al. 1996).

Johnsson et al. (2002) developed a decision support tool SOILNB on the basis of the modelling framework SOIL/SOILN. SOILNB could be used to quantify nitrate leaching from agricultural land even if the availability of detailed data was limited. SOILNB was used to find management practices that could reduce nitrate leaching such as the inclusion of catch crops. Two crop rotations were simulated; one without catch crop, with bare soil during winter period and the other one with catch crops and cropped soils during winter period. A six years crop rotation was repeated three times, for both scenarios of rotation, to reduce the effect of climate variation. An extra year was included before the eighteen years series to diminish the effects of uncertain initial conditions. The results showed that nitrate leaching was almost double for the crop rotation with bare soil during winter period compared to the crop rotation with cropped soils during winter period. The most important reason for this difference was the crop management the proceeding, year; in the crop rotation with bare soils the previous crop left large amounts of mineral N whereas in the crop rotation with catch crop the previous crop left small amounts of mineral N in the soil. The development of a semi-automatic system has been initiated to export the results to an external hydrological model, so that transport and concentration in stream could be calculated.

Wyland et al. (1996) used a simplified water balance model to calculate drainage during winter and an economic analysis to evaluate the total costs and profitability of catch crops on an intensive vegetable cropping system. Nitrate concentration in soil was averaged from field sampling. Two catch crop treatments were sown, phacelia and merced rye. The data files included in the economic analysis considered all farm operations, equipment, materials, labour used through the year and crop yields from relevant market rates. The economic analysis calculated gross returns, total costs, monthly cash flow and equipment schedules for both catch crops treatments and the fallow control. Moreover, it summarised water, fertilizer, energy and labour used during winter and throughout vegetal cropping season, with and without a winter cover crop. Statistical analyses were conducted using General Linear Model procedures for analysis of variance. The catch crops removed N and water from the surface layer reducing significantly nitrate leaching. Minimum tillage techniques could reduce both the cost of incorporation and the risk of disrupting tight planting schedules. The costs of cover cropping were relatively small in comparison to winter management of bare soil. From the economic point of view, the greatest barrier for replacing winter fallow with by cover crops lies in the risk of disrupting the spring vegetable planting schedule.

Korsaeth et al. (2002) analysed N flows in the soil-plant system with two simulation models: COUP model (Jansson 2000), for heat and water transport, and SOILN_NO (Vold et al. 1999), for soil N. COUP model, a reprogrammed version of SOIL model, has a one dimensional vertical structure and provides driving variables for SOIL_NO model. SOIL_NO model is a modified version of SOILN model and includes the major transformations of N in soil. The N model considers two litter pools, the readily decomposable and the slowly decomposable, as well as a pool for microbial biomass and a pool for stable humus. The incorporation of green manure and barley straw with two ploughing dates, late autumn or following spring, were investigated by experimental methods and were further analysed with simulation models. Early autumn ploughing gave the largest simulated N leaching, compared to scenarios with ploughing late in autumn or in spring. Net N immobilization augmented with increasing time lag between incorporation of green manure and subsequent plant N uptake. The environmental and agronomic target should be therefore maximizing the direct utilization of mineral N by the subsequent crop.

11.8.3 Crop rotation

The inputs generally used in crop rotation simulation models are crop yields, organic and inorganic fertilizer applications, field capacity and hydraulic properties of the soil and daily meteorological data concerning potential evapotranspiration and precipitation. Models are constructed by linking different modules and they generally include water soil and N sub-models. The outputs from the sub-models are linked to GIS to allow the spatialisation of the results (Gibbons et al. 2005, Kyllmar et al. 2005, Richter et al. 1998, Trabada-Crende and Vinten 1998).

Richter et al. (1998) took into account the residue incorporation and the mineral N after harvesting. Moreover, they used a digital map at catchment scale to determine the crop rotations, where no cover crops were included. They also considered water flow and nitrate transport that were simulated only vertically using the MINERVA model (Kersebaum and Richter 1991), an 1-D model. SUCROS model (van Keulen et al. 1982), a simulation crop growth model, was applied for the assessment of crop development and N uptake by the plants. In the N cycle the atmospheric deposition and the denitrification were ignored, meanwhile the ammonia volatilisation was approximated by a simple exponential function. Their study was focused on field level in two different set-aside scenarios: continuous (for five years) and rotational. The results obtained showed that continuous set-aside management at field scale had fewer losses than rotational set-aside management. Since both treatments had the same global effect at catchment's level, they showed the importance of catchment studies. Their methodology would need some improvements to measure the mineral N accumulated in the soil under various types of set-aside managements and different soil classes.

Trabada-Crende and Vinten (1998) focused their attention in a NVZ. The nitrate leaching to the aquifer was calculated using the soil and water model WATBAL (Berghuis-van Dijk 1985) and the N cycle model ANIMO (Rijtema and Kroes 1991) for arable land or N-CYCLE model (Rodda et al. 1995) for grassland. They added FLOWPATH (Franz and Guiguer 1990), a groundwater flow submodel, to the simulation framework to study nitrate concentrations in groundwater. The information collected about crop rotations was stored in a database managed by a GIS. They investigated the effects of changing the current agricultural management by reducing the crop rotation intensity or by incorporating organic matter with a high C/N ratio (Paper Mill Sludge). They reported that partial extensification of crop rotations reduced nitrate leaching but causing great losses of profits in the horticultural sector. Besides, the level imposed by the Nitrate EC Directive was not satisfied. Paper mill sludge proved its aptitude to decrease the risk of leaching without cost, but its possible toxicity should be tested.

Kyllmar et al. (2005) used SOILNB model, a management oriented model at regional level that used climate series of twenty years of daily values. Crop rotations were obtained by using a randomise procedure for the region. This procedure made the occurrence of each crop proportional to its real representation in the region. Catch crops were also considered. From Kyllmar et al. (2005)'s point of view, crop rotation and certain changes in manure application could reduce nitrate leaching. They suggested some further research like the analysis of the relationship between fertilization level and yield.

The model framework, SUNDIAL (Smith et al. 1996), described by Gibbons et al. (2005) was linked to a farm level mixed integer economic model. This economic model maximised the farm gross margin for one week or one year step. The inputs used in the economic model were the crop prices and the area payments from the Agenda 2000. The aim of their work was to measure the most cost-effective reduction of nitrate leaching by reducing N fertilizer applications. With respect to the N cycle, they considered the weekly drainage, the nitrate leaching and the nitrate concentration. The annual atmospheric deposition was supposed to be up to 35 kg/ha. A response function N/yield was applied to four different rotations with potato as the main crop combined with other arable crops. According to their study, a wide range of practices were available. Otherwise, their potential effect in the profitability should be tested to find the most cost effective strategy. If the assumptions made by Gibbons et al. (2005) were considered, it would be relatively costly to reach the levels imposed by the EC Nitrate Directive. In addition, it could be interesting to consider the impact of nitrate leaching control in the nitrous oxide and ammonia losses.

After having described different simulation methodologies a detailed description of the application of STICS model, which is used in the ARTIX framework, to different nitrate leaching studies is provided below.

11.9 Application of STICS to model alternative agricultural practices

The Simulateur MulTIdisciplinaire pour les Cultures Standard (STICS) is a soil-crop model that has been developed at INRA since 1996 (Brisson and al. 1998). "It is a daily time-step crop model with input variables relating to climate, soil and crop systems. Its output variables relate to yield in terms of quantity and quality and to the environment in terms of drainage and nitrate leaching" (Brisson et al. 2003).

The agricultural management practices to reduce nitrate leaching have been considered in some applications of STICS (Dorsainvil 2002, Houlès et al. 2004, Minette and Justes 2005, Schnebelen et al. 2004).

Schnebelen et al. (2004) used STICS and an upscaling approach to simulate the impact of agricultural practices at both plot and regional levels. It was used to study the implementation of the *French Code of Good Agricultural Practices* in a NVZ located in the "Petite Beauce". The modifications proposed to the conventional management were a balance accounting method and the introduction of cover crops in autumn and in winter. Two different types of simulations were performed with STICS: annual simulations and continuous simulations. For the annual simulations, STICS was initialised at the beginning of every crop cycle using measurements of the soil mineral N and the soil water content. Besides, for the continuous simulation STICS model was only initialised at the beginning of the first year, and it provided the soil water content and the soil mineral N for the next year over a period of 7 year. The continuous simulations were used to compare different alternative agricultural practices. The simulations were made at plot level and then up-scaled to regional level. STICS simulation procedure required the homogeneity of the simulating units in terms of environmental variables. The procedure used to define the homogenous spatial units involved the implementation of the GIS ArcInfo (ESRI 1999). Schnebelen et al. (2004) concluded that the smallest nitrate soil concentrations were always obtained after the cover crops. The simulations confirmed that the introduction of catch crops before spring was an effective method to reduce nitrate leaching. Though, the impact of the current crop on nitrate leaching was difficult to analyse because it also depended on previous crops. The nitrate concentration produced in plots with cover crops was, on average, slightly lower than the EU limit for drinking water (50 mg/l).

Lacroix et al. (2004) evaluated, by using STICS, the environmental and economic impact of the management practices recommended by the European Union. The management practices considered included those practices recommended by the *Code of Good Agricultural Practices*, the reduction of fertilizing inputs and covers crops under an agri-environmental measure and the set-aside of the less productive fields. They took into account the environmental efficiency and the economic costs for short and long terms implementation, for every management scenario. According to Lacroix et al. (2004) the practices recommended by the European Union applied at short term did not permit to accomplish the Nitrate Directive. On the other hand, at long term, the reduction of fertilization in intensive farms reduced slightly the nitrate pollution. Moreover, also at long term, the catch crops were very efficient in the absorption of the remaining soil N. Finally, the set-aside strategy had a high cost that could only be assumed if it produced also important environmental benefits. In very risky areas harder measures than the ones suggested by the European Union should be implemented to reduce nitrate pollution. As a result, the productive system should change with a reduction in the productive intensity.

Dorsainvil (2002) considered the use of catch crops between two main crops to reduce nitrate leaching. The impact of those catch crops was measured during the fallow period and also during the cultivation of the main crop. The STICS model was adapted to two different catch crops and then it was used to simulate their effect on water and N dynamics. The calibration of STICS model was performed by using a data set from field experiments, and then the model was evaluated with data from different French regions. Dorsainvil (2002) suggested that the catch crop did not have to be sown too early or harvested too late, in order to obtain the best results.

Within the framework of MIRAjE, STICS model runs in a particular way detailed in the next section.

11.10 Description of MIRAjE modules

The STICS model has been linked to the AROPAj model in order to assess, apart from the environmental effects, the economic impacts of the alternative agricultural measures promoted by the political measures. Both models are included in a framework called MIRAjE.

11.10.1 AROPAj

AROPAj model is a supply-oriented model, based on mixed integer and linear programming methods, to assess the effects of the CAP on different countries (De Cara et al. 2004, Jayet 2004).

The primary source of data is the Farm Accounting Data Network (FADN). FADN provides data of farms at regional level for the 101 regions of the EU-15. The typology procedure consists in the classification of the sample into homogenous farm types according to their farming system, yields, total area, animal numbers and altitude class. Each producer is supposed to choose the supply level and the input demand to maximize its gross margin. AROPAj model considers 32 different crops producing activities, including the set-aside, and thirty one livestock categories. Farmers can sell their crop production at the market price or use it for animal feeding. The constraints can be divided in: crop area allocation; livestock feed requirements; initial endowments of quasi-fixed factors (land and livestock); cattle livestock demography and restrictions imposed by the CAP. A numerical algorithm based on Monte-Carlo and gradient methods is used to calibrate the parameters for which data is not available. The reference yield and the total expenditure of fertilizers are calculated for each farm type and crop. The AROPAj model determines the allocation according to the fixed reference yields and fertilization levels and costs from the FADN (De Cara et al. 2004).

AROPAj has been adapted to include the assessment of some environmental issues, mainly related to the climate change (De Cara and Jayet 2000, De Cara et al. 2004). E. g. De Cara et al. (2004) assessed the potential abatement of Green House Gases (GHG) for a range of CO_2 prices that could be achieved through an emission tax in agriculture.

The coupling of the crop model STICS with AROPAj has provided on-going improvements in relation to the relaxation of fixed yield assumption (Bamière et al. 2005, Godard, Bamière, Debove, Cara, Jayet and Niang 2005).

The relaxation of fixed yields provides the possibility of taking into account price variations for fertilizer and crops. To simulate that, a concave yield-response function to nitrogen inputs from STICS is considered. Then, nitrogen fertilization and its corresponding crop yield are calculated with the conditions of maximization of gross margin for a given crop, with a selling price, and with a certain N fertilization price. The following condition is obtained:

$$\frac{\partial y_j\left(N_j\right)}{\partial N_j} = \frac{p_f}{\nu_f \cdot p_j}$$

where $y_j(N_j)$ is the yield function for an N level of N fertilization for the crop j; p_f is the price of the fertilizer; ν_f is the share of the nitrogen in the fertilizer f; and p_j is the selling price of the crop.

11.10.2 STICS

The STICS model had been selected for the MIRAjE framework due to its capability to simulate the wide range of crops and cropping systems considered by AROPAj, which mean multiple pedo-climatic conditions.

The application of STICS in MIRAjE focuses on crops that are not included in crop rotations because it is linked to the static model AROPAj. Moreover, for the initialization of the main crop, it considers two types of possible preceding crops, a cereal (represented by soft wheat) or a legume (represented by pea).

11.10.3 Linkage of STICS to AROPAj

The model framework MIRAjE relies on a "soft" coupling of the AROPAj and STICS models (Godard, Bamière, Debove, Cara, Jayet and Niang 2005).

The STICS model provides response curves to N fertilization for farm types for a given agronomic, pedological and climatic context. N is considered to be the main limiting factor to crop growth. STICS input parameters come from the FADN and AROPAj for supplied organic manure and irrigation; regional experts provided other crop management data; and the Monitoring Agriculture with Remote Sensing (MARS) project is the source of soil and climate data.

The response curves have the following expression:

$$y = y_{\max} - (y_{\max} - y_{\min}) \cdot e^{-tN}$$

where y is the yield; y_{max} is the maximum yield; y_{min} is the minimum yield; t is the rate of increase; and N is the amount of N fertilizer.

First, different curves are obtained for every crop. To select one of them two criteria are taken into account: the reference yield obtained in the AROPAj calibration step, and then the minimal distance between the price ratio $\frac{p_f^0}{v_f \cdot p_j^0}$ and the derivate value of the response function where yield equals the reference yield.

Afterwards, the agronomic curve is adjusted to exactly fit the price ratio by making slight modifications of the increase rate t. The new increase rate is defined as follows:

$$t_a = \frac{p_f}{\nu_f p_j (y_{max} - y^0)}$$

were t_a is the adjusted value of the rate t.

Finally, and adjusted function of the fertilizing costs is introduced in the economic model to take into account the calibrated system:

$$c_{af}(N) = \frac{p_f}{\nu_f} N + c_f^0 - c_{af}^0$$

were c_{af} is the adjusted cost function of N fertilization; and c_f^0 is the cost for the fertilization level obtained from the economic model, and c_{af}^0 is the fertilization cost for the yield obtained by the economic model and the N fertilization level from the adjusted response curve.

11.11 Agricultural practices that could be simulated by MIRAjE

11.11.1 Appropriate cropping sequence

STICS model has demonstrated its capability of simulation the effects of different crop rotations and the inclusion of catch crops on the nitrate leaching at the base of the soil (Dorsainvil 2002, Lacroix et al. 2004, Schnebelen et al. 2004).

The STICS model would be applied to measure the temporal changes of nitrate leaching at the base of the soil profile. The six sequences presented in Table 11.1 involve an homogenous soil and three consecutive years of daily climate data. Each one of the six sequences correspond to a set of two or three STICS simulations, each of them has its own technical set of parameters subjected to the crop. Actually, we can reasonably use only one set of management parameters for each crop in a given region, where we have defined an homogenous climate and soil parameters.

<table>
<tr><th rowspan="2">Seq.</th><th colspan="4">Year 1</th><th colspan="12">Year 2</th><th colspan="8">Year 3</th><th rowspan="2">NSS</th></tr>
<tr><th>S</th><th>O</th><th>N</th><th>D</th><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>Jn</th><th>Jl</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>Jn</th><th>Jl</th><th>A</th></tr>
<tr><td>1</td><td>I</td><td colspan="10">W</td><td colspan="7">B</td><td colspan="6">S</td><td>2</td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td>I</td><td colspan="5">S</td><td colspan="7">B</td><td colspan="6">S</td><td>2</td></tr>
<tr><td>3</td><td>I</td><td colspan="10">W</td><td>B</td><td colspan="12">W</td><td>2</td></tr>
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<tr><td>5</td><td>I</td><td colspan="10">W</td><td>B</td><td colspan="6">C</td><td colspan="6">S</td><td>3</td></tr>
<tr><td>6</td><td></td><td></td><td></td><td></td><td></td><td>I</td><td colspan="5">S</td><td>B</td><td colspan="6">C</td><td colspan="6">S</td><td>3</td></tr>
</table>

NSS : number of STICS simulations

STICS simulation:

I	Initialisation
B	Bare soil
W	Winter crops: soft and durum wheat, winter barley and rapeseed
S	Spring crops: grain and silage maize, sunflower, potato and sugar beet
C	Catch crops: white mustard and Italian ray grass

Table 11.1: Three year crop rotation.

The aim of these simulations with STICS would be to differentiate the risk levels of nitrate leaching when the crop rotations change and when we introduce a catch crop. A further application of these simulations would be the establishment of a tax to nitrate leaching that could be included in the AROPAj model.

We could use the same soil database as the one used by Godard, Bamière, Debove, Cara, Jayet and Niang (2005). Climate data could also be equal to the one currently used by the same authors, as soon as the simulation years correspond to the simulation years of the economic model. Crop management parameters for the main crops, that have already been considered in previous simulations, could be easily reused (Godard, Brisson, Roger-Estrade and Jayet 2005). The main crops that were considered were soft and durum wheat, silage and grain maize, spring and winter barley, rapeseed, sunflower, potato and sugar beet. In contrast, the catch crop, for example white mustard, would have to be parameterized for every region to be considered in the simulations. The parameters that should be included are: the sowing or plantation date, the crop variety, the sowing density and the decision criterion for harvest (e.g. a date subjected to the following crop sowing date…).

Table 11.1 shows all the types of cropping sequences, catch crops could be introduced just in two of them. “A priori” the most risky sequences are the ones with the longest time period with bare soil during winter. That situation is precisely met when a spring crop follows whether a winter or a spring crop (sequences 1 and 2 in table 11.1). In both scenarios the introduction of catch crops (sequences 5 and 6 in table 11.1) should give significant nitrate leaching reduction by leaving the shortest time period as possible of bare soil. Indeed, in those sequences the length of the bare soil period is under technical control.

An assumed intermediate risk level would be found in the scenarios 3 and 4. Those sequences finish with a winter crop, and are preceded by a short period of bare soil, which length depends on the type of crop.

Apart from the time period of bare soil, other risky circumstances for nitrate leaching could appear during the vegetation of the crops. The combination of the level of nitrogen available in the soil solution, the soil water content, from irrigation and rainfall, and the ability of the crop to uptake the nitrogen, depending on its nutrient necessities, determine the nitrate leaching risk level. The nitrogen consumption by the crop depends directly on the root growth and on the crop development stage, that is usually expressed in cumulative degree-days. For instance, if a high level of nitrogen is available for the crop and there are high intensity precipitations when the crops are not able to absorb nitrogen, or are less demanding of nitrogen, then the risk of nitrate leaching is very high.

The measurement of the nitrate concentration in soil could be done in different moments. It could be measured either at the beginning or the end of winter period (Schnebelen et al. 2004), with soil covered by a catch crop or with bare soil (Korsaeth et al. 2002, Wyland et al. 1996). Comparing the two latter situations would enable an assessment of the risk level during the winter period. In addition, it would be interesting to measure the nitrate concentration during the crop vegetation period at the less nitrate demanding moment, because then the risk of leaching could be high. Some authors recommend also a measurement at the harvest of each crop from the sequences (Richter et al. 1998, Schnebelen et al. 2004).

Besides, we could sum up the nitrate leaching to calculate the mean values for a cropping year (Johnsson et al. 2002, Kyllmar et al. 2005), or measure the nitrate leaching weekly like in Gibbons et al. (2005).

11.11.2 Balanced N fertilization

According to the literature consulted, the taxation on the N fertilizers bought by the farmers is a suitable measure to reduce the nitrate leaching pollution (Berntsen et al. 2003, Vatn et al. 1996). The economic models, like AROPAj, calculate the economic consequences of the tax, based on what the farmer ought to do to optimise the gross margin. In order to evaluate the economic and environmental effects of the taxation the STICS model has to be implemented too.

In a first step of the work, AROPAj model is applied to the 734 European farm groups, considering a tax on the N content of marketed fertilizers (from 0 to 40%, with an increment of 10%) and a livestock adjustment (from 0 to 30%, with an increment of 15%). The yield response curves from STICS are not considered.

The objective of these simulations is to assess the impact of a tax on N in mineral fertilizers on the gross margin and the volume of fertilizers bought by farm groups.

Some representative figures, that represent the effects of changing both parameters at the same time, are obtained for the 734 farm groups aggregated.

Figure 11.2 shows that the evolution of gross margin is influenced by the livestock adjustment and the N tax increase, while, nevertheless, the bought fertilizer depends just on the N tax level. Whenever the N tax increases the gross margin and the quantity of bought fertilizer decreases. Moreover, the augmentation of the livestock adjustment favours the raise of the gross margin. As Figure 11.3 shows, the cereal surface and gross margin evolutions are similar, both increase with an augmentation in livestock adjustment, and drop when N tax is enhanced.

The same kind of figures could be obtained just for the whole Spain or one Spanish region. We have selected Castilla-La Mancha to compare its results with the ones obtained for all the European

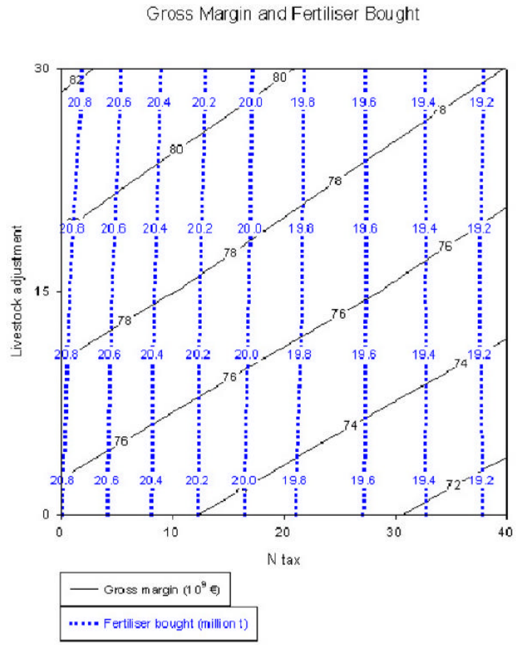

Figure 11.2: Gross margin and Fertilizer bought for the aggregated UE 15 farm groups.

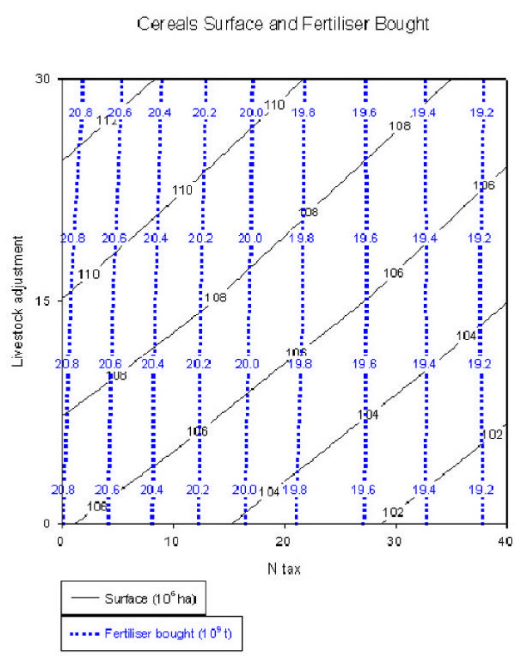

Figure 11.3: Cereal surface for the aggregated UE15 farm groups.

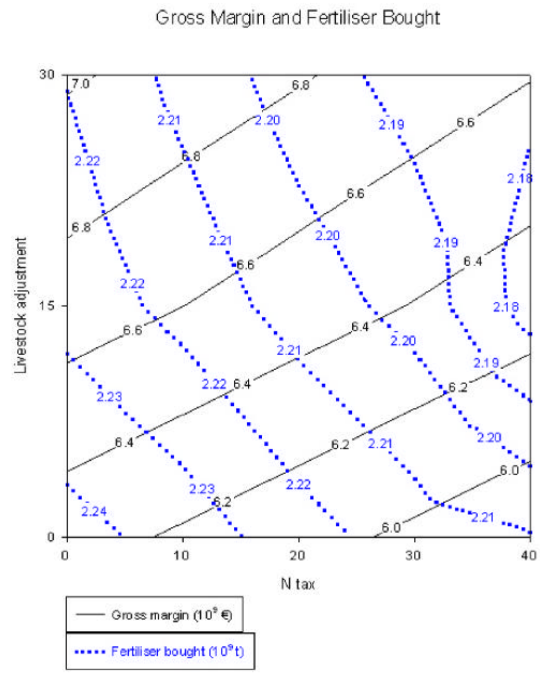

Figure 11.4: Gross margin and bought fertilizer for the aggregated Spanish farm groups.

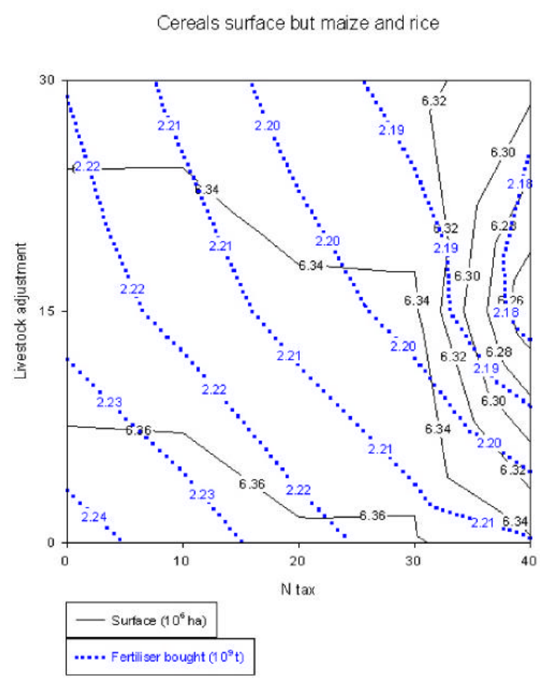

Figure 11.5: Cereal surface for the aggregated Spanish farm groups.

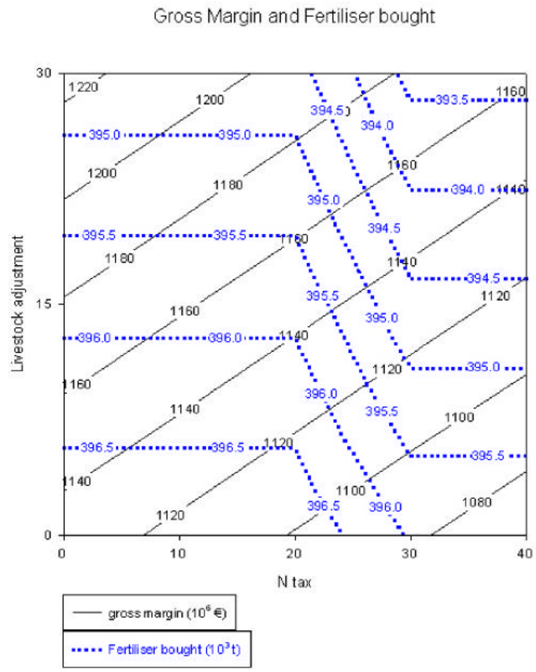

Figure 11.6: Gross margin and bought Fertilizer for the farm groups of Castilla-La Mancha (Spanish region).

countries and all the Spanish regions aggregated. Figure 11.6 illustrates the evolution of the gross margin and the amount of bought fertilizers for all the farm groups that belong to the region of Castilla-La Mancha. The gross margin's progress is represented by the same kind of curves as in figure 11.4. They highlight an increase in the gross margin when the flexibility of the livestock raises and a decrease of gross margin when the N tax becomes higher. The amount of fertilizer bought it inversely correlated to the flexibility of the livestock adjustment. Moreover, it does not depend on the N tax in the intervals where N tax value is less than 20%, and also if it is greater than 30%. On the contrary, the amount of fertilizer bought decreases in the N tax interval from an 20% to 30%.

In contrast to what happens at the Spanish level, cereals surface is not related to a change in the N tax values. On the other hand, when the livestock adjustment increases cereals surface decreases.

A further study of the present simulation could take into account the yield response curves to the N fertilization given by STICS, in both approaches, at national and regional levels.

11.12 Conclusions

- It is a fact that there is a substantial pollution in drinking water caused by nitrates from the agricultural sector. Hence, agricultural practices have to be oriented towards more environmental friendly management. The suitable agricultural practices are included in certain political measures that are applied at European, national or regional levels. Other methods, such as a taxation on N fertilizers, could be added to the existing or new political instruments.

- The application of the general normative has to be locally adapted owing to each environmental situation precise different handling. In order to evaluate the success of each step some

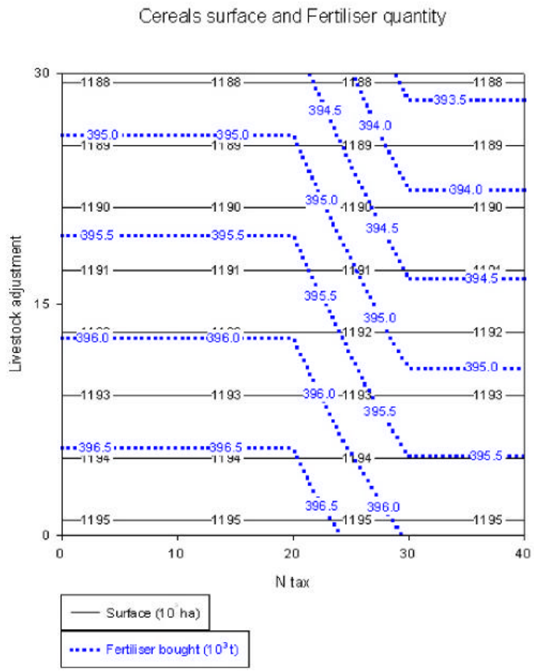

Figure 11.7: Cereal surface but maize and rice for the farm groups of Castilla-La Mancha.

measurements and simulations models are needed.

- Several models have proved their capacity to simulate different alternative agricultural management practices. Even though they use different methodologies they are generally constructed by linking a Nitrogen module to a crop growth and water modules. Some of them are connected with an hydrological simulation models to determine the concentration of nitrates in ground water. Furthermore they can be coupled or linked to an economic model in order to assess the economical effects of certain environmental and agricultural policies. Nevertheless, Duch models are usually adapted to the studied region and rarely extended to the whole EU level, for example.

- Some applications of the nitrate pollution models have been oriented to evaluate the efficiency of the management practices recommended by the *Code of Good Agricultural Practices* included in the *Nitrate Directive*. The results showed that those practices are not enough to reduce the nitrate concentration of 50 mg/l in groundwater in those regions that have been declared NVZ (Nitrate Vulnerable Zones). In those areas with high risk of nitrate pollution there should be a change in their productive orientation.

- The success of more drastic measures would depend on the establishment of a Support Scheme, and on a ex-ante economic evaluation. AROPAj model could provide an insight of the economical effects of the new environmental and agricultural requirements.

- The MIRAjE framework that includes STICS, as crop simulation model, and AROPAj, as economic model, could be used to evaluate the physical and economical effects of different political tools to reduce nitrate leaching in the European regions. Initially, two types of implementations have been suggested. The first one would be the introduction of a catch crop in the crop rotation, during more nitrate leaching risky period. Another one would be the addition of a tax to the price of N fertilizers.

- In a first phase, AROPAj model is applied without being coupled to STICS model. Some results have been obtained from AROPAj model after the introduction of a tax on the N fertilizer price. The results do not reveal the changes that could have been expected owing to the fixed character of the N fertilization when STICS model is not considered. Next applications of the same types of simulations linked to STICS would provide different results and improve the environmental assessment of the measure. STICS supply the enviromental assessment while AROPAj evaluates the economic consequences taking into account different levels of compensatory payments and taxes.

ANNEXE: Table with Initial Review

Reference	Agricultural practices	Methodology	Data	Keywords	Country	Scale	Conclusions
Poupa et al. (2005)		Model STICS: algorithmic reconstruction of STICS			France	Plot	
Korsaeth et al. (2002)	Catch crop: Green manure incorporation with ploughing	Model Experimental: laboratory and field experiments to study N dynamics Simulation models: nitrogen flows in the soil-plant system	Inorganic N, microbial N demand and plant uptake	Barley straw; green manure; leaching; model; residual N effect; time of ploughing; white clover		Field	Timing of agronomic operations are important to determine the inorganic N lost and the fraction assimilated by the microorganism, a proper synchronization is needed
Beaudoin (2005)	Catch crops	Model STICS: stock of water and mineral N in 8 years of simultion in different types of soils. The model is generalised using a GIS	Soil cartography, agronomic data, principal crops and catch crops, stock of water and N		France (Basin de Bruyéres)	Regional	The model test takes into account that only water and nitrogen can be limiting. Make a simulation in a basin area needs a lot of work but can detect interactions that cannot be observed from isolated plots.
Minette and Justes (2005)	Catch crops	Model STICS	14 different soils, 3 meteorology stations with data for 35 years		France	Regional	Differences in catch crop growth in different meteorologic stations. Definition of leaching risk for different soils, that depends mainly on the N mineralization and the sensitivity to vertical water infiltration
Gustafson et al. (2000)	Catch crops: Fertilizer, Catch crops and Winter crops, hydrological conditions	Experimental	Concentration of nitrates in superficial and groundwater		Sweden	Field	The upper limit for N-removal is set by the hydrological conditions. To achieve the governmental objective of N load reduction cultivation changes are needed with restoration of ponds and wetlands
Grignani and Zavattaro (2000)	Catch crops: Agricultural practices, continuous maize rotation/ continuous soil Cover crops	Experimental: mineral concentration of N in soil solution sampled every two weeks for two years	Fertilization level, crop removals, soil-water-nitrate concentration	Cultivation system; fertilizer efficiency; N leaching; soil nitrate content	Italy (NW)	Farm	The system with cover crop buffered the oscillation of the soil-water-nitrate concentration. There is no simple explanation to the relationship between N uptake, N removal/fertilizer ratio, soil pH and sand content Recommendation: Increase N efficiency to reduce N leaching
Gomez (2002)	Catch crops: Inter cropping period, mineral N applied, soil depth, organic N soil content	Model STICS: definition of homogeneous areas to make the simulations. ArcInfo is used to relate all the information	Meteorology data; land use; soil data; yields from enquiries and experts advice		France (Bassin de la Seine)	Regional	Sensitivity analysis related to crop production and soil depth. Establishment of N needed related to the yield that is going to be obtained N concentration decreases when water flow increases by the effect of dilution
Johnsson et al. (2002)	Catch crops: Agricultural management practices, Land use, Agroenvironmental conditions	Model Decission support tool: SOILNDB to quantify nitrogen leaching losses based on: SOIL and SOILN to describe water and heat fluxes, nitrogen transformation and transport process in the soil Use of a parameter algorithms	Parameter database	Decision support tool; modelling; N leaching; large scale; automatic; parametrisation			Includes and illustrative example of how the model can be used to compare nitrate leaching under alternative management practices.
Wyland et al. (1996)	Catch crops: Surface soil dynamics, Winter cover crop rotation	Model Economic model: Economic analysis and on farm cost of cover crops where calculated		Nitrate leaching; microbial biomass; cover crops; broccoli; nutrient availability; plant plot interaction; economic analysis		Plots	Reduction on nitrate leaching from cover-cropped plots compared with fallow control during winter The costs of cover cropping were minor compared with conventional winter management of fallowed fields

Reference	Agricultural practices	Methodology	Data	Keywords	Country	Scale	Conclusions
Webster et al. (1999)	Crop rotation	Experimental: ceramic suction cups	N leaching	Ceramic cup; immobilization; ley; long-term experiment; mineralization; nitrate leaching; rotation		Plot	The amount of N leached was not related to fertilizer addition. The rotations that included ley could conserve N better
Flichman and Jacquet (2003)	Crop rotation and N fertilization	Model Coupled economic (linear programming model with land and water constraints) and agronomic models (EPIC-PHASE, that measures the quantity of nitrates leached)	Yield, nitrogen fertilizer amount, nitrate pollution		France	Farm (Midi-Pyrénées)	The non-convexities found in the relationship between nitrogen fertilizers and pollution is due to changes in management practices and crops at farm level. For an unique crop the production function is concave and the pollution function is convex.
Kutra and Aksomaitiene (2003)	Crop rotation: Agronomic Efficiency, ratio between fertilizer applied/yield, N balance and N mineral content	Experimental	N content, Organic matter after harvest, N balance for different crop rotations	Nutrient balance; crop rotation; leaching; crop yield; agronomy efficiency			The lowest environmental impact by N leaching occurred in grassland rotations. The highest Agronomy efficiency (AE) occurred in the rotation with sugar beet and spring cereals area was reduced
Nevens and Reheul (2002)	Crop rotation: Forage crop rotations	Experimental	N release Mineral N fertilization rates	Economically optimum N fertilization rate; fodder beet; ley-arable rotation; permanent arable plots; residual mineral soil N; silage maize		Plot	Starting the arable forage crop sequence with fodder beet following the grassland ploughing and adjusting the N fertilization minimized the risks on high amounts of residual soil N and N leaching losses
Clotuche et al. (1998)	Crop rotation: Set-aside introduced by CAP	Experimental: measurement of nitrate quantities in soil profile of 1.5 m depth to evaluate nitrate pollution risk	Nitrate concentration in soil	Rotational set-aside; nitrate; red clover; perennial rye grass		Plot	The sowing of a set-aside cover before winter leads to a reduction in leaching risks
Gibbons et al. (2005)	Crop rotation: Weather, N reductions, winter cover before spring crops	Model Simulation model: Database of crop treatment IACR SUNDIAL model to generate nitrogen losses Economic model	Crop treatments, nitrogen loss, 10 years weather	Nitrate loss; farm level models; decision making; management strategies; sandy soils	England	Farm level	The most cost-efficient reductions of loss where achived by targeted reductions in N applications followed by growing winter cover before spring crops
Kyllmar et al. (2005)	Crop rotation: Main crop, following crop and fertilizing regime	Model Process-based modelling system SOILNDB	Regional agricultural statistics	Process-based model; coefficient method; N leaching; arable field; catchment; SOILNBD	Sweden	Regional	Changes in crop rotation have a large potential for reducing N leaching
Richter et al. (1998)	Crop rotation: Rotational set-aside, green fallow	Model Simulation model: Models at different scales (field and catchment). Simulation of N dynamics using digitalised maps	Soil properties, land use, crop management for 6 years period	Land use; crop rotation; green fallow; N turn over; nitrate leaching; modelling; sensitivity analysis; spatial variability		Field and catchment	The sensitivity of continous and rotational set-aside was analyzed

Reference	Agricultural practices	Methodology	Data	Keywords	Country	Scale	Conclusions
Trabada-Crende and Vinten (1998)	Crop rotation: Crop intensity, application of organic material with high C/N	Model Simulation model: Nitrogen cycle simulation models calibrated for local conditions. Validation with: finite-difference groundwater flow model FLOWPATH	Fertilizer application, rotations		Scotland	Local: Nitrate Vulnerable Zone	To achieve a nitrate concentration which complies with the EC-legislation it is necessary to remove all intensive rotations from the catchment and grow only cereals and grass
Li et al. (2005)	Intercropping: Intercropping, Adding organic materials with N fertilizer	Experimental	Nitrate accumulation in soil Crop rotations	Wheat; maize; faba bean; intercropping; nitrate	China	Field	Intercropping decreases the accumulation of nitrate in the soil profile, adding organic materials also reduces the nitrate accumulation.
Borgesen et al. (2001)	Livestock: Number of LU/ha	Model Deterministic model: Simulation results using a deterministic simulation model that provides to an statistical model called General Nitrogen Leaching model. N leaching is considered as a linear function of the number of LU/ha for the selected class variables	Statistical farm data: farm type, number of animals, cultivated area, irrigated area (1985-1994) and soil data	N leaching; simulation model DAISY; regional scale; upscaling; Denmark		Regional (municipality or country)	Approach used in scenario studies of the effects of legislation on N fertilization schedules and on N leaching. Results for municipalities are summarised to give the results at national level. The approach worked well to estimate the effect of the changes in N fertilization schedules caused by the implementation of the legislation
Cuttle and Scholefield (1995)	Management practices: Reduce intensity of cultivation, reduce the content of N in animals diet		Nitrate leaching, yield			Farm	Decrease of N leaching without loosing crop yield by increasing the N fertilization efficiency.
Vatn et al. (1996)	Management practices: Reduced N levels; split fertilization; changed cropping; catch crops; reduced tillage, delayed/spring tillage; changes in manure handling/spreading techniques; timing of manure application; changes in feeding practices	Model Coupled model: Experimental and model prediction SOILN-NO	Laboratory data, field measurements of C and N transformations, plan N uptake, ammonium and nitrate transformation, nitrate leaching. Crop performance input for simulation model		Norway	Farm	Model predictions cannot replace empirical data, but may be an useful tool for extrapolation and interpolation. Nitrate leaching is strongly influenced by the performance of crops
Pervanchon et al. (2005)	Nitrogen fertilization	Indicator: Agro-ecological indicator comparing nitrogen losses to a threshold of the level of acceptance for the environment. Validated with measurements in field	Residual mineral nitrogen in soil at the begining of the draining period in grassland fields	N balance; soil residual N, agroecological indicator; permanent grassland; N management; pollution			Indicator gave realistic results and was valid to indicate the degree of pollution risk in agricultural management
Verhagen and Bouma (1998)	Nitrogen fertilization Soil mineral N after harvest, Precipitation	Model Simulation model: Dynamic simulation for 65 soil profiles, taking into account spatial and temporal variability	N fertilization, concentration of nitrates in water, local weather conditions	N leaching; threshold values; soil profiles	Netherlands (Northern part)	Field	Spatial interpolation of the required N profile provided N target maps to focus and evaluate N fertilizer management
Lewis et al. (2003)	Nitrogen fertilization and slurry application	Model Event driven physically based models: Swedish soil water model and a nitrogen cycle model SOILN	Input parameters calibrated for specific sites in previous studies on hydrology and NO_3 transport with associated crops	Simulation; physically based models; N; leaching; losses; yields; fertilizer and slurry management; environmental risk assessment	Sweden	Farm	Supply N-budget tables for an expert agricultural decision system. Application of slurry in autumn leads to larger losses through N leaching. Variations depending on soils and climate.

Reference	Agricultural practices	Methodology	Data	Keywords	Country	Scale	Conclusions
Maticic (1999)	Nitrogen fertilization and Standard: LU/ha	Normative approach	N input from mineral fertilizers, animal wastes, atmospheric deposition, crops uptake and ammonia losses	Groundwater; pollution; nitrate; standard; strategy	Slovenia	Regional and farm level	In intensive arable regions with high intensity of animal husbandry nitrogen surplus are more important.
Brown et al. (in press)	Nitrogen fertilization management	Model 'NGAUGE' Decision support System: empirical based model	Soil texture, weather zone, grazing and manure applications	Nitrogen; decision support system; fertilizer recommendation; grassland; model	Great Britain	Farm level: grassland farms	N fertilizer recommendations and N budgets
Oenema et al. (1998)	Nitrogen fertilization: Nitrogen surpluses at soil surface	Accounting system: Nitrogen and Phosphorous accounting system MINAS from 1998	Statistics data	Agriculture; dairy farms; denitrification; grassland, mineralization; nutrition budgets; nitrate leaching; sandy soils; policy	Netherlands	Farm (whole farm)	The results indicate that MINAS is effective, additional measures are needed for agricultural land on dry sandy soils
Dauden and Quilez (2004)	Nitrogen fertilization: Pig slurry application different amounts Mineral fertilization	Experimental	3 years: Crop yield of corn, nitrate leached, aboveground biomass, nitrogen plant uptake	Soil nitrate content; N budget; N losses; surface irrigation; mediterranean climate	Spain	Field	Higher susceptibility to nitrate leaching from mineral treatment that from slurry administration
Webb et al. (2000)	Nitrogen fertilization: Type of soil, type of rotation	Experimental determination of annual fluxes of N fluxes in three sites in three seasons	Nitrate leaching, NH_3, N_2O, $N_2$and crop uptake, and N deposition	N cycle; N balance; emissions pollution	UK	Site	In arable crops where no organic manures are applied priority in reducing losses of N is given to nitrate leaching
Berntsen et al. (2003)	Nitrogen fertilization: Tax in N mineral fertilizer and imported feedstuff, a tax in surplus	Model Linear programming module of model FASSET ver. 1.0 to evaluate the impacts of the taxes for each farm type, the dynamic simulation module of FASSET evaluated the environmental and economic consequences of different plans	Crops rotation, farm type, fertilizer use and pig production	Nitrate leaching; integrated modelling; non-point source pollution; N tax; sustainable development; dynamic simulation model		Farm (whole farm)	None of the taxation policies was the most cost-efficient for all the farm types. Efficient taxation must differentiate between farm types.
Granlund et al. (2000)	Nitrogen fertilization: Cultivation practices imposed by an Agri-environmental Support Scheme	Model Deterministic model	Detailed data from 400 farms	Agriculture; N; fertilization; manure; modelling	Finland	Regional	Regional assessment from farm level were made by combining model calculations with digital maps (soils, crops and fertilization) using GIS. To achieve national and international target nitrate reductions, fertilization and manure spreading should be reduced to the actual nitrogen requirements of crops

Reference	Agricultural practices	Methodology	Data	Keywords	Country	Scale	Conclusions
Jansen et al. (1999)	Nitrogen fertilization: Scale, level of maximum, way of grouping the farms, biophysical situation of farms	Model Linear programming model: To find the optimal spatial allocation of variants to reach desired nitrate concentration at minimum cost	Current land use and management variants	Regional agricultural policies; linear programming; optimisation; N; manure; fertilizer; environmental pollution	Netherlands	Regional and subregion	Political decisions about the scale have a strong effect on the cost/benefit relationship
Oenema et al. (2005)	Nitrogen fertilization: N surplus and P surplus, hydrological conditions, land use and soil type	Model Mathematical and database model: Integrated set of mathematical models and databases	Nutrient balance (N and P)	Agriculture; balances; eutrophication; N; P; delta	Netherlands	National	For improving ecological state: low N and P surpluses in agriculture, . . . , and decreasing discharges from other sources
Ramos et al. (2002)	Nitrogen fertilization: N fertilizer treatment	Model Simultion model: Simulation studies	N content in the 0-60 cm layer of the soil	Nitrate leaching; vegetables; citrus; N fertilizers; fertilizer recommendation system	Spain (Valencia)	Region	
de Paz and Ramos (2004)	Nitrogen fertilization rates	Model GIS and model: Agricultural Management System (GLEAMS) model coupled to a GIS	Analysis of NO_3^- in soil, N leaching, crop evapotranspiration and rainfall	GIS; GLEAMS; nitrate leaching; N fertilization	Spain (Valencia)	Regional	N min recommendation system was the most efficient for vegetables. Problems with nitrate content in groundwater
Bouma and Droogers (1998)	Organic farming: Long-term organic and conventional management	Model Indicator: A land quality indicator, actual/potential yield with acceptable leaching of nitrates Simulation of production for 30 years Yields were calculated considering probabilities	Weather variability, nitrogen fertilization scenarios, nitrate leaching to the groundwater	Organic farming; environmental quality; simulation modelling	The Netherlands	Fields	Quality indicators were consistently higher for organic farming management
Kemmitt et al. (2005)	pH	Experimental	$[NO_3^-]$ and Dissolve Organic Nitrogen (DON)	Acidification; nitrate leaching; nitrate vulnerable zones; nitrogen cycling; ph; soil acidity			Soil pH management considered as a tool to control leaching
Catt et al. (2000)	Tillage	Experimental	Nitrate concentration in drain flow at 60 cm, surface runoff and interflow for 2 years	Drain flow; surface layer flow; nitrate loss; mineralization; leaching; swallow tillage; direct drilling	UK	Plot	At long term, more nitrate is leached from land subjected to periods of zero tillage and zero ploughing than from land ploughed every year.
Malhi et al. (2001)	Tillage: N efficiency depends on soil, climatic factors, tillage management, microclimate, microbial activity and distribution of fertilizer			Cereal; method of N placement; N loss; N recovery; N use efficiency; no-tillage; time of application; yield; zero tillage; Canadian Great Plains			Optimum fertilizer management system must be considered: balance between rate of application, cost and availability of equipment, soil disturbance, seedbed quality, moisture conservation, time and labour constraints and fertilizer use efficiency.
Stenberg et al. (1999), Webster et al. (1999)	Tillage: Mouldboard ploughing: early autumn, late autumn or spring, catchcrop	Experimental	Soil mineral content and nitrate leaching	Soil tillage; soil mineral N; nitrate leaching; Lollium perenne; sandy loam	Sweden (South)	Plot	Time of tillage influenced nitrate leaching: it's greater with early than with late tillage, due to the increased N mineralization and the growth of weeds and volunteer plants in autumn, causing decrease in yield

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12 Linking agri-environmental indicators to economic models in order to assess the environmental impacts of the 2003 CAP reform

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Abstract

Although the environmental impact of agricultural policies is potentially large, the Common agricultural policy (CAP), including its 2003 Luxembourg reform, has mainly been assessed as regards its effects on socio-economic variables and on international trade. One of the main reasons for this situation is that the currently prevailing information systems mostly focus on the economic performance of the sector. Yet in recent years progress has been made on developing agri-environmental indicators. The present paper first surveys those indicators that are, or could be linked to applied economic models with a focus on the models participating in the GENEDEC project. We present the European project IRENA, the OECD forthcoming set of agri-environmental indicators and the French IDERICA dataset. We classify these indicators in eight topics: excess application of nutrients, excess water abstraction, greenhouse gases, energy consumption and production, air pollution by ammonia, pesticides, loss in on-farm landscape diversity and biodiversity, loss in off-farm landscape diversity and biodiversity, and soil erosion. It turns out that the large progress made in the last few years in the production of agri-environmental indicators has started to trickle down to applied economic models and that in the future, many more indicators could be added in these models.

12.1 Introduction

Up to now, the Common agricultural policy (CAP), including its 2003 Luxembourg reform, has mainly been assessed as regards its effects on socio-economic variables and on international trade. One of the main reasons for this situation is that the currently prevailing information systems mostly focus on the economic performance of the sector. However the environmental impact of agricultural policies is potentially large since these policies affect land use, crop choices and agricultural practices.

Measuring agri-environmental performance is not an easy task, but progress has been made on developing common methodologies to measure such performance through the construction of agri-environmental indicators which are simplified statements meant to capture the key factors involved in the complex relationships between agriculture and environment. An assessment of the environmental impacts of the 2003 CAP reform (as well as of any agricultural policy) requires models featuring such agri-environmental indicators among their output variables. In the last few years, the availability of agri-environmental indicators has improved a lot, which opens the prospect of a significant improvement in the environmental assessment of the CAP reform. The present paper surveys the agri-environmental indicators that are, or could be linked, to applied economic models with a focus on the models participating in the GENEDEC project, and develops on possible improvements.

The rest of the paper is organised as follows. We present in section 2 the main sets of agri-environmental indicators, which could be useful to assess the environmental impacts of the CAP reforms, i.e., the European project IRENA, the OECD forthcoming set of agri-environmental indicators and the French IDERICA dataset. We then propose in section 3 a selection of these indicators based on their relevance and ease of implementation in applied models. These proposed indicators are classified in eight topics: excess application of nutrients (3.1), excess water abstraction (3.2), greenhouse gases, energy consumption & production (3.3), air pollution by ammonia (3.4), pesticides (3.5), loss in on-farm landscape diversity and biodiversity (3.6), loss in off-farm landscape diversity and biodiversity (3.7) and soil erosion (3.8). There are many ways to classify agri-environmental issues and this one is by no means definitive but it has the advantage of eliminating redundancies. Section 4 concludes.

12.2 Main existing sets of agri-environmental indicators

The two main databases available (or soon available) are IRENA and the OECD environmental indicators for agriculture.

IRENA (Indicator Reporting on the integration of ENvironmental concerns into Agricultural policy) is financed by Environment DG and Agriculture DG, and managed and coordinated by the European Environment Agency (EEA). It benefits from the co-operation of the joint Research Centre (JRC) and Eurostat. It covers the EU 15 and many indicators are available at an infra-national level, generally the NUTS- 2 or 3 levels, depending on the Member State. It consists of more than 70 indicators, gathered in 35 families. The main report (EEA, 2005) has been published in December 2005 while a shorter, more policy-oriented report has been issued in March 2006 (EEA, 2006). Furthermore for almost each of the 35+ family of indicator, a spreadsheet containing the data and a complementary text (IRENA Indicator Fact Sheets) are downloadable from

http://webpubs.eea.europa.eu/content/irena/Latestproducts.htm.

The **OECD** dataset - environmental indicators for agriculture - has a longer history. Indeed, the OECD has played a major role in methodological discussions on agri-environmental indicators and in the work of calculating and interpreting agri-environmental indicator trends. The last published version (volume 3) was issued in 2001 but a new one (volume 4) is scheduled for the beginning of 2007. We use the latter in the present chapter. Compared to IRENA, one drawback is that it does not include information at the regional (nor at another infra-national) level but it covers a wider geographical scope, including some new EU members States and allowing a comparison with non-EU OECD members. Moreover it often includes longer time-series and some indicators not retained by IRENA. The opposite is also true, which strengthens the need to look at both datasets.

From our perspective, both suffer from the same weakness: they do not assess the ability of these indicators to be linked to economic models. This motivates the inclusion of a third dataset in our review: IDERICA.

IDERICA (Girardin et al., 2004) has a much narrower geographical coverage since it is limited to France. Yet its interest for our review is that it is based mainly on FADN (more precisely the French FADN, Réseau d'Information Comptable Agricole or RICA, hence the name IDERICA for Indicateurs de Durabilité bases sur le Réseau d'Information Comptable Agricole). For some indicators, data from the Recensement agricole (the French agricultural census) is also used by IDERICA.

In a few cases, we will also mention the **Eurostat**[1] and **FAOstat**[2] web sites, which provide some data included neither in IRENA nor in the OECD dataset.

IRENA is structured according to the DPSIR scheme (Driving forces, Pressures and benefits, State, Impact - cf. figure 12.1) while the OECD follows a simplified version of the same model, labelled DSR (Driving Force, State, Response). Some of the "Pressure and benefits" indicators in IRENA are included in the "Driving forces" for the OECD, while others are considered "State" indicators. IDERICA is mostly limited to indicators pertaining to Driving forces.

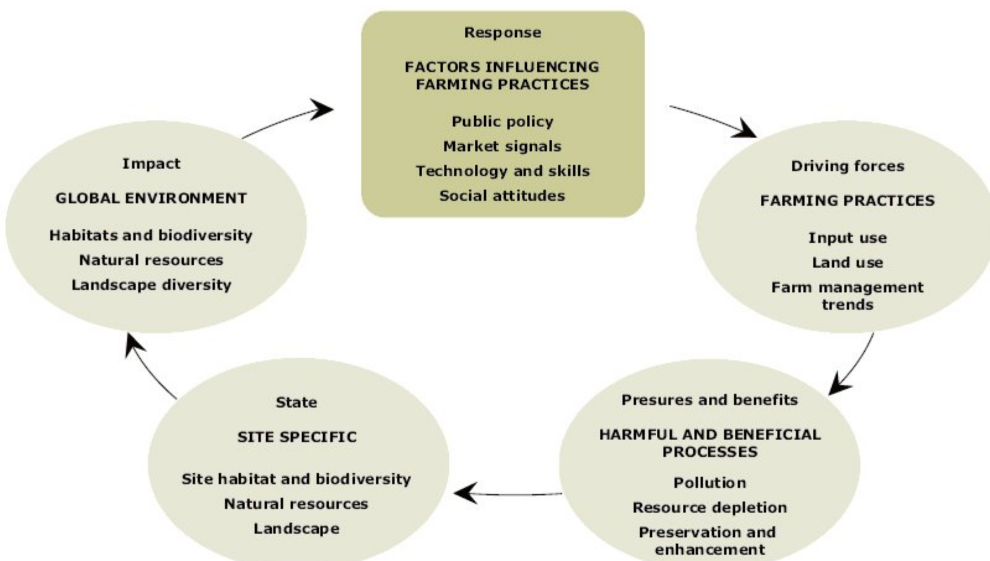


Figure 12.1: The DPSIR framework for agriculture. *(Source: EEA, 2006, p. 12).*

Among theses categories, the State and Impact families of indicators are generally too far away from economics to be linked to economic models - they are more relevant to ecological models. Consequently, we will not consider them in the present report.

[1] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136206,0_45570467&_dad=portal&_schema=PORTAL
[2] http://faostat.fao.org/

12.3 Proposed selection of indicators

We focus here on the indicators that could provide interesting results in the purpose of linking them to an economic model. The most important criteria is the measurability and the possibility to calculate the indicator result from the output of a model. However, policy-relevance is important as well: they should address the key environmental issues faced by governments and other stakeholders in the agriculture sector.

12.3.1 Excess application of nutrients

Mineral fertilisers especially nitrogen (N) and phosphorus (P_2O_5) are widely used to optimize production as they are necessary nutrients for plants growth. Indeed, a nutrient deficiency leads to a lower soil fertility and therefore may have a negative impact on crop yields. On the other hand an excessive use of nutrients increases the risk of harmful impacts on the environment caused by nutrients runoff from farmland. Nutrient surpluses can lead to water pollution (excessive nitrate level and eutrophication), air pollution (by ammonia) and contribute to climate change (through N_2O - a greenhouse gas - emissions). An additional issue concerns the sustainability of world phosphorous reserves, which are diminishing.

Several factors affect the impact nutrients may have on the environment:

- The biophysical processes of nitrogen and phosphorus in the agricultural system illustrated by nutrient cycles and the environmental assimilative capacity determined by soil type and climatic factors.
- Farming practices and the type of crop (as the nutrients' requirements differ from one to another) and the livestock systems.

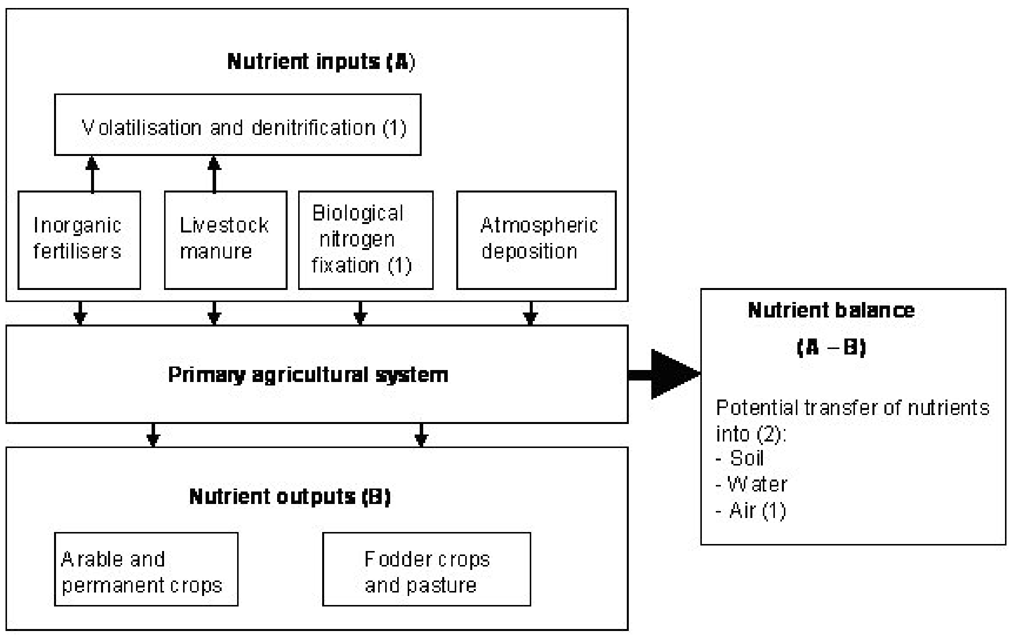
Gross nutrient (nitrogen and phosphorous) balance

Both the OECD and IRENA (indicator n. 18) propose soil surface nitrogen and phosphorus balances as indicators of nutrients leaching risk. In the case of the OECD the phosphorus balance is already effective whereas in IRENA, it is only suggested for future monitoring. Gross nutrient balance is defined as the difference between inputs and outputs per ha and per year. Both datasets adopt the same methodology of estimation (cf. figure 12.2). It was jointly developed by OECD country nutrient expert and the OECD and Eurostat Secretariats.

These indicators are certainly useful but they are not totally reliable, especially for nitrogen, since biological nitrogen fixation is difficult to estimate and the same stands for ammonia volatilisation and losses via denitrification. Besides the balance is not an indicator of actual fate of nutrients, but only of potential excess in water and/or soil. Finally, the importance of climatic factors makes it difficult to interpret differences between regions.

Implementation of these indicators in economic models is certainly possible but it faces several hurdles. First, it requires nutrient-yield relationships. This now exists for nitrogen in several models, including AROPAj, the core model of the GENEDEC project. To our knowledge, it does not exist yet for phosphorus. Second, the physical amounts of nitrogen and phosphorous are not in FADN so they have either to be estimated from FADN or to be informed through other databases.

As is apparent from figure 12.3 below, the excess of both nitrogen and phosphorus has declined in the EU 15 since 1990. A milder decline also appears in Japan and there is no clear trend in Australia. Finally in the US, the surplus in both nutrients has worsened in recent years.



Notes:
1. Applies to the nitrogen balance only.
2. In most situations an excess of nutrients are transported into the environment, potentially polluting soils, water and air, but a deficit of nutrients in soils can also occur to the detriment of soil fertility and crop productivity.

Figure 12.2: Main elements in the gross nutrient (nitrogen and phosphorous) balance calculation. *(Source: OECD, 2007, ch. 3).*

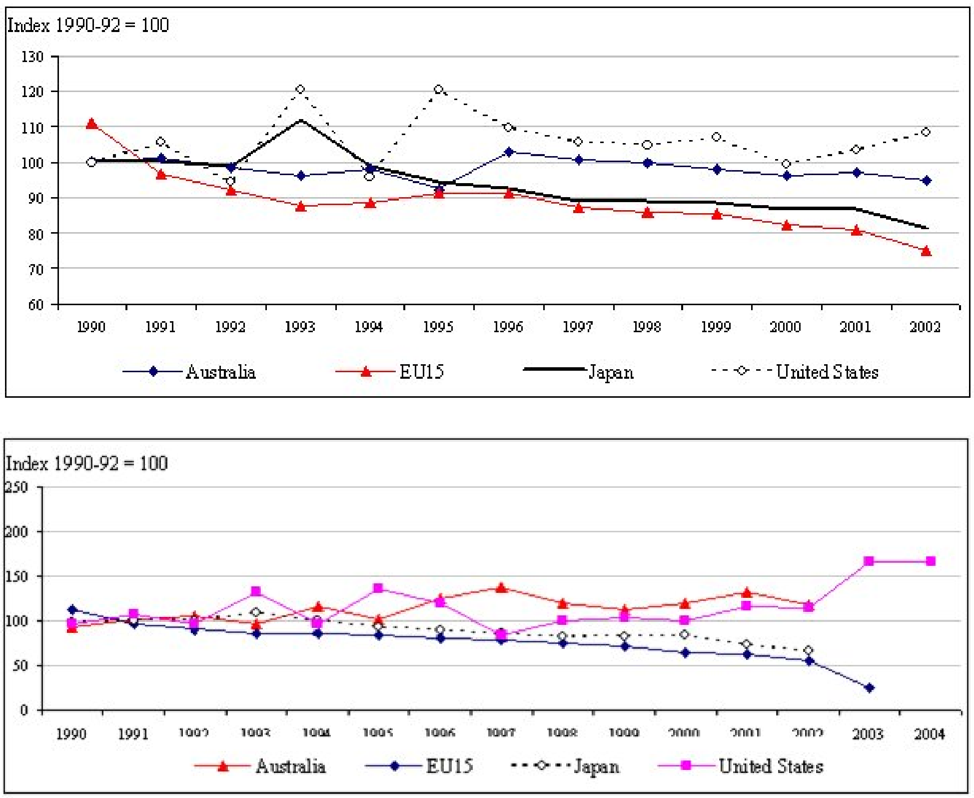


Figure 12.3: Index of trends of nitrogen (upper panel) and phosphorus (lower panel) balances in the EU 15 versus selected OECD countries. *(Source: OECD, 2007 ch. 3).*

Mineral fertiliser consumption

IRENA indicator n. 8 provides a simpler indicator: mineral fertiliser consumption. Compared to the nutrient balances, it is further away from the actual environmental damage, except for the depletion of world phosphorus reserves. Yet it requires less data and suffers from less uncertainty since there is no need to estimate nitrogen biological fixation, denitrification or ammonia volatilisation.

IRENA 8.1 provides mineral fertiliser consumption (nitrogen and phosphorus) at the Member State level, based on FAOstat data, and covers 1990-2002[3]. Perhaps more interesting for implementation in economic models is IRENA 8.2, which provides, for 18 crops and every Member State, the amount of nitrogen and phosphorus per ha per year based on EFMA (European Fertiliser Manufacturer Association) estimates (figure 12.4). Yet these data come from a private organisation and their accuracy remains to be assessed.

As shown in figure 12.4, the amount of fertiliser differs widely, both across Member States and across crops. Hence a change in crop choice, which may be induced by the CAP reform, would impact the amount of fertilisers applied, even if it did not change the amount for each crop. Thus this kind of results would show up even in an economic model without nutrient-yield relationship. However for models based on FADN, the other hurdle mentioned above remains since FADN does not provide the physical amount of nutrients. The next indicator targets this problem.

Nitrogen polluting pressure

This indicator is provided by IDERICA (indicator A13) based on French FADN data only. The physical amount of nitrogen is first computed based on the following assumptions:

- 76% nitrogen fertilisers in total fertilisers
- 36% N in nitrogen fertilisers
- 1 kg N = 0.45 €
- 3% N in concentrated food
- 1 kg concentrated food = 0.18 €
- 0.6% N in other food
- 1 kg other food = 0.011 €

A score is then computed the following way:

- N inputs < 170 kg N /ha: -1 point
- N inputs between 170 & 160: 0 point
- ...
- N inputs below 70: 10 points

In addition, if nitrogen catch crops are grown on at least 10% of the area, then 3 points are added. The more points a holding gets at the end, the higher it ranks as regards this sustainability indicator.

This method allows a simple computation of nitrogen inputs from FADN data. However, as for the previous indicator, nitrogen outputs are not accounted for, so it is far away from the actual damage.

[3]The Eurostat web site provides the same information with shorter time series, but includes also potash consumption. The FAOstat web site provides these data back to 1961 and broken down between the fertiliser types (e.g., ammonium nitrate).

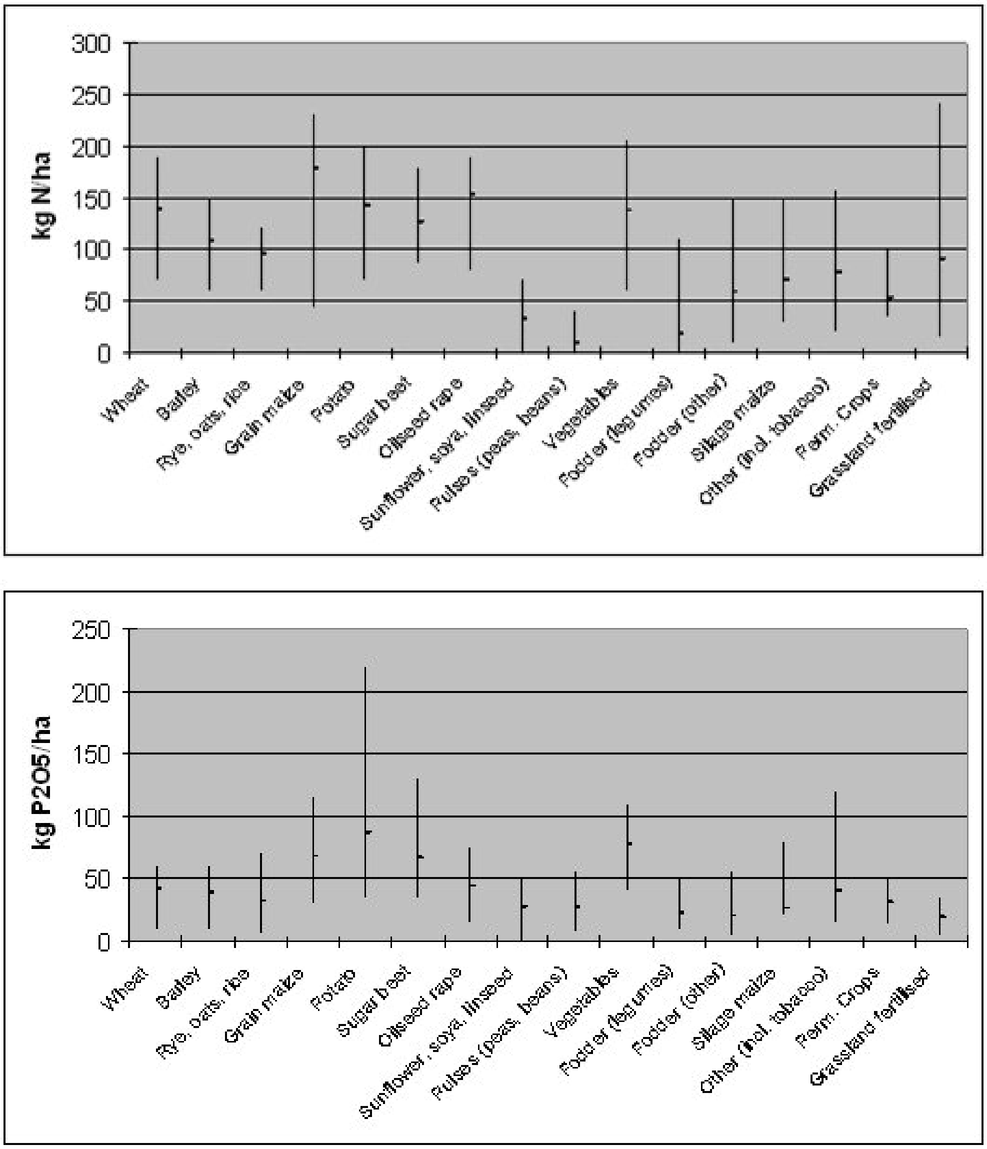


Figure 12.4: Amount of nitrogen (upper panel) and phosphorus (lower panel) per ha for 1999 or 2000: UE 15 mean and range across Member States. *(Source: own computations from IRENA08.XLS, available from* `http://webpubs.eea.europa.eu/content/irena/Latestproducts.htm`*)*

12.3.2 Excess water use

In several Member States competition for water resources between agriculture, industry, household consumers, recreational activities and the environment is growing. IRENA and the OECD provide the two same main indicators, with some more information in IRENA but sometimes longer time series in the OECD dataset.

Irrigated/irrigable area

Irrigable area is available at the Member State level from IRENA (indicator n. 10) for 1990, 1993, 1997 and 2000, based on FADN and FSS. The OECD provides the time series for 1990-2003 and the FAOstat web site for 1961-2003. For France, Greece and Spain, irrigable area is available per main irrigated crop (IRENA 10, from the FSS). Also, the grain maize area irrigated at least once a year is provided by IRENA 10 at the NUTS2/3 level, again from the FSS.

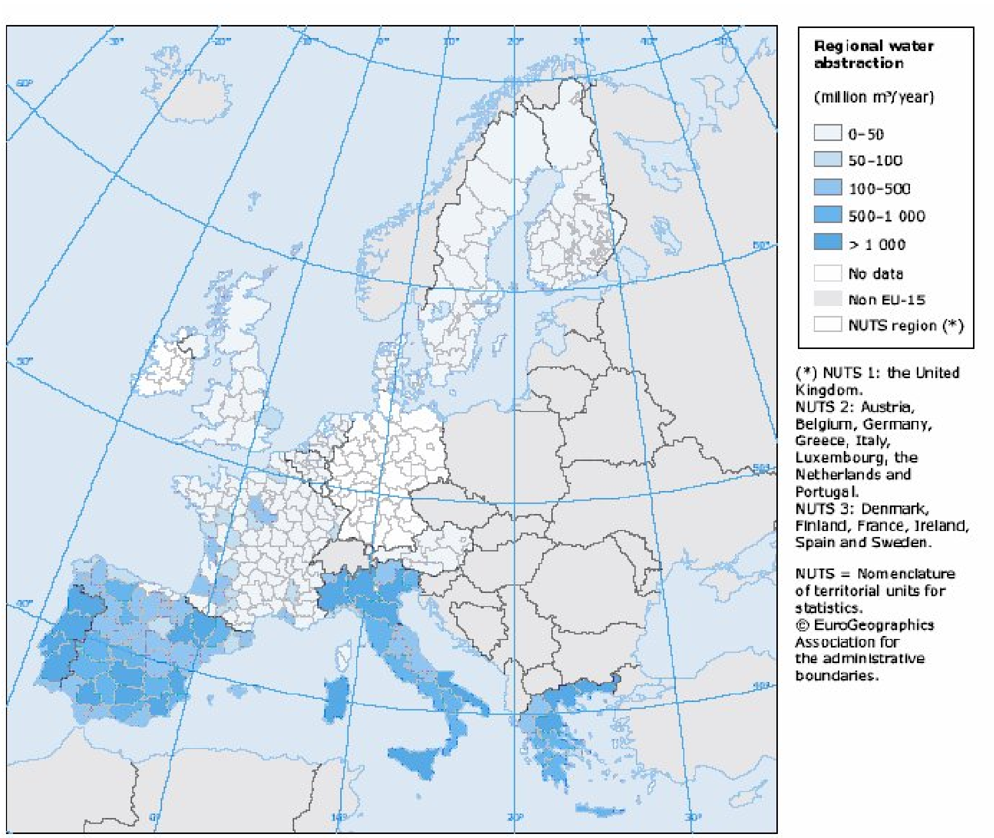
Some economic models such as PROMAPA.G (cf. chapter 6 in this deliverable) break down the crops area in irrigated and non-irrigated but the total irrigated area seems to be fixed. Going further would require information on water and irrigation costs and relationships between irrigation level and yield.

The IDERICA A18 indicator builds an irrigation index as follows: 5 points are given in case of no irrigation, 1 point if irrigation concerns less than 1/3 of the UAA, 1 point if water supplies are drawn from storage reservoirs and another point if there is a water meter. Note that the last two data are not available in the French FADN and are taken from the agricultural census, which would render their implementation in a European-scale model difficult if not impossible.

Agricultural water use

Water abstraction rates in m^3/year and m^3/ha/year are provided by IRENA (indicator n. 22) whereas the OECD provides water use in m^3/year. The former provides the indicator at the NUTS2/3 level for most Member States in 2000 (cf. figure 12.5 below) whereas the latter provides a 1990-2002 time series at the country level. Water abstraction rates at the national level are reported by Member States (OECD/Eurostat questionnaire) and IRENA regional water abstraction rates are estimated by weighting national reported water abstraction rates by regional irrigable area values. Note that according to the IRENA Indicator Fact Sheet 22, some surprising results suggest that reported national water abstraction rates are underestimated in some Member States.

In theory, the terms ”water use” and ”water withdrawal” refer to water abstraction minus return flows from irrigation. Conversely ”water consumption” does not deduct the latter. Both exclude precipitation directly onto agricultural land (OECD, 2007). In practice datasets do not seem to comply with these precise definitions. Indeed a comparison of the IRENA and OECD figures for France yields disturbing results: water use provided by the OECD is equal to or higher than water abstraction according to IRENA 22, whereas it should be lower. Note that the Eurostat web site seems to provide the same data as the OECD dataset (although with more missing values). Implementation in large-scale economic models would require a lot of work since water-yield relationships and data on water cost would be needed. Implementation in a small-scale model has been done e.g. by Butlen and Quirion (2006) in the frame of the GENEDEC project.



Source: Community survey on the structure of agricultural holdings (FSS), Eurostat combined with information from OECD/Eurostat questionnaire.

Figure 12.5: Regional water abstraction rates for agriculture during 2000. *(Source: EAA, 2006, p. 47).*

12.3.3 Greenhouse gas (GHG) emissions and energy net consumption

Gross GHG emissions

Both IRENA (indicator n. 19) and the OECD provide methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions from 1990 onward, distinguishing various emission sources (enteric fermentation, manure management, rice cultivation and field burning of agricultural residues). These emissions are estimated using simple emission factors, following the IPCC methodology.

CH_4 and N_2O emissions are already included and endogenously computed in some economic models such as AROPAj (they form the large majority of direct GHG emissions from agriculture). In chapter 9 of this deliverable, these emissions are computed following the IPCC methodology (which is relevant for compliance with the Kyoto Protocol). In chapter 10, they are computed using the CERES crop model, which allows a more precise assessment.

Yet other indicators are useful to assess the contribution of agriculture to GHG emissions, hence the usefulness of the following indicators.

Carbon storage in soils

First, soils are an important reservoir of carbon; land use and agricultural practices influence the amount of carbon stored in soils, hence may induce CO_2 emissions or storage. IRENA indicator n. 29 provide an estimation of organic carbon content in the surface horizon ($0 - 30$ cm) of soils at the NUTS2/3 levels, displayed on figure 12.6 below. This information is not based on actual measurement but calculated using data on soil, land cover and temperature, with a model that estimates the rate of organic carbon degradation. At the moment time-series information is not available hence the stock variation is unknown, apart from a few case studies. Many OECD countries currently develop indicators of net GHG emissions from agriculture, taking account of the variation in the carbon stock (cf. e.g. Lefebvre et al., 2005, for Canada).

In principle nothing would prevent to link the biophysical model used to produce this indicator to a large-scale economic model, but the accuracy of the former model would need to be checked.

Energy consumption and indirect GHG emissions

Second, some CO_2 emissions are "embedded" in CO_2-intensive goods such as electricity and nitrogen fertilisers. The OECD provides time-series information on on-farm energy consumption, from the International Energy Agency (IEA). This amount has been almost constant from 1990 to 2003. The IRENA indicator n. 11 provides an estimate of energy use in MJ/ha UAA broken down by energy vector, including electricity and energy embedded in N and P_2O_5 fertilisers. The amount of fertilisers in taken from the FAO, the UAA from Eurostat, while energy embedded per kg of N and P_2O_5 is assessed by the LEI on the basis on Dutch data and assumed valid in the rest of the UE. For the EU 15 in average in 2000, the estimated energy embedded in fertilisers amounts to 4.4 GJ/ha UAA, whereas the final energy consumption amounts to 7.2 GJ/ha, mostly petroleum products. The IRENA material available does not compare the direct emissions of N_2O and CH_4, the emissions from energy embedded in fertilisers and the emissions from energy use. In figure 12.7, we display such a comparison, realised through a simple calculation based on IPCC emission factors and the EU average emission factor for electricity. It turns out that direct N_2O and CH_4 emissions clearly dominate.

As regards the implementation of GHG emissions from energy use and fertilisers production in economic models, the IDERICA A 19 indicator is interesting in that in allows a simple computation at the farm level from FADN, based on the following assumptions:

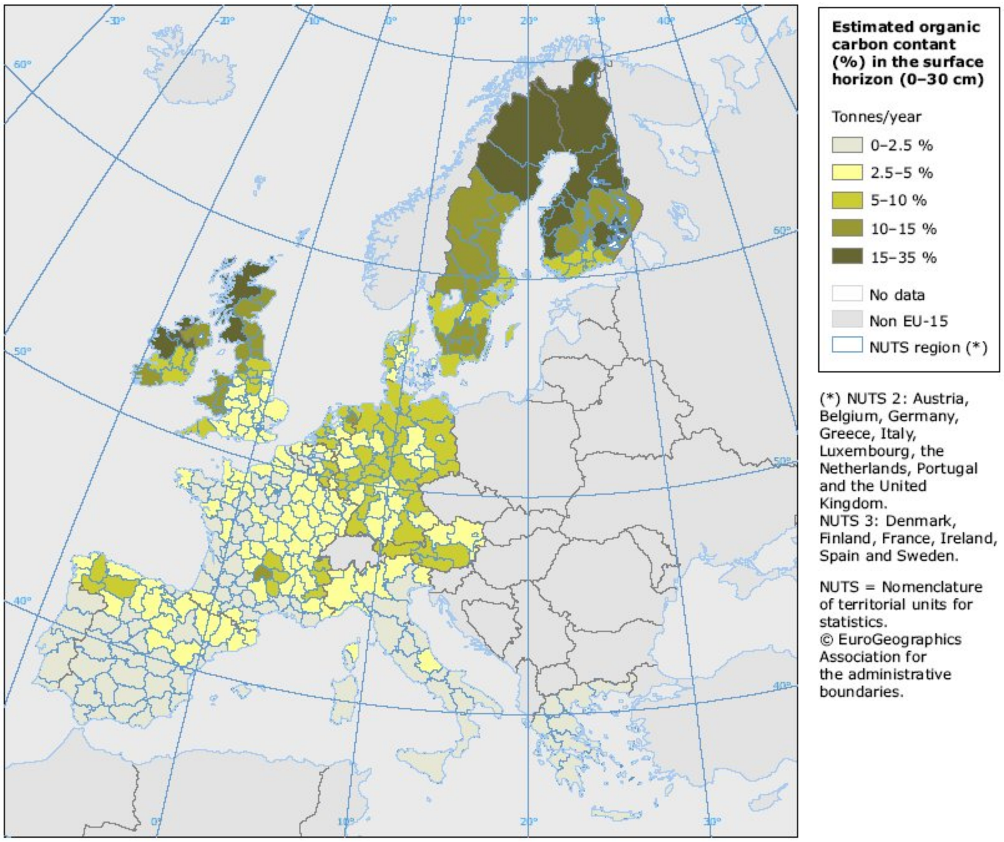


Figure 12.6: .Estimated organic carbon content (%) in the surface horizon (0 30 cm) of soils. *(Source: EAA, 2006, p. 73)*.

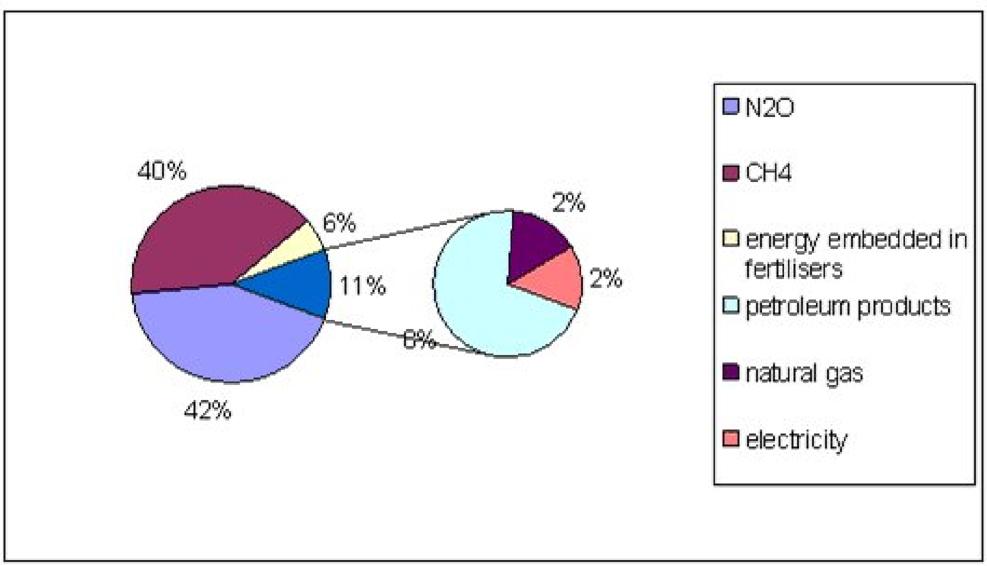


Figure 12.7: GHG emissions from agriculture in EU 15 in 2000, including fertilisers and electricity production. *(Source: own calculation based on IRENA 11, IRENA 19, IPCC and EU average emission factors)*.

- 1 kg N = 0.45 €, 1 N unit = 56 MJ[4]
- 76% N fertiliser in total fertilisers, 36% N in N fertiliser
- 1 l fuel = 47 MJ, Fuel price = 33 €/ 100 l
- 2000 €for water use
- Electricity price = 0.07 €/ kWh

Renewable energy production

Third, the agriculture sector produces renewable energy, which substitutes non-renewable (fossil or nuclear) energy. IRENA indicator n. 27 provides the crop area and energy production devoted to renewable energy production and the amount of energy produced. This indicator distinguishes bio-diesel crops (57% of the energy produced), ethanol crops (10%), short-rotation forestry (13%), agricultural biogas (3%) and cereal straw (17%).

This indicator is based on several sources: European Bio diesel board, EUObserv'ER, Statistics Sweden, IEA, FAOstat and FSS. Only the latter, that provides the production of short-rotation forestry, is available at a regional level. The implementation of indicators on bio-energy production in economic models seems possible if regional and farm-level data become available. In addition one needs to distinguish energy crops grown on set-aside land (roughly 1/2 of the total) from the others.

12.3.4 Air pollution by ammonia

Agriculture is not the main contributor to air pollution but contributes to the problem through ammonia (NH_3) emissions, which occur as a result of volatilisation from livestock excretions. A smaller fraction results from the volatilisation of ammonia from nitrogenous fertilisers and from fertilised crops. Ammonia along with nitrogen oxides and sulphur dioxide contributes to acidification of soil and water, which damages certain ecosystems. Moreover ammonia may contribute to eutrophication of ecosystems and to the formation of aerosols which may impair human health at high concentration. Finally, near the source, it may produce an unpleasant odour and affect health.

94% of ammonia emissions in the EU are due to agriculture, which emitted one third of acidifying substances in 2003[5]. This share has increased in recent years (from 1/5 in 1990) because emissions from nitrogen oxides and sulphur dioxide decreased much more than ammonia emissions. Moreover the National Emission Ceilings (NEC) directive 2001/81/EC sets Member State targets for ammonia emissions and most MS are likely to miss their target. Both IRENA (indicator n. 18sub) and the OECD provide basically the same information, i.e., national emissions from NH_3, reported by Member States following the UNECE/EMEP Convention. These figures are computed on the basis of emission factors and information on livestock and nitrogen fertilisers. Implementation of this indicator in economic models in thus feasible and has been done in AROPAj (cf. chapters 10 and 11).

[4] This value is close to that calculated by the LEI and used in IRENA 11 (58.17 MJ in 1999).

[5] Ammonia, nitrogen oxide and especially sulphur oxide are converted to tons of acid equivalent to make this calculation.

12.3.5 Pesticides

Pesticides use and pesticides sales

IRENA indicator n. 9 gathers data on pesticides use and on pesticides sales. The former are provided by the European Crop Protection Association (ECPA), broken down by active ingredient, main crop and Member State for 1992-1999[6]. These data should be taken with some care since they are not subject to statistical validation, according to IRENA Indicator Fact Sheet 20. The latter is provided by Member States for 1992-2002, broken down in four use classes (herbicides, fungicides, insecticides and other pesticides). Unfortunately there are large and unexplained differences between use and sales data, although a part of the explanation is that there are other users of pesticides than agriculture (e.g. gardens, forestry and golf courses). The current status of pesticide statistics at Community level was discussed at a workshop on 19 May 2003 at Eurostat, and the need for more harmonisation of pesticide statistics and common classifications have been expressed (cf. IRENA Indicator Fact Sheet 09).

The OECD also provides an indicator labelled ”pesticides use”, which (according to OECD 2007) rather refers to pesticides sales. Figures differ significantly from IRENA sales data, for unclear reasons. The Eurostat web site provides almost the same figures as the OECD, with more missing values, but broken down in four use classes (herbicides, fungicides, insecticides and other pesticides). A finer desegregation is also available but only for some Member States and some years.

As regards the implementation in economic models, pesticides use seems more relevant than pesticides sales. ECPA data are broken down by Member State, main crop and active ingredients (although this information is not presented in IRENA documents), so application rates may be computed and included in a model. Any change in land use and crop choice induced by a change in agricultural policy would then induce a change in the amount of pesticides used. Going further would require making the pesticide application rate endogenous, hence to model the pesticide-yield relationship, undoubtedly a difficult task because of the stochastic nature of pests attacks.

The French FADN provides the cost of crop protection products, which is used by IDERICA. Indicator IDERICA A15 divides this cost by the UAA (minus the area permanently covered by grass) to assess the sustainability of farm holdings as regards pesticide use.

Risks from pesticides

The indicators presented above may be useful only if there is a relatively robust relationship between the tonnage (or cost for IDERICA A15) of pesticides and toxicity. Yet this relationship depends on many factors. Changes in the herbicide market in the 1980s provide an illustration, as new products came on to the market that were much more biologically active than their predecessors and were therefore used in smaller quantities (OECD, 2007). To solve this problem several pesticide risk indicators have been developed. The OECD (2005) Pesticide Programme analysed and compared six models that can be used to derive such indicators. For example, figure 12.8 displays the evolution of two Norwegian risk indicators and of pesticides sales. It appears that risk indicators evolve in the same direction as sales but show more variability. The explanation is that in 1998 and 1999, a large stockpiling of pesticides with the highest health and environmental risk occurred because a tax on pesticides, differentiated by toxicity, has been announced. Conversely for succeeding years the risk values are lower, perhaps reflecting the impact of the tax.

Unfortunately, these indicators require information on pesticides types, which is not available EU-wide yet. As a consequence their inclusion in Europe-wide economic models seems difficult.

[6] Ammonia, nitrogen oxide and especially sulphur oxide are converted to tons of acid equivalent to make this calculation.

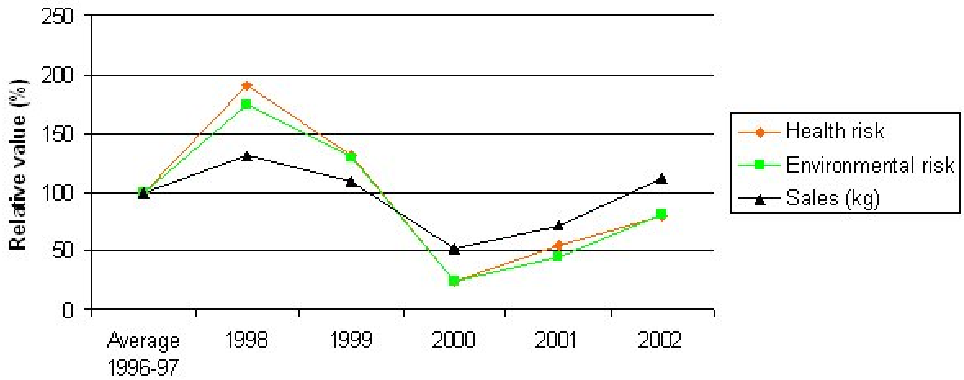


Figure 12.8: .Norway: Trends of health risk, environmental risk and sales of pesticides. Average 1996-97 = 100. *(Source: OECD (2007) from Norwegian Agricultural Inspection Service, 2003).*

Soil contamination by pesticides

IRENA 20 provides a rough estimate of pesticide soil contamination. The methodology used is adapted from FOCUS (1996) work "Soil persistence models and EU registration". The selected approach consists in calculating the quantity of herbicides in the soil profile based on the assumption of first-order degradation kinetics. The average annual quantity of herbicides present in soils under cereals, maize and sugar beet cultivation is computed based on an estimated average application rate (from ECPA, see section 3.5.1 above), herbicide degradation properties, and average monthly temperatures. As an illustration, figure 12.9 displays the indicator for cereals and indicates an increase in soil contamination between 1994 and 1999.

The major limitation of the methodology comes from the lack of detailed information concerning pesticide use. For instance, the calculated average dose of herbicide applied on specific crops relies entirely on the estimated use data provided by the European Crop Protection Association (ECPA) to EUROSTAT. The results should thus be taken with caution as these data are not subject to statistical validation. In addition, not all active ingredient uses are reported (cf. IRENA Indicator Fact Sheet 20).

It seems that nothing prevents the inclusion of such a simple pesticide-dynamics model in large-scale economic models but the above limitations have to be kept in mind.

12.3.6 On farm biodiversity

The OECD provides the number of plant varieties registered and certified for marketing for 1990-2002 but data are not available for all Member States. Both the OECD and IRENA (indicator n. 25) provide time-series information on the share of the five dominant crop varieties in total marketed crop production for the main crops but again, many data are lacking. Both datasets also provide information (time-series for the OECD) on the number of livestock breeds registered or certified for marketing. The OECD also provides the share of the three major livestock breeds in total livestock numbers. At last, both IRENA and the OECD provide information on endangered breeds.

All these indicators on breed diversity and plant varieties seem extremely difficult to include in economic models. Conversely it may be possible to include some indicators on the within-farm crop and animal diversity. Indeed the IDERICA dataset include five such indicators, all computed from the French FADN.

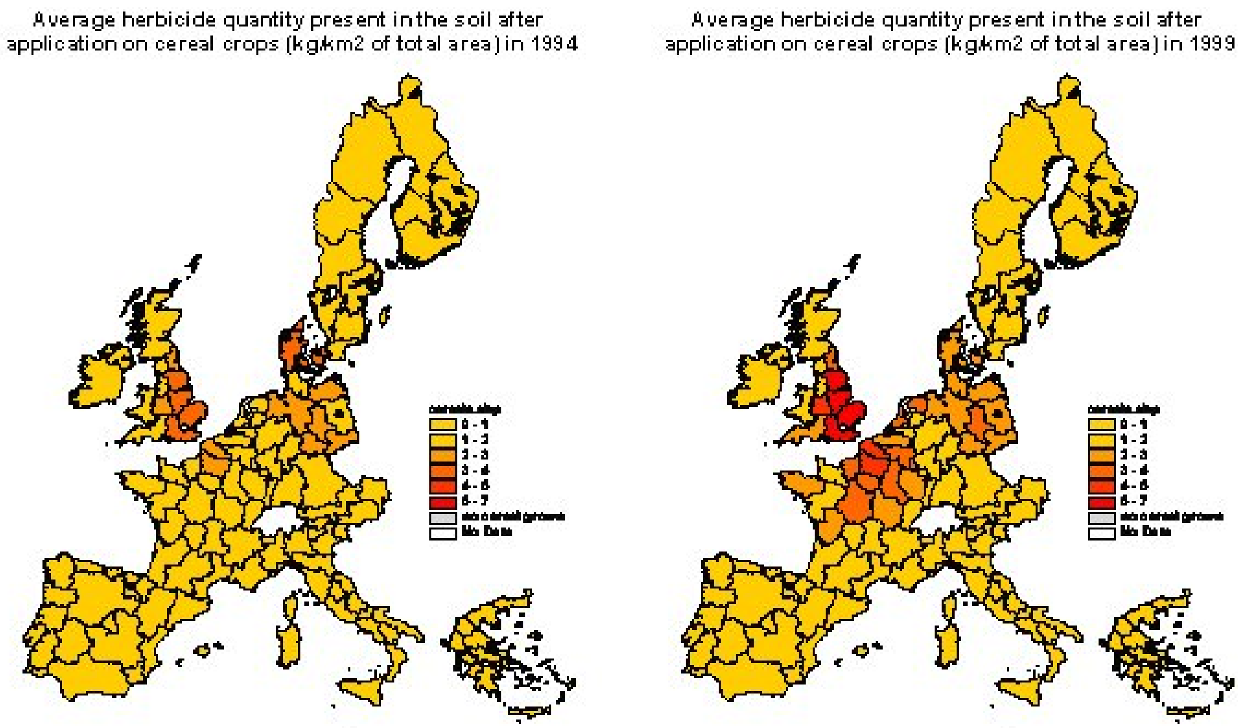


Figure 12.9: Average calculated quantity of herbicide present in soils under cereal cultivation for 1994 (left) and 1999 (right). *(Source: IRENA Indicator Fact Sheet 20).*

- **IDERICA A1**: diversity of annual and temporary crops. The indicator is computed as follows: 2 points per specie with an area higher than 1 ha, plus 3 points if there are leguminous plants on more than 10% of the UAA.
- **IDERICA A2**: diversity of permanent crops. Two points are given for each specie, plus 2 to 8 points according to the area in pasture (permanent or temporary for more than 5 years)
- **IDERICA A4**: animal diversity. Five points are given per animal specie above a specie-specific threshold
- **IDERICA A6**: rotations. This indicator is computed as follows: 8 points if no crop represents more than 20% of the UAA, 7 points if no crop represents more than 25% of the UAA, etc., and 0 point if one crop accounts for more than 1/2 of the UAA. In addition 2 points are added in case of significant (>10%) intra-plot mix.

Although these indicators seem useful to assess the on-farm biodiversity, making them endogenous in an economic model is undoubtedly a difficult task.

12.3.7 Loss in off-farm landscape diversity and biodiversity

Up to now, we have mostly focused on the detrimental environmental impact of intensive agriculture. Indeed, as we have seen, intensification of agriculture (more output per unit of land or labour) often harms the environment. This includes a loss in landscape diversity and wild biodiversity.

Yet land abandonment and decline in traditional farming practices, reflecting a trend of urbanisation or rural depopulation, is also often detrimental to the environment. Indeed it impacts biodiversity (since many species have co-evolved with traditional agricultural practices over many centuries) landscape and soils. Included in the last category are natural hazards such as the risk of soil erosion and landslides. Admittedly, in some limited cases, abandonment increases landscape diversity and biodiversity, when the natural habitat is itself particularly diverse and/or when abandoned agricultural activity is poor from this point of view. Yet in most cases, particularly in the mountains, abandonment means a loss in low-intensity farming marked by a high level of diversity. To quote MacDonald et al. (2000) in their large-scale study, "abandonment generally has an undesirable effect on the environmental parameters examined".

A lot of indicators of landscape and biodiversity exist, but most of them seem difficult to link to economic models, with a few exceptions analysed below.

Permanent pasture

A major share of agricultural semi-natural habitats consist of permanent pasture, which for most OECD countries declined during the period 1990-2002 (OECD, 2007). The OECD database provides time-series information on the area of permanent pasture at the national level, based on FAOstat. IRENA (indicator n. 13) provides the area of permanent grassland and meadow based on the FSS, at the NUTS2/3 level. Unfortunately there are significant and unexplained differences between the sources. Note that IRENA 13 also provides the area covered by three Grazing_Livestock FADN farm types, which also differs from the previous two data.

Such an indicator is available in some economic models based on FADN data, such as AROPAj and FARMIS, two models participating in the GENEDEC project. For the former, see chapter 2 of the present deliverable, in which the author concludes that decoupling leads to an increase in pasture area. For the latter, see Kuepker and Kleinhanss (2006) who conclude that decoupling would lead to an increase in extensive grassland area.

Farms economically at risk in zones ecologically vulnerable to abandonment

The expected damage of abandonment may be approximated by the number of farms economically at risk in conjunction with geo-referenced indicators of the ecological vulnerability to abandonment. Regarding the former, IDERICA indicator C1 (economic viability) is computed from FADN as follows

- VE = (EBITDA - (prov. for depreciation/2 + debt service)) / labour units
- 0 point if VE $<$ 1 annual French minimum wage
- 1 point if 1 $>$ VE $>$ 1.2 annual French minimum wage
- ...
- 30 points if VE $>$ 3 annual French minimum wage

A somewhat similar analysis for beef and dairy farms in Ireland is presented in the presentation by Hennessy (2006) in the frame of the GENEDEC project. The author concludes that decoupling reduces the number of dairy farms but increases farm viability.

As regard the latter, the IRENA indicator n. 33 provides the important bird areas classified as threatened by agricultural abandonment, displayed in figure 12.10.

12.3.8 Soil erosion

About 17 per cent of the total land area in Europe (excluding Russia) is affected by soil erosion to some degree (EEA, 2000). Erosion rate is very sensitive to both climate and land use, as well as to detailed conservation practice at farm level. The Mediterranean region is particularly prone to erosion because it is subject to long dry periods followed by heavy bursts of erosive rain, falling on steep slopes with fragile soils. The main causes of soil erosion are still inappropriate agricultural practices, deforestation, overgrazing, forest fires and construction activities (IRENA Fact Indicator Sheet 23).

IRENA indicator n. 23 is based on the Pan-European Soil Erosion Risk Assessment - PESERA - approach (Gobin et al., 2003), which uses a process-based and spatially distributed model to quantify soil erosion by water and assess its risk across Europe. The resulting 1km x 1km annual soil erosion risk map reports estimated soil losses in t/ha/year. No time-series information is available.

Unfortunately the implementation of such an indicator in an economic model would require a lot of information especially on farm management - crop rotations, type of tillage, etc. - to assess the impact of CAP reforms. The IDERICA indicator A17 (winter crop coverage) provides a much simpler solution. The following formula is calculated from the French FADN as follows:

- Ratio = (Spring crop area - N catch crop area) / (total area)
- If ratio $<$ 0.25: 4 points
- ...
- If ratio $>$ 0.4: 0 points
- 5 points are added if permanent pasture is above a threshold.

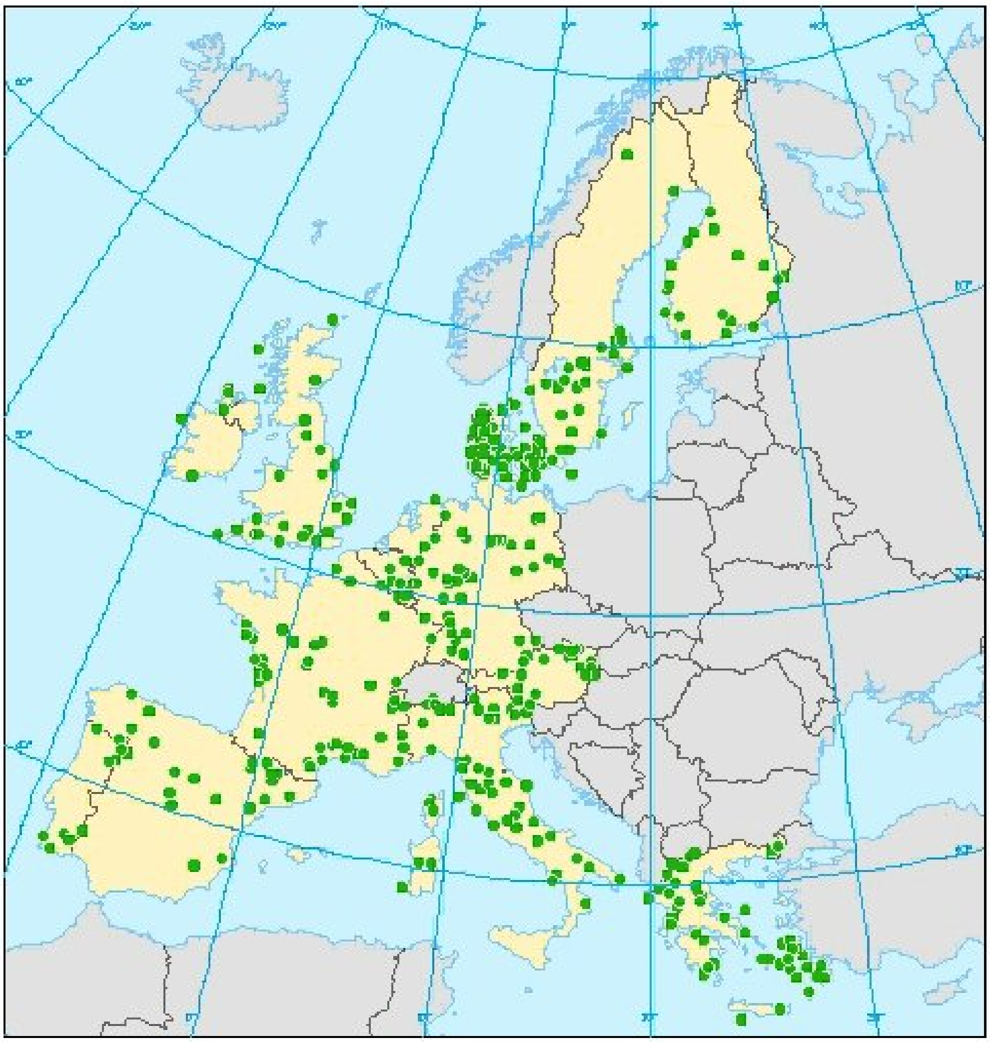


Figure 12.10: Important bird areas classified as threatened by agricultural abandonment. *(Source: IRENA Indicator Fact Sheet 33, from Heath and Evans, 2000).*

12.4 Conclusion: indicators that are or could be implemented

The large progress made in the last few years in the production of agri-environmental indicators has started to trickle down to applied economic models. Table 12.1 below provides a synthesis in this regard. It shows that several indicators are already implemented: nitrogen balance (3.1.1), irrigated area (3.2.1), greenhouse gases emissions (3.3.1), air pollution by ammonia (3.4) and permanent pasture (3.7.1). In the future, many more indicators could be added in these models, mostly in three ways.

First, even without building input-yield relationships or relying on farm-level data, some indicators could be included in farm-type models. This is the case for mineral fertiliser consumption (3.1.2), which could be implemented rather easily by assuming that the coefficients per Member State and per crop provided by EFMA stand irrespective of the CAP reform. The CAP reform would then induce a crop switch hence a change in mineral fertiliser consumption. The same stands for pesticides use (3.5.1) and ECPA data.

Second, a lot of IDERICA indicators could be implemented in models based on FADN data, on condition that the EU FADN contains the same information as the French FADN: nitrogen polluting pressure (3.1.3), irrigation index (3.2.1), energy consumption and indirect GHG emissions (3.3.3), on-farm biodiversity (3.6) and farms economically at risk in zones ecologically vulnerable to abandonment (3.7.2), soil erosion (3.8).

Three, some indicators may be implemented by running the simple biophysical model already used to produce these indicators, downstream of the economic model. Carbon storage in soils (3.3.2) and soil contamination by pesticides (3.5.3) could be included this way. However the spatial resolution of the economic models is coarser than that of these biophysical models hence would require some approximation. Moreover, the reliability of the latter should be checked against observations.

	Indicator	Implementation in large-scale economic models	Main reference
3.1.1	Gross nitrogen balance (OECD & IRENA 18)	Implemented in AROPAj	This deliverable, ch. 9, 10 and 11
3.1.1	Gross phosphorus balance (OECD & IRENA 18)	Difficult to implement: requires phosphorus-yield relationships	EEA (2005) OECD (2007)
3.1.2	Mineral fertilisers consumption (IRENA 8.2)	Difficult to implement and less relevant	EEA (2005)
3.1.2	Mineral fertilisers consumption per crop (IRENA 8.2)	Seems possible to implement but need to check the reliability of EFMA data	EEA (2005)
3.1.3	Nitrogen polluting pressure (IDERICA A 13)	Seems possible to implement in models based on FADN	Girardin et al. (2004)
3.2.1	Irrigated/irrigable area (IRENA 10, OECD and FAOstat)	Implemented in PROMAPA.G	EEA (2005) OECD (2007) This deliverable, ch. 6
3.2.1	Irrigation index (IDERICA A18)	Seems possible to implement in models based on FADN	Girardin et al. (2004)
3.2.2	Agricultural water use (IRENA 10, OECD and FAOstat)	Difficult to implement in large scale models: requires water-yield relationships and scarce data. Implemented in small-scale models	Butlen and Quirion (2006) EEA (2005) OECD (2007)
3.3.1	Gross greenhouse gases emissions (IRENA 19 & OECD)	Implemented in AROPAj	This deliverable, ch. 9, 10 and 11
3.3.2	Carbon storage in soils (IRENA 29)	Seems possible to implement downstream of economic models but need to check reliability of the biophysical model	EEA (2005)
3.3.3	Energy consumption and indirect GHG emissions (IRENA 11, OECD & IDERICA A19)	Seems possible to implement in models based on FADN with IDERICA assumptions	Girardin et al. (2004)
3.3.4	Renewable energy consumption (IRENA 27)	Requires regional and/or farm-level data	EEA (2005)
3.4	Air pollution by ammonia	Implemented in AROPAj	This deliverable, ch. 10 and 11
3.5.1	Pesticides sales (IRENA 9 and OECD)	Not very relevant	EEA (2005) OECD (2007)
3.5.1	Pesticides use (IRENA 9 and IDERICA A15)	Seems possible but need to check the reliability of ECPA data	EEA (2005)
3.5.2	Risks from pesticides (OECD)	Would require EU-wide information on pesticide types, not available yet	OECD (2007)
3.5.3	Soil contamination by pesticides (IRENA 20)	Seems possible to implement downstream of economic models but need to check reliability of the biophysical model and ECPA data	EEA (2005)
3.6	On-farm biodiversity (OECD, IRENA 25 & IDERICA A1, A2, A4 & A6)	Seems possible to implement in models based on FADN with IDERICA assumptions	Girardin et al. (2004)
3.7.1	Permanent pasture (OECD & IRENA 13)	Implemented e.g. in AROPAj and FARMIS	This deliverable, ch. 2, Kuepker and Kleinhanss (2006)
3.7.2	Farms economically at risk in zones ecologically vulnerable to abandonment (IDERICA C1 & IRENA 33)	Seems possible to implement in models based on FADN with IDERICA assumptions	EEA (2005) Girardin et al. (2004) Hennessy (2006)
3.8	Soil erosion (IRENA 23 & IDERICA A17)	Seems possible to implement in models based on FADN with IDERICA assumptions	EEA (2005) Girardin et al. (2004)

Table 12.1: Synthesis

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Part V

Data management, and elements for spatial analysis

Introduction of the part V

Spatial analysis takes part of the work when we need to use data based on geographical characteristics, when we deliver illustration of modelling outputs aiming at demonstrating of spatial differentiation, and when we consider that policy making could interfere with local and down scaled concerns.

A particular effort is realized with database construction, leading to the ArTix one. This is done with respect to the European rules related to the access and the use of statistical information.

Methodological aspects are devoted to land use location and farm group location. Applications and illustrations are proposed when the AROPAj model is used. In case of success, this will be enlarged and systematically used for the last workpackage of GENEDEC, namely the package devoted to "working out of recommendations" for policy making.

13 The ArTix database : data, architecture, softwares and applications

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Abstract

The ArTix project was developed within the framework of the coupling between the agricultural supply economic model AROPAJ and the growth crop model STICS. It is composed of a database and some dedicated software applications. It thus constitutes a useful and adaptable tool in order to handle this coupling by gathering various data (topics and scales) and by organizing them compared to the inputs waited by the STICS model.

Introduction

A first reading of Chapter 9 is needed to well understand what follows. In fact, this chapter deals with the technical tools developed for and by the work of Godard (2005) which is presented in this Chapter 9. This one explains the methodology she proposed in her PhD thesis aiming at adding an agronomic approach in an economic model of European Union (EU) agriculture. Also, it justifies the choices about models and presents them, their constraints and their scales of work. The economic model is AROPAJ, an agricultural supply economic model which fixes the scale of farm-type for all EU and provides for all of them some useful data. The agronomic model is STICS, a generic and robust crop model. To summarize, the methodology proposed is to model the relationship between the yield and the nitrogen fertilization for the main crops of EU using those two models, in order to increase the sensitivity of the economic model to different kinds of agricultural policy scenarios.

The implementation of endogenous yields requires a large set of information related to a variety of fields (economics, soil sciences, etc...) and various scales. The data management key feature of this research led to the elaboration of a database bringing together and organizing all the information required by the different modeling steps. The database ArTix contains data from the AROPAJ estimates, and first of all gives us the possibility to obtain more quickly and friendly individual or aggregated data for farm-types. It also gathers information about soils, climate, plants, and crop management techniques required by the STICS model. Thus, the ArTix database and its dedicated applications result in a very helpful tool to manage the AROPAJ/STICS "coupling", that is to say to build response curves to nitrogen fertilizer.

In a first part, this chapter recalls the technical steps to obtain the response curves, to show the number of needed STICS simulations and thus to justify the data organization in a database. The second part briefly exposes the software tools used both to make and to use the database, it also presents the ones to program the applications dedicated to the response curves. The software choices are so justified, as well as the necessary competences in data processing this technical aspects of the coupling methodology. The ArTix database content and organization is presented in the third, the fourth and the fifth parts. The first one details the core of the database coming from the AROPAJ model around the farm-type concept. The second one insists on the database content in relation to the STICS model. The third one shows with diagrams and tables the database's relational model and what its entities and associations are composed of. A last part presents the ArTix Java software developed at the same time that the database mainly to manage the STICS simulations.

13.1 Main steps of the AROPAJ/STICS "coupling"

The modelling curve proposed to link the yield and the nitrogen fertilization has an exponential form corresponding to the following formula where r represents the yield and N the input nitrogen fertilization :

$$r(N) = \alpha + (\beta - \alpha).e^{-\tau N}$$

The curve's parameters α, β and τ are obtained when the STICS results are fitted on the modelling curve, within SAS software. Several curves are obtained according to different STICS inputs. One is selected through an economic criteria which is based on three data. Two of them come from AROPAJ which gives, for a farm-type and a year, the reference yield (r0) and the crop price (p). The third, which comes from other sources, is the fertilizer price (w). In a STICS simulation, that is to say for a set of input files, the crop model gives, among other things, the corresponding output yield. To determine α, β and τ it is necessary to have the output yield corresponding to a variation of the fertilizer nitrogen amount as inputs with a small enough interval but on a wide enough range. The selected step is 20 units of nitrogen between 0 and 600 units, which is a range going beyond realistic application rates but that gives a chance to better extimate β value. This choice implies thirty one STICS simulations just for a set of STICS inputs.

For STICS, a set of inputs, is composed of a plant, a soil, a climate, the whole methods of cultivation and the simulation initialization parameters (mainly nitrogen and water soil contents). Those elements will be exposed and explained in details in the continuation of this report and more especially in their relation to the STICS input files. Those STICS inputs are set up in a consistent but not too rigid way. Indeed, the farming cases represented in the AROPAj model have to be modeled as well as possible. The adopted solution is, for a given crop, a farm-type and a year of harvest, to first run STICS with several potential inputs (soils, varieties, ...) and a range of 0 to 600 units nitrogen applications. Then, the best N-response curve and so the best corresponding inputs are selected in a way to best fit the economic criteria. Thus, the STICS output yields are generated for five potential soils, two distinct preceding crops and three variety and a sowing date or a variety and three sowing dates according to the crop. This makes thirty distinct combinations of inputs to find the best response curve of a crop in a given farm-type. In some cases, the irrigation is not selected in advance but determined also by the adjustment and thus the two cases, irrigated and not irrigated, are processed, which doubles the number of inputs combinations for STICS. To be selected among the range of potential ones, the best N-response curve first has to reach the reference yield and second, its tangent at this point has to be the closer to the ratio of the fertilizer price over the crop price. Then, the selected parameters of the curve (α, β and τ) could be integrated in AROPAJ to improve the modelling of crop production activities regarding nitrogen. See Figure 9.3 in Chapter 9 which schematizes the curve adjustment and the selection procedure.

Concretely, building a N-response curve for a farm type and for a crop on about thirty nitrogen amounts and for thirty combinations of potential entries represents nine hundred STICS simulations. Given that there is approximatively a thousand of farm-types in the EU with fifteen countries and ten field crops to process, it is thus obvious that this methodology must be based on valid and organized data and systematic and automatic treatments produced on these data. It is the vocation of the ArTix project which lies on these two dimensions: data and process.

Figure 13.1 reminds those main steps of the AROPAJ/STICS coupling. It also summarizes the others aspects that will be presented in details in the rest of this chapter. It shows especially the types of data involved in the ArTix database, their sources, related to the AROPAJ and the STICS models, and their organization and relationships.

13.2 The software choices for the database and its applications

13.2.1 The management system and the standard tools

A PostgreSQL platform

The ArTix database is implemented on a PostGreSQL Relational Database Management System (RDMS). Although it could be implemented on an other platform, such as MySQL, the choice of PostGreSQL is justified. It is the most complete open source relational database system recognised by industry and users' community for its reliability, its data integrity and its correctness. It is free and more and more in conformity with the SQL standards and runs on all major operating systems (Windows, Unix). It also has native programming interfaces for C/C++ or Java among others and has a big users' contributed documentation. So, it is well adapted to a researchers community.

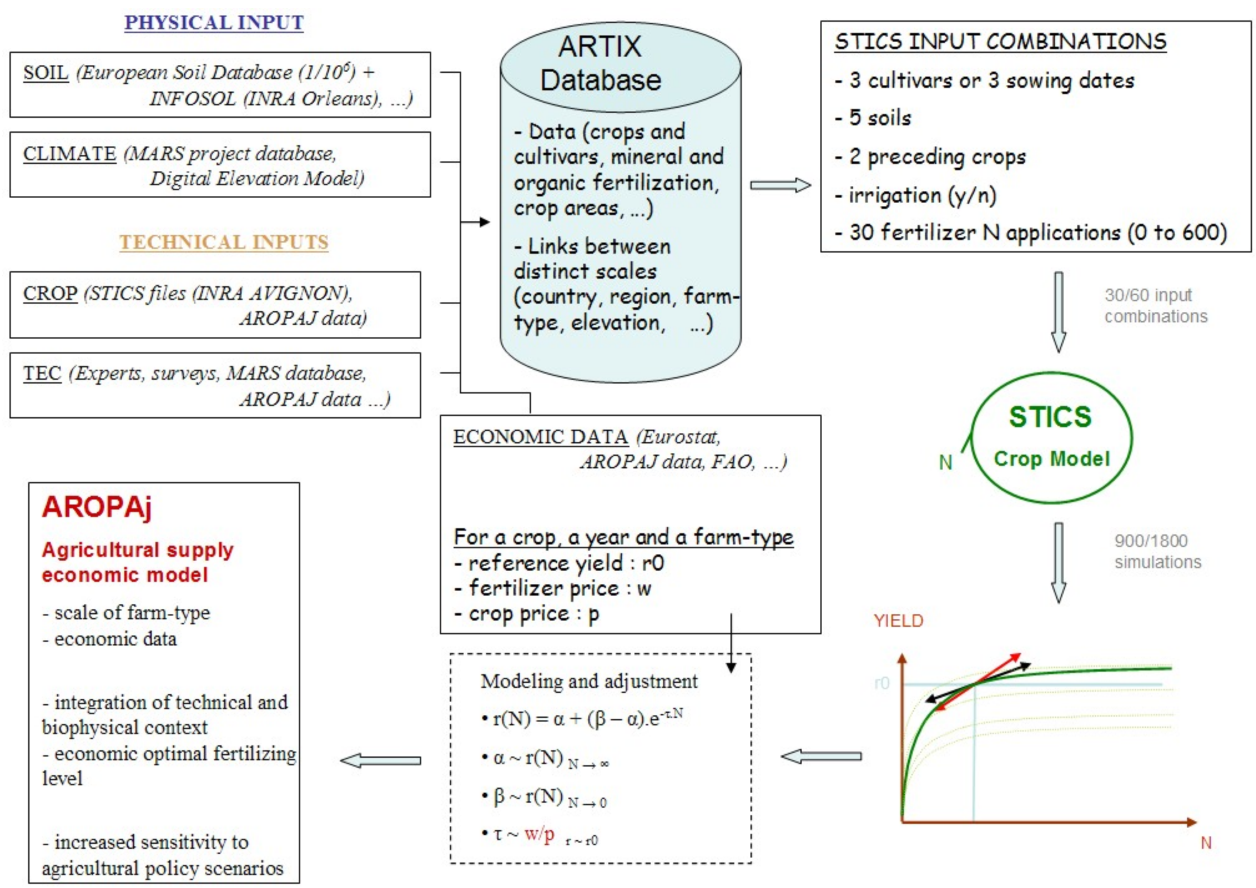

Figure 13.1: Steps of AROPAJ/STICS coupling and the ArTix database

SQL to handle the data

The Structured Query Language (SQL) is a standard and standardized data-processing pseudo-language, intended to query or handle a relational database with some aspects. Firstly, the Data Definition Language (DDL) handles the data structure, such as to define the data types or the constraints on data values. Secondly, the Data Manipulation Language (DML) covers all the data manipulation aspects, such as to select, add or update data. Thirdly, the Data Control Language (DCL) makes it possible to give some different rights to the database users depending on the data handling they want to do or on the user group they are member of. Lastly, some other modules intend to ensure the transactions or to write procedures, functions or releases.

PgAdminIII as user friendly platform

All the main simple handling on data, such as selection, can be done directly using SQL because it uses very intuitive terms. But, for more difficult aspects, as to define a users group, without knowing any SQL commands, it can be more easy to use an administration and development platform such as PgAdminIII. It is one of the most popular and feature rich open source platform for PostgreSQL. This free application may be used on the main operating systems, such as Windows, Linux, or others, to manage the database. It is designed to answer the main needs of the users, from writing simple SQL queries to developing complex databases. It especially disposes of a graphical interface that makes administration very easy.

13.2.2 Complementary softwares used to perform the AROPAJ/STICS "coupling"

Java to interact with the database

In our main application, the coupling, we have to communicate with our database in an automatic way at the same time that the crop model is running. The data in the database have to be used in the meanwhile as results have to be returned in it progressively. To cope with this issue to this problematic, a dedicated interface in Java between the user, the STICS model and the ArTix database was programmed. Java was chosen because it is both a programming language and a platform of execution. It is portable on several operating systems such as Windows, Linux, or others. Java also makes it possible to develop autonomous applications but also, and especially, Client/Server applications. It is the most useful aspect, for example when users simultaneously work. This Java interface will be exposed in the continuation of this report.

SAS for the statistics

The SAS software unable to perfrom the second part of the coupling. It firstly provides the adjustment of an exponential response curve on STICS outputs and secondly, it selects the best curve and so the corresponding STICS inputs combination. SAS is not a freeware but very reliable and already integradted solutions to manage those two aspects easily. Moreover, it is widely used by the scientific community on the major operating systems.

13.3 The ArTix database hard core : AROPAJ farm-types

As previously said, the AROPAJ model fixes the farm-type as the scale of work. So it constitutes the hard core of the ArTix database. This section deals with this aspect, showing the entities an associations involved in the farm-type definition. In the Chapter 9 of this report, parts 2.3 and 2.4 explain also how the farm-types are build and the data source but what follows could be point out.

13.3.1 Data sources : transformed FADN

The first source of economic data is the Farm Accounting Data Network (FADN). It provides accounting data, as animal numbers, crop yield, price and areas, and others for a sample of surveyed farmers. The 1997 FADN provides informations for about 60,000 sample farms which represent a total of roughly 2.5 millions European farmers. The rough idea of sample farms is the same for the 2002 FADN but they represent rather 2 millions of real farmers. The main part of those sample farmers, roughly 50,000, are included in the AROPAJ model to be grouped into farm-types. The remaining farms, growing permanent crops (vinyeards, orchards, etc...), are excluded because AROPAJ runs on a year, and thus, just considers annual crop and livestock farmers.

The data saved and used by the ArTix database are not the FADN data but statistic averages of the sames data (area, price, ...) for farm-types. Those ones are statistical group of a sample of farms, at least 15 sample farms for a farm-type. Thus, the ArTix database absolutely respects the confidentiality restrictions of FADN data and prevents the link with individual data. Nevertheless, the database keeps from FADN data the number of real farmers and of farm samples corresponding to each farm-type.

13.3.2 Typology and farm-types

The selected sample farms are grouped in farm-types according to three main variables : region, average elevation and main type of farming. In the 2002 typology, the average economic size is also used. There are 3 elevation classes, 8 classes of economic size and 14 type of farming in the FADN classification. Each farm-type results from the aggregation of sample farms located in the same region and which have similar types(s) of farming, elevation classes(s) and economic size(s).

13.3.3 Entities and associations involved

The farm-types belong to FADN regions but depend on the AROPAJ model version, 1997 or 2002. The entities required by this grouping are thus the 3 or 4 variables used for the typology. This one implies the definition of an AROPAJ country which stands for a country or just a part of it. In fact, if a country contains more than 99 farm-types, it has to be divided. Thus, a new entity appears. So, a farm-type is totally identified by a single combination of an integer strictly smaller than 100 and another integer representing the region it belongs to. This identification can also be made with a single combination of an integer strictly smaller than 100 and the AROPAJ country code.

The associations between those entities are exposed on Figure 13.2. The entities or associations which do not directly appear in the database are in dotted line. Let us use a example to explain the cardinalities shown on Figure 13.2. The type of farming list is largest than the ones involved in a typology (i.e. one type of farming (in the database table) could be absent (0) or present in some (n) typologies) although the economic size list is just composed of the ones potentially involved in a typology (1 to n).

Tables 13.1 and 13.2 present the variables of the ArTix databases tables corresponding to the farm-types. Detailed characteristics of each farm-types are available in the typology table, for example the real population corresponding to a farm-type or all the types of farming it is composed of.

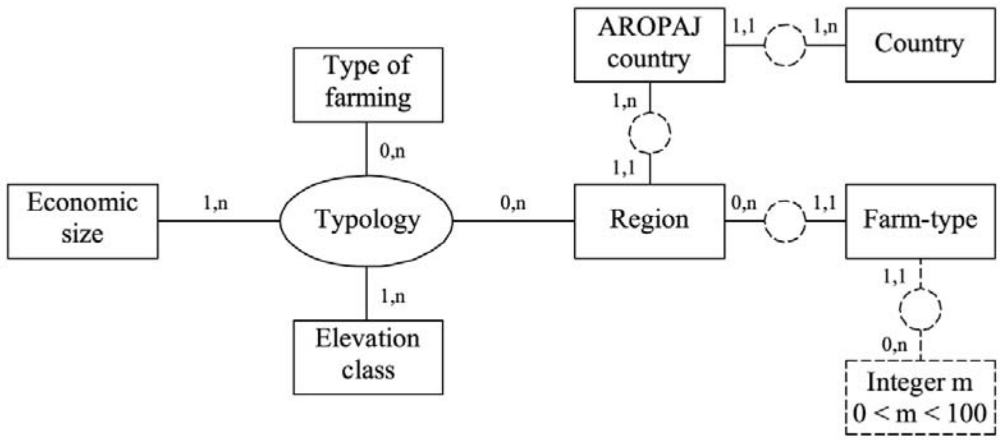

Figure 13.2: Schema of basic AROPAJ entities

TABLES	VARIABLES	TABLES	VARIABLES
PAYS	codPays	REGION	codRegion
(Country)	libPays	(Region)	lib1Region
————	—–		lib2Region
PAYS_AROPAJ	cod4PaysA		cod4PaysA
(AROPAJ_Country)	cod3PaysA	————	—–
	libPaysA	GROUPE-TYPE	codGType
	codPays	(Farm-type)	libGType

Table 13.1: ArTix database tables referring to the farm-types

TABLES	VARIABLES	TABLES	VARIABLES
ALTITUDE	codAlti	TYPOLOGIE	codRegion
(Elevation_class)	libAlti	(Typology)	codStdOTE
————	—–	(rest)	codAlti
TAILLE_ECO	codEcoSize		codEcoSize
(Economic_size)	libEcoSize		codAltiMoy
————	—–		dimEchantillon
OTE	codStdOTE		dimPopulation
(Type_of_farming)	codIntOTE		codGType
	libOTE		achatK
————	—–		achatP
TYPOLOGIE	annee		

Table 13.2: ArTix database tables referring to the typology

13.3.4 Contents for 1997 and 2002 AROPAJ typologies

Table 13.3 gives a rough idea of the number of those basic entities involved in the two versions of the ArTix database corresponding to the 1997 and 2002 AROPAJ typologies.

YEARS	1997	2002
Countries	15	15
AROPAJ countries	17	20
Regions	101	101
Farm-types	734	1074
AROPAJ countries by countries	1 to 2	1 to 3
Regions by countries	1 to 22	1 to 22
Farm-types by countries	5 to 161	13 to 278
Regions by AROPAJ countries	1 to 17	1 to 13
Farm-types by AROPAJ countries	5 to 99	13 to 99
Farm-types by regions	1 to 23	1 to 38

Table 13.3: Rough idea of basic entities in the ArTix database

13.4 The ArTix database in relation to STICS

13.4.1 Input files for the STICS model

The ArTix database does not directly interact with the STICS model to provide it the input data. That is done by the Java dedicated software application which builds the input files. Many more detailed information about the input and output files, and the use of the STICS model in a general way is available on the web site of Avignon INRA center. For our use of STICS, the data categories needed to run the model are the following :

- Soil parameters : the permanent characteristics of soils are stored in a file named 'param.SOL' and the soils initializations parameters are stored in the 'travail.USM' simulation file. In the case of two simulations consecutively ran, final soil N and water content of the first simulation are temporarily stored in a 'recup.tmp' file. The values are then used as initialization values for the second and main simulation.

- Climate preset variables : the input file of STICS named 'stat.DAT' contains daily values of climatic variables which must cover all the crop simulation period. So, in our cases with a preceding crop, we have to successively use two climate files.

- Plant specifications : those data are stored in a file usually named 'cropName.PLT'. They can be downloaded from the STICS web site and contain common physiological parameters for plant as well as cultivar specific ones. Thus, a same plant file is used for all the simulations of a given crop.

- Farming technique parameters : those data are stored in a file usually named 'treated-Case.TEC'. They entail main technical operation definitions such as fertilization practices (time, rate and type of fertilizer application), tillage pratices, use of organic residues or irrigation. The wide range of parameters and their definition mode, thanks to decision rules, makes the file uneasy to fill in.

The plant and farming techniques file names are freely defined by the use. The only constraint is the number of characters the names are composed of and so the chosen names must be both synthetic and explicit in relation to the cases processed in the simulations.

So, for each crop of each farm-type, a set of STICS inputs has to be defined. On the one hand, soil and climate data constitute the physical inputs and on the other hand the remaining ones are the technical inputs. The physical inputs are mainly defined using the adaptation of existing databases, the technical ones are dertermined thanks to experts' knowledges and decision rules. The STICS inputs setup is detailed in the following paragraphs.

13.4.2 Soils

As previously said, the soils attributed to each farm-type, are the ones the area of which is larger in the region, of course having the same elevation class. Through the selection process, only one of these five soils is finally selected for one crop of the farm-type. Firstly, STICS soil parameters were defined using existing European soil database (King et al. (1994), The European Soil Bureau (1998)) and pedo-transfer rules, particularly, the one used of organic carbon content (Jones et al. (2005)). Secondly, each type of soil area in each region was calculated. This work , so the part of the ArTix database connected to the soils, was done by Christine Le Bas, member of the INFOSOL Unit of INRA Orleans Center within the framework of the GICC project (Management and Impacts of Climate Changes).

Soil data are handled and pre-processed by the ArTix Java application. This way, the database itself only stores all the elements to link the soil types (names, physical parameters,...), the typological units of soil (areas and elevations) and the FADN regions.

13.4.3 Climates

Data sources : MARS project climate database

The climate database is provided by the Joint Research Center of Ispra (Italy) and comes from the MARS (Monitoring Agriculture by Remote Sensing) project. The database covers the whole EU with a grid of 50 by 50 km . The database contains average climate variables for each cell of this grid (van der Goot (1998)) A Digital Elevation Model allows us to determine the median elevation of each cell. The available climatic data which are used to set up the climate file for STICS are :

- daily maximum temperature in °C
- daily minimum temperature in °C
- mean daily vapour pressure in hPa
- mean daily windspeed at 10m in m/s
- mean daily rainfall in mm
- Penman potential evapotranspiration in mm/day
- daily global radiation in kJ/m2/day

The attribution of the climate and the data used

Using a Geographic Information System (GIS), each grid cell was attributed to the region where the intersect area was the biggest. Then, for each combination (region, elevation class), the average of each climatic variable is calculated.

The climatic data have to be consistent with the economic data used, namely they have to correspond to a specific year, 1997 or 2002, that could have affect yield by any particular climatic event. Knowing that a preceding crop is also simulated to initialize the main crop and that it could be a winter crop, 2 years before the harvest one are also needed. Thus, for the first version of the AROPAJ typology, the climatic data of 1995, 1996 and 1997 are used and for the second version, the ones of 2000, 2001 and 2002.

Considering the numerous data coming from the MARS project database, they were not saved in the ArTix database itself. Only the elements to link climate data to the farm-types were stored in the database to build climatic files. This step is performed before running the STICS model for the cases to study. Thus, all annual climatic data are stored in an external database and called at the same time as ArTix when the climatic files are built.

13.4.4 Plant parameters

As previously said, STICS input files for the plants are already available, some cultivars were parameterized for maize to deal with Northern and Southern Europe producing areas. The ArTix database role about those files is mainly to link the STICS simulated plants and the crop producing activities of the AROPAJ model. The latter considers about thirty activities, while a STICS plant file is available, it is linked to each of those activities (namely soft and durum wheat, silage and grain corn, rapeseed, sunflower, barley, sugar beet). As the AROPAj model does not make the difference between spring and winter barleys, an additional hypothesis was made : crop producing farm-types were supposed to grow srping barley and cattle producing farm-types were supposed to grow winter barley. Nevertheless, only one set of economic criteria (areas, prices) was used for the "barley" producing activity.

13.4.5 The "technical" inputs : methods of cultivation

The management practices entail several parameters, and mainly, cultivar, simulation initialization, fertilization and irrigation practices.

Data sources

The technical inputs mainly come from expert statements and decision rules as no available exhaustive databases exist for management practices at European scale (Godard (2005)). However, the MARS project database was partly used to define crop stages, when no other detailed data are available.

Organic and mineral fertilization

It is main and central part of the management practices definition, about the two nitrogen sources, organic and/or mineral. The total nitrogen fertilizer supply is split into one to three dressings given N-sensitive development stages. The ArTix database directly contains the splitting definition for each crop and the fertilizer types used for N, P and K crop weeds. The fertilizer types set up following expert knowledge for each crop of each region are stored in the database. The on-farm manure supplies completes the N-fertilizer supply. The amount of each type of manure (manure, slurry and poultry droppings) spread on each type of crop is determined from the AROPAJ model parameters and "observed values", namely the number and type of animals grown in each farm type. The corresponding data (maximal spreading amount, amount of manure from distinct type of animals, ...) data are stored in the ArTix database.

13.4.6 Additional data in the ArTix database

Some other informations are stored in the ArTix database. They can be used at various stages of the methodology of N-response curve settings. The most important of those information are fertilizer prices. The main data source is the FAOstat database, completed by some other sources when necessary as such as EuroStat database. The sources are well indicated in the database table about the fertilizer prices and the web sites are indicated in references.

13.5 The ArTix database : detailed content and diagrams

This section describes the distinct ArTix database tables, thanks to diagrams and tables. It also shows their relation with the STICS model files.

13.5.1 Soils

Table 13.4 presents the tables 'soil' and 'type of stone' which group "in bulk" the 'param.SOL' file variables. The table 'Typological unit of soil' contains the various soil characterisctics. The 'Region_soil' table links the regions, the soils and the typological units of soil as well as their area within each region : the five largest soils in term of area in each region are easily identified (see Figure 13.3). The soil N and water contents initialization values appearing in the 'travail.USM' file are calculated thanks to those tables but are only saved in the simulation table (named 'usm', see the table in Appendix).

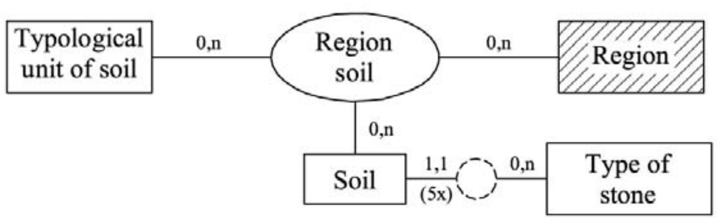

Figure 13.3: Schema of entities and associations in relation to the soils

13.5.2 Climates

Table 13.5 presents the 'Climatic_cell' table which links the regions, the elevation classes and the cells of the MARS project database grid. It makes possible to affect a climate for a year and a farm-type according to those three elements. As shown in Table 13.5, the daily climatic data are not in the ArTix database.

13.5.3 Crops and plants

Table 13.6 presents the 'Crop' table which links the AROPAJ crop producing activities and the plants parameterized for the STICS model. This table also entails a lot of variables which are used

TABLES	VARIABLES	TABLES	VARIABLES
SOL	numSol	SOL	ind_solGonf
(Soil)	libSol	(Soil)	ind_rmtCapil
	argi	(rest)	ind_drainage
	Norg		capilJour
	profHum		humCapil
	calc		profImper
	ph		ecartDrain
	concSeuil		kSol
	albedo		profDrain
	q0	————	——
	ruiSolNu	TYPE_CAILLOUX	codTypCail
	obstarac	(Type_of_stone)	libTypCail
	epc1 (2,3,4 and 5)	————	——
	hccf1 (2,3,4 and 5)	UTS	codUTS
	hMin1 (2,3,4 and 5)	(Typological_Unit_of_Soil)	Zmin
	daf1 (2,3,4 and 5)		Zmax
	cailloux1 (2,3,4 and 5)	————	——
	codTypCail1 (2,3,4 and 5)	REGION_SOL	codRegion
	infil1 (2,3,4 and 5)	(Region_soil)	numSol
	epd1 (2,3,4 and 5)		nomSolRegion
	ind_nitrific		codUTS
	ind_cailloux		surface1UTS
	ind_macroPoros		surface2UTS

Table 13.4: ArTix database tables referring to the soils

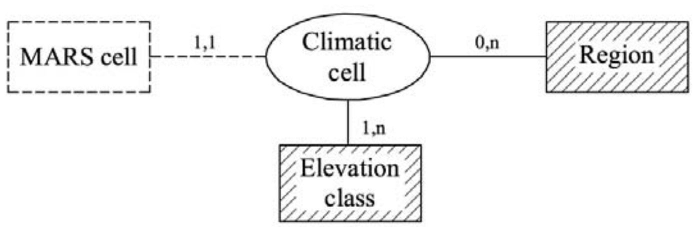

Figure 13.4: Schema of entities and associations in relation to the climate

TABLES	VARIABLES	TABLES	VARIABLES
CELLULE_CLIMATIQUE	annee	CELLULE_CLIMATIQUE	codAltiMed
(Climatic_cell)	numCellule	(rest)	codAltiMoy
	codRegion		lati

Table 13.5: ArTix database tables referring to the climate

for technical parameterization either directly (e.g. density) or not (e.g. priority order for irrigation in relation to the others crops). The 'type of crop' table simply recalls whether the crop is a winter or a spring one.

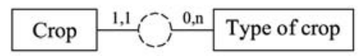

Figure 13.5: Schema of entities and associations corresponding to the crop

TABLES	VARIABLES	TABLES	VARIABLES
ACTIVITE_VEGETALE	codActVeg	ACTIVITE_VEGETALE	huileRec
(Crop)	libActVeg	(rest)	sucreRec
	rangIrrig		codRecolte
	listeCultures		codEauMin
	codTypCult		nomFicPlante
	densite		txHumidRec
	profSem		nbAn
	cadenceRec	——————	——
	cnGrainRec	TYPE_CULTURE	
	H2OGrainMin	(Type_of_crop)	
	H2OGrainMax		

Table 13.6: ArTix database tables referring to the crop

13.5.4 The technical inputs : methods of cultivation

Cultivars and sowing dates

The potential cultivars for each crop, and the corresponding fertilization calendar are found in the 'cultivar' table, precising the crop. The table 'itk_cropclimate' stores the phenological data coming from the MARS project database and makes it possible to attribute an average sowing date (moySow) while no information exist in the 'itk_cropregion' table. The latter entails the three potential sowing dates for each crop cultivars and regions (minimum, maximum and average). The 'fractionN' table corresponds to the decision rules about the N fertiliation splitting in three supplies, given the crop and the total N supply.

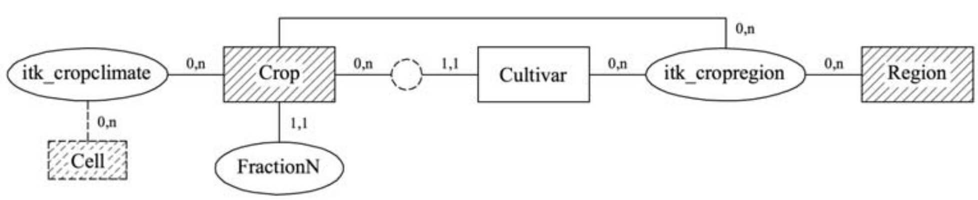

Figure 13.6: Schema of entities and associations in relation to the cultivar and sowing

TABLES	VARIABLES	TABLES	VARIABLES
VARIETAL	codActVeg	FRACTIONN	part2N
(Cultivar)	numVariete	(rest)	part3N
	libVariete	————	——
	jour1ApportN	ITK_CULTUREREGION	codRegion
	jour2ApportN	(itk_cropregion)	codActVeg
	jour3ApportN		gpreco
————	——		ipltMin
FRACTIONN	codActVeg		ipltMoy
(FractionN)	totalN		ipltMax
	part1N		iRecButoir

Table 13.7: ArTix database tables referring to the cultivar and sowing

TABLES	VARIABLES	TABLES	VARIABLES
ITK_CULTURECLIMAT	codActVeg	ITK_CULTURECLIMAT	moyRip
(itk_cropclimate)	numCellule	(rest)	moyIne
	moySow		moyGra
	moyEme		moyMil
	moyFle		moySta
	moyLle		moyPhy
	moyHar		moyTub
	moyTil		TSUM_hd_sd
	moySho		TSUM_fd_sd
	moyEar		TSUM_hd_fd
	moyFlo		TSUM_hd_1JAn

Table 13.8: ArTix database tables referring to the phenological data

Organic fertilizers

The 'itk_cropfarmtype' table contains the amount of on-farm manure which could be spread on field, according to the type of crop (winter, spring), to the type of effluent (poultry droppings, type of manure...) and to the type and number of animals in the farm-type (the on-farm production level of each animal). This table results from the application of decision rules (as such as the maximum of manure amount that can be spread over each type of crop) and uses numerous and various data.

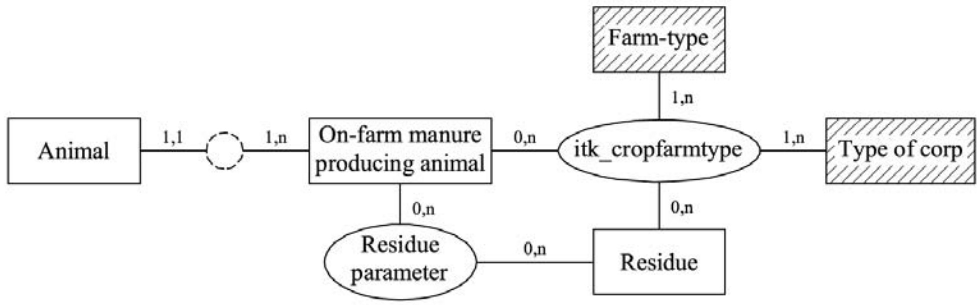

Figure 13.7: Schema of entities and associations in relation to the on-farm manures and animals

TABLES	VARIABLES	TABLES	VARIABLES
ACTIVITE_ANIMALE	codActAnim	RESIDUS	codRes
(Animals)	libActAnim	(residue)	libRes
	codProdDej	————	——
————	——	PARAM_RESIDUS	codRes
PRODUCTEUR_DEJECTION	codProdDej	(residue parameters)	codProdDej
(On-farm manure producing animals)	libProdDej		Cres
————	——		CsurN
ITK_CULTUREGTYPE	cod4PaysA		eauRes
(itk_cropfarmtype)	codGType		NminRes
	codTypCult		numLigne
	codRes		NTotal
	codProdDej		
	qtiteDej		

Table 13.9: ArTix database tables referring to the on-farm manures and animals

Mineral fertilizers

The 'Stics fertilizer' table contains the mineral fertilizer parameterized in the STICS model. The 'Type of fertilizer' table contains information about N, P and K contents and chemical forms. It is used to build technical information files, as well as 'itk_cropfartypefertilizer' table that precises the proportion of the two fertilizers used for each crop and each farm-type.

13.5.5 The AROPAJ data and other economic data

The ArTix database also contains economic data from the AROPAj model (aggregation of FADN data). Table 13.11 corresponds to the 'mgg_par' file and Table 13.12 entails data needed to perform

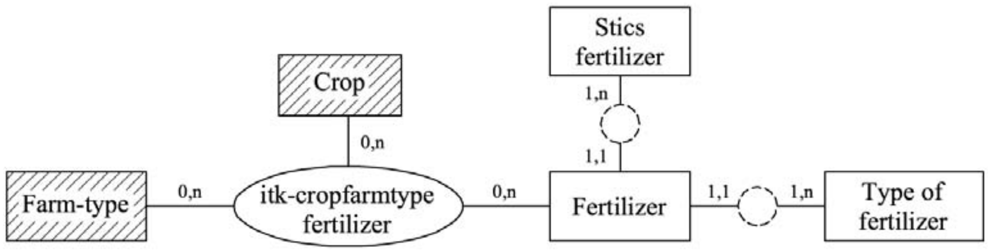

Figure 13.8: Schema of entities and associations in relation to the mineral fertilizers

TABLES	VARIABLES	TABLES	VARIABLES
ENGRAIS	codEngrais	ENGRAISSTICS	codEngSTICS
(Fertilizer)	libEngrais	(Stics Fertilizer)	libEngSTICS
	codTypEng		efficience
	teneurN	————	——
	teneurP2O5	ITK_CULTUREGTYPENGRAIS	cod4PaysA
	teneurK2O	(itk_cropfarmtypefertilizer)	codGType
	synEngrais		codActVeg
	codEngSTICS		codEngF
————	——		codEngC
TYPE_ENGRAIS	codTypEng		partEngF
(Type_of_fertilizer)	libTypEng		partEngC

Table 13.10: ArTix database tables referring to the mineral fertilizers

the coupling and more especially the best curve selection step.

The data from AROPAJ used to define technical inputs

The 'mgg_par' table is a very important table for the ArTix database. In fact, it gathers the whole data coming from the calibration procedure of the AROPAJ model. For example, this table contains the total irrigated area of each farm-type used to determinate if those farm-type crops are irrigated or not. So, in the first case, the key is the farm-type (a data for each one) but in the second, the key is composed of the farm-type and the crop. There is some similar cases in relation to the animals, to the AROPAJ_country, ...

So, this table should be improved as no unique primary key is defined. A procedure is now used to automatically detect potential errors, the improvements are in progress in a way to properly and more efficiently use the AROPAJ parameters.

TABLES	VARIABLES	TABLES	VARIABLES
MGG_PAR	annee	MGG_PAR	codN
	codRubMgg	(rest)	valmgg
	cod4PaysA	————	——
	codActVeg	RUBRIQUE_UNITE	codRubUnit
	codActAnim	(heading and unit)	libRubUnit
	codGType		unite
	codL		infos

Table 13.11: ArTix database tables referring to the data coming from AROPAJ

The additional economic data used for the curve selection step

As well as the crop prices and the crop optimal yields, given in the 'mgg_par' table, the curve selection step of the AROPAJ/STICS coupling requires fertilizer prices. The latter are stored in the 'fertilizer_price' table as well as their source and unit. Those elements make possible the calculation of the price of the combination of the two fertilizers used in the STICS simulations.

TABLES	VARIABLES	TABLES	VARIABLES
PRIX_ENGRAIS	annee	CONSOMMATION_ENGRAIS	annee
(Fertilizer_price)	codPays	(Fertilizer_cosumption)	codPays
	codEngrais		codEngrais
	codSource		quantite
	prixEngrais		unite
	unite		infos
	infos	————	——
————	——	TAUX_MONNAIE	annee
SOURCES	codSource	(Exchange_rate)	codPays
	libSource		devise
			valeur

Table 13.12: ArTix database tables refering to other economic data

13.5.6 The STICS simulations

The 'Unit of simulation'(USM) table gathers all the information necessary to identify a STICS simulation and its results. Thus this table recalls user choices (crop, region, ...) and gives the corresponding input already defined in the database and retained to be processed (for example, the three sowing dates or cultivars). Moreover, it contains all the elements calculated after the user choices according to the whole decision rules, such as the five soils retained. Table 13.13 in Appendix exposes all the variables of this table.

13.6 Software applications and possibilities offered by the database

This section presents the first version of the Java software application, also named ArTix. So, it constitutes a layer over the STICS model and over the ArTix database, binding them on the layer of input and output STICS files and thus making possible the "coupling". A second version is currently in development, to improve the speed and the effeciency of the processes. For example, this second version will be able to process more cases without any user intervention.

13.6.1 Client-Server aspects

The Java ArTix software is accessible to the users by a server. The users have to connect to the server to implement the software. Several files needed to used ArTix are stored on this server. For example, there is a file to define all the available databases for the users (then they connect on with a specific login and password). Packages needed by the application can also be found there. In relation to STICS, climate files and reference files needed to build all the technical input files for the simulations are also avalaible from this server.

To use the functionalities of this software which are linked to STICS, the users have to have two local directories (C:/ArTix/ and C:/Program File/INRA/WinStics5.0/). The first one is used to generate in local host the STICS files (soil, climate, technical, ...), before putting them on the server or just to consult them. The second one is compulsory because the STICS simulations are "physically run" at this location. This client server aspect of the software makes it possible to be used by users apart from the others what is very useful.

13.6.2 Main functionality and graphic interface

The main window of the user interface is shown in Figure 13.9, it is used to chose the case(s) to process. The user-friendly dimension of this software clearly appears. The distinct elements of choice are about:

- the typology and the geographic situation (years, country, region and farm-type(s)),
- the crop(s)(which one(s), with a preceding crop or not),
- the climatic conditions (harvest years),
- the nitrogen fertilization scenario (mineral and/or on-farm manure, doses and steps of the range).

Then, the possible STICS inputs (five soils, three cultivars or sowing dates, irrigation conditions) are automatically reckoned, the corresponding files generated, and the STICS model run, with no other user interventions.

At the end of the simulations selected with this interface, a synthesis table is shown to check the well doing of the successive run and the main results. This table is a simplified view of the ArTix database table of simulation (named 'usm'). Then the corresponding output points can be extracted and transfered to the SAS programs to build the nitrogen response curves with another functionality of this Java software. Finally, another functionality returns the parameters of the curves (among others α, β and τ) to the ArTix database (in the usm table).

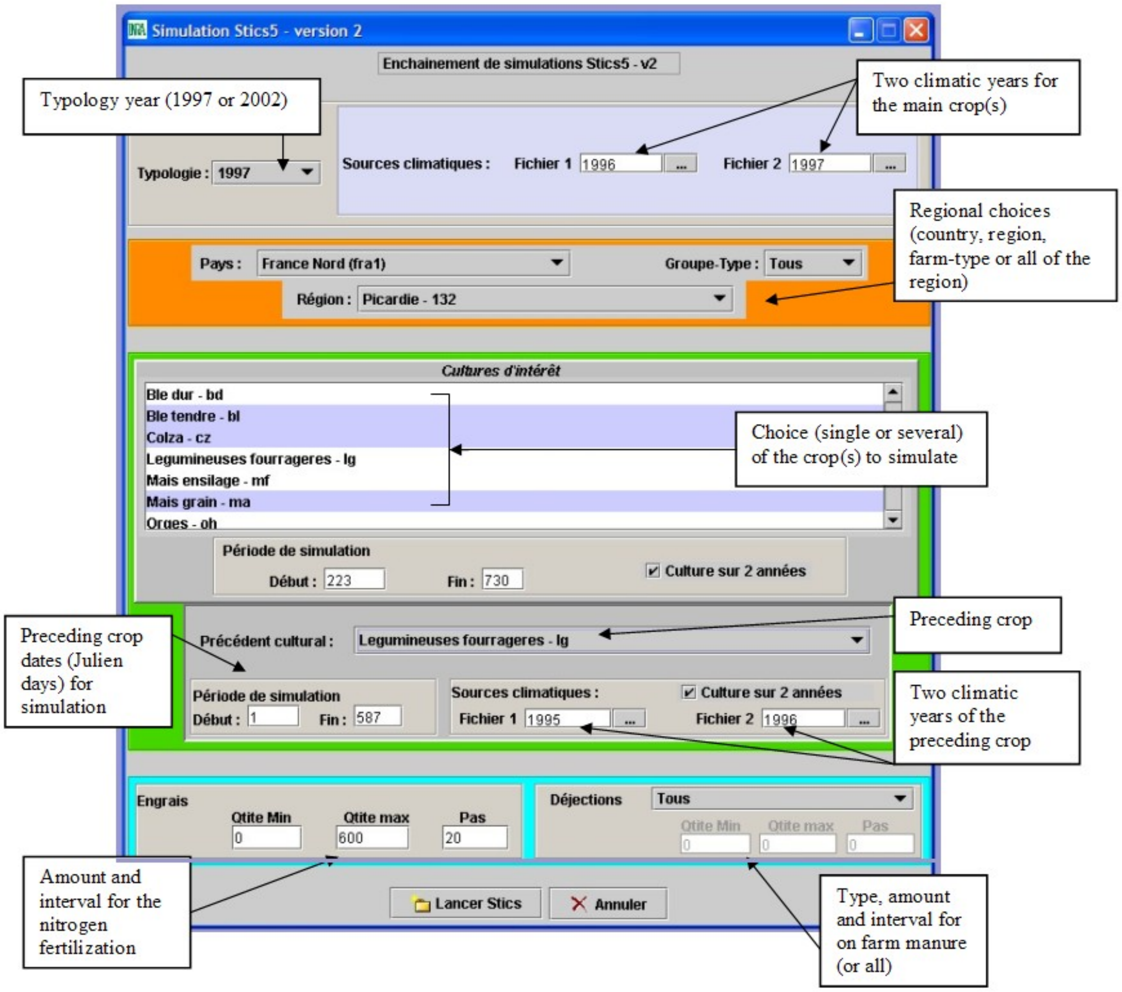

Figure 13.9: Schema of the main interactive window of ArTix Java Software.

13.6.3 Additional functionalities

In addition to this main functionality, the ArTix Java software offers other ones to manage the database content or to handle the set up of STICS files. Actually, the first functionality can also be performed using PgAdminIII. Nevertheless, one must be aware of at least a little of the database architecture to do so. On the contrary, using the Artix Java software does not require any advanced knowledge of the database. This software also entails connection functionalities, especially to connect to other organized data sources (for example the climate databases). Moreover, it provides file importing and exporting facilities. They can be used to locally export STICS input files (which can be useful to run isolated simulations), or to directly import data from ASCII files to implement particular tables.

13.7 Conclusion

13.7.1 Preliminary remarks

First, this project ArTix was born and evolved at the same time as the PhD-thesis of Godard (2005). It was thus gradually built, for example, under technical constraints or because of the time spent to gather information or to set up the decision rules which make the moset of the available data. While it is a very complete and useful database and software facility, weaknesses and flaws need to be maked up for. Also, the project was developed around 1997 AROPAJ typology and needs additional developments to deal with 2002 one. Another important point is the lack of homogeneity in the database content and therefore processes.

Moreover, as the two technical aspects of this project, the database and the Java software application were jointly elaborated, they are strongly dependent one on the other. So, it is important to keep in mind this close connection while modifying the data organization or process logic in a way to make the project evolve properly.

13.7.2 Developments and improvements in progress

Some tables have been completed with additional or new data. The corrections mainly concerned the 'mgg_par' table containing the AROPAJ calibration step data. In fact, the lack of a primary key in this table led to not easily identified errors. The rearrangement of this table data in several tables, better organized and containing primary key, is an important improvement under development. More generally speaking, improvements in the database structure (relational schema) are needed already in progress to make the database more comprehensible and accessible.

Another improvement way for this project is to make the data more homogeneous, in particular in relation to STICS input files. This means to simplify the Java software treatments by storing data in the database at the scale required by their use. For example, instead of determining the irrigation status of the crops while running the STICS simulations, it could be quicker and less memory-demanding to reckon irrigated areas once for all and store them in a specific table. The latter would get an appropriate primary key (such as farm-type, crop and typological year). Only one query for one crop studied would thus give access to the needed infromation. As it is the way that the one-farm manure is handled, this would bring homogeneity to our data process approach. Overall this is a way to reduce process time and complexity and to better organize the database in relation to the data use.

A second version of the database corresponding to the 2002 AROPAJ typology is now available. It is made up on the same relational schema as the first version, which make it compatible with the current version of the Java software. This enables a temporary use as the software improved version will soon be available. Moreover, simple programs have been developed to easily adapt to the forthcoming version of AROPAJ and their future typologies.

At the same time, a new version of the database and software application are currently under development. The goal is to make the database more readable (homogeneous) and to simplify and accelerate the actual AROPAJ/STICS "coupling". Currently, all the aspects related to STICS have to be processed on a Windows operating system because of a STICS version dedicated to Windows. So, this new version is dedicated to a Unix operating system, with a Unix version of STICS. As well, all the curve selection step is done with the use of SAS software and it is easier to handle this step with a Unix version than in a Windows one. Moreover, as most of the users are accustomed to Unix and already use it for various projects, they could easily connect and adapt specific applications to Artix project.

13.7.3 Interests and perspectives

The Artix project entails a double interest. On the one hand, the database offers a structured storage and organizes both agronomic and economic data. On the other hand, this project gives some simple, complete and adaptable tools to jointly use those data. Those two aspects, information organization and connection offer interesting prospects.

Thus, other couplings could be considered, based on the same principle and more or less on the same data and also based on the same agronomic model or on others. For example, the response curves of nitrous oxide emissions to nitrogen fertilizer modelling was based on the data and decision rules from the ArTix database (see Chapter 12). In the same way, the processing tools (Java software, SAS programs) could de adapted to those new modelling projects. The database data could easily be linked to a GIS (Geographic Information System) in order to provide spatialization of the information at various scales.

Appendix

Table 13.13 presents all variables saved in the ArTix database table of simulation (usm).

Web sites

- http://www.postgresql.org
- http://www.pgadmin.org
- http://java.sun.com
- http://www.avignon.inra.fr/stics/
- http://faostat.fao.org/
- http://epp.eurostat.ec.europa.eu/

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Jones, R. J. A., Hiederer, R., Rusco, E. and Montanarella, L.: 2005, Estimating organic carbon in the soils of Europe for policy support, *European Journal of Soil Science* (A paraître).
URL: *http://www.blackwell-synergy.com/loi/ejs*

King, D., Daroussin, J. and Tavernier, R.: 1994, Development of a soil geographic database from the Soil Map of the European Communities, *Catena* **21**, 37–56.

The European Soil Bureau: 1998, The European Soil Data Base, *version 1.0*, European Soil Bureau.

TABLES	VARIABLES	TABLES	VARIABLES	TABLES	VARIABLES
USM	numusm	USM	nh4initf4	USM	innsveg
(Unit of	anneerica	(rest)	nh4initf5	(rest)	tculttairveg
simulation)	cod4paysa		lai0		exofacveg
	codgtype		masec0		swfacrep
	codregion		zrac0		turfacrep
	codalti		magrain0		innsrep
	typalti		qnplante0		tculttairrep
	iwater		resperenne0		exofacrep
	ifwater		stade0		resmes
	codactveg		codengrais1		totapn
	gpreco		partengrais1		totn2engrais
	codcultprec		codengrais2		qnengrais1
	culturean		partengrais2		qnengrais2
	wdata1		infos		totnengstics
	wdata2		numligneres		execstics
	ftec		iplt		res_a
	preflai		ansemis		res_b
	ichsol		ancours		res_t
	codcalirrig		irrigok		n0
	totengitk		mafruit		der_r_n0
	hinitf1		datlev		prn_vs_c
	hinitf2		datamf		r_n1
	hinitf3		datlax		dif_m1
	hinitf4		datsen		minabsdifm1
	hinitf5		datlan		dif_m2
	no3initf1		datflo		minabsdifm2
	no3initf2		datdrp		res_aeng
	no3initf3		datdes		res_beng
	no3initf4		datmat		res_teng
	no3initf5		datrec		res_adej
	densinitial1		bioaer		res_bdej
	densinitial2		nbgrain		res_tdej
	densinitial3		densplt		coeffeqeng
	densinitial4		poidsgrain		denitno3
	densinitial5		effengrais		volatileng
	nh4initf1		indrecolte		lixivno3
	nh4initf2		swfacveg		qnorgeng
	nh4initf3		turfacveg		qno3f

Table 13.13: ArTix database tables refering to the simulations (usm)

van der Goot, E.: 1998, Spatial interpolation of daily meteorological data for the crop growth monitoring system (CGMS), *in* M. Bindi and B. Gozzini (eds), *Seminar on data spatial distribution in meteorology and climatology Volterra, 28 sept. - 3 Oct 1997*, Office for official publications of the European Communities, Luxembourg.

14 Crops location based on coupled databases, methodological aspects

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Abstract

The objective of this study is to design and evaluate an approach to spatial disaggregation, a possible tool to assess economic and environmental impacts of the last CAP reform of EU agriculture (e.g., the study of water pollution due to agriculture). The proposed approach uses agricultural data in conjunction with biophysical processes to break down agricultural FADN regional data into $100m \times 100m$ pixel spatial units. It is a two-step procedure. First, we estimate a land use model using a Multinomial Logit (MNL) model. Second, we disaggregate the observed FADN regional land use shares using a Generalized Cross Entropy (GCE) approach, taking the first step predictions as priors. This procedure has been applied to the French Picardie region. Results indicates a significant correlation between observed and estimated land use shares. We conclude that our approach is a convenient tool to disaggregate data and more generally to homogenize data available at different scales.

14.1 Introduction

The latest reform of the Common Agricultural Policy (CAP) aims to encourage environmental-friendly farming practices in order to preserve the quality and the diversity of rural areas. A precise evaluation of the economic and environmental impacts of this policy is in order. However, if for example, an accurate study of non-point water nitrogen pollution generated by agriculture is to be carried out spatial variance in physical variables (soil, climate) and farming systems needs to be taken into account. Disaggregated agricultural data with precise geographical references are needed.

At this time, most of the available homogeneous agricultural data covering the entire EU that such an evaluation requires is provided by the Farm Accountancy Data Network (FADN). The data results from an annual survey carried out by the Member States and is provided in an aggregated form at the level of administrative regions, defined by the Nomenclature of Territorial Units for Statistics, better known as NUTS II. However, these data do not come with precise geographical references. If an agri-environmental evaluation of the CAP reform is to be thorough, data concerning agricultural activity and biophysical variables are needed at a very precise scale. Knowing where crops are located is the foundation upon which an environmental evaluation can take place. Conceiving a disaggregation tool that breaks down the NUTS II level data to a finer scale is the necessary groundwork.

A valid spatial disaggregation procedure is very important in agricultural economics for the following two reasons:

First of all, it would deal with the lack of data at the disaggregated level. Just (2000) has highlighted that in order to thoroughly study farmer behavior, it is necessary to carry out microeconomic analysis with precise individual data. He pointed out that "... To demonstrate production issues more clearly and provide more meaningful answers, agricultural production research must focus on decision making at the farm level rather than continue to demonstrate points and methodology with aggregate data simply because they are available". Howitt and Reynaud (2003) have also suggested that a valid disaggregation method that helps to face the lack of data problem would be very useful.

Second of all it would help better study the interaction between economic models and biophysical models. It is necessary to take into account biophysical variables (soil characteristics, climate and altitude) in economic modeling to better analyze farmer behavior and the effects of public policies. Usually, economic data concerning farms are available at the aggregated scale whereas biophysical data are provided on a finer level. Disaggregation of agricultural production data would permit to carry out an economic analysis at the disaggregated level in combination with biophysical models. More generally, a disaggregation method is necessary to define a compatible scale between different sources of data.

In this paper, we propose a disaggregation procedure to generate plausible disaggregated estimates of the spatial allocation of crops on a very fine scale. Disaggregation methods are already being used in the fields of climate science, geography, political science, and marketing[1]. However, to our knowledge, few recent papers[2] have dealt with spatial disaggregation in agricultural economics (Howitt and Reynaud (2003), You and Wood (2004) and Kempen et al. (2005)).

[1] In Climate Science, space and time disaggregation (downscaling) techniques are usually used to derive finer-scale weather forecasts. In Political Science, King (1997) addresses the issue of "ecological inference" which consists of inferring individual behavior from aggregate data. He proposed a statistical method to reconstruct the interior cells of a set of contingency tables from their marginal totals. He applied this method to the estimation of election turnout by race. In marketing, researchers rely on aggregated data (Data census) on characteristics of a general population to infer individual characteristics of consumers.

[2] Lence and Miller (1998a) and Lence and Miller (1998b) proposed a GCE approach to estimate activity specific input allocations consistent with aggregated information. Miller (1999)proposed a ME approach to disaggregate land use shares from the multi-county level to a county level.

Howitt and Reynaud (2003) have developed a dynamic disaggregation method of agricultural land use. They estimated crop choice for a sample of Californian farmers at a disaggregated (6 districts) level using data from an aggregated level (region). First, the authors specified a model of crop allocation at the aggregated level defined as a dynamic Markov process. Second, the results of the regional model were disaggregated using the Maximum Entropy (ME) approach. Their model included 8 possible agricultural activities: alfalfa, cotton, field, grain, pasture, tomato, vegetables and subtropical.

You and Wood (2004) have proposed a spatial disaggregation model for crop production statistics based on a cross-entropy approach. They used various information sources (satellite, biophysical crop suitability assessments, population density) to disaggregate Brazilian crop production data to a pixel level ($9km \times 9km$). They applied a cross-entropy spatial allocation model using the biophysical and social-economic attribute of each location as priors. They used the FAO/IIASA database that provides data on the biophysical suitability of a given location for production, production systems and potential yields. They took into consideration 3 possible production systems (irrigated, high-input rainfed, low-input rainfed) and 8 crops (rice, wheat, maize, cassava, potato, sorghum, bean and soybean).

Kempen et al. (2005) have used a spatial disaggregation procedure combining a logit model with posterior density estimators to break down production data available at the regional level to a homogeneous spatial mapping unit (HSMU) level covering the entire EU. A given HSMU was defined as the area inside which the cropping pattern and technology are relatively homogeneous. The authors used the Corine Land Cover data in combination with data on soil, climate and relief to conceive the HSMU. They took into consideration 8 possible land uses: cereals, oilseed and pulses, industrial crops, labor intensive crops, permanent crops, fodder production, fallow land, as well as other land cover.

Our work differs from these previous studies in that our approach shows how partial land use data available at the disaggregated level can be combined with biophysical data equally available at the disaggregated level to disaggregate regional aggregated data and to constitute more complete information at the disaggregated level. The objective of the disaggregation approach proposed in this study is not to perfectly match the real world, rather to derive a fairly more informative idea of the spatial distribution of production of individual crops than available regional data allow for.

In this paper we propose a two-step disaggregation procedure. In the first step, we estimate a land use model in which we combine data on land use, land cover, soil, climate, and altitude. In the second step, using estimations from the first step as "priors", we disaggregate the FADN data available at the regional administrative level by the Cross-Entropy method. The idea is to disaggregate to a finer scale the FADN crop allocation data available at the regional level.

In section 2 the disaggregation approach is presented. In section 3 the application of the model to the Picardie region is analyzed. In the section 4 we draw some conclusions and propose further uses and possible enhancement of the model.

14.2 The spatial disaggregation model

14.2.1 The problem

Assume that we have statistically representative data on crop distribution at an aggregate level, for example at the regional level. Assume that regions are either very large areas or very heterogenous in terms of crop allocations. Then, the observed data are not very useful in terms of spatial analysis. One needs to reallocate these data which do not have any geographical references to a more realistic geographical positioning. The more precise data allocation would be better adapted to carrying out specific studies on spatially distributed variables, such as environmental studies.

Assume that, in some cases, we have some individual data at a very disaggregated level. These data, combined with other pedo-climatic information, can be used to estimate the probability of observing a particular crop at individual points.

Actually, this is the problem researchers face in agricultural economics when handling data concerning EU : FADN data is only available at the disaggregated level and other data sources do not supply information on compatible scale.

Figure (14.1) illustrates the problem tackled in this study. Consider a region r with two crops, w for wheat and m for maize. In regional data we have information about P_{wr} and P_{mr}, i.e., the aggregated share of land in region r allocated to crops w and m, respectively. For the same region r, we also have available individual observations on land use, land cover classes and other data on soil, climate and altitude.

The question is how to estimate p_{wri} and p_{mri}, the probability to observe each crop w and m in each pixel i of the region r. So that all available information is on the same scale and aggregated land use shares are disaggregated at the pixel level.

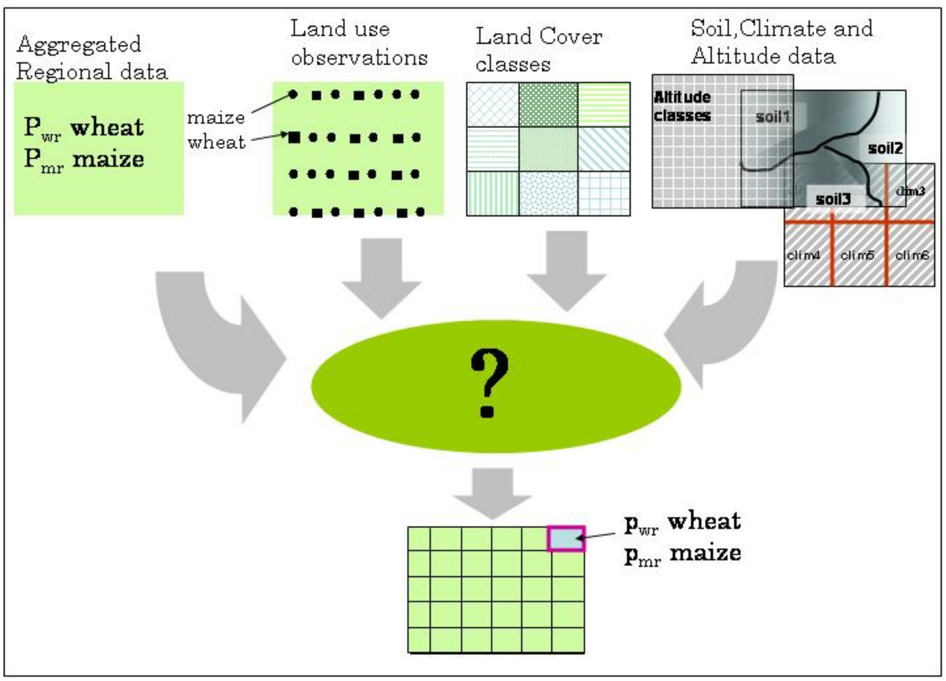


Figure 14.1: The problem illustrated for available data concerning a region r.

14.2.2 The proposed approach

Assume that we observe land use at several points l $(l = 1, ..., L)$ of the region r. The probability of observing the crop c at the point l in the region r, p_{lrc} could be explained by different factors: economic (prices, subsidies), climatic (temperature, rain), soil (soil texture, ph) and time (rotations). We can write:

$$p_{lrc} = f(price, subsidies, soil, rain, temperature, altitude, slope, time). \tag{14.1}$$

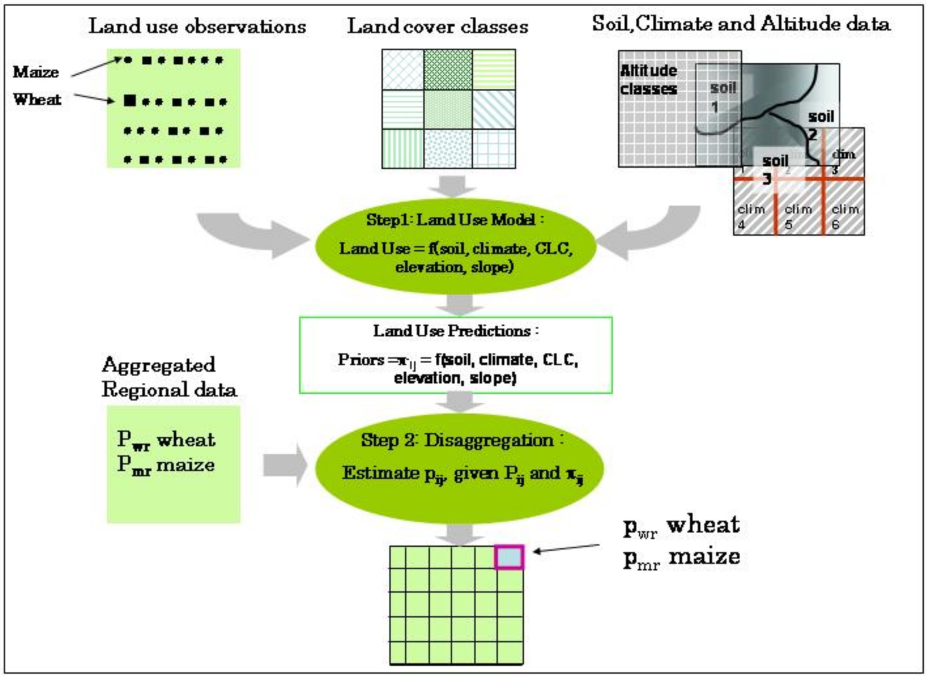


Figure 14.2: The proposed approach to disaggregate the data in a region r.

The approach under study is a two step procedure. First, we estimate the relationship between the observed crop at points ($l = 1, ..., L$) and the explanatory variables by an econometric model then we predict the land use in every pixel i ($i = 1, ..., N$) of the region r. Second, using these predictions as "priors", we disaggregate the aggregated regional data as shown in figure (14.2).

14.2.3 The model

The proposed model is a two-step procedure. In the first step, we estimate a land use model. In the second step, using estimations from the first step as "priors", we disaggregate the FADN data available at the regional administrative level by the Cross-Entropy method.

The land use model

Economic specification Land use models (or land allocation models) have been widely used in agricultural production economics[3] to determine how a farmer allocate his land between possible land uses. As proposed by Wu and Segerson (1995), we used a simple static profit maximization model under risk neutrality.

Consider a farmer who has L_j acres of land of type j ($j = 1, ..., J$). Land types are distinguished by a number of different biophysical characteristics that affect soil productivity (soil type, altitude, slope,etc). The total acreage for the farm is then $L = \sum_j L_j$. For each land type, the farmer must decide how to allocate the L_j acres to each land use c ($c = 1, ..., C$). We assume that for each land type the farmer chooses the land allocation that maximizes total profit. The profit function for crop c grown on land type j is denoted $\pi_{cj}(x_{ic}, l_{jc})$, where x_c is a vector of exogenous input prices, crop prices and other economic decision variables. Therefore,

[3] see Plantinga (1996) and Wu and Segerson (1995)

$$\max_{l_{jc}} \sum_{c=1}^{C} \pi_{cj}(x_{ic}, l_{jc}) \tag{14.2}$$

subject to:

$$\sum_{c=1}^{C} l_{jc} = L_j \tag{14.3}$$

The solution to this problem gives the optimal land allocation $l^*_{jc} = l_{jc}(x_c, L_j)$ for type j land. Thus the optimal share of total land allocated to crop c is

$$s^*_c(X) = \frac{1}{L} \sum_{j=1}^{J} l^*_{jc} \tag{14.4}$$

Econometric specification As explained by Wu and Segerson (1995), there are two approaches to the estimation of the share equations in (14.4). The first is to specify a flexible functional form (such as translog) for the profit function and then derive the implied functional forms of the share equations. The second approach is to assume a flexible functional form for the share equations themselves[4].

In this study, we chose the second approach and assumed that the share equations take the logistic form this is equivalent to using the logit[5] model which explains the observed land use by exogenous explanatory variables.

The multinomial logit MNL model estimates the probability outcome associated with each category of land use depending on a set of explanatory variables. The probability of observing the crop j at location i can be expressed as:

$$p_{ij} = \frac{exp(\beta^{'}_j x_{ij})}{\sum_{j=1}^{C} exp(\beta^{'}_j x_{ij})}, \tag{14.5}$$

where C is the number of possible land use categories, $\beta^{'}_j$ is a vector of parameters to be estimated for land use j, and x_{ij} are explanatory variables associated with crop j and location i.

The log-likelihood function of a sample of size N is given by:

$$\ln(L(\beta)) = \sum_{i=1}^{N} \sum_{j=1}^{C} lnp_{ij}^{y_{ij}}, \tag{14.6}$$

where y_{ij} is a dummy variable such that $y_{ij} = 1$ if crop j is observed at location i and $y_{ij} = 0$ otherwise.

The disaggregation model: the Generalised Cross Entropy approach

The objective here is to use land use estimation results to find a disaggregated spatial allocation of FADN agriculture production available at the regional level. We used the Generalised Cross Entropy approach to carry out the disaggregation procedure. This approach allowed for the inclusion of

[4]see Wu and Segerson (1995) for the advantages of each approach

[5]The logit model was first introduced in the context of binary choice models, where the logistic distribution is used to derive the probability. They have been generalized to more than two alternatives known as multinomial logit models (Maddala (1986)).

prior knowledge about crop distribution or any factors that influence such distribution. We also included constraints that ensure the data compatibility requirement that is the sum of the entire area allocated to a given crop at the disaggregated level must be equal to the area of the same crop observed at the aggregated level.

The entropy concept in information theory[6] was originally proposed by Shannon (1948). For a given probability distribution $(p_1, p_2, ...p_C)$, Shannon's information entropy is defined as

$$H(p_1, p_2, ...p_C) = -\sum_{c=1}^{C} p_c ln p_c. \tag{14.7}$$

To estimate the unknown probabilities p_c, Jaynes (1957a) and Jaynes (1957b) proposed maximizing entropy, subject to sample-moment information and adding up constraints on the probabilities. That approach was based on the following idea: the frequency that maximizes entropy is a reasonable estimate of the true distribution when we lack other information. If we have any additional information from previous experiments or observations, we can use those *priors* to alter this estimate.

Good (1963) introduced the notion of Cross Entropy[7] (CE). Unlike the ME approach, where we maximize uncertainty implied by the probabilities, in the CE framework we minimize the CE, which is a measure of discrepancy between the posterior probabilities p and their priors q. This yields the minimization problem :

$$Min_p CE(p_1, p_2, ...p_C, q_1, q_2, ...q_C) = \sum_{c=1}^{C} p_c \; ln(p_c/q_c), \tag{14.8}$$

subject to all relevant adding up constraints on probabilities.

The cross entropy minimization approach provides a model formulation in which the discrepancies between the estimated probability p and its prior probability q are minimized subject to certain constrains.

In this study, the GCE approach was applied to estimate agricultural land use choices at a disaggregated level using the aggregated FADN NUTS II level data. The estimation of the land use model by the Multinomial logit provided us with some prior knowledge about the land share of each crop j in each pixel i. This corresponds to the prior probabilities $\hat{\pi}_{ij}$ that will enabled us to derive probabilities p_{ij} to observe crop j in pixel i by solving the non-linear optimisation program:

$$\min_p \; CE(p_{ij}, \hat{\pi}_{ij}, \epsilon) = \sum_{i=1}^{I}\sum_{j=1}^{C} p_{ij} \; ln(p_{ij}/\hat{\pi}_{ij}) + \sum_{j=1}^{C}\sum_{n=1}^{N} \varepsilon_{jn} ln(\varepsilon_{jn}). \tag{14.9}$$

subject to:

$$\sum_{i=1}^{I} p_{ij} \times s_i + \sum_{n=1}^{N} \zeta_n \varepsilon_{jn} = S_j^{FADN}, \forall j = 1, ..., C \tag{14.10}$$

$$\sum_{j=1}^{C} p_{ij} = 1, \forall i = 1, ..., I \; and \; p_{ij} \in [0, 1]. \tag{14.11}$$

[6]For more details about information and entropy econometrics see Golan (2002).

[7]The Cross entropy, or Relative Entropy, is also known as the Kullback-Leibler distance or divergence. This distance is not, in general, symmetric

$$\sum_{n=1}^{N} \varepsilon_{jn} = 1, \forall j = 1, ..., C \; and \; \varepsilon_{jn} \in [0,1]. \tag{14.12}$$

where s_i is the area of pixel i and S_j^{FADN} is the area allocated to crop j at the regional level according to the FADN observations. $\zeta_1,\ldots,\zeta_N$ with $N \geqslant 2$ is the support set associated with probabilities $\varepsilon_{j1},\ldots,\varepsilon_{jN}$ such that $\varepsilon_j = \sum_{n=1}^{N} \zeta_n \varepsilon_{jn}$.

Equation (14.10) is the data compatibility constraint, which ensures that the predicted land allocated to a specific crop j across all pixels is equal to the observed area allocated at the regional level to crop j, according to FADN observations.

Equation (14.11) is the adding-up constraint that ensures that the area allocated to all crops in a given pixel i is exactly equal to the area of pixel i. Equation (14.12) ensures that $\varepsilon_{j1},\ldots,\varepsilon_{jN}$ is a probability distribution.

14.3 The spatial disaggregation model application

We applied our spatial disaggregation approach to the French Picardie region. Picardie is one of France's main agricultural regions. 88% of it's land is dedicated to agricultural use and most of it involves field crops[8].

The first step of the disaggregation procedure is to estimate the land use model to explain the observed land use (LUCAS observations) by the land cover (CLC observations), soil variables (European Soil database) as well as climate (European Climate database), elevation and altitude (Digital Elevation Model database). In the second step we use the first step estimations to disaggregate the FADN observations. The different types of data used in this study are described hereafter.

14.3.1 Data description

FADN

The mission of the FADN (Farm Accountancy Data Network) is to gather accountancy data from farms to evaluate the income of farmers and the impacts of CAP reforms.

The FADN data is collected every year and involves all EU member states. The annual sample covers approximately 90 % of the total utilized agricultural area (UAA) and accounts for more than 90 % of the total agricultural production of the EU. The information collected for each sampled farm involves approximately 1,000 variables. These variables concern physical and structural data, such as location, crop areas, livestock numbers, labor force, etc. They also concern economic and financial data, such as the value of production of the different crops, stocks, sales, purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures.

In order to study the effects of agricultural practices on the environment we need to disaggregate the FADN data for the following reasons:

- the data is available at the level of administrative units (NUTS II). This level is not appropriate to carry out precise environmental studies;
- the data is available according to crop type. We need to localize the information more accurately to be able to study the effects of public policy;
- the data contains no information on topography, pedology and climatology. This kind of information is necessary to study the effects of agricultural practices on the environment.

[8]Source: Yearly Agricultural Statistics, AGRESTE (2003)

LUCAS

The Land Use/Cover Area frame statistical Survey (LUCAS) is conducted by Eurostat to obtain at the EU level harmonized data of the main Land Use/Cover areas. LUCAS is a two-step survey: a field survey in spring (step 1) to collect data on land cover/use as well as the environment and a farmer interview in autumn (step 2)to gather information on yields, agricultural practices and techniques[9].

The LUCAS [10] covers the entire EU and uses a systematic area frame sampling with a two-stage sampling design. The total land area of Europe is divided into a $18km \times 18km$ grid. Primary Sampling Units (PSU) are defined as cells of this grid while Secondary Sampling Units (SSU) are 10 observation points evenly distributed across the centre of each PSU. Within each PSU the SSU make up two rows of 5 points each. All points are 300 m apart from each other. The SSU[11]., which are represented as circles of $3m$ in diameter, are units under investigation in step I of the LUCAS survey.

Sampling is carried out independently by each member state. Data on land use/land cover are collected for approximately 10.000 PSU.

The step I data for 2003 are readily available[12]. The data contains information about land use and land cover as well as qualitative information about the existence of infrastructure for irrigation and drainage as well as soil erosion and traces of natural hazards.

Corine Land Cover

Corine (COoRdination of INformation on the Environment) land Cover is a geographical database that provides EU wide geo-referenced data. It is furnished by the European Environment Agency.

Corine Land Cover (CLC) provides a map of the European environmental landscape based on an interpretation of satellite images. CLC also provides comparable digital maps of land cover for each country in Europe. This is useful for environmental analysis and comparisons as well as for policy making and assessment.

CLC inventory involves 44 classes[13] covering agricultural as well as urban and natural areas. CLC deals only with land cover. Land use and land cover are two different notions. They are defined as follows[14] :

- Land cover is the observed physical cover, as seen from the ground or through remote sensing, including vegetation (natural or planted) and constructions (buildings, roads, etc.) which cover the earth's surface. Water, ice, bare rock, or sand surfaces count as land cover.

- Land use is based upon function, the purpose to which the land is being put. Thus, land use can be defined as a series of activities undertaken to produce one or more goods or services. A given land use may take place on one or more than one piece of land, and a given piece of land may be put to several land uses. Definition of land use in this way provides a basis for precise and quantitative economic and environmental impact analysis, and permits clear-cut distinctions between land uses if required.

CLC only deals with land cover while LUCAS deals with both land use and land cover.

[9] For more information about the LUCAS survey, see Eurostat (2003).

[10] LUCAS nomenclature is presented in the appendix 14.5.1

[11] The SSU area is equal to $7m^2$ and the PSU area is equal to $1500m \times 600m = 90ha$.

[12] It is impossible to have access to step II data which are classified confidential.

[13] CLC classes are available on the web site http://terrestrial.eionet.eu.int/CLC2000/classes)

[14] source: Environmental Protection Agency

Other pedo-climatic data

We used the following data sources:

- the European Soil map at the scale of $1/1,000,000$. It covers the enlarged EU and candidate countries. The variables used from this database are: soil type, texture, carbon content, use, etc;
- the Climate Database of Europe at the resolution of 50 km. The variables used from this database are: temperature (min, max) and pluviometry;
- the Digital Elevation Model of Europe at the resolution of 1 km. We used two varaibles from this database: altitude and derived slopes, after classification in 5 and 4 classes respectively.

Table 14.1 summarizes the data used in this study.

Table 14.1: Data Description

Data	Description	Resolution and Scale
FADN	Accountancy data of professional farms	Regional level
Climate	Climate data	50 km x 50 km
Soil	Soil characteristics	1 km x 1 km
DEM	Elevation, Slope	90m x 90m
CLC	Land cover	100m x 100m
LUCAS	Land use/Land cover	1 PSU each 18 km and 10 SSU in each PSU

All data layers are converted and overlaid on a 100m x 100m pixel grid basis. Land use estimation and disaggregation are conduced within this geo-referenced database.

14.3.2 Descriptive statistics

In this study we considered the following possible land uses: Wheat-Barley-Rap (WBR), Root Crops (RC), Grassland (GL), Fallow Land (FL), Maize (M), Other Crops (OC), and non-agricutural use (NAU). The land use categories correspond to the observed land use in LUCAS grouped according to systems of production and agronomic rotations.

Table (14.2) shows land use allocations in the Picardie region according to the FADN and LUCAS data.

Table 14.2: Land Use shares in the Picardie Region (Sources: FADN (2002) and LUCAS(2002))

Land use	Abbreviation	% FADN	% LUCAS
Wheat-Barley-Rape	WBR	40.15	41.12
Root Crops	RC	10.21	9.60
Grassland	GL	5.72	13.04
Fallow Land	FL	3.69	2.90
Maize	MA	4.71	5.07
Other Crops	OC	7.93	5.62
Non-agricultural use	NAU	27.60	22.64

14.3.3 The land use model: priors estimation

The crop choice is influenced by soil and climate as well as economic and management variables. The land use model adopted here explains the discret variable (land use) as a function of explanatory variables (land cover, soil, climate and altitude).

We estimated a land use model using the Multinomial Logit model (MNL) to explain the the observed land use categories: Wheat-Barley-Rape (WBR), Root Crops (RC), Grassland (GL), Fallow Land (FL), Maize (MA), Other Crops (OC) and Non-Agricultural use (NAU). Results of the estimation of the MNL model are reportedin the appendix 14.5.3.

The comparison between the observed and estimated land use categories showed that the MNL model correctly predicted the observed agricultural land use in 60% of the cases. Wheat-Barley-Rape (WBR) land use was correctly predicted in 94% of the cases, and Grassland (GL) in 33% of the cases. In 82% of the cases the observed land use Maize (MA) was predicted in the category WBR, due to the fact that these two land use categories need almost the same biophysical conditions and that the only difference being irrigation. In fact, Maize needs to be irrigated which is not the case for Wheat-Barley-Rape. The introduction of a proxy for irrigation would make the MNL model more accurate. However, such data is not currently available.

The estimated parameters from the MNL model have been used to predict the land use in every $100m \times 100m$ pixel in the Picardie region. Results of the prediction are presented in the table (14.3). These predicted land use shares were taken as "priors" for the CE disaggregation step.

14.3.4 Results of the disaggregation and validation of the disaggregation procedure

Table 14.3: Predicted land use shares from the MNL model and estimated land use shares in % from the GCE disaggregation (standard deviations are in parentheses)

	MNL predictions	GCE estimations
WBR	0.331	0.401
	(0.212)	(0.291)
FL	0.170	0.036
	(0.140)	(0.093)
GL	0.234	0.056
	(0.132)	(0.112)
MA	0.058	0.046
	(0.037)	(0.051)
RC	0.011	0.101
	(0.010)	(0.178)
OC	0.022	0.078
	(0.022)	(0.084)
NAU	0.171	0.275
	(0.225)	(0.306)

<

Table (14.3) presents the estimated land use shares resulting from the disaggregation of the observed FADN shares. To assess how well our disaggregation procedure performed we compared

Table 14.4: Prediction errors summary

Land use	Mean	Std	Median	Min	Max
WBR	0.1027968	0.1046577	0.0673689	0.000677008	0.5531284
OC	0.0466817	0.0375451	0.0357326	0.000923701	0.1735203
GL	0.0611364	0.0974040	0.0297749	0.000039340	0.7263724
FL	0.0260029	0.0287235	0.0197241	0.000331247	0.2181732
RC	0.0766727	0.0934438	0.0412169	0.000045774	0.5916441
MA	0.0215908	0.0186490	0.0159716	0.000122670	0.0896442

the estimated land use shares with observed data at the disaggregated level. Agricultural data at the disaggregated level is available from the last *Recensement General Agricole*(RGA) organized in 2000. The RGA is a general inventory of French agriculture. It is organized by the statistical services of the *French Ministry of Agriculture and Fisheries*. This census is organized almost every 10 years and collects very detailed data about agriculture (farming population, crops areas, animals, production, labor, etc).

The disaggregation results were validated by comparing the predicted land use shares with the observed ones. This comparison was carried out keeping in mind that:

- The RGA data is available at the district (*canton*) level. We had to aggregate the results of our disaggregation model from the pixel level ($100m \times 100m$) to the district level to make them comparable with the RGA observations.
- The RGA data was from 2000 while data from Lucas was from 2003 and data from the FADN was from 2002.
- The RGA is an exhaustive inventory while the FADN is a survey which concerns only professional farms. The two data sets are not readily comparable but the RGA is the only exhaustive data available at the most disaggregated level (district) in France.

In order to evaluate the accuracy of the disaggregation results Figure 14.3 shows the comparison between the estimated and observed shares[15] for the agricultural land use. It shows that the GCE land use shares estimations are quite close to the observed ones: most of the points on the graphics are very close to the $Y = X$ line.

The spatial presentation of these prediction errors are shown in Figure 14.4.

We have also calculated the prediction errors as the root of squared weighted difference between observed and predicted land use shares:

$$Prediction\ error = e_{ck} = \sqrt{(p_{ck}^{RGA} - p_{ck}^{GCE})^2 \times \frac{AA_k}{\sum_k AA_k}},\ \forall c = 1, ..., C\ and\ \forall k = 1, ..., K, \quad (14.13)$$

where e_{ck} is the prediction error for land use c in district k, p_{ck}^{RGA} is the RGA observed land share allocated to land use c in district k and p_{ck}^{GCE} is the generalised cross-entropy estimated land share allocated to the land use c in district k. AA_k is the agricultural area in the district k and $\sum_k AA_k$ is the total agricultural area in the Picardie region. We have weighted the errors by this

[15]Note that for comparability raisons the observed and estimated shares where weighted by the proportion of agricultural land area in each district.

Figure 14.3: Predicted and observed shares for the agricultural land use

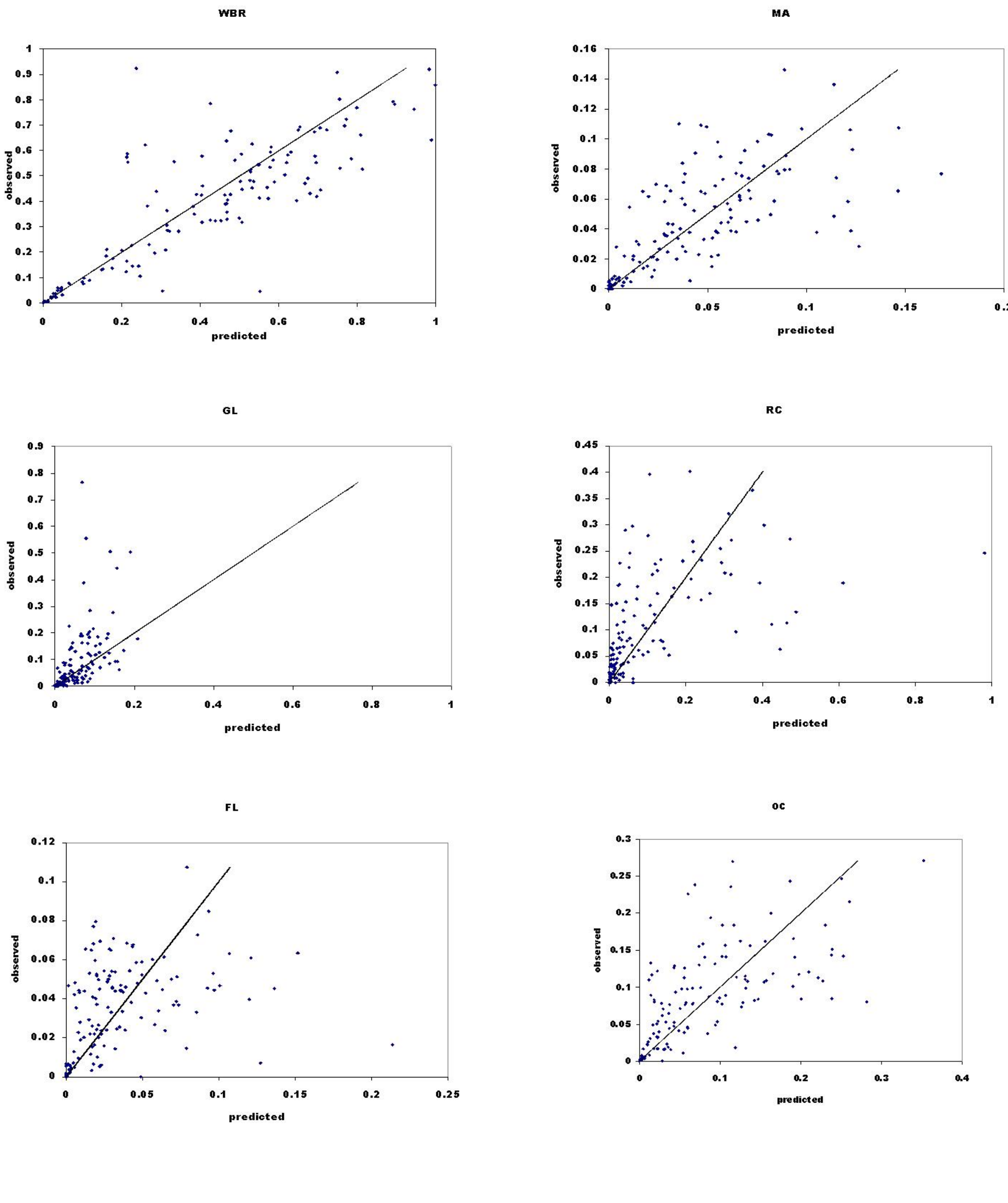
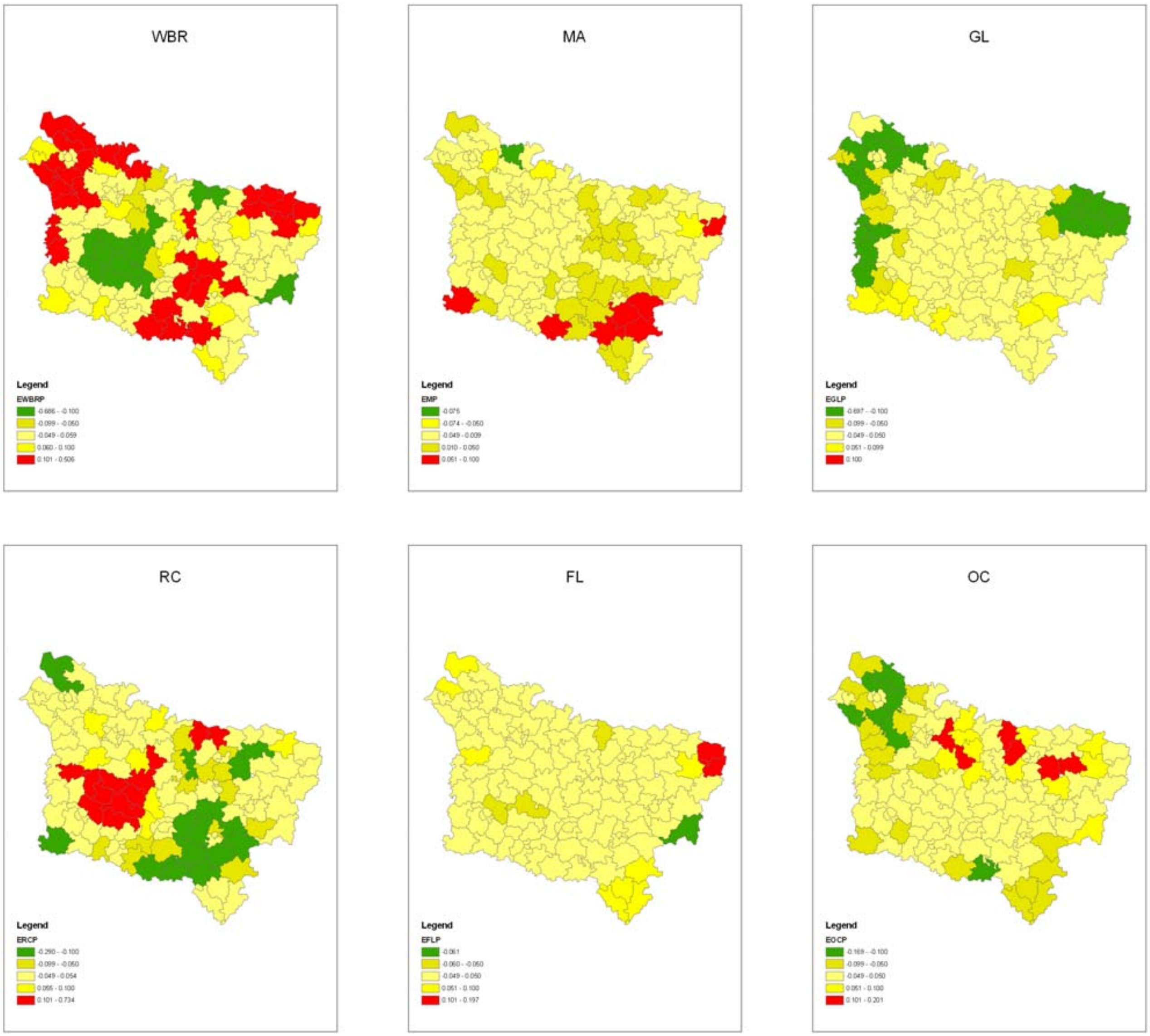


Figure 14.4: Prediction Errors by district



coefficient to take into account the fact that the districts in the Picardie regions don't have the same agricultural area. For example, a prediction error of 0.01 doesn't have the same meaning in a district with 90% of agricultural area and in a district with only 10% of agricultural area.

The summary of these prediction errors are presented in the table 14.4. We will interpret here the Median of the errors which have more sense than the mean of errors in our case. This is beacuse as shown in Figure 14.3, there are some outiers that makes the mean of errors very high even if the predictions are quite good. This is the cas of the land use WBR, table 14.4 shows that the mean error of this land use is equal to 0.1046 even if the value of the Median error shows that in 50% of districts the prediction errors are less than 0.0673. Table 14.4 shows also that predictions of MA and FL are very good since the Median error is less than 0.02. Concerning the land uses OC, GL and RC prediction errors are less than 0.04 in more than 50% of districts.

Another useful mean to validate our predictions was by calculating the Weighted Root Mean Squared Error (WRMSE) weighted by the area of each district. For district k the WRMSE is defined by:

$$WRMSE_k = \sqrt{\frac{1}{C}\sum_{c=1}^{C}(p_{ck}^{GCE} - p_{ck}^{RGA})^2 \times \frac{s_k}{S}},\ \forall k = 1, ..., K, \qquad (14.14)$$

where s_k is the area of the district k and $S = \sum_{k=1}^{K} s_k$ is the area of the region Picardie.

The WRMSE was calculated for the 133 districts of the Picardie region. The WRMSE values showed a reasonable level of precision as the mean value was equal to 0.0743 with a standard deviation equal to 0.060 and a median value equal to 0.0556. The distribution of the WRMSE is shown in figure 14.14.

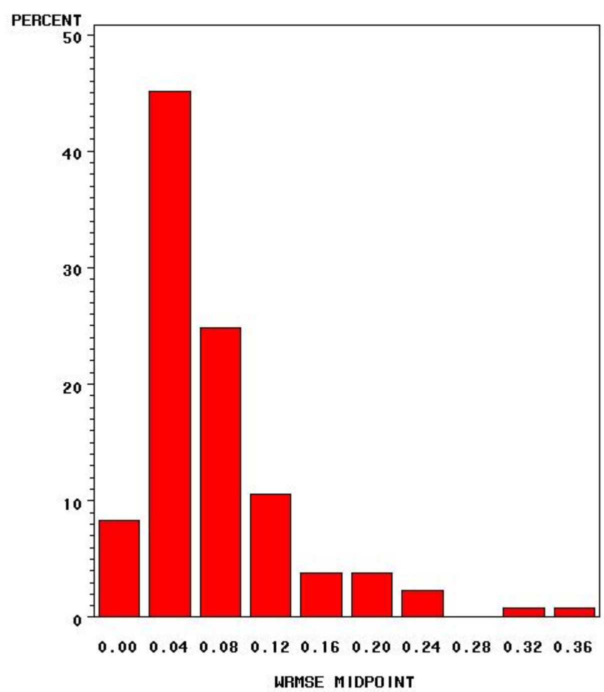


Figure 14.5: The distribution the the WRMSE within the districts of the Picardie region

14.4 Conclusion and research perspectives

In this study, we conceived a spatial disaggregation approach to agricultural data. The approach is a two-step procedure. In the first step, we estimated a land use model at a disaggregated level. In the second step, we disaggregated the observed aggregated data at the regional level to a $100m \times 100m$ pixel level considering the outcome of the first step as priors and using the cross-entropy (CE) method. The objective our approach was not to perfectly "predict" the real world but to derive a fairly more informative idea of the spatial distribution of production of individual crops than available regional data allow for.

We applied our approach by disaggregating the 2002 FADN data available for the Picardie region, which is one of France's main agricultural regions, to a pixel level. We considered the following land use categories: Wheat-Barley-Rape (WBR), Root Crops (RC), Grassland (GL), Fallow Land (FL), Maize (MA), Other Crops (OC) and Non-Agricultural Use (NAU). We used data from the last *Recensement General Agricole*(RGA) taken in 2000 to test the accuracy of our disaggregation approach. The comparison between the estimated and observed land shares presented relatively significant correlation. We have also calculated the Weighted Root Mean Squared Error (WRMSE) as a measure of the quality of prediction. The median value of the WRMSE was equal to 0.0556, a quite precise estimation of land use shares.

The approach proposed here could be a remedy for the lack of data at the disaggregated as well as precisely located data. In the context of agricultural economics such a tool can be used for a more accurate evaluation of the last CAP reform across Europe. For example, a study of non-point water nitrogen pollution due to agriculture is anticipated.

Although our approach provided promising results, it can be enhanced in several ways. To make the land use model more precise in terms of observed land use explanation, we foresee adding a spatial auto-correlation to the model. This should give another dimension to the information as well as provide us with more precise priors, and the more precise the priors, the more precise the whole disaggregation procedure.

Another possible improvement is to consider land use choice as a dynamic process, already applied in other studies[16]. This will allow taking into account risk aversion for profit stabilization (e.g.,crop rotation to reduce losses due to soil erosion and disease as well as to reduce use of pesticides and fertilizers).

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[16]see Thomas (2003)

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14.5 Appendix

14.5.1 LUCAS nomenclature (source:Eurostat)

Level 1	Description	Level 2	Description	Level 3	Description
A	Artificial Land	A1	Built-up Areas	A11	Buildings with 1 to 3 floors
				A12	Buildings with more than 3 floors
				A13	Greenhouses
		A2	Artificial non built-up area	A21	Non built-up area features
				A22	Non built-up linear features
B	Cropland	B1	Cereals	B11	Common wheat
				B12	Durum Wheat
				B13	Barley
				B14	Rye
				B15	Oats
				B16	Maize
				B17	Rice
				B18	Other cereals
		B2	Root Crops	B21	Potatoes
				B22	Sugar beet
				B23	Other root crops
		B3	Non permanent Industrial Crops	B31	Sunflower
				B32	Rape and turnip seeds
				B33	Soya
				B34	Cotton
				B35	Other fibre and oleaginous crops
				B36	Tobacco
				B37	Other non permanent industrial crops
		B4	Dry Pulses, Vegetables And Flowers	B41	Dry pulses
				B42	Tomatoes
				B43	Other fresh vegetables
				B44	Floriculture and ornamental plants
				B45	Strawberries
		B5	Temporary Grasslands	B50	Temporary grasslands
		B6	Fallow Land	B60	Fallow land
		B7	Permanent Crops: Fruit Trees, Berries	B71	Apple fruit
				B72	Pear fruit
				B73	Cherry fruit
				B74	Nuts trees
				B75	Other fruit trees and berries
				B76	Oranges
				B77	Other citrus fruit
		B8	Other Permanent Crops	B81	Olive groves
				B82	Vineyards
				B83	Nurseries
				B84	Permanent industrial crops
C	Woodland	C1	Forest Area	C11	Broadleaved forest
				C12	Coniferous forest
				C13	Mixed forest
		C2	Other Tree Area	C21	Other broadleaved tree area
				C22	Other coniferous tree area
				C23	Other mixed tree area
D	Shrubland			D01	Shrubland with sparse tree cover
				D02	Shrubland without tree cover
E	Permanent Grassland			E01	Permanent grassland with sparse tree/shrub cover
				E02	Permanent grassland without tree/shrub cover
F	Bare Land			F00	Bare land
G	Water and Wetland			G01	Inland water bodies
				G02	Inland running water
				G03	Coastal water bodies
				G04	Wetland
				G05	Glaciers, permanent snow

14.5.2 Variables dictionnary

- AGLIM1 Dominant limitation to agricultural use. AGLIM2 Secondary limitation to agricultural use.

1 No limitation to agricultural use
2 Gravelly (over 35
3 Stony (presence of stones diameter > 7.5 cm, impracticable mechanisation)
4 Lithic (coherent and hard rock within 50 cm)
5 Concretionary (over 35
6 Petrocalcic (cemented or indurated calcic horizon within 100cm)
7 Saline (electric conductivity > 4 mS.cm-1 within 100 cm)
8 Sodic (Na/T > 6
9 Glaciers and snow-caps 10 Soils disturbed by man
20 Fragic
21 Drained
22 Quasi permanently flooded
30 Eroded phase, erosion
31 Phreatic phase

- TEXT1 Dominant surface textural class. TEXT2 Secondary surface textural class. (Present in: STU)

9 No texture (histosols, ...)
1 Coarse (clay < 18
2 Medium (18
3 Medium fine (clay < 35
4 Fine (35
5 Very fine (clay > 60

- USE1 Dominant land use. USE2 Secondary land use.

1 Pasture, grassland, grazingland
2 Poplars
3 Arable land, cereals
4 Wasteland, shrub
5 Forest, coppice
6 Horticulture
7 Vineyards
8 Garrigue
9 Bush, macchia
10 Moor
11 Halophile grassland
12 Arboriculture, orchard
13 Industrial crops
14 Rice
15 Cotton
16 Vegetables
17 Olive-trees
18 Recreation
19 Extensive pasture, grazing, rough pasture
20 Dehesa (extensive agricultural-pasture system in forest parks in Spain)
21 Cultivos enarenados (artificial soils for orchards in SE Spain)
22 Wildlife, above timberline

- USE = Regrouped land use class.

HG = Halophile Grassland
MG = Managed Grassland

SN = Semi-natural
C = Cultivated

- OC TOP = Topsoil organic carbon content.

  H = High ($>$ 6 %)
  M = Medium (2 - 6 %)
  L = Low (1 - 2 %)
  V = Very low ($<$ 1 %)

- CEC TOP = Topsoil cation exchange capacity.

  H = High ($>$ 40 cmol(+)/kg)
  M = Medium (15-40 cmol(+)/kg)
  L = Low ($<$ 15 cmol(+)/kg)

- CEC SUB = Subsoil cation exchange capacity.

  H = High ($>$ 40 cmol(+)/kg)
  M = Medium (15-40 cmol(+)/kg)
  L = Low ($<$ 15 cmol(+)/kg)

- BS TOP = Base saturation of the topsoil.

  H = High ($>$ 75
  M = Medium (50 - 75
  L = Low ($<$ 50

- BS SUB = Base saturation of the subsoil.

  H = High ($>$ 50
  L = Low ($<$ 50

- AWC TOP = Topsoil available water capacity.

  L = Low ($<$ 100 mm/m)
  M = Medium (100 - 140 mm/m)
  H = High (140 - 190 mm/m)
  VH = Very high ($>$ 190 mm/m)

- AWC SUB = Subsoil available water capacity.

  VL = Very low (0 mm/m)
  L = Low ($<$ 100 mm/m)
  M = Medium (100 - 140 mm/m)
  H = High (140 - 190 mm/m)
  VH = Very high ($>$ 190 mm/m)

- Slope

  1 0 to 8 %
  2 8 to 15 %
  3 15 to 25 %
  4 25 to 100 %
  5 more than 100 %

- Altitude

  1 less than 0 m
  2 0 to 300 m
  3 300 to 600 m
  4 600 to 900 m
  5 more than 900 m

14.5.3 MNL land use model estimation

Multinomial logistic regression — Num of obs= 552
LR chi2(54) = 401.87
Prob > chi2 = 0.0000
Log likelihood = -686.67987 — Pseudo R2=0.2264

lucas	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FL						
clc	-.4600917	.1092683	-4.21	0.000	-.6742536	-.2459299
pente	.7319158	.6400789	1.14	0.253	-.5226157	1.986447
tempe	-1.524793	.5985942	-2.55	0.011	-2.698016	-.3515695
sumpluie	.0130234	.0062675	2.08	0.038	.0007393	.0253076
aglim1	-.0978907	.428782	-0.23	0.819	-.938288	.7425065
text1	1.091689	.6837958	1.60	0.110	-.2485258	2.431905
use1	.3372622	.4507946	0.75	0.454	-.5462789	1.220803
use2	.3384087	.3383342	1.00	0.317	-.3247141	1.001531
bs_topord	-.5742076	.6416391	-0.89	0.371	-1.831797	.683382
_cons	-3.269791	4.685273	-0.70	0.485	-12.45276	5.913175
GL						
clc	-.1653223	.0382051	-4.33	0.000	-.240203	-.0904417
pente	-.2686118	.3432901	-0.78	0.434	-.9414481	.4042244
tempe	-.9466376	.3074954	-3.08	0.002	-1.549318	-.3439576
sumpluie	.0073529	.0040245	1.83	0.068	-.000535	.0152408
aglim1	-.386947	.2102225	-1.84	0.066	-.7989756	.0250817
text1	.159317	.2626366	0.61	0.544	-.3554413	.6740753
use1	.2160169	.1734098	1.25	0.213	-.12386	.5558938
use2	-.0823122	.1356594	-0.61	0.544	-.3481997	.1835753
bs_topord	.0650768	.3271625	0.20	0.842	-.5761499	.7063035
_cons	.1112044	2.655079	0.04	0.967	-5.092655	5.315064
MA						
clc	-.4274517	.0835959	-5.11	0.000	-.5912967	-.2636068
pente	-1.410436	1.028144	-1.37	0.170	-3.42556	.6046881
tempe	-.7430153	.4369509	-1.70	0.089	-1.599423	.1133928
sumpluie	.008672	.0056529	1.53	0.125	-.0024075	.0197515
aglim1	-.6222883	.3228939	-1.93	0.054	-1.255149	.0105721
text1	-.037741	.4141996	-0.09	0.927	-.8495573	.7740752
use1	.360638	.2747547	1.31	0.189	-.1778713	.8991473
use2	-.1262292	.2143537	-0.59	0.556	-.5463548	.2938963
bs_topord	.4004811	.5512593	0.73	0.468	-.6799672	1.480929
_cons	2.388908	3.855646	0.62	0.536	-5.16802	9.945835
OC						
clc	-.467485	.092237	-5.07	0.000	-.6482663	-.2867037
pente	-.7559726	.7799871	-0.97	0.332	-2.284719	.772774
tempe	-.2032464	.4472353	-0.45	0.650	-1.079811	.6733186
sumpluie	-.004709	.0104843	-0.45	0.653	-.025258	.0158399
aglim1	-.2554944	.2918827	-0.88	0.381	-.827574	.3165851
text1	-.6505456	.4859317	-1.34	0.181	-1.602954	.301863
use1	.6332023	.4163619	1.52	0.128	-.182852	1.449257

```
        use2 |   .2281754   .2644641     0.86   0.388    -.2901648    .7465156
   bs_topord |   1.078734   .8190738     1.32   0.188    -.5266211    2.684089
       _cons |   5.190848   6.624019     0.78   0.433     -7.79199    18.17369
-------------+----------------------------------------------------------------
RC           |
         clc |  -.6205463   .1218246    -5.09   0.000    -.8593181   -.3817744
       pente |    -.66564   .6843416    -0.97   0.331    -2.006925    .6756448
       tempe |  -.3650603   .3957119    -0.92   0.356    -1.140641    .4105209
    sumpluie |  -.0049855   .0084641    -0.59   0.556    -.0215748    .0116039
      aglim1 |  -.1566753   .3600204    -0.44   0.663    -.8623024    .5489517
       text1 |    .038905   .6706194     0.06   0.954    -1.275485    1.353295
        use1 |  -.2582596   .8360402    -0.31   0.757    -1.896868    1.380349
        use2 |   .1486926   .2310511     0.64   0.520    -.3041592    .6015445
   bs_topord |   2.505107   1.004137     2.49   0.013     .5370346    4.473179
       _cons |   3.473699   6.431591     0.54   0.589    -9.131988    16.07939
-------------+----------------------------------------------------------------
WBR          |
         clc |  -.5605429   .0537293   -10.43   0.000    -.6658504   -.4552354
       pente |  -.1552953   .3716608    -0.42   0.676    -.8837372    .5731466
       tempe |  -.7150957   .2978446    -2.40   0.016     -1.29886   -.1313311
    sumpluie |   .0027716   .0044201     0.63   0.531    -.0058916    .0114348
      aglim1 |  -.4165371   .2000345    -2.08   0.037    -.8085974   -.0244768
       text1 |  -.0782074   .2857678    -0.27   0.784    -.6383021    .4818873
        use1 |   .3882743   .1858408     2.09   0.037      .024033    .7525155
        use2 |  -.0668274   .1375463    -0.49   0.627    -.3364131    .2027583
   bs_topord |   .8321398   .3771222     2.21   0.027     .0929939    1.571286
       _cons |   6.193031   2.890874     2.14   0.032     .5270227    11.85904
------------------------------------------------------------------------------
(lucas==NAU is the base outcome)
```

15 Farm group location and downscaling of modelling results

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Abstract

The AROPAj economic model was developed by INRA to evaluate the environmental and economic impacts of agricultural (Common Agricultural Policy) and environmental policies in the European Union (EU). AROPAj aims to model farming outputs (greenhouse effects, carbon sequestration, nitrate leaching,...) using agricultural input variables (such as livestock numbers, gross margins, farm production system), agronomic constraints and policy requirements. AROPAj is based on individual production systems: representative farm-types, from the Farm Accountancy Data Network (FADN) and works at the region level (FADN regions). As a consequence, farm-groups do not have a given location within a specified FADN region; only a set of statistical data (numbers and sizes) are available at the FADN regions level. In order to take into account local management and policies, we need information about where can be found more precisely the farm types within a region. The aim of this paper is to provide a methodology for mapping the AROPAj farm-groups within FADN regions. Statistically, this consists in disaggregating (or geographically "downscaling") the environmental information associated to the farm groups available on administrative units (FADN regions) into a more detailed geographical level.

Farm-groups used in AROPAj result from a classification of farms described within each FADN region. The classification is based on 3 criteria/characteristics: their altitude, their economic size and their type of farming. Downscaling data at FADN-region scale to a finer scale requires the linking of the available information with geo-referenced database which can explain or be an indicator of farm-group productions. For instance, CORINE Land Cover (CLC) database which maps land cover over the EU at *100 m* resolution, can be used as one of the basis information for the spatial disaggregation. Nevertheless, CLC nomenclature is not detailed enough to distinguish different kinds of agricultural land use on *100 m* resolution. For this, additional information is required on land use, like the LUCAS database (Land Use/Cover Area Frame Statistical Survey) which allows for specifying, geographically, the proportion of different crops in each CLC class.

In order to describe each CLC class according to the LUCAS classes, we propose an approach that breaks down agricultural FADN regional data into *100m x 100m* raster cell spatial units. It is a two-step procedure. First, we estimate a land cover/use model using a Multinomial Logit (MNL) model. Second, we disaggregate the observed FADN regional land use shares using a Cross Entropy (CE) approach, taking the first step predictions as priors.

Once each *100m x 100m* raster cell unit is described in terms of land cover shares (per FADN region), the probability of each farm-group is allocated to all raster cells units of the region. The areas occupied by each agricultural activity within a Farm-group of the FADN region being known, the allocation is achieved by assuming that a farm-group with an important activity will be found on the map where the land cover establishes that this activity is important. Afterwards, the use of altitude information permits to refer to AROPAj farm-groups.

To conclude, this method is purely econometric and has the advantages to be fast and quantitative, then to associate to the final results the quality of the allocation.

15.1 Introduction

The AROPAj economic model was developed by INRA (Institut National de la Recherche Agronomique, at Grignon, France) to evaluate the environmental and socio-economic impacts of agricultural and environmental policies (notably the Common Agricultural Policy, CAP). At first, the model was built for France and then extended to the European Union (EU15). AROPAj aims to model farming outputs (greenhouse effects, carbon sequestration, nitrate leaching . . .) using agricultural input variables (such as livestock numbers, gross margins, farm production system. . .), agronomic constraints and policy requirements. AROPAj is based on individual production systems: representative farm-groups[1] from the Farm Accountancy Data Network (FADN[2]) and works at the regional level (FADN regions).

As a consequence, farm-groups do not have a given location within a specified FADN region; only a set of statistical data (numbers and sizes) are available at the FADN regions level. Even though the number and area of each farm-group is known for every FADN region, their precise location within the FADN regions is not. In order to take into account local management and policies, there is a need of information about where the farm types within a region can be found.

The aim of GENEDEC WP3.4 is to provide a methodology for mapping the AROPAj farm-groups within FADN regions. From a statistical point of view, this consists in disaggregating (or geographically "downscaling") the environmental information associated to the farm-types available for administrative units (FADN regions) into a more detailed geographical level.

15.2 Methodology

The principle of spatially distribute a variable Y known for an (administrative) unit A into a smaller geographical unit can be summarized by the need to have a set of subunits $B_k$that are completely into unit A and their sum fully describes A; and on which "sub-variables" Y_k are available; so that the sum of those Y_k on the B_k is equal to Y.

$$Y = \sum_{B_k \subset A} Y_k \qquad (E1)$$

Then, one approach frequently used is to consider a covariable Z (or a set of co-variables) known of each subunit B_k and for which a relationship can be established with Y. That is to say that a function f exists (on each subunit B_k) so that:

$$Y_k = fct(Z_k) \qquad (E2)$$

In the present study, the unit A is an FADN region, while Y will characterize the AROPAj farm groups. The next paragraph is dedicated to gain a better knowledge of farm-groups and, once variable(s) describing them will be identified, to find a spatial unit, an underlying structure of the FADN regions on which the AROPAj farm-groups could be disaggregated.

15.2.1 Farm groups

Farm-groups used in AROPAj result from a classification of farms observed within each FADN region. The classification is based on 3 criteria/characteristics:

[1] http://www.grignon.inra.fr/economie-publique/genedec/reserv/echangdoc/pajrc/typo.pdf

[2] http://ec.europa.eu/agriculture/rica/index_en.cfm

- altitude
- economic size
- type of farming

The classification[3] is achieved using a mathematical clustering (k-means method with Euclidian distance), so that farms for a same class are the most similar possible (according to the 3 selected criteria) and that clusters are quite separated between them (AROPAj, 2005).

The criterion *altitude* corresponds to the average altitude of holdings (3 classes: 0-300m, 300-600m and higher than 600m). The *economic size* of a farm (defined by the concept of Standard Gross Margin[4], and expressed in terms of European Size Unit, ESU) comes from the FADN database, as well as the *type of farming* (TF) variable.

	Type of farming	
Specialist field crop	TF13	Specialist cereals, oilseed and protein crops
	TF14	General field cropping (root crops, vegetables, ...)
Milk	TF411	Milk
	TF412	Milk& cattle rearing
Specialist grazing livestock	TF42	Specilist cattle-rearing and fattening
	TF43	Cattle-dairying, rearing and fattening combined
	TF44	Sheep, goats and other grazing livestock
Granivores	TF5	Specialist granivores (Poultry, pigs, ...)
Mixed cropping	TF6	Mixed cropping (Permanent crops, market gardenning, ...)
Mixed livestock	TF71	Mixed livestock, mainly grazing livestock
	TF72	Mixed livestock, mainly granivores
Mixed crops-livestock	TF81	Field crops-grazing livestock combined
	TF82	Various crops and livestock combined

Table 15.1: Types of farming

The FADN Type of Farming is the last parameter used for the AROPAj classification, and 13 types of farming proposed in the FADN classification are considered here (see Table 15.1) and it is mainly about differencing farms specialized in a particular field crop, or in a given kind of livestock, or farms mixing crops and/or livestock.

Moreover, beside this definition, information available for each farm-group includes the population of agricultural holdings, as well as the utilised agricultural area (UAA) and its surfaces dedicated to each activity (crop cultivation).

As en example;

Table 15.2 presents the 9 farm-groups found in the French region Rhône-alpes (FADN number 192), farm-groups numbered from 35 to 43.

Table 15.3 describes one of the 9 farm-groups of Rhône-alpes region (Farm-group n.35). This table shows that farms from this farm-group are found in an altitude lower than 300m (Altitude class 1). Farm-types column shows that farms belong to either farm-types class 6, 13, 14, 71 or 411 and have an economic size as shown in corresponding column.

[3]Note that a farm-group is made up of at least 15 farms for confidentiality reasons

[4]http://ec.europa.eu/comm/agriculture/rica/methodology1_en.cfm and http://ec.europa.eu/comm/agriculture/rica/diffusion_en.cfm#sg

Farm Group	Region (FADN)	Country (AROPAj)	C2	C1	Farm-Group ID.	Farm-Group Population (1000)	Farm-Group Area UAA (1000ha)
35	192	Fra2	1	1	101019202	3.706	48.0109
36	192	Fra2	1	2	102019202	3.234	34.1161
37	192	Fra2	1	3	103019202	5.196	44.933
38	192	Fra2	1	4	104019202	0.997	80.5821
39	192	Fra2	1	5	105019202	2.693	60.3667
40	192	Fra2	2	1	201019202	0.962	105.3546
41	192	Fra2	2	2	202019202	2.089	77.3485
42	192	Fra2	3	2	302019202	0.318	167.2286
43	192	Fra2	4	2	402019202	2.04	50.3594

Table 15.2: Farm groups in the French region "Rhône-Alpes" in the AROPAj model

Altitude Class	Farm-types	Economic Size	Nb of farms	Nb total
1	6	2	1	5
		4	1	
		5	2	
		6	1	
	13	3	2	17
		4	2	
		5	4	
		6	9	
	14	4	2	8
		5	1	
		6	5	
	81	5	3	8
		6	5	
	411	5	3	3
			Total	41

Table 15.3: Description of Farm group 35

15.2.2 Farm groups spatialisation

Spatial unit for the downscaling process

Downscaling data from FADN-region scale to a finer scale requires the linking of the available information with a geo-referenced database which can indicate the agricultural activity (Specific crop production, pastures,..).

Because a land cover map of Europe is a tool available and widely used now (this will be detailed in next paragraph), it appears that points (raster cells) of such map could be used as an underlying structure of the FADN regions on which variable Y could be disaggregated. There are the subunits $B_k$of Equations (E1) and (E2).

As an economic and financial parameter, the *Economic size* criterion is difficult or intrinsically impossible to disaggregate. The *Altitude* criterion might be "easy" to link with maps (through Digital Elevation Model) but is obviously not sufficient to localize precisely farm-groups. The *type of farming* criterion refers to holding orientation and activities; there is an intuitive possibility to establish relationship between land cover information and type of farming TF13 or TF14 (specialist cereals, specialist field crops, see Table 15.1). However there is some difficulties to disaggregate livestock data to grid cell (see the discussion paragraph hereafter), difficulties to differentiate, thanks to a land cover map, areas used for grazing livestock or granivores (TF71, TF72), or for Milk production (TF411 and TF412), or for mixed crops-livestock (TF81 and TF82).

On the other hand, there is a clear link between agricultural activities and the land cover. The agricultural activities define the land cover and reciprocally it is possible to allocate certain agricultural activities to certain types of land cover (at least at the level of a European region). In another word it is possible to establish that the activity is, "somehow", a function of the land cover. As seen before, information on the importance and area occupied by the different activities for each Farm-group is available. Referring again to Equation (E2), the land cover becomes the co-variables Z_k.

From land cover map to Farm groups allocation

Let's assume now that a land cover map is available, giving on any points (raster cell) the probability to find each land cover category (agricultural activity).

The proposed methodology is as follow:

Firstly, the *Altitude* criterion is used to exclude points where a given farm-group can not be found. Farm groups allocation will be proceeded by class of altitude, reducing therefore the possible number of farm group present in any subunit (land cover map raster cells).

Secondly, let's assume that a farm-group with an important activity will be found on the map where the land cover establishes that this activity is important there.

That is to say, for a given FADN region; let's note *("the target")*

- *Farm-Group Probability* $\mathrm{Pr}^{FG}[\mathrm{i}_0,\mathrm{K}]$: Probability to find farm-group K on point i_0

And let's consider *("available information")*

- the *Land Cover Probability* $\mathrm{Pr}^{LC}[\mathrm{i}_0,\mathrm{J}]$: Probability to find the land cover J on point i_0
- S(J,K) is the area occupied by activity J in farm-group K

Then:

(E3) $\mathrm{Pr}^{FG}[i_o,k] = \sum_j \frac{\mathrm{Pr}^{LC}[i_0,j]\times S(j,k_0)}{\sum_k S(j,k)}$

With[5] $\sum_K($ $\Pr^{FG}[i,K]$ $) = 1$ $\forall$i (in a given FADN region)

(E3) will be applied to the whole map of an FADN region to map the probability of each raster cell of this map to belong to the farm groups.

15.3 Land Cover estimation

The initial disaggregation problem is the spatialisation of agricultural activities (as a function of land cover) from an FADN region to the points of a land cover map of this FADN region.

The CORINE Land Cover (CEC, 1993) database maps land cover over the EU at 100 meter resolution and can be used as one of the basis information for the spatial disaggregation. The CORINE Land Cover[6] (CLC) is a geographic land cover/land use database encompassing the European countries, built up to give precise and easy information on land cover of the European territory. CLC was elaborated based on the visual interpretation of satellite images and refined with ancillary data (aerial photographs, topographic maps, local knowledge ...). As a result, CLC describes land cover according to a 3 levels nomenclature (up to 44 classes for the last level).

Because of its resolution and availability all over Europe, CLC is frequently used as a means for the reassignment of information on a large unit into a finer unit (EEA, 2001).

Nevertheless, CLC nomenclature is not detailed enough to distinguish different kinds of agricultural land cover on 100 m resolution. Therefore, additional information is required on land use, like the LUCAS database (Land Use/Cover Area frame Survey[7]) which (thanks to detailed agricultural categories within its nomenclature) allows a detailed specification of the type of crops that can be found locally. However, LUCAS gives information only on a set of points which sample the EU territory[8].

Moreover, crops cultivation is depending on factors such as soil (texture and typology) or climate, as well as economic and management variables. Information on these factors is available at the European level through the Soil Geographical Data Base, Digital Elevation Model and Climatic database.

Considering the available data, one might estimate relationships between a set of explanatory variables (ranging from the land cover - CLC classes -, altitude, slope, climatic parameters, soil characteristics...) and the land cover/type of crops on a set of LUCAS points within an FADN region. Then, once those relationships are established thanks to an econometric model, it is possible to estimate the land use in every 100x100m raster cell of the FADN region considered (all the explanatory variables must be therefore available on every raster cells). Figure 1 illustrates this approach.

For this purpose, it is proposed to use a Multinomial Logit model (MNL) (see Chakir, 2006, as well as the Chapter 14 of this report), which intend to explain the observed land cover categories (LUCAS classes: Cereals, Root Crops, Permanent Crops, Grassland, Fallow Land... but also Non Agricultural Use) in function of explanatory variables (CLC, Altitude, Slope, Climatic parameters, Soil characteristic parameters).

[5]Effectively: $0 < \Pr^{LC}[i_0,j] < 1$ and $S(J,K_0) < \sum_K S(J,K)$ $\forall$ K_0thus ($S(J,K_0)$ / $\sum_K S(J,K_0)$) < 1

[6]See http://org.eea.europa.eu/documents/brochure/CLC2000brochure
and http://ec.europa.eu/agriculture/publi/landscape/about.htm

[7]See Gallego, ed. (2002) and in particular the article *Area frame surveys: Aim, Principals and Operational Surveys* http://agrienv.jrc.it/publications/ECpubs/agri-ind/

[8]LUCAS is a non stratified systematic survey and not a map (unlike CLC): it consist in a cluster every 18 km with for each cluster 10 sub sampling points. 57 land classes are separated including 34 agricultural classes.

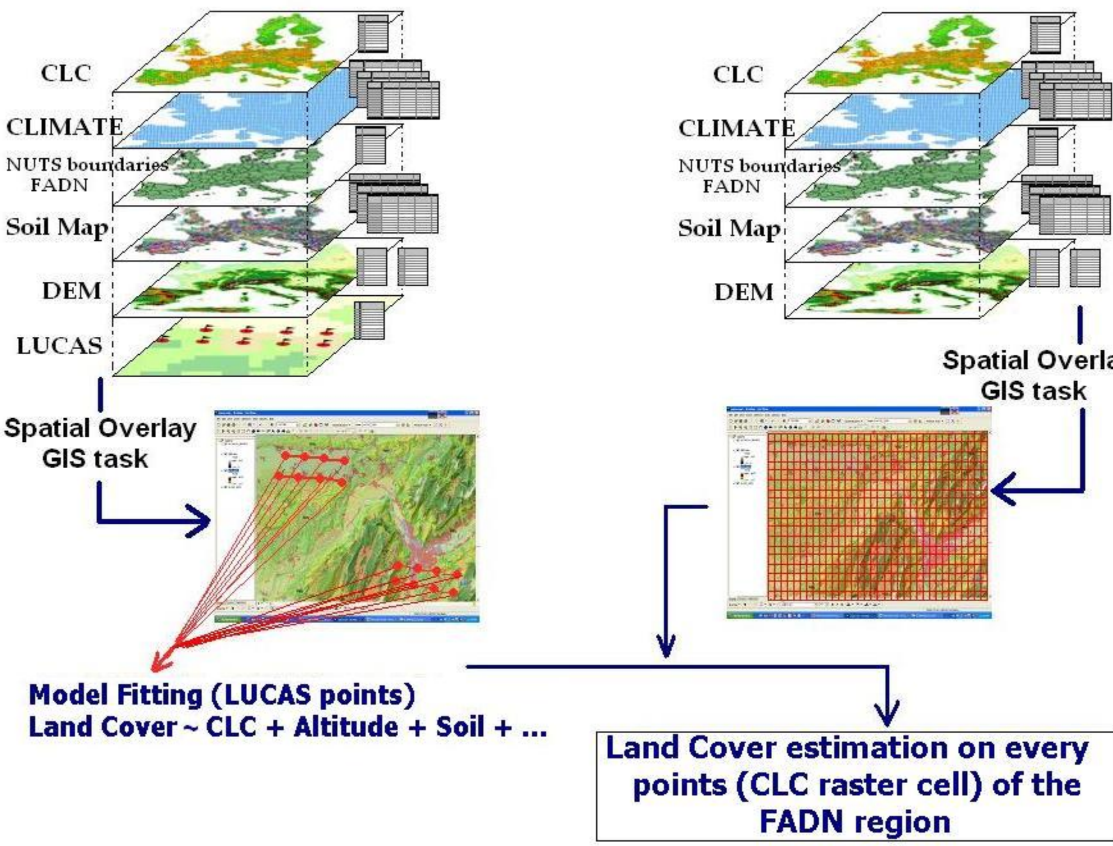

Figure 15.1: Land cover estimation procedure (for an FADN region): Data preparation for the Multinomial Logit model (MNL) fitting on (Lucas points, Left) and prediction on all CLC raster cells within the FADN region (Right).

However, this method does not take into account an important, rich and unique source of information: the FADN database. For a region, the proportion of every land use and crop cultivated is indeed known. And it is very likely that the predicted area occupied by crop c in the region r (sum of raster cells containing crop c multiplied by raster cells surface) does not match with the area dedicated to this crop into this region according to the FADN database.

Therefore, the land cover estimates will be refine/optimize. In other words, it is about minimizing the difference between the estimated land use share (derived from probabilities estimated by the MLN model) and the observed land uses share (FADN data). On this purpose, it is proposed to use the General Cross Entropy method (GCE); deriving probabilities to observe a given crop into each raster cell of the FADN region using "prior" information (first probabilities estimations from the MNL model) and constraints (FADN observed land cover share). Details on this method and its application in this case study can be found in Chakir (2006) as well as in Chapter 14 of this report.

15.4 Application/Results: a case study

As an example; a case study for the French region Rhône-Alpes (FADN#192) is presented. Rhône-Alpes is a large region (43698 km^2) located on the eastern border of the country, towards the south. Its economy is second in size in France and the agriculture sector is important in particular for meats, dairy and grapes

Following the methodology presented above, the land cover map is estimated firstly using a Multinomial Logit (MNL) model. Categories of LUCAS nomenclature have been re-classified in order to work on the 10 kinds of land cover indicated in Table 15.4.

LUCAS Nomenclature (Land cover type classification)			Simplified Nomenclature
Level 1 A, C, D, F, G			NAU Non Agricultural Use
Level 1 B	Level 2 B1	Level 3 B11,B13, B32	CE Cereals
		Level 3 B14,B15,B17,B18	OC Other Crops
		Level 3 B16	MA Maize
	Level 2 B2		OC Other Crops
	Level 2 B3	Level3 B31,B33,B34,B35,B36,B37	OL Oleaginous
	Level 2 B4	Level 3 B41, B42, B43, B44	OC Other Crops
	Level 2 B5		TG Temporary Grassland
	Level 2 B6		FL Fallow Land
	Level 2 B7		PC Permanent Crops (fruit trees)
	Level 2 B8		VY Vineyards
Level 1 E			PG Permanent Grassland

Table 15.4: LUCAS nomenclature re-classification

The "best" model selected for land cover estimation in Rhône-Alpes is as follow:

LUCAS ~ CLC + Slope + Altitude + SumTp + SumRainfall + AGLIM1 + TEXT1 g+ AWC.TOP + USE1 + BS.TOP + *CLC x SumRainfall* + *AGLIM1 x SumTp* + *TEXT1 x SumRainfall* + *SumTp x SumRainfall* + *USE1 x Slope* + *BS.TOP xAGLIM1* + *BS.TOP x SumRainfall*

Where AGLIM1 (*Dominant limitation to agricultural use)*, BS.TOP (*Base saturation of the topsoil)*, TEXT1 (*Dominant surface textural class)*, AWC.TOP (Topsoil available water capacity) and USE1 (*Dominant land use*) come from the EU Soil database (see annex); SumTp (*Sum of*

Temperature), SumRainfall (*Sum of Rainfall*) from the MARS climatic database, Slope and Altitude from the Digital Elevation Model.

With this model, the general agreement (predicted vs. observed) is 75.6% (906 points out of 1199). Details are shown here after in the contingency table (Table 15.5):

	Observed											
Predicted		CE	FL	MA	NAU	OC	OL	PC	PG	TG	VY	Total
	CE	**25**	0	7	7	1	3	1	4	1	0	49
	FL	0	**3**	1	2	2	0	1	0	0	0	9
	MA	6	0	**20**	6	0	2	0	2	1	0	37
	NAU	8	0	5	**630**	0	1	4	65	5	5	723
	OC	0	0	1	0	**3**	0	1	0	0	0	5
	OL	0	0	1	0	2	**4**	0	1	1	0	9
	PC	0	0	0	0	1	0	**8**	1	0	0	11
	PG	26	0	14	65	1	4	2	**187**	17	2	318
	TG	0	0	1	1	0	0	0	2	**7**	0	11
	VY	0	1	0	3	0	1	0	3	0	**19**	27
	Total	65	4	50	715	10	15	17	265	32	26	1199

Table 15.5: Contingency table for Land Cover Categories in Rhône-Alpes, Observed vs. Predicted with the MNL model.

The ratio of correctly predicted NAU points reaches 88.1%. Area covered by Permanent Grassland is important in Rhône-Alpes; the model depicts 70.6% of points labeled such in LUCAS. Among the different crop cultivated in this region, cereals are the most important (mainly Wheat and Maize). The model predicts correctly cereals only in 38.46% of the cases and maize in 40% of the cases (major part of "missed cereals" is found in Grassland).

MNL Model (M1) is then run on all the raster cells of the Rhône-Alpes map. Once points used for non agricultural purpose are putted aside, it remains 3,818,386 100x100m raster cells to work on (that is to say 3,818,386 ha). For each of them, the MNL gives a probability to "host" the different land cover categories.

Taking these results as *prior* probabilities, the Cross Entropy (CE) method is then used to optimize the estimations in terms of area covered by each land cover category. The optimization process converged and the estimated area are very close (almost equal) to the observed ones (Table 15.6, column MLN+CE).

Finally, estimated land cover map is used to compute the probability of each pixel to host the Farms-groups. As seen in paragraph 2.1, there is 9 Farm-groups in Rhône-Alpes (numbered from 35 to 43). Farm-groups number 35, 38 and 40 belong to the first altitude class (<300m), while Farms-groups 36, 41, 42 and 43 are found in the 2^{nd} altitude class (300-600m); and Farms-groups 37 and 39 regroup farms situated at an altitude higher than 600m (3^{rd} class).

Table 15.7 presents the area occupied in each Farm-group by the different land cover categories. Equation (E3) is applied to those data and previously estimated (MLN+CE) land cover probabilities.

Resulting maps are shown in Figure 2 for Farm-Group 40, Figure 3 for Farm-group 37 and in Figure 4 which presents for each 100x100m raster cell (that is to say 1 ha) the most probable Farm-Group.

	Observed		Estimated		Estimated	
(ha)			MNL		MNL+CE	
CE	182,100	4.73%	190,199	4.93%	182,412	4.73%
FL	41,500	1.08%	60,224	1.56%	41,458	1.08%
MA	147,606	3.11%	120,000	3.83%	119,815	3.11%
NAU	2,204,555	57.22%	1,984,214	51.50%	2,205,204	57.24%
OC	114,100	2.96%	145,608	3.78%	114,718	2.96%
OL	45,500	1.18%	60,006	1.58%	45,291	1.17%
PC	4,900	1.29%	98,145	2.55%	48,929	1.27%
PG	892,700	23.48%	816,214	21.19%	892,161	23.16%
TG	143,100	3.80%	106,972	2.78%	142,626	3.70%
VY	60,000	1.56%	2433,64	6.32%	60,018	1.56%

Table 15.6: Land Cover Superficies comparison: Observed (left column), estimated with the Multinomial Logit (MNL, middle) and estimated with both Multinomial Logit + Cross Entropy (MNL+CE, right).

		Farm-Groups								
(1000ha)		35	36	37	38	39	40	41	42	43
Vegetal Activities	CE	14.77	8.44	3.18	14.73	1.95	28.18	11.94	35.28	6.18
	FL	3.21	1.09	0.16	2.47	0.23	6.77	2.74	8.1	0.3
	MA	14.46	3.05	2.66	19.23	0.91	40.71	14.37	25.57	5.23
	OC	0.34	0.27	0.13	0	0.12	5.71	0.33	1.02	0.08
	OL	6.09	1.24	0	2.69	0	6.52	2.55	4.15	0.84
	PC	1.37	0.45	0.4	0	0.06	1.88	2.02	0.65	0.44
	PG	4.53	15.08	29.17	20.8	41.46	8.91	34.34	62.69	25.9
	TG	3.9	3.85	9.45	20.28	14.84	8.22	10.87	27.63	11.38
	VY	0.84	1.37	0	0.38	0.71	1.59	0.34	3.74	0.54

Table 15.7: Area occupied in each farm group by different land cover categories

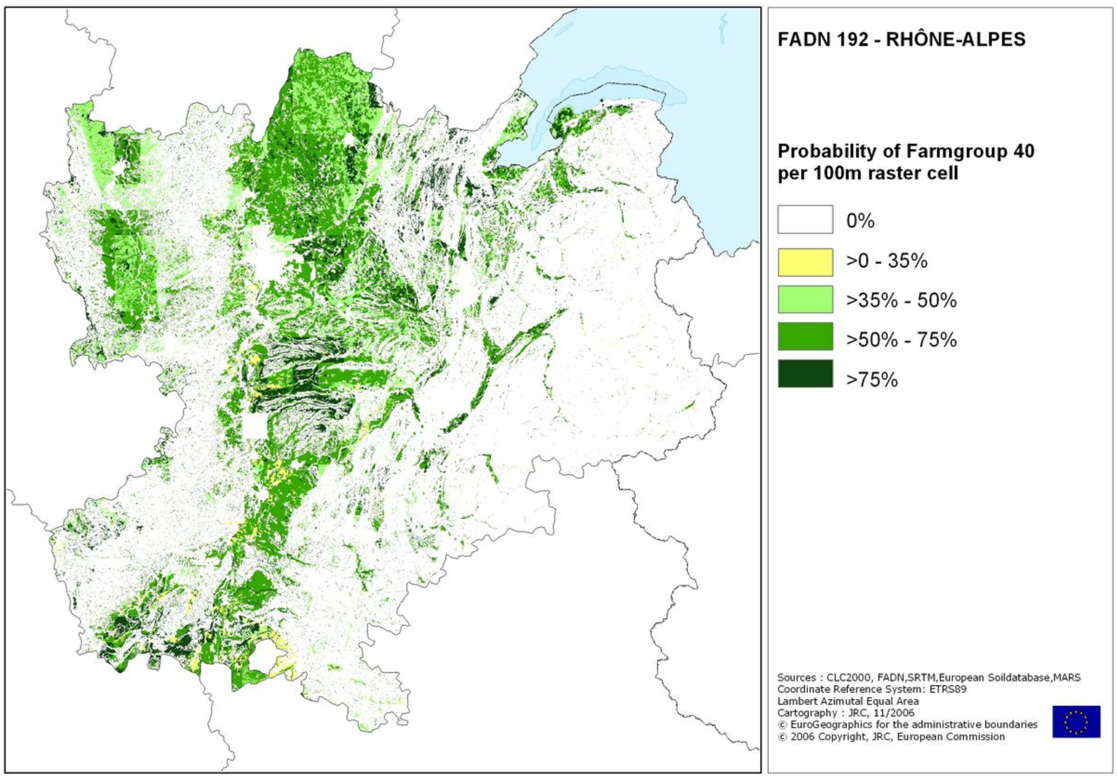

Figure 15.2: Probability map for AROPAj-V1 Farm-Group 40 in Rhône-Alpes.

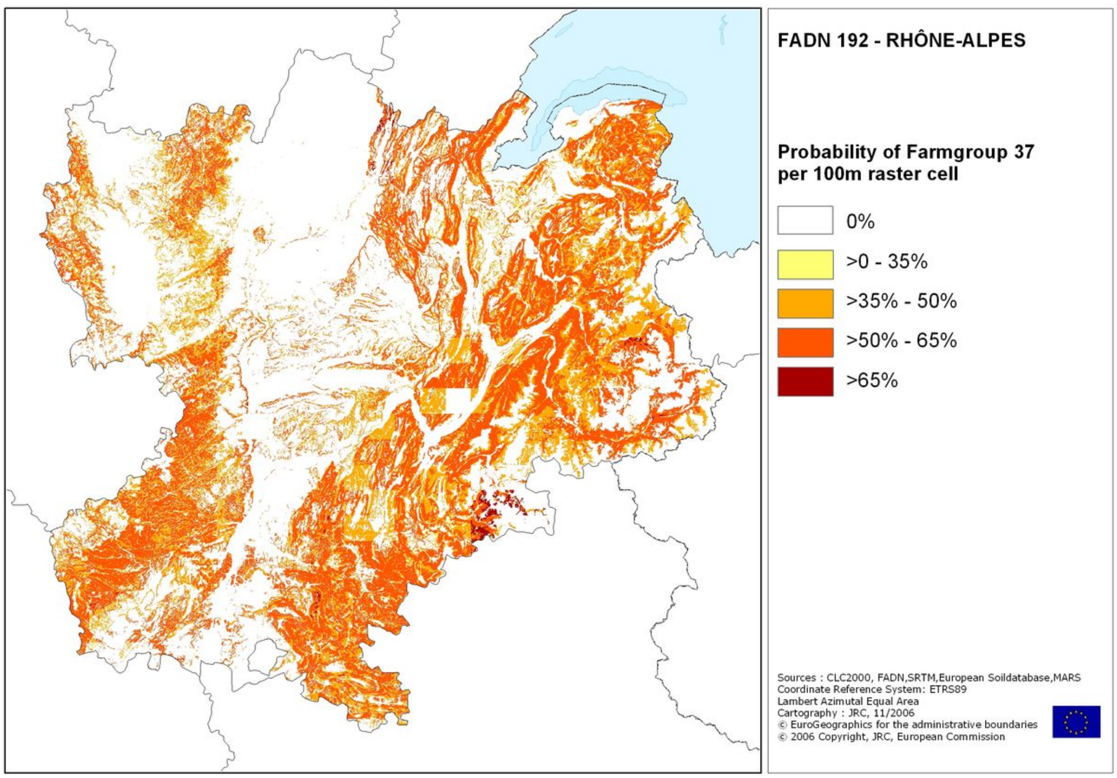

Figure 15.3: Probability map for AROPAj-V1 Farm-Group 37 in Rhône-Alpes.

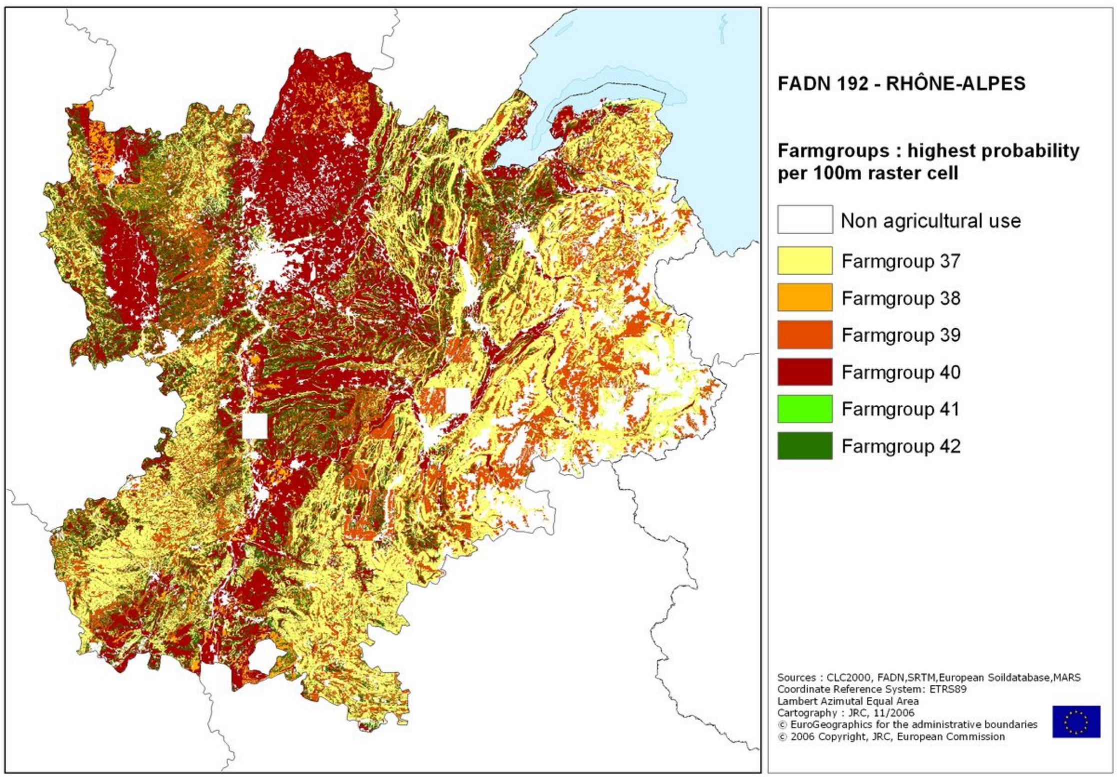

Figure 15.4: Map of the most probable Farm-Groups in Rhône-Alpes.

15.5 Discussion

The proposed method will be used for every FADN region of the European Union. Computing procedures and scripts have been written to facilitate its application.

It is important to note that LUCAS nomenclature simplification, as presented in Table 15.4, should highly depends on the FADN region and should be adapted to all regions specificities (for instance when working on a region producing rise or where olive trees grow).

The resulting map presents some geometric artefacts that can be explained from the resolution of the soil map used in this case, 10kmx10km, while it is now possible to work at a 1x1km resolution (see Annex).

Moreover, there is a large heterogeneity of input data used for disaggregating farm groups and crop production. It is wise to consider that the origin of those artefacts might be found in the limited information available on the relation between the target variable and the co-variables used (see the review of disaggregation methods done by the SENSOR Project (SENSOR, 2006). The selection of those co-variables is based on the availability of datasets covering Europe. They however vary largely in terms of quality and resolution.

On one hand, altitude and slopes are collected and processed at 90 meters resolution and resampled at 100 meters, on the other hand climatic data are generated by interpolation of meteorological measurements at a resolution of 50 x 50 km. In addition, some co-variables have only an influence on steep slopes, like the exposure to sun. Additional datasets are becoming available for all of Europe and could be used for improving the results.

One could as well consider using another approach based on knowledge rules. See in particular the results of the ELPEN project for disaggregating livestock data per grid cell[9], but the proposed approach is largely dependent of expert knowledge and valid for specific geographic areas. There is a risk of loosing the comparability of results through Europe.

15.6 Conclusion and perspectives

The mapping of the AROPAj Farm-groups will be done through the information on surfaces occupied by agricultural activities associated to each farm groups (specific crops cultivation, permanent grassland, etc...). This information is linked to a land cover map and the CORINE Land Cover is the main support to establish this land cover map, and the spatial unit of the dissaggregation will be the 100x100m CLC raster cells. Nevertheless CLC nomenclature being not detailed enough to distinguish some agricultural activities, it is necessary to re-estimate the land cover using data from the LUCAS frame survey and others variables related to the soil, climate, etc...

Thus, say to attribute a land cover category (kind of crop) to each raster cell a process is ran consisting firstly in modelling the land cover with a Multinomial Logit (MNL) and, in a second step, the observed FADN regional land cover shares using a Cross Entropy (CE) approach, taking the MLN predictions (first step) as priors.

Afterwards, the use of superficies data of different agricultural activities for each Farm-group (linked to the 100x100m land cover map) as well as the use of altitude information permits to refer to AROPAj Farm-groups.

To conclude, this method is purely econometric and has the advantages to be fast and quantitative. It will be used on each FADN region of the EU15 (EU25), thanks to a semi-automatic computing procedure.

[9]http://www.macaulay.ac.uk/elpen/index1.htm

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Annex: Datasets

This document gives an overview of datasets that were used in this study.

There is for each dataset a short description as also indications of area coverage and where to find the dataset.

The datasets described are:

1. Corine Land Cover (2000)
2. DEM (SRTM) (2003)
3. FADN (1989-2004)
4. LUCAS2001/2003
5. MARS database (1975-ongoing)
6. SOIL database v2.0 (2006)

Corine Land Cover2000

What?

CORINE = CO-oRdination on INformation of the Environment Land Cover

The CORINE landcover is a geographical database which provides a map of the European environmental landscape based on an interpretation of satellite images. The CLC deals with land cover: the observed physical cover including vegetation (natural or planted) and constructions (buildings, roads…) which cover the surface of the earth. The CLC inventory involves 44 classes covering artificial areas, agricultural areas, forests and semi-natural areas, wetlands and water bodies. The CLC2000 is an update for the reference year 2000 of the first CLC(1990). The mapping scale is 1:100.000.

Area coverage

Available for EU 25 (overseas: only for Spain (Canarias))

Where to find?
http://dataservice.eea.eu.int/dataservice/

DEM (SRTM 2003)

What?
DEM = Digital Elevation Model

A DEM is a representation of the elevation of the terrain by coordinates and numerical descriptions of altitude. The information is stored in a raster format. That is, the map will normally divide the area into rectangular raster-cells and store the elevation of each cell. e.g. the SRTM (NASA Shuttle Radar Topographic Mission) - a 90m DEM-raster - contains the elevation in meters for each 90m cell making up the raster data.

The 100m SRTM is available at the JRC : that is the resampled original 90m SRTM compliant with the recommended INSPIRE guidelines (resampled at 100m, aligned with the proposed reference grid and projected in the ETRS89 Lambert Azimuthal Equal Area (ETRS_LAEA).

Area coverage
Available for EU25 (+ overseas territories)
Where to find?
90m SRTM : http://srtm.csi.cgiar.org/[10]
100m SRTM : JRC-contact

FADN

What?The Accountancy Data Network of the European Union (FADN) has been established since 1965.
The aim of the network is to gather accountancy data from farms for the determination of incomes and business analysis of agricultural holdings.

Currently, the annual sample covers approximately 80.000 holdings. They represent a population of about 5.000.000 farms in the 25 Member States, which cover approximately 90% of the total utilized agricultural area (UAA) and account for more than 90% of the total agricultural production of the Union.

To ensure that this sample reflects the heterogeneity of farming before the sample of farms, Liaison Agencies stratify the field of observation is defined according to 3 criteria: region, economic size and type of farming. Farms are selected in the sample according to a selection plan that guarantees its representativity. An individual weight is applied to each farm in the sample, this corresponding to the number of farms in the 3-way stratification cell of the field of observations divided by the number of farms in the corresponding cell in the sample. This weighting system is used in the calculation of standard results.

The information collected, for each sample farm, concerns approximately 1000 variables transmitted by Liaison Agencies.

These variables described in a Farm Return refer to:

- Physical and structural data, such as location, crop areas, livestock numbers, labour force, etc.

[10] Free data distributed by NASA/USGS, the data quality is very high and the data is consistent all over Europe.

- Economic and financial data, such as the value of production of the different crops, stocks, sales and purchases, production costs, assets, liabilities, production quotas and subsidies, including those connected with the application of CAP measures.

Data at the level of individual farms are not released outside the Directorate General for Agriculture of the Commission. Only aggregated results for a group of farms and for farms within regions and Member States are published.

Data is available from 1989 until 2004.

Area coverageEU25

Where to find?

http://ec.europa.eu/agriculture/rica/index_en.cfm

LUCAS 2001/2003 (Land Use/Cover Area frame Survey)

What?LUCAS is a statistical sample survey observing a sample of the land and not an exhaustive mapping exercise covering all Member States of the European Union.

Area frame sampling has been chosen as statistical sampling method because LUCAS is a multi-purpose information system and needs to cover all the territory of the EU Member States and not only the agriculture area (DELINCÉ 2000, AVIKAINEN et al. 2001).

The sampling design enables the production of area estimates for land cover / land use categories at the European level. The sampling consists of 2 stages: Primary Sampling Units (PSUs) that are cells of a regular grid with a size of 18km by 18km and Secondary Sampling Units (SSUs) that are 10 points regularly distributed (in a rectangular of 1500m by 600m side length) around the centre of each PSU (see figure 1). The sampling results in around 10.000 PSU's all over the EU territory. This number of PSU's has been chosen to optimise the cost structure and the precision at the European level.

LUCAS consists of 2 phases:

· during phase 1 (field survey), data on land cover / land use and environmental features are collected in the field during spring of the year at around 100.000 observation points in Europe;

· phase 2 (interview survey) is concerned with interviewing about 5.000 farmers in autumn of the year to obtain additional technical and environmental information.

The land cover classification is defined in 3 levels of detail with 57 classes at the 3rd level (2nd level: 17 classes; 1st level: 7 classes). Land use is distinguished in 14 classes at the 3rd level.

LUCAS provides the possibility to register multiple land cover and use types to allow classification of specific land cover / use types occurring e.g. in Mediterranean countries (for example olive trees in wheat fields).

Area coverage

LUCAS2001/2003 : EU15

Where to find?

EUROSTAT-contact

http://forum.europa.eu.int/irc/dsis/landstat/info/data/methodology.htm

MARS-database (1975-today)

What?

MARS (Monitoring Agriculture with Remote Sensing)

Meteo data derived from global atmospherical model:

The European MARS meteorological database holds daily measured climatic data for Europe (grid 50x50Km). MARS FOOD regularly receives daily, 10-daily and monthly outputs of the ECMWF (European Centre for Medium-Range Weather Forecast) atmospherical model.

The following parameters can be downloaded from the website:

- average temperature
- maximum temperature
- minimum temperature
- precipitation sum
- evapo-transpiration sum (ES0, bare soil)
- evapo-transpiration sum (E0, over water)
- evapo-transpiration sum (ET0, Penman-Monteith)
- global radiation sum
- average snow depth
- minimum snow depth (not available yet)
- maximum snow depth (not available yet)
- climatic water balance (not available yet)

where the corresponding units are:

- Temperature: Degree Celsius (℃)
- Precipitation: Millimetre (mm)
- Evapo-Transpiration: Millimetre (mm)
- Climatic Water Balance: Millimetre (mm)
- Global Radiation: Watt hours per square metre (Wh/m^2)
- Snow height: Centimetre (cm)

The variables used in this study will be Temperature and Precipitation

Area coverage

Available for EU25 (+ overseas territories)

Where to find?

http://agrifish.jrc.it/marsfood/ecmwf.htm

Soil Database 2006

What?

EU-soil database (ESDB)

The European Soil Database contains 4 discrete datasets:

- the Soil Geographical Database of Eurasia at scale 1:1,000,000 (SGDBE), which is a digitized European soil map and related attributes;
- the PedoTransfer Rules Database (PTRDB) which holds a number of pedotransfer rules which can be applied to the SGDBE;
- the Soil Profile Analytical Database of Europa (SPADBE);
- the Database of Hydraulic Properties of European Soils (HYPRES);

The European Soil Databasev2.0 contains a large number of soil related parameters (73) in raster data files with cell sizes of 10km x 10km. These rasters are in the public domain access and allow expert users to use the data for instance to run soil, water and air related models/pedotransfer rules e.g. Limitation to agricultural use. The 1km x 1km rasters are available after a prior registration.

The database contains a list of Soil Typological Units (**STU**). The STUs represent soil names and are described by variables (attributes) specifying the nature and properties of the soils: for example the texture, the water regime, the stoniness, etc. The geographical representation was chosen at a scale corresponding to the 1:1,000,000.

At this scale, it is not feasible to delineate (trace the shape of) the STUs. Therefore they are grouped into Soil Mapping Units (**SMU**) to form soil associations and to illustrate the functioning of pedological systems within the landscapes. Each SMU corresponds to a part of the mapped territory and as such is represented by one or more polygons in a geometrical dataset.

Area coverage

Available for EU 25

Where to find?

European Soil Bureau: http://eusoils.jrc.it

16 Locating of farm groups linked to the AROPAj typology

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Abstract

We consider that the location of agricultural activities is available, possibly provided by chapter 14 and using different sources of information about land use (FADN, CLC, LUCAS, the BES, ...). We know that FADN provides the average areas devoted to the different crops of the AROPAj farm groups. Combining these two sources of information first leads us to design a method for the spatial location of the AROPAj farm groups. This will be useful for re-locate the crop likelihood when the allocation of the agricultural land is related to any option of the CAP implemented in the AROPAj model.

16.1 Introduction

Numerous and large series of data are available and used by the GENEDEC programme. A lot of micro-economic data are devoted to farming systems on one hand. On the other hand a lot of physical information is also made available through the databses developed and managed by the JRC. These data are provided with territorial linkage through different approaches (ponctual information is provided by LUCAS, covering of the territory is provided by CORINE LAND COVER).

We use a part of these data for the elaboration of the typology of farms, leading to the AROPAj farm groups. This typology is mainly based on the farm types defined by the FADN system, by the synthetic code related to altitude, and by the synthetic criterion which is the normalized economic size. Clustering is made separately inside each FADN Region. We scrupulously respect the rule in the FADN use, when no sub-regional location information is used, and when each farm groups belongs at least fifteen farms in the FADN sample.

In other words we have a large amount of spatialized physical information in one hand. In the other hand economic models based on limited spatial information are designed to assess the impacts of policies. All these data are assumed to be available for the same year. That means the "physical information" is summarized by a "photography" of the agricultural land use. The farm groups delivers an economic structure of the possible linkage between the different agrictural activities taken into account.

Researchers as much as policy makers would like to improve the quality of the outputs when they need to assess the spatial distribution of economic information provided by the models. With respect to the existing right of access and the use of available data, is it possible to design a route for the mapping of economic model outputs which would be something else than fictive homogeneous regional maps.

16.2 Defining and formalizing of the problem

In the whole rest of this chapter we consider that the macro-level of the analysis is the FADN region. Let us consider the I pixels included in one Region, each pixel being characterized by the value of the suffix i. What we propose further should be consistent with possible frontier pixels. Let us consider the J agriculural activities taken account by the economic model, when each activity is denoted by j. Let us consider the K farm groups related to the K AROPAj sub-models which cover the regional agricultural economy.

The starting point is the crop location provided by the chapter 14. We consider that all available physical information is contained by the mapping of agricultural activities summarized by the likelihood $P_{i,j}$. This parameter characterizes the chance in finding of the activity j on the pixel i during the entire observation year. We have :

$$\forall i : 1 \leq i \leq I : \sum_{j=1}^{J} P_{i,j} = 1$$

The calibrating step of the AROPAj model is partly based on the estimates of the area used for the activity j by the farm group k. These estimates are directly provided by the FADN. Let us denote theses areas by $S_{j,k}$. The total land related to the farm group k is $\sum_{j=1}^{J} S_{j,k}$. Let us note that the total land covered by AROPAj (i.e. $\sum_{j,k} S_{j,k}$) generally differs with the total area obtained by the sum of all pixels included in the Region. This is due first to the fact pixels are not quite devoted to agricutral use, second to the fact that AROPAj does not include all agricultural activities (i.e. olive oil) and not all farm types (i.e. farm types "2" and "3" from the FADN typology).

The problem is now defined as following. Let us looking for the likelihood $Q_{i,k}$ of locating the farm group k on the pixel i, with respect to the normalization constraint :

$$\forall i 1 \leq i \leq I : \sum_{k=1}^{K} Q_{i,k} = 1$$

16.3 A feasible solution

We consider the possibility of estimating the location of any farm group k without using of the typology characteristics like the elevation criterion. In addition, we focus on the structure of farm groups which could be expressed by the share of the land among the different acitivities j. That means that intensive animal producers would be less better located.

The undelined idea of this principle is to deliver a location estimate which is closer to the structure of farm groups than to the land use photography.

The proposed solution is now :

$$\forall i : 1 \leq i \leq I : Q_{i,k} = \sum_{j=1}^{J} \frac{P_{i,j} S_{j,k}}{\sum\limits_{k'=1}^{K} S_{j,k'}}$$

It is easy to check that :

$$\forall i 1 \leq i \leq I : \sum_{k=1}^{K} Q_{i,k} = 1$$

That comes imediately when we compute the sum $\sum\limits_{k=1}^{K} Q_{i,k}$ using $\sum\limits_{j=1}^{J} P_{i,j} = 1$ and $\sum\limits_{k'=1}^{K} S_{j,k'}$ which is not dependent of the k index.

16.4 Interpretation and limit

This example is initially set by Raja Chakir. Let us consider a Region shared into four pixels. Two farm groups produce two kinds of agricultural output, wheat ($j = 1$) and maize ($j = 2$).

Let us assume that location of crops is quite homogeneous considering any pixel among the four pixels. More precisely, the three pixels $1, 2, 3$ are devoted to wheat (i.e. $P_{i,1} = 1$ and $P_{i,2} = 0$ for $1 \leq j \leq 3$) and the pixel 4 is entirely devoted to maize (i.e. $P_{4,1} = 0$ and $P_{4,2} = 1$). We assume that the pixel area is normalized to 1 ha.

Table 16.1: Matrix $P_{i,j}$

	wheat ($j = 1$)	maize ($j = 2$)
$i = 1$	1	0
$i = 2$	1	0
$i = 3$	1	0
$i = 4$	0	1

The sharing of land is structurally set such than the farm group $k = 1$ produces wheat on 2 ha and maize on 2/3 ha, and the farm group $k = 2$ produces wheat on 1 ha and maize on 1/3 ha. That gives us the areas $S_{j,k}$ for $j = 1, 2$ and for $k = 1, 2$.

Table 16.2: Matrix $S_{j,k}$

	k	
	1	2
$j = 1$ (wheat)	2	1
$j = 2$ (maize)	2/3	1/3

In this case, the location of farm groups computed by the method proposed above leads to the following mapping of the farm groups (see table 16.3).

Table 16.3: Matrix $Q_{i,k}$

	k	
	1	2
$i = 1$	2/3	1/3
$i = 2$	2/3	1/3
$i = 3$	2/3	1/3
$i = 4$	1/3	2/3

The mapping of any result related to the farm group k has to be spread over the territory proportionaly to the likelihood location $Q_{i,k}$ in any pixel i. Let us consider the output of crop area itself when this output is exactly equal to $S_{j,k}$ (i.e. when the calibrating process leads to the observed areas). The table 16.4 delivers a quite homogeneous sharing of crops over the whole territory, denoted by $T_{i,j}$.

Table 16.4: Matrix Estimated $T_{i,j}$

	wheat ($j = 1$)	maize ($j = 2$)
$i = 1$	3/4	1/4
$i = 2$	3/4	1/4
$i = 3$	3/4	1/4
$i = 4$	3/4	1/4

The matrices $P_{i,j}$ and $T_{i,j}$ are indeed quite different. Nevertheless the result is consistent with the proportionally identical structure of the two farms (3/4 and 1/4 of the land is respectively devoted to wheat and maize). The yearly photography of the land use is transformed in a more structural view of this land use.

Let us turn toward the last example, when the calibrating process leads to something lightly different of the areas estimated through the FADN (see the new matrix $S'_{j,k}$ delivered by the table 16.5).

The matrices giving the likelihood of farm group locating ($Q'_{i,k}$) and the structural likelihood of crop locating ($T'_{j,k}$) are expressed respectively on table 16.6 and table 16.7.

The tiny difference between the two final results delivered by the tables 16.4 and 16.7 expresses well that the regional farming structure and the land use can be taken into account by the method chosen for the farm group locating.

Table 16.5: Matrix $S'_{j,k}$

	k = 1	2
$j = 1$ (wheat)	2	1
$j = 2$ (maize)	1/2	1/2

Table 16.6: Matrix $Q'_{i,k}$

	k = 1	2
$i = 1$	2/3	1/3
$i = 2$	2/3	1/3
$i = 3$	2/3	1/3
$i = 4$	1/2	1/2

The method could be generalized by better using of the locating criterion which contributes to farm cluster. That should require an additional mapping of the 3 digital elevation classes used in the FADN, through the likelihood $E_{i,l}$ delivering the chance to have the digital elevation class l in the pixel i. In the same time we need to define the contribution of the farm group k over the 3 digital elevation classes. A difficulty arises now when we turn back to the FADN. We could be in conflict with the confidentiality restriction set by the Commission, when some farm sub-groups related to specific farming system and related to less than 15 farms of the sample could be clustered.

Finally, due to this restriction and to parcimony and simplicity criteria, we decide to use the method described above in the section 16.3.

16.5 Application of the method

We apply the method of location of farm groups and re-location of crops to the Region Rhônes-Alpes for a cluster of cereals (all cereals except corn). The result is delivered on maps of the figure 16.1. The mapping is based on the matrices P_{ij} and T_{ij} estimated by the methods developed and presented in chapters 14 and 15.

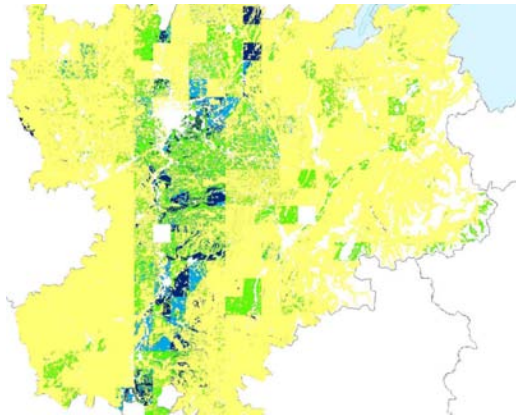
The geometric artefacts appearing on these maps are discussed in the section 15.5 of the chapter 15.

The next and last step of the process would be to apply the re-location of crop likelihood when different CAP options are implemented in the AROPAj model. Some efforts remains in term of computing automation facing to numerous crops and regions. The question of upscaling should

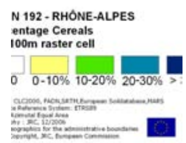
Table 16.7: Matrix Estimated $T'_{i,j}$

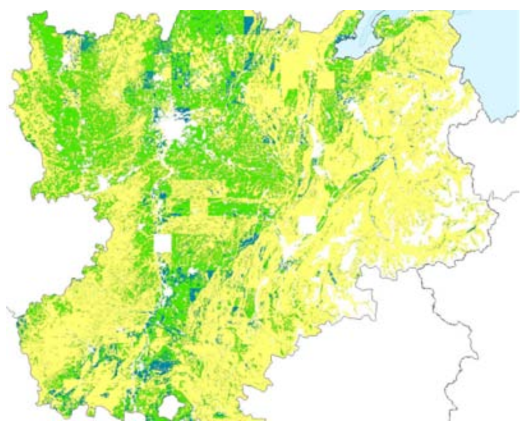
	wheat ($j = 1$)	maize ($j = 2$)
$i = 1$	34/45	11/45
$i = 2$	34/45	11/45
$i = 3$	34/45	11/45
$i = 4$	11/15	4/15

arise when mapping is applied to the member State or the European levels.



Initial location of cereals (P_{ij}, where "j" denotes cereals except corn).





Re-location of cereals based on the AROPAj farm groups (T_{ij}, where "j" denotes cereals except corn).

Figure 16.1: Initial and transformed likelihood mapping of cereals in the Rhône-Alpes region.