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THE EFFECTS OF DECOUPLING ON TWO ITALIAN REGIONS
An Agent-Based Model

Antonello Lobianco

PhD Studies

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PhD Studies **2**

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Contents

1 Introduction

This *Tesi di Dottorato* (Ph.D. Thesis) describes the work done and the results achieved adapting and employing the *Agricultural Policy Simulator* (AgriPoliS) to the Mediterranean context.

AgriPoliS is a spatially explicit modelling framework that underlies an innovative methodology to conceive agriculture as a complex evolving system, made of an heterogeneous set of individual acting “agents” (that is, farmers).

Currently there is a wide interest in agent-based modelling within the scientific comunity. Last year Elsevier published a Handbook of Computational Economics wholly focused on agent-based modelling (Tesfatsion & Kenneth, 2006) and there is a very active development on “toolkits” that help writing multi-agent models (see section 2.3).

This methodology, when applied to agriculture, allows very precise modelling of agricultural policy instruments. However, differently from traditional mathematical programming, it is also able to explicitly take into account the interrelations that exist along the system. For example, farms compete each other on a common pool of resources (land, milk quota..) and if some farms do not “leave” the system, the neighbour farms can’t grow in size.

With AgriPoliS it is generally possible to write models that suit the specificity of the region under study. However adaptation was required in this case as some key characteristics of the Mediterranean agriculture were not implemented in the original AgriPoliS. These include the presence of different soil types, perennial crop productions (mainly wine, olive oil, and fruits), irrigation adoption and quality traits. This adapted model framework (we call it *AgriPoliS::Med*) was then applied to two Mediterranean (Italian) regional cases to simulate the effects of alternative CAP reform scenarios.

This thesis is a development of two working papers already produced along the research activity in AgriPoliS::Med (Lobianco & Esposti, 2006*a*,*b*), with the addition of a theoretical background on agent-based modelling and a closer comparison of our results with those emerging from the works of other authors. Further developments are an analysis of shock effects on some key-parameters of the model (sensitivity analysis) and a more deep evaluation of environmental effects.

This thesis is therefore structured as follows.

Chapter 2 provides a generic background of the multi-agent methodology and the motivations that have lead to its implementation. It firstly exposes the concept of complex systems (section 2.1), and suggests computational simulation as an effective way to model such systems (section 2.2). The chapter continues focusing on the simulation of a sub-category of complex systems, that is social systems, where concepts as *agent behaviours* and *expectations* become crucial. As agent-based modelling is more and more carried out through the support of specialised software packages, in this chapter we included a brief review of them (section 2.3). A focus on the application of agent-based modelling in the agriculture and natural resource domains closes the chapter (section 2.4).

Chapter 3 describes in detail AgriPoliS and it is divided in six sections. The first gives a general overview of the model. Section 3.2 describes the dynamics along the model, that is the set of tasks that individual farms attend on each simulated period. Notably, the simulation tasks are preceded by an initialisation phase that is responsible to set the initial conditions. Section 3.3 details how individual agent behaviours are modelled in AgriPoliS. As farmers take all their decisions (production, investments...) solving Mixer Integer linear Programming (MIP) models, this section also deals with the underlining libraries that AgriPoliS employs to mathematically solve this problems. The following two sections (3.4, 3.5) hold the steps required to write a regional model with AgriPoliS, the former presenting those that are common to any region (not just Mediterranean ones), while the latter describing only the steps required to specifically model Mediterranean regions. Finally section 3.6 presents the subsets of functions added to AgriPoliS for the analysis of environmental effects.

While the chapter 3 describes the model structure, chapter 4 is used to describe the policy analysis performed *using* AgriPoliS::Med. Starting with a description of the characteristics of the Mediterranean agriculture (section 4.1) and the selected case-study regions (section 4.2), the chapter continues with a description of the data sources used in the model (section 4.3) and the description of what we call the “virtual region” we base our simulations (section 4.4). The chapter ends presenting the implementation of the major Common Agricultural Policy (CAP) instruments within the Mediterranean counties (section 4.5) and how this CAP instruments are reflected in the policy scenarios (sec. 4.6).

Simulation results are hence presented and commented in chapter 5. Within this chapter section 5.1 exposes the main results, section 5.2 focus on the environmental results, and section 5.3 provides the reader with some information on the reliability of our results. While in this chapter only main (commented) results are reported, the reader can find a wider set of results in the Appendix (Table A.11).

Finally, chapter 6 concludes.

2 Multi-agent models: a bottom-up approach in analysing complex systems

> *Darwin's theory of evolution by natural selection is satisfying because it shows us a way in which simplicity could change into complexity, how unordered atoms could group themselves into ever more complex patterns until they ended up manufacturing people.*
>
> *(Richard Dawkins, The selfish gene)*

2.1 The issue of complexity

In the common language, the concept of *complexity* is very often confused with those of *complicated*. However "complicated" is composed with the Latin root "plic" (that means "to fold", "to hide") while complexity contain the Latin root "plex" ("to weave"). So complexity by itself has nothing to share with the idea of a difficult to explain, hidden system. Complexity refer instead to a system with many interwoven independent components resulting in a whole that is different from the sum of its parts.

In other words, complicated is the opposite of simple, while complexity is the opposite of independent[1].

Complex systems are often non-linear and highly dynamics - and so hard to model and highly sensitive to initial conditions. Furthermore they all show emerging properties that are non deductable by the observation of their single components: this properties "emerge" instead from the mutual interactions that such parts assume in the system.

Complexity often arise in many real-word systems. A whole issue of *Science* is devoted to present fields of study that had to face with the problem of complexity. Within this issue Goldenfeld & Kadanoff (1999) refer to complexity in physics, pointing on the right observation scale of the problem. In the same issue Arthur (1999) gives a clear introduction of the meaning of complexity applied on economic systems, particularly when we want analise out of equilibrium cases. In his article he observe the fundamental difference between biological and physical systems on

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[1] That's said, many *complex* systems are also *complicated* systems.

one side and economic systems on the other side, that is the presence in the latter systems of individual strategic behaviours.

2.2 Computational simulation

Complex systems are often chaotic, in the meaning that the high sensibility to initial conditions and the high level of dynamics make this kind of systems, that we believe to be deterministic, to seem driven by random forces.

In this context, if an analytical (deductive) description of a complex system is infeasible and a statistical (inductive) analysis is disturbed by the chaotic phenotype of the system, a third way to investigate such systems is through simulation.

With simulation we can define our assumptions on the systems (both in the field of the proprieties of each component of the system and in the properties of their relations) and observe the emerging phenomena that that specific system, derived from rigorously specified set of assumptions is showing (Axelrod & Tesfatsion, 2006).

Today this approach of investigating new phenomena gained advantage of the advancing on elaboration capabilities of modern computers and on expressiveness of modern object-oriented programming languages [2]. On section 2.3 I quote a brief list of toolkits used today to write agent-based models and I describe the parallelism between the concepts of the object-oriented programming language layer and those of the agent-based model layer.

2.2.1 Cellular automata

Cellular Automata (CA) were the first models suited for computational simulation. The concept were invented in the early '50 by von Neumann as models to study self-replication (Neumann, 1966). Since then CA has been widely used to study a very wide array of biological, physical and ecological systems, e.g. cancer cells spread (Ribba et al., 2004), lava flow pattern following eruption (Avolio & Gregorio,

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[2] Referred to the elaboration capabilities, a typical personal computer made in 2006 has a calculation speed 4 time faster than one made in 2000 and 15,000 times greater than one made in 1980 (Wikipedia, 2006*b*). Referring instead to the expressiveness of the programming language, a single line of code of today-language (e.g. C++ or Java) is able to perform a much deeper action than a code using a low-level primitive language (e.g. Assembler). On the great consequences of this second topic see also Berra & Meo (2001) and Judd (2006).

2004) or wildfire propagation (G.A.Trunfio, 2004).

CA are discrete, spatially extended dynamic systems composed of adjacent cells arranged as a multi-dimensional grid. Each cell is characterised by an internal state whose value belongs to a finite set. The state changes according to a transition function that depends on the state of the neighbouring cells and of the cell itself at previous time(s). The system is homogeneous in the sense that each cell has the same rule for updating his state and on most CA models the upgrading of the cells states arise simultaneously.

Game of Life One of the best widely known example of Cellular Automata is the *Game of Life*, invented by John Conway in 1970(Gardner, 1970).

It definitively shows how complex patterns can be produced from interacting cells, even when the rules are very simple.

The game consist of an infinite bi-dimensional grid of squared cells that can assume just two states, namely *live* or *dead.* At each time step each cell "evolves" following this rules:

1. Any live cell with one or no neighbours dies, as if by loneliness;
2. Any live cell with four or more neighbours dies, as if by overpopulation;
3. Any live cell with two or three neighbours survive to the next generation;
4. Any dead cell with exactly three live neighbours comes to life.

The "player" is required to set only the first generation of cells, and then he/she will let the system evolve over time. Depending of the initial state, the system can evolve very differently.

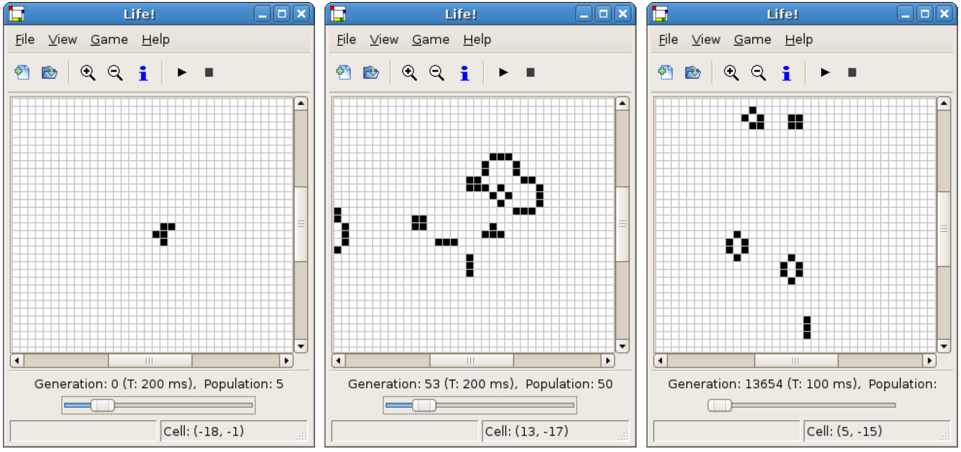
For example Figure 2.1 shows the evolution of a commone figure called *R-pentomino.*

This simple figure evolves in a very complex way, creating a massive sort of new shapes before founding a stable (oscillating) state on step 1103.

Aside from stable patterns it was early found that some initial sets can arise to infinite grow, as it is the case of the so-called *glider-gun* shown on Figure 2.2 (Gosper, 1984).

A list of software for running the Game of Life algorithm is kept in the wikipedia entry (Wikipedia, 2006*a*).

Figure 2.1: Game of Life - *R-pentomino*

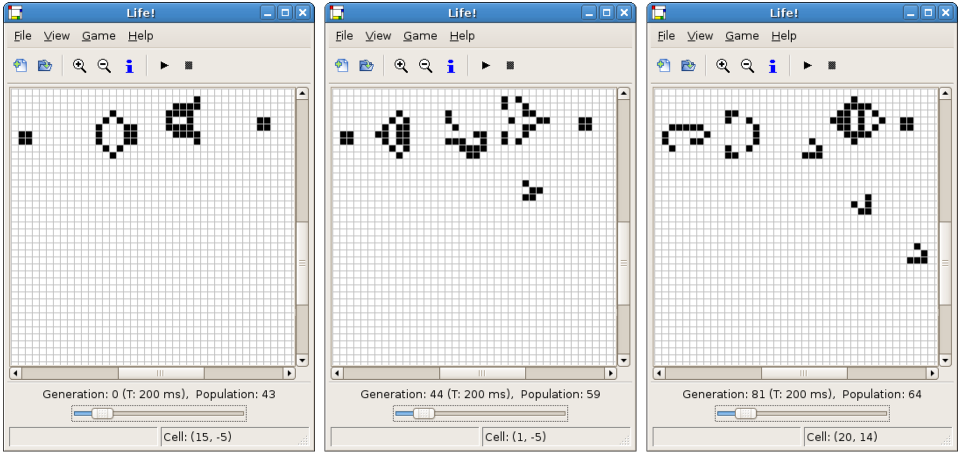


Generation: 0 (T: 200 ms), Population: 5
Cell: (-18, -1)

Generation: 53 (T: 200 ms), Population: 50
Cell: (13, -17)

Generation: 13654 (T: 100 ms), Population:
Cell: (5, -15)

Figure 2.2: Game of Life - *Glider gun*



Generation: 0 (T: 200 ms), Population: 43
Cell: (15, -5)

Generation: 44 (T: 200 ms), Population: 59
Cell: (1, -5)

Generation: 81 (T: 200 ms), Population: 64
Cell: (20, 14)

2.2.2 Modelling behaviours: Agent Based Modelling

Cellular automaton models are very usefull in modelling natural systems, but when the basic "units" of the system do not "simply" react in a mechanical way to exogenous conditions but have heterogeneous goals, are able to learn from the previous experience - and so to adapt and react in a unique way - the system is classified as a *Complex Adaptative Systems* (CAS), the single units of the system are called *Agents* and their modelling *Agent Based Modelling* (ABM).

This is often the case in social sciences. While traditional economical models often assume a normative behavioural foundation of individual action that lead to other strong assumptions like homogeneity, unbounded rationality and convexity, ABM is able to relax this assumptions.

However a new class of problems arise in ABM, like the level of information assumed to be known by the agents and the way agents change their behaviour (Schelling, 1978). As an example on the importance of this issues Bossel & Strobel (1978), in critiquing Meadows et al. (1972) predictions on natural resources shortcomings in her famous World3 model, pointed the failing of the model to include the reacting of the society to the evolving situation (cf. Janssen & Ostrom, 2006).

The way individual agents behave, learn and adapt is the field of study of *Artificial Intelligence* (AI), that apply methodologies like Genetic Algorithms (Holland, 1975; Goldberg, 1989) and Game Theory (Neumann & Morgenstern, 1944; Friedman, 1986).

2.3 Computer aid in model deployment

At the very practical end agent-based models consist almost always of computer code that instructs the machine to build and run the required simulations. As outlined on note 2 modern computer language get advantage of a so called *object-oriented* paradigm. This methodology, that has its opposite in the *procedural programming* paradigm, refer to the idea of writing programs building a series of entities, called *objects*, that embed their proprieties (data) and methods (functions) in one discrete entity. These objects can be hierarchically organised in classes (it can, and usually do, exists more instances of the same object) and they can be designed to hide their own implementation, showing to the "outside world" (the other objects in the code) only a well defined interface that specify what operations that object can do.

The program consist of defining this objects and writing the flow of messages between them.

As it could be inferred, there is a very strong parallelism between the object-oriented computer languages paradigm and the ABM methodology. Agents are typically modelled as objects at the level of the computer code, even if the opposite is not always true, e.g. a land plot is an *object* in the computer code but is not an *agent* in the model. See also Tesfatsion (2006) for an introduction to the object-oriented programming with a special focus on the multi-agent modelling and Stroustrup (1997) for a reference manual of the C++ programming paradigm language.

In a typical usage computer code has to load real-world data, parameters and options, initialise a virtual system based on this data, run a set of simulations (including the not-trivial task of coordinate the agents) and finally provide the results back to the researcher in terms of some sort of output.

As many of this tasks are common in agent-based simulations it came natural that researchers had seek for a way to externalise this routines and concentrate on their modelling task. So a whole set of specialised environments had arisen, that help the researchers to deploy their models quickly. This modelling frameworks are much easier lo learn than a generic programming language, but have neverless their counterside: models written with an ABM framework are generically slower than models written using directly a generic computer language and, above all, all ABM frameworks have some sort of rigidity that constrain the author on the tasks his model can perform.

Neverless it rest to the knowledge of the single researcher to remove such rigidities, as most of this frameworks are released as *open-source* projects, letting free the user to analyse the framework code and eventually add the functionality his model require.

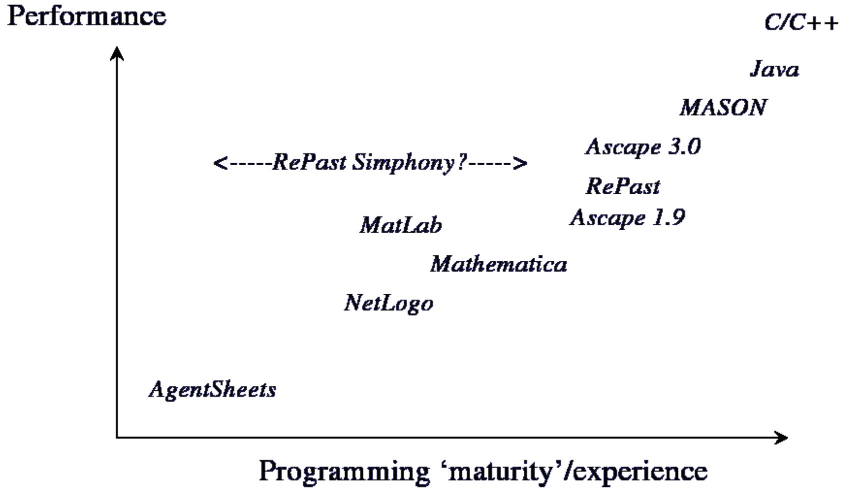
Figure 2.3 arrange some ABM frameworks and generic programming language on a Cartesian plane where the two axis are the performance (run-time speed) and the easy-to-use. However the performance axis could be replaced perfectly with the flexibility of the framework, as those more performants are also the most flexible tools.

One of the oldest ABM framework is Swarm (Minar et al., 1996). Swarm was initially developed at the Santa Fe Institute and it has a huge *community* of users and developers that assure a good assistance to the researchers and the presence of a large asset of third-party modules. It's Achilles' heel is the fact to be coded in Object-C, a quite odd language that is relatively uncommon and slower compared with other computer languages available today.

More recently a fork of Swarm was started to allow models to be coded indifferently in several languages (at present Java, Python and C#). The project got the name Repast from its built-in regression feature, and it get quickly used by a large number of researcher, especially in the economic domain (Collier, 2003).

I finally mention CORMAS, a French ABM framework specialised in natural resources ABM (Bousquet et al., 1998). While the other two cited ABM frameworks can model the space dimension through third-party modules or through researches own written code, CORMAS has spatial modelling embedded in the core system. However it is built with and use Smalltalk, a very old and slow language that confine the usage of this framework mainly in the didactic domain. As example, Castella et al. (2005) have applied a multi-agent model for catching the impact of government policy reforms on farmers' practices and land use in Vietnam using CORMAS. However they applied the model over a grid of only 50x50 cells, that seems really insufficient to catch the heterogeneity of the farmers.

Figure 2.3: Performance VS easiness of some ABM frameworks and generic programming languages



Source: Axtell (2006)

The model described in this dissertation, AgriPoliS::Med, do not use any third-party frameworks, and it is coded in C++. This was chosen for the limitations just described above. AgriPoliS::Med has a very deep modelling of the farm activities, and no ABM toolkit had the flexibility and the computational speed required.

2.3.1 Geographical Information Systems and Agent-based models frameworks

While some frameworks have some sort of spatial dimension, or it is possible to implement it any-how within the model's own code, unfortunately we still miss the opportunity to link existing agent-based computational laboratories with generic Geographical Information Systems (GIS) capabilities (Dibble, 2006).

It is not just a matter of loading spatially-explicit data or displaying results, but it is rather a matter of performing the spatial analysis GIS are very well designed to handle.

As example, Boero (2006*b*) proposes a spatially explicit agent-based model of Industrial Districts (IDs) in an Italian region, but he considered the distance over the spatial dimension as the physical distance between the various agents locations. A GIS would have let him to calculate the distance according to one or more layers of network facilities (e.g. roads for human resources and railways for heavy products).

A GIS within the model can also help the agents to increase their sensitivity information, e.g. "how much of X is within distance Y?" (buffering) or "which and where are the biggest uninterrupted instances of element X?"(islands)

The necessity to better combine agent-based models (or toolkits) with current GIS is also recognised by An (2005). In their paper they report that they had to re-code readily usable GIS functionality in their model and had to export model outcomes to GIS for further spatial analysis. Parker (2004) provides a review of current GIS integration in ABM toolkits. This integration however is mostly limited to Input/Output of data and visualisation.

To read more about the current status of the GIS-ABM coupling I suggest the recent paper of Castle and Crooks (Castle & Crooks, 2006).

2.4 ABM in agriculture and natural resources economics

While agent-based modelling is now largely used in general economic models, and in particular in the finance and market domains (see Hommes 2006; LeBaron 2006 and Marks 2006; MacKie-Mason & Wellman 2006 for recent surveys of several models) in the field of natural resources economics agent-based literature is still relatively scarce. The main challenge here is the need of combining the modelling of proper individual behaviours for the social part with the modelling of explicit spatial dimension for the ecological part.

Boero (2006*a*), reviewing a set of three books on this topic, points to the necessity of considering all the emergence properties economics are used to consider along the temporal dimension (e.g. equilibrium, bifurcations, self-organisation) also along the spatial dimension. Parker (2003) has review several ABM applications involving land use changes in various scientific areas, including agricultural economics, natural resource management, archaeology and urban simulation.

Spatial explicit ABM usage within the agricultural context was pioneered by Balmann (1997) with the AgriPoliS model. Berger (2001) refined the Balmann work with focus on technology adoption and irrigation.

Later on Balmann & Happe (2000) adapted AgriPoliS using a Genetic Algorithms in simulating farmers behaviours in the land renting market.

Directly derived form Happe's PhD thesis, Happe et al. (2004) describes in detail AgriPoliS. Its focus is on the methodological advantage of using ABM in agriculture as compared with other instruments as partial and general equilibrium model on one side and individual farm-level models on the other.

ABM has the benefit of catching the fundamental behaviour at the micro-level of the individuals farms, without the need of aggregating them in "representative" agents. Maybe even more important, ABM is the only tool that can catch the iterations of the heterogeneous farms when they deal with competition over common finite resources, e.g. land.

The Balmann/Happe model is spatially explicit, a characteristic that can not be neglected when modelling the agricultural sector. For example the spatial heterogeneity allows the model to associate on each plot a different rental price and investigate possible land abandonment phenomenas even when the land is *on average* profitable.

3 The improved AgriPoliS model

3.1 AgriPoliS: an overview

AgriPoliS is a multi-agent model framework, spatially explicit, developed in C++ language from mid '90s[3]. With AgriPoliS it is possible to write Mixed Integer linear Programming (MIP) models that suit the specificity of the region under study.

Simulations along this thesis are generated using AgriPollis::Med which is an improvement of AgriPoliS to cover specific issues of Mediterranean agriculture (see. section 3.5).

AgriPoliS allows to model heterogeneous farms behaviours under various external situations (typically, under different policy scenarios) and observe regional results by aggregating these micro-level behaviours.

In AgriPoliS agents are mainly farmers[4]. They have their own goals; in AgriPoliS, the farmer's objective is the maximisation of household income. To achieve this objective, farmers solve a MIP problem that, in some aspects, is specific for each farmer. Outside the linear programming problem, they can also decide to rent other agricultural plots or to release rented land.

AgriPoliS uses a mixed integer linear programming approach to simulate each agent behaviour. On the one hand, this approach is very flexible, as it can cover the whole range of farm activities, from growing specific crops to investing in new machinery or hiring new labour units. Furthermore, it is simple to add new regional-specific activities.

On the other hand, however, linear programming techniques require a long calibration phase to assure a balanced choice of farm activities, avoiding unrealistic outcomes.

Any farmer in the model is a real farmer whose data are taken from the FADN

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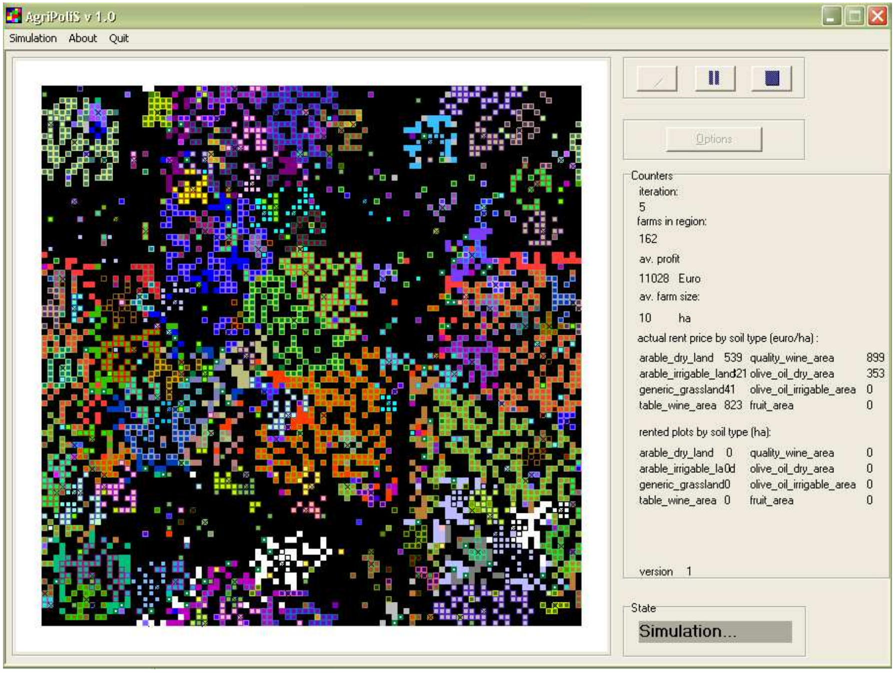
[3] Detailed information on AgriPoliS can be found on (Happe et al., 2004; K. Happe & Balmann, 2006) or (Sahrbacher et al., 2005).

[4] Other agents in the model perform some specific tasks, e.g. managing land or coordinating product markets.

Figure 3.1: Example of an AgriPoliS Screenshot



```
Counters
 iteration:
 5
 farms in region:
 162
 av. profit
 11028  Euro
 av. farm size:
 10      ha
 actual rent price by soil type (euro/ha) :
 arable_dry_land   539  quality_wine_area         899
 arable_irrigable_land21 olive_oil_dry_area       353
 generic_grassland41    olive_oil_irrigable_area  0
 table_wine_area  823  fruit_area                 0

 rented plots by soil type (ha):
 arable_dry_land   0    quality_wine_area         0
 arable_irrigable_la0d  olive_oil_dry_area        0
 generic_grassland0     olive_oil_irrigable_area  0
 table_wine_area  0     fruit_area                0

 version  1
State
 Simulation...
```

dataset and explicitly associated to a spatial location. Due to privacy-protection regulations, however, we don't have access to the real farm localisation. Therefore, we have to distribute farms randomly in the virtual region. Space (i.e. location) is important in the model because it influences transport costs and indirectly makes the farmers interact each other, e.g. by competing for the same land plots. Figure 3.1 is a screenshot of a simulation carried out Marche region data where each pixel is a plot of the "virtual region" and each "colour" identifies a distinct farm, black being "not agricultural area".

Using this multi-agent approach, AgriPoliS is able to represent the regional agricultural structure as a complex evolving system. Each farmer has its own factor endowment, but farmers also differ in terms of age, spatial location and capacity, that is a "managerial coefficient" representing the heterogeneous farmer managerial abilities.

3.2 Model dynamics

The first step of the program is the initialisation of the environment that will "host" the agents. It means to establish which are the available activities, investment possibilities and soil types. The relationship between these items must also be initialised, thus defining the structure of the linear programming matrices available to farmers.

Once the "environment" is established, agents can be initialised too. This second step involves the identification of the heterogeneous agents: allocate resources to them, define their age, as well as the vintage of their assets. Farms must also be localised in the region and plots must be assigned to them. The final initialisation step is to assign the managerial coefficient to farmers.

Most data requested by these steps are collected from FADN (Farm Accountancy Data Network), both in terms of aggregated data (used to calculate the coefficients) and in terms of single-farm records (used to initialise the agents through an upscaling process that will be described below), while some data (farmers geo-localisation, vintages, managerial coefficients) is randomised within appropriate bounds.

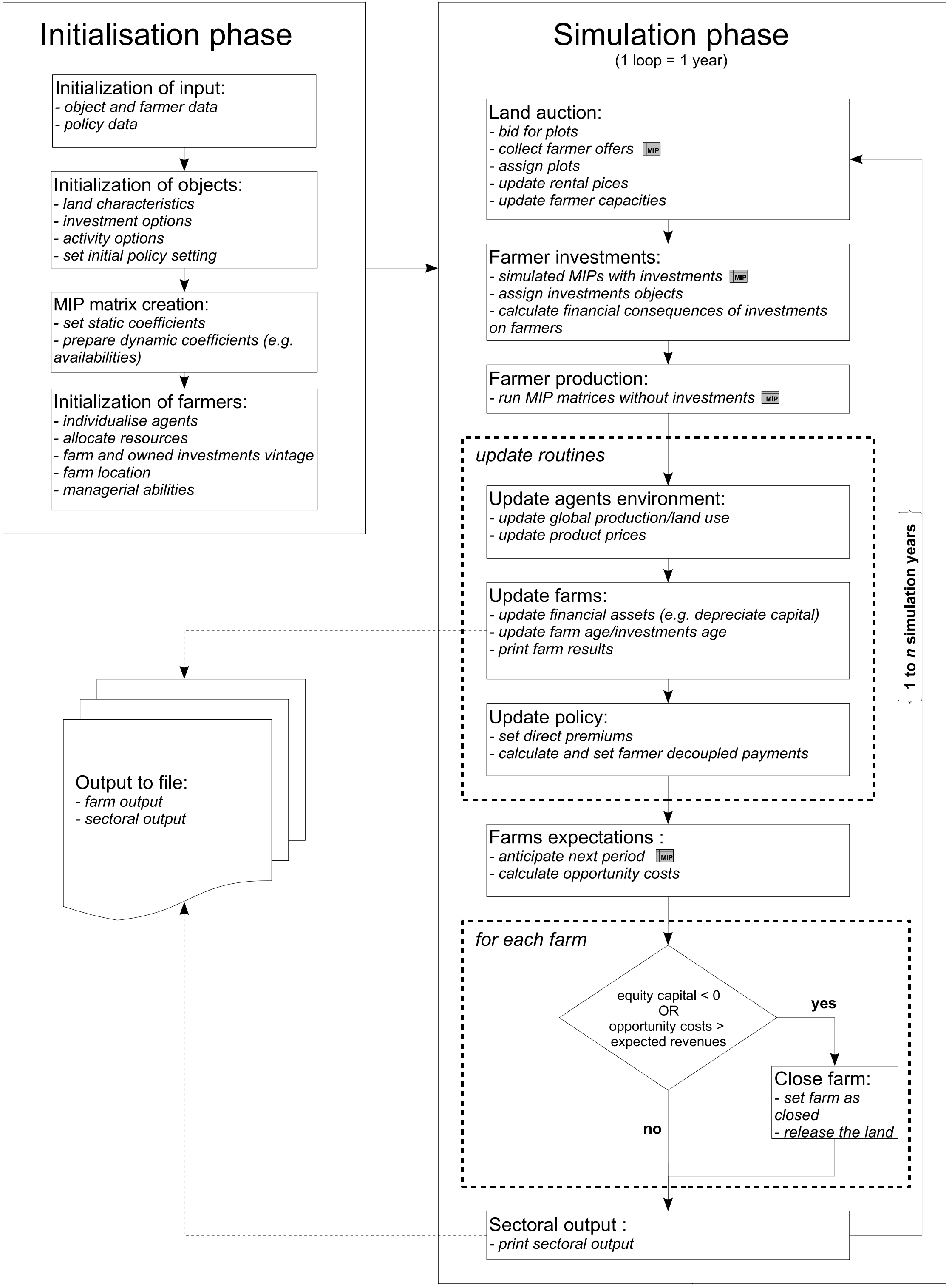
After the initialisation phase is concluded, simulations can be run for the requested years. The reference period for each simulation loop is one year. This is also the assumed perspective of the farmers, that are unable to consider any longer period in their planning activities. However, due to the presence of investments, mid and long-term investment decisions have to be adapted to this limited perspective. Each loop performs the operations described in Figure 3.2, also allowing farmers to rent new land, to invest, to produce and finally to decide whether to remain in the business or to leave the sector. Specific routines are also executed to update the agent environment, the farm attributes and the policy relevant variables. An example of these functions is updating the asset vintage until it is eventually dismissed whenever overpasses its lifetime. The model is written in C++ language, an object-oriented language capable of representing complex structures in a nearly natural way.

A full description of AgriPoliS dynamic is in Happe & Balmann (2005).

3.3 Agent behaviour

Farmers autonomously make their decisions solving a MIP problem as shown in Figure 3.3. Symbol MIP in Figure 3.2 denotes a step in the model when one or more MIP problems have to be computed at the farm level. This happens any time farmers bid for renting a land plot in order to calculate its shadow price, or plan new investments, or produce using the given assets or, finally, anticipate the

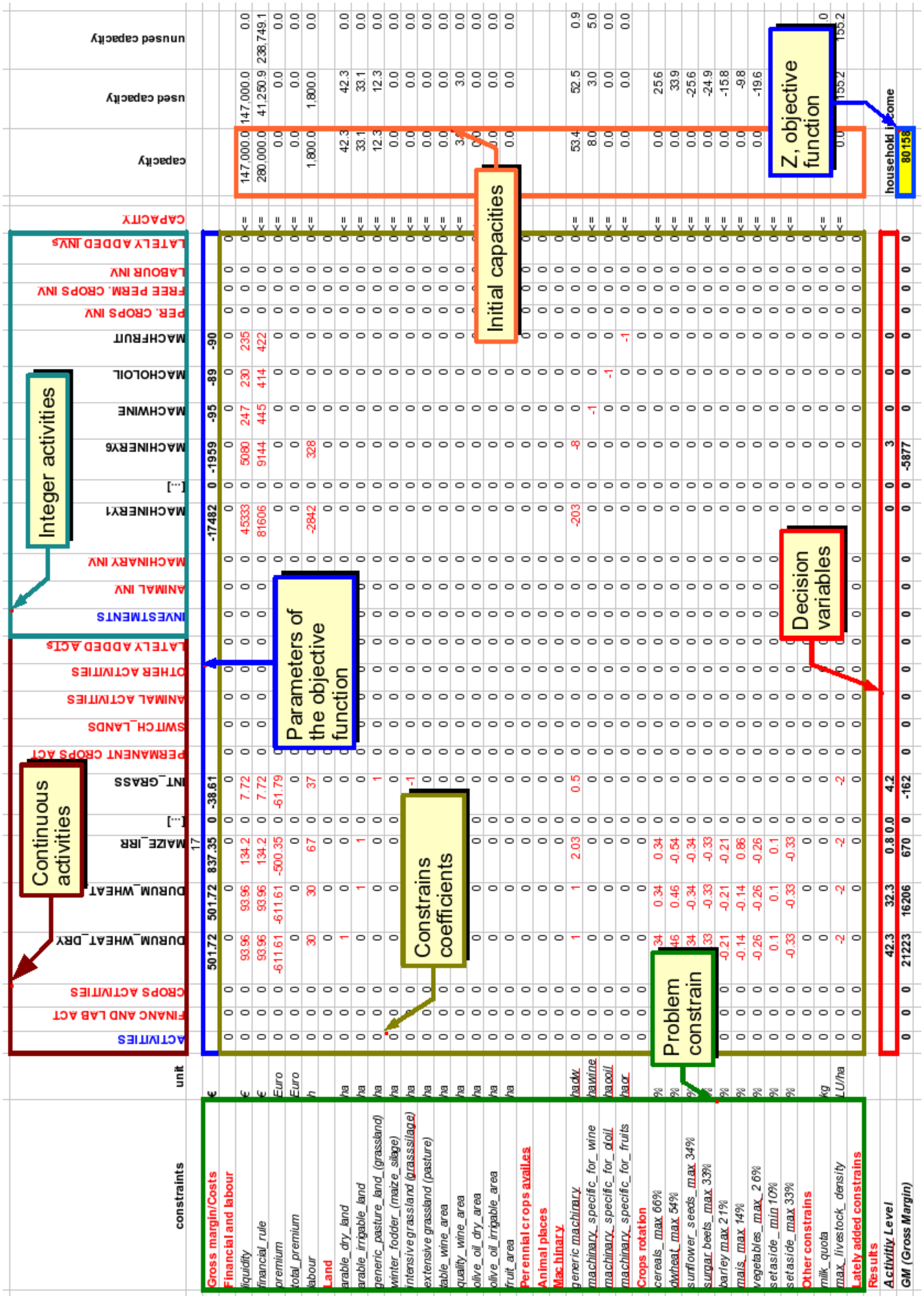
Figure 3.2: AgriPoliS model dynamics



Source: Our elaboration on Sahrbacher et al. (2005)

following period.

Figure 3.3: Mixed integer matrix



From FADN data we can establish the initial farm's endowment: financial assets, availability of land, machinery, animals and so on. From a linear programming point of view, these data represent the right terms of the constrain equations. Any farmer choose from a list of activity options. We divide them in two categories: activities that can be run entirely within one year and activities that generate results over multiple years (investments). The decision variables are the quantity of these activities the farmer actually implement, once the problem is solved. Investments are bounded to be integer and the same investment type is available in different size-options, allowing scale-effects to emerge in the model. As the farm objective is the maximisation of household income, the parameters of the objective functions are the gross margins of the various activities. Both available resources and activity gross margins differ across farms. While the former is obvious, the latter is a consequence of the heterogeneous managerial coefficients. The matrix of the constraint coefficients links the available activities with their technical requirements. This matrix is initialised in the model initialisation phase, and it is the only part of the MIP that is fixed across farms and over time.

AgriPoliS can also take into account changes of resource endowment and activity gross margins, generated either endogenously to the MIP core, in case these changes occur as a consequence of the solving procedure (e.g., an investment improves the number of available activities) or exogenously to it, in case these changes occur in other parts of the model (e.g., renting/releasing land, or as a consequence of market prices changes).

Paris (1991); Arfini (2000) present respectively an in-deep analytical description and a literature review of linear programming techniques applied to farm problems.

3.3.1 Solution of the MIP problems

In AgriPoliS MIP problems have to be computed for each individual farm and in several steps during each simulated period, resulting in levels of thousands computations for period. It follows that the speed of the solving algorithm become a critical factor. In both regions the matrices are relatively large (Table 3.1), however they are very sparse allowing specialised software to solve the problems in terms of fractions of second.

In fact, AgriPoliS use external libraries to solve this problems. AgriPoliS class **RegLpInfo()** is responsible to establish the direction of the objective function (in our case, a maximisation), the set of bounds, objective coefficients and constrain coefficients. At this point the problem "object" is solved calling an external Dynamically Linked Library (DLL).

In steps requiring investment decisions, information about integer variables are added to the problem and this is solved again using the appropriate algorithm provided by the DLL.

AgriPoliS originally used the Frontline Systems Solver DLL (Frontline, 2006) that employs the Simplex method (that is guaranteed to find the optimal solution, if one exist) in conjunction with a Branch & Bound method when a mixed integer optimisation is required. In 2005 we switched to the open-source GNU Linear Programming Kit (GLPK) V. 4.10 (Makhorin, 2007) as our benchmarks proved it to be substantially faster while providing consistent results.

Similarly to the Frontline DLL, GLPK utilises a two-phase revised Simplex method to retrieve continuous solutions, and then apply a Branch & Bound method in case of integer optimisation. GLPK recently added an interior-point algorithm, but we found it to be still too unstable at that time. Both Frontline and GLPK report with an error message impossible solutions (e.g. due to constrains conflicts or unbounded solutions), but while the former do not force the main program (AgriPoliS) to stop, the latter do it, resulting very useful during debugging stage as it guarantees that each problem is correctly solved.

Table 3.1: MIP problem - matrix dimensions

	Colli Esini	Piana di Sibari
Activities:	67	88
- *perennial crops farm activities*	4	5
- *perennial crops investments*	4	5
- *perennial crops spec. machinery*	3	3
- *perennial crops land to oth. land switches*	5	5
Constrains:	41	41

3.4 Regional modelling in AgriPoliS

3.4.1 Regional selection and upscaling

The first step in developing a regional model with AgriPoliS is the choice of a convenient area depending on the modelling purposes. From this region, some tens of "typical farms" are selected and any of them is multiplied by a scaling coefficient to obtain a virtual region. This virtual region contains only typical farms, but its aggregate values are as close as possible to the real one. A 0-coefficient means that the farm is not selected, while a non-0 coefficient implies that the farm becomes one of the typical farms of our virtual region. The key point is to find these scaling coefficients that minimise the difference between the virtual region and the real one. This modelling stage is called "upscaling" and it is well documented in Sahrbacher et al. (2005). There are some specific requirements for a real region to be suitable for AgriPoliS:

- Internal homogeneity: AgriPoliS randomly assigns the location of the selected farms within the virtual area and technical coefficients are constant among them. Thus, to generate realistic simulations, we have to keep the variance of productivity as small as possible within the same soil type in the region.

- Number of FADN farms (farm level data requirement): As we use FADN data to select the typical farms, as well to calculate some technical coefficients, we need a great enough number of observations (FADN farms) within the selected region.

- Available regional agricultural statistics: these data are needed to calibrate the upscaling stage with respect to the "real world".

3.4.2 Technical and economic parameters

AgriPoliS allows farmers to choose among a large amount of crop and animal activities. For each crop activity, six parameters have to be exogenously defined within the model: direct cost*, direct revenue*, direct premium*, machinery requirement, labour requirement and crop rotation constraint. The asterisk denotes parameters that, though initially exogenous, have some function within AgriPoliS possibly affecting them, thus making them endogenous. Costs, revenues and premiums are calculated from FADN data:

$$\{cost, revenue, premium\}_{R,p} = \frac{\sum_{i=1}^{n_p} \{cost, revenue, premium\}_{i,p}}{\sum_{i=1}^{n_p} area_{i,p}} \tag{3.1}$$

where R indicates the region, p the product (activity) and i the individual farm; n_p is the number of farms producing p in the FADN dataset.

In AgriPoliS the machinery requirements to grow the various crops are expressed as an index where the durum wheat requirement is fixed to 1; thus, for example, the machinery level required for vegetables is 2.5, that is two and half times the durum wheat requirement. Data in this respect have been collected from bibliographical sources. Agri-services are also admitted and expressed as units of machinery. Labour requirements are also derived from bibliographical available information, but we integrate them with *ad hoc* assumptions when data are not available (as in the case of some irrigated crops), and we calibrate them running single year simulations. Crop rotation constraints define the upper limit that any particular crop activity can reach on a farm level. Though expression of technical and physical aspects, these constraints are empirically derived from FADN data.

For animals activities, we have neither machinery requirements nor crop rotation constrains. However, we must calculate additional technical parameters: the feeding balance and the livestock units used in the livestock density constraints. With respect to the feeding balance, we assume that forage is exclusively produced within the farm and not traded. In order to provide enough feed to animals, the farmer can allocate the available arable land and grassland to different forage activities like maize silage, intensive grassland or pasture. Thus, the farmer must determine how much land allocated to these activities can actually internally satisfy the feed requirements of the various types of animals. The sub-matrix of relevant coefficients of animal feed requirements is provided on Table 3.2.

To calculate coefficients $c_{0,0} \dots c_{2,3} \dots c_{c,a}$, expressed in hectares, we need four different information: first the overall quantity of feed that each kind of animal requires, expressed in AUE [5]. Then, as the energy requested by animals can be provided utilising various sources (e.g. pasture or silage), we need to know how the share of different kinds of feed is combined to satisfy the animal requirements in that specific region. While the total energy requirement by each animal type is relatively constant, the specific composition of their diet can be quite different among regions as it is partially influenced by the resources that are locally available. Finally, on a crop side, we need to know the average yield [ton/ha] and the AUE

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[5] AUE stand for Animal Unit Equivalent, a standard animal forage requirement measure

Table 3.2: Sub-matrix on animal feeding requirements (ha)

	[...]	CROPS_SILAGE_DRY	CROPS_SILAGE_DRY_IL	INT_GRASS	EXT_GRASS	[...]	BEEF_CATTLE	SUCKLER_COWS	DAIRY	OVINS	[...]
[...]											
arable_dry_land		1									
arable_irrigable_land			1								
generic_pasture_land				1	1						
- *winter_fodder* *(maize silage)*		-1	-1				$C_{0,0}$	$C_{0,1}$	$C_{0,2}$	$C_{0,3}$	
- *intensive_ grassland* *(grassilage)*				-1			$C_{1,0}$	$C_{1,1}$	$C_{1,2}$	$C_{1,3}$	
- *extensive_ grassland* *(pasture)*					-1		$C_{2,0}$	$C_{2,1}$	$C_{2,2}$	$C_{2,3}$	
[...]											

concentration [AUE/ton] of available forage activities to calculate the area required to feed a single animal:

$$c_{c,a} = \frac{ReqAUE_a * AUEAllocation_{c,a}}{yield_c * EP_c} \tag{3.2}$$

where:

$c_{c,a}$ = requested area (ha) of crop activity c for animal a;

$ReqAUE_a$ = avg. requested Animal Unit Equivalent (AUE) for animal a (source: bibliography);

$AUEAllocation_{c,a}$ = proportion of animal a AUE requirements obtained from crop c (source: our assumption on the base of the regional characteristics);

$yield_c$ = avg. crop c yield (ton/AUE) (source: calculated from FADN);

EP_c = crop c AUE equivalent (AUE/ton) (source: bibliography).

3.4.3 Investments

Investments for new stables are special activities associated to livestock productions. Stables are modelled assuming fixed lifetime and maintenance costs. Their gross margin is always negative, that is just the costs they generate, but they are mandatory to perform livestock activities: for an animal production to be available at least one stable must be available. In AgriPoliS, new stable investments, as well all investments, are bounded integer, allowing scale effects over different size-options. To keep investment decisions consistent with the production matrix, all associated costs are annualised and a "financial rule" is established, as a constraint, to avoid over-investments (Sahrbacher et al., 2005; Happe et al., 2004).

For each investment AgriPoliS identifies five coefficients: *investment capacity, working hours per unit, investment costs, maintenance costs* and *useful life.* Investment capacity defines the size of the investment. We establish six investment-size options for each type of stable. Five of them are obtained running a 5-kmeans cluster analysis on FADN data. The remaining one is set at a 20% higher capacity than the fifth size-option to provide a further option for farms that would eventually increase their size during simulations. Labour requirement is initially set only for the investment size that is prevalent in the region. This value is taken from bibliographical references about the associated livestock activity. Then, a bigger size investments is assumed to have lower labour requirements, while smaller-than-average stables are modelled to be more labour intensive. AgriPoliS does not differentiate among labour types. Therefore, the labour-saving effect of the bigger size is modelled as a *release* of labour. Thus, many farmers could have financial resources to acquire bigger investments and, then, would release labour units for other unrelated activities. Investment coefficients about labour use thus require a careful calibration to take into account such consequences.

Machinery investments are quite similar to new stables, as they are activities sharing the same design: different size-options, negative gross margins and profitable mandatory associated activities. They are annualised to be consistent with one-year activities when the model runs, and they need the same types of investment coefficients than stables. We selected the typical capacity parameters running a cluster analysis on the farm asset data available in our FADN dataset.

Machinery is required to run all the crop activities (including permanent crops) but not for animal activities, where possible machinery costs are already included in the whole stable costs.

3.5 Specific Mediterranean issues: AgriPoliS::Med

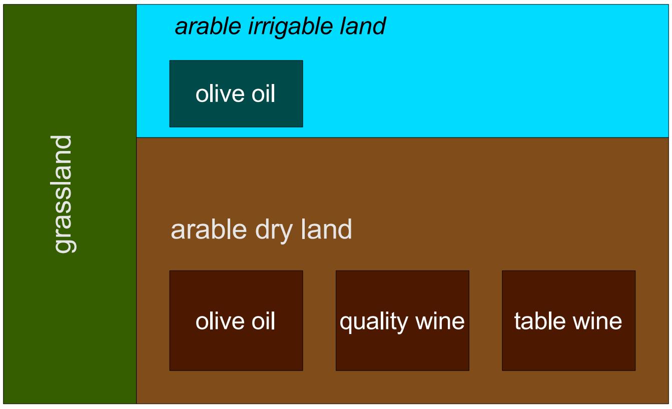
According to the IDEMA workplan, a specific Mediterranean extension of AgriPoliS has been created; we call it AgriPoliS::Med.

With respect to AgriPoliS, AgriPoliS::Med also models some specific characters of Mediterranean agriculture, specifically wide heterogeneity and inclusion of perennial crops like wine grapes, olives and fruits. In this section, we describe how we adapt the model to these specific characteristics of the Mediterranean context. In some cases, like the introduction of different soil types or the calculation of financial indicators related to perennial crops, it is necessary to change the *source code* of AgriPoliS; in others cases, like the introduction of irrigation and quality differentiation, we have only to change the input data read by the model.

3.5.1 Land use

One main limitation of the original AgriPoliS, when applied within the Mediterranean context, is the presence of only two soil types, arable land and grass land. This makes the model unsuitable to represent the high heterogeneity of Mediterranean agriculture. Thus, AgriPoliS::Med allows an arbitrary number of soil types to enter the model; the actual version includes seven soil types. Rather than classified on the base of their physical, chemical or ecological features, we distinguish soil types according to their practical use. Consistently with the original model, soils are initially divided in arable and grassland. Then, we further differentiate arable land according to two criteria: irrigable or not irrigable land (a critical question for many Mediterranean products); suitable or not suitable land for perennial crops. Land available for irrigable and perennial crops is hence fixed in the model; but farmers can temporarily choose to allocate this available land to annual dry crops. Figure 3.4 shows this basic soil classification. With respect to AgriPoliS, AgriPoliS::Med also extends the plot size options, as plots smaller than 1ha are admitted to take into account the typical presence, in the Mediterranean context, of many very small family farms.

Figure 3.4: Soil types in AgriPoliS::Med



3.5.2 Quality differentiation

As mentioned above, mainly due to different soil and climate conditions, Mediterranean agriculture is highly heterogeneous in terms of product quality. Among the modelled activities, we consider wine as the product with the largest differentiation both in the production process and in the final product. We distinguish between grapes for table wine and grapes for "Quality Wines Produced in Specified Regions" (Quality Wines PSR or VQPRD). In this case, the main difference from the farmer point of view is the location of vineyards: only those located within a well-defined area can produce grapes for a specific quality wine. Once this spatial constraint is satisfied, other requirements have to be satisfied to produce such wines. However, each quality wine has its own very detailed rules and prescriptions. We can not explicitly model all of them. Nonetheless, FADN records allow to model this different quality of wine in terms of different yields, revenues and costs. Based on FADN data and sectoral bibliography, we also admit different parameters in terms of machinery and labour requirements for the two categories.

Furthermore, plots within Quality Wines PSR areas are allowed to have different rental prices and a different impact on the farm financial endowments. While asset values are taken from national statistics, rental prices are endogenous in the model, as they derive from the competition between farmers on the land market.[6]

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[6] AgriPoliS however needs a set of initial values that are usually collected from national statistics.

3.5.3 Irrigation

Unlike quality differentiation, irrigation doesn't influence the final product but strongly changes the production main parameters, that is, costs, labour requirements and yields. We use FADN and census data to distinguish among three categories of products: those cropped on dry land, those that can be cultivated either on dry or on irrigated land, and, finally, those usually grown only on irrigated land. At regional level, we have information only on irrigable land, not on irrigated land. However, the model admits that farmers may grow dry products either on dry or on irrigable land. In this latter case farmers choose to not irrigate their irrigable land. Thus, we can use available data to calibrate and run the model and to simulate different water usage according to different policies. The complete matrix of irrigation options for the various crops is reported in Figure 3.3.

3.5.4 Perennial crop investments

In AgriPoliS::Med, the major adjustment with respect to the original AgriPoliS model concerns perennial crops. Their modelling requires strong modification of how investment objects and investment decisions are included in AgriPoliS. In particular, new stables and machinery investments are modelled in AgriPoliS according to several hypotheses that can not be maintained in the case of perennial crops investments: firstly, they do promptly become productive and then they maintain the same productivity level from the first year till the end of the asset useful life; secondly, the financial implications of these investments it is simply derived by modelling an initial cost for the investment, partially funded with debt capital, and then assuming a fixed maintenance cost; finally, they are modelled with a punctual localisation of these assets in the farm, thus avoiding any link between the investment objects and the agricultural plots.

Methodological issues in mathematically modeling perennial crops, including multi-period, replanting decisions, *risk minimisation vs profit maximisation* trade-off, has been investigated in Cembalo (2002). However, the current AgriPoliS design makes difficult to deal with all these issues without imposing strong and even unaffordable computational requirements. For example, fully linking plots with new plants also differentiating between owned and rented land would require the introduction of many more activity options and resources in the MIP. Thus, on all these aspects, a compromise has been found between the need of a proper

Table 3.3: Irrigation options for all available product

	dry on dry land	dry on irrigable land	irrigated	FADN DATA (percentual points)			
				Colli Esini (Marche)	*irrigated*	Piana di Sibari (Calabria)	*irrigated*
Durum wheat	x	x		47.8	*0.2*	20.5	*2.3*
Soft wheat	x	x		0.3	*0.0*	4.1	*0.0*
Sugar beets	x	x		12.7	*2.3*	0.0	*0.0*
Sunflower seeds	x	x		12.0	*0.0*	0.0	*0.0*
Oat	x	x		0.0	*0.0*	7.6	*6.1*
Maize	x	x	x	2.9	*22.8*	1.0	*49.6*
Crops silage	x	x		0.0	*0.0*	0.0	*0.0*
Barley	x	x	x	1.7	*0.8*	2.1	*18.5*
Vegetables			x	1.2	*27.3*	2.3	*82.1*
Intensive grassland	x			4.6	*0.0*	18.6	*7.1*
Extensive grassland	x			0.2	*0.0*	6.2	*2.1*
Set aside	x			2.1	*0.0*	1.1	*0.0*
Table wine grapes	x			0.8	*0.9*	1.3	*1.4*
Quality wine grapes (DOC)	x			7.1	*0.0*	0.3	*0.0*
Olives for oil	x		x	1.4	*0.0*	16.8	*16.3*
Fruit (oranges)			x	0.0	*0.0*	12.4	*91.0*

OTHER CROPS (not modelled):				5.3		5.6	

Source: Own figure, FADN

perennial crop modelling and the practical computational limitations.

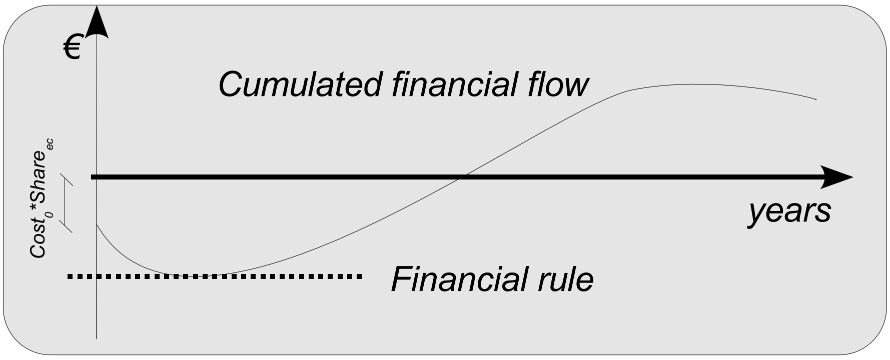
Financial variables To model the financial profile of the perennial crops, we use a "financial rule" in order to "allow" the farmer to evaluate these profitable investments avoiding over-investment and still keeping the limited one-year perspective. In practice, this financial rule is a constraint on the total capital available to the farmer (including debt capital). To calculate this constraint, we have to explicitly consider the time dimension of perennial crop investments and, in particular, the starting planting costs as well the negative income occurring in the initial period of low (or null) yield. Firstly, over the 1,..,n,...N years of useful life, we compute the vector of cumulated discounted financial flows ($CumFinFlow_n$):

$$\begin{aligned} CumFinFlow_n &= CumFinFlow_{n-1} \\ &+ \frac{(Yield_n * MkPrice_n + Premium_n - Cost_n)}{(1+i_{ec})^n} \end{aligned} \tag{3.3}$$

where:
i_{ec} = interest rate for the equity capital;
$MkPrice_n$ = market price of the perennial crop product.
Secondly, we calculate the financial rule as the minimum value of this vector plus the initial investment cost covered by the equity capital:

$$FinRule = -min\left\{CumFinFlow_1...CumFinFlow_N\right\} + Cost_0 * Share_{ec} \tag{3.4}$$

where:
$Cost_0$ = initial costs;
$Share_ec$ = share of the initial investment covered by equity capital.
Graphically, the financial rule can be depicted as follows:



Therefore, the financial rule is the maximum amount of own capital, on yearly base, the farm must provide taking into account the initial investment costs and all the subsequent costs before becoming productive. The financial rule drives the farmer's initial investment decision to avoid shortage of capital in the following years. Thus, the following step is the calculation of the required liquidity to cover the financial rule, that is the annualised opportunity cost of the own equity capital:

$$Liquidity = FinRule * f$$

where f is a annualisation factor calculated as:

$$f = \frac{(1+i_{ec})^N}{(1+i_{ec})^N - 1} - \frac{1}{N * i_{ec}} \tag{3.5}$$

To eventually assess whether or not to invest in new plantings and the size of these investments, a final value must be calculated and included in the objective function. It is the average cost of the investment, in AgriPoliS normally obtained as the sum of the maintenance costs, the average deprecation costs and the debt capital costs. However, maintenance costs are skipped for perennial crops as they are already included in the associated production activities and derived from FADN data. Hence, the average (annualised) cost for perennial crops is calculated as:

$$\begin{aligned} AC \quad = \quad & \frac{(FinancialRule + (1 - Share_{ec}) * Cost_0)}{N} \\ & +(1 - Share_{ec}) * Cost_0 * f \end{aligned} \tag{3.6}$$

where the first term of the right hand side is the average depreciation of the whole investment costs while the second term is the cost of debt capital.

Spatial implications of perennial crops Perennial crop activities can be run only on specialised land-types. However, we can not force these "objects" to be allocated in such plots, as they have not any spatial dimension. In other words, the model does not provide any information on where these plantings are located. Nonetheless, we can try to reproduce these spatial implications by adding spatial-related coefficients in the respective MIP sub-matrix. An example for quality wine is provided in Table 3.4:

Quality wine plantings are a cost for the farmer (negative gross margin) but they are mandatory to run the associated activity. AgriPoliS continuously upgrades the capacity of these plantings, taking into account their lifetime and new investments. Specialised perennial crop land can also be used on a temporary base for arable crop activities, but the opposite does not hold. In fact, suitable land for perennial crops is considered just as a subset of the arable land (see Figure 3.4), as

Table 3.4: Sub-matrix on wine spacial aspects (ha)

		[...]	QWINE PROD. ACTIVITY	[...]	QWINE2ARABLE	[...]	QWINE NEW PLANT	[...]
gross margin	euro		pos		0		neg	
[...]								
arable dry land	ha				-1			
[...]								
qwine land	ha		1		1			
[...]								
qwine plants	ha		1				-0.5	
[...]								

perennial crops often require further specific space-related characteristics, e.g. exposition. In principle, this design would allow farms to unrealistically continuously alternate, in the same plot, perennial and arable crops. But this effect is avoided by the fact that, in the model, perennial crop investments represent a high proportion of the total production costs of the associated activities, and hence, once the investment decision is taken on a given plot, the activity is maintained for several years.

Technical coefficients In order to calculate the above-mentioned financial variables of the new investment options and of the associated activities, some further technical data are needed. Concerning physical coefficients, the first obvious value is the investment lifetime. Here, we consider values that are consistent with the economic life of new plantings, though we acknowledge that the biological life of perennial plants may be much longer (for instance, even thousand years for olive trees). Similarly, yields and technical requirements should refer to new plantings, that are particularly suitable for mechanisation of several operations, rather than old-style labour-intensive plants. In order to calculate the financial values mentioned above (e.g., the current asset values and the costs the farmer incur before the plantings become productive) we need the series of yield over time. These data are taken from the specific literature but some assumptions are still needed. Firstly, we assume that the asset value of the planting linearly grows over time till it becomes fully productive, and thereafter linearly decreases to 0 at the end of lifetime. Secondly, since a vector of year-by-year yield is not available for the plantings in the studied regions, we calculate the average yield from our FADN data and then we reconstruct the time series using bibliographical national data.

With regard to factor requirements, we use bibliographical data for labour while we make some assumptions based on FADN data for machinery. In particular, we assume that 20% of machinery requirements can be specifically attributed to perennial crops, with different machinery for vineyards, for olive fiels and for fruit trees, while the remaining machinery requirements can be shared with the other modelled crops, with a "general purposes" machinery available in different size classes. It must be also noted that agri-services are widely used in the Mediterranean context. Therefore, in AgriPoliS::Med they are expressed as hours of services instead of units of machinery, given that from our FADN data we can derive the hours of agri-services bought by farmers as well as their cost. Therefore, here agri-services provide both machinery and the associated labour, while in the original AgriPoliS agri-services provide uniquely machinery.

Other economic and financial variables regarding perennial crops have been computed from FADN data. In particular, to estimate annualised costs we introduce correction coefficients to mimic the higher costs of plantings when over-aged. Since for perennial crops it is not possible to distinguish investment maintenance costs from activity (cultivation) costs, all costs are assigned to the associated activity and the investment maintenance costs are fixed to 0.

Due to the long lifetime of perennial crop investments, it would be unrealistic to assume always the same length for this lifetime and for the debt capital borrowed to fund them. Whenever a shorter length of debt capital is assumed, appropriate financial functions have been included within the AgriPoliS::Med code to allow for the correct calculation of the financial variables (e.g., the asset value and the remaining debt).

Finally, the market price of the associated perennial crop products, as well as their coupled actual subsidies, are derived from available FADN data.

3.6 Environmental modelling

Given its micro-behaviour foundations, AgriPoliS can be usefully adapted to produce environmental analysis. In particular three lines of research has been selected to work with it (Brady, 2005).

The first one links farmer activities with polluting inputs, like pesticides and land nutrients. This is a very simple but yet powerful way to investigate policy influence over the environment, especially if data are further processed with specific agronomic models. While it wasn't implemented in the current version, it would be relatively easy to introduce modelling of environmental premiums and/or penalties that influence farmer behaviours.

The second line of research is to investigate biodiversity. This was done recognising different biodiversity value to different land uses (in terms of number of threatened species). However we had available only very highly aggregated data from the IUCN Red List of threatened species Baillie et al. (2004).

Finally the third line of environmental research, that take advantage of the explicit spacial feature of AgriPoliS, is the analysis of the landscape to see how the landscape *mosaic* change under different agricultural policies.

To perform this study AgriPoliS has been adapted to explicitly allocate farmer's production on specific farmer's plots[7]. This require two steps: first, identifying the blocks of contiguous plots of homogeneous land for each farmer[8]; secondly allocating the production along this blocks, under the hypothesis that farmers was trying to "concentrate" their production on the less possible number of blocks. To perform this second step we need to further process the farm output using a quadratic objective function:

$$Z = Max(\sum_{p=1}^{P}\sum_{b=1}^{B} x_{p,b}^2) \tag{3.7}$$

---

[7] Previously AgriPoliS was calculating output production for each farms taking into account spacial variables (e.g. transport costs), but whitout the need to specify *where* this production was realised.

[8] This is a good example of the need of better coupling existing GIS programs with multi-agents models, as noticed in section 2.3.1: the algorithm that identify the so-called "islands" is usually available on all GIS packages but to use it within the model we had to recode it from scratch.

sub

$$\sum_{b=1}^{B} x_{p,b} \leq p \qquad p = 1..P \tag{3.8}$$

$$\sum_{p=1}^{P} x_{p,b} \leq b \qquad b = 1..B \tag{3.9}$$

where $p = 1..P$ indicates the products, $b = 1..B$ the continuous blocks and $x_{p,b}$ is the allocated product p on block b.

We are now able to calibrate the distribution by size classes and by products of blocks of contiguous plots between the model output and the real region, using plots information from AGEA, the national agency in charge of granting agricultural subsidies.

We investigated the possibility to use more informative indexes, as the Fractal Dimension [9] and/or the Patch Elongation Index [10], however we didn't have the spacial information needed to calculate this indexes at the great detail level used in AgriPoliS (individual product allocation).

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[9] Fractal dimension is defined as D=2ln(perimeter)/ln(area) and its range fluctuate between 1(for basic shapes) to 2 (for most complex shapes) (Lovejoy, 1982; Turner & Ruscher, 1988).

[10] Patch elongation index is defined as G=perimeter/square(area). The larger the value of G, the more elongated the patch is (Carrere, 1990).

4 Policy analysis with AgriPoliS::Med

4.1 Main characters of Mediterranean agriculture

As the main goal AgriPollis::Med is to adapt AgriPoliS to the Mediterranean agriculture to capture the effects of decoupling policies on that specific context, we first need to investigate the relevant characteristics of *Mediterranean* agriculture.

By "Mediterranean region" it is usually meant the Mediterranean sea and all its bordering countries (plus Portugal). Thus, this wide area extends between the temperate and the tropical zone. In this paper we consider as Mediterranean countries (Med countries) the following EU25 member states: *Cyprus*, *Greece*, *Italy*, *Malta*, *Portugal* and *Spain*. Though from a strictly geographical point of view also France and Slovenia contain Mediterranean coasts, we exclude these countries from our analysis.

Data presented in this paper refer to 2003 (the last available year for all countries), but they still consider the EU enlargement. This can create problems when comparing data of Med countries with the continental ones. For this reason, in the appendix, we also report 2000 data only including Old Member States, OMS, because the New Member States (NMS) do not equally distribute between the two groups, as the most of them falls within the continental group. Thus, their specific characteristics may actually "disturb" the comparison between Mediterranean and continental agriculture. For example, the presence of farmers in terms of % on total population is just 3.5% higher in Med countries than in continental ones, but it would be 5.3% higher considering only OMS.

4.1.1 Environmental conditions

The main characteristics of the Mediterranean agriculture are strongly influenced by the specific environmental conditions of the whole region. Its climate is similar to the temperate zone in winter and to the tropical zone in summer. Winter is temperate and rainy, while summer is hot and dry. The typical Mediterranean soil is dry and superficial. If sloped and clay, it may likely face erosion processes.

The articulate contours of the region and the presence of wide mountain areas in the surroundings have two strong consequences. First, rain distribution is highly irregular over years. Vegetation specifically evolved to stand with periodical shortage of water in the warmest period, and to adapt their biological cycles to take advantage of the most favourable years. Many agricultural productions are influenced by this factor. For example, olive production is highly discontinuous among years. Second, climate is quite heterogeneous within the Mediterranean region, with relatively small areas showing a large array of different conditions. This variety, combined with different geomorphology, explains the rich biodiversity and, from an agricultural point of view, the high number of different cultivated species, varieties and qualitative features.

4.1.2 Land use

Compared with the continental EU, Mediterranean countries are characterised by a higher share of agricultural area. The Utilised Agricultural Area (UAA) in the two groups is 40% and 48% of the total area, respectively. The share of arable and grass land on total land is not significantly different, but in the Mediterranean context a higher presence of perennial crops is observed (Table 4.1).

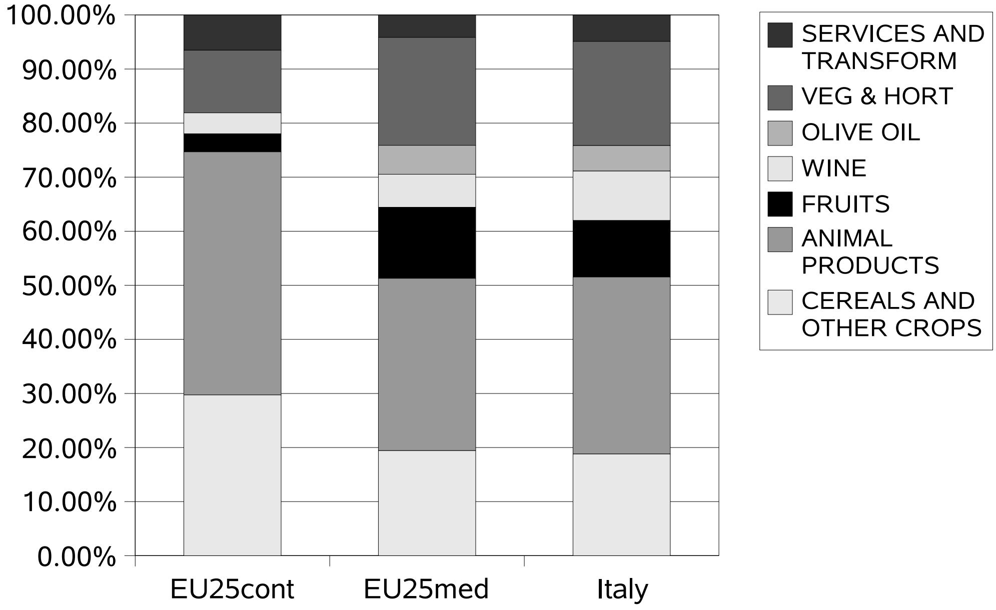
Table 4.1: Agricultural land use as % on total land

	Total land [1,000 ha]	Arable land	Permanent grassland	Perennial crops	Other land
EU25cont	293,538	24.5%	14.2%	0.7%	60.6%
EU25med	104,014	24.3%	14.2%	9.1%	52.4%
Italy	30,134	26.41%	14.5%	8.9%	50.2%

Source: Eurostat

Figure 4.1 confirms, on the output side, the greater relevance of perennial crops in the Mediterranean context together with vegetables. In the continental agriculture the output generated by cereals, other crops (including potatoes, sugar beet and forage) and animals products amounts to 75% of the whole agricultural output, whereas they are just 51% in the Mediterranean context. At the opposite, perennial crops (wine, fruits and olives) plus vegetables and horticulture products count in the continental agriculture only 19% compared with 45% in the Mediterranean output.

Figure 4.1: Agricultural output shares based on EAA (Economic Accounts for Agriculture)



Source: Eurostat

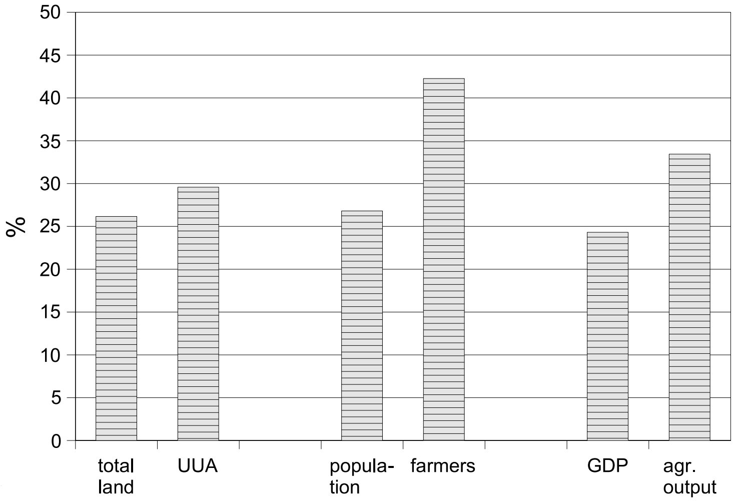
4.1.3 Farm size

Figure 4.2 provides a simple insight into the main social and economic characteristics of Mediterranean agriculture. Figure 4.2**a** reports the share of Med-countries in the (enlarged) EU context. Mediterranean agriculture represents about 30% of the whole EU25 agricultural land, but it shows higher values in terms of output and, above all, of farmers. Figure 4.2**b** shows how agriculture performs within the whole economy. We can note that on any aspect (land, labour, GDP) agriculture shows a higher share in the Mediterranean countries, to confirm the relatively greater importance this sector still has. Finally, figure 4.2**c** analyses the farm average size. It definitively demonstrates that Mediterranean agriculture is characterised by much smaller farms, in terms of avg. land and labour units endowment and, above all, in terms of output.

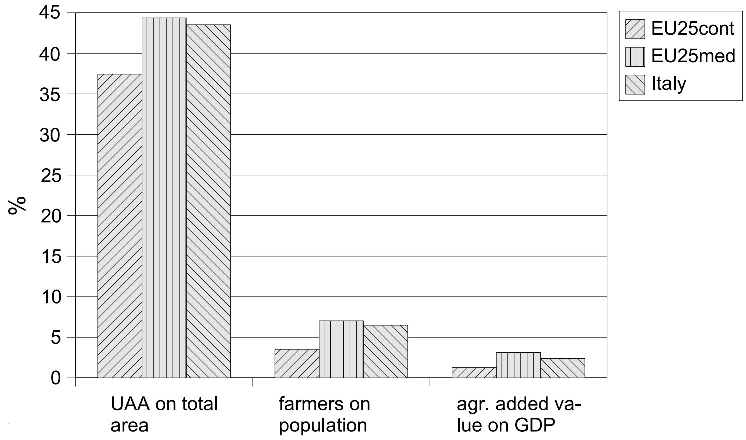
Looking at figure 4.2 as a whole, it becomes evident that Mediterranean agriculture is relatively more intensive in terms of both *per ha* labour and output, but it is undermined by a strong land fragmentation, making farms too small to generate an acceptable family income. Thus, it is not a surprise that such small farms are unable to attract young farmers. Figure 4.3 shows the distribution of

Figure 4.2: Mediterranean agriculture: main characters

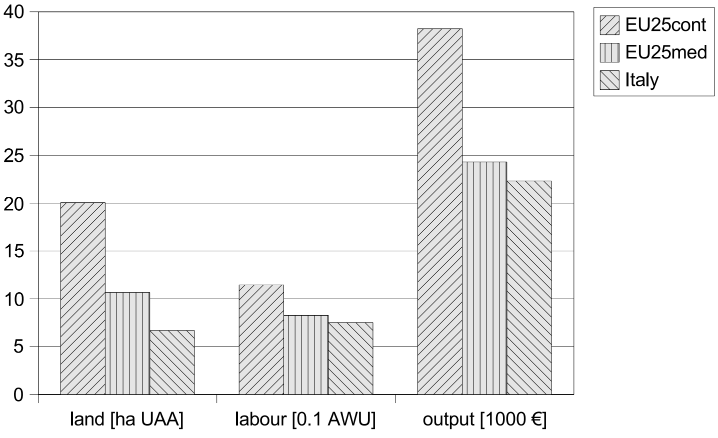
a - share of Mediterranean countries in EU25



b - share of agriculture in the whole economy



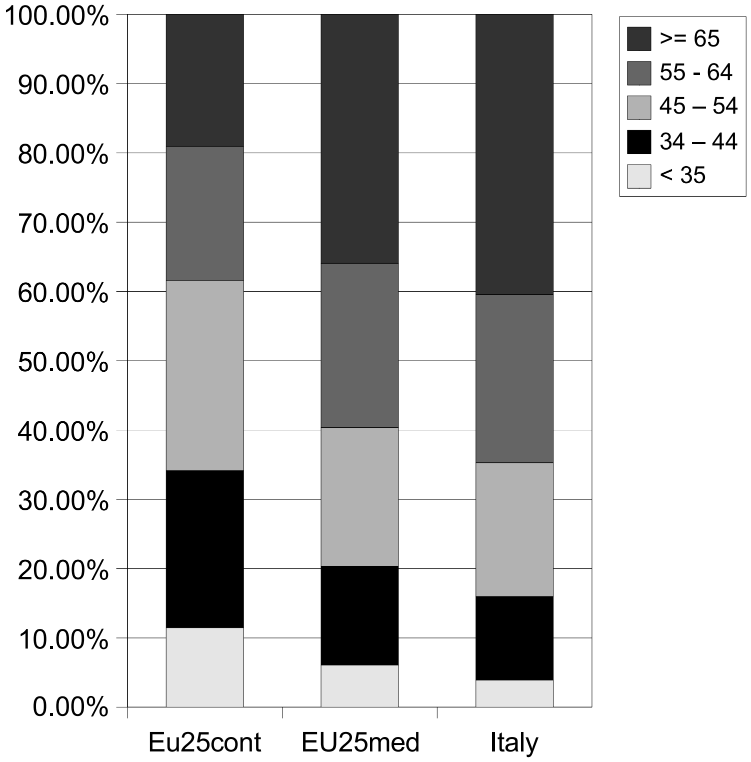
c - farm size in terms of land, labour and output



Source: EUROSTAT

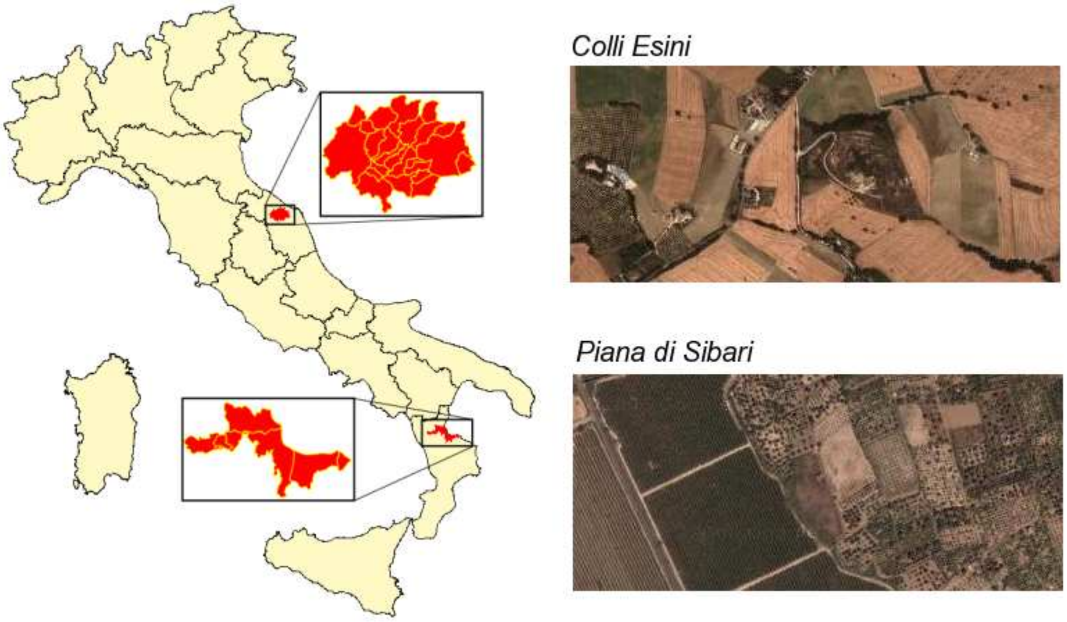
farmers by age class: in Med-countries 36% of farmers are more than 65 years old, almost double of continental agriculture. Young farmers, that is younger than 35 years old, are only 6% (11% in continental agriculture). Figure 4.3 also shows how this problem is particularly serious in some Med-countries, for example in Italy where the two mentioned values are 40% and 4% respectively.

Figure 4.3: Farmers by age class



Source: EUROSTAT

Figure 4.4: Geographical location of Colli Esini and Piana di Sibari regions



4.2 Selected regions

To better represent the differentiated effects of decoupling, we work in parallel on two regions, to capture a gradient of these characteristics. One region should have just "partial" Mediterranean characters, whereas the second one presents these characteristics more extremely.

After having investigated agricultural productions, farm structure and FADN data availability of various Italian regions, we selected the "Colli Esini" area, a portion of Marche region, as the "intermediate" Mediterranean case, and "Piana di Sibari", a portion of Calabria region, as the extreme Mediterranean one. The geographical location of the two regions is reported in Figure 4.4.

Several figures clearly show this gradient of Mediterranean characteristics between Marche and Calabria: the share of agricultural GDP of Mediterranean crops is around 40% on Marche and reach 65% for Calabria [11]. At the same time the average farm size (UAA) is 8.4 ha for Marche and just 3.7 ha for Calabria. Finally, land rent price is not very much different in the two regions; however, the rented land share is more than double in Marche (26% and 11%, respectively).

Within Marche region, the Colli Esini area was chosen for being a quite homo-

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[11] By "Mediterranean crops" we mean wine, olive oil, durum wheat, citrus fruits, vegetables. Data elaborated from Eurostat

geneous area with enough FADN farms (159, according to 2001 dataset). It is made by 24 municipalities (LAU2 [12]) for a total of around 50,0000 UAA hectares. These municipalities belong to the same labour-district, following ISTAT classification, though this is not identified by an official administrative border.

Colli Esini is a hilly area located between the coast and the inner mountainous part of the region. It contains about 6000 farms, with an average size comparable with the whole Marche region. The high majority (89%) of these farms are exclusively based on family labour. Area is mostly cultivated with arable crops (87%), with a significant permanent crops' area (9%, mainly vineyards) and a very limited grassland area (2%). Finally, animal productions are occasional with the only significant production being pig meat (7900 pigs over 50 kg).

Piana di Sibari is a geographically well delimited flat area (the word "piana" in Italian means "flat") that overlooks the Ionian sea on east and is surrounded by mountains in all other directions, protecting it from strong winds and leading to a dry climate (it rains less than 600mm/year, mainly in winter). The region is actually smaller than Colli Esini (29,000 UAA ha) and it consist of only 7 large municipalities LAU2; FADN records are only 134 (in 2001 dataset).

Considering census data, thus including all farms, Piana di Sibari presents a surprisingly high number of farms (10626), leading to an average size of only 2.75 UAA ha/farm. Most of these farms, however, does not carry out any real commercial activity. In modelling the virtual region, we dropped a large portion of these very small farms also considering that, comprehensibly, no FADN data were available for them. Thus, we limited the attention to the remaining 4631 farms, the majority of which still does not use extra-family labour (76%). Actually, we could expect even higher share of family labour, but most farm activities in this area are highly labour intensive: in the region we have only 30% of arable land, while the rest is devoted to labour intensive permanent crops (65%, mainly citrus crops and olive trees), with a residual share of grassland (5%). Animal productions are scarce, with just around 2000 dairy cows and 1350 pigs in the whole area.

More details about the modelled regions are reported in the Appendix, as well as in Brady (2007) especially with respect to landscape and environmental aspects.

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[12] LAU stand for *Local Administrative Units*. LAU1 were formally know as NUTS4 and LAU2 as NUTS5

4.3 Data sources

4.3.1 Regional level

We used real regional data to define our virtual regions. The primary source for data at the regional level is the ISTAT 2000 agricultural Census reporting the following variables:

- Farm dimension: total farms, average area and farm distribution on several size classes;
- Labour: total farm and family labour and farm distribution by share of family labour;
- Agricultural land use: land usage by each crop (then aggregated by land type);
- Animals: distribution of animals by type, age and size.

However, in Census all economic information about the farms are missing. Furthermore, as we do not have access to single-farm data on the Census dataset, we are also unable to assign each farm to a typology. Therefore, we use the FADN farm-type distribution as a proxy for the real regional farm distribution by typology.

4.3.2 Farm level

All our farm-level data come from the FADN 2001 dataset. In principle, the FADN sample should include only active farms, that is with commercial activity. However the minimum economic size admitted in the dataset in 2001 is just 2 ESU, that is 2,400 euros [13]. As comparison, the minimum size for France and Germany in 2001 is 8 ESU, and for United Kingdom and Netherlands is 16 ESU. The presence of very small farms in our dataset strongly influences our results as on these farms structural time trends seems to overcome the impact of any implemented policy.

In addition, we have access to a limited sub-set of single-farm FADN dataset. In particular, we miss the exact indication of animals owned by farmers, available information only concerning the Livestock Units owned by each farm for that

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[13] Starting from 2002 the minimum economic size was increased to 4 ESU, still relatively small.

specific type (e.g. beef cattle, dairy...). Thus, we apply the animal distribution by age class obtained from the Census data to derive the *number of animals* from the *Livestock Units.*

4.3.3 Technical and economic coefficients

The third set of information still missing in our datasets are the technological and economical parameters that frame the space where farmers' decisions are modelled. We collected these parameters mainly from Porciani (2001) and, for region-specific parameters (e.g. yield), we calculated them directly from the FADN dataset[14].

4.4 The resulting "virtual" region

With the regional-level data and the single-farm data from the FADN dataset, we can perform the "upscaling" step. Using optimisation techniques, we apply to each farm of the FADN dataset a scaling coefficient with the objective to obtain a "virtual region", only containing heterogeneous FADN farms, with aggregated values close to the figures of the real region we are investigating.

The parameters considered in this upscaling stage are:

- No. of farms;
- No. of farms by size and farm-type classes;
- UAA and irrigated UAA;
- UAA by farm-type classes;
- Land use {*arable land, grassland, vineyards (table wine and quality wine), olive groves*};
- No. of animals {*beef cattle, pigs*}.

The Italian FADN does not report the number of animals owned by each farm but only the livestock units allocated to each type of livestock activity (e.g. dairy, beef production. . .). So we can not allocate these livestock units appropriately.

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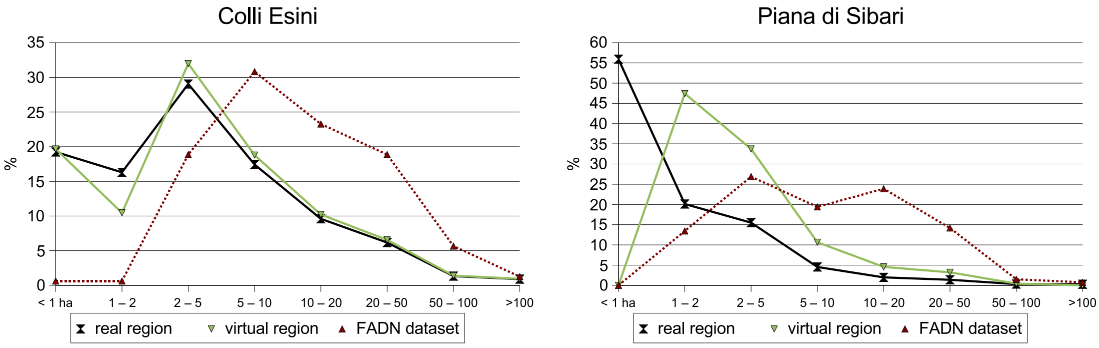
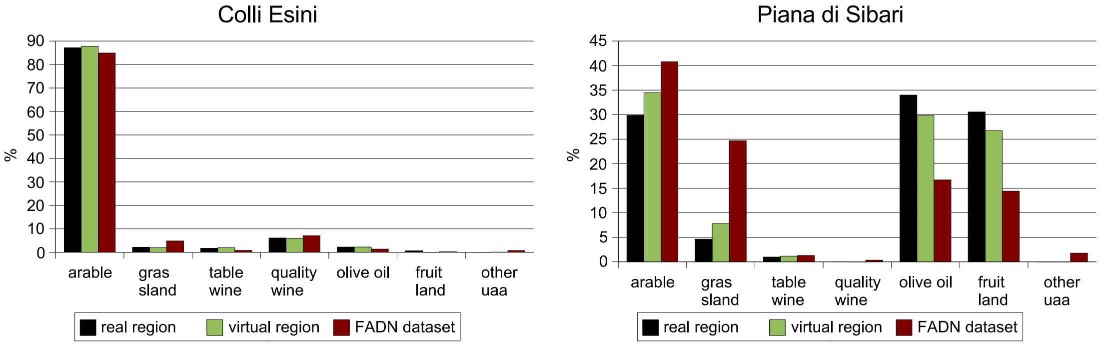
[14] A subset of the matrix containing the initial gross margins and the resource requirements for each activity is shown on Figure 3.3. The complete matrix is available under request by the authors.

Figure 4.5: Farm dimension



Sources: our calculations on ISTAT Census 2000 and FADN 2001 datasets.

Figure 4.6: Land Use

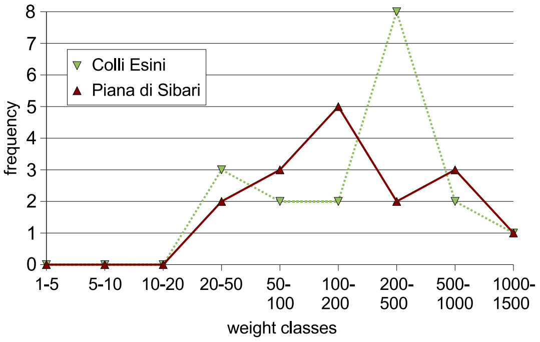


Sources: our calculations on ISTAT Census 2000 and FADN 2001 datasets.

Nevertheless, at regional level, data report the distribution of animals by age and category and we can apply this same information to our farms to get the farm level data.

Figures 4.5 and 4.6 compare the farm size distribution and on the land use in the real and virtual regions, and in the FADN dataset. We can appreciate that in both cases (Marche and Calabria), even if the lower limit of the FADN dataset is largely below the EU standards, the FADN farms are still considerable bigger than the whole regional sample. In the Piana di Sibari we have the specific problem that we do not have any farm smaller than one hectare in the FADN sample, even if in the real region this size class shows the highest numerousness. Despite this, we are able to select our FADN farms in such a way that the size distribution in our virtual region is quite similar to the real region. In particular, referring to the land use, we can notice that the upscaling process was able to give us a virtual region much more similar to the real one than the unadjusted FADN dataset.

Figure 4.7: Upscaling coefficient distribution



Sources: our calculations

Figure 4.7 shows the distribution of the upscaling coefficients applied to any FADN farm to generate the virtual region; for example, a coefficient of 150 applied to a specific FADN farm means that this farm will enter our virtual region 150 times. Although, these 150 farms come from the same FADN record, each one is different, as the model assigns it a random spatial location in the virtual region and a random age to its endowments. A detailed quantitative comparison among the real region, the virtual region and the FADN dataset is reported in Table A.7.

4.5 Common Agricultural Policy and Mediterranean agriculture

4.5.1 The 2003-2004 CAP reform

In 2003, a major reform of the Common Agricultural Policy (CAP) was agreed. Initially known as the "mid-term reform", the 2003 reform went far behind a simple revion of the previous "Agenda 2000" policy, and with Regulation (EC) 1782/2003 introduced new political instruments, and in particular Single-Farm Payment (SFP) scheme. Following this reform three different types of payment can be recognised: Single-Farm Payment, optional coupled payments (on the base of national decisions), coupled payments.

Single farm payment is an aid scheme provided to farmers, decoupled from production activities but subjected to certain commitments. Its value is calculated in the old member states from the historical records of the previously coupled payments that each farmer received from the EU during a fixed reference period, usually made of three years. Most previous payments concerning the cereal, beef and veal and sheep and goat sectors, now falls within this SFP scheme. Moreover, with Regulation (EC) 864/2004 the original Regulation (EC) 1782/2003 was amended to include new products in the single-farm scheme: cotton, hop, tobacco and olive oil.

Table 4.2 summarises the national decisions in the Mediterranean countries. It can be noticed that all the Med countries decided for a coupled payments for seed production, recognising the importance that locally produced seeds have for the whole crop sector. Concerning the Tobacco payments the main concern was to maintain this labour-intensive production, also considering that it is typically made in regions with few other labour alternatives. In general terms, with regard to the remaining decoupling decisions, it is possible to distinguish between two groups. On the one hand, Greece and Italy decided for a higher level of decoupling. However, they kept a high rate of "quality" payments, as allowed by art.69 of the same Regulation (see Table 4.3). On the other hand, Portugal and Spain make a lower utilisation of "quality" payments but decided to keep payments as coupled as possible.

Finally Table 4.4 shows those CAP payments that remain coupled even after the 2003-2004 reform. Many of these support schemes refer to Mediterranean products, as *durum wheat*, *rice*, *nuts* and *cotton*.

4.5.2 CMOs for fruit, vegetables and wine

Except for nuts, the common organisations of fruit, vegetables and wine markets were not affected by the 2003 CAP reform. Policies on fruit and vegetables emphasise the importance of product standardisation and the role of producer organisations. These organisations can decide when and how much product should be withdrawn from the market. However, a withdrawn limit[15] on the marketed quantity is established. In addition to price stabilisation measures, direct payments are recognised to producers of some processed fruits and vegetables [16], with a EU-level quota system that proportionally lower the support in case of overproduction. Furthermore, Regulation (EC) 2699/2000 established that such aids can

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[15] 5% for citrus fruits, 8,5% for apples and pears and 10% for other products.

[16] 34.5 euros/tonne for tomatoes, 47.70 for peaches and 161.70 for pears.

Table 4.2: Optional coupled payments (based on national decisions)

	Art.	**Greece**	**Italy**	**Portugal**	**Spain**
Seed aid	70	100%	100%	100%	100%
Arable crops area payment	66				25%
Hops area aid	68bis				
Sheep and goat premiums	67				
- ewe premium				50%	
- sheep and goat premium					50%
Beef and Veal payments	68				
- suckler cow				100%	100%
- slaughter premium calves				100%	100%
- slaughter premium adults				40%	40%
Olive oil[a]	110 octies				6.4%
Tobacco[b]	110 undecies		60%[c]	50%	60%

[a] Greece and Italy apply 5% deduction on olive oil aids for funding programmes established by producer organisations.

[b] From 2010 full mandatory decoupling.

[c] Tobacco is fully decoupled in the Puglia Region.

Source: Reg. 1782/2003, EU Commission

Table 4.3: Quality payments (proportion on ceilings, art. 69)

	Greece	**Italy**	**Portugal**	**Spain**
- arable crops	10%	7%	1%	
- beef and veal sector	10%	8%	1%	7%
- dairy				10%
- sheep and goat	5%	5%	1%	
- cotton				10%
- olive oil	4%		10%	
- tobacco	2%			5%

Source: Reg. 1782/2003, EU Commission

Table 4.4: Still coupled payments

	Art.	**Premium [e/unit]**	**EU limits**	**Med limits**	**Italian limits**	**Unit**
Durum wheat	72	40	3,190,000	2,975,000	1,646,000	ha
Protein crop	76	55.57	1,400,000			ha
Rice	79	458.27[a]	392,801	369,561	219,588	ha
Nuts	83	120.75[b]	800,000	780,700	130,100	ha
Energy crops	88	45	1,500,000			ha
Starch potato	93	66.32[c]	1,948,761	1,943	0	tonne
Cotton[d]	110bis	624.78	440,360	440,360	0	ha

[a] Average EU value for the 2005/2006 onward period. Average Med amount is 465.60, Italian value is 453.00.

[b] Upper limit of EU aid. It can be integrated with a national grant for further 120,75 euro/ha and it can be differentiated by different products.

[c] 2005/2006 onward.

[d] This value refer to the coupled part of the cotton aid, while 65% of the previous cotton payments is included in the single-farm payment.

Source: Reg. 1782/2003

not exceed the difference between the world price and the minimum price paid in the EU.

Policies on the wine sector are quite different, particularly for the remarkable attention paid to structural interventions accompanying the market mechanisms. In the wine sector, whereas we can note a overall reduction of both production and consumption, we can still observe a structural shift of demand toward quality wines. A more competitive world wine market strengthened the need of restructuring the supply side to meet the consumer quality expectations. Regulation (EC) 1493/99 included measures to limit the total vineyards area, with both a ban of new plantings and an abandonment premium, but at the same time it established a support system for the restructuring and conversion of current vineyards. Finally, some traditional market aid schemes were maintained to stabilise the market in case of surplus production. Such aids include premiums for private storage of table wine and distillation premiums.

4.6 Policy scenarios

AgriPoliS::Med is able to generate projections under different policy scenarios [17]. In the initial period the model "collects" the subsides received by each farm, then automatically calculates the single-farm payment (SFP) due to any different farmer and finally assigns the SFP to farmers. This allows flexible implemention of the various policy scenarios. We can describe them according to several type of parameters and how these vary across the three policy scenarios.

Fixed parameters. These parameters usually do not vary across scenarios. They refer to basic coefficients (e.g. milk per cow or labour hours for standard annual work unit), to quotas (e.g. milk quota) and to modulation thresholds.

Product specific parameters. For each commodity, we specify if a payment scheme is active, which kind of payment will be converted into the SFP calculations (e.g. euros/ha, euros/cow..) and, finally, for how many years AgriPoliS::Med has to collect these data to calculate the SFP; for most product it is a three years period, but in case of olive oil it is a 4 years period.

Time specific parameters. Here we include some options, for instance the activation of the regional implementation (i.e., the SFP has the same value per hectare for all farmers in the region) or of the farm-specific implementation (each farm receive a SFP depending on the payments got during the reference period), or the full-decoupling option that differ from the farm-specific payment as it doesn't require the statutory management requirements and it is payable also in case of abandonment ("bond scheme"). We can also choose year-by-year the application of the degree of modulation for the various payments.

Time and product specific parameters. These parameters allow us to select, for any product and year, how much payment is still coupled and how much decoupled payment, calculated in the reference period, should be considered. Using

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[17] Several other modelling approaches can be followed to analyse the impact of policy reform and, in particular, of decoupling on farm structure and production, as well on markets. In this respect, see papers presented at the 93rd EAAE Seminar, held in Prague on September 22nd and 23rd 2006.

these two parameters we can set partially decoupled payments (this mixed scheme currently applies, for instance, to durum wheat).

4.6.1 Scenario 1: Agenda 2000

This is the baseline scenario. It simply is the continuation of the coupled payment scheme under the Agenda 2000 regime, thus without SFP, modulation and cross-compliance. However, in this scenario we don't include the dairy coupled payment because our price data refer to 2001, when high milk price support was still in action. In the following years, the price support declined and was replaced by the "compensation" scheme introduced by Agenda 2000. Nonetheless, as in AgriPoliS::Med prices are fixed and it is not possible to model their reduction starting from the initial specific year, we do not introduce the direct payment to avoid a misleading double support.

4.6.2 Scenario 2: Actual implementation

This scenario is the closest to the real implementation of the 2003 reform in Italy. In table 4.5 we summarise such implementation. As our model starts generating projections from 2001 and being based it is based on 2001 FADN data, we miss the 2000 reference year and, to maintain the three years reference period, we shift it one year onward, that is to 2001-2003 (2001-2004 for olive oil). In addition, as mentioned, we can not properly model dairy decoupling. As the activation of the decoupling scheme is not a product-specific option in AgriPoliS::Med, we are forced to start the decoupling period in the same year for all product (i.e. 2005).

Besides these simplifying assumptions, this implementation still maintain most characteristics of the real decoupling scheme adopted in Italy (e.g, the application of art. 69): payments maintain a 7% coupled support, livestock sector 8%, sheep and goat and olive oil 5%. These payments do not enter the SFP but are payed back to farmers in terms of coupled support (for example, 88 euros/ha for durum wheat). Finally, this scenario implements modulation with a 3% retention in 2005, 4% in 2006 and 5% onward, for SFPs higher than 5000 euros.

4.6.3 Scenario 3: "Bond scheme"

The "bond scheme" scenario is extremely simple as it mainly differs from the actual implementation for the fact that it doesn't imply any statutory management and

Table 4.5: Italian agricultural policy implementation

Actual implementation

	cereals	**livestock**	**dairy payments**	**olive oil**	**tobacco**
2000	REF COUP	REF COUP	REF PR. SUP	REF COUP	REF COUP
2001	REF COUP	REF COUP	REF PR. SUP	REF COUP	REF COUP
2002	REF COUP	REF COUP	REF COUP	REF COUP	REF COUP
2003	COUP	COUP	COUP	REF COUP	COUP
2004	COUP	COUP	COUP	COUP	COUP
2005	DEC	DEC	COUP	COUP	COUP
2006	DEC	DEC	DEC	DEC	DEC
2007	DEC	DEC	DEC	DEC	DEC
2008	DEC	DEC	DEC	DEC	DEC

AgriPoliS::Med implementation

	cereals	**livestock**	**dairy payments**	**olive oil**	**tobacco**
2001	REF COUP	REF COUP	PR. SUP	REF COUP	REF COUP
2002	REF COUP	REF COUP	PR. SUP	REF COUP	REF COUP
2003	REF COUP	REF COUP	PR. SUP	REF COUP	REF COUP
2004	COUP	COUP	PR. SUP	REF COUP	COUP
2005	DEC	DEC	PR. SUP	DEC	DEC
2006	DEC	DEC	PR. SUP	DEC	DEC
2007	DEC	DEC	PR. SUP	DEC	DEC
2008	DEC	DEC	PR. SUP	DEC	DEC

REF->reference period (payments are calculated for the SFP)

COUP->coupled payments

PR. SUP -> price support

DEC->SFP

maintenance requirements in order to preserve the SFP rights. Consequently, farmers can abandon the agricultural sector and still receive the payment. A further difference is that all premiums are fully decoupled, but this is a minor difference in case of Italy where most payments are already fully decoupled in the actual implementation.

5 Results

In this section are presented results of model simulations under alternative policy scenarios, particularly pointing out the differences emerging between the two regions under study[18].

5.1 Model results

Farm numerousness and size In both regions simulations start with a very high number of farms. AgriPoliS::Med only models farm behaviour in economic terms, though. Many farms are actually very small and the reasons why they are still "active" farms have often to be seek for social and even cultural factors, rather than for classical economic motivations.

Quite surprisingly, Figure 5.1 shows that farm abandonment is higher in Colli Esini region, where average size is relatively larger, compared to Piana di Sibari. This may be explained by the fact that in Colli Esini, with the exception of farms producing quality wine, most farms can grow only low-income cereals, so their "small size" constraint has a much more binding effect on their profitability. On the contrary, most Piana di Sibari farms can rely on intensive productions that can support a profitable farm activity even in small farm sizes.

Looking at figures 5.1 and 5.2, the decision to abandon the farm activity actually seems more related to a pre-existing structural trend than being influenced by the CAP reform. During period 1990-2003 in Italy we observed an average 2.32% abandonment rate (Figure 5.2). Our scenarios (with the exclusion of the "bond scheme") show a comparable abandonment rate, ranging between 3.19% and 3.32% for Colli Esini and 1.78% and 1.96% for Piana di Sibari (see Table A.6). The complete decoupling scenario ("bond scheme") has a larger impact in Colli Esini. We can explain this again with the different productions in the two areas: as decoupling mainly affects cereals and livestock productions, Colli Esini is much more sensible to CAP regime change than Piana Di Sibari.

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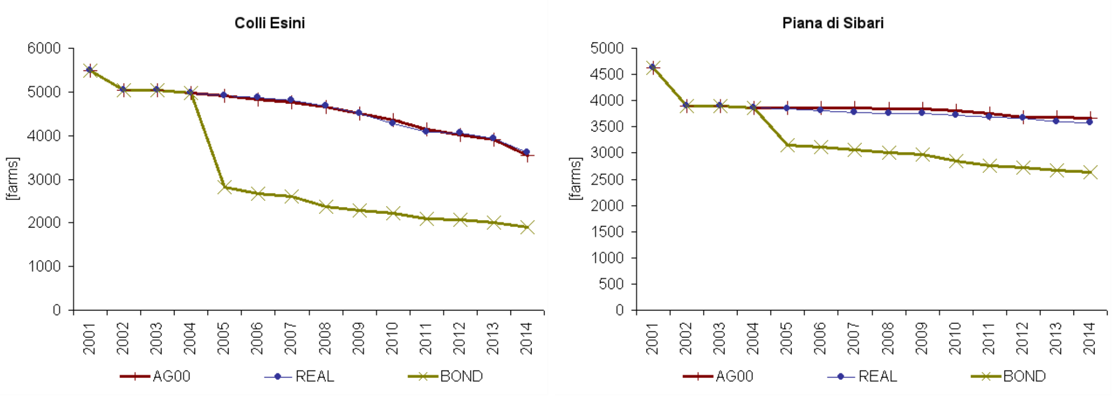
[18] Results on this section can be replicated using the CVS version of AgriPoliS::Med hosted on our server, checking out by date *26.September.2006* and tag *pcrops*.

Figure 5.1: Total number of farms

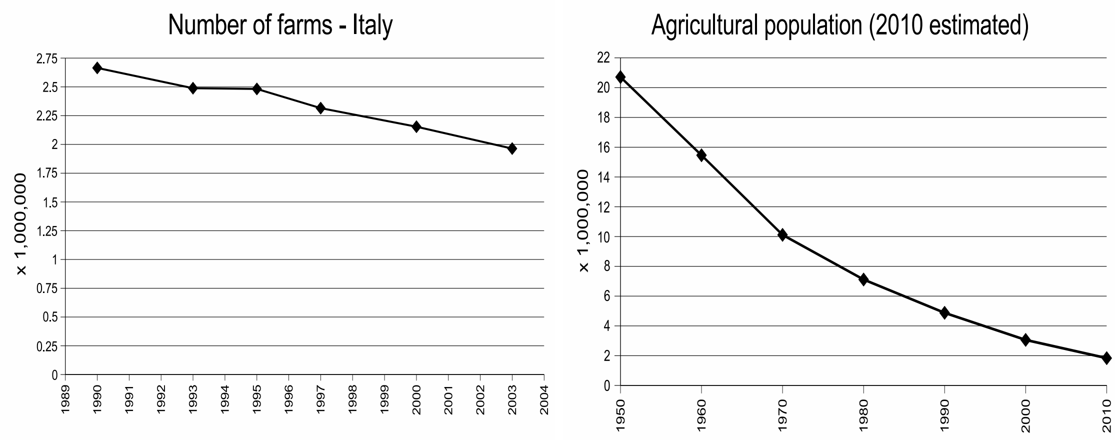


Colli Esini

Piana di Sibari

Source: own model results

Figure 5.2: Long-time trends in Italian Agriculture



Number of farms - Italy

Agricultural population (2010 estimated)

Source: Eurostat; FAOSTAT

To better understand the structural impact of policy scenarios we divide our farms in five size classes [19] and we observe their evolution during the simulations (figures 5.3 and 5.4). Notably, our results show that are not the smallest farms quit the activity: in Colli Esini region all farms within size class 0 cultivate perennial crops (mainly wine production), while class 1 farms mostly cultivate arable crops. Therefore, while under the continuation of Agenda2000 or the actual CAP reform implementation, these small arable crop farms still survive, in the "bond scheme" scenario they mostly abandon agriculture but smaller competitive wine farms remain.

In Piana di Sibari, however, we have not this particular situation and farm quitting is much more homogeneous across size classes, with an higher abandonment rate in the two smallest classes, as expected. Even in this region, the "bond scheme" scenario has a stronger impact on arable crop farms, that mainly belong to the second size class.

Figure 5.5 reports the two regions at the beginning and at the end of the simulation runs (where each colour represents a different farm). All scenarios, but particularly the "bond scheme", show a simplification of the farm structure where the remaining farms grow using the land made available by the quitting farms.

Land rental prices In our model, rental contracts endogenously arise from agent's iterations; consequently, we can observe effects of different policies on rental prices (figures 5.6 to 5.9).

As expected, we have a decline of arable land rental price in the "bond scheme" scenario, caused by a remarkable drop of land demand.

This strong fall in rental price is comparable with a recent OECD report (Dewbre & Brooks, 2006) on the effects of a sharp (50%) reduction on all agricultural subsides and trade tariffes. Under this scenario they expect a 53% drop in land rental prices whitin EU.

On the contrary, under the "actual implementation" scenario, the rental price

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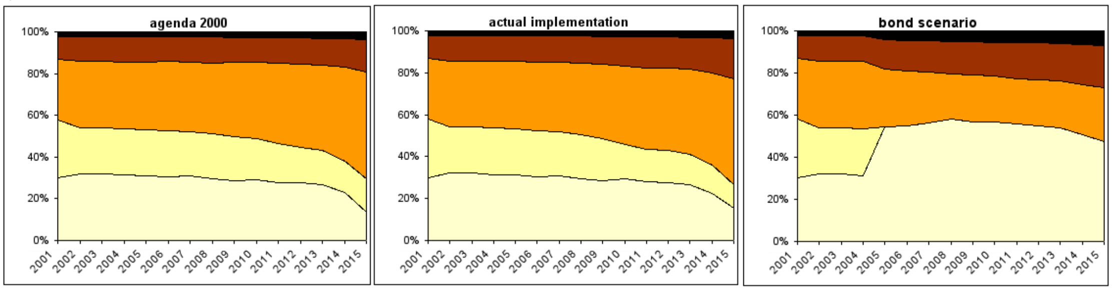
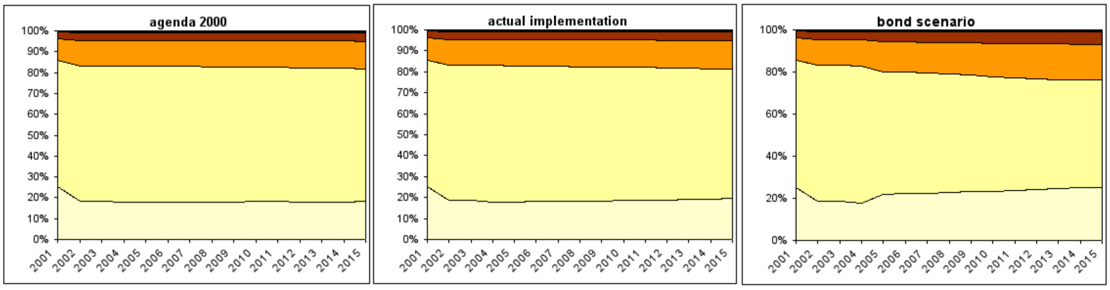
[19] We apply the following classification based on UAA and on the Italian small-size standards:
0 (micro-farms) : <2ha;
1 (small) : <6ha;
2 (middle) :<15ha;
3 (large) : <50ha;
4 (extra-large) : >=50ha.

Figure 5.3: Farms distribution by initial size classes

Colli Esini



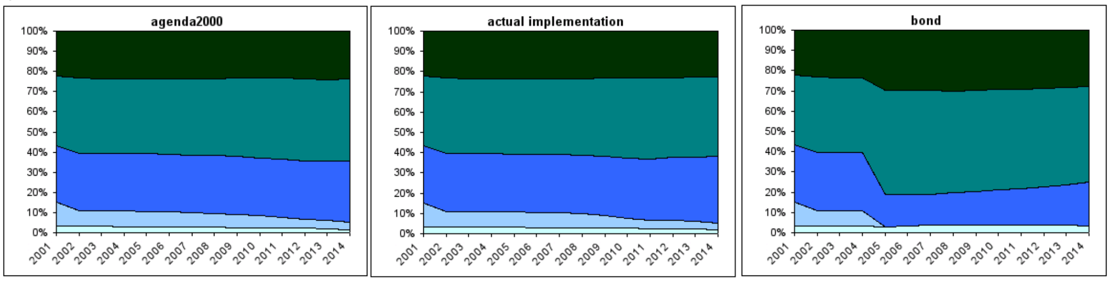
Piana Di Sibari



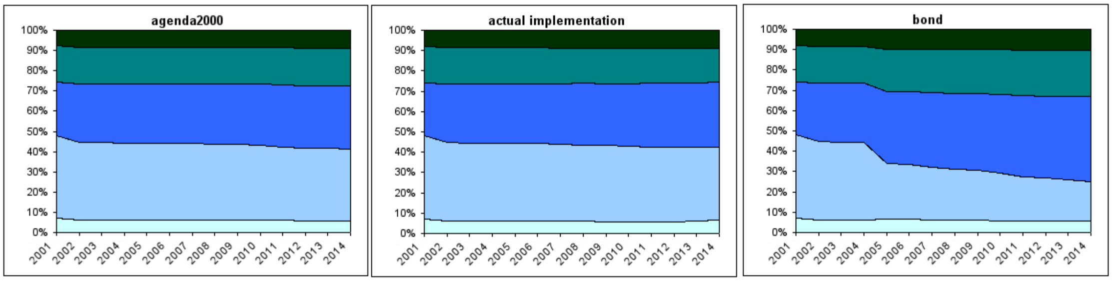
Source: own model results (classes are those of note 19, smallest farms being on bottom)

Figure 5.4: Land distribution by initial size classes

Colli Esini



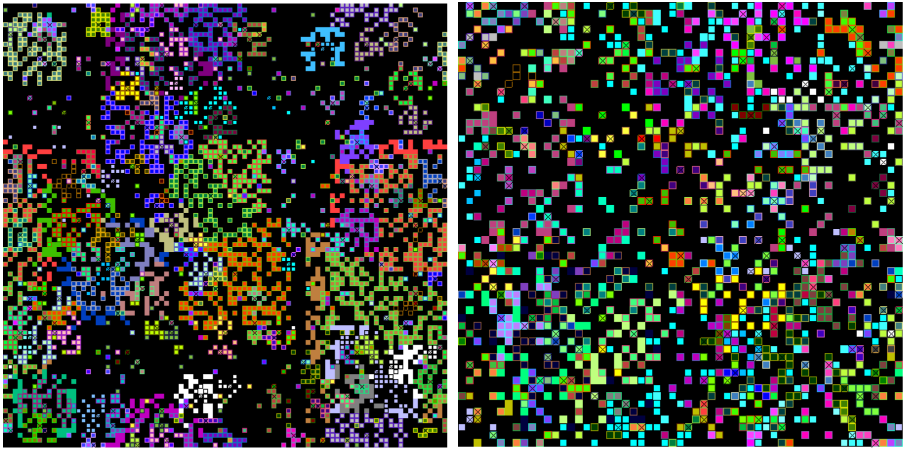
Piana Di Sibari



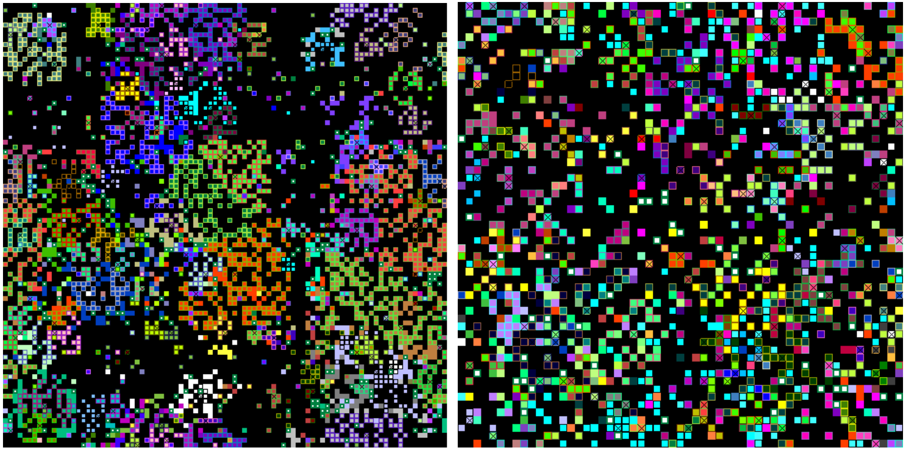
Source: own model results (classes are those of note 19, smallest farms being on bottom)

Figure 5.5: Spacial farm allocation on Colli Esini (*left*) and Piana di Sibari (*right*)

2001 - Starting simulation



2015 - Actual Implementation



2015 - Bond scheme

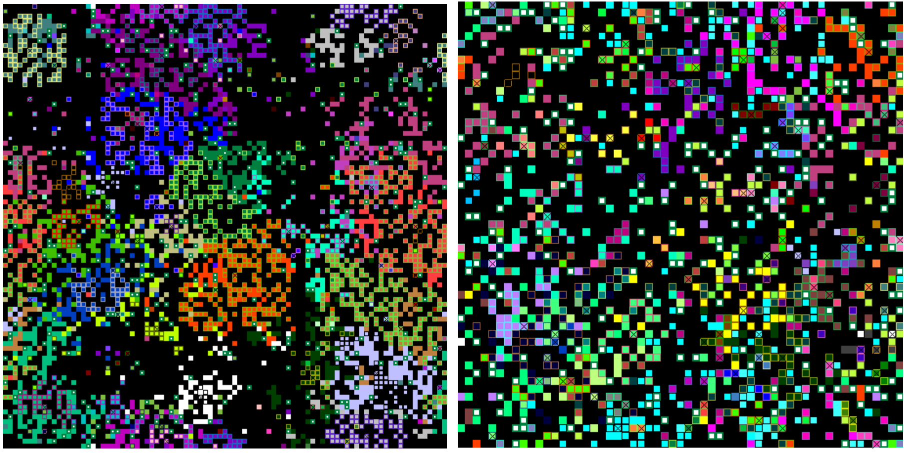
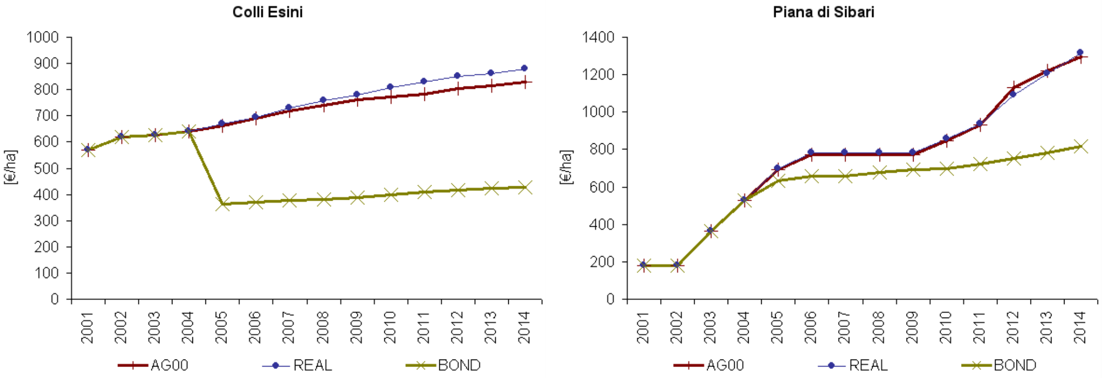
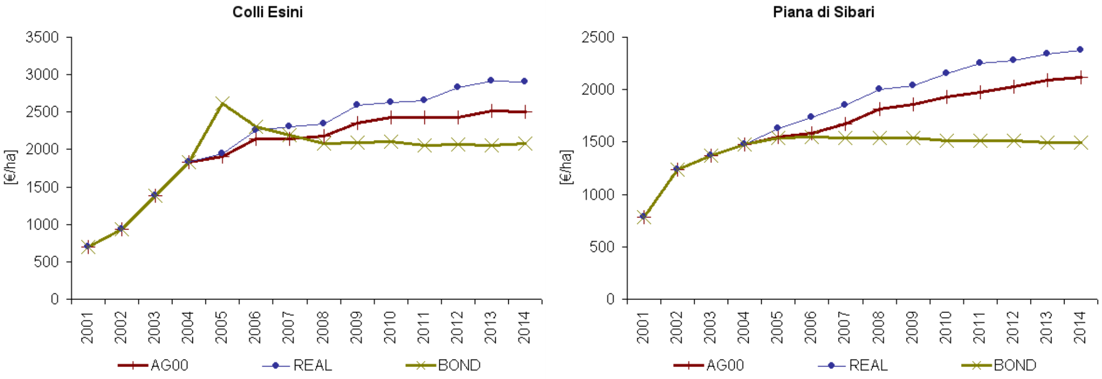


Figure 5.6: Arable land rental prices

Arable dry land



Irrigable dry land



Source: own model results

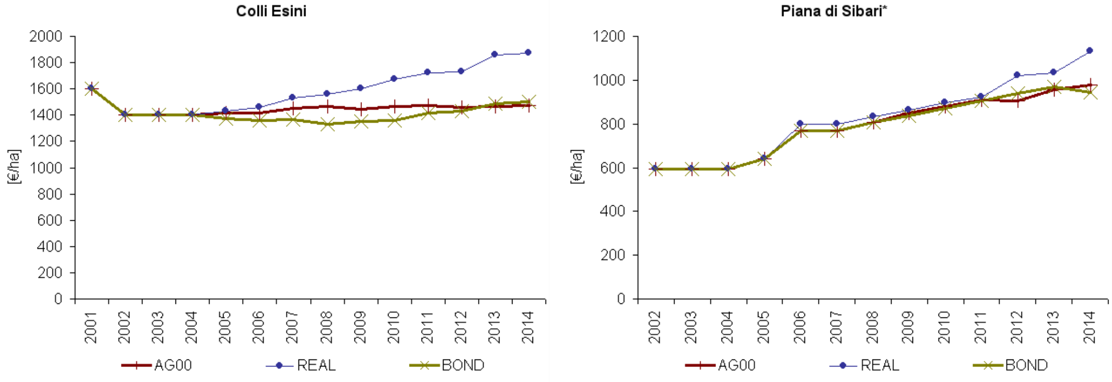
seems to increase, especially for irrigable land that allows production of more profitable crops (e.g. vegetables).

Rental prices of land types associated with commodities not involved in the CAP reform (e.g. grapes, fruit) show no decline. Rather they slightly rise in the "actual implementation" scenario.

It must be noticed, however, that our results may over-estimate decoupling effects on perennial crop land rental price, as land renting is actually very uncommon for perennial crops.

In particular, citrus fruit land shows a growing (nominal) rental price under partial decoupling, but its price remains constant under full decoupling. Finally, rental price of olive oil dry area is strongly influenced by the effects of decoupling. The "bond scheme" scenario seems to have a stronger effect in Piana di Sibari, as olive oil production is much more common in this region and many farms are

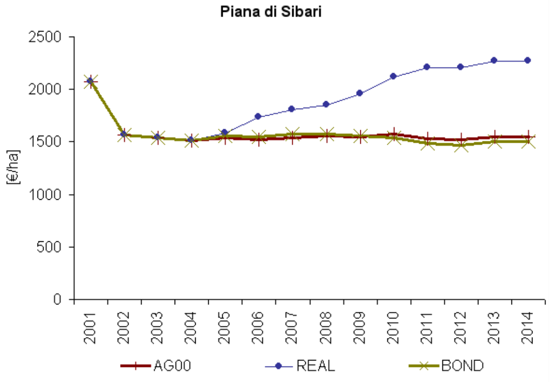
Figure 5.7: Rental price of table wine area



Source: own model results

* No table wine area rented on 2001.

Figure 5.8: Rental price of citrus fruit land

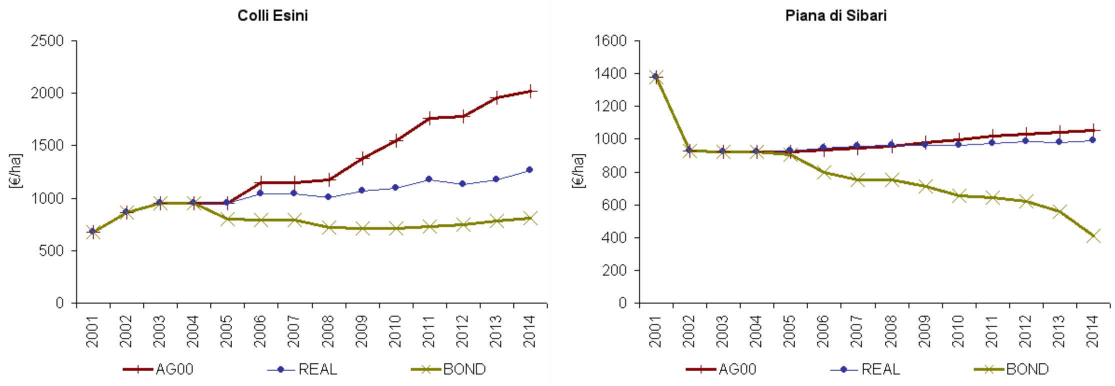


Source: own model results

specialised in this crop. On the contrary, in Colli Esini olive oil production is often just a marginal activity for farms where the main product is something else, often wine grapes; thus, we don't observe a major impact on in its land rental price.

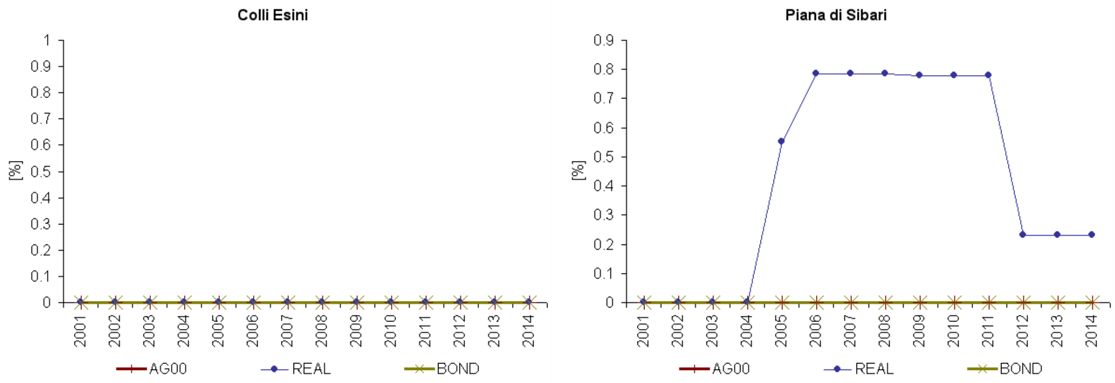
Land use Despite decoupling may have significant impact on farm profitability and rental prices, its impact on land use even in the "bond scheme" seems to be very limited. We can explain this outcomes with the high fragmentation of Italian agriculture in many small farms; thus, land demand is always high (for this reason land prices are much higher than most other EU countries). As AgriPoliS::Med is able to model scale effects (through the availability of many investments in different size options), it can well catch the attempts of farms to increase their size in order to produce more efficiently. As rental contracts are assigned through

Figure 5.9: Rental price of dry olive oil area



Source: own model results

Figure 5.10: Idle grassland [%]



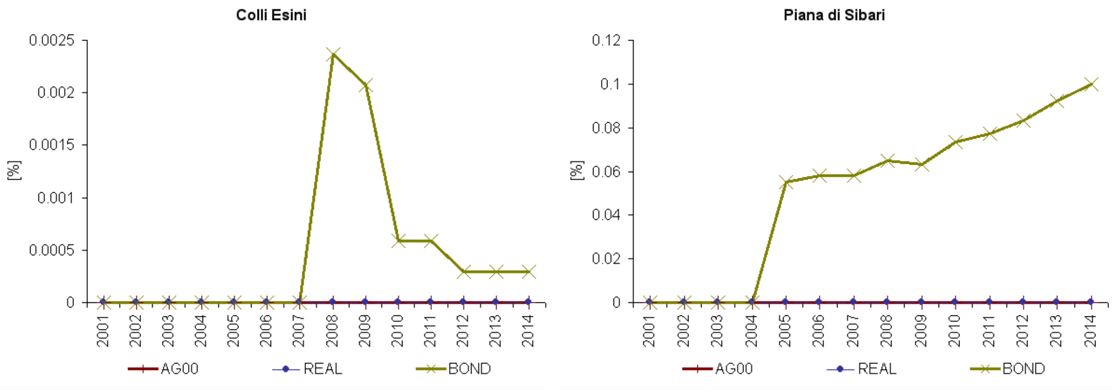
Source: own model results

an auction without minimal level constraints, if land supply increases and, at the same time, demand declines as result of farm quitting, the rental price may decline until it becomes profitable for farmers to rent it. So, due to rental price changes, we observe a very small land abandonment and we don't register land abandonment even in full decoupling case, i.e under the "bond scheme" scenario (Figure 5.11). Figure 5.10 shows the only case where our model generates an amount of land used for management obligations only (as required by cross-compliance and statutory management requirements).

Other models predict a limited effect of SFP or further subsides cuts on land use.

van Meijl et al. (2006) use a well-know agricultural-focused CGE model (GTAP) coupled with a biophysical (IMAGE) model of land productivity. In their *Global*

Figure 5.11: Land abandonment [%]



Source: own model results

Economy scenario (roughly comparable with our *bond scheme* one) they predict agricultural land in the EU25 to drop very limited (-2.3% over 30 years). This result would be the consequence of two opposite effects: the policy effect that alone would reduce the EU25 agricultural land of 8%, but a contemporaneous increase in world global demand of agricultural products would increase it of 5.7%, ending with a net forecasted effect of -2.3%.

Since most statistics on 2005 land allocation among agricultural production activities in Italy are now available, we can also start to see directly in the official statistics the effects of the decoupling on the land use.

Table 5.1 shows how on the first year of the application of the reform (2005) cereals have lost 279,700 ha (-6.5%) of land. However only a limited share of this land was converted to fodder; instead all other usage of arable land has increased. Interesting, it seems there were no land-abandonment from agriculture caused by the reform: in 2005 agricultural land has dropped of 117,600 ha, but this is ever less than the average 162,700 ha that yearly moved away from agriculture during the 1990-2004 period.

Analysing the Corine Land Cover dataset Lobianco (2006) reports that only 31.2% of the agricultural land that changed usage between the Corine Land cover 1990 version and the 2000 version moved toward natural systems[20]. 33,4% of it remained instead whitin the agriculture sector (under a different category) and the mayority (35,4%) moved toward urbanized usage Influence of land demand for

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[20] The temporal period between the two surveys is only roughly 10 years, as fotographic data acquisition vary between the regions

urbanised usage is often omitted in agricultural economics analyses, but it seems the it is the first driving force in agricultural land allocation, even higher than policies.

Table 5.1: Pre- and after- Fischler reform land allocation (1,000 ha, Italy)

	1980-2004		2004-2005		2005-2006	
	1,000 ha[a]	%[a]	1,000 ha	%	1,000 ha	%
Cereals (including rice)	-34.7	-0.7	-279.7	-6.5	-123.4	-3.1
Protein crops	-7.4	-2.9	+4.5	+5.8	-2.2	-2.7
Root crops	-10.1	-2.0	+64.7	+25.1	-49.4	-15.3
Industrial crops	+8.6	+8.2	+8.7	+2.8	+25.1	+7.8
Total Fodder	-101.1[b]	-1.3[b]	+84.3	+1.3	n./a.	n./a.
SUM	-162.7[b]	-1.2[b]	-117.6	-1.0	n./a.	n./a.

[a] yearly values;

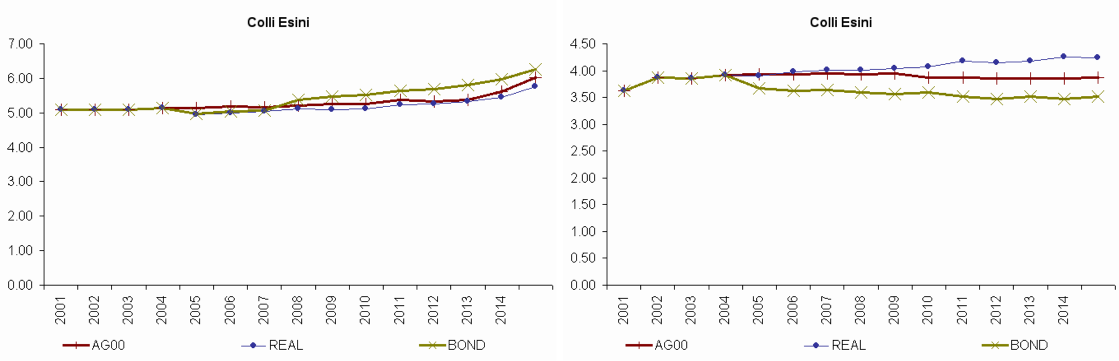
[b] 1990-2004.

Source: Eurostat, table pvprovga

Farm diversification We are also interested to assess if, as effect of decoupling, farms tend to specialise on some sectors or, on the contrary, to diversify production. To answer this question, we calculated the average number of products by farms. From model results (figure 5.12), we observe that farms produce a higher number of products over years, and this could be interpreted as a general tendency to diversification. However, this is better explained by the increase in the average size. In fact, once we adjust our coefficient by the farm size (figure 5.13), we notice that, on average, farms actually tend to produce a smaller number of products, that is, to specialise.

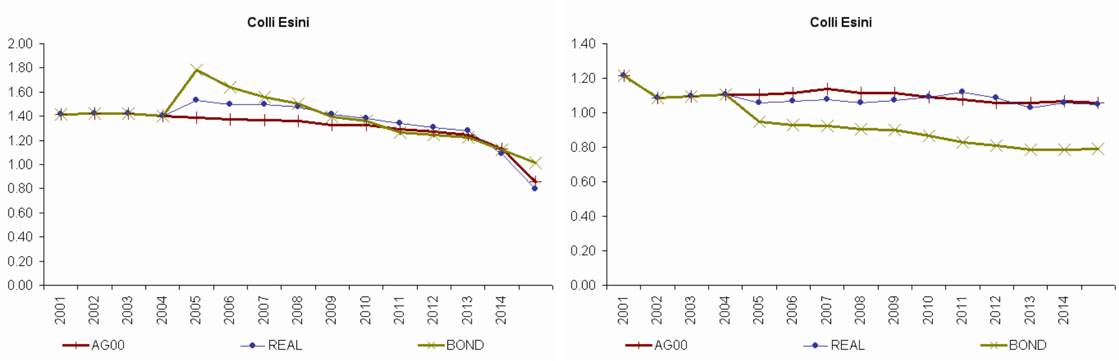
We can also observe that, again, the “actual implementation” scenario has a very small impact on this specialisation-diversification process. We can explain the larger impact of the “bond scheme” scenario on Piana di Sibari by the fact that here the land dropped by small farms is used by bigger farms with the same kind of specialisation and looking for scale effects, whereas in Colli Esini this “available” land is used also by small perennial crops’ farms taking advantage of the decline of arable and grass land rental price.

Figure 5.12: Average products by farm



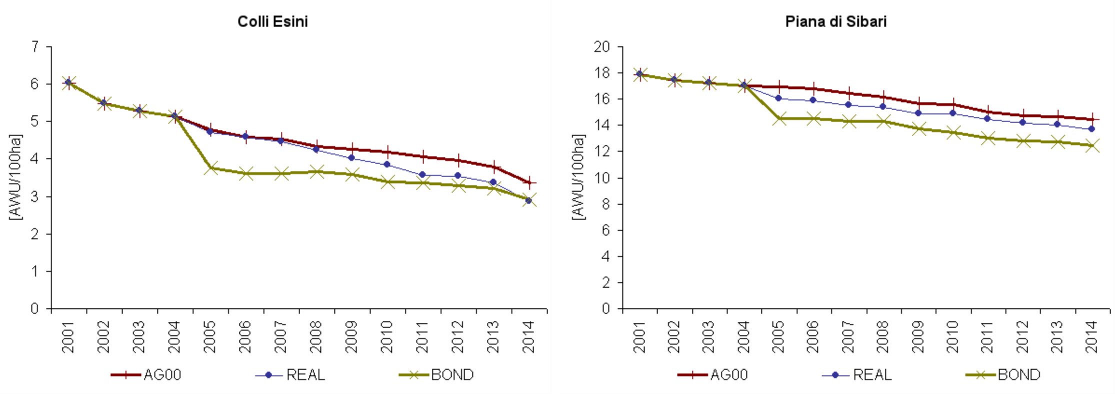
Source: own model results

Figure 5.13: Average products by farm - adjusted



Source: own model results

Figure 5.14: Total agricultural labour [AWU/100ha]



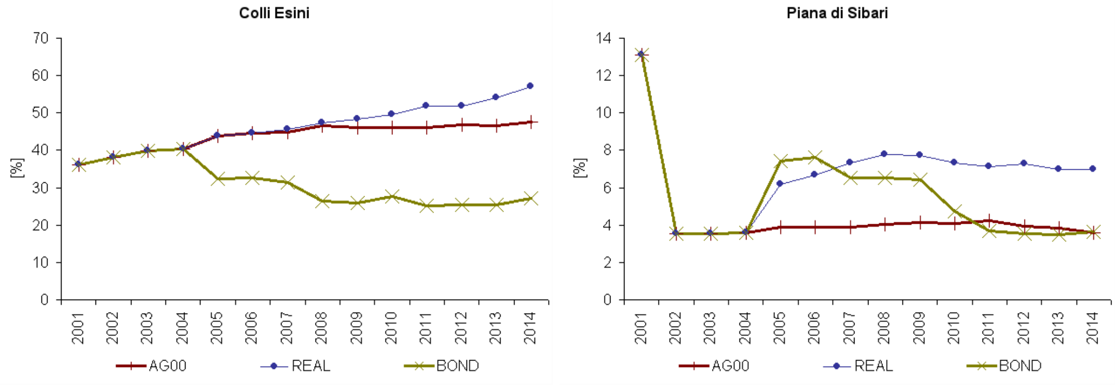
Source: own model results

Labour Labour figures clearly show a structural declining trend in both regions (Figure 5.14). In the model, this labour saving pattern is a consequence of new investments having smaller labour requirements than the older ones they replace (due to technological progress) and, above all, of the emerging size effects, that is bigger size investments requiring less per unit labour than smaller ones. Figure 5.14 also indicates a strong effect of the “bond scheme” scenario on labour reduction and a smaller effect of the “actual implementation” scenario. While the former case is evidently a result of abandonment of the smallest and inefficient arable crop farms, the effects of the latter are of more doubt interpretation, and it may be ascribable to fall in specific production activities.

A limited reduction in the total agricultural labour, as result of the application of the Fischler reform, is forecasted also in Manfredi (2005). Using the *MEG Ismea* model, a static applied general equilibrium model, he presents some outlines of the ISMEA model for the national performance of the agricultural sector. As in our *actual implementation* scenario, in his paper the agricultural labour level seems to have a very limited decline compared with baseline, in measure of -0.76% for family labour and -0.11% for hired work.

Figure 5.15 reports the attitude of farmers and their families to work off-farm. In Colli Esini the “bond scheme” scenario reflects abandonment of farms that previously were already more off-farm oriented; on the contrary, under the “actual implementation” scenario such farms remain in the model but are more oriented toward labour-saving productions. Piana di Sibari results show a more complex path. We notice an initial drop of off-farm labour that is probably caused by a poor

Figure 5.15: Off-farm labour [%]



Source: own model results

calibration of the model on this aspect; then we observe an increase of off-farm labour in two scenarios and a decline in the "bond scheme" case, as in the other region. In both regions, however, "actual implementation" seems to increase the share of off-farm labour. This is a clear direct effect of the scenario construction (but also of policy design) that forces farms to remain in the sector to maintain the right to the SFP.

Farm profitability Figure 5.16 shows the average per ha net profit of the farm[21]. We define farm net profit as the sum of the revenues originated by product sale, direct premiums and decoupled premiums (SFP) less all explicit costs (including capital depreciation). Therefore, we do not include opportunity costs of owned factors (labour, land and capital). Per ha profit shows a slight but constant decline over time. On top of this trend the "actual implementation" scenario seems to have a small impact in our results, with a stronger drop in the "bond scheme" scenario. However this stronger decline is partially fictitious, as the figure reports the profits only of the active farms, ignoring those farms that left the agricultural activity, but under the "bond scheme" even farmers who quit production still receive the SFP.

When considering instead the total family incomes (including off-farm labout) Manfredi (2005) suggests very slight wage rise (0.48%) as effects of the Fischler reform in Italy. AgriPoliS::Med has different outcomes in the two regions: in the

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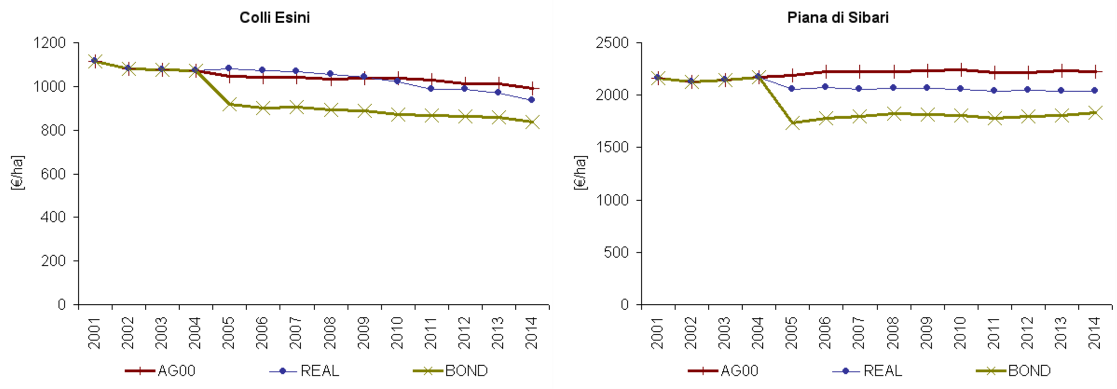
[21] Since land abandonment is negligible, Figure 5.16 also shows the tendency of the *total* agricultural profit in the regions.

Figure 5.16: Farm net profit per ha [euro/ha]



Source: own model results

Colli Esini the model output a quite strong rise of 19.43%, but at the same time in the Piana di Sibari where, for the modality of the reform that “froze“ the status-quo, the transfers from CAP payments remain almost half than in the Colli Esini region, it reports a substancial invariance (-0.23%)[22].

When looking at the real decoupling rate (Figure 5.17), we notice that it reflects the different product composition in the two regions. In Colli Esini the share of crops supported by the CAP is higher and even in the “actual implementation” we observe a considerable level of coupled support (18.3%), mainly consisting of durum wheat and other “quality” payments [23]. At the opposite, in Piana di Sibari, even in the “actual implementation”, we achieve an almost full decoupling rate.

Specific crops and livestock productions Though AgriPoliS::Med is more suited to the analysis of the impacts on farm structure rather than on specific commodity productions (for instance, prices are fixed and exogenous), we can still look at the impact of the three policy scenarios on major Mediterranean crops.

With regard to durum wheat, simulations reveals a significantly heterogeneous situation between the two regions, with Colli Esini showing almost no change and Piana di Sibari, at the opposite, a quite negative impact. As the gross margin of this crop is higher in Calabria (860 euro/ha compared to 502 euro/ha in Colli Esini), the reason of this sharp decline relies on the complex mix of alternative options decoupling gives to farmers. In particular, it seems that in Colli Esini

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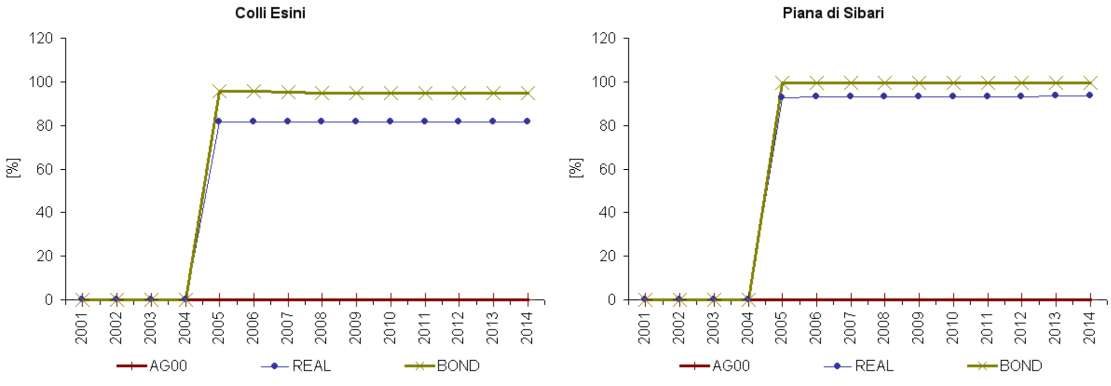
[22] This results refer to the ”Total incomes by AWU“ variable and they are influenced by dynamic effects as farm quitting and farm enlargement.

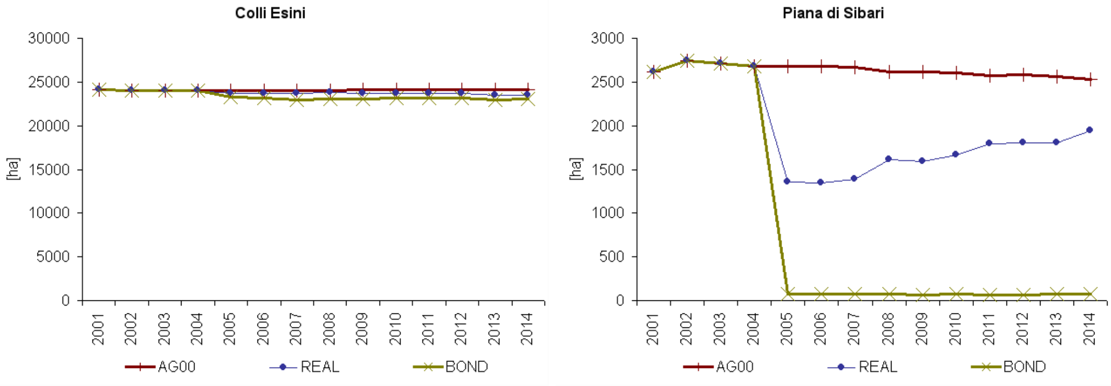
[23] Reg EU 1782/2003, art. 69 and art. 72

Figure 5.17: Real decoupling rate - [%]



Source: own model results

Figure 5.18: Durum Wheat area



Source: own model results

there are no viable alternatives to durum wheat, while in Piana di Sibari it is possible to re-allocate labour, land and other resources to other more profitable farm activities.

Figure 5.19 shows how labour intensive and highly profitable crops, like vegetables, may benefit from decopulping due to reallocation of production factors from previously supported commodities. In this respect, it must be reminded that our decoupling scenarios, even "actual implementation", admit that land dropped by previously supported crops may then eventually be allocated to vegetable crops, though this is not allowed in the current regulation [24].

In some perennial crops (e.g. grapes and fruit production) we don't observe a significant response to CAP change. On the contrary, the impact seems quite

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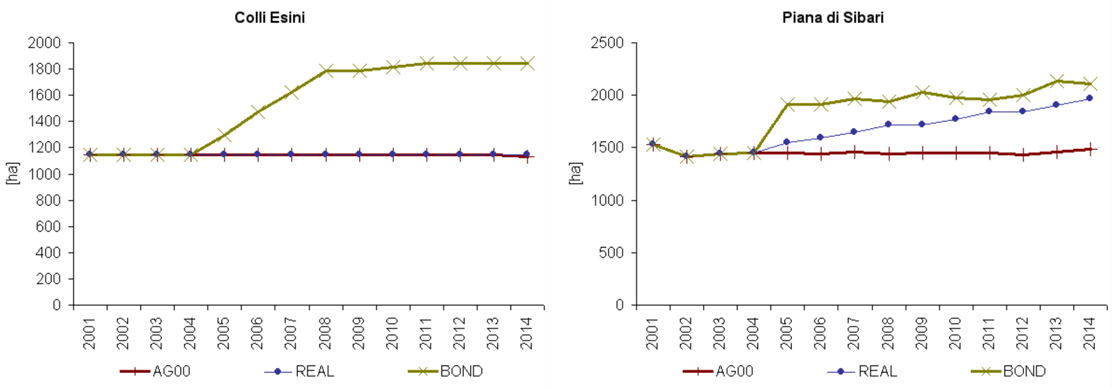
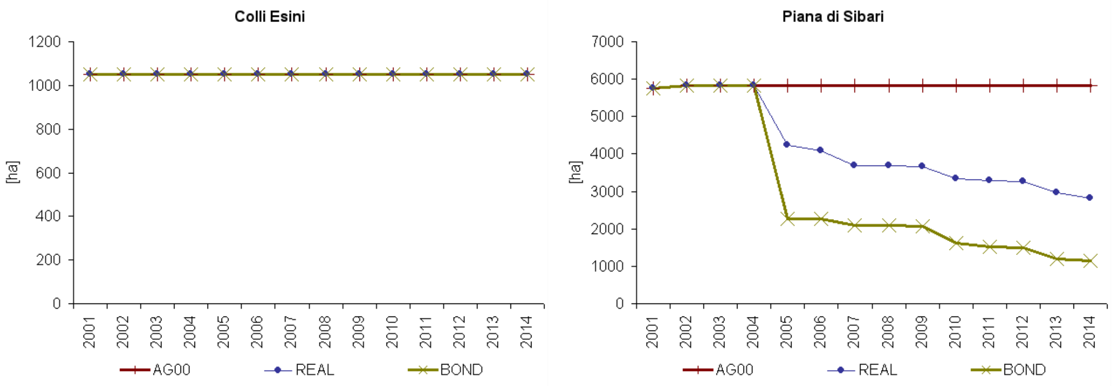
[24] Reg. EU 1782/2003 n. 1782, art. 51

Figure 5.19: Vegetables area



Source: own model results

Figure 5.20: Olives area



Source: own model results

large on olive production, even with significant regional differences: while in Colli Esini we don't have impact on the indeed marginal olive oil production, we actually observe a sharp decline in Piana di Sibari. As already mentioned, the reason seems to be that olive farms in Colli Esini are not "specialised" in this production, being mostly wine producers. In Piana di Sibari, specialised olive farms are much more affected by the decoupling.

For the Colli Esini region we have the opportunity to confront our results in terms of individual crop allocation with INEA (2004). This report uses very similar baseline and actual implementation scenarios and apply them along the Marche Region with a spacial detail that allows very close confrontation of the results. It employs a Positive Mathematical Programming approach (Arfini, 2000; Heckelei

& Britz, 2005) in conjunction with local FADN and AGEA[25] data to catch the effect of the reform on farmers production behaviours.

In general, despite the different approach, the sign of the effect coincide, even if in some instances the magnitude differs (Table 5.2). Notably INEA (2004) predicts, for the "Ancona-collina" location, no differences on incomes between the old Agenda 2000 scenario and the reformed CAP, when instead our model forecast a strong increase due to the reform.

Table 5.2 also shows the first available statistics on crop land allocation after the 2003 CAP reform. The most surprising outcomes is the reduction on vegetable areas, that conflict with the idea of transferring production factors (labour, machinery..) from previously highly supported activities to lesser ones.

Table 5.2: Forecasted Fischler reform effects on crop land allocation

	INEA	AgriPoliS::Med	EUROSTAT
	Ancona hills	*Colli Esini*	*Italy*
	(static comp.)	(2014)	(2006 vs 2004)
Durum wheat	–	-	–
Maize	–	–	-
Sugar beet	+	++	++
Vegetables	+	+	–
Set-aside	=	++	n./a.
Farmer incomes	=	++	n./a.

= => +- 0.5%
+ (-) => up +(-) 5%
++ (–) => over +(-) 5%

A final remark on the livestock sector. In both regions livestock is almost negligible, with Colli Esini reaching a maximum of 0.06 LU/ha in 2014 under the "agenda 2000" scenario and Piana di Sibari a maximum of 0.16 LU/ha in 2014 under the "bond scheme" scenario. Again, the impact seems to depend more on farms structure than on direct effects of CAP reform on these activities.

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[25] AGEA is the national agency in charge of granting agricultural subsidies.

5.2 Agricultural decoupling effects on the Environment

This section shows results obtained applying the methodologies exposed on section 3.6. At this stage only nutrient excess and pesticides results are reported, as work on water usage as well as land mosaic is not yet completed, and results will be published in Brady (2007).

Figure 5.21 shows our results on the surplus of nutrients in the three scenarios. We refer to the *surplus* of nutrients instead of their *usage* as AgriPoliS::Med is able to calculate a simple balance of nutrients, where the input is made of mineral and organic fertilisation and the output is made of the minerals included in the harvested production: what it remains from this balance is the possibly polluting surplus[26].

It has to be clarified that our policy scenarios do not include any limitation on the nutrients and pesticides usage. Even the *actual implementation* scenario simply states that farmers need to crop all their land to cash the SFP, but it doesn't impose any other cross-compliance measure.

To be precise the model includes two bounds on environmental aspects that cost farmers a penalty if exceeded, but they refer to animal activity - *livestock density* and *organic fertilisation* (manure)[27]. Both regions are very bare of livestock activity and far away to reach these limits, so they do not influence results. Furthermore, these environmental bounds are implemented in the MIP and they don't change under different policy settings.

While we generally do not observe substantial environmental consequences of the Fischler CAP reform, with the exception of a reduction in nutrient surplus in the Piana di Sibari likely due to a reduction in olive plantation area, environmental consequences of further liberalisations could be much higher.

Our results in the Colli Esini region shown a quite surprisingly increase of nutrient surplus in the bond scheme. The higher increase is in the phosphorous and nitrogenous, that is ascribable to an increase in the sugar beet and vegetables harvested area and a simultaneous drop of durum wheat area. Compared with other crops, durum wheat requires lesser nitrogenous fertilisation and at the same

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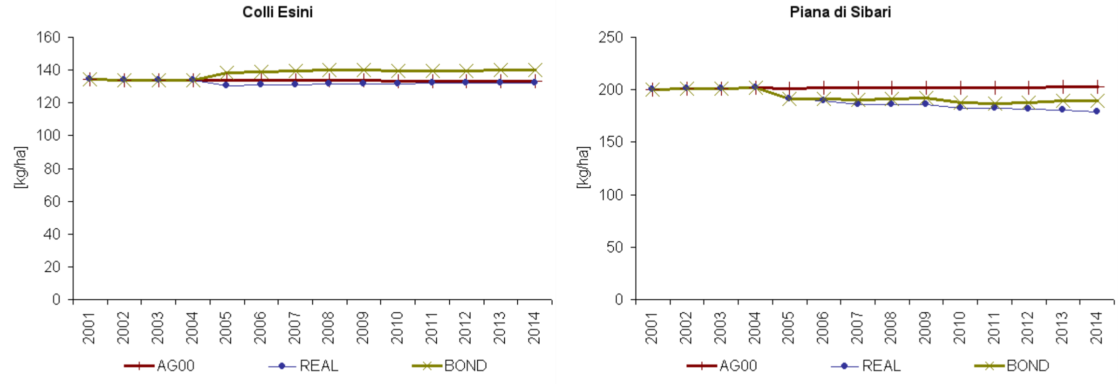
[26] We are aware of the simplicity of this approach, that doesn't contemplate nitrogen fixation nor natural degradation. However, nothing prevent to link AgriPoliS::Med with a proper specialised soil and environmental model.

[27] In case of manure a market is established to its trade.

Figure 5.21: Nutrients Excess (N, P_2O_5, K_2O)



Source: own model results

time retains a larger share of this element within the harvested production.

Nitrogenous and phosphorus increase is partially counterbalanced by potassium drop in the actual implementation, imputable to the strong oilseed drop in the model.

At the opposite on Piana di Sibari we expect a significant drop in all the three categories of nutrients we considered. This is even more important as the average surplus in this region in considerably higher than in the Colli Esini one. This results seems ascribable to the fall in olive plantation area as described in the previous section: olive production has, together with oranges, the highest *per-unit* surplus of nitrogen between the crops we consider.

Figure 5.22 shows the pesticide usage. This was simply obtained from the production levels and a fixed coefficient for each production activity. In this Figure is considered the sum of three categories of pesticides: fungicides, insecticides and herbicides[28].

Both region show a considerable grow in pesticide usage on the bond scheme. The increase is slightly higher in the Colli Esini (+20.7%) that in the Piana di Sibari (+17.7%). However in absolute terms, it is the latter region to shows more concerning values, being its pesticide level more than four times those of Colli Esini.

In particular insecticides have the largest share within the pesticides category, and are those with the highest contribution to the pesticide rice. Within the modelled crops, insecticide usage is particularly high in vegetables and oranges

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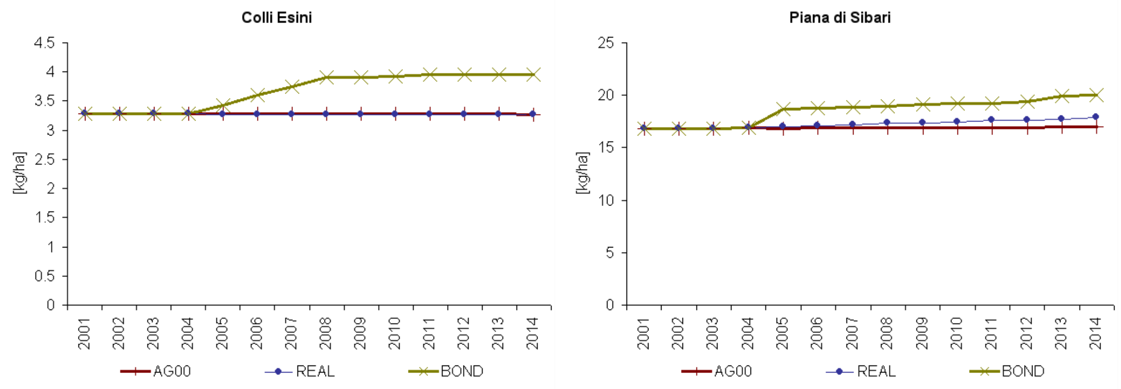
[28] Details of their individual trends can be found on Table A.11.

Figure 5.22: Pesticide usage



Source: own model results

production, and this latter explain the much higher usage in the Piana di Sibari.

5.3 Result validation and sensitivity analyses

Due to the presence of highly non linear parts and of random elements, validating an AB model is rarely a straightforward task.

It is easy to be mistaken in validating the behaviour of the specific system we designed rather than the general system we want investigate. Furthermore we had the specific issue that our FADN sample was available only as a punctual observation along the temporal dimension, preventing us from dynamically calibrating the model with our dataset. (For theoretical implication of validating ABM see Fagiolo et al., 2006).

However, following the McCarl & Spreen (2003) terminology, we performed the following validations exercises:

Validation by Construct:

- - once discussed in internal research meetings [29], our results seems to behave satisfactorily according to the experts attending such meetings;
- - constraints were imposed along the bound matrix to take into account natural agronomic (crop-rotations) limits.

Validation by Results:

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[29] Halle (June 2006) and Prague (September 2006)

- - one-year comparison of activity made by our agents with those made by real farmers (static comparison);
- - sensitivity analysis on key exogenous parameters (next section);
- - comparison of our results with other author forecasting on analogous scenarios.

5.3.1 Sensitivity analyses on key exogenous parameters

In order to test the robustness of our results we performed various sensitivity analyses on key exogenous parameters.

On this section are reported some considerations on the tests we performed with reference to the Colli Esini region. First, we investigated the effects of the *rent adjust factor*. This is a coefficient that decrease the maximum price a farmer is willing to offer for renting a new plot, and it is used to take into account the transaction costs, taxes and all other costs involved in the renting process plus a marginal profit for the farmer. Figure 5.23 shows the effects of different values of this coefficient. The greater effects is obviously on rental prices, that are reduced roughly proportionally. When rent adjust factor is equal to 1, the offer coincide with the farmer shadow price and the new plot doesn't produce any marginal profit to the tenant. This is why the profit per land unit is lower when the coefficient is higher. This coefficient indirectly influence the farm finance: when the rent adjust coefficient is set to 0.5 the number of active farmers on 2014 is 4.71% higher then when it is set to 1. Equally the quantity of agricultural labour is just marginally influenced by this coefficient (-4.12% under the same scenario).

Secondly we investigated effects of different *transport costs*. This parameter is theoretically very important, as directly influence farmer interrelations in terms of competition level over the most important production factor, that is, agricultural land.

When this value is low, farms compete along many farmer over many plots. Figure 5.24 (*left side*) shows how this higher land demand leads on higher grassland prices[30]. However farmers finance is not highly affected by this coefficient (Figure

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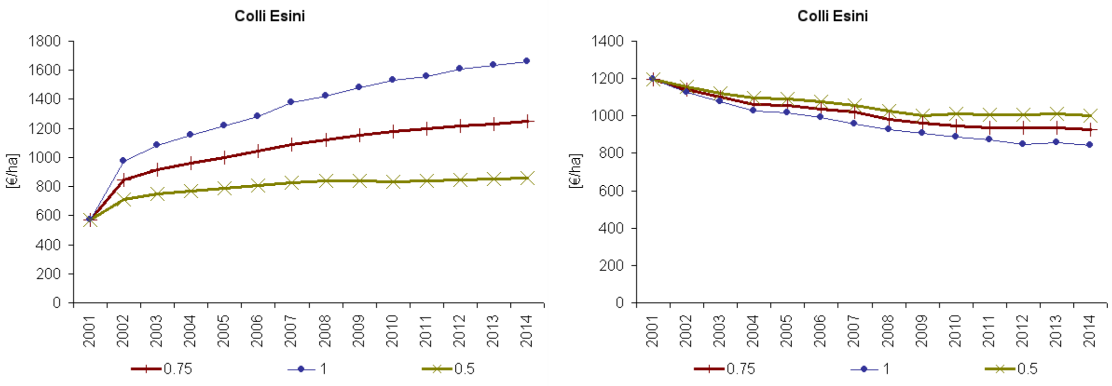
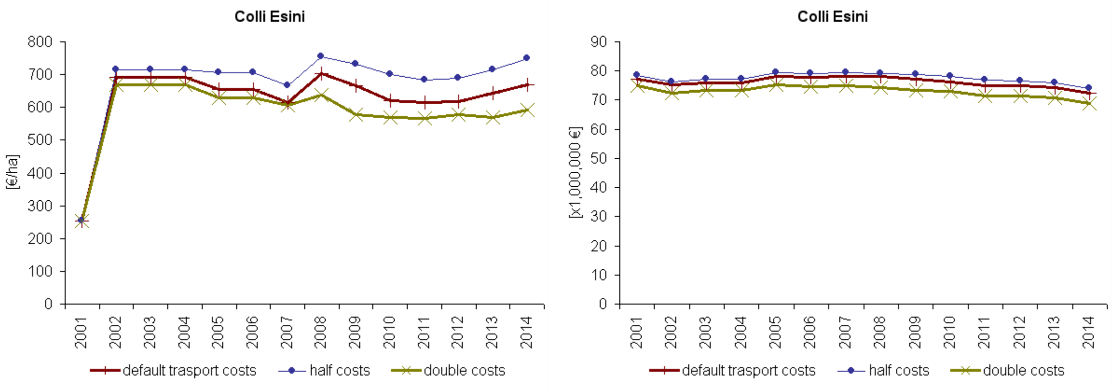
[30] As in the Colli Esini region grassland is very scarce, the average distance from farmsteads is high and so the influence of transport costs is also high. According, arable land rental price is less affected.

Figure 5.23: Effects of different rend adjust factors on arable land price *(left)* and profit *(right)*



Source: own model results

Figure 5.24: Effects of different transport costs on grassland price *(left)* and total incomes *(right)*



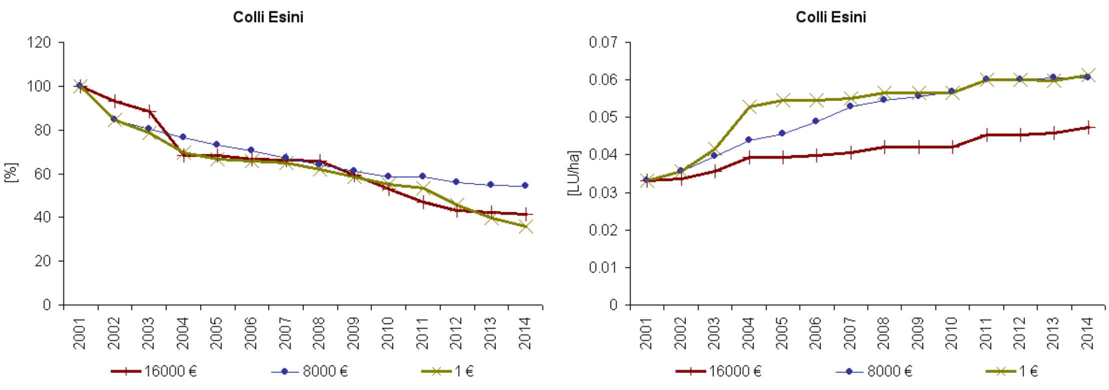
Source: own model results

5.24, *right side*). The reason is that in both regions we have modelled, plots (and farms) are very small, so that distance costs in this areas don't assume the importance thy have in other regions.

The final parameter we analysed, the *minimum withdraw*, is directly related with the farmer finance. It represents the minimum consumption made by the farm family during the year. If the incomes are higher, the farm family will spend this minimum plus a proportion of the higher incomes, if it is lower, the farm family will still consume it, ending up to use its own capital till eventually be forced to exit the agricultural sector for liquidity shortage.

However, has it involves directly the farmer's financial resources, effects of this

Figure 5.25: Effects of different minimum farmer whitdraw levels on farm numbers *(left)* and livestock activity *(right)*



Source: own model results

parameter seems to be much more complex, e.g. it seems that extreme values lead both to a higher farm abandonment from the agricultural activity. Lickely higher values stress excessively the farmer finance, while smaller values intensify the competition between farmers.

Notably, this coefficient has a direct effect on the livestock sector, maybe because this sector is highly capital-intensive: higher withdraws reduce the available capital for new stables, causing a reduction of the livestock activities (Figure 5.25).

6 Concluding remarks

Agricultural systems, and in particular the highly-diversified Mediterranean ones, can be conceived as complex systems where an heterogeneous set of farmers pursues its own aims, reacting to environmental changes and, at the same time, influencing with its own actions the environment, intended as the set of the physical, political, social and economic layers (including other farmers).

This two-way connections between farmers and their environment can be modelled through computational simulation. In particular agent-based modelling can simulate both the farmer behaviour and the effects of these connections.

In this dissertation we review AgriPoliS::Med, a spatially explicit, dynamic, multi-agent model framework where the main objective is the analysis of the relations between the political layer and the individual farmers[31].

We use samples of heterogeneous farms to build an agent-based model suitable to simulate the effects of different agricultural policies on these heterogeneous farm structures and output composition. Farm samples are collected from two Italian regions differing in terms of typical Mediterranean agricultural characteristics. These samples are then rescaled to build two virtual regions showing, on aggregate figures, similar characters with respect to the real regions.

Differences in farm structure are often the key explanation of different responses to CAP change in the two regions. Furthermore, the long-run structural trends often overlap and even offset the effects arising form different policy implementations. This is the case of the sharp decline in number of farms and in agricultural labour. Nonetheless, even in the "bond scheme" scenario we don't observe a substantial land abandonment. Eventually, within the model, it is the decline of land rental price to allow land to be reallocated to other agricultural activities. In our model however we neither consider marginal areas nor land demand from other sectors (e.g. "urban" uses).

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[31] While AgriPoliS::Med employs monodirectional connections between farmers and the political layer, it can be adapted to model bidirectional connections, where farmers can vote and influence the political layer (see for example Kellermann, 2002).

We also investigate which farmers can gain better opportunities in the new CAP scenarios, that is under decoupling. Our simulations show that size by itself is not necessarily a key factor, as arable crop farms need a much larger size to achieve scale economies and to be competitive compared with permanent crop farms that may remain profitable also with a smaller land size. At the end, we expect that the decoupling scheme, as introduced in Italy after the 2003 CAP reform, causes quite limited changes on land use and on farm structure. On the contrary, a more radical reform, like the "bond scheme" scenario, would allow farms to leave the sector, still receiving the SFP, and this would remarkably change the farm regional structure. However, even in this case, we don't observe radical changes on several aggregated agricultural figures, e.g. productions and land use.

The main advantage of AgriPoliS is probably its flexibility in providing a general framework for agricultural computational modelling. As a matter, AgriPoliS was easily adapted to contempt some specific characteristics of the Mediterranean agriculture, like quality differentiation, perennial crops and irrigation constrains (AgriPoliS::Med).

However, while the analysis of the farmer behaviour and, in general, of farm structures is very detailed in AgriPoliS::Med, its connections between farmers and their environment could be improved. Connections with the political layer could be improved especially in the recognition of the increasing importance of the cross compliance measures: in the *actual implementation* scenario farmers need to crop all their land to cash the SFP. However no specific requirements are imposed in terms of nutrients or pesticide.

Although they are of great importance in the Mediterranean agriculture, connections with the local social and economic layers are relatively weak in current AgriPoliS::Med version. For example, the ageing problem is strongly affecting the Mediterranean agriculture (section 4.1.3), but this aspect is not considered by AgriPoliS::Med.

In general, a less farm centric modelling approach could better reflect the scientific and political interest in understanding the social phenomena emerging in the rural areas and the contribution of agriculture to them.

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A Appendix

Table A.1: Land use [ha]

	2003			2000		
	EU25	EU25med	Italy	EU15	EU15med	Italy
Total land	397,552	104,014	30,134	323,428	103,008	30,132
Arable land	97,073	25,253	7,959	71,749	23,330	7,261
Perm. grassland	56,401	14,767	4,377	44,935	14,782	3,418
Perennial crops	11,606	9,494	2,674	9,994	8,482	2,347
Other land	232,472	54,499	15,124	196,749	56,414	17,106

Source: Eurostat

Table A.2: General territorial, social and economic data

	2003			2000		
	EU25	EU25med	Italy	EU15	EU15med	Italy
Total area[a]	398	104	30	323	103	30
UAA[a]	156	46	13	127	47	13
Population[b]	455,846	122,195	57,605	377,023	118,355	56,949
Agr. labour force[c]						
- heads[b]	20,342	8,597	3,738	13,547	8,898	3,964
- AWU[b]	9,161	3,095	1,323	5,688	3,049	1,208
Agr. holdings[b]	9,811	4,330	1,963	6,771	4,674	2,154
GDP[d]	9,823	2,389	1,301	8,609	2,042	1,167
Agr. Output[d]	158	69	29	147	62	28

[a] x1,000,000 hectares

[b] x1,000

[c] Regular labour force

[d] x1,000,000,000 euros

Source: Eurostat

Table A.3: Agricultural output [milions of euro]

	2003			2000		
	EU25	EU25med	Italy	EU15	EU15med	Italy
Cereals and oth. crops	82,730	20,448	8,238	76,685	21,595	8,910
Animal products	127,730	33,538	14,341	116,854	30,943	13,571
Fruits	20,857	13,832	4,576	16,386	11,771	4,340
Wine	14,509	6,422	4,011	16,191	6,644	3,998
Olive oil	5,634	5,634	2,065	5,102	5,102	2,008
Veg & Hort	45,295	21,020	8,442	37,190	16,146	7,512
Services and transf	18,039	4,363	2,141	14,606	3,813	1,671

Source: Eurostat (Economic Accounts for Agriculture)

Table A.4: Farm holders by age class [1,000 heads]

	2003			2000		
	EU25	EU25med	Italy	EU15	EU15med	Italy
< 35	835	217	76	529	310	111
34 - 44	1,788	567	235	1,094	635	263
45 - 54	2,318	841	376	1,469	947	434
55 - 64	2,070	1,024	474	1,539	1,126	504
>= 65	2,650	1,623	788	1,871	1,581	826

Source: Eurostat

Table A.5: Region delimitation

Colli Esini		**Piana di Sibari**	
National code	**LAU2 Name**	**National code**	**LAU2 Name**
42003	Arcevia	78009	Altomonte
42004	Barbara	78029	Cassano allo Ionio
42005	Belvedere Ostrense	78044	Corigliano Calabro
42008	Castelbellino	78047	Crosia
42011	Castelleone di Suasa	78108	Rossano
42012	Castelplanio	78121	San Lorenzo del Vallo
42016	Cupramontana	78142	Spezzano Albanese
42021	Jesi		
42023	Maiolati Spontini		
42024	Mergo		
42025	Monsano		
42026	Montecarotto		
42029	Monte Roberto		
42031	Morro d'Alba		
42035	Ostra		
42036	Ostra Vetere		
42037	Poggio San Marcello		
42040	Rosora		
42041	San Marcello		
42042	San Paolo di Jesi		
42043	Santa Maria Nuova		
42046	Serra de' Conti		
42047	Serra San Quirico		
42049	Staffolo		

Table A.6: Farms average yearly abandonment rate (%)

	period	observed	ag2000	actual	bond
Italy	1990-2003	-2,32			
Colli Esini	2001-2014		-3,32	-3,19	-7,88
Piana di Sibari	2001-2014		-1,78	-1,96	-4,21

Source: Eurostat, model results

Table A.7: Comparison between the real and virtual regions and the FADN dataset

		Colli Esini			Piana di Sibari		
		Real region	Virtual region	FADN dataset	Real region	Virtual region	FADN dataset
Total farms		5,785	5,510	159	10,626	4,631	134
Total UAA		49,093	49,292	2,688	29,178	18,683	1,511
Irrigated UAA		2,022	2,105	45	9,728	7,130	305
Number of farms in different size unit	< 1 ha	1,113	1,084	1	5,941	0	0
	1 – 2	943	576	1	2,137	2,196	18
	2 – 5	1,680	1,762	30	1,647	1,562	36
	5 – 10	1,008	1,035	49	482	493	26
	10 – 20	555	563	37	210	211	32
	20 – 50	357	361	30	146	149	19
	50 – 100	77	77	9	33	20	2
	>100	52	52	2	30	0	1
Land use	arable	42,718	43,248	2,283	8,618	6,487	620
	grassland	1,052	971	130	1,334	1,469	375
	table wine	830	968	21	282	218	20
	quality wine	2,985	2,959	190	6	0	5
	olive oil	1,092	1,103	37	9,816	5,609	254
	fruit land	319	0	6	8,820	5,033	219
	other uaa	0	42	21	0	0	27
Farm type (farm number)	arable	.	3,581	105	.	778	21
	wine	.	642	14	.	0	0
	olive	.	0	0	.	86	18
	fruit	.	0	4	.	2,439	59
	livestock	.	0	0	.	185	7
	milk	.	0	0	.	141	4
	mixed	.	1,287	36	.	1,002	25
Farm type (UAA)	arable	.	38,394	2,052	.	3,735	310
	wine	.	1,236	70	.	0	0
	olive	.	0	0	.	2,236	196
	fruit	.	0	42	.	5,493	328
	livestock	.	0	0	.	518	42
	milk	.	0	0	.	704	61
	mixed	.	9,662	525	.	5,998	574
Livestock (number of animal)	beef cattle	3,059	2,972	118	2,531	1,680	80
	dairy cows	700	0	0	2,042	1,635	199
	pigs	16,933	17,040	93	3,121	2,944	59
	ovins	10,882	0	0	3,664	4,292	2,000
	goats	733	0	0	2,480	3,386	1,426
	poultry	1,806,093	0	0	16,750	0	0

Source: Census 2000, FADN 2001, upscaling results

Table A.8: FADN farms' upscaling weight distribution

	Discarded	1-5	5-10	10-20	20-50	50-100	100-200	200-500	500-1000	1000-1500
Colli Esini	**141**	**0**	**0**	**0**	**3**	**2**	**2**	**8**	**2**	**1**
Piana di Sibari	**118**	**0**	**0**	**0**	**2**	**3**	**5**	**2**	**3**	**1**

Source: upscaling results

Table A.9: Farm distribution by 2001 farm size

	ag2000					actImpl					bond				
year	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
2001	55	51	53	20	4	55	51	53	20	4	55	51	53	20	4
2002	54	37	53	20	4	54	37	53	20	4	54	37	53	20	4
2003	54	37	53	20	4	54	37	53	20	4	54	37	53	20	4
2004	52	37	53	20	4	52	37	53	20	4	52	37	53	20	4
2005	51	36	53	20	4	51	36	53	20	4	51	0	26	13	4
2006	49	36	53	19	4	49	36	53	20	4	49	0	23	13	4
2007	49	34	53	19	4	49	34	53	20	4	49	0	21	13	4
2008	46	33	53	19	4	46	33	53	20	4	46	0	17	12	4
2009	43	32	53	18	4	43	30	53	20	4	43	0	17	12	4
2010	42	29	53	17	4	42	23	53	20	4	42	0	16	12	4
2011	38	26	53	17	4	38	21	53	20	4	39	0	15	12	4
2012	37	23	53	17	4	37	21	53	20	4	38	0	15	12	4
2013	35	21	53	17	4	35	19	53	20	4	36	0	15	12	4
2014	27	18	53	16	4	27	16	53	20	4	32	0	15	12	4

	ag2000					actImpl					bond				
year	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
2001	39	93	16	5	1	39	93	16	5	1	39	93	16	5	1
2002	24	84	16	5	1	24	84	16	5	1	24	84	16	5	1
2003	24	84	16	5	1	24	84	16	5	1	24	84	16	5	1
2004	23	84	16	5	1	23	84	16	5	1	23	84	16	5	1
2005	23	84	16	5	1	23	83	16	5	1	23	61	15	5	1
2006	23	84	16	5	1	23	82	16	5	1	23	60	15	5	1
2007	23	84	16	5	1	23	81	16	5	1	23	58	15	5	1
2008	23	83	16	5	1	23	80	16	5	1	23	56	15	5	1
2009	23	83	16	5	1	23	80	16	5	1	23	55	15	5	1
2010	23	82	16	5	1	23	79	16	5	1	22	52	15	5	1
2011	23	80	16	5	1	23	78	16	5	1	22	49	15	5	1
2012	22	79	16	5	1	23	77	16	5	1	22	48	15	5	1
2013	22	79	16	5	1	23	75	16	5	1	22	46	15	5	1
2014	22	78	16	5	1	23	74	16	5	1	22	45	15	5	1

Source: model results

Table A.10: Land distribution by 2001 farm size

	ag2000					actImpl					bond				
year	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
2001	55.0	198.0	480.0	584.5	374.5	55.0	198.0	480.0	584.5	374.5	55.0	198.0	480.0	584.5	374.5
2002	54.0	132.0	482.5	628.5	395.0	54.0	132.0	482.5	628.5	395.0	54.0	132.0	482.5	628.5	395.0
2003	54.0	132.0	483.0	625.0	398.0	54.0	132.0	483.0	625.0	398.0	54.0	132.0	483.0	625.0	398.0
2004	52.0	132.0	483.5	625.0	399.5	52.0	132.0	483.5	625.0	399.5	52.0	132.0	483.5	625.0	399.5
2005	51.0	128.0	484.0	631.0	398.0	52.5	128.0	484.5	630.0	397.0	51.0	0.0	269.5	865.0	506.5
2006	49.0	128.0	484.0	634.0	397.0	50.5	129.0	485.0	631.5	396.0	55.0	0.0	261.5	870.5	505.0
2007	49.0	120.0	484.5	637.5	401.0	51.5	122.0	486.0	633.0	399.5	61.0	0.0	259.0	868.0	504.0
2008	46.0	116.5	484.5	646.0	399.0	49.0	118.5	489.0	637.5	398.0	66.0	0.0	266.0	846.0	510.0
2009	43.0	112.5	485.5	654.5	396.5	46.0	107.5	493.0	652.5	393.0	64.0	0.0	280.5	842.0	502.0
2010	42.0	100.5	486.0	668.0	395.5	45.5	80.0	501.5	672.5	392.5	64.5	0.0	292.0	836.0	498.5
2011	38.0	90.0	488.0	680.5	395.5	40.0	73.5	510.0	674.0	394.5	64.0	0.0	300.5	834.0	492.5
2012	37.0	77.0	490.5	683.5	404.0	40.0	75.0	520.0	669.5	387.5	63.0	0.0	322.0	821.5	485.0
2013	35.0	70.5	494.0	686.0	406.5	38.0	67.5	531.5	668.0	387.0	61.0	0.0	337.5	817.5	475.5
2014	27.0	60.5	514.0	690.0	400.5	30.0	57.5	562.0	659.5	383.0	55.0	0.0	366.5	803.0	467.0

	ag2000					actImpl					bond				
year	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
2001	46.5	268.5	171.0	118.0	51.0	46.5	268.5	171.0	118.0	51.0	46.5	268.5	171.0	118.0	51.0
2002	41.0	251.0	190.5	117.5	55.0	41.0	251.0	190.5	117.5	55.0	41.0	251.0	190.5	117.5	55.0
2003	41.0	249.5	191.0	118.5	55.0	41.0	249.5	191.0	118.5	55.0	41.0	249.5	191.0	118.5	55.0
2004	40.0	249.5	191.0	119.5	55.0	40.0	249.5	191.0	119.5	55.0	40.0	249.5	191.0	119.5	55.0
2005	40.0	249.5	191.0	119.5	55.0	40.5	250.0	191.5	117.5	55.5	39.5	170.0	219.5	130.0	60.0
2006	40.0	249.0	192.0	119.0	55.0	40.5	249.0	192.0	116.5	57.0	39.5	166.0	222.5	129.0	60.0
2007	39.5	248.5	193.0	119.0	55.0	40.5	247.5	195.5	114.0	57.5	39.0	159.5	225.0	133.5	60.0
2008	40.0	245.0	196.0	119.0	55.0	40.0	244.5	199.5	112.5	58.5	38.5	153.0	227.0	134.0	60.0
2009	40.0	245.0	195.5	119.5	55.0	38.0	245.5	199.5	113.0	59.0	37.0	150.0	232.5	134.0	60.0
2010	40.0	242.0	198.5	119.5	55.0	38.0	243.5	201.5	112.0	60.0	35.5	141.0	236.0	134.5	60.0
2011	40.0	236.5	201.0	121.0	56.5	37.0	242.0	205.5	110.5	60.0	34.0	132.0	240.5	136.5	61.5
2012	38.5	234.5	203.5	120.5	58.0	37.5	240.0	207.0	110.5	60.0	34.5	127.0	242.0	135.5	61.5
2013	38.5	234.5	202.5	121.0	58.5	40.5	238.0	206.5	110.0	60.0	34.5	119.5	245.0	134.5	61.0
2014	38.5	230.5	206.0	121.0	59.0	42.5	235.0	210.5	107.5	59.5	33.5	114.5	247.5	133.5	60.5

Source: model results

Table A.11: **Detailed model results**

Colli Esini Results

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total number of farms - [farms]														
- *AG00*	5490	5040	5040	4980	4920	4830	4770	4650	4500	4350	4140	4020	3900	3540
- *REAL*	5490	5040	5040	4980	4920	4860	4800	4680	4500	4260	4080	4050	3930	3600
- *BOND*	5490	5040	5040	4980	2820	2670	2610	2370	2280	2220	2100	2070	2010	1890
Profit - [euro/ha]														
- *AG00*	1116	1079	1075	1074	1047	1043	1044	1033	1040	1038	1028	1011	1012	991
- *REAL*	1116	1079	1075	1074	1079	1072	1069	1054	1040	1020	988	987	967	934
- *BOND*	1116	1079	1075	1074	916	900	907	892	890	870	866	861	858	837
Rental price of arable dry land - [euro/ha]														
- *AG00*	570	618	628	641	663	690	718	740	760	771	784	804	814	828
- *REAL*	570	618	628	641	668	695	730	758	780	808	829	852	863	878
- *BOND*	570	618	628	641	363	369	376	381	388	398	409	415	422	426
Rental price of arable irrigable land - [euro/ha]														
- *AG00*	700	938	1384	1834	1908	2148	2141	2177	2350	2427	2431	2423	2515	2501
- *REAL*	700	938	1384	1834	1937	2253	2303	2346	2595	2629	2659	2821	2909	2905
- *BOND*	700	938	1384	1834	2619	2301	2195	2078	2090	2102	2057	2063	2051	2074
Rental price of generic grassland - [euro/ha]														
- *AG00*	254	691	691	691	887	887	1109	1342	1343	1394	1457	1457	1502	1563
- *REAL*	254	691	691	691	655	655	614	703	666	619	615	617	644	668
- *BOND*	254	691	691	691	91	91	91	72	78	76	90	103	116	114
Rental price of table wine area - [euro/ha]														
- *AG00*	1600	1403	1403	1403	1415	1419	1455	1469	1442	1467	1470	1459	1464	1473
- *REAL*	1600	1403	1403	1403	1430	1457	1531	1557	1600	1669	1720	1729	1856	1870
- *BOND*	1600	1403	1403	1403	1370	1358	1364	1335	1352	1362	1415	1431	1489	1499
Rental price of quality wine area - [euro/ha]														
- *AG00*	0	1798	1798	1798	1798	1798	1798	1792	1792	1749	1782	1782	1771	1757
- *REAL*	0	1798	1798	1798	1798	1798	1798	1782	1782	1743	1936	1961	1972	1995

- *BOND*	0	1798	1798	1798	1758	1758	1758	1734	1750	1736	1770	1793	1813	1812
Rental price of olives for oil dry area - [euro/ha]														
- *AG00*	678	860	954	954	954	1152	1152	1172	1375	1548	1759	1779	1960	2019
- *REAL*	678	860	954	954	954	1040	1040	1003	1065	1096	1171	1128	1175	1261
- *BOND*	678	860	954	954	801	795	795	716	709	716	734	747	787	807
Rental price of olives for oil irrigable area - [euro/ha]														
- *AG00*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *REAL*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *BOND*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rental price of citrus fruit area - [euro/ha]														
- *AG00*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *REAL*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *BOND*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Share of unused occupied land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idle arable dry land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idle arable irrigable land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idle grassland - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beef - [LU/ha]														
- *AG00*	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.06	0.06
- *REAL*	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03
- *BOND*	0.04	0.05	0.05	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Suckler cows - [LU/ha]

- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Dairy - [LU/ha]

- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Ovins and goats - [LU/ha]

- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Total livestock - [LU/ha]

- *AG00*	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
- *REAL*	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04
- *BOND*	0.04	0.05	0.05	0.05	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Total agricultural labour - [AWU/100ha]

- *AG00*	6.03	5.47	5.27	5.12	4.78	4.58	4.54	4.34	4.26	4.18	4.06	3.97	3.80	3.35
- *REAL*	6.03	5.47	5.27	5.12	4.70	4.58	4.47	4.24	4.01	3.85	3.55	3.53	3.36	2.87
- *BOND*	6.03	5.47	5.27	5.12	3.77	3.62	3.61	3.67	3.58	3.38	3.37	3.29	3.22	2.92

Share of family labour - [%]

- *AG00*	92.86	92.29	92.61	92.74	92.45	92.48	92.22	92.37	92.50	92.26	91.21	90.82	92.40	92.91
- *REAL*	92.86	92.29	92.61	92.74	93.39	93.38	93.29	93.31	93.56	93.39	92.63	92.59	92.78	92.61
- *BOND*	92.86	92.29	92.61	92.74	93.55	93.86	94.85	94.74	94.73	94.84	94.69	95.59	95.28	96.15

Share of family labour spent off farm - [%]

- *AG00*	36.04	38.02	39.81	40.33	43.89	44.56	44.94	46.48	45.97	46.15	46.01	46.92	46.70	47.59
- *REAL*	36.04	38.02	39.81	40.33	43.95	44.64	45.47	47.35	48.40	49.49	51.73	51.80	53.95	57.15
- *BOND*	36.04	38.02	39.81	40.33	32.29	32.73	31.39	26.53	25.88	27.72	25.25	25.32	25.43	27.13

Total incomes by farm (profit + off farm incomes) - [euro]

- *AG00*	14052	14917	15080	15269	15539	15785	16025	16417	16856	17359	17926	18293	18715	19947
- *REAL*	14052	14917	15080	15269	15874	16027	16277	16668	17159	17903	18388	18499	18937	20074
- *BOND*	14052	14917	15080	15269	20333	21089	21518	22401	23059	23459	24223	24444	25059	26132

Share of incomes from off farm activity - [%]

- *AG00*	26.58	27.17	28.23	28.31	30.46	30.55	30.69	31.34	30.42	30.24	29.69	30.20	29.63	28.74
- *REAL*	26.58	27.17	28.23	28.31	29.86	30.12	30.55	31.42	31.64	32.13	33.15	33.13	34.03	34.43
- *BOND*	26.58	27.17	28.23	28.31	18.88	18.83	18.04	14.95	14.27	15.21	13.64	13.63	13.52	13.96
Farm incomes by farm - [euro]														
- *AG00*	10317	10864	10823	10947	10805	10963	11106	11272	11729	12109	12604	12769	13169	14214
- *REAL*	10317	10864	10823	10947	11133	11199	11305	11431	11731	12151	12293	12370	12493	13163
- *BOND*	10317	10864	10823	10947	16494	17117	17637	19051	19768	19891	20918	21112	21670	22484
Total development of total transfers - [x1,000,000 euro]														
- *AG00*	22.43	22.60	22.62	22.58	22.55	22.50	22.56	22.50	22.60	22.75	22.73	22.74	22.78	22.98
- *REAL*	22.43	22.60	22.62	22.58	23.37	23.28	23.20	23.17	23.17	23.13	23.11	23.11	23.09	23.09
- *BOND*	22.43	22.60	22.62	22.58	14.38	14.02	13.77	12.56	12.53	12.42	12.29	12.28	12.26	12.23
Transfers by farm - [x1,000 euro]														
- *AG00*	4.09	4.48	4.49	4.53	4.58	4.66	4.73	4.84	5.02	5.23	5.49	5.66	5.84	6.49
- *REAL*	4.09	4.48	4.49	4.53	4.75	4.79	4.83	4.95	5.15	5.43	5.66	5.71	5.88	6.42
- *BOND*	4.09	4.48	4.49	4.53	5.10	5.25	5.27	5.30	5.50	5.59	5.85	5.93	6.10	6.47
Transfers by hectar - [euro]														
- *AG00*	442	445	446	445	444	443	444	443	445	448	448	448	449	453
- *REAL*	442	445	446	445	460	459	457	456	456	456	455	455	455	455
- *BOND*	442	445	446	445	283	276	271	248	247	245	242	242	242	241
Real decoupling rate - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	81.51	81.60	81.56	81.61	81.59	81.64	81.66	81.67	81.68	81.68
- *BOND*	0.00	0.00	0.00	0.00	95.61	95.50	95.42	94.98	94.97	94.92	94.87	94.86	94.86	94.84
Share of irrigated land - [%]														
- *AG00*	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.99	2.99	2.99	3.00	3.08
- *REAL*	2.98	2.98	2.98	2.98	2.26	2.26	2.26	2.26	2.34	2.45	2.60	2.64	2.83	3.01
- *BOND*	2.98	2.98	2.98	2.98	2.70	3.13	3.43	3.82	3.82	3.93	3.99	3.99	3.99	3.99
Durum wheat - [ha]														
- *AG00*	24085	24034	24040	24045	24048	24059	24059	24073	24081	24081	24122	24125	24138	24171
- *REAL*	24085	24034	24040	24045	23717	23740	23741	23756	23746	23715	23671	23682	23492	23527
- *BOND*	24085	24034	24040	24045	23247	23191	22972	23050	23032	23209	23143	23166	22992	23040
Sugar beet - [ha]														
- *AG00*	7899	8147	8156	8249	8342	8448	8420	8623	8426	8184	8163	8237	8185	7887

- *REAL*	7899	8147	8156	8249	11216	11216	11216	11216	11216	11216	11216	11216	11216	11216
- *BOND*	7899	8147	8156	8249	11216	11205	11186	11149	11141	11134	11119	11115	11111	11111
Maize - [ha]														
- *AG00*	5092	5018	4966	4908	4864	4791	4753	4687	4740	4921	4896	4725	4772	4823
- *REAL*	5092	5018	4966	4908	2466	2587	2611	2702	2723	2829	2861	2885	2986	2955
- *BOND*	5092	5018	4966	4908	4216	4246	4355	4336	4365	4168	4234	4214	4412	4414
Vegetables - [ha]														
- *AG00*	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1132
- *REAL*	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145
- *BOND*	1145	1145	1145	1145	1294	1473	1623	1787	1787	1816	1846	1846	1846	1846
Set-aside - [ha]														
- *AG00*	4372	4372	4372	4372	4372	4372	4372	4372	4372	4372	4372	4372	4372	4373
- *REAL*	4372	4372	4372	4372	5456	5262	5261	5188	5247	5210	5214	5167	5196	5232
- *BOND*	4372	4372	4372	4372	4357	4339	4324	4308	4308	4305	4302	4302	4302	4302
Total permanent crops - [ha]														
- *AG00*	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905
- *REAL*	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905
- *BOND*	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905	4905
Vineyards - [ha]														
- *AG00*	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855
- *REAL*	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855
- *BOND*	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855	3855
Olives (for oil) - [ha]														
- *AG00*	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
- *REAL*	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
- *BOND*	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
Citrus fruits - [ha]														
- *AG00*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *REAL*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *BOND*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average farm size - [ha]														
- *AG00*	9.25	10.07	10.07	10.19	10.32	10.51	10.64	10.92	11.28	11.67	12.26	12.63	13.02	14.34
- *REAL*	9.25	10.07	10.07	10.19	10.32	10.44	10.58	10.85	11.28	11.92	12.44	12.53	12.92	14.10

- *BOND*	9.25	10.07	10.07	10.19	18.00	19.01	19.45	21.37	22.22	22.85	24.16	24.51	25.25	26.85
Share of initial number of farms - [%]														
- *AG00*	100.00	91.80	91.80	90.71	89.62	87.98	86.89	84.70	81.97	79.23	75.41	73.22	71.04	64.48
- *REAL*	100.00	91.80	91.80	90.71	89.62	88.52	87.43	85.25	81.97	77.60	74.32	73.77	71.58	65.57
- *BOND*	100.00	91.80	91.80	90.71	51.37	48.63	47.54	43.17	41.53	40.44	38.25	37.70	36.61	34.43
Total incomes by AWU - [euro/AWU]														
- *AG00*	25212	27072	28419	29250	31502	32767	33199	34641	35068	35620	35976	36517	37889	41497
- *REAL*	25212	27072	28419	29250	32761	33480	34466	36211	37910	39072	41578	41809	43666	49562
- *BOND*	25212	27072	28419	29250	29981	30636	30621	28562	28986	30410	29745	30293	30803	33338
Total incomes of agr families - [x1,000,000 euro]														
- *AG00*	77.15	75.18	76.01	76.04	76.45	76.24	76.44	76.34	75.85	75.51	74.21	73.54	72.99	70.61
- *REAL*	77.15	75.18	76.01	76.04	78.10	77.89	78.13	78.01	77.22	76.27	75.02	74.92	74.42	72.27
- *BOND*	77.15	75.18	76.01	76.04	57.34	56.31	56.16	53.09	52.57	52.08	50.87	50.60	50.37	49.39
Excess of nutrients - [kg/ha]														
- *AG00*	134.1	133.8	133.8	133.8	133.8	133.7	133.7	133.5	133.5	133.4	133.4	133.3	133.2	133.0
- *REAL*	134.1	133.8	133.8	133.8	130.2	130.9	131.0	131.3	131.3	131.7	131.9	131.9	132.3	132.1
- *BOND*	134.1	133.8	133.8	133.8	138.5	139.0	139.7	140.2	140.2	139.4	139.7	139.6	140.3	140.2
Pesticides - [kg/ha]														
- *AG00*	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.27
- *REAL*	3.29	3.29	3.29	3.29	3.26	3.26	3.26	3.27	3.27	3.27	3.27	3.27	3.27	3.27
- *BOND*	3.29	3.29	3.29	3.29	3.43	3.60	3.74	3.90	3.90	3.92	3.95	3.95	3.95	3.95
Nitrogen (N) - [kg/ha]														
- *AG00*	31.42	31.12	31.05	31.05	31.03	31.02	30.92	30.85	30.81	30.70	30.74	30.62	30.56	30.34
- *REAL*	31.42	31.12	31.05	31.05	30.75	30.96	31.08	31.21	31.27	31.54	31.61	31.62	31.53	31.49
- *BOND*	31.42	31.12	31.05	31.05	34.71	34.80	35.07	35.39	35.40	35.04	35.14	35.09	35.36	35.33
Phosphorous (P2O5) - [kg/ha]														
- *AG00*	21.91	21.89	21.88	21.92	21.95	21.99	21.95	22.02	21.93	21.80	21.82	21.82	21.78	21.61
- *REAL*	21.91	21.89	21.88	21.92	22.86	22.94	22.97	23.01	23.03	23.11	23.13	23.14	23.05	23.07
- *BOND*	21.91	21.89	21.88	21.92	24.01	24.12	24.21	24.45	24.44	24.40	24.42	24.40	24.42	24.42
Potassium (K2O) - [kg/ha]														
- *AG00*	80.79	80.84	80.88	80.83	80.79	80.72	80.82	80.68	80.79	80.89	80.82	80.91	80.90	81.07
- *REAL*	80.79	80.84	80.88	80.83	76.59	76.97	76.90	77.10	77.03	77.08	77.13	77.19	77.68	77.56
- *BOND*	80.79	80.84	80.88	80.83	79.75	80.06	80.47	80.32	80.37	79.98	80.11	80.11	80.47	80.46

Fungicides - [kg/ha]														
- *AG00*	2.27	2.27	2.27	2.27	2.27	2.28	2.28	2.28	2.28	2.27	2.27	2.27	2.27	2.26
- *REAL*	2.27	2.27	2.27	2.27	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
- *BOND*	2.27	2.27	2.27	2.27	2.37	2.43	2.49	2.55	2.55	2.55	2.56	2.56	2.56	2.56
Herbicides - [kg/ha]														
- *AG00*	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27
- *REAL*	0.27	0.27	0.26	0.26	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
- *BOND*	0.27	0.27	0.26	0.26	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Insecticides - [kg/ha]														
- *AG00*	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.74
- *REAL*	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
- *BOND*	0.75	0.75	0.75	0.75	0.84	0.94	1.03	1.13	1.13	1.14	1.16	1.16	1.16	1.16

Piana di Sibari Results

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total number of farms - [farms]														
- *AG00*	4620	3900	3900	3870	3870	3870	3870	3840	3840	3810	3750	3690	3690	3660
- *REAL*	4620	3900	3900	3870	3840	3810	3780	3750	3750	3720	3690	3660	3600	3570
- *BOND*	4620	3900	3900	3870	3150	3120	3060	3000	2970	2850	2760	2730	2670	2640
Profit - [euro/ha]														
- *AG00*	2166	2128	2147	2166	2190	2223	2227	2225	2232	2244	2216	2218	2233	2222
- *REAL*	2166	2128	2147	2166	2058	2077	2059	2065	2067	2051	2041	2047	2039	2034
- *BOND*	2166	2128	2147	2166	1736	1783	1798	1824	1817	1804	1783	1798	1810	1831
Rental price of arable dry land - [euro/ha]														
- *AG00*	180	180	364	526	692	774	774	774	774	849	933	1133	1218	1296
- *REAL*	180	180	364	526	699	781	781	781	781	857	938	1090	1206	1315
- *BOND*	180	180	364	526	631	656	656	676	690	698	722	750	781	815
Rental price of arable irrigable land - [euro/ha]														
- *AG00*	780	1235	1371	1473	1545	1580	1672	1812	1858	1934	1977	2025	2086	2116
- *REAL*	780	1235	1371	1473	1625	1732	1851	2000	2036	2153	2249	2278	2340	2377
- *BOND*	780	1235	1371	1473	1543	1552	1542	1538	1538	1511	1511	1510	1498	1491
Rental price of generic grassland - [euro/ha]														
- *AG00*	104	753	835	861	891	950	1048	1140	1142	1207	1279	1369	1411	1499
- *REAL*	104	753	835	861	899	965	1049	1134	1132	1152	1232	1355	1388	1453
- *BOND*	104	753	835	861	871	853	884	888	870	827	805	838	830	832
Rental price of table wine area - [euro/ha]														
- *AG00*	0	594	594	594	641	770	770	806	851	881	908	906	956	977
- *REAL*	0	594	594	594	641	801	801	834	864	897	923	1020	1035	1132
- *BOND*	0	594	594	594	641	770	770	806	838	869	906	938	968	946
Rental price of quality wine area - [euro/ha]														
- *AG00*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *REAL*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *BOND*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rental price of olives for oil dry area - [euro/ha]														

- *AG00*	1380	927	922	922	921	933	943	959	977	995	1020	1028	1042	1054
- *REAL*	1380	927	922	922	927	945	955	959	962	961	971	982	980	989
- *BOND*	1380	927	922	922	906	796	750	750	712	655	644	620	557	410
Rental price of olives for oil irrigable area - [euro/ha]														
- *AG00*	1720	1779	1795	1807	1886	1896	1962	2006	2036	2079	2134	2149	2168	2175
- *REAL*	1720	1779	1795	1807	1701	1661	1635	1584	1570	1537	1511	1502	1499	1517
- *BOND*	1720	1779	1795	1807	500	458	329	298	239	219	175	162	153	156
Rental price of citrus fruit area - [euro/ha]														
- *AG00*	2070	1566	1541	1516	1536	1524	1543	1557	1547	1575	1529	1522	1551	1548
- *REAL*	2070	1566	1541	1516	1582	1739	1802	1847	1956	2119	2209	2209	2270	2270
- *BOND*	2070	1566	1541	1516	1557	1552	1570	1576	1553	1542	1482	1467	1502	1505
Share of unused occupied land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.05	0.06	0.06	0.06	0.06	0.07	0.08	0.08	0.09	0.10
Idle arable dry land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idle arable irrigable land - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idle grassland - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.55	0.78	0.78	0.78	0.78	0.78	0.78	0.23	0.23	0.23
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beef - [LU/ha]														
- *AG00*	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
- *REAL*	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
- *BOND*	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
Suckler cows - [LU/ha]														
- *AG00*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

- *REAL*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
- *BOND*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dairy - [LU/ha]														
- *AG00*	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
- *REAL*	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
- *BOND*	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03
Ovins and goats - [LU/ha]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *BOND*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total livestock - [LU/ha]														
- *AG00*	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14
- *REAL*	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.14	0.14
- *BOND*	0.13	0.13	0.13	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16
Total agricultural labour - [AWU/100ha]														
- *AG00*	17.89	17.42	17.20	17.01	16.93	16.81	16.42	16.16	15.64	15.56	15.00	14.74	14.67	14.45
- *REAL*	17.89	17.42	17.20	17.01	16.03	15.90	15.49	15.38	14.90	14.86	14.45	14.20	14.00	13.64
- *BOND*	17.89	17.42	17.20	17.01	14.54	14.49	14.34	14.29	13.71	13.45	12.99	12.80	12.72	12.45
Share of family labour - [%]														
- *AG00*	92.40	67.68	67.90	68.29	68.32	68.66	69.49	69.52	71.37	71.38	72.13	72.32	72.74	72.45
- *REAL*	92.40	67.68	67.90	68.29	68.80	68.65	68.76	68.35	70.19	69.73	70.91	71.27	71.22	72.15
- *BOND*	92.40	67.68	67.90	68.29	63.47	63.36	63.12	62.60	64.02	63.41	63.73	64.08	63.36	63.91
Share of family labour spent off farm - [%]														
- *AG00*	13.11	3.55	3.54	3.59	3.86	3.89	3.89	4.05	4.12	4.06	4.22	3.96	3.82	3.57
- *REAL*	13.11	3.55	3.54	3.59	6.20	6.67	7.34	7.78	7.70	7.31	7.14	7.28	6.98	6.98
- *BOND*	13.11	3.55	3.54	3.59	7.41	7.60	6.53	6.53	6.43	4.71	3.71	3.55	3.50	3.66
Total incomes by farm (profit + off farm incomes) - [euro]														
- *AG00*	10085	10951	11118	11268	11408	11575	11666	11792	11836	11983	12037	12223	12296	12436
- *REAL*	10085	10951	11118	11268	11038	11215	11327	11474	11514	11608	11634	11768	11895	12009
- *BOND*	10085	10951	11118	11268	10831	11143	11373	11621	11704	12008	12145	12287	12510	12700
Share of incomes from off farm activity - [%]														
- *AG00*	8.67	2.10	2.69	2.38	2.51	2.48	3.08	3.46	3.49	3.43	3.52	3.35	3.27	4.07
- *REAL*	8.67	2.10	2.69	2.38	4.61	4.49	5.49	5.67	5.95	6.68	6.60	6.63	6.45	6.75

- *BOND*	8.67	2.10	2.69	2.38	5.49	5.06	4.36	3.86	3.77	4.03	3.52	3.42	3.37	3.41
Farm incomes by farm - [euro]														
- *AG00*	9211	10721	10818	11000	11122	11287	11306	11384	11423	11572	11613	11813	11894	11930
- *REAL*	9211	10721	10818	11000	10530	10712	10705	10823	10829	10833	10867	10988	11127	11198
- *BOND*	9211	10721	10818	11000	10236	10579	10877	11172	11262	11524	11718	11867	12089	12267
Total development of total transfers - [x1,000,000 euro]														
- *AG00*	12.30	14.06	14.07	14.06	14.06	14.06	14.05	14.04	14.05	14.04	14.04	14.06	14.04	14.02
- *REAL*	12.30	14.06	14.07	14.06	12.17	12.18	12.19	12.20	12.19	12.17	12.17	12.17	12.15	12.14
- *BOND*	12.30	14.06	14.07	14.06	8.98	8.98	8.83	8.68	8.62	8.36	8.15	8.06	7.94	7.84
Transfers by farm - [x1,000 euro]														
- *AG00*	2.66	3.60	3.61	3.63	3.63	3.63	3.63	3.66	3.66	3.69	3.74	3.81	3.81	3.83
- *REAL*	2.66	3.60	3.61	3.63	3.17	3.20	3.22	3.25	3.25	3.27	3.30	3.33	3.38	3.40
- *BOND*	2.66	3.60	3.61	3.63	2.85	2.88	2.88	2.89	2.90	2.94	2.95	2.95	2.97	2.97
Transfers by hectar - [euro]														
- *AG00*	626	715	716	715	716	716	715	715	715	715	714	715	715	714
- *REAL*	626	715	716	715	619	620	620	621	620	619	619	619	618	618
- *BOND*	626	715	716	715	484	485	477	472	468	459	450	448	445	443
Real decoupling rate - [%]														
- *AG00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- *REAL*	0.00	0.00	0.00	0.00	92.85	92.97	93.17	93.04	93.07	93.20	93.16	93.16	93.33	93.31
- *BOND*	0.00	0.00	0.00	0.00	99.52	99.53	99.53	99.53	99.52	99.52	99.49	99.50	99.47	99.46
Share of irrigated land - [%]														
- *AG00*	55.47	56.68	56.89	57.05	57.13	57.20	57.28	57.41	57.43	57.52	57.67	57.75	57.81	57.90
- *REAL*	55.47	56.68	56.89	57.05	57.16	57.06	57.18	57.28	57.31	57.11	57.13	57.26	57.05	57.03
- *BOND*	55.47	56.68	56.89	57.05	56.69	56.92	57.15	57.29	57.79	57.60	57.66	58.31	58.55	58.54
Durum wheat - [ha]														
- *AG00*	2613	2740	2711	2682	2681	2681	2667	2621	2613	2603	2575	2587	2565	2528
- *REAL*	2613	2740	2711	2682	1358	1351	1386	1610	1587	1664	1795	1808	1802	1947
- *BOND*	2613	2740	2711	2682	78	78	75	72	67	75	67	67	75	70
Sugar beet - [ha]														
- *AG00*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *REAL*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- *BOND*	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Maize - [ha]														
- *AG00*	1501	1485	1502	1521	1544	1551	1542	1570	1570	1590	1619	1654	1639	1625
- *REAL*	1501	1485	1502	1521	1540	1564	1625	1651	1656	1684	1733	1712	1774	1816
- *BOND*	1501	1485	1502	1521	1950	1948	1983	1958	2012	1986	1969	1992	2077	2061
Vegetables - [ha]														
- *AG00*	1529	1418	1442	1454	1449	1439	1463	1445	1449	1448	1448	1429	1456	1488
- *REAL*	1529	1418	1442	1454	1547	1593	1645	1715	1715	1767	1843	1845	1907	1966
- *BOND*	1529	1418	1442	1454	1916	1914	1965	1939	2025	1979	1956	1998	2134	2107
Set-aside - [ha]														
- *AG00*	340	358	385	412	429	432	432	436	435	436	442	446	443	443
- *REAL*	340	358	385	412	484	504	514	526	528	521	533	535	539	543
- *BOND*	340	358	385	412	533	537	547	543	553	551	542	550	565	559
Total permanent crops - [ha]														
- *AG00*	10895	11070	11070	11070	11070	11085	11085	11100	11100	11100	11100	11100	11100	11100
- *REAL*	10895	11070	11070	11070	9492	9353	8957	8957	8930	8603	8551	8519	8221	8089
- *BOND*	10895	11070	11070	11070	7543	7538	7355	7365	7324	6874	6778	6755	6456	6411
Vineyards - [ha]														
- *AG00*	225	225	225	225	225	225	225	225	225	225	225	225	225	225
- *REAL*	225	225	225	225	225	225	225	225	225	225	225	225	225	225
- *BOND*	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Olives (for oil) - [ha]														
- *AG00*	5750	5835	5835	5835	5835	5835	5835	5835	5835	5835	5835	5835	5835	5835
- *REAL*	5750	5835	5835	5835	4227	4088	3692	3692	3665	3338	3286	3254	2956	2824
- *BOND*	5750	5835	5835	5835	2278	2273	2090	2100	2059	1609	1513	1490	1191	1146
Citrus fruits - [ha]														
- *AG00*	4920	5010	5010	5010	5010	5025	5025	5040	5040	5040	5040	5040	5040	5040
- *REAL*	4920	5010	5010	5010	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040
- *BOND*	4920	5010	5010	5010	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040
Average farm size - [ha]														
- *AG00*	4.25	5.04	5.04	5.08	5.08	5.08	5.08	5.12	5.12	5.16	5.24	5.33	5.33	5.37
- *REAL*	4.25	5.04	5.04	5.08	5.12	5.16	5.20	5.24	5.24	5.28	5.33	5.37	5.46	5.50
- *BOND*	4.25	5.04	5.04	5.08	5.90	5.93	6.05	6.13	6.20	6.39	6.57	6.60	6.68	6.70
Share of initial number of farms - [%]														

- *AG00*	100.00	84.42	84.42	83.77	83.77	83.77	83.77	83.12	83.12	82.47	81.17	79.87	79.87	79.22
- *REAL*	100.00	84.42	84.42	83.77	83.12	82.47	81.82	81.17	81.17	80.52	79.87	79.22	77.92	77.27
- *BOND*	100.00	84.42	84.42	83.77	68.18	67.53	66.23	64.94	64.29	61.69	59.74	59.09	57.79	57.14
Total incomes by AWU - [euro/AWU]														
- *AG00*	13253	12473	12827	13046	13271	13559	13991	14257	14792	14934	15314	15573	15741	16032
- *REAL*	13253	12473	12827	13046	13454	13675	14067	14241	14748	14791	15116	15437	15566	15995
- *BOND*	13253	12473	12827	13046	12634	12959	13110	13278	13780	13969	14227	14542	14719	15223
Total incomes of agr families - [x1,000,000 euro]														
- *AG00*	46.59	42.71	43.36	43.61	44.15	44.79	45.15	45.28	45.45	45.65	45.14	45.10	45.37	45.52
- *REAL*	46.59	42.71	43.36	43.61	42.39	42.73	42.81	43.03	43.18	43.18	42.93	43.07	42.82	42.87
- *BOND*	46.59	42.71	43.36	43.61	34.12	34.77	34.80	34.86	34.76	34.22	33.52	33.54	33.40	33.53
Excess of nutrients - [kg/ha]														
- *AG00*	199.8	201.0	201.3	201.5	201.5	201.6	201.7	202.1	202.2	202.2	202.4	202.4	202.5	202.8
- *REAL*	199.8	201.0	201.3	201.5	190.9	189.9	186.3	186.1	185.9	182.5	182.6	181.9	180.2	179.1
- *BOND*	199.8	201.0	201.3	201.5	191.1	191.4	190.4	191.0	192.4	187.6	186.5	187.9	189.3	189.7
Pesticides - [kg/ha]														
- *AG00*	16.82	16.78	16.83	16.86	16.85	16.87	16.93	16.92	16.93	16.93	16.93	16.88	16.95	17.03
- *REAL*	16.82	16.78	16.83	16.86	16.99	17.09	17.17	17.34	17.34	17.43	17.61	17.61	17.74	17.87
- *BOND*	16.82	16.78	16.83	16.86	18.72	18.78	18.89	18.96	19.15	19.18	19.18	19.42	19.96	20.04
Nitrogen (N) - [kg/ha]														
- *AG00*	77.39	78.08	78.10	78.18	78.03	78.11	78.15	78.34	78.33	78.24	78.33	78.27	78.34	78.43
- *REAL*	77.39	78.08	78.10	78.18	73.27	72.50	70.28	69.71	69.62	67.54	67.14	66.86	65.52	64.51
- *BOND*	77.39	78.08	78.10	78.18	70.74	70.66	69.86	70.20	70.44	67.91	67.45	67.57	67.21	67.27
Phosphorous (P2O5) - [kg/ha]														
- *AG00*	24.33	24.45	24.47	24.49	24.45	24.44	24.48	24.47	24.47	24.45	24.46	24.41	24.46	24.51
- *REAL*	24.33	24.45	24.47	24.49	23.31	23.22	22.84	22.87	22.85	22.48	22.58	22.51	22.37	22.30
- *BOND*	24.33	24.45	24.47	24.49	23.56	23.56	23.53	23.57	23.86	23.22	23.08	23.28	23.70	23.69
Potassium (K2O) - [kg/ha]														
- *AG00*	98.06	98.45	98.73	98.87	99.01	99.04	99.10	99.30	99.38	99.47	99.60	99.68	99.74	99.86
- *REAL*	98.06	98.45	98.73	98.87	94.33	94.19	93.20	93.48	93.41	92.43	92.90	92.55	92.32	92.27
- *BOND*	98.06	98.45	98.73	98.87	96.84	97.13	97.04	97.27	98.10	96.43	95.96	97.10	98.38	98.70
Fungicides - [kg/ha]														
- *AG00*	6.65	6.64	6.67	6.68	6.67	6.68	6.70	6.70	6.70	6.70	6.70	6.68	6.71	6.73

- *REAL*	6.65	6.64	6.67	6.68	6.64	6.67	6.68	6.74	6.74	6.75	6.82	6.81	6.84	6.88
- *BOND*	6.65	6.64	6.67	6.68	7.19	7.21	7.24	7.27	7.33	7.32	7.32	7.41	7.59	7.62
Herbicides - [kg/ha]														
- *AG00*	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.38
- *REAL*	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.39	0.39	0.39	0.40	0.40	0.40	0.41
- *BOND*	0.37	0.37	0.37	0.37	0.43	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.47	0.47
Insecticides - [kg/ha]														
- *AG00*	9.80	9.77	9.80	9.82	9.81	9.82	9.86	9.85	9.86	9.86	9.86	9.83	9.87	9.92
- *REAL*	9.80	9.77	9.80	9.82	9.97	10.04	10.11	10.22	10.22	10.29	10.40	10.40	10.49	10.58
- *BOND*	9.80	9.77	9.80	9.82	11.10	11.13	11.21	11.25	11.37	11.41	11.42	11.56	11.90	11.95

AgriPoliS is a spatially explicit multi-agent model framework, developed in C++ language and suitable for long-term simulations of agricultural policies.

The main feature of models developed with AgriPoliS is their ability to simulate the interaction among a large set of heterogeneous farmers and between them and the environment in which they operate.

This dissertation describes an extension of the framework that allows AgriPoliS models to deal with typical characters of the Mediterranean agriculture (AgriPoliS::Med).

It can be divided in two parts: while the first one (chapters 2 and 3) provides a generic background of the multi-agent methodology and details AgriPoliS::Med, the second part (chapters 4 and 5) describes its implementation over alternative policy scenarios and the results obtained with reference to two regions located in Central and Southern Italy.

Results suggest that the effects of decoupling policies in the Mediterranean agriculture, as implemented in the 2003 reform, are often dominated by effects of structural trends and only a "bond scheme" would change the regional farm structures substantially. In no scenario remarkable agricultural land abandonment is observed.

Further development of this subject from the author can be found on the RegMAS.org project.

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