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Irrigation water management and policy on farm decision: The case study of the RENANA irrigation board

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$: United States dollar.

%: percentage unit.

€ ha^{-1} yr^{-1}: euro by hectare by year.

€ ha^{-1}: euro by hectare.

€ hr^{-1}: euro by hour.

€ m^{-3}: euro by cubic meter.

€ Q^{-1}: euro by quintal.

€ yr^{-1}: Euro per year.

€: Euro sign (used in participating European Union member countries (Euro zone)).

°C: degree Celsius.

AEM: Agri-Environmental Measures.

AEP: Agri-Environmental Policy.

AID: Advanced Integrated Defense.

BOD_5: The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.

CAP: Common Agricultural Policy.

CBA: Cost-Benefit Analysis.

CEA: Cost-Effectiveness Analysis.

CER: Board of second level that manages the Emilia Romagna canal (in Italian: Consorzio del Canale Emilia Romagnolo).

cf.: An abbreviation for the Latin word *confer*, meaning "compare" or "consult".

CFC: Chlorofluorocarbon.

CIS: Common Implementation Strategy.

CMO: Common Market Organizations.

COP: Cereals, Oilseeds and Protein crops.

CSO: Common Strategic Orientation.

CSS: Countryside Stewardship Scheme.

DEIAGRA: Department of Agricultural Economics and Engineering (in Italian: Dipartimento di Economica e Ingegneria Agraria).

Dlg: Legislative Decree.

DPO: Denomination of Protected Indication.

DSR: Driving force-State-Response framework.

e.g.: (*exempli gratia*) means "for example", "for instance".

EA: Effective Analysis.

EAFRD: European Agricultural Fund for Rural Development.

EC: European Community.

EIA: Environmental Impact Assessment.

Eq.: equation.

ES: Environmental Stewardship.

ESA: Environmentally Sensitive Areas.

ESU: Economic Size Unit (in Italian UDE: Unità di Dimensione Economica).

etc.: (*et cetera*) (archaic abbreviations include *&c.* and *&/c.*) means "and the others".

EU: European Union.

FADN: Farm Accountancy Data Network (in Italian RICA: Rete d'Informazione Contabile Agricola).

Fig.: figure.

GAMS: General Algebraic Modeling System.

GAP: Good Agricultural Practices.

GDP: Global Domestic Product.

GFP: Good Farming Practices.

GIA: Gender Impact Assessment.

GNI: Gross National Income.

GVP: Gross Vendible Production (in Italian PLV: Produzione Lorda Vendibile).

Ha: hectare, SI (metric system) unit of surface area.

HCA: Hierarchical Cluster Analysis.

HNV: High Naturalistic Value.

HP: Horse Power.

i.e.: (*id est*) means "that is" or "in other words".

IBP: Introduction of Biological Production.

IEPP: Institute for European Environmental Policy.

IIP: Introduction of Integrated Production.

Km^2: square kilometer.

m: meter.

M€: Millions of euro.

m^{-3} ha^{-1}: cubic meter by hectare.

m^3 s^{-1}: cubic meter by second.

MAE: Mean Absolute Error.

MBP: Maintenance of Biological Production.

MCDM: Multi-Criteria Decision Making.

MCM: million cubic meters.

MIP: Maintenance of Integrated Production.

mm: millimeter.

mm^3 yr^{-1}: Million cubic meters by year.

MVO: Minimum Vital Outflow (in Italian DMV: Diflusso Minimo Vitale).

NSP: National Strategic Priorities.

OECD: Organization for Economic Co-operation and Development.

PAD: Percentage Absolute Deviation.

PGI: Protected Geographical Indication.

pH: Potentiometric Hydrogen ion concentration.

PMP: Positive Mathematical Programming.

Q ha^{-1}: quintal by hectare.

RAEP: Regional Agency for Environmental Prevention (in Italian ARPA: Agenzia Regionale per la Prevenzione e l'Ambiente).

RDP: Rural Development Program.

RIB: Reclamation and Irrigation Board.

RPRD: Regional Program for Rural Development.

SAU: Operational or effective farm size (in Italian: Superficie Agricola Utile).

Sc: Soil cover indicator.

SEA: Strategic environmental assessment.

SWOT: Strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities and Threats.

T yr^{-1}: Tons by year.

Tab.: Table.

UK: United Kingdom.

ULA: Unit of Labor in Agriculture (in Italian: Unità di Lavoro in Agricoltura).

WFD: Water Framework Directive.

WPP: Water Protection Plan (in Italian PTA: Piano di Tutela delle Acque).

CHAPTER I

1. Introduction

In most European Union (EU) countries agriculture sector has biggest impact on land use and utilization of natural resources. It has a very significant influence on population settlement in rural areas, landscape shape, and overall environmental impacts on degradation of the natural resource base (Brouwer, 2004). As for water, agriculture is the most demanding sector, accounting for 40 to 80% of total water use in the EU (Massarutto, 2003). Above all in Southern EU Member States, irrigation is an essential precondition for the economic sustainability of agricultural activity. It accounts for more than half of total national abstraction, rising to more than 80% in some regions (EEA, 2009). On the other side, irrigated agriculture represents the most profitable part of agricultre and produces higher-value crops that account for 46% of the world agriculture's economic output (Klop *et al*., 2008).

Besides agriculture, population growth, as well as economic development and climatic change are creating an important pressure on water resources competing for sufficient quantities of good quality water then accelerating resource degradation especially in the Southern Europe. Such deterioration process and its impact on the environement and on agriculture are of great concern among the scientific community given that water is a natural resource producing goods and generating services, valuable to humans.

From a political point of view, the 2003 Common Agricultural Policy (CAP) reforms (known also as Fischler reforms) have set European agriculture the challenge of building multi-functional, sustainable and competitive farming systems compatible with an increased protection of the environment and conservation of natural resources. On the other side the implementation of the Water Framework Directive, ask to member states' agricultural sectors to contribute in achieving good qualitative and quantitative status of their water resources. Such commitment is today necessary and indispensable more than ever in order to preserve and protect natural resources (Gallerani *et al*., 2005; Mejías *et al*., 2003).

Indeed, both 2003 CAP reforms and the new Water Framework Directive (WFD) – present opportunities to combine their efforts in order to improve resources management, within a logic of environmental sustainability.

Indeed, Giannoccaro *et al*. (2008) working on the efficiency of volumetric water pricing found coherently with the WFD principles that this pricing method showed the highest level efficiency in terms of agricultural inputs, outputs and emissions. While Huffaker and Whittlesey (2000) showed the importance of investments in improving the on-farm irrigation efficiencies of individual farms in order to maximize the net economic benefits of water allocation.

The scope of this dissertation is the analysis of irrigation water management issues at regional level taking into consideration the quantitative aspects arising in a water scarcity context. It will be divided into two main targets:

- Water quantity management throughout the optimization of the cropping pattern.
- The economic and environmental evaluation of some agricultural and water policy measures implemented within the Fishler CAP reform and the Water Framework Directive.

According to the recent literature, the effects of such policy measures on the agricultural sector are very heterogeneous; they depend on farm types, crop pattern and regions. Pujol *et al*. (2006) addressed in his work the effects of water pricing in two different case studies, i.e. Spain and Italy. Although both case studies are located in a drought zone, the study shows that potential improvements in water resources are associated with the level of specialization of farms, with the actual level of water availability, as well as the size and the structure (fixed vs. proportional) of transaction costs.

For instance Scardigno and Bazzani (2008) showed that impact of water pricing on farmers' choices in Apulia region depends on the availability of alternative water sources, the specialization of the farms as well as their localization in the region. Viaggi *et al*., (2009) confirmed that the response is more or less rigid because of a low water demand in their case study located in Emilia Romagna.

In this dissertation discussion of water issues will be focused on the Italian region of Emilia Romagna. From a quantitative point of view, water consumption in agriculture estimated to be about 46% of the total water consumption (mainly due to the irrigation sector) is in continuous increase. Besides, also the regional total withdrawal seems to be increasing in the recent years (RPRD, 2007). Some authors argued that the need for irrigation has increased in the pas 10 years between 20 and 22% (Mannini and Bottau, 2009).

In Emilia Romagna – as for all Italian regions – agricultural water distribution systems for managed by "Reclamation and Irrigation Boards" (RIB: associations of farmers that control the management and distribution of water resources). They operate under a regulation enforced by regional laws in order to assure the following: (1) drainage of waters; (2) protection of soils; (3) protection of water and natural resources; (4) irrigation and valorization of the territory. Thus, as the first decision making level, the RIB is directly involved in the application of the EU directive at a regional level.

Analyzing strenght and weakness of the water resources managment, as well as the opportunities and threats, prior requirements for intervention are identified:

- Reducing total level of water resource used in agriculture.
- Reducing pollution of waters from agricultural inputs in sensitive areas.
- Consolidating and extending farms and methods of production with better environmentally sustainable performance.

Therefore, research is an effective instrument to give input for a rational planning and decision making in water management. Furthermore, in the light of the latest changes in agricultural and water policies and taking into consideration the measures adopted at local level in the latest version of the Regional Rural Development Plan and the Water Protection Plan of Emilia Romagna, many questions could be asked:

- How the above mentioned CAP reforms are going to impact irrigation water demand in Emilia Romagna?

- How the RIB is going to modify its management practices to cover its costs while at the same time insure a qualitative water service to farmer?
- How farmers are going to adapt to such upcoming changes?

To give valid scientific answers to the board, this thesis used a stochastic mathematical programming. As it allows to analyze the interlinkages between different policies, farm income and resource use level, taking into consideration the risky choices in the farm planning process (Hardaker *et al*., 2004). Mathematical programming is able to support a whole-farm planning process and it allows estimating maximum benefits under conditions of constrained resources, finding an optimal solution through an optimization problem (Mannini *et al*., 2007). Moreover, mathematical programming is becoming essential in the planning process not only at the farm level but also at the regional level. It is an important economic and management instrument that may be used by RIBs in order to understand water and land use policies, examine the different aspects behind them that can generate socio-economic changes on the local territory (Raggi and Viaggi, 2009, Bazzani *et al*., 2004).

The dissertation will be articulated in eight different chapters including the introduction and the conclusions, in order to cover all the theoretical and practical aspects related to our case study. The second chapter is an overview of the correlation existing between water, agriculture, development and environment. It puts in evidence the fundamental importance of this combination (environment – agriculture – water) in generating development and economic growth. Further, it will present a review of the EU agricultural and water policies and their local implementation; a description of the current situation of water quality and quantity in Emilia Romagna and the water management and planning trough the RIB.

Chapter three provides a theoretical explanation of the methodology used currently in the field of economic evaluation, followed by a literature review to highlight the studies done till now on this concern, either for the valuation of the agricultural policy measures or for the valuation of the impact of the water framework directive.

The fourth chapter is a socio-economic presentation of Emilia Romagna region in general, Bologna province and the case study in particular in order to understand the structure of the agricultural sector. It includes a cluster analysis of the RICA database and finally a statistical analysis of the sample under study. Subsequent to this chapter, chapter five includes the materials and methods used. It explains the mathematical programming methodology adapted, and concludes by exposing the model of the district with all the variables considered.

Results of the model are represented in the sixth chapter followed by results of the simulations, with graphs, tables, and interpretation. This chapter includes also a discussion of these results. It contrasts them with previous similar studies and identifies advantages and disadvantages of the simulations by looking on the impact generated on farmers, the RIB and water resources.

The thesis is concluded in the seventh chapter with the most important findings and recommendations to both farmers and decision makers at the RIB. These findings should help farmers maximize their profits and adopt the best agricultural plans. It helps the RIB as well in understanding more the actual situation of the district, and in planning the future on solid scientific information.

CHAPTER II

2. Environment, Agriculture and Water Resources: A Background

A natural resource ecosystem is an integrated ecological system, one element of which is a product of direct or indirect use of man. The product may be biological as in the case of forests, ranges, agricultural products, fish, and wild life; physical as in the case of water, air, and soil; or both. In all cases, the distinguishing facet of a natural resource ecosystem is that man has a direct involvement in the complex set of ecological interactions (Van Dyne, 1969).

All resources do not have the same features; some are fixed, while some are more fixed than others. The risk of losing them and the need for conservation actions are different among them. However, in general the supplies of natural resources can be categorized into three major types (USDA, 2004):

- Perpetual resources that persist regardless of anything we do (The sun keeps shining and the rain continues to fall some days).
- Renewable resources like plants and animals that naturally perpetuate themselves without any actions from people.
- Nonrenewable resources like fossil fuels and minerals that have fixed amounts for all time.

As one of a large number of natural resources, water has a multidimensional concept. It is a renewable resource: in fact the term “biological cycle” implies renewal but the length of time between the completion of the cycle varies vary greatly from one locality to another. Some water moves quickly through the entire cycle while other water may be detained in surface or underground reservoirs for extended periods. In this sense water is unlike most mineral resources which, having been mined, are non-renewable within the historical time frame.

Water is intimately linked with all aspects of the natural environment and with most human activities. So water issues must be viewed in a broad context, this means that water must be examined not only in its role as essential to all life systems on Planet Earth, but also in its role as indispensable to most human activity and thus to socio-economic development (Young *et al*., 1994). It is therefore relevant to mention some of the more important settings.

2.1. Role of water in the environment and in development

Water is linked with all aspects of the natural environment; it plays a central role in natural processes at and near to the surface of the Earth, in the atmosphere immediately above the surface and in the soils and rocks immediately below the surface. The quantities of water and the length of residence time of water at any place at or near to the surface is the result of the interaction of climate and the characteristics of the surface.

Water is always present in the biosphere extending up into the atmosphere, through the oceans and down few kilometers below the Earth's surface. In the atmosphere it is found as vapor, as liquid droplets and as small ice particles. On the earth therefore, it is found as snow, ice and liquid form. In the soil it is also found in all three forms, while in deeper aquifers it is usually only found as a liquid under pressure.

Driven by the energy from the sun, water moves through the biosphere, transporting and redistributing heat and, because many chemical substances can dissolve in water, it transports chemicals too. Almost all life forms depend on water. Life began in the oceans and without water life would cease to exist.

Life prospers and declines according to the abundance of water; consequently the different life forms have become adapted to varying amounts of water. Thus, each life form, whether plant or animal, has a developed tolerance for a certain variability in the amount of water available. Species have also come to tolerate a certain mix and concentration of chemicals. If the chemical mix changes, often within the medium of water, and commonly due to human activities, then tolerance limits may once again be exceeded and life will suffer.

Thus all ecosystems, or groupings of life forms within a particular part of the overall environment, are vitally dependent on particular quantities of water passing through the system with a certain speed and regularity and maintaining a specific chemical mix. The productivity and diversity of freshwater ecosystems, riverine systems, lakes, wetlands, estuaries and like areas are threatened when the balance of this mix is altered.

While water is the basis for maintenance of the natural environment, it is also basic to human activities. Thus, it is of critical importance for all socio-economic development, and the expected doubling of global population will have far reaching impacts on natural resources. Demands on the resource base will also increase as societies attain higher standards of living.

Basic human needs are all intimately dependent on an adequate supply of water with certain minimum standards of quality. All food production, whether derived from plants or animals requires water. The maintenance of basic health standards is linked to adequate supplies of water of sufficient quality.

Water is fundamental to virtually every economic activity. Large quantities are consumed for industrial and municipal use. Water is used as well in generating electricity. But the major sector of consumption is in excellence irrigation: some 80% of the water is used for that purpose in agriculture.

Thus agriculture is in important sector in terms of water use. Lemly *et al*., (2000) in a global study of wetlands sums it up by stating, “The conflict between irrigated agriculture and wildlife conservation has reached a critical point at a global scale.” And it seems likely that the main competition for water over the next century will be between agriculture and the environment (Rijsberman and Molden, 2001).

2.2. Role of agriculture in the environment and in development

Agriculture, perceived as a system composed of different elements interacting between them and with surrounding environment, is considered by far the largest managed ecosystems in the world (of the total land area of about 13 billion hectares, crops and pasture occupy almost 5 billion hectares), and has a fundamental role to sustain human life. It supplies food and drinking water, maintains a stock of continuously evolving genetic resources, preserves and regenerates soils, fix nitrogen and carbon, recycles nutrients, controls floods, filters pollutants, pollinates crops and much more (FAO, 2007).

For many decades along, especially from the green revolution on, modern agriculture has been very successful in providing the ecosystem services for which markets exist – crops, livestock, fish, and forest products – in ever greater quantities. But the expansion of these services has often been achieved at a high cost to other non-market ecosystem services such as environmental and well-being services.

In the lat nineties of the former century, with the introduction of the sustainability concept, sustainable agriculture integrated three main goals: environmental stewardship, farm profitability, and prosperous farming communities. So at the present, the role of agriculture is together with supplying market ecosystem services, is to improve the non-market environmental services provided to humanity. Enhancing these services, while producing a further doubling of conventional output to meet the demands of a growing global population, is one of the great challenges facing world agriculture in the twenty-first century.

Agriculture is a primary sector fundamental for the development of any economy. Although the participation of the agricultural sector to economic growth in developing countries is very low respecting to other sectors of the economy, it is now typically regarded as an active and co-equal partner with the industrial sector. Agricultural progress has been a crucial factor in worldwide socio-economic change, and still, is together with fishing provider of food supply and investment opportunities that generates trade exchanges, and employees' recruitments, and is a source for the national global domestic product (GDP).

As of 2006, an estimated 36.1% of the world's workers are employed in agriculture. However, the relative significance of farming has dropped steadily since the beginning of industrialization, and in 2006 – for the first time in history – the services sector overtook agriculture as the economic sector employing the most people worldwide (ILO, 2007). Despite the fact that agriculture employs over one-third of the world's population, agricultural production accounts for less than five percent of the gross world product which is an aggregate of all GDPs (CIA, 2008).

But at this point it is important to distinct three worlds where agriculture operates. First of all, the agriculture-based countries (**Tab. 2.1**) where agriculture and its associated industries are essential to growth and to reducing mass poverty and food insecurity. In fact, in this world agriculture generates on average 29% of the gross domestic product (GDP) and employs 65 percent of the labor force (World Bank, 2007), and more than 80% of the decline in rural poverty is attributable to better conditions in rural areas.

Secondly, the transforming countries (**Tab. 2.1**), rapidly rising rural-urban income disparities and continuing extreme rural poverty are major sources of social and political tensions. In this world, agriculture can pursue multiple pathways out of poverty and income disparities through shifting to high value agriculture, decentralizing non-farm economic activity to rural areas, and providing assistance to help move people out of agriculture. Agriculture in this world is no longer a major source of economic growth, contributing on average only 7% to GDP growth, but poverty remains overwhelmingly rural (82% of all poor), (World Bank, 2007).

Finally, in the urbanized countries (**Tab. 2.1**), agriculture can help reduce the remaining rural poverty if smallholders become direct suppliers in modern food markets, good jobs are created in agriculture and agro-industry, and markets for environmental services are introduced. Contribution of agriculture in this world is directly even less to economic growth, 5% on average, and poverty is mostly urban. Even so, rural areas still have 45%

of the poor, and agribusiness and the food industry and services account for as much as one third of GDP (World Bank, 2007).

Table 2.1. Characteristics of three country types.

Indicator	Agriculture-based countries	Transforming countries	Urbanized countries
Rural population in 2005 (millions)	417	2220	255
Share of population rural in 2005 (millions)	68	63	26
GDP per capita in 2005 (2000 U.S.$)	379	1068	3489
Share of agriculture in GDP in 2005 (%)	29	13	6
Number of rural poor in 2002 (millions)	170	583	32
Rural poverty rate in 2002 (%)	51	28	13
Note: Poverty line is 1.08 $ a day, in 1993 purchasing power parity dollars.			

(Modified from: Ravallion et al., 2007).

2.3. The impact of irrigation and agriculture on the environment

The environmental impact of irrigation is an issue of increasing importance to agriculture, it depends on local water availability and other water uses, on the historical background of how irrigation systems have developed and on the particular characteristics of the irrigation practices used, and although farm land in some regions has been irrigated for many centuries, the changes that occurred recent decades have given rise to a number of significant environmental impacts which are becoming more pronounced. Irrigation can affect the environment through (Baldock *et al.*, 2000):

- Direct impacts upon water sources – both their quality and quantity, affecting ground and surface waters.
- Direct impacts upon soils – both quality (e.g. through contamination) and quantity (through erosion).
- Direct impacts upon biodiversity and landscapes – by displacing former habitats and creating new ones, by degrading or maintaining existing habitats, and by affecting the diversity and composition of landscapes.
- Secondary impacts arising from the intensification of agricultural production permitted by irrigation, such as increased fertilizer use.

These effects may be gradual (e.g. declines in certain species arising from pollution) or particularly dramatic (e.g. flooding a valley to create a reservoir for irrigation, or canalizing a river and thereby reducing the stability of its flow).

In its report to the Environment Directorate of the European Commission the Institute for European Environmental Policy (IEPP) recognized the main types of environmental impact from irrigation to include generally the following (Baldock *et al*., 2000):

- Pollution of water and aquatic ecosystems from nutrients and pesticides.
- Damage by abstraction of irrigation water.
- Negative impact is where irrigation displays formerly high natural value ecosystems.
- Where irrigation has been practiced for some time, there have been gains to biodiversity and landscape.
- Irrigation can increase the rate of erosion of cultivated soils on slopes, leading also to deterioration in water quality downstream, due to siltation.
- Lowering of the groundwater table can lead to salinization of water or land or contamination by minerals of groundwater sources.
- Negative and positive effects of large scale water infrastructure constructed as part of irrigation projects and schemes.

For instance, the use of organic or inorganic fertilizers and pesticides produces changes in soil ecology. The population of soil organisms can be altered significantly, thereby causing changes in the chemical composition of the soil: its pH, electrical conductivity and capacity for cationic exchange. In some cases the effects produced by an excess of specific nutrients – above all micronutrients like magnesium, iron and boron which may be present in the sources of irrigation water – can cause problems of phyto-toxicity.

The use of agrochemicals as well, can have serious effects on plant and animal populations in agricultural ecosystems. It can alter biochemical processes in soils, for instance increasing de-nitrification or slowing down the mineralization of organic matter. Irrigation can lead to higher levels of use of nitrogen and phosphorous, subsequently these nutrients can be washed through soils by irrigation, potentially leading to water systems saturated by nutrients. This can cause eutrophication and damage to fragile aquatic species and habitats as well as the contamination of drinking water sources.

The over-exploitation of water resources is a phenomenon that appears when surface water is scarce and irrigation is practiced, in this case, groundwater is often used. Excessive abstraction can produce a wide variety of negative environmental effects, the most serious resulting from the exhaustion of the resource when abstraction is greater than natural recharge. Reductions in the level or availability of groundwater can cause the drainage of marshes, peat bogs and fens, as well as low or even zero flow in rivers that are normally fed by the groundwater table. The drop in the level of groundwater due to over-abstraction can either be restricted to the cone of influence of a few wells, or across a wider area due to the juxtaposition of the cones of influence of different wells. It can cause the complete lowering of groundwater level for an entire aquifer, wherever abstractions exceed the aquifer's natural capacity for refilling. The degree of alteration in the aquifer's hydrological cycle and knock-on effects on ecosystems will increase as the fall in the level of the water increases, leading eventually to an exhaustion of resources. This drop in the water table brings with it the need to carry out pumping at a greater depth, with a consequent increase in energy use and economic cost. The problem can worsen to such an extent that it makes the use of irrigation systems that require large flows impractical.

From another side, the alterations caused by the introduction of irrigation will often have dramatic effects on habitats, landscapes and biodiversity. Throughout the agro ecosystems, there are areas where the spread of modern agriculture has displaced valuable semi-natural ecosystems, in the particular case of irrigated agriculture.

The profound changes produced by the introduction of irrigation will inevitably include the disappearance of pre-existing ecosystems. The changes in the vegetation and the fauna of an area can affect other nearby areas and even distant ones (as happens with migratory species). Such changes can have dramatic effects upon the populations of many most vulnerable species. Wetland areas are particularly affected by intensive agricultural practices supported by irrigation.

Erosion is another impact caused by irrigation on the environment, and the erosive phenomena in irrigated areas could be of two kinds: natural erosion by the action of rain or wind, and erosion produced by irrigation water. Lighter, more drought-prone sand, silt or chalk soils are generally more easily eroded than heavy clays. Whenever land is cultivated excessively and its organic matter is not replenished erosion will be accentuated. The slope, both length and gradient, is an important factor in determining the degree of erosion by water, while the size of fields and absence of field boundaries can be a factor determining erosivity by wind. Erosion by irrigation water can include: the impact of drops of water on the soil surface (e.g. from pressurized sprinkler systems), laminar erosion from flooding (e.g. in gravity systems), and erosion in furrows and ditches, in any system where water flows across the land. Each irrigation system may cause one or more of these effects, depending on its characteristics. It is considered that most erosion caused by surface irrigation occurs with canalized flows in furrows.

Salinization is another impact of irrigation on the environment and the factors which determine this risk are the drainage systems available on irrigated land, the amount of water used, and the quality of water used in irrigation. Where land drains are deficient or blocked it can cause not only water logging of soils but also an increase in the salinity of the soil, particularly if this already has an excess of salts or if it is irrigated with saline water. Salinization of water by marine intrusion arises where water abstractions from aquifers exceed natural recharging rates, and the level of the water table drops. This occurs in most coastal irrigated areas.

The construction of large dams to create enhanced water sources for irrigation (and other purposes) can have dramatic effects on landscapes and biodiversity. There have been several cases where new dams have flooded historic landscapes and displaced traditional communities, as well as submerging valuable natural and semi-natural habitats of some importance for rare species of wildlife. Bringing very large quantities of water from distant areas by means of integral irrigation plans, reservoirs or canalization of rivers can lead to an unnatural increase in groundwater level in some regions. The dangers of this are the swamping of the soil, a decrease in its aeration and parallel chemical processes, with important repercussions on soil micro fauna and vegetation. Both agricultural and wild plants may suffer significantly retarded growth rates.

In some regions, the recharging of rivers in dry periods with irrigation water which has been transported from mountainous areas can have significant impacts upon local flora and fauna. Cold and clear water released into the area causes a thermal shock to wildlife and can be highly erosive. Another phenomenon in these areas has been the effect of canalization of rivers as part of irrigation infrastructure projects, which has been damaging to local aquatic biodiversity.

But finally we cannot ignore the positive impacts upon biodiversity and landscape that the traditional irrigation systems may generally be viewed as having a positive effect on the environment, in that they have sustained a small-scale, labor intensive agriculture which has increased the diversity of some historic landscapes, particularly in southern Europe.

The very small units of intensive agriculture that characterize many traditional irrigated lands today have tended to move either into intensive crops under plastic which generate a high yield per unit area; or into tree crops which require less labor-intensive management. In this context, there is a growing use of drip irrigation systems which have the following environmental benefits:

- Less land is abandoned and the amount of vegetation on the slopes increases. This diminishes the risks of desertification and erosion.
- Less work is needed to farm these areas. The irrigation water includes all the nutrients needed as well as being more efficient in its application. Drip irrigation together with the fact that little cultivation is required for the crops on the slopes (olives, almonds, and tree fruit) mean that the soil is preserved, although it also increases the use of herbicides.

Some irrigated agriculture has created new habitats for certain species of fauna. This is especially true in the rice-producing regions. Where, during the reproductive season the rice fields of are used by many aquatic birds for breeding and feeding.

The impact of agriculture on the quality and quantity of species and eco-system diversity, is to a large extent determined by the expansion (or contraction) of the farmed land area, and the intensity of agricultural production in terms of input use and farming practices. A number of agro-ecosystems can serve to maintain wild species diversity, such as some pasture and grassland systems. The complex ecology of flora and fauna have adapted to and been influenced by farming activities over thousands of years.

Along with important positive effects, the intensification of agricultural production also has negative effects on the environment. Agriculture burdens the environment (the air, soil, and water) mainly through the deforestation activity for agricultural land use, the use of mechanization, large inputs of energy, and various land improvement works.

As described in details in the previous paragraph, agriculture can generate negative impact on environment mainly through irrigation practices, as well as from farms wastes and chemical residues. These impacts are either qualitative or quantitative and they can be from a non-point or point source pollution agricultural pollution.

Agriculture, especially the development of mechanization in agriculture produces emissions of air-borne pollutants such as dusts allergens dispersed and odors (Defra, 1998a). From one side, agricultural activities can give off various gases which help to cause atmospheric problems such as the ammonia, which contributes to eutrophication and to making soils acid and can disrupt sensitive ecosystems and greenhouse gases which contribute to global warming: carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs). From another side, dark smoke or smoke nuisance from agriculture can be caused by the burning of crop residues, packaging, plastics, tires, waste oil or animal carcasses in the open or in unsuitable equipment. Some of these activities in particular those which involve housed livestock, storing wastes or spreading livestock wastes are those most likely to cause odor problems.

Soil is a basic, limited resource that will continue to be essential for many human activities. It includes both topsoil and subsoil to a depth of at least one meter. The biological, physical and chemical characteristics of soil need to be protected for it to perform its important functions, including the production of food, raw materials and energy. Agriculture has an important role to play in protecting soils; otherwise, it could generate serious and long term damages to soil resources changing their physical, chemical and biological characteristics, sometimes irreversibly (Defra, 1998b).

Biological and chemical degradation deals with chemical and biological processes which affect soil fertility, including the biological activity of its organisms, the acidification of soils, soil's nutrient reserves and its organic matter content.

From a part, soils contain many living organisms ranging from microscopic bacteria and fungi to burrowing animals. All play a part in maintaining the natural soil processes which are vital for maintaining the chemical and physical fertility of the soil. Some organisms can play an important part in what happens to contaminants that may be in the soil while others are of value in the biological control of crop pests. Earthworms are one of the most obvious organisms that benefit the soil. Along with other organisms, they are sensitive to certain heavy metals, chemicals and contaminants. These include some pesticides designed to control particular problems but which affect a wide range of organisms. Excessive amounts of fertilizers or manures which contain a high proportion of their nitrogen in the form of ammonium, such as ammonium sulfate and certain animal manures or slurries, may reduce the number of earthworms in soil too.

From another, acidification is a natural process which occurs in all soils, but which can be increased by man's activities. The extent to which it happens depends on the composition of the soil, deposition from the atmosphere, cropping, nitrogen fertilizers and other management practices. Unless the soil is naturally well supplied with calcium or magnesium carbonate or is regularly limed, the pH of the soil is reduced until a new balance point is reached. Very acid soils at a pH below 4 will only support a limited range of plant species and are not normally suitable for agricultural production. Water draining from acid soils may contain substances, particularly aluminum, which can have an adverse effect on the quality of surface and ground waters. These can harm not plants and animals but fish, living in streams or lakes and generate degradation of a whole ecosystem.

In addition, a correct balance of available nutrients is necessary to promote satisfactory plant growth. A balanced supply is composed of macro-elements required by the crop in big quantities (nitrogen, phosphorus, potassium, magnesium, calcium and sulfur), and micro or trace elements required but in smaller quantities (iron, manganese, copper, zinc, molybdenum, boron and chlorine). Nutrients can be organic, non organic and are also deposited from the atmosphere, particularly sulfur, nitrogen and some of the trace elements. As long as the soil pH and organic matter content are maintained at appropriate values and the fertilizers or manures applied are in the range of the crops needs, most of the additional nutrient requirements of plants can be met causing any environmental damage. But problems are created when the equilibrium is broken and nutrients percolate to rich waters.

Finally, the amount and type of organic matter in the top layer of a soil influences its physical, chemical and biological properties. In particular, it affects its structural stability (and so the likelihood of erosion), how easy it is to cultivate, how much water it can retain and the nutrients available to plants. It also influences the behavior of contaminants. Changes in management can result in increases or decreases in organic matter content.

Physical degradation of soils is defined as the irreversible or only slowly reversible physical damage to soil. It can have many aspects from which soil compaction, removing top-soils, soil erosion. Compaction of top-soils, or more especially sub-soils, may seriously damage soils and can only be reversed very slowly and at significant cost. Compaction restricts root growth and reduces infiltration of water into soil. It can increase run-off, which may lead to greater flooding, increased erosion and the transfer of potential pollutants (including nutrients and pesticides) to surface waters. As the air getting into the soil is also restricted, the biological activity and root growth is affected. This reduces the fertility of the soil and, more specifically, the availability of plant nutrients. This phenomenon is observed in agricultural ecosystems using agricultural or other machinery or in livestock farms when heads are allowed to graze when the soil is too wet.

Another aspect of soil degradation is the loss of topsoil, either by removal for trade, or indirectly by erosion. The formation of fertile, rich topsoil with high organic matter content is a very slow natural process, so the removal or erosion of topsoil reduces the productivity of the land by reducing the water and nutrients available to plants, and making the soil more likely to suffer from structural damage. Soil erosion, which is the loss of soil particles by the action of wind and water, is a common type of soil degradation that can be prevented by plantations that generally protect the soil against erosion. Risk of soil erosion is increased where soil organic matter content is low. Repeated erosion results in a gradual loss of topsoil and reduces the fertility of the soil by selectively removing the fine soil particles which are rich in nutrients. Rooting depth and the quantity of soil water available for crops is reduced. Apart from soil loss, damage can be caused to agricultural crops by washing soil from the roots or blasting them with soil particles during wind erosion. Erosion can increase flooding by increasing run-off and blocking ditches and drains. Surface waters may be contaminated by sediment and by the nutrients and pesticides in the eroded soil. Fish spawning grounds can be seriously damaged by sediment deposited in the beds of gravel streams. Obvious cases of erosion, as detailed below, occur in lowland England and Wales, but significant problems can also occur in upland areas where overgrazing and/or recreational activities have affected the vegetation cover.

2.4. Availability and quality of water resources in the Emilia Romagna

The agricultural sector in Emilia Romagna presents a very high pressure on the quality of the water resources, regarding to the national mean values, obviously with remarkable territorial differentiations. In spite of the alarming situation threatening the water resources, primary and partial analyses have demonstrated probable positive effects for the water brought thanks for the extensification of farms, supported, or however correlated to the introduction of “decoupling” to the Common Agricultural Policy (CAP).

As cited by PTA, 2006, the water consumptions in agriculture (due mainly to the irrigation sector), in continuous increase in the latest thirty years, is estimated about

58% the total water consumption (**Fig. 2.1**). Besides, the regional total withdraw seems to be increasing, with a net difference between the withdrawn quantity and the water requirement at the users' level with reflect the low efficiency in the distribution (**Fig. 2.2**).

The dependency of the region from the aquifer withdrawal, although increasing remain high; but instead, the extraction designated to the irrigation sector appears to be continuously increasing. The surface water withdraws in destination to the irrigation field represents the 82% of the total surface water extraction. Except the Po, many rivers of the region present a situation of water scarcity especially in the summer period. Furthermore, an increase of regional water stress is observed in the last few decades, correlated not only to the increase of the withdrawals but also to the climatic changes and the effect of the decrease of rainfall, complicated from the total losses in the irrigation network, estimated currently around 26%. Till summer 2007, for instance, irrigation season was normal and no serious problems were mentioned from the part of the RIB (Reclamation and Irrigation Board). But according to the data of the hydrometric stations ARPA, in the course of the month of July 2007, the hydrometric levels of the Po from which depend most of the regional RIBs are notably worsening because of the decline of the precipitations (INEA, 2007 (a); Brizzi, 2006).

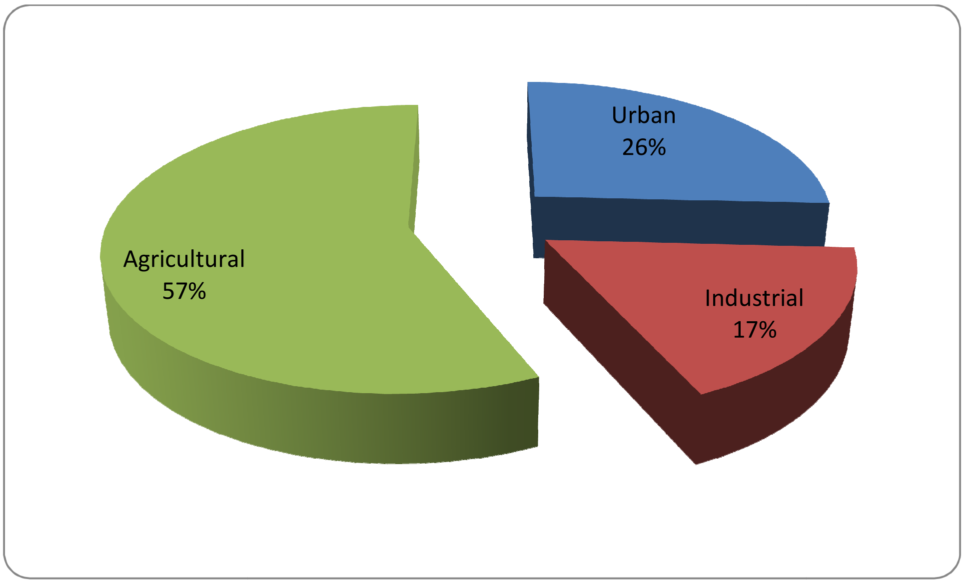


Figure 2.1: Water demand by economic sector in Emilia Romagna.

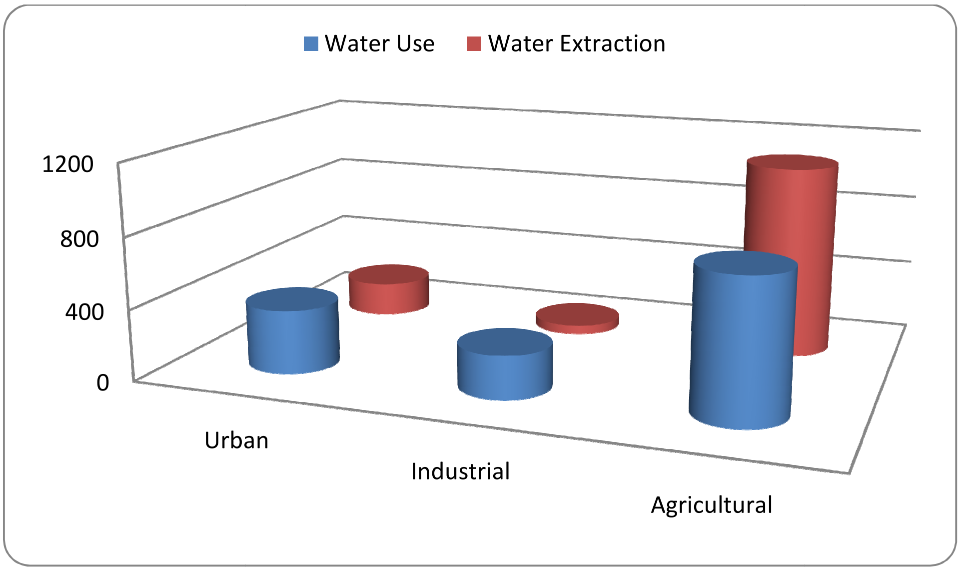


Figure 2.2: Withdrawn and required water between the economic sectors.

In Emilia Romagna, with regard to the water resources quality, the monitoring data (the quality of the superficial water bodies of the Region is controlled through a network of monitoring stations for the environmental quality) evidences a mediocre regional water bodies' quality. In reference to the groundwater and surface quality, the nitrates as the nitrogen in general and the phytosanitary products which are correlated to the agricultural activities, have been identified at the European level between the two major water contaminators of the regional rivers.

The following table shows in Emilia Romagna the annual discharges of pollutants in the water bodies from agriculture and livestock production (**Tab. 2.2**).

Table 2.2. Annual discharges of pollutants from agriculture and livestock production in Emilia Romagna.

Element	Origin				
	Bovine ($T\ yr^{-1}$)	Suine ($T\ yr^{-1}$)	Poultry ($T\ yr^{-1}$)	Fertilization ($T\ yr^{-1}$)	Total ($T\ yr^{-1}$)
BOD_5	55910	31912	63730	–	155551
Nitrogen	22514	13391	7617	129375	172897
phosphorus	11882	6110	5408	46251	69652

(Modified from: PTA, 2006).

2.5. Water Resource Management and Planning

Water resource management refers to activities that aim to coordinate humans' goals with the conditions (ecological, hydrological) of water systems. Water management includes physical and non physical instruments as listed in the following table (**Tab. 2.3**). This coordination is insured by entities called the "Reclamation and Irrigation Board" (RIB).

Table 2.3. Instruments for water management.

Physical instruments	Non-physical instruments
Impoundments (dams, reservoirs, etc.) and diversions (transfers) typically for water supply or energy production.	Regulatory controls (e.g. emission limit standards, designation of protected areas and control of certain activities within boundary zones, etc.).
Wells for groundwater abstraction (or for groundwater injection and aquifer recharge).	Economic measures (e.g. pricing of water use, taxing of water abstractions, etc.).
River regulation works (channelization, etc.) typically for navigation or flood protection.	Measures aimed at the civil society (e.g. programs for public awareness for water saving).
River restoration projects for ecological aesthetic or recreational purposes. Pollution control technologies.	

(Source: Kallis et al., 2004).

Such Boards were born in Italy on a private and voluntary basis due to free initiative of groups of farmers who felt the need to gather into associations and take over the responsibility for community concern activities on land where their holdings are located in order to improve the latter for production purposes. After 1865, the legislation devoted special attention to the problems of irrigation, the defense of waters and of the RIBs, thus accepting the requests raised by the increasing general interest for the sector with respect to the economic and social needs to be satisfied for the agricultural development. The institutional functions granted to the RIBs in the Italian Regulations can be grouped into four categories (Martucelli, 1999):

- Execution of public works and systems (intake works, storage work, conveyance and delivery works, drainage, lifting plants, hydraulic management). According to the said royal decree of 1933, the State gives in concession to the reclamation boards, the execution of the public works of their competence;

- Execution of works and actions concerning several fields falling within the competence of the private citizens and compulsory for the latter (actions necessary for the use of the works indicated in the previous point.
- Maintenance and operation of all the public works and systems indicated in the first point.
- Assistance to the associated owners for the transformation of the cropping patterns at the farm level and for irrigation.

So the RIBs are also responsible for the implementation and management of irrigation systems by ensuring both maintenance and operation and thus developing the irrigation of the fields located in their scheme.

In Emilia Romagna, these boards operate enforced by the regional most recent and innovative laws 42/84 and 16/87, in order to assure drainage of waters, the protection of soils, the protection of the water and natural resources, the irrigation and the valorization of the territory. The administrative organization of the Consortium is presented schematically in the following organizational chart (**Fig. 2.3**), even though the flowchart of the technical staff varies slightly from a RIB to another but it is always guided by three major operative services (CBR, 2008):

- Administrative service.
- Technical service.
- Agricultural service.

Furthermore, water resource planning is a rational, staged process of selecting and implementing the best mix of water management measures and instruments in order to achieve defined goals. It involves a process starting with a scoping of the problems to be addressed and collection of data to appraise conditions. This is followed by the definition of the goals that the plan should fulfill the elaboration of the goals into a set of criteria upon which to assess alternative options and the identification of alternative management measures and instruments.

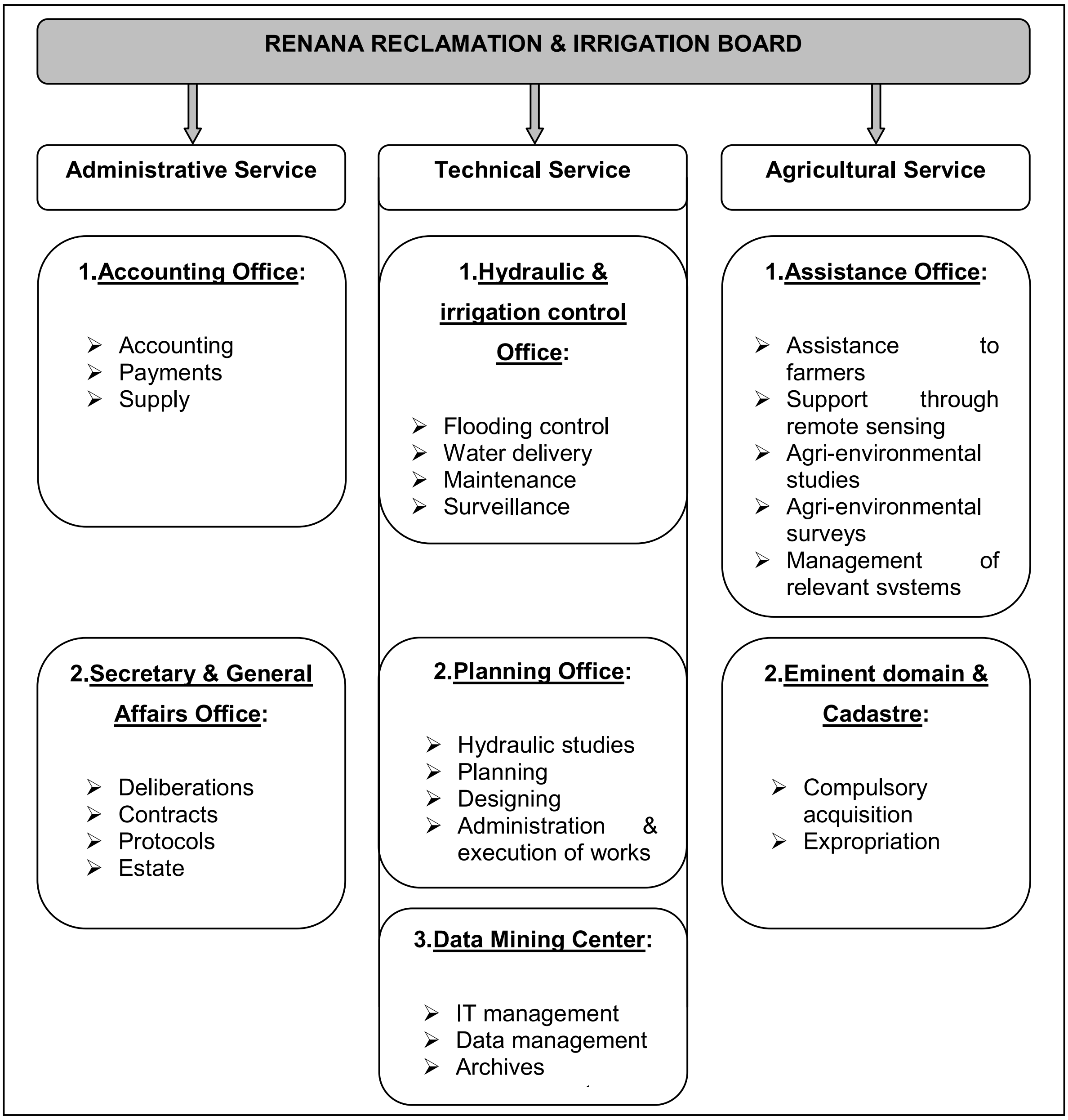


Figure 2.3: Technical Organization of the Renana RIB.

Alternatives are then comparatively evaluated upon the identified criteria leading to the compilation of an optimal mix of measures and instruments in a program or action plan. Continuous collection of data and monitoring of the results of the measures and instruments accompany the plan's implementation. New problems and needs arise leading to a new cycle of planning. This should be seen as a continuous, iterative process, the different stages being inter-related, rather than a "one-through" clearly defined process of consecutive steps.

Water resource planning requires that quantity and quality issues are addressed together, that a full range of options is taken into account (physical and non-physical) and that the evaluation includes multiple criteria (technical feasibility, cost, environmental, social, etc.). The next figure (**Fig. 2.4**) portrays such generic planning process applicable at different spatial and organizational levels (Kallis *et al.*, 2004). A national agency can prepare a water resource plan at the national level and a municipal authority or water utility at the local, urban or metropolitan level. The river basin provides an appropriate territorial unit for water resources planning, accounting for the interdependency of water quantity and quality, water and adjacent land-based resources, and upstream and downstream effects.

2.6. Agricultural and Water Policies

The European Union has confirmed with the reformed agricultural policy (CAP), the new directive in water matter (Water Framework Directive – WFD) and many other directives the concern of all member states to protect their rural areas and natural resources and rationalize their use in a way to generate a sustainable development.

The CAP establishes the legal framework for a sustainable development of the European rural areas it has evolved to meet society's changing needs, so that to provide farmers with a reasonable standard of living, consumers with quality food at fair prices and to preserve the rural heritage and the natural environment.

Whereas the WFD set up the legal framework for the regulation of water use in Europe, introduces several innovations into water management and policy Central to these is integrated water management at the scale of river basin. The incorporation of economic approaches throughout the implementation of the WFD constitutes also a clear innovation. These innovations allowed to pointing out issues of water scarcity.

At regional level, the concrete planning instruments to achieve the these policies reside in the regional rural development program 2007-2013 and the plan of water directive which define the tangible measures adopted in the region to reach objectives fixed by the European community (***cf.* Annex 1**).

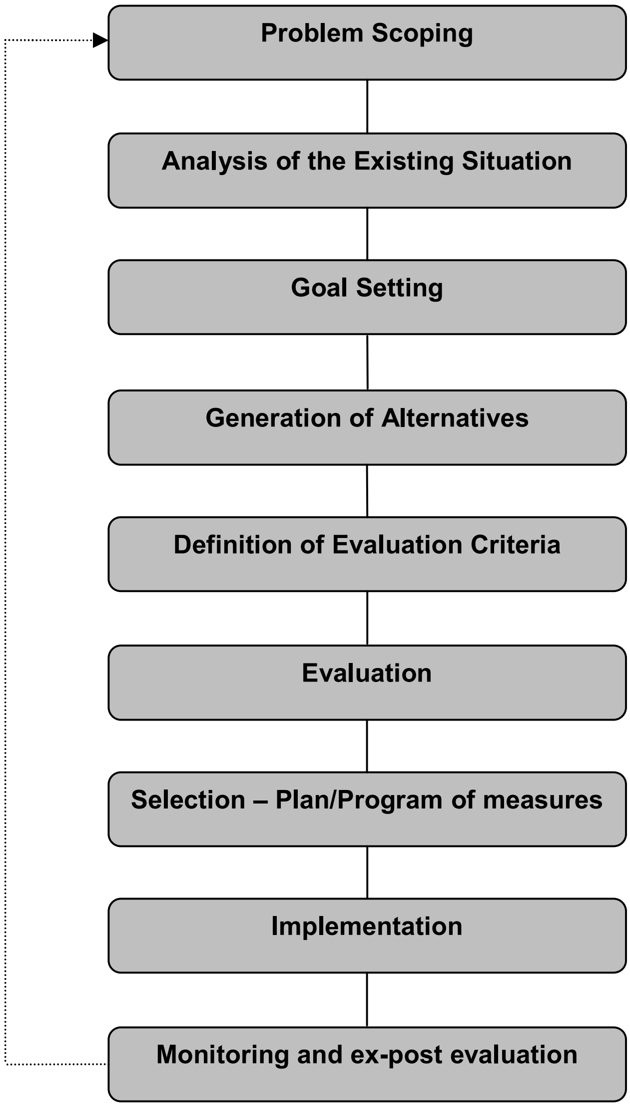


Figure 2.4: A generic water resource planning process.

2.6.1. The regional program for rural development

The allocation for expenditure in agriculture (including rural development) was for 2006 of about 50,191 Million Euros (M€) representing the 41% of total EU expenditure (from which, 7.8 M€ for rural development), and following the perspectives the expenditure for rural development will maintain its upward trend during the 2007-2013 financial programming period (EC, 2007(a)). At the same time, in accordance with the ongoing reforms in agricultural sectors, the share of direct aids and market-related expenditure in the EU budget will continue to decrease; for instance, the budget allocated for agriculture (including rural development) in 2007 is of 56.30 M€ of which 12.40 M€ for rural development with an increase of 3% from 2006. Therefore, the part of Italy on agriculture, was of 5,486 M€ equivalent to 11% representing the 50.20% of total expenditure allocated to Italy and the 0.37% of the Union Gross National Income (GNI).

The total appropriations provided for in the 2007- 2013 financial framework amount to 864,316 M€ in commitments (1.05% of GNI) and 820,780 M€ in payments (1.00% of GNI). The breakdown by heading is as follows (EC, 2007(b)):

1. Sustainable growth, 382,139 M€ of which;
   - Competitiveness for growth and employment, 74,098 M€.
   - Cohesion for growth and employment, 308,041 M€.
2. Preservation and management of natural resources, 371,344 M€ of which;
   - Market-related expenditure and direct payments, 293,105 M€.

The regional rural development program adopted by the Emilia Romagna region and approved by the European Commission will insure to the region about 934 M€ of public fund (between EU, Italian government and regional funds) and will generate opportunities of investments of about 1,500 M€ (RPRD, 2007).

The general objective of this program is to integrate and address all available resources and instruments for a sustainable economic development in environmental terms such a way to guarantee better competitiveness of the agricultural system and the required social cohesion. It is articulated in 4 pillars for intervention each one subdivided into measures and for some measures proposed specific actions (***cf.* Annex 2**), perfectly in correlation with the Common Strategic Orientation (CSO) and the National Strategic Priorities (NSP) (***cf.* Annex 3**).

Pillar 1: Enforcement of competitiveness of agriculture and forestry system throughout the integration between subjects operating in different sectors, the innovation of products and processes, knowledge transfer, the quality intended as distinct and protected in the market.

Pillar 2: To support a sustainable allocation and management of agriculture and forestry to increase competitiveness and social cohesion of the regional system.

Pillar 3: To maintain a sustainable agricultural and forestry management and utilization of the territory and its natural resources to enhance competitiveness and the social cohesion of the regional system.

Pillar 4: To promote a qualitative rural environment and an integrated development strategy that praise the multifunctional rule of agriculture, through the reorganization of productive factors of farms, orienting them to activities complementary to the primary one and enhancing economic, social and environmental functions.

2.6.2. The regional water protection plan

The water protection plan (WPP or PTA in Italian: Piano di Tutela delle Acque) is the tool which has been designed in order to reach the objectives of the European Water Framework Directive 2000/60/EC, and other national decrees (as the legislative decree (Dlgs) 152/99 (***cf.* Annex 1**)), and is composed of the following main parts (PTA, 2006):

- General report comprising the cognitive framework.
- Assessment of environmental and territorial sustainability (VALSAT).
- Regulations
- Table 1 – protection area of groundwater in the foothill-plain: recharge areas – scale: 1:250000.

In order to reach by December 31st 2016 the objectives of environmental quality (for significant bodies of water) and quality objectives for specific destination (for water bodies having a specific function), the basin authorities in the regional territory, have outlined the objectives at basin level defining both qualitative and quantitative parameters.

And to reach the above mentioned objectives, the WPP has defined a program of protection and improvement for water bodies for specific destination, and a program of measures for the fulfillment of environmental quality objectives in significant bodies.

2.6.2.1. Quantitative protection measures

This type of measures comprises a set of provisions for the promotion of utilization modes of surface and ground waters. The quantitative protection of the natural surface water bodies is defined in the WPP by regulations governing concessions for public water deviations from water courses, that depends on the fact that the minimum flow to be left in the water course bed downstream the abstraction, should be the Minimum Vital Outflow (MVO or in Italian DMV: Diflusso Minimo Vitale). For the quantitative protection of groundwater bodies, a drop in abstraction is necessary which would eliminate the annual aquifer deficit. This protection can be improved as well by the increased recharge from MVO compliance (PTA, 2006).

Conservation measures focus on the regulations governing discharges and saving policies in the domestic and production sectors, partially attained through the dissemination of water saving techniques, with incentives produced by specific awareness-raising campaigns and economic benefits. On the other hand, the WPP prescribes a resource conservation plans through actions for leakage reduction and infrastructures, to reach by 2016 a yield at regional level equal to 82% (PTA, 2006).

In agriculture, where water demand for irrigation is very high and the impact of MVO application quite relevant, differentiated strategies have been established for water saving: the progressive selection of irrigation techniques which entail more saving coupled with economic benefits (Contini, 2008; PTA, 2006), and concomitant services (monitoring of weather and soil conditions) offered to farmers for the streamlined planning of irrigation; the drafting of conservation plans for water saving in agriculture by drainage and irrigation Consortia, envisaging actions for efficiency improvement of water main and distribution networks. Treated waste water can also conveyed to irrigation, coming from water treatment plants assuring the compliance with threshold values defined by the plan.

Treated waste waters can be used, besides agriculture, also for irrigation of parks and green areas, for non industrial or industrial use or for ecological purposes, through specific re-use plans (PTA, 2006). The table below (**Tab. 2.4**), shows a summary of the evolution of water demand in the Agricultural and livestock in Emilia Romagna till 2016 and the potential volumes that could be saved thanks to the implementation of the WPP.

Table 2.4. Data of water demand in agriculture and livestock in Emilia Romagna up to 2016.

Year	Indicators	R – S (mm^3 yr^{-1})				W – S (mm^3 yr^{-1})			
		UL		SL		SW		GW	
2000	252×10^3 irrigated ha 1453×10^3 bovine	829		1405		1183		222	
2008	261×10^3 irrigated ha 1370×10^3 bovine	786	6	1306	45	1076	60	230	-15
2016	269×10^3 irrigated ha 1285×10^3 bovine	802	-10	1299	50	1084	59	215	-9

R – S: Requirements and Savings in (Mm^3 yr^{-1}).
W – S: Withdrawal and Savings in (Mm^3 yr^{-1}).
UL: at the Users level.
SL: at the source level.
SW: Surface water.
GW: Groundwater.

(Modified from: PTA, 2006).

2.6.2.2. Qualitative protection measures

Measures for qualitative protection focus mainly on the control of point discharges of domestic waste water, the control of diffuse discharges of husbandry and finally the protection of water for human consumption. The control of point and diffuse discharge is carried out via the application of regulatory tools, whereas the protection of water for human consumption is carried out either through the conservation of abstraction points of surface or ground water conveyed to third parties via public-interest drinking water main system, or through the protection of water resources (PTA, 2006).

2.6.2.3. Operational measures

In a tangible way, the intervention of the region is carried out throughout several directions, as following (Internet 1, 2007):

- The Water Protection Plan: four working groups has been constituted, one for each river basin authority, that operate supported by the regional agency for environmental prevention (RAEP, in italian: Agenzia Regionale per la Prevenzione e l'Ambiente (ARPA)) to guarantee and update the implementation of the WFD for ground and surface waters as well as for marine waters.
- The regional program for water conservation and saving: to promote a rational and efficient use of this resource. The region has the intention as well to develop new conservation and saving politics and governance of the water demand.
- Irrigation: the region, in collaboration with the provinces and the local Reclamation and Irrigation Boards (RIB) invest directly in the research, experimentation and realization of technical assistance. For instance since 23 October 2007 has lunched the operative plan for water saving through the improvement of the efficiency of farms water irrigation systems. This support is of 30% of the system cost and can be increase to 40% in hills. At this point, farmer should take an engagement to use the new irrigation system with IRRINET criteria that provides free irrigation advices about irrigation schedules and volumes based on the water balance method.
- Integrated water service: the region is involved in the macro regulation of this service which represents the public service of potable water, domestic discharges and waste water treatments.
- Water bodies for specific destination: to protect these bodies, the region in collaboration with provinces, works on the development of qualitative/quantitative monitoring bodies, and the diffusion of results.

- Water discharges: in includes the domestic, urban and industrial discharges including dangerous discharges. The region has a role of coordination between the European Union, the ministries and the entities involved in tasks as normalization, communication, control and evaluation.

2.7. Recapitulation for the first chapter

Along these pages of this chapter we elicited the correlation between water, development and the environment from a part and the correlation between water development and the agricultural activity from another part, to put in evidence the fundamental importance of this combination (environment – agriculture – water) to generate development or economic growth. From another side, we tried to highlight the actual situation of water quality and quantity in Emilia Romagna and the needs of this sector in the region. We explained how the water management and planning should be done theoretically and the role of the RIB at this level; we have explained and deepened the European and regional agricultural and water policies and their components. This said, it will justify the integration of agri-environmental and decision-making concerns in the latest modifications of the European and regional agricultural policies, as well as the water policies, and will give a good reason for the interest of scientists to study the relation and understand its economic impacts, through economic evaluation in the coming chapter.

CHAPTER III

3. Economic Evaluation of Policies: Methods and Reviews

Through the introduction of new regulations and/or policies or the amendment of existing ones, these may impact different sectors of the society, and environment. Evaluation provides better knowledge of the impacts and implications of these policies for decision maker as support, in order to increase the accountability and the transparency of actions from one side, and to form a basis for new guidelines for future applications, strategic planning and operational decision-making.

Evermore, evaluation is “a process of judgment of interventions according to their results, impacts and the needs they aim to satisfy” (EU, 2006). Evaluation looks at the effectiveness (the extent to which objectives are achieved), the efficiency (best relationship between resources employed and results achieved), and at the relevance of an intervention (the extent to which an intervention’s objectives are pertinent to needs, problems and issues).

This chapter will give an overview of the evaluation methods used in the field of economic valuation as proposed by Evalsed which is an online resource supported by the European Union that gives guidance in evaluation. It will be followed by a literature review on valuation of changes introduced to the common agricultural policy in 2003, also called Fischler reform.

In addition, economic evaluation holds a key position in the WFD implementation process, because in water management decisions, authorities have to decide whether to authorize or not a new water abstraction or dam, assess or not a new irrigable area, proceed or not with the restoration of a polluted river, designate or not an area as protected, or even to design new water tariffs. So in practice, there will always be a need for evaluations of individual projects, policies, etc. For this purpose, a final part will be about a literature review on the evaluation of the WFD to discuss what have been done in this area.

3.1. Methods for evaluation

The evaluation process as reported by the second sourcebook on Evalsed (Sourcebook 2, 2003) is done following four different stages:

- Planning and structuring.
- Obtaining data.
- Analyzing information.
- Evaluative judgment.

Yet, the technique adopted in each stage can vary according to the stage in the program/policy cycle (ex ante, midterm and ex post analysis). Additionally, the appropriateness of the methods and techniques depends on the scope of the evaluation, which could range from an overall evaluation of a multi-sectoral program, to an in-depth study of a particular evaluation question.

The crosses in the table below (**Tab. 3.1**), indicate the circumstances in which the methods and techniques that will be detailed in the coming paragraphs, are used for each stage. The organization of the table is done according to three main criteria:

- The four stages of the evaluation process: planning and structuring; obtaining data; analyzing information; evaluative judgment.
- Prospective (ex ante) and retrospective analysis (ex post).
- Overall and in-depth analysis.

3.2. Ex-ante Mid-term and Ex-post evaluation

Referred to many guidelines and studies of the EU, (EU, 2004; EU, 2002; EU, 1999), ex-ante evaluation is "*a process that supports the preparation of proposals for new or renewed Community actions. Its purpose is to gather information and carry out analyses which help to ensure that the delivery of policy objectives will be successful …*"

While a mid-term evaluation, which is carried out at the half-way stage of the intervention, "*can build on the work of an earlier ex ante evaluation by assessing the continued relevance of objectives …*"

Whereas, ex-post evaluation "*embraces the entire intervention period, with a special interest on the impacts, efficiency and effectiveness of the intervention …*"

Table 3.1 (a). Circumstances in which the methods and techniques are used in Ex ante evaluation.

Prospective (ex ante)							
		Overall			**In-depth**		
	Design	Obtaining data	Analyzing data	Judgment	Obtaining data	Analyzing data	Judgment
PLANNING AND STRUCTURING EVALUATION							
Concept or issue mapping	x						
Stakeholder consultation	x	x			x		
Evaluability assessment	x						
Logic models	x		x				
Formative/developmental evaluation	x		x	x		x	x
OBTAINING DATA							
Social surveys		x			x		
Beneficiary surveys							
Individual (stakeholder) interviews		x			x		
Priority evaluation				x			x
Focus groups		x	x		x	x	
Case studies		x	x				
Local evaluation							
Participatory approaches & methods	x			x			x
Use of secondary source data		x					
Use of administrative data		x					
Observational techniques							
ANALYSING INFORMATION							
Input/output analysis			x				
Econometric models			x				
Regression analysis							

Experimental and quasi-experimental approaches							
Delphi survey						x	x
SWOT	x						
TOOLS TO INFORM EVALUATIVE JUDGEMENTS							
Cost-benefit analysis							x
Benchmarking							
Cost effectiveness analysis						x	x
Economic impact assessment							x
Gender impact assessment							x
Environmental impact assessment							x
Strategic environmental assessment			x	x		x	x
Multi-criteria analysis				x			x
Expert panels			x	x		x	x

(Source: Sourcebook 2, 2003).

Table 3.1 (b). Circumstances in which the methods and techniques are used in Midterm and Ex post evaluation.

	Retrospective (midterm, ex post)					
	Overall			**In-depth**		
	Obtaining data	Analyzing data	Judgment	Obtaining data	Analyzing data	Judgment
PLANNING AND STRUCTURING EVALUATION						
Concept or issue mapping						
Stakeholder consultation	x			x		
Evaluability assessment						
Logic models		x			x	
Formative/developmental evaluation						
OBTAINING DATA						
Social surveys	x			x		
Beneficiary surveys	x			x		
Individual (stakeholder) interviews	x			x		
Priority evaluation						
Focus groups	x	x		x	x	
Case studies	x	x		x	x	

Local evaluation	x	x		x	x	
Participatory approaches & methods						x
Use of secondary source data	x					
Use of administrative data	x					
Observational techniques				x	x	
ANALYSING INFORMATION						
Input/output analysis		x				
Econometric models		x				
Regression analysis					x	
Experimental and quasi-experimental approaches				x	x	
Delphi survey						
SWOT			x			
TOOLS TO INFORM EVALUATIVE JUDGEMENTS						
Cost-benefit analysis				x		
Benchmarking			x	x		x
Cost effectiveness analysis						x
Economic impact assessment			x			x
Gender impact assessment			x			x
Environmental impact assessment			x			x
Strategic environmental assessment						
Multi-criteria analysis			x			
Expert panels		x	x		x	x

(Source: Sourcebook 2, 2003).

3.2.1. Planning and structuring evaluation

For the design and planning of an evaluation methodology many techniques are described and used to define the objectives of an evaluation and to establish parameters to focus on during the evaluation process:

- Concepts and issue mapping: used to define the effects that are to be evaluated and to establish the main parameters upon which the evaluation should or could focus.
- Stakeholder consultation: used in identifying evaluation priorities and questions at the outset of the evaluation.

- Evaluability assessment: establishes whether a program or policy can be evaluated and what might be the barriers to its effective and useful evaluation.
- Logic models: support the objective definition of a project, as well as its formulation in operational terms, and its implementation, monitoring and evaluation.
- Formative/developmental evaluation: seeks to strengthen or improve a program or intervention by examining, amongst other things, the delivery of the program, the quality of its implementation and the organizational context, personnel, structures and procedures.

3.2.2. Obtaining data

Data collection must identify the available and relevant information. Moreover, it must specify the validity and use of the quantitative and qualitative data used. The techniques can consist of:

- Social surveys, considered as one of the basic tools of the social science. It has the advantage of producing structured and quantified information.
- Beneficiary surveys: can be considered a particular application of social surveys. The purpose is to elicit information from those directly affected by an intervention.
- Individual (stakeholder) interviews: consists of an in-depth interview with actors of a program to collect specific information related to the individual.
- Priority evaluation: named as priority-evaluator technique is based on the simulation of choices in a market place and usually involves the use of social surveys to collect information.
- Focus groups: is one of a family of group based discussion methods, it takes the form of structured discussion that involves the progressive sharing and refinement of participants' views and ideas.
- Case studies: this method involves in-depth study of a phenomenon in a natural setting, drawing on a multitude of perspectives. The phenomena may concern individuals, programs, groups of people or decision-making processes.

- Local evaluation: is a common evaluation practice for large scale decentralized programs to require program managers and other stakeholders to conduct evaluations at local level.
- Participatory approaches and methods: participatory monitoring and evaluation is an umbrella term for a set of new approaches that stress the importance of taking local people's perspectives into account and giving them a greater say in planning and managing the evaluation process.
- Secondary source data: "Secondary" is used to refer to data that the evaluator was not responsible for directly collecting (as opposed to primary data which is generated by the evaluation itself).
- Use of administrative data: administrative data refers to the information that is routinely collected as part of the administration of socio-economic development programs.
- Observational techniques: it is a form of naturalistic inquiry; allow investigation of phenomena in their naturally occurring settings, through observing behavior and interactions as they occur.

3.2.3. Analyzing information

The analysis phase process and compares data and estimates effects. The evaluation methods and their limits, as well as the reasoning followed and the underlying hypothesis of this logic and its validity limits must be transparent. Within this context the assessments of the study should be based on the analyses regarding the judgment criteria defined in the structuring phase and the limits and validity of the judgments should be specified. The judgment phase makes assessments based on the analysis regarding the judgment criteria defined in the structuring phase. The limits and validity of the judgment should be transparent.

- Input/output analysis: it is a method used to characterize economic activity in a given time period, and to predict the reaction of a regional economy to simulation. It uses matrices to describe the way in which the productive system satisfies final demand.

- Econometric models: an econometric model is one of a range of tools used to replicate and simulate the main mechanisms of a regional, national or international economic system. An econometric model is generally defined by the use that data play in informing the model structure, namely to calculate the model's coefficients through a variety of possible estimation methods.
- Regression analysis: Regression analysis is the statistical technique that identifies the relationship between two or more quantitative variables: a dependent variable whose value is to be predicted, and an independent or explanatory variable (or variables), about which knowledge is available. The technique is used to find the equation that represents the relationship between the variables. A simple regression analysis can show that the relation between an independent variable x and a dependent variable y is linear, using the simple linear regression equation $y = a + bx$ (where $a\ and\ b$ are constants). Multiple regression will provide an equation that predicts one variable from two or more independent variables, $y = a + bx_1 + cx_2 + dx_3$.
- Experimental and quasi-experimental approaches: they attempt to replicate the kinds of conditions, in a "social" context, under which the behaviors of so-called "natural science phenomena" are observed and understood in the laboratory.
- Delphi survey: The Delphi Method is based on a structured process for collecting and synthesizing knowledge from a group of experts by means of a series of questionnaires accompanied by controlled opinion feedback. The questionnaires are presented in the form of an anonymous and iterative consultation procedure by means of surveys (postal and/or e-mail).
- SWOT: this decision-making tool owes its name to the fact that it examines the strengths and weaknesses within the firm, as well as the opportunities and threats of the market. It is one of the classical tools of strategic analysis, particularly helpful in the planning, during ex ante evaluation and during the implementation stage of a program. The SWOT was required by the EU regulations in the operative programs and in the mid-term evaluation in the context of the structural funds 2000-2006 programming period.

3.2.4. Tools to inform evaluative judgments

This phase makes assessments based on the analysis regarding the judgment criteria defined in the structuring phase. The limits and validity of the judgment should be transparent.

- Cost-benefit analysis: Cost-benefit analysis (CBA) is a method of evaluating the net economic impact of a public project. Projects typically involve public investments, but in principle the same methodology is applicable to a variety of interventions, for example, subsidies for private projects, reforms in regulation, new tax rates. The aim of CBA is to determine whether a project is desirable from the point of view of social welfare, by means of the algebraic sum of the time-discounted economic costs and benefits of the project.
- Benchmarking: Benchmarking was originally developed by companies operating in an industrial environment to improve competition and has therefore been applied most widely at the level of the business enterprise. The technique is based on the exchange and comparison of information between organizations in a given field, one or more of which is regarded as an example of good or best practice. The information normally relates to the processes and outcomes of specific aspects of the organizations involved. Benchmarking is now applied more widely, including the systematic comparison of the characteristics and attributes of regional and sub regional territories. In the field of "New Public Management" benchmarking has been applied in the management of public services and municipal administrations. It is also relevant in the ongoing evaluation of public interventions.
- Cost effectiveness analysis: Cost-effectiveness analysis (CEA) is a tool that can help to ensure efficient use of investment resources in sectors where benefits are difficult to value. It is a tool for the selection of alternative projects with the same objectives (quantified in physical terms). EA can identify the alternative that, for a given output level, minimizes the actual value of costs, or, alternatively, for a given cost, maximizes the output level. The method is used when measurement of benefits in monetary terms is impossible, or the information required is difficult to determine or in

any other case when any attempt to make a precise monetary measurement of benefits would be tricky or open to considerable dispute.

- Economic impact assessment: Economic impact assessment is a further tool to assess the amount of change which can be inputted to a program. It is used to quantitatively estimate an impact. The assessment is usually performed by analysts, with the assistance of decision-makers.
- Gender impact assessment: Gender Impact Assessment (GIA) is the core tool for implementing gender mainstreaming. It helps to estimate the different effects (positive, negative or neutral) of any policy or activity implemented in terms of gender equality. GIA should be carried out at an early stage in the policy decision-making process (before the approval and implementation of a Program) so that the policy can be adapted or re-oriented.
- Environmental impact assessment: EIA is a process by which the likely significant effects of a project or development on the environment are identified, assessed and then taken into account by the competent authority in the decision-making process. It is a systematic process that examines in advance the environmental impacts of proposed development actions and therefore can contribute to better projects from an environmental perspective.
- Strategic environmental assessment: SEA is a systematic process for evaluating the environmental consequences of proposed policy, plan or program initiatives in order to ensure that they are fully included and appropriately addressed at the earliest stage of decision-making, on a par with economic and social considerations. SEA is intended to integrate the environment into strategic decision-making, as distinct from Environmental Impact Assessment (EIA), which is directed at projects.
- Multi-criteria analysis: It is used to make a comparative assessment of alternative projects or heterogeneous measures. With this technique, several criteria can be taken into account simultaneously in a complex situation. The method is designed to help decision-makers to integrate the different options, reflecting the opinions of the actors concerned, into a prospective or retrospective framework. Participation of the decision-makers in the process is a central part of the approach. The results are

usually directed at providing operational advice or recommendations for future activities.

- Expert panels: An "expert panel" is a specially constituted work group that meets for evaluation. Expert panels are usually made up of independent specialists recognized in the fields covered by the evaluated program in the evaluation process, usually as a mechanism for synthesizing information from a range of sources, drawing on a range of viewpoints, in order to arrive at overall conclusions. To some extent, the expert panel draws largely upon legal practices in that results are usually based on reaching a consensus of opinion. Expert panels are a means of arriving at a value judgment on the program and its effects, which incorporates the main information available on the program, as well as numerous previous and external experiences.

3.3. Evaluation of the Common Agricultural Policy – A review

As reported in many of the EU guidelines for evaluation of development programs (EU, 2002), any evaluation should follow the usual "steps of the evaluation process", described in The Guide and Sourcebooks of Evalsed i.e., structuring, data collection, analysis, judgment.

In some cases the economic valuation will not be other than the evaluation of the impacts rather than of the policy or measure per se – this for example, could be when dealing with agri-environment measures (EU, 2005; Marggraf, 2003), or even the WFD measures – because impacts of such measures are complex to analyze given the difficulty to isolate the effect of measures from those of the many other drivers that influence outcomes.

From another side, many authors argue that since policies exist in a political and economic environment, they should not be evaluated on an individual basis. The total effect of a package of policies need not be the sum of the isolated effects of the single policies. A package of policies might have a small or zero net effect, even though the single policies might have significant effects on production (Gohin *et al*., 2000; Cahill, 1997). On this basis, many studies have been carried out to analyze the combined impact of different policies on the European agriculture.

One of the policies extensively studied is the decoupling of the subsidies that was introduced to change farmers' incentives in order to enhance a more market oriented agriculture. Consistently with the aim of the decoupling to make the amount of direct payments received by a farmer independent of cultivated crops, it is likely that in certain conditions the overall intensity of farming will diminish, when there is less economic incentive to produce high-yield crops (Aakkula *et al*., 2006).

Nevertheless, Balkhausen *et al*., 2005 confirm that effects of decoupling can be very heterogeneous, depending on farm types, fields and regions, later confirmed by Piorr *et al*., 2009. Even though in the EU-15 a general drop in maize and protein crops production is observed, consequently in irrigated land (Balkhausen and Banse, 2007).

Amongst those who discussed decoupling, Serra *et al*., 2005 and Happe and Balmann, 2003 studied the income and risk effect of such policy change, while others considered land use and cropping pattern (Piorr *et al*., 2009; Varela Ortega *et al*., 2006; Balkhausen *et al*., 2005). These modifications have direct impact on irrigated production that is replaced, depending on the case study by rain fed agriculture (set aside, cereals, arable fodder and grass). Consequently, water use diminishes.

Indeed, Júdez and Piniés (2006) analyzing the impact of decoupling on cereals in Spain, showed that decoupling could increase the irrigable land area with an increasing pressure on irrigation water resources. Besides, this policy change involves a 10% decline in the gross margin. These results partially confirm a previous study led in the Aragon region (North-east Spain), that concluded that farms are boosted toward more water intensive agriculture through the introduction of new irrigation technologies and expansion of more profitable irrigated crops such as horticultural and fruit crops (Mema and Albiac Murillo, 2004). As for economic viability and environmental effects of this shift of production, the authors mentioned that they must be carefully addressed.

Whereas a study carried out in Andalucía regions showed that irrigated crops like maize, cotton and durum wheat will be reduced except for bread wheat since it provides farmers with a high gross margin (Varela Ortega *et al*., 2006), the author stressed that these reduction in COP crops will be more prominent in the inland region of continental agriculture (Castilla) than in the Mediterranean region (Andalucia) with a more varied cropping mix and productive potential.

The 2003 CAP reform in Greece leads to a shift from cotton production to rain fed agriculture or less irrigated crops like cereals, this generates a drop in irrigated surface and water use, while the negative impact on farmers' income is not significant (Rozakis *et al*., 2008; Scardigno and Viaggi, 2007). Similar conclusions are expressed by other studies on the impact of decoupling on cotton production in Greece; results stressed an increase in farmers' welfare and in environmental quality (Butlen and Quirion, 2006; Manos *et al*., 2005).

This is conform with the results of another Spanish case study where irrigated area occupied mainly by cotton decreased after decoupling with respect to non irrigated area, threatening the profitability of its cultivation and consequently the survival of the sector (Arriaza and Gómez Limón, 2007; Blanco Fonsceca, 2007; Arriaza and Gómez Limón, 2006; Blanco Fonseca and Iglesias Martinez, 2005).

In France, Buisson (2005) mentioned that the impact of decoupling on the national agriculture will be a reduction in irrigated surface of about 8% and in water demand 7%, with a very limited impact on farmers' income, mainly due to the decline of irrigated maize and protein crops. These percentages can vary considerably in regions where water conflicts are stronger like the South-Western regions.

According to Arfini *et al*., (2007), the impact of decoupling in Italy is notable on land allocation in particular for cereals that are reduced for an increase in fodder plants occupation. Conversely, the another case study the 2003 CAP reform could cause a decrease in durum wheat, tomato and uncultivated surface, while it causes an opposite effect on vegetables and other cereals (Dono, 2006). As for economic results, a reduction of farmers' income is observed in all cases, water use decreases due mainly to the change in the crop pattern.

However, results of single farm payment in another Italian case study showed an extensification of the region land use, this leads to an increase of arable lands (Piorr *et al*., 2009). Yet, these changes are differentiated in terms of occurrence of different crops in different field types.

According to the literature review, in Apulia region in southern Italy, decoupling will reduce the total cultivated area, and industrial crops (tomatoes, sugar beet and tobacco) and even cereals which are irrigated crops in the area will be substituted by grass land (Scardigno and Bazzani, 2008). This change will resize the irrigated land and irrigation water, but no significant modification is observed in farmers' income.

Different types of models were used for this purpose (behavioral partial or general equilibrium model, programming model, stochastic bio economical model). For instance, Gelan and Schwarz (2006) formulated and implemented a Computable General Equilibrium model (CGE) using a social accounting matrix in order to capture system-wide impacts of the CAP reform on the Scottish GDP. The simulation results suggest that the Scottish agricultural sector may encounter declines in output and factor as a result of the 2003 policy reform.

The impact of direct payments on different agricultural sectors was studied in the UK as well, using a Partial General Equilibrium model, the simulations imply a decline in the output of some agricultural products like the sheep and beef sectors as a response to decoupling implementation but this impact is not significant in other sectors like cereals and dairy milk (Moss *et al*., 2002).

Also, the agri-environmental measures in different European countries were subject to many evaluation studies (Langeveld *et al*., 2007; Badertscher, 2005; Baschet, 2005; Carels and Van Gijseghem, 2005; Lankoski, 2005; Norell and Sjödahl, 2005; Osterburg, 2005; Radley, 2005; Zezza, 2005; Carey *et al*., 2003; Marggraf, 2003).

Stolze *et al*., 2000 held a study in 18 different European countries, to evaluate the organic farming, with a qualitative multi-criteria analysis. The primary sources of information for this study were documented research results published in the countries investigated accompanied by investigations to clarify the country specific background and including expert assessment. The methodology of an expert survey has been chosen for data collection. The data analysis was compared between conventional and organic farming using input/output analysis, in the base of a set of environmental indicators for the agricultural sector, developed within the DSR framework by the OECD.

In the planning phase some authors used stakeholder interviews (Carels and Van Gijseghem, 2005; Norell and Sjödahl, 2005; Carey *et al*., 2003). Different methods were used in the data collection phase; many studies adopted field surveys (Carels and Van Gijseghem, 2005; Lankoski, 2005; Carey *et al*., 2003), others used a combination of different methods depending on the variability in the case studies (Baschet, 2005; Radley, 2005; Zezza, 2005).

In order to evaluate the German agri-environmental programs, and both ecological effectiveness and economic efficiency, Marggraf (2003), has developed and applied experts' opinions obtained from a Delphi study so that it could be used as indicators followed by a cost-effectiveness and cost-benefit analysis to study both the ecological effectiveness and the economic efficiency. Whereas Carels and Van Gijseghem, (2005) in Belgium analyzed the data with SWOT method followed by expert panel for evaluative judgment.

Many other evaluation techniques adopted modeling approaches for information analysis; in some cases an integrated ecological and mathematical model (Norell and Sjödahl, 2005), in other cases an economic model as it is the case in Denmark and Switzerland (Badertscher, 2005; Larsen, 2005) and in others conceptual models and indicators like the evaluation of Good Agricultural Practices/Good Farming Practices (GAP/GFP) in the Netherlands' (Langeveld *et al*., 2007). Finally, in the Finish the analysis of the surveys' data was achieved by the mean of belief network modeling, followed by a social welfare assessment for the evaluative judgment (Lankoski, 2005).

From another side, in Germany, a new method was develop do deal with policy evaluation. The long-term impacts of the agri-environmental policy where measured using farm accounting data of identical farms for a time series, statistical cluster analysis was used for selecting similar farms with and without support for agri-environmental measures (AEM) and finally statistical analysis was adopted to compare between groups and over time (Osterburg, 2005). This method was recommended by the OECD which encouraged the use of statistical methods for analyzing the cause and effects linkages between policies and environmental outcomes.

3.4. Evaluation of the Water Framework Directive – A review

In recent years, many economical studies have been developed all over the member states to evaluate the economic impact of the WFD implementation. In particular, water pricing principles and provisions established in the Directive were analyzed. Results showed a big variation from a case study to another even within the same country, for different agricultural production systems (Bartolini *et al*., 2007; Gallerani *et al*., 2005). For instance, in some cases water pricing can change completely the land use of the area, especially for high water demand crops like rice, cotton and sugar beet that can be substituted with other rain fed crops (Berbel *et al*., 2005; Manos *et al*., 2005; Morris *et al*., 2005(a)), even more, it can lead to a complete abandonment of agricultural activity (Bartolini *et al*., 2007). But from another side, such measure could be insignificant in the cereal farms of Lombardia in Italy, where water consumption is concentrated on the most profitable crops (Gallerani *et al*., 2005). But there is no doubt that water pricing will influence directly water consumption that goes decreasing. Further, aspects of adaption to such policy changes can be observed at the level of technology modification, like the transformation from sprinkler to drip irrigation (Blanco Fonseca, 2007), or even the adoption of complementary irrigation instead of the complete irrigation.

Besides the land use, the environmental impacts of the implementation of such measures are widely argued. While in some areas water price can generate positive environmental impacts (Berbel *et al*., 2005; Manos *et al*., 2005; Pinheiro and Saraiva, 2005), like decreasing non point pollution by fertilizers when decreasing irrigation, in some other studies, taxing water consumption can induce negative influence (Gómez-Limón and Riesgo, 2005), in soils prone to desertification.

Moreover, the efficiency of some measures of the Directive was discussed. Giannocaro *et al*., 2008 showed the volumetric water pricing could be the most efficient method for pricing water in irrigation, while Huffaker and Whittlesey, 2000 were in favor of economic incentives to improve on-farm irrigation efficiency.

For some authors, implementation of water pricing required by the WFD combined with other agricultural policies could be a useful economic tool in determining water consumption (Gómez-Limón and Riesgo, 2005). But the negative economic impacts of such policy were relevant in some studies (Gallerani *et al*., 2005), on farmers' welfare and in consequence the social impacts that can generate, in particular when the irrigated agriculture is of high importance in the local economy like the citrus crops in Sicily, Italy. In fact all studies reviewed, observed an inverse correlation between water pricing and farmers' income (Bartolini *et al*., 2007; Berbel *et al*., 2005; Gallerani *et al*., 2005; Gómez-Limón and Riesgo, 2005; Manos *et al*., 2005; Morris *et al*., 2005(a); Pinheiro and Saraiva, 2005).

The tools used to deal with this matter were numerous, some authors used discrete stochastic modeling, others used linear programming and some others used multi-criteria decision making models. A Portuguese study has evaluated the effects of alternative policies of water price for irrigation on the farm income and the production pattern, having in account the recovery of the public investment and the operating costs with irrigation infrastructures (Noeme and Fragoso, 2004). In the outcomes of the sequential discrete stochastic model used to simulate the different policies there was a net relation between the price increase and the decrease in water demand and in consequence the farm income. By the mean of linear program, Gómez-Limón and Riesgo (2004) published a paper about applying the volumetric water pricing required by the WFD. Results showed a net decrease in the farm income with in ascending tariffs for all the 3 clusters represented in the model.

Saraiva and Pinheiro (2007), using a Multi-Criteria Decision Making (MCDM) model, concluded that Farmers' income varies in the opposite direction of water pricing or consumption quotas and that the most water consumptive crops (rice, maize and sugar beet), or with reduced profitability, are the most affected in the quota and volumetric pricing situations.

In this sense, policy impact analysis in the agricultural sector has traditionally relied on Positive Mathematical Programming (PMP). Varela Ortega *et al*. (1998), for instance, conducted a study to assess the socio-economic impacts of water pricing policies in several irrigation districts. Another Spanish study developed a positive mathematical programming that allows to simulate farmers' behavior and to assess the impacts of different policy options (Blanco Fonseca, 2007). The results of the model gave detailed information about water consumption that goes decreasing with increasing volumetric water tariffs, crop allocation decisions where arable crops substitute irrigated agriculture, technology adoption (the drip irrigation replaces completely sprinkler systems).

Viaggi *et al*., (2009) stressed out the importance of water demand evaluation and the combined impacts at the RIBs' level or even at water shed level, of a package of policies like the CAP and the WFD measures given that a lot of the studies done in the water sector were at the farm level. Though, given the difficulty of data availability this situation as the authors expressed can lead to management problems due to lack of information.

In this purpose, a meta-integrated territorial mathematical simulation model was built for Apulia Region (Southern Italy), in order to evaluate the impact of different policies on agriculture (Scardigno and Bazzani, 2008). The results of the analysis showed that agricultural policies measures do not affect land use pattern or agricultural pressure on water resources, but can have major effects on income. Conversely, water policy and market conditions could impact farmers' choices and could have an important environmental pressure.

To respond to this need of research, Raggi and Viaggi (2009) and Viaggi *et al*., (2009) laid a study in a RIB of Northern Italy; this study was done through a PMP model at the farm level. The results concluded that the response to water price in the RIB is direct but the response could be more or less rigid depending on the type of farms, this fact is explained by a low water demand in the RIB. The authors mentioned that this study may be very important at the decision level of the RIB for future development of the irrigation activity on the local territory.

Some other cases analyzed the water pricing measure and it aspects on the RIB's income. Indeed, in the 12th Congress of the European Association of Agricultural Economists, Dono and Severini (2008), presented a study to evaluate the farmer behavior on the WFD's application when they have alternative water resources (Private wells in this case), the results of the analysis performed by means of a mathematical programming model show that farmers substitute the water supplied by the irrigation board with that extracted from farm wells. In addition to the negative environmental impact on the ground water that is in clear contradiction with the basic objectives of the WFD, the substitution of surface water by groundwater endangers the economic sustainability of the irrigation boards, which are very useful institutions in water allocation.

The same aspect was covered once again by Dono *el al.*, (2007), who studied the management of the water bodies, covered by the RIBs and evaluated different policies to cope with the requirements of the WFD. The authors built a model using the mathematical programming, to optimize the economic activity of different agricultural and industrial farms represented in the watershed. In the study authors simulated the changes in the land use and the farm income with the change of different policies. They underlined the fact that the farm income could increase of about 10% only if the RIB take an engagement of a good administration and management.

This same subject was approached by other studies with different modeling tools like multicriterial programming techniques to build integrated decision support systems (Bazzani, 2005; Bazzani *et al*., 2004). Pujol *et al*., (2006) as well simulated by the mean of multi-criteria decision model the impact of water markets policy on agriculture in the internal river basins of Catalonia in Spain where the competition upon water resources is very peculiar. Results showed that water pricing could guarantee an optimal reassignment of the resource in situations of supply restrictions, and although compared to the situation without markets they would not mean higher economic profits for the irrigators, they could prevent conflicts between them. Nevertheless, doubts exist about their acceptance among farmers.

3.5. Recapitulation of the second chapter

The purpose of this chapter was to give an overview of different approaches and methodologies that are used to realize economic evaluation of policy. Then, a literature review of the evaluation studies of Common Agricultural Policies and WFD was illustrated where, the policy studied, the methodology adopted and the major results and the recommendations were shortly elucidated.

This was followed by a literature review to highlight the studies done till now in this concern, either for the valuation of the agricultural policy or for the valuation of the impact of the water framework directive. We elucidated shortly in this literature, the policy studied, the methodology adopted and the major results and the recommendations in case there are any.

We can conclude from the review of all these studies that variation is obvious depending on many factors, and WFD and CAP are equally important determining agricultural, environmental and socio-economic future of the member states and the local communities. For, it is always suggested to test the combined impact of these policies at local levels in different geographical areas, different agricultural systems and different pressures. Given that farmers operate within RIBs that proved high efficiency management water demand and distribution, it is always recommended to take into consideration the economic impacts of these institutions when such structural changes occur.

This done it will help in the choice of our methodology and will justify some decisions made. Once concluded this chapter, it would be useful to target the next one which will introduce the study case and detail the socio-economic situation of the area.

CHAPTER IV

4. Socio-Economic Description of the Study Area

Emilia Romagna is an administrative region of Northern Italy comprising the two historic regions of Emilia and Romagna. It has Bologna as Capital and it covers an area of 22,124 Km² (**Fig. 4.1**), nearly half of it (around 50%) consists of plains while 25% is hilly and 25% mountainous. The geographical bounds are between 43.44 and 45.08 of latitude and between 9.12 and 12.45 of longitude. Referred to the census of January 2006 the population in Emilia Romagna is of 4,187,557 residents with in increment of 4.85% with respect to the same period of 2002.

Figure 4.1: The administrative map of Emilia Romagna.

Since 2000, in the agricultural sector, the reduction of the number of farms 15.60% have the same trend with the national tendency, particularly the farms of small dimensions comprised between 2 and 10 hectares. The reorganization has interested also the economic size (-12% in terms of ESU) interesting in marked measure (-23%) for farms less than 10 hectares, (-8.50%) regarding those beyond such dimension. This negative variation is on the base of the increase of the business medium dimensions (RPRD, 2007).

Indeed, in the 2003 the medium dimension of the regional agricultural farms, in terms of SAU 12.30 ha $farm^{-1}$ or in economic terms 22.80 ESU, seems to be higher to the national mean (6.70 hectares, 9.90 ESU), showing a similar position compared to other regions of North Italy and a higher position compared to the European average of EU 15 as well as EU 25. From the comparison with the communitarian context it emerges clearly that, although in terms of economic dimensions the regional companies are placed over the average of the EU 15 that EU 25, the profile of the physical dimensions (SAU) increases clearly respectively 20.20 ha $farm^{-1}$ and 15.80 ha $farm^{-1}$.

In terms of farm efficiency, the ESU/ULA values are less in the inferior classes of SAU, evidencing greater difficulties connected to the increase of the labor costs and to the optimization of the job factor (**Tab. 4.1**).

Referred to ISTAT (2007), the agricultural land use in the region is divided as follows: seed cultivation 77.60%, wood cultivation 13.60% and to grassland and pastures 8% present mainly in mountainous areas of the region. The reduction of farms' number that took place in the period 2000-2005, has interested the cereals 18.40%, the fruit production 13.30% and the bovine livestock 28.30%. Relatively to the aspect of farm management, it prevails that 97% are managed by farmers, in particular, with family labor employments.

Table 4.1. Numbers from agriculture in Emilia Romagna.

Characteristics	1970	1982	1990	2000	2003
Number of farms	198,216.00	174,767.00	150,736.00	107,888.00	873,220.00
Farm size (SAU) ha	1,348,279.00	1,273,835.00	1,232,219.00	1,115,380.00	1,074,552.00
Working days	89,476.00	54,690.00	38,283.00	25,818.00	21,258.00
Mean SAU ha	6.80	7.30	8.20	10.30	12.30
Working days ha^{-1}	66.00	43.00	31.00	23.00	20.00

(RPRD, 2007).

The Region, although characterized with an elevated rate of education, shows a relatively consistent quota 5.90% of farmers not in possession of any degree, phenomenon that however can be attributed to the elevated mean age of farmers. Relatively to the professional formation of farmers, approximately 79% of them are in possess of a technical formation exclusively, while the remaining 20.10% have agrarian formation. Regarding the national data, the Emilia Romagna is between Italian regions with highest levels of elementary and complete agrarian formation of farmers. It goes considered, however, as the general position of Italy regarding the average of the European States (RPRD, 2007).

The regional agriculture suffers from an insufficient ability of the sector to attract young people; from 2000 to 2003 (**Tab. 4.2**). In fact, the percentage of farmers of age less than 35 years has remained constant (5.20%). The insufficient generational dynamism is confirmed from the low relationship between the young conductors and those of advanced age to the 55 years, at the regional level have been attested to 8.40% in 2003 higher to the national mean of 6% that, however, very far, to the EU 25 mean of 18%. The composition by range of age of farmers as reported to 2005, shows a clear prevalence of the over 50 (30% of them are over 60).

Table 4.2. Distribution of farmer by age in Emilia Romagna (2002-2005).

Range of farmers' age	2002		2005		Variation %
	Number	%	Number	%	
From 18 to 29 years	1,812.00	2.60	1,375.00	2.10	– 24.10
From 30 to 49 years	17,301.00	24.50	15,828.00	24.70	– 8.50
From 50 to 69 years	31,630.00	44.70	27,425.00	42.80	– 13.30
≥ 70 years	19,994.00	28.30	19,380.00	30.30	–3.10
Not classified	6.00	0	3.00	0	–50.00
Total Farmers	**70,743.00**	**100.0**	**64,011.00**	**100.0**	**– 9.50**

(RPRD, 2007).

The cooperative reality in the region is greatly developed within the primary sector with the highest percentage of cooperatives between the Italian regions (15% of the national total). 59% of the farms of which 39% livestock and 7% of the production-transformation farms commercialize their own products through such structures. With reference to these cooperatives, in the last years a decrease in the number of 5.50% has been recorded relatively to a trend already registered along the previous decade. A local study at the level has listed some facts about the number of agricultural farms the surface used and the operational of effective farm size (SAU) in Emilia Romagna (**Tab. 4.3)**.

Table 4.3. Type of possession, number of farms, total surface and total SAU.

Type of possession	N. of farms		Surface		SAU	
	N.	%	Ha	%	Ha	%
Private property	75,430.00	78.55	871,120.20	66.70	664,966.78	64.57
Collective property	32.00	0.03	10,596.65	0.81	3,349.57	0.33
Conferring from public	18.00	0.02	5,769.11	0.44	776.98	0.08
Conferring from privates	85.00	0.09	2,819.96	0.22	2,615.31	0.25
Renting from public sector	949.00	0.99	16,465.90	1.26	14,622.33	1.42
Renting from privates	17,419.00	18.14	380,099.10	29.10	326,980.53	31.75
Free use	2,101.00	2.19	19,139.22	1.47	16,604.57	1.61
Total	**96,034.00**	**100.0**	**1,306,010.14**	**100.0**	**1,029,916.07**	**100.0**

(Source: RPRD, 2007).

In the period of 2000-2005, the agricultural sector was subject to a generalized loss in competitiveness. In the 2005, the value of the agricultural production of the region has undergone a reduction of 6% regarding the values recorded in the 2000 (**Tab. 4.4**). Considering the agricultural sector alone, the total GVP between the years 2005-2007 was subject to a continuous increase (***cf. Annex 4***) which reached the 12.90% in the latest 2007 (PLV, 2007).

The sugar beet has had a contraction of Gross Vendible Product (GVP) of the 3.80%, due in particular to the prices reduction of 20%, and the Soya of 52.30%, inducing a big decline of production around 50.80%. Compared to the national level the performances of the Soya are aligned with those regional ones, while they are in opposite trend those relative to the sugar beet 22%. The GVP of bread wheat has declined of 8.50%, contained in the productive increment of 4.10% that has reduced the price of 12% with respect to 2000.

Table 4.4. Agricultural GVP for main productions (M€).

Production	2000	2001	2002	2003	2004	2005	Var. %
Field crop	1,112.40	1,210.70	1,095.90	1,188.30	1,214.00	1,108.40	– 0.40
Cereals	338.80	3390	336.50	378.20	384.00	337.80	– 0.30
Horticulture	482.50	583.10	438.90	528.90	482.20	435.90	– 9.60
Industrial crop	218.40	176.90	152.40	131.10	161.70	195.20	– 10.70
Other field crop	72.70	111.70	168.10	150.10	186.10	139.50	91.80
Fruit crop	868.10	1090.40	653.50	711.70	841.70	798.90	– 8.00
Wine grape	260.30	266.70	236.80	236.50	243.00	207.00	– 20.50
Livestock	1,707.60	1,749.90	1,687.20	1,844.00	1,651.90	1,556.10	– 8.90
Bovine meat	174.10	147.70	140.40	137.40	164.60	174.10	0
Pork meat	302.40	374.70	311.10	310.90	306.90	281.30	– 7.00
Poultry & rabbit	289.10	263.50	236.20	290.00	260.90	231.70	– 19.90
Ovicaprine	5.00	5.40	5.20	5.20	4.60	4.30	– 13.40
Dairy milk	731.00	763.00	793.60	868.30	716.50	671.00	– 8.20
eggs	183.60	175.50	180.00	211.10	177.50	173.30	– 5.60
Other livestock	22.40	20.00	20.60	20.90	20.90	20.50	– 8.50
Total	**3,688.20**	**4,051.00**	**3,690.50**	**3,998.60**	**3,707.60**	**3,463.50**	**– 6.10**

(RPRD, 2007).

In the livestock production, meaningful negative quotations are registered in pork meat and the bovine milk (mean annual reduction of about 12%). Moreover, poultry production has shown a sharpened decline in the latest months of 2005, because of the avian flu.

The evolution of the added value of agriculture, forestry and fishery in the period 2000-2004 has marked an increase of 4.50%, slightly lower than the national data 6.80%, this difference is mainly caused by the increase of production costs specially energetic cost. Less influencing were labor costs which were marked by a slight increase of 1.5% yearly, aligned with trends registered at the national level.

The highest one is the added value recorded in food-Industry sector in the period 2000-2003 (something like 16%). However the increase supported, has been more contained than the one registered at the national level of 21.20%. In terms of productivity, the regional data show an annual medium increment of 2.30% and 7% with respect to 2000, inferior of 1.30% compared to the national productivity of 8.30%.

Therefore in the food-industry, the productivity has registered an annual mean growth of 3.10%, with a total increment of 14.90%, tendency aligned with the national one of 16% and with the EU 15.

The Emilia Romagna is the in excellence the Italian region that boasts the supremacy in terms of recognized and protected productions with communitarian labels: 14 DPO (denomination of protected origin), and 11 PGI (Protected Geographical Indication).

In 2005 exchanges in food industry sector have participated in the determination of the trade balance for 13.40% of the imports and 15.60% of the exports, with an almost invariable weight compared to 2000. It has assisted as well to an increase of export of commercial trades in the order of 17%, higher than the record registered from imports 12%; such trend has had much positive effect on the trade balance that has had an improvement of 36% with respect to 2004.

Limitedly to the agricultural and livestock productions an increment of the exports of 2.50% has been evidenced which, considering the course of 2000-2005 of the regional agricultural GVP, has generated stationary trend of the index of the propensity to export (the value of agricultural exports/GVP) equal to 11.30% (0.60% compared to 2000). The same index at national level, has been attested to 8.30% in 2005, and has evidenced a similar trend (0.40%). In food industry, the increase of imports and exports registered has been respectively of 19% and 20%; almost similar to the national trends (15% and 23%). Europe (in particular EU 15) constitutes for Emilia Romagna, the main market for trades (Approximately 77% of the agricultural export value).

4.1. Structure of farms in Bologna – The FADN database

Agriculture in Bologna is changing so fast in the last decades inside the socio-economic system. If we consider for instance the weight of the added value in agriculture with respect to the total economic activity we realize that it was subject to a drastic change, decreasing from 2.60% in 1992 to 1.20% in 2007 that switched to the industrial sector and services.

To understand the growth of the agricultural sector in bologna, it was very useful to begin an analysis of the FADN database, which constitutes a wide information network on the Italian territory, for farm accounting. This analysis is a kind of classification of the data, which is an important component of virtually all scientific research. Statistical techniques concerned with classification are essentially of two types, the one that we are going to use in the analysis is the cluster analysis, which aims to uncover groups of observations from initially unclassified data. I will go in the details of the cluster analysis in the next paragraph, as far as I explain the sample of farms included in the analysis.

As mentioned above, we used for the analysis the FADN database for the farms in the province of Bologna in 2006. It is a sample of 245 farms on about 10,559 ha of SAU, most of them located on the plain (67.35%), while 26.53% are on the hills and the rest (6.12%), occupies the mountainous area. The physical dimension is mainly distributed between 5 and 50 ha for about 69.50%, while the economic size is largely composed of big farms (46.53% of farms have 114 ESU), while small and medium farms are represented respectively by 22.45% and 31.02% in the sample (Tab. 4.5). The land use of the sample is dominated by fruit crops (Fig. 4.2) that represent about 52.65% of the total number of farms.

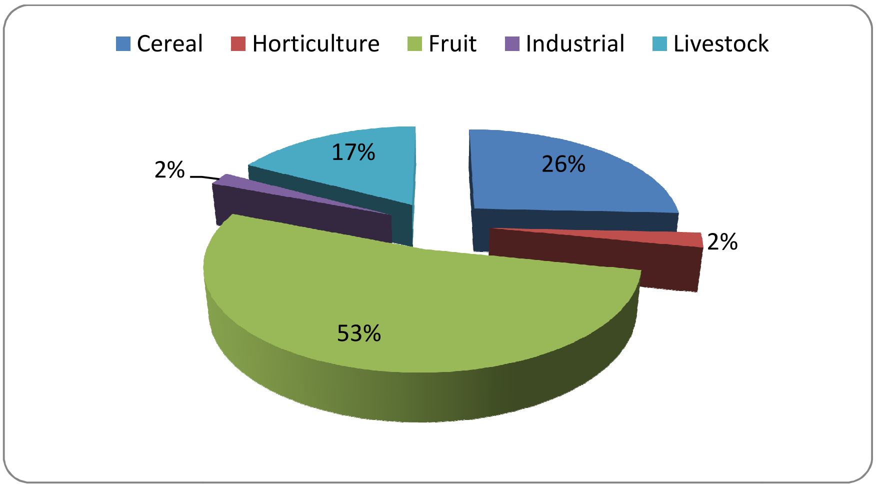


Figure 4.2: The land use of the sample's farms.

Table 4.5. Dimension of farms and distribution with respect to geographical location.

Geographical location	Mountain		Hill		Plain		Total	
Number & percentage	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Physical Dimension (SAU)								
< 5 ha	1	6.67	7	10.77	26	15.76	34	13.88
5 – 10 ha	2	13.33	9	13.85	32	19.39	43	17.55
10 – 20 ha	2	13.33	17	26.15	51	30.91	70	28.57
20 – 50 ha	8	53.33	20	30.77	29	17.58	57	23.27
> 50 ha	2	13.33	12	18.46	27	16.36	41	16.73
Total	**15**	**100.0**	**65**	**100.0**	**165**	**100.0**	**245**	**100.0**
Economic Size (ESU)								
< 16 ESU	3	20.00	14	21.54	38.00	23.03	55	22.45
16 – 40 ESU	6	40.00	18	27.69	52.00	31.52	76	31.02
> 40 ESU	6	40.00	33	50.77	75.00	45.45	114	46.53
Total	**15**	**100.0**	**65**	**100.0**	**165.0**	**100.0**	**245**	**100.0**

4.1.1. Cluster analysis

Many clustering techniques begin not with the raw data but with a matrix of inter-individual measures of distance or similarity calculated from the raw data. Here we shall concentrate on distance measures, of which the most common is the *Euclidean distance* given by:

$$d_{if} = \left[\sum_{l=1}^{q} (x_{il} - x_{jl})^2\right]^{\frac{1}{2}}$$

Where d_{ij} is the Euclidean distance for two individuals $i \; and \; j$, each measured on q variables, $x_{il}, x_{jl}, l = 1, \ldots, q$.

Euclidean distances are the starting point for many clustering techniques, but care is needed if the variables are on very different scales, in which case some form of standardization will be needed (Everitt *et al.*, 2001).

To proceed in a cluster analysis first we have to choose variable on which we want the groups to be similar, next, we must decide whether to standardize the variables in some way so that they all contribute equally to the distance or similarity between cases. Finally, we have to decide which clustering procedure to use, based on the number of cases and types of variables that we want to use for forming clusters.

The K-means is a method of clustering that produces a partition of the data into a particular number of groups set by the investigator. From an initial partition, individuals are moved into other groups if they are "closer" to its mean vector than that of their current group (Euclidean distance is generally used here). After each move, the relevant cluster mean vectors are updated. The procedure continues until all individuals in a cluster are closer to their own cluster mean vector than to that of any other cluster.

Essentially the technique seeks to minimize the variability within clusters and maximize variability between clusters. Finding the optimal number of groups will also be an issue with this type of clustering. In practice, a k-means solution is usually found for a range of values of k, and then one of the largely ad hoc techniques described in Everitt *et al.* (2001) for indicating the correct number of groups applied. Different methods of cluster analysis applied to the same set of data often result in different solutions. A data consideration that conditions the application of this method: variables should be quantitative at the interval or ratio level.

Agglomerative hierarchical techniques are a class of clustering techniques that proceed by a series of steps in which progressively larger groups are formed by joining together groups formed earlier in the process. The initial step involves combining the two individuals who are closest (according to whatever distance measure is being used). The process goes from individuals to a final stage in which all individuals are combined; with the closest two groups being combined at each stage. At each stage, more and more individuals are linked together to form larger and larger clusters of increasingly dissimilar elements. In most applications of these methods, the researcher will want to determine the stage at which the solution provides the best description of the structure in the data, i.e., determine the number of clusters.

Different methods arise from the different possibilities for defining inter-group distance. Two widely applied methods are complete linkage in which the distance between groups is defined as the distance between the most remote pair of individuals, one from each group, and average linkage in which inter-group distance is taken as the average of all inter-individual distances made up of pairs of individuals, one from each group. The series of steps in this type of clustering can be conveniently summarized in a tree-like diagram known as a dendrogram.

If variables are measured on different scales, variables with large values contribute more to the distance measure than variables with small values. Hierarchical cluster analysis (HCA) is an exploratory tool designed to reveal natural groupings (or clusters) within a data set that would otherwise not be apparent. It is most useful when you want to cluster a small number (less than a few hundred) of objects. The agglomeration schedule which is the numerical summary of the cluster solution becomes very long when the cases to analyze are many which complicate the reading and the analysis of the data.

When the data set is very large and a clustering procedure that can rapidly form clusters on the basis of either categorical or continuous data is needed, neither of the previous two procedures fills the bill, the two-step cluster is the best adapted to such cases. Hierarchical clustering requires a matrix of distances between all pairs of cases, and k-means requires shuffling cases in and out of clusters and knowing the number of clusters in advance. The two-step cluster requires only one pass of data and it can produce solutions based on mixtures of continuous and categorical variables and for varying numbers of clusters. The clustering algorithm is based on a distance measure that gives the best results if all variables are independent, continuous variables have a normal distribution, and categorical variables have a multinomial distribution.

- Pre-clustering: This first step of the procedure is formation of pre-clusters. The goal is to reduce the size of the matrix that contains distances between all possible pairs of cases. When pre-clustering is complete, all cases in the same pre-cluster are treated as a single entity. The size of the distance matrix is no longer dependent on the number of cases but on the number of pre-clusters.

- Hierarchical clustering of pre-clusters: In this step, the standard hierarchical clustering algorithm is uses on the pre-clusters.

4.1.2. Characteristics of the clusters

The technique used in our case is the Agglomerative hierarchical technique. As described above, agglomerative hierarchical clustering is a bottom-up clustering method where clusters have sub-clusters, which in turn have sub-clusters, etc. agglomerative hierarchical clustering starts with every single object in a single cluster. Then, in each successive iteration it agglomerates (merges) the closest pair of clusters by satisfying some similarity criteria, until all of the data is in one cluster. The hierarchy within the final cluster has the following properties:

- Clusters generated in early stages are nested in those generated in later stages.
- Clusters with different sizes in the tree can be valuable for discovery.

So the whole issue is to find an appropriate definition of the “distance” between two clusters. There are many ways to do that, we used Ward technique to define this distance. Using Ward's Method we will start out with all sample units in n clusters of size 1 each. In the first step of the algorithm, $n-1$ clusters are formed, one of size two and the remaining of size 1. The error sum of squares and r^2 values are then computed. The pair of sample units that yield the smallest error sum of squares, or equivalently, the largest r^2 value will form the first cluster. Then, in the second step of the algorithm, $n-2$ clusters are formed from that $n-1$ clusters defined in step 2. These may include two clusters of size 2, or a single cluster of size 3 including the two items clustered in step 1. Again, the value of r^2 is maximized. Thus, at each step of the algorithm clusters or observations are combined in such a way as to minimize the results of error from the squares or alternatively maximize the r^2 value. The algorithm stops when all sample units are combined into a single large cluster of size n.

The set of data that we classified is composed of 245 farms and the variables are nine in total and are of two types: categorical and continuous, and they are as follows:

- Operational farm size (SAU).
- Irrigable SAU/SAU.
- Irrigated SAU/SAU.
- Rented land/SAU.
- Immobilization/SAU.
- Land capital.
- Horse power (HP)/SAU.
- Altitude.
- Use of family labor.

The hierarchical technique has identified 6 groups or clusters (A, B, C, D, E, F, and G). The clusters A and B are dominated by fruit farms in the plain; they are constituted respectively of 88 and 85 farms having a mean SAU of 20.80 ha for cluster A and for B 16.60 ha. In cluster C, farms are 37; they are mainly mixed farms with a mean SAU of 27.80 ha. Cluster D is composed of 22 farms that have a mean SAU of 39.10 ha, mainly livestock mountainous farms. Clusters E and F are both composed respectively of 11 and 2 cereal farms in the plain, they have a respective mean SAU of 230 and 1,450.80 ha. The mean values for the variables used in the clustering for each groups are represented in the following table (**Tab. 4.6(a) and 4.6(b)**).

Table 4.6(a). General characteristics of the clusters.

Variables	Cluster A		Cluster B		Cluster C	
	Mean	Var.	Mean	Var.	Mean	Var.
Altitude (m)	27.32	0.56	45.21	0.36	164.24	0.24
Horse power/SAU (hp)	7.92	1.05	21.01	0.86	10.54	1.11
Immobilization/SAU (10^6€)	0.67	3.70	0.83	8.04	0.52	2.78
Use of family labor (%)	94.55	0.17	48.25	0.45	77.19	0.42
Number of land capital	2.11	0.48	1.80	0.50	2.35	0.42
Irrigable SAU/SAU (%)	59.7	0.62	31.00	1.30	16.90	2.11
Irrigated SAU/SAU (%)	18.5	1.50	10.10	2.59	5.50	4.11
Rented land/SAU (%)	25.2	1.45	34.90	1.19	43.10	1.03
Mean SAU (ha)	20.84	0.95	16.57	1.15	27.81	0.94

Table 4.6(b). General characteristics of the clusters.

Variables	Cluster D		Cluster E		Cluster F	
	Mean	**Var.**	**Mean**	**Var.**	**Mean**	**Var.**
Altitude (m)	686.86	0.10	31.64	0.50	21.00	27.00
Horse power/SAU (hp)	4.62	1.07	2.40	1.20	1.32	37.00
Immobilization/SAU (10^6€)	-	-	-	-	-	0
Use of family labor (%)	65.03	0.45	43.46	1.06	-	0
Number of land capital	2.68	0.40	5.00	0.27	9.00	16.00
Irrigable SAU/SAU (%)	54.90	0.85	80.10	0.46	-	0
Irrigated SAU/SAU (%)	0	-	13.50	2.18	-	0
Rented land/SAU (%)	58.20	0.74	55.10	0.84	0.12	141.00
Mean SAU (ha)	39.05	0.73	229.68	0.48	1450.76	18.00

Some indexes for economic efficiency like the GVP, variable and fixed costs and marginal revenue, are calculated by cluster and are reported in **table 4.7**, while in **table 4.8** are tabulated the source of water for irrigation and the irrigation method. The tables will be followed by some of the box plots of some variables used in the aim of this cluster; they represent the distribution with respect to the mean value of each cluster and the standard variation (**Fig. 4.3, 4.4, 4.5 and 4.6**).

Table 4.7. Indexes of economic efficiency by cluster.

Efficiency Index	Clusters						Total sample
	A	**B**	**C**	**D**	**E**	**F**	
GVP/SAU (€)	4,086.40	5,474.20	5,123.40	2,328.90	2,127.40	1,436.80	4,457.10
GVPcereal/GVP (%)	34.70	36.70	13.90	17.30	59.90	62.60	32.00
GVPfruit/GVP (%)	49.50	48.80	52.70	0.40	4.90	-	42.90
GVPzootec/GVP (%)	4.80	4.10	21.10	65.90	14.20	-	12.90
GVPforest/GVP (%)	-	-	0.40	0.10	0.10	-	0.10
Var.cost/SAU (€)	1,508.70	2,164.00	3,219.30	1,138.80	903.10	508.40	1,925.80
Var.cost/PLV (%)	36.90	39.50	62.80	48.90	42.50	35.40	43.20
Fixedcost/SAU (€)	1,651.30	2,630.90	1,319.70	700.50	978.60	1,018.70	1,820.30
Marginalrev/SAU (€)	2,619.00	3,321.00	2,105.00	1,636.00	1,384.00	928.00	2,627.00
Marginalrev/PLV (%)	64.10	60.70	41.10	70.30	65.10	64.60	58.90

Table 4.8. Irrigation source and method by cluster.

Irrigation source	Clusters						Total sample
	A	B	C	D	E	F	
Not specified	17.00	57.60	78.40	31.80	9.10	100.00	42.00
Collective network	55.70	11.80	0	4.50	54.50	0	26.90
River	4.50	7.10	10.80	50.00	0	0	10.20
Well	19.30	16.50	5.40	9.10	27.30	0	15.50
Other type	3.40	7.10	5.40	4.50	9.10	0	5.30
Irrigation source	**Clusters**						**Total sample**
	A	**B**	**C**	**D**	**E**	**F**	
Not specified	17.00	57.60	78.40	31.80	9.10	100.00	42.00
Drip irrigation	18.20	14.10	10.80	0	9.10	0	13.50
Sprinkler irrigation	29.50	10.60	0	0	54.50	0	16.70
Gravity	12.50	0	0	0	0	0	4.50
Other type	22.70	17.60	68.20	68.20	27.30	0	23.30

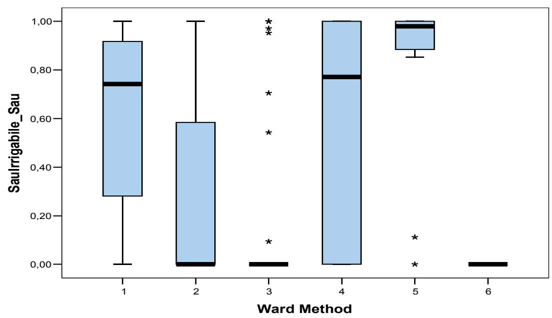


Figure 4.3: Distribution of the irrigable SAU between clusters.

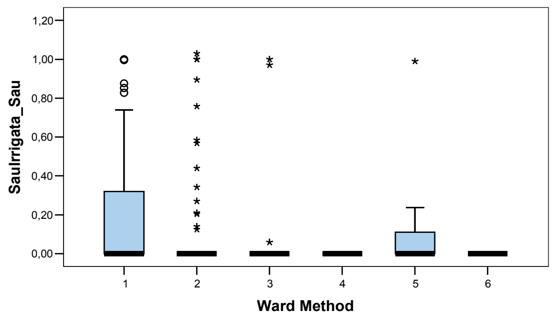


Figure 4.4: Distribution of the irrigated SAU between clusters.

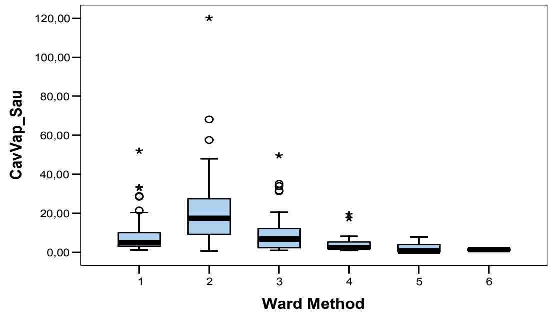


Figure 4.5: Distribution of the Horse Power between clusters.

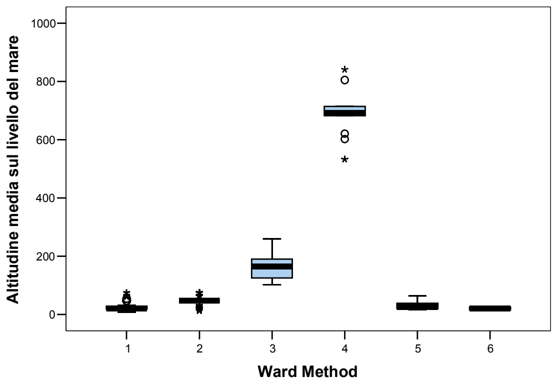


Figure 4.6: Distribution of the altitude between clusters.

4.2. Description of Renana RIB

The region is included in the most important agricultural area of the country. A valley, mostly rich in water courses with deep alluvial soils, encircled on three sides with mountains, while to east it is opened to the Adriatic sea, which characterizes the region with a climate between continental and Mediterranean with warm and humid summers and very hard winters with an homogenous distribution of precipitations along the year (INEA, 2007 (b)).

The Renana Reclamation and Irrigation Board (RIB) is an Agency of public rights, whose constitution goes back to 1909. It operates enforced by the regional most recent and innovative regional laws 42/84 and 16/87, in order to insure the drainage of waters, the protection of soils, the protection of the water and natural resources, the irrigation and the valorization of the territory.

4.2.1. Boundaries of the RIB

The territory of the Renana RIB (**Fig. 4.7**) is comprised in the interregional basin of the Reno River, a water course that constitutes, with the Santerno, an alluvial watershed, due to the sandstone and marls formations in the mountains where it emerges, that has a very high retention capacity. The river, with its affluent, takes origin in the Appennino, an area characterized by a high rainfall, from 1,000 to 1,500 mm yr^{-1}.

The administrative territory of the Consortium is extended on approximately 187,603 ha, most of them situated in the Province of Bologna, between the Reno river and the Sillaro stream, of which about 119,129 ha are situated in the plain (I° District), and about 68,474 ha are in the hills and mountains (in the II° District), that constitute the main drainage basins of the Reno River, namely those of the Savena, Zena, Idice, Quaderna and Sillaro that include many municipalities of the province (**Tab. 4.9**).

The plain instead, has the shape of a quadrilateral, enclosed to North-West and the North-East from the course of the Reno river (than form two advanced sides of the quadrilateral), to South-East it combines the delta of the river with the city of Imola (whose center remains outside the territory of the Consortium) and to South-West from with Via Emilia, in the Imola-Bologna feature. The territory of the Consortium covers great part of the territory of the province of Bologna, but it comprises areas pertaining also to Florence, Ferrara and Ravenna (**Tab. 4.10**).

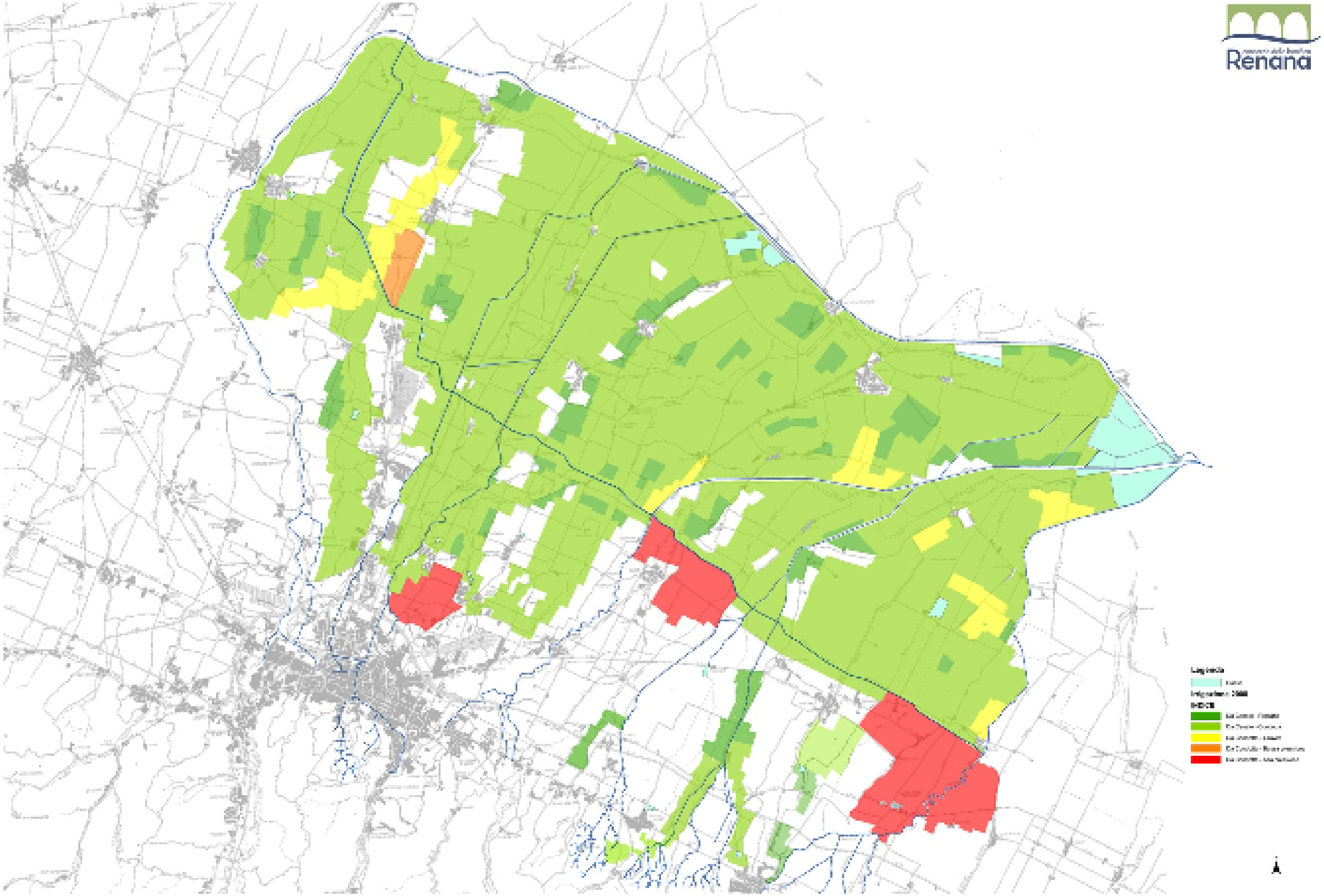


Figure 4.7: A map representing the territory of the Renana RIB.

Table 4.9. Province, municipalities and relative surfaces included in the second district of the RIB.

Province	Municipality	Surface (ha)
Bologna	Bologna	4,738.00
	Casalecchio	154.00
	Casalfiumanese	5,426.00
	Castel del Rio	921.00
	Castel S. Pietro	9,480.00
	Dozza	1,324.00
	Fontanelice	222.00
	Imola	1,038.00
	Loiano	5,239.00
	Monghidoro	4,820.00
	Monterenzio	10,536.00
	Monzuno	1,634.00
	Ozzano Emilia	3,793.00
	Pianoro	10,320.00
	Sasso Marconi	440.00
	S. Benedetto V.S.	1,757.00
	S. Lazzaro di S.	3,041.00
Firenze	Fierenzuola	3,591.00
Total		**68,474.00**

(Source: CBR, 2008).

Table 4.10. Province, municipalities and relative surfaces included in the first district of the RIB.

Province	Municipality	Surface (ha)
	Argelato	3,513.00
	Baricella	4,221.00
	bentivoglio	5,115.00
	Bologna	6,016.00
	budrio	12,013.00
	Calderara di R.	58.00
	Castel d'Argile	2,813.00
	Castel Guelfo	2,855.00
	Castel Maggiore	3,089.00
	Castel S. Pietro	5,368.00
	Castenaso	3,573.00
	Dozza	1,100.00
Bologna	Galliera	3,716.00
	Granarolo	3,441.00
	Imola	5,192.00
	Malalbergo	5,383.00
	Medicina	15,833.00
	Minerbio	4,304.00
	Molinella	12,026.00
	Ozzano Emilia	2,701.00
	Pieve di Cento	1,585.00
	Sala Bolognese	377.00
	S. Giorgio di Piano	3,048.00
	S. Lazzaro di Savena	1,429.00
	S. Pietro in Casale	6,581.00
Ferrara	Argenta	3,743.00
Ravenna	Massalombarda	36.00
Totale		**119,129.00**

(Source: CBR, 2008).

4.2.2. Orography e geomorphology

We are going to limit our description of these characteristics and the ones that will follow to the territory of Plain, that will be the object of our study, this area in fact, is delimited to the North and to the West by the Reno River and the Sillaro stream, and it is a recent geologic layer formed by clay and alluvial formations. Land is characterized by the inclination that goes from South to North, that is from the Emilia road towards the Reno and is subdivided in high lands and low lands; the high lands, are next to the Emilia road, and have an altitude that varies approximately from 50 to 14, while the low lands, go decreasing from 14 m approximately to 5 m near to the Reno (**Fig. 4.8**). The Plain then is crossed diagonally from the Idice stream that divides it in two fields completely separated.

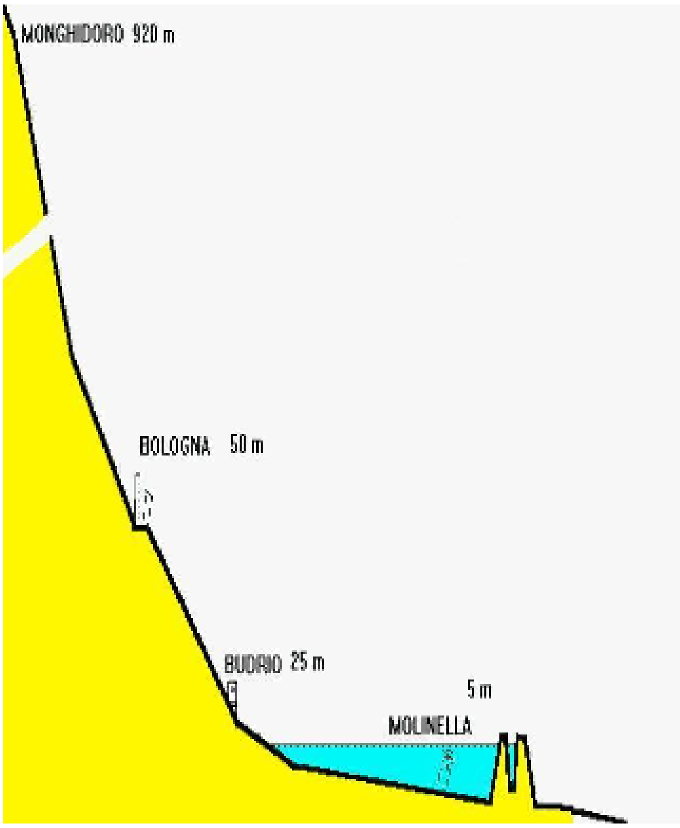


Figure 4.8: Territorial altitudinal scheme of the Renana RIB.

4.2.3. Pedology and land use

The present lands are the result of the alteration of alluvial sediments, transported and deposited from the Appennine's rivers and streams, mainly the Reno, the Savena, the Idice and the Sillaro. Sedimentation happened through long chemical, physical and biological processes conditioned by local climate factors, vegetation, morphology and antropic actions. The territory of the South and North, can be divided, according to soil type into three various territorial parts:

- Close to the mountains, the alluvial zones exist, constituted from deposition of alluvial sediments.
- Going to the North-East, the landscape gradually changes. The rivers and the streams become more and more narrow and elevated with respect to the plain by means of a system of artificial levees. Lands are characterized by relatively rough alluvial material, deposited from water courses. These sections have created lands of high fertility, with melted texture, well drained and easily workable for agriculture.
- Beside these "high" lands, there is the depressed area invaded in the past by emersion and flooding that prevented any type of stable cultivation. This “low” land is characterized currently, by a strong clay formation.

4.2.4. Climate and hydrology

The mean annual temperatures for the period 1926-1985, are comprised in the plain between 13°C and 14°C. Winter is characterized for mean temperatures of 3°C, and summer for 23-24°C. Spring and fall have almost the same former annual mean temperature (**Tab. 4.11**).

The main annual rainfall varies in the territory of the Consortium between 600 mm in Galliera and Malalbergo, and 800 mm in Bologna, and riches 1,500 mm in the mountains (**Fig. 4.9**). The general trend of rainfall in the plain is summarized in a table for the period 1921-1985 (**Tab. 4.12**). The values of the potential mean evaporation registered in the period 1980-1992 in some stations equipped with evapometers class A, are as well listed in a table (**Tab. 4.13**).

Table 4.11. Mean temperatures by months and year for the period 1926-1985.

Station	Ferrara	Bologna	Imola
Period (years)	56	51	5
January (°C)	1.70	2.50	2.20
February (°C)	4.10	5.10	4.30
March (°C)	8.60	9.60	8.60
April (°C)	13.20	13.90	12.80
May (°C)	17.50	18.10	17.00
June (°C)	21.70	22.50	21.30
July (°C)	24.60	25.10	23.90
August (°C)	23.70	24.50	23.50
September (°C)	20.10	21.10	20.10
October (°C)	14.00	15.20	14.60
November (°C)	8.30	8.80	8.60
December (°C)	3.30	4.00	3.70
Mean (°C)	**13.40**	**14.20**	**13.40**

(Source: CBR, 2008).

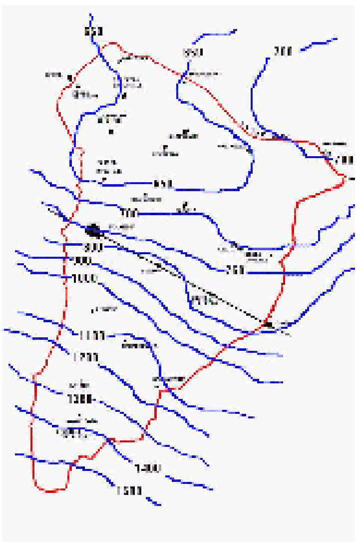


Figure 4.9: Mean annual distribution of precipitation in the RIB.

Table 4.12. Mean seasonal rainfall and number of raining days.

Rainfall	Winter		Spring		Summer		Fall	
	mm	Days	mm	Days	mm	Days	mm	Days
Bagno di Piano	156	20	176	24	128	14	199	21
Bologna	184	22	205	24	144	15	244	23
S. Pietro di Casale	163	18	185	23	130	13	211	23
Malalbergo	152	19	180	24	131	15	210	24
Baricella	147	22	165	22	128	15	205	21
Alberino	144	22	164	23	130	14	19	23
Castel S. Pietro	193	23	213	25	132	15	232	2
Sant'Antonio	151	23	180	24	140	14	222	23
Medicina	148	21	181	23	142	16	213	22

(Source: CBR, 2008).

Table 4.13. Mean annual evaporation in the RIB.

Station	Mean Potential Evaporated (mm yr^{-1})
Bologna-Borgo Panigale	657
Forlì	711
Molinella	712
Pieve di Cento (C.E.R.)	711
Vigarano	713

(Source: CBR, 2008).

4.2.5. Hydrography of the RIB

Water delivery is of two types, either continuous or discontinuous, the realization of the Emilia Romagna Channel that crosses the territory of the Consortium, has given a potential of 16.85 m^3 s^{-1} for irrigation to cover about 68,500 ha and gave the possibility of continuous distribution of water to farms. The aquifer is used for agriculture and industry above all in the high and medium plain, but it is believed that for the quality of its water, this resource should be conserved for urban uses.

The Navile and Savena system covers approximately 10,000 ha with a medium capacity of 3.00 m^3 s^{-1}, derived from the Reno River, and for water distribution it uses most of the

RIB channels. The irrigation system of the RIB for pumping and distribution are schematically described in the following table (**Tab. 4.14**).

The total number of agricultural farms included in the Consortium is around 3,000 fams, of which, approximately 1,600 of them are irrigable through systems managed by the RIB occupying an irrigable surface in the order of 68,500 ha from which something like 15,000 ha are irrigated. The tariff paid by members depends on the modality of water delivery by hectare of land. Therefore, it is of 14.7 € ha^{-1} for irrigable surface by gravity and discontinuous delivery, of 26 € ha^{-1} for irrigable surface by gravity and continuous delivery, and finally of 52.7 € ha^{-1} for irrigable surface under pressure and continuous delivery.

The quality of water distributed through the channels of the RIB is unfortunately conditioned by the concentration of sewage from Bologna discharged in the system, while the availability of water is related to the frequency and the regularity of water discharge from the Suviana Dam built upstream on the river system.

Table 4.14. Mean synthesis of the irrigation function of the Renana in 2003/2005.

	Media 2003/2005
Irrigable surface with pressure (ha)	7,170.00
Irrigable surface by gravity (ha)	61,460.00
Total Irrigable Surface (ha)	**68,630.00**
Quantity of water distributed (m^3)	75,835,000.00
Water allocation from the CER to the Renana (m^3 s^{-1})	16.60
Monthly peak flow (m^3 s^{-1})	4.25
Seasonal mean flow (m^3 s^{-1})	2.85
% of saturation of the allocation with respect to the peak flow (m^3 s^{-1})	25.60
% of saturation of the allocation with respect to the mean flow (m^3 s^{-1})	17.17

(Source: CBR, 2008).

4.2.6. Socio-economic aspect of the Renana RIB

A first observation that can be done is strongly influenced by the presence of the city of Bologna as an urban concentration; and is the presence in the territory of the

Consortium of human settlement higher than other parts of Bologna province. In fact, over less than half of the provincial surface, the territory of the RIB includes more than 60% of the population. The settlements are still evolving, and the movement of populations from a point to another is relevant and still active. The most important phenomenon is the immigration of population from the urban center of Bologna to the urban municipalities around the city. Except this general tendency, some single municipalities have independent trends and they present a demographic decrease, especially those of the mountains and the hills.

The structure of the agricultural sector in the territory of the Consortium is the result of a strong evolution that modified the two past agricultural forms: the cultivated high lands in the mountain (podere) with sharecropping conduction or even with family conduction, and farms in plain of specialized industrial cultivation or fruit crops, in most cases with capitalistic conduction.

The trends of the past and those of today in action, lead to a coupling in technical and economic terms of cultivated high lands, to a change of the productive pattern (in the sense of simplification and specialization), and to the maintenance of the familiar conduction, but to the end of the sharecropping. From another side, an expansion and specialization are observed also in the plain areas in farms with capitalistic conduction, with general increased trends in using mechanization, with, therefore demobilization of capitals inside the farms. Such trends are noticeable in all the provincial farms, but with respect, farms of the RIB territory have bigger dimensions (**Tab. 4.15**).

Regarding the land use, and according to the Agricultural Census of 1990, the territory of the Consortium is occupied for 82% by cereals (equal to 59.20% of the provincial percentage of cereals, while the SAU of the territory of the Consortium is equal to 56.10% of that provincial one), while 11.90% are of permanent cultivations mainly, specialized orchards and vineyards. Only a small part, 6.10%, concentrated in the marginal zones of the territory (where agriculture is mostly extensive), is occupied with permanent grass and pasture. Forage crops, a time important for livestock farms cover currently only a quarter of the surface used for cereals. These are localized as well, mostly in the hills and mountains or in the poor lands of the plain.

Table 4.15. Conduction of farms.

Mode of conduction	Number		Surface (ha)		Farm surface
	absolute	%	absolute	%	Ha
Conduction with only farmer	9,153	85.70	97,742.00	67.50	10.70
Conduction with family labor	8,087	75.70	75,061.00	51.90	9.70
Conduction with family labor prevalent	798	7.50	13,874.00	9.60	17.40
Conduction with hired labor prevalent	68	2.50	8,807.00	6.10	32.90
Capitalistic conduction	1,390	13.00	45,158.00	31.20	32.50
Sharecropping	140	1.30	1,873.00	1.30	13.40
Total	**19,636**	**100.0**	**144,773.00**	**100.10**	**13.60**

(Source: CBR, 2008).

In the territory for instance, livestock, either bovine or pigs, is very weak even if very diffused. In fact, less than the half of farms have livestock activities, especially family based farms, but only tenth (approximately 1,100 farms) are specialized in bovines (with 29 heads in average by farm) and as much are specialized in pigs (with 34 heads in average by farm).

Another productive aspect of the territory is that it concentrates more than 70% of the horticultural production of the province, reaching 2,120 ha (for a total of 2,964 provincial hectares); it is however, of a surface that is little bit more than 2% of the surface occupied by cereals. The water availability is, naturally, a favorable factor for the expansion of horticulture and fruit production.

According to estimated data, the irrigated SAU which corresponds to the surface of farms that practice irrigation, as mentioned in the last census, is approximately about 10,000 ha, while the effective one does not exceed the 15,000 ha. This fact can explain the intensification of vegetable production. From another side, the equipment of farms in the territory seems to be very high with a tractor for every 6-7 ha of SAU (the territory of the Consortium comprises the 56.4% of the tractors of the entire province).

Finally, to complete the picture of the agricultural structure in the territory of the consortium, we should mention data about labors. Indeed, according to the same census of agriculture of 1990, 2,836,000 days (the 50.20% of the provincial total), and equivalent to 25 days (200 hours of job) in average by hectare of SAU.

4.3. Structure of agricultural farms in the RIB – the Survey

The cluster analysis previously explained which was based on the FADN database (in Italian RICA: The Farm Accountancy Data Network) was integrated with a local survey lead near to a group of farms in the Renana RIB to get a narrower view of the situation and obtain some detailed data from the farms that the FADN database cannot give. Together with the general information and the structure and the economical situation of the farms this survey was very useful giving us specific data about costs and spending at the farm level and for each crop.

The sample of this survey was composed of 47 farms, all included in the boundaries of the RIB and located in the plain, extended on 1,344.32 ha, with a mean SAU of 28.60 ha. Most of the farms are completely owned by farmers (about 49%) or even mixed (a part owned and another part rented) except about 6.38% of them completely rented for agricultural activity (**Fig. 4.10**). To distinguish the land use of this sample, we considered the surface occupation of the irrigated crop; the area shows that it is divided between the three major groups: Arable crops production which is the widespread activity in the area that occupies about 42.55% of the total surface, followed by fruits for about 29.79% and horticulture for 27.66% (**Fig. 4.11**).

The survey shows that farms with a medium physical dimension (between 10 and 20 ha) are the most numerous and the less numerous ones are large farms (above 100 ha) but they cover about 21% of the total SAU, as much as the medium farms cover (**Tab. 4.16**).

Regarding the management of farms, the conduction in all farms is by the farmer himself, and sometimes he can recall for fixed family labors or hired ones, therefore we can distinguish farms with fixed family labor that are about 91.49%, farms with fixed hired labor represent 8.51% of the total, farms with seasonal family labor (63.83%) and farms with seasonal hired labor (36.12%).

While studying the socio-economic conditions of agriculture it is relevant to mention the age of farmers, as an indicator for the regeneration and the development of the sector, for, young farmers in our sample between 18 and 29 years old, is only about 2.13%, but the lack of young farmers cannot be considered very alarming because the biggest part of farmers are included in the range of age 30-49 years old while farmers more than 70 years of age represent only 19.15% of the sample (**Tab. 4.17**). Another indicator to underline from the previous table, is the fact that the mean SAU by range of age decreases with the increase of farmers' age, which means that older farmers have smaller farms, in other words more the farmer is young more the willing to enlarge and innovate exists, this fact is true not only in agriculture but in the others sectors of the economy.

Talking about innovation and investment, the survey included question about future prospective for the farm and possible investments, and it seems that 60.87% of farmers are planning to buy more machineries, about 30.43% are willing to increase the SAU cultivated, 21.74% are willing to invest in new orchard settlements and finally, about 17.39% want to just maintain the capital as it is.

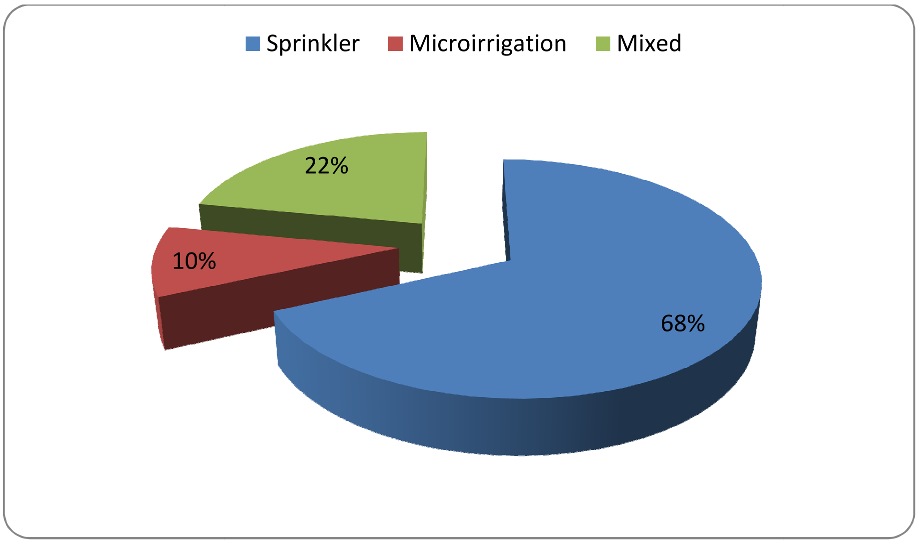


Figure 4.10: Type of possession of farms.

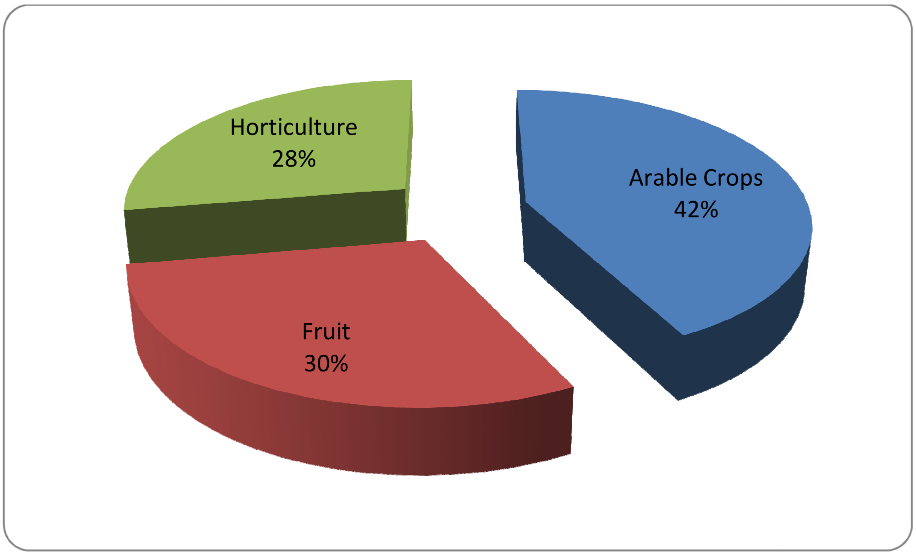


Figure 4.11: Land use of the sample.

Table 4.16. Distribution of farms by size and SAU.

Size	% of farms	% of total SAU	Mean SAU (ha)
<10 ha	23.40	5.84	7.14
10 – 20 ha	42.55	23.65	15.90
20 – 100 ha	29.79	49.31	47.35
>100 ha	4.26	21.20	142.50
Total	**100.0**	**100.0**	**53.22**

Table 4.17. Distribution of farms by age of farmers.

Age of farmer	% of farms	% of total SAU	Mean SAU (ha)
18 – 29 years	2.13	1.45	19.50
30 – 49 years	48.94	54.09	31.61
50 – 70 years	31.91	34.08	30.54
>70 years	17.02	10.38	17.45
Total	**100.0**	**100.0**	**24.78**

It was noted in the sample that many farms are irrigated. The 87.23% from which 8.51% are completely irrigated for only 12.77% that practice a rainfed technique and the overall irrigable SAU represents about 39.93% of the total SAU (**Tab. 4.18**). most of those irrigated farms take irrigation water from the RIB network (87.23%) that could be either in pressure or in gravity, in the first case it represents the 58.54% of the farms whereas in the second case it about 41.46%.

The prevailing irrigation system used on farm is the sprinkler irrigation that correspond to 68.29% of the irrigated farms (**Fig. 4.12**), but to be mentioned that in 34.05% of the farms surveyed the system is older than 10 years which means for an irrigation system almost aged and to be renewed and the willing for modernization is not relatively high, around 74.47% (**Tab. 4.18**).

Table 4.18. Numbers about irrigation in the sample.

On farm irrigation	**% of farms**	**% of total SAU**	**Mean SAU (ha)**
Completely irrigated	8.51	3.35	11.25
Partially irrigated	87.23	75.25	24.67
Irrigated		*39.93*	
Not irrigated		*60.07*	
Rainfed	12.77	24.75	55.45
Total	**100.0**	**100.0**	**24.78**
Age of irrigation systems	**% of farms**	**% of total SAU**	**Mean SAU (ha)**
No answer	14.89	25.98	49.90
<5 years	19.15	21.60	32.26
Between 6 and 10 years	31.91	36.59	32.79
>10 years	34.05	15.83	13.30
Total	**100.0**	**100.0**	**32.06**
Tendency to modernization	**% of farms**	**% of total SAU**	**Mean SAU (ha)**
No answer	10.64	24.08	64.74
Willing to renew	74.47	10.96	4.21
Integration of existing one with other	14.89	64.96	124.75
Total	**100.0**	**100.0**	**64.57**

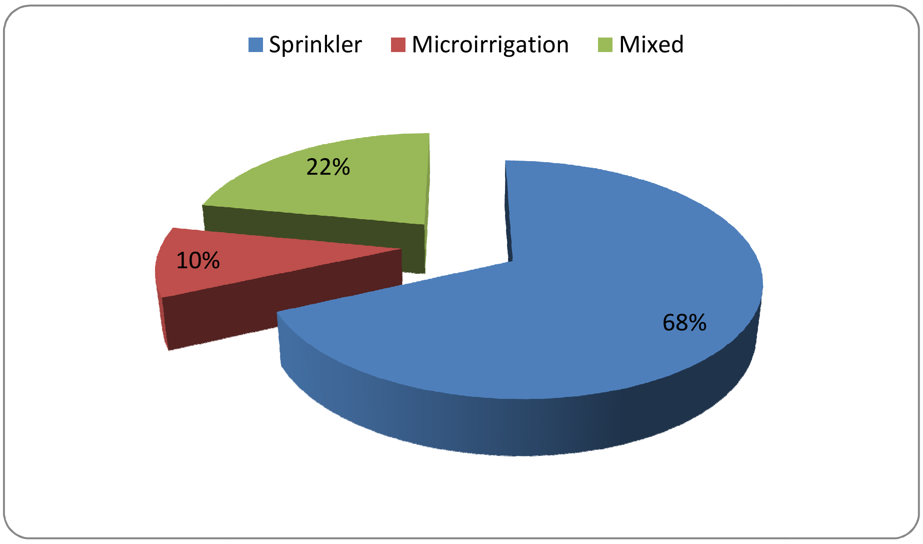


Figure 4.12: On farm irrigation systems.

CHAPTER V

5. Materials and Methods

The methodology adopted in the purpose of our analysis will be the same methodology developed by Tavistock institute (Sourcebook 2, 2003) and which has been previously explained in details in the third chapter. The techniques in each of the three stages of the method are the following:

- Planning and structuring evaluation.
- Obtaining data.
- Analyzing data.

The planning and structuring evaluation was done through a stakeholders' consultation, aimed at eliciting stakeholders' preferences, identifying common ground and differences in stakeholders' objectives, and finally determining a manageable set of priorities. The primary purpose of the stakeholders' consultation is to give steerage to the evaluation and to ensure that it meets the expectations, needs and interests of the stakeholders.

Data were obtained through both social and beneficiary surveys, as well as on the basis of secondary source data. Finally, a mathematical programming model able to represent the agricultural activities carried out in the area of the RIB was built in order to analyze the collected data and to simulate different future scenarios.

The beneficiary survey was carried out near to the CER and the RIB; and was addressed at collecting data and information about technical parameters (e.g. total availability of water, irrigable and irrigated areas, modality of water distribution by area, water tariffs) that were used later in the modeling phase. Social survey was conducted with users to elicit structural and economic parameters like the percentile distribution of farm typology and crops inside each typology, yields, labor requirements, on-farm fixed costs and variable costs by crop, etc.

5.1. The representative farms

On the basis of the cluster analysis described in details in chapter 4, three representative farms were identified in the territory of the Renana RIB. The survey carried out on a smaller scale to verify the effectiveness on the field of such a regional database; and finally, discussing these results with local stakeholders.

The arable crops farms that represent in the survey about 42% of all farms have a mean surface of 81.13 ha of which 61.72% are rented. This type of farms have up to one hired labor working part time on farm and the land occupation of such a farm is in about 97.73% arable crops and is as in the following table (**Tab. 5.1**). The main crops in this table are those occupying the biggest area of the farm and that identify the orientation of the farm.

The fruit farms which represent about 30% of the farms surveyed are represented with the medium farm (between 10 and 20 ha), with a mean surface of 14.66 ha of which 15.35% rented (about 2.25 ha); it has about 2 seasonal hired labor on farm and has a land use represented in the previous table (**Tab. 5.1**).

The horticultural oriented farms which represent about 28% of the farms in the RIB are mainly big farms and have a mean surface of about 44.75 ha, 64.6% rented (about 37.82 ha), have three seasonal hired labor and have a land use as listed in the above table (**Tab. 5.1**). Land use of arable crops occupies a big part of this farm typology (about 60%) but given the soil characteristics that are absent in the case of the first group of farms (arable crops farms); these farms produce horticultural crops on about 40% of the surface.

Table 5.1. Land occupation of the representative farms.

Arable Crops Farm					
Main Crops	**Surface**		**Secondary Crops**	**Surface**	
	(ha)	**(%)**		**(ha)**	**(%)**
Bread Wheat	8.59	10.57	Spring Onion	0.71	0.88
Durum Wheat	19.71	24.30	Autumn Onion	1.00	1.23
Maize	10.79	13.29	Grapevine	0.13	0.16
Sorghum	8.86	10.92			
Alfalfa	23.36	28.79			
Sugar beet	6.86	8.45			
Set aside	1.14	1.41			
Total	**79.29**	**97.73**	**Total**	**1.84**	**2.27**
Fruit Farm					
Main Crops	**Surface**		**Secondary Crops**	**Surface**	
	(ha)	**(%)**		**(ha)**	**(%)**
Peach	3.95	25.58	Bread Wheat	0.87	5.97
Pear	4.35	29.67	Durum Wheat	0.34	2.30
Plum	0.52	3.53	Maize	0.29	1.96
Grapevine	0.89	6.10	Sorghum	1.21	8.22
Apple	0.19	1.28	Alfalfa	0.76	5.19
Apricot	0.13	0.85	Potatoes	0.42	2.86
			Sugar beet	0.25	1.71
			Set aside	0.50	3.41
Total	**10.02**	**68.35**	**Total**	**4.64**	**31.63**
Horticultural Farm					
Main Crops	**Surface**		**Horticultural Crops**	**Surface**	
	(ha)	**(%)**		**(ha)**	**(%)**
Durum Wheat	8.73	19.50	Potatoes	7.26	16.22
Bread Wheat	10.17	22.74	Spring Onion	3.67	8.19
Maize	2.50	5.59	Autumn Onion	2.42	5.40
Sorghum	0.78	1.74	**Total**	**13.34**	**29.82**
Sugar beet	7.71	17.22	**Secondary Crops**	**Surface**	
Soybean	0.70	1.56		**(ha)**	**(%)**
Set aside	0.25	0.56	Pear	0.57	1.27
Total	**30.84**	**60.92**	**Total**	**0.57**	**1.27**

To represent the whole plain area of the RIB, these representative farms where reported to the total, respecting the percentile of each type of production that are 42.55%, 27.66% and 29.79% respectively for arable crops, horticultural and fruit farms. In this way we divided the area in three main blocks each one representing one type of farms, these blocks are represented in the following table (**Tab. 5.2**). The land occupation by crop in the total area respects as well the distribution in the single farms as following (**Tab. 5.3**).

Table 5.2. Distribution on the total area of different blocks.

Block	Ha	%
Block of arable crops:	50,689.39	42.55
Owned surface	19,403.90	38.28
Rented surface	31,285.49	61.72
Block of horticultures:	32,951.08	27.66
Owned surface	12,112.82	36.76
Rented surface	20,838.26	64.60
Block of fruits:	35,488.53	29.79
Owned surface	30,041.04	84.65
Rented surface	5,447.49	15.35
Total	**119,129.00**	**100.0**

Table 5.3. Land occupation by crop in the RIB.

Arable Crops Occupation	Ha	%
Arable Crops Occupation:	82,454.61	69.21
Maize	9,275.84	7.79
Bread Wheat	14,964.91	12.56
Durum Wheat	19,561.28	16.42
Alfalfa	16,436.76	13.80
Sorghum	9,027.27	7.58
Sugar beet	10,816.51	9.08
Set aside	2,108.44	1.77
Soybean	515.47	0.43
Horticulture Occupation:	11,913.62	10.00
Potatoes	6,362.81	5.13
Autumn onion	2,404.42	2.02
Spring onion	3,146.39	2.64
Fruit Occupation:	24,760.77	20.78
Peach	9,077.12	7.62
Pear	10,946.75	9.19
Plum	1,736.76	1.46
Grapevine	2,243.71	1.88
Apple	453.86	0.38
Apricot	302.57	0.25
Total	**119,129.00**	**100.0**

5.2. Mathematical modeling

Modeling can be defined as the process of application of fundamental knowledge or experience to simulate or describe the performance of a real system to achieve certain goals. Models can be cost-effective and efficient tools whenever it is more feasible to work with a substitute than with the real, often complex systems. Modeling has long been an integral component in organizing, synthesizing, and rationalizing observations of and measurements from real systems and in understanding their causes and effects.

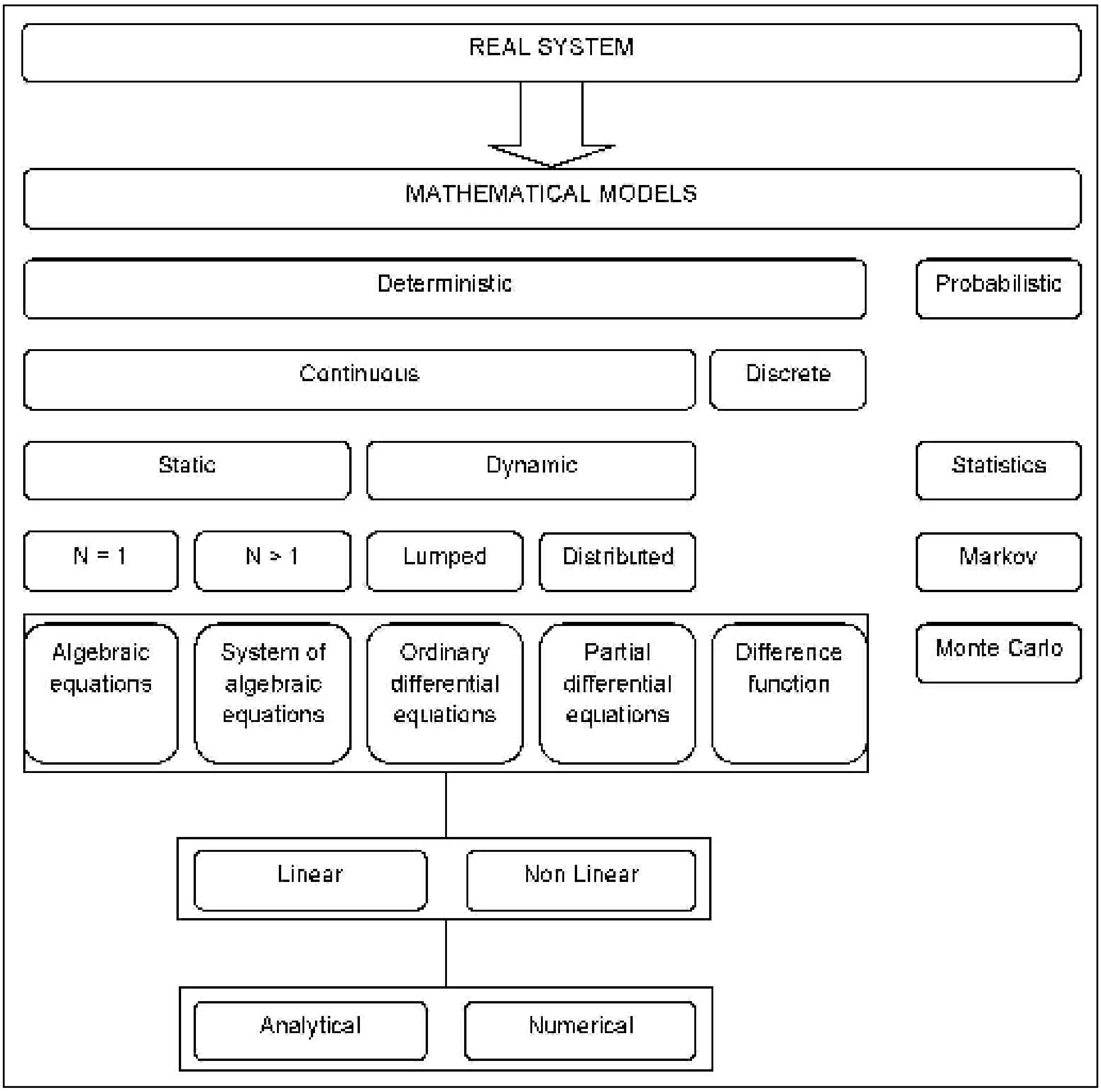
In agriculture, mathematical modeling had its origins in attempts to model the economics of agricultural production, including its spatial dimension, because the mathematical programming format is a particularly suitable one for agriculture (Swinton and Black, 2000). In the environment, Mathematical modeling can be traced back to the 1900s (Bennett, 2002). Nowadays, driven mainly by regulatory forces, environmental studies have to be multidisciplinary, dealing with a wide range of pollutants undergoing complex biotic and abiotic processes in the soil, surface water, groundwater, ocean water, and atmospheric compartments of the ecosphere.

While most common modeling approaches can be classified into three basic types, (Bennett, 2002) physical modeling, empirical modeling, and mathematical modeling, Schoemaker (1982) identifies four purposes for systems models.

- Descriptive models: used to characterize the system; their performance, in turn, allows modelers to evaluate whether they have adequately described the important aspects.
- Predictive models: forecast future system behavior. Descriptive models may serve a predictive purpose, but many predictive models are much simpler than descriptive ones.
- Postdictive models: tend to be human logical constructions that allow us to explain after-the-fact what system constraints or special phenomena caused a given outcome.
- Prescriptive models: are normative models that offer guidance on how a system should be managed to meet some goal.

The emergence of mathematical techniques to model real systems has alleviated many of the limitations of physical and empirical modeling. Mathematical modeling, in essence, involves the transformation of the system under study from its natural environment to a mathematical environment in terms of abstract symbols and equations.

Mathematical models can also be classified into various types depending on the nature of the variables, the mathematical approaches used, and the behavior of the system. The following sub-section identifies some of the more common and important types of classification, which will be summarized in a comparison graph in the end of the sub-sections (**Fig. 5.1**).



(*Source: Bennett, 2002*).

Figure 5.1: Classification of mathematical models (N = number of variables).

5.2.1. Different types of mathematical modeling

When the variables (in a static system) or their changes (in a dynamic system) are well defined with certainty, the relationships between the variables are fixed, and the outcomes are unique, then the model of that system is said to be deterministic. If some unpredictable randomness or probabilities are associated with at least one of the variables or the outcomes, the model is considered probabilistic. Deterministic models are built of algebraic and differential equations, while probabilistic models include statistical features.

When the variables in a system are continuous functions of time, then the model for the system is classified as continuous. If the changes in the variables occur randomly or periodically, then the corresponding model is termed discrete. In continuous systems, changes occur continuously as time advances evenly. In discrete models, changes occur only when the discrete events occur, irrespective of the passage of time (time between those events is seldom uniform).

When a system is at steady state, its inputs and outputs do not vary with passage of time and are average values. The model describing the system under those conditions is known as static or steady state. The results of a static model are obtained by a single computation of all of the equations. On the contrary, when the system behavior is time-dependent, its model is called dynamic. The output of a dynamic model at any time will be dependent on the output at a previous time step and the inputs during the current time step. The results of a dynamic model are obtained by repetitive computation of all equations as time changes. Static models, in general, are built of algebraic equations resulting in a numerical form of output, while dynamic models are built of differential equations that yield solutions in the form of functions.

When an equation contains only one variable in each term and each variable appears only to the first power, that equation is termed linear, if not, it is known as nonlinear. If a model is built of linear equations, the model responses are additive in their effects, i.e., the output is directly proportional to the input, and outputs satisfy the principle of super positioning. For instance, if an input $I1$ to a system produces an output$O1$, and another input $I2$ produces an output of $O2$, then a combined input of $(\propto I1 + \beta I2)$ will produce an output of $(\propto O1 + \beta O2)$. Super positioning cannot be applied in nonlinear models.

5.2.2. Risk in the farm

Variation of input or output prices and of crops' yields makes the farmers' income unstable and risky. Type and severity of the risks confronting farmers vary with farming system, with the climate, policy, and institutional setting, e.g. wet or dry year, or a high or low price. Numerous empirical studies have demonstrated that farmers typically behave in risk-averse ways (Binswanger 1980; Dillon and Scandizzo 1978). As such, farmers often prefer farm plans that provide a satisfactory level of security even if this means sacrificing income on average.

Different methods have been developed to deal with risk in price and yield on farm (Hazell and Norton, 1986):

- Mean Variance Analysis (E, V): results from expected utility theory if a farmer has a quadratic utility function for income.
- Linear programming approximations: several methods have been proposed for obtaining approximate solutions to the E, V problem through linear programming (Separable linear programming, Marginal risk constrained linear programming model, motad model).
- Mean-Standard Deviation (E, σ) Analysis: A useful decision rule rationalized by Baumol (1963) is the expected gain-confidence limit (E, L), where $L = E - \varphi\sigma$ and φ (taken to be positive) is a risk-aversion parameter.

(E, L) says that if income is normally distributed, then for a specific value of φ say φ_0, $L = E - \varphi_0\sigma$ identifies a particular fractile of the income distribution for each farm plan. For example, if $\varphi = 1.65$, then $L = E - 1.65\sigma$ identifies the 5% income fractile. A 5% income fractile is the value of income which, for a given income distribution $f(Y)$, will be exceeded 95% of the time. Baumol argues that a prudent individual (with risk parameter

φ_0), should always select a farm plan that has the maximum value of E for a given value of $L = E - \varphi_0\sigma$. The set of such farm plans comprises the efficient E and L.

Independently of gross margin risks, a farmer may also face risks in resource supplies for example the uneven availability of irrigation water. When the risk in farm planning exists due to resource availability, in this case risk might occur in the constraint side of the model (McCarl and Spreen, 1997). This type of probability in water availability has been considered in different studies (Lu *et al*., 2009; Marques *et al*., 2005; Mejías *et al*., 2003; Torkamani and Hardaker, 1996).

5.3. Structure of a GAMS model

Optimization is performed in the modeling language of a General Algebraic Modeling System (GAMS), using a CONOPT3 solver, which can handle large scale and non-linear mathematical programming problems.

For the remainder of this dissertation, we will discuss the basic components of GAMS, with reference to our farms described above. The basic components are listed in the table below (**Tab. 5.4**), while the source of our data and its organization into input of the model will be discussed later on.

Table 5.4. The basic components of a GAMS model.

Inputs	Outputs
Sets: Declaration Assignment of members	Echo Print
Data (Parameters, Tables, Scalars): Declaration Assignment of values	Reference Maps
Variables: Declaration Assignment of type	Equation Listings
Assignment of bounds and/or initial values (optional)	Status Reports
Equations: Declaration Definition	Results
Model and Solve statements	–
Display statement (optional)	–

(*Source: Rosenthal, 2007*).

5.4. Data and data sources

The crops considered in the model are those cultivated in the representative farms, and the techniques are those used for production in Emilia Romagna that can be either rain fed or irrigated (could be partial or complete irrigation). The irrigation systems as well are those used on farms in the case study, they are either drip irrigation systems and we selected three types of them which are the most used in the area and five models of sprinkler irrigation, the most used. The combination of the feasible sets by crop technique and irrigation system and the land use by crop along the months of the year are the fruit of observation and discussion with stakeholders.

Different application efficiencies have been considered for the different irrigation systems: 65% and 75% for the sprinkler and the drip respectively. All the data used for the input files was discussed with the concerned stakeholders to check their viability.

Farm surface and the rented surface represent the mean surfaces of the representative farms of the different groups of farms. We considered for renting cost the mean value of 535 € ha^{-1} and fixed cost depending on the typology are 235 € ha^{-1} for arable crops farms, for horticultural farms 566.58 € ha^{-1} and for fruits farms 1596.98 € ha^{-1}. An anti-hail costs for fruits farms has been considered equal to 1400.56 € ha^{-1}. For hired labor, a cost of 8.48 € hr^{-1} and 11.11 € hr^{-1} was considered for generic and specialized respectively. In the case of family labor we considered a full time job which is 48 hours a week, given that a farmer is a full time working in his farm.

Crop yields data were obtained with the integration of different sources (**Tab. 5.5**): the survey and the average of historical data for the province of Bologna from 1996 up to 2008 (Internet 4, 2009). For each crop, three different cultivation techniques (rain fed, complementary irrigation and full irrigation) were considered and in order to get the yield response curve to water application, we calculated by crop a mean factor of change in the yield that we multiplied by yield.

In order to calculate the water requirements per crop (**Tab. 5.5**) we used the annual reports of the CER (CER, different issues); where water requirements are obtained from evapotranspiration data using Hargreaves equation, then for the crop coefficient factor (K_c), The FAO values where applied for each crop and each growth stage (FAO, 1998), and in many cases, corrected with local research carried out in Emilia Romagna.

Crop prices (**Tab. 5.5**) are the average of historical data for the region of Emilia Romagna for the same period of time (Agricultural Observatory, different issues). Labor requirements are taken from the survey for each crop and integrated with some values of the CER to include the labor requirement for irrigation activity.

Table 5.5. Water requirements, Crop yield, and crop price by agricultural product.

Crops	**Water requirements**	**Crop yield**	**Crop price**
	(m^3 ha^{-1})	**(Q ha^{-1})**	**(€ Q^{-1})**
Arable Crops:			
Maize	2,500.00	116.16	14.62
Bread Wheat	1,600.00	65.00	16.24
Durum Wheat	1,600.00	75.00	20.83
Alfalfa	1,600.00	118.65	10.78
Sorghum	1,787.50	100.00	13.42
Sugar beet	2,400.00	614.83	3.90
Set aside	0	0	0
Soybean	1,500.00	41.77	26.82
Horticultural:			
Potatoes	1,200.00	490.00	18.56
Autumn onion	1,275.00	550.00	15.75
Spring onion	1,275.00	520.00	15.25
Fruits:			
Peach	950.50	280.00	42.80
Pear	1,680.00	280.00	44.70
Plum	1,870.20	270.00	50.80
Grapevine	978.16	250.00	31.00
Apple	1,481.73	350.00	30.20
Apricot	2,242.00	200.00	59.10

Water availability for the RIB is about 75 MCM distributed on about 68,000 ha, something like 1,500 ha of which are fisheries with very high water consumption.

Considering transport and distribution network inefficiencies the remaining quantity of water for agricultural purposes is a rough estimation of 33 MCM annually. Irrigable land is divided between different modalities of distribution: pressurized water delivery, gravity and continuous water delivery and gravity and discontinuous water delivery. Each distribution modality is associated with different levels and probabilities of water availability (**Tab. 5.6**).

Table 5.6. On-farm annual water availability ($m^3\ ha^{-1}$).

Probability (%)	**Modality of Distribution**		
	Pressurized	Gravity continuous	Gravity discontinuous
1/3	800 ($m^3\ ha^{-1}$)	800 ($m^3\ ha^{-1}$)	800 ($m^3\ ha^{-1}$)
1/3	800 ($m^3\ ha^{-1}$)	400 ($m^3\ ha^{-1}$)	0 ($m^3\ ha^{-1}$)
1/3	800 ($m^3\ ha^{-1}$)	200 ($m^3\ ha^{-1}$)	0 ($m^3\ ha^{-1}$)

Water tariffs are given from the Renana RIB (CBR, 2008): it is 52.7 € ha^{-1} for pressurized water delivery, 26 € ha^{-1} for gravity and continuous water delivery and 14.7 € ha^{-1} for gravity and discontinuous water delivery while farms not receiving this service do not pay any money.

The CER was of big help for us, giving us the possibility to access to its archive to get some information regarding water requirements and crop coefficient and some climatic data. For instance, costs of irrigation systems used in Emilia Romagna were modified from the total costs calculated by the CER (SETI, 2008), and then compared with observed costs to check how trustful they are and if they can respond to our requirements. These costs were divided into two items: the fixed irrigation cost calculated as the amount of the depreciation value over 10 to 15 years depending on the system and the cost of the maintenance of the irrigation equipment calculated as a percentage of the investment cost (0.5%); both the items were included in the total farm fixed cost. Besides the fixed irrigation costs and the cost of maintenance for the irrigation equipment, costs of energy and machinery used to irrigate were also considered.

To distinguish between the different techniques, the cost of irrigation was calculated for “full irrigation technique” and for “partial irrigation technique” taking into account the number of interventions done.

Given that in 2006 the latest CAP reform (Fischler reform) was already implemented (Frascarelli, 2007), we transformed the CMO payments for cereals and sugar beet into single farm payment: we multiplied the mean over three years of the yield by the coupled payments divided by the mean area of the representative farm and we have gotten 336 € ha^{-1} for cereals and 429 € ha^{-1} for sugar beet. The same calculations were done to get the Single Farm Payment which was equivalent to 235 € ha^{-1}.

In the end, the variable costs by crop were taken from the questionnaire and in some cases where it was impossible to calculate for certain crops, we elaborated variable costs using regional and DEIAGRA accountability studies done in previous years (**Tab. 5.7**).

Table 5.7. Variable costs of different crop production.

Crops	Variable costs (€ ha^{-1})
Arable Crops:	
Maize	760.00
Bread Wheat	645.00
Durum Wheat	700.00
Alfalfa	567.00
Sorghum	698.00
Sugar beet	1,388.00
Set aside	0
Soybean	811.39
Horticultural:	
Potatoes	3,330.00
Autumn onion	3,060.00
Spring onion	3,100.00
Fruits:	
Peach	3,177.98
Pear	3187.10
Plum	3,096.88
Grapevine	3,071.41
Apple	5,716.74
Apricot	4,228.26

Finally, the model risk coefficient is a direct representation of risk-averse behavior at the farm level and it is established at 0.35 as will be explained later.

5.5. The farms aggregated model

The aggregation of the single farm models into one model to represent the complete board was done through blocks representing the different typologies in the case study (Dono *el al*., 2008), thus the main difference between a block and another is the type of agricultural production on farm. Each block represents a macro farm representing the group of farms of the same type.

Following the analysis of the specification of agricultural production in the region, yield and commodity price uncertainty as well as risk associated with the availability of irrigation water were found to be the main stochastic parameters to be considered in the model development process. Risk associated with price fluctuations and yield variability is taken into account in the objective function of the model, and is considered as economic risk (Saraiva and Pinheiro, 2007; Gómez Limón and Berbel, 2000); risk associated with unreliable water supply is taken into account in the constraints part of the model and considered as a technical risk and will be discussed later on.

The objective function of our model is the maximization of the net farm income and the minimization of its variability (**Eq. 5.1**). The net farm income is defined as the difference between the gross margins and fixed and variable costs (Blanco Fonseca, 2007). The result obtained is the some of the revenues for all the input production of the farmer i.e. landed property, family labor and capital.

$$U = Z - (\varphi \times \sigma) \qquad (\boldsymbol{eq. 5.1})$$

$$Where:$$

$$Z = Expected\ net\ income.$$

$$\varphi = Aversion\ coefficient.$$

$$\sigma = Standard\ deviation.$$

$$\sigma = \frac{1}{K_1^{50}} \sqrt{\sum_K (ZK_K - Z)^2} \qquad (\boldsymbol{eq.5.2})$$

$$Standard\ deviation = \frac{1}{Number\ of\ years} \sqrt{\sum_{number\ of\ years} (Random\ Income - Expected\ income)^2}$$

$$Z = \left[\sum\nolimits_{c,d,t,i} GM_{c,d,t,i} \times X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i}\right] + \left[\sum\nolimits_{c,d,t,i} 0 \times X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i}\right] + \left[\sum\nolimits_{cp,d,t,i} 336 \times X_{cp,d,t,i} \times CT_{cp,t,i} \times DI_{d,i}\right] + \left[\sum\nolimits_{cb,d,t,i} 429 \times X_{cb,d,t,i} \times CT_{cb,t,i} \times DI_{d,i}\right] - [RC \times rentland] - [OCC + OCH + OCF] - \left[\sum\nolimits_{cf,d,t,i} AHC \times X_{cf,d,t,i} \times CT_{cf,t,i} \times DI_{d,i}\right] - \left[\sum\nolimits_{cf,d,t,i} InC_{cf} \times X_{cf,d,t,i} \times CT_{cf,t,i} \times DI_{d,i}\right] - \left[\sum\nolimits_{c,d,t,i} FC_{d,i} \times X_{c,t,i} \times CT_{c,t,i} \times DI_{d,i} \times DD_d\right]_1^d - \left[\sum\nolimits_d WT_d \times fland_d\right] - \left[\sum\nolimits_{c,d,t,ii} mwt \times GIR_{c,t,ii} \times X_{c,d,t,ii} \times CT_{c,t,ii} \times DI_{d,ii}\right] - \left[\sum\nolimits_{c,d,t,i} h1labor_c \times wg1 \times X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i}\right] - \left[\sum\nolimits_{c,d,t,i} h2labor_c \times wg2 \times X_{c,d,t,i} \times CTc,t,i \times DId,i - c,d,t,ih3laborc \times wg1 \times Xc,d,t,i \times CTc,t,i \times DId,i\right. \qquad (\boldsymbol{eq.5.3})$$

More in details, the expected income is the sum of the gross margin value plus the payments received from the European Union in the Common Market Organizations policy (CMO), subtracted all the direct and indirect costs of the farm: fixed costs, land rent cost, hired labor wages (generic and specialized), flat water and volumetric water tariffs, insurance and by crop variable costs. In an easiest way, this equation can be written as:

$$\begin{aligned} Expected\ income &= [Expected\ Gross\ Margin] + [Single\ Farm\ Payments] + [COM\ Cereals] \\ &+ [COM\ sugar\ beet] - [Rent\ cost] - [Fixed\ costs] \\ &- [Anti - hail\ costs\ for\ fruits] - [Installation\ costs\ for\ ochards] \\ &- [Irrigation\ fixed\ costs]_1^d - [Water\ costs] — [Labor\ costs] \end{aligned}$$

Similar to the equation of the expected income, the equation of the random income depends on the standard variation of the yield and price by crop over a range of 50 years. In easier presentation of the equation is:

$$ZK_{(kp,ky)} = [\sum_{c,d,t,i,kp,ky} GM\_K_{c,d,t,i,kp,ky} \times X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i}] + [\sum_{c,d,t,i} 0 \times X_{c,d,t,i} \times$$

$$CTc,t,i\times DId,i+cp,d,t,i336\times Xcp,d,t,i\times CTcp,t,i\times DId,i+cb,d,t,i429\times Xcb,d,t,i\times CTcb,t,i\times DId,i$$

$$-RC\times rentland-OCC+OCH+OCF-cf,d,t,iAHC\times Xcf,d,t,i\times CTcf,t,i\times DId,i-cf,d,t,iInCcf\times X$$

$$cf,d,t,i\times CTcf,t,i\times DId,i-c,d,t,iFCd,i\times Xc,t,i\times CTc,t,i\times DId,i\times DDd1d-dWTd\times flandd-c,d,t,ii$$

$$mwt\times GIRc,t,ii\times Xc,d,t,ii\times CTc,t,ii\times DId,ii$$

$$-[\sum_{c,d,t,i} h1labor_c \times wg1 \times X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i}] - [\sum_{c,d,t,i} h2labor_c \times wg2 \times X_{c,d,t,i} \times$$

$$CTc,t,i\times DId,i-c,d,t,ih3laborc\times wg1\times Xc,d,t,i\times CTc,t,i\times DId,i \qquad (\textbf{eq.5.4})$$

$$\begin{aligned} Random\ income &= [Random\ Gross\ Margin] + [Single\ Farm\ Payments] + [COM\ Cereals] \\ &+ [COM\ sugar\ beet] - [Rent\ cost] - [Fixed\ costs] \\ &- [Anti - hail\ costs\ for\ fruits] - [Installation\ costs\ for\ ochards] \\ &- [Irrigation\ fixed\ costs]_1^d - [Water\ costs] — [Labor\ costs] \end{aligned}$$

The values of the expected and random gross margins are given by the following formulas (**Eq.s 5.5 and 5.6**):

$$GM_{c,d,t,i} = (Y_{c,t} \times Pr_c - VC_c - IC_{d,t,i}) \times DI_{d,i} \qquad (\boldsymbol{eq.5.5})$$

$$\begin{aligned} Expected\ Gross\ Margin &= (Expected\ Yield \times Expected\ Price \times Crop\ Variable\ Costs \\ &- Irrigation\ Variable\ Costs) \end{aligned}$$

$$GM\_K_{c,d,t,i,kp,ky} = (Y\_K_{c,t,ky} \times \Pr\ \_K_{c,kp} - VC_c - IC_{d,t,i}) \times DI_{d,i} \qquad (\boldsymbol{eq.5.6})$$

$$\begin{aligned} Random\ Gross\ Margin &= (Random\ Yield \times Random\ Price \times Crop\ Variable\ Costs \\ &- Irrigation\ Variable\ Costs) \end{aligned}$$

In order to quantify the aversion risk coefficient, we solved the model for different values of the coefficient among a range between 0 and 1.65. The selected value, equal to 0.35, is the value that better calibrate the model (Teague *et al.*, 1995; Hazell, *et al.*, 1983).

This Constant Relative Risk Aversion coefficient was used also for calibration purposes. In fact, Howitt *et al*., (2002) and Heckelei, (2002) considered that the parameter of the constant relative risk aversion coefficient can be parameterized and used as a calibration parameter to calibrate the model and adjust results to the observed situation given that the risk preference of the decision maker is usually not available for the modeler.

5.6. Model Constraints

The objective function is subject to three main groups of constraints, the first one is general and regards total and rented land and family labor; the second one is about rotation and land occupation and the third one concerns water availability.

In the first group, the land constraints (**Eq.s 5.7 and 5.8**) fix the upper limit of total and rented land availability, where the total land should be 119,129 ha as a maximum value which is relative to the total surface of the RIB from which only 62,557.76 ha are owned and the rest could be rented. The family labor constraint (**Eq. 5.9**) which should not exceed the total labor availability that is equivalent to 80 hours by hectare a year. The equations of each of these constraints are as follows:

$$[Land]_1^m..\sum_{c,d,t,i} X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i} \times L\_use_{c,m} \leq [\sum_d fland_d] + rentland; \qquad (\boldsymbol{eq}.5.7)$$

$$Land\ Constraint: (land\ Occupation) \leq Total\ surface\ of\ the\ RIB$$

$$Rent..Rentland \leq 0.7358 \times \sum_d fland_d\ ; \qquad (\boldsymbol{eq}.5.8)$$

$$Rent\ Constraint: Rented\ Land \leq 0.7358 \times Owned\ Land;$$

$$Labor..\sum_{c,d,t,i} X_{c,d,t,i} \times CT_{c,t,i} \times DI_{d,i} \times Labreq_{c,t,i} \leq flabor; \qquad (\boldsymbol{eq}.5.9)$$

$$Labor\ Constraint: Total\ labor\ requirements \leq Family\ Labor\ Availability$$

In the second group, we have the rotation constraint (**Eq. 5.10**) for arable crops. Since for environmental and technical reasons regarding fertility of soil, a set of crops was identified that cannot be produced for two consecutive years on the same land, a rotation is required in a way to have the same crop cultivated on the same land only after five years. The other two constraints regarding horticultural crops and maize occupation (**Eq. 5.11 and 5.12**); horticultural crops should not exceed the mean horticultural occupation in the surveyed farms because of soil unadaptability to such type of crops, and maize production is fixed since it is associated to the livestock activity present in some farms. The equations of this group are:

$[Rotation]_1^{cr}..\sum_{d,t,i} X_{cr,d,t,i} \times CT_{cr,t,i} \times DI_{d,i} \leq 0.20 \times \left[(\sum_d fland_d) + rentland - \right.$
$d,t,iXcf,d,t,i \times CTcf,t,i \times DId,i;$ ***(eq.5.10)***

$$Rotation\ Constraint: Total\ Land\ occupation\ by\ crop\ requiring\ rotation \leq 0.20 \times (Total\ land - fruit\ occupation)$$

$F\_horticulture..\sum_{hc,d,t,i} X_{hc,d,t,i} \times CT_{hc,t,i} \times DI_{d,i} \leq [(0.1 \times \sum_d fland_d) + (0.1 \times$
$rentland;$ ***(eq.5.11)***

$$Horticulture\ Constraint: Horticulture\ Land\ Occupation \leq 0.1 \times Total\ land$$

$maize..\sum_{d,t,i} X_{'maize',d,t,i} \times CT_{'maize',t,i} \times DI_{d,i} = 0.07785 \times 119126;$ $(\boldsymbol{eq. 5.12})$

$$Maize\ Constraint: Maize\ Land\ Occupation = 0.07785 \times Total\ land$$

The remaining group of constraints concerns irrigation water. Irrigation water consumption depends on crop, technique and irrigation system; irrigation water availability depends on the modality of water delivery in the different areas of the RIB (**Eq. 5.13, 5.14, 5.15 and 5.16**). The other constraints are to associate a fix land to each modality of distribution of water (**Eq.s 5.17, 5.18 and 5.19**).

$Waterdp..\sum_{c,t,ii} GIR_{c,t,ii} \times X_{c,'dp',t,ii} \times CT_{c,t,ii} \times DI_{'dp',ii} \leq \sum_p fwater_{p,'dp'} \times pfwater_p \times$
$fland'dp';$ ***(eq.5.12)***

$$Water\ Consumption\ in\ dp \leq Probabilistic\ Total\ Water\ availability\ for\ the\ area\ served\ by\ dp$$

$$Waterdg1..\sum_{c,t,ii} GIR_{c,t,ii} \times X_{c,'dg1',t,ii} \times CT_{c,t,ii} \times DI_{'dg1',ii} \leq \sum_p fwater_{p,'dg1'} \times pfwaterp \times fland'dg1'; \qquad (\boldsymbol{eq.5.13})$$

$$Water\ Consumption\ in\ dg1 \leq Probabilistic\ Total\ Water\ Disponibility\ for\ the\ area\ served\ by\ dg1$$

$$Waterdg2..\sum_{c,t,ii} GIR_{c,t,ii} \times X_{c,'dg2',t,ii} \times CT_{c,t,ii} \times DI_{'dg2',ii} \leq \sum_p fwater_{p,'dg2'} \times pfwaterp \times fland'dg2'; \qquad (\boldsymbol{eq.5.14})$$

$$Water\ Consumption\ in\ dg2 \leq Probabilistic\ Total\ Water\ Disponibility\ for\ the\ area\ served\ by\ dg2$$

$$Waterav..Water\ availability = \sum_{p,d} fwater_{p,d} \times pfwater_p \times fland_d\ ; \qquad (\boldsymbol{eq.5.15})$$

$$Total\ Water\ Consumption = Sum\ of\ Water\ Disponibility\ for\ the\ three\ areas$$

$$[Irridp]_1^m..\sum_{c,t,ii} X_{c,dp,t,ii} \times CT_{c,t,ii} \times DI_{dp,ii} \times L\_use_{c,m} \leq fland_{dp}; \qquad (\boldsymbol{eq.5.16})$$

$$Land\ irrigated\ with\ pressurized\ channel \leq Land\ covered\ by\ pressurized\ channel$$

$$[Irridg1]_1^m..\sum_{c,t,ii} X_{c,dg1,t,ii} \times CT_{c,t,ii} \times DI_{dg1,ii} \times L\_use_{c,m} \leq fland_{dg1}; \qquad (\boldsymbol{eq.5.17})$$

$$Land\ irrigated\ with\ continuous\ gravity \leq Land\ covered\ by\ continous\ gravity$$

$$[Irridg2]_1^m..\sum_{c,t,ii} X_{c,dg2,t,ii} \times CT_{c,t,ii} \times DI_{dg2,ii} \times L\_use_{c,m} \leq fland_{dg2}; \qquad (\boldsymbol{eq.5.18})$$

$$Land\ irrigated\ with\ discontinuous\ gravity \leq Land\ covered\ by\ discontinous\ gravity$$

5.7. Indicators

A set of key indicators were used to interpret the output of the modeling process and to assess the performance of agriculture and irrigation in terms of economic, social and environmental criteria. These indicators were picked from the list of the OECD of agric-environmental indicators and were calculated as a result of the modeling exercise (Morris *et al*., 2005(b); OECD, 2001).

5.7.1. Agricultural output

Economic forces shape the performance of the agricultural sector and its role in the national economy (OECD, 2001). Agriculture's contribution to gross domestic product through the value of agricultural output could be an indicator to observe the impact of different policies on the economic performance of this sector.

5.7.2. Change in agricultural land

Land use changes represent the integrating element between the economic, societal and environmental influences on agriculture. The change of marginal farming land to other land uses has raised concerns related to the associated harmful environmental and socioeconomic impacts in some countries, but equally the conversion of this land may enhance its biodiversity and related amenity values (OECD, 2001). Changes in farm land use from arable crops to pasture, more to less intensive cropping systems, and in terms of different cropping patterns can have major environmental effects, such as through altering soil erosion rates.

5.7.3. Net income

Net farm income is calculated as the difference between gross output and all expenses, including depreciation at the farm level. While nominal net farm incomes have risen for most OECD countries over the past 10 years, the performance in real terms has been variable and over recent years net farm incomes have sharply declined for some countries (OECD, 2001). We will observe along this dissertation the changes in this parameter due to policy changes.

5.7.4. Soil Cover (Sc)

Plant and crop residue cover protects soils from erosion, reduces run-off nutrients and pesticides habitat for biodiversity. An increase in the cumulative soil cover, the greater the protection from soil erosion, compaction and run off, and the greater the contribution to biodiversity. Hence, soil coverage for the whole year is the ideal target. Soil cover will be calculated as the number of days in a year that the soil (agricultural land) is covered with vegetation (OECD, 2001), in order to evaluate the ecological impact of different policy modifications. The risks of soil erosion are acceptable when the Sc value is above 50%:

$$Sc = \frac{\sum_c X_c \times V_c}{\sum_c X_c}; \qquad (\boldsymbol{eq.5.19})$$

Where X_c is the surface of crop c and V_c is the fraction of time during which the crop c covers the soil over the year.

5.7.5. Water use

Water use is defined by the OECD as the share of a nation's total water use represented by agricultural water use. For our purposes, water use is intended as the required amount of irrigation water measured at the farm gate (and thus includes all waste and inefficient use on the farm). This is proposed as "related information" (OECD, 2001). It is proposed in this form by the European Commission for the Evaluation of AEPs, and in this simple form is a clear measure of water use in agriculture.

5.8. Model calibration

The model has been designed to simulate actual (2006-2007) behavior of the farms; therefore before using it for policy analysis, its predictive capacity must be tested. There are no formal tests of validation for mathematical programming models (Hazell and Norton, 1986; Norton *et al*., 1978), but measures of goodness of fit can be used to check how closely the model predicts the levels of areas planted, production, prices and levels of input use (Schmid and Sinabell, 2005).

In order to obtain robust results from policy and technological changes introduced in the scenario simulations, several model parameters are usually calibrated to produce values which are close to the observed situation (Schmid and Sinabell, 2005).

Several methods exist to calibrate the model parameters so that the actual situation is reproduced to the extent possible. Additional constraints such as crop rotation, technology, price and policy constraints are then introduced to force the model to reproduce as closely as possible the observed situation (McCarl, 1982).

A measure used by most researchers to evaluate the fit of models is the mean absolute error (MAE) (Willmott and Matsuura, 2005; Anderson and Woessner, 1992; Willmott *et al.*, 1985). The MAE is used to measure how close forecasts or solutions of the cropping pattern are to the actual situation. Other authors (Blanco *et al.,* 2008; Hazell and Norton, 1986; Norton *et al.*, 1978) used the same measurement but they called it the percentage absolute deviation (PAD) between observed and predicted values. Where:

$$PAD = \sum_{i=i}^{n} \left| X_i^O - X_i^P \right| \div \sum_{i=i}^{n} X_i^O$$

Given that X_i^O is the observed value of the variable and X_i^P the predicted value.

Hazell and Norton, (1986) suggest the following rule for evaluating the performance of a model: a PAD of 15% or more indicates the model may need some correction, a PAD below 10% is good, and a PAD of 5% would be exceptional.

5.9. Model limitations

The model developed in the framework of this study is a tool for analyzing different management strategies of the Renana RIB on the light of different agricultural and water policies, thereby improving farm income and the water resources situation. There are, however, several limitations of this approach. In the model, the objective of all producers is considered jointly; in reality, however, the objectives of individual producers might differ (Janssen and Van Ittersum, 2007).

Due to the limitations associated with data availability, the model considers only a group of major crops cultivated in the area while a lot of other crops are excluded especially in horticulture because they present a low land occupation and we could not find any agronomic or economic study to collect the data necessary for the model. Continuous yield response functions to fertilizer, labor and machinery use could improve the model, and could have given us the possibility to study some other environmental impacts of irrigation water related not only to water quantity but to quality as well. However, this was not possible under existing data availability.

Additional data related to different soil types in the study area could be very helpful improving the model results given that soil texture could be an important limitation to practice some cultivations like horticulture, in our case we just considered this limitation as a constraint that could not be exceeded, where a mean percentage of the total surface that should be occupied by horticultural.

The model represents the agricultural activity isolated from other extra agricultural activities that could take place in some farms of the RIB, e.g. livestock production agro-tourism and others. This could increase the error in the model and could change the economic outcome of such farms and sometimes it could modify the land use with respect to the need of such activities.

It is auspicious to mention that some farmers' decisions are not justified only economically. Verifying this fact with stakeholders and farmers we realized that this could have two main reasons: either misinformation or even some social and cultural habits earned from previous generations. Our model is, in its current version, not able to reproduce and take into account this kind of factors.

5.10. Scenarios

Once the model was calibrated and approved, the solution obtained is called the baseline scenario. In addition to the baseline scenario, many scenarios were simulated: each scenario reflects an expected policy and/or technological change to be implemented. The results of each scenario contribute to the decision making process as they shed light on the potential positive and negative economic and environmental implications (in terms of water quantity) of proposed policy changes. A general description of the scenarios is presented in **Table 5.8**, and a full description of each scenario, with the main parameters changed among the different simulations is presented in the subsequent paragraphs. Each scenario was ultimately designed to understand three primary effects: firstly, changes in farmer income; secondly, changes for the RIB, in terms of economic implications, savings in water distributed, and technological changes in the infrastructure for water distribution; and thirdly changes in the total land occupation.

Table 5.8. Short description of different scenarios.

N°	Scenario name	Scenario description
1	Baseline scenario	The baseline examines the expected income, crop and water allocation under usual farming conditions, reflecting the actual situation of the RIB.
2	Decoupling	This scenario examines the same indicators substituting the coupled payments by a single farm payment independently of the cropping pattern chosen by farmers.
3	WFD	This scenario is constituted of three simulations (a, b and c) to examine from one side the impact of the incentives provided by the Water Protection Plan of Emilia Romagna to farmers in order to increase the efficiency in irrigation, and from another the response in case of drought to a cut off in irrigation water and impact in an eventual volumetric tariff.
4	Changing irrigable land	These scenarios consist in nine different simulations (a, b, c, d, e, f, g, h and i) to study the impact on farmers' expected income, and crop and water allocation in case the RIB decided to increase the area of irrigable land.
5	Changing fixed water tariff	This scenario studies the effect of fixed water tariff change (increase or decrease) on farmers' income and on the revenue of the RIB.
6	Changing irrigable area, fixed tariff & quantity	This scenario simulates changes to the baseline scenario, in case of change in the total irrigable area, the fixed water tariff and in water quantity (increase or decrease), it is composed of four different simulations.

All these scenarios briefly described in the above table can be classified into three main groups, one concerning the Common Agricultural Policy and its evolution since the baseline scenario (Group I), another one in relation to the Water Framework Directive (Group II) and the last one regarding the management and the decision making of the RIB (Group III). The major changes between the scenarios are the communitarian payments, the irrigable land, the efficiency and fixed costs of irrigation systems, the fixed water tariff and the volumetric water tariff.

In the baseline scenario as explained previously, the efficiency of irrigation systems is considered 65% for sprinkler and 75% for drip, fixed costs are those calculated and updated by the CER (SETI, 2008). The irrigable area has no volumetric water tariff and is divided into three parts: one served by pressurized and continuous system and covers about 7170 ha with a fixed water tariff of 52.7 € ha^{-1}, one served by gravity and continuous system and covers about 54560 ha with a fixed water tariff of 14.7 € ha^{-1} and another one of 6900 ha with gravity and discontinuous system with a fixed water tariff of 14.7 € ha^{-1}. The CAP payments for cereals and sugar beet were of 336 and 429 € ha^{-1} respectively.

The only change applied to group I was the sector payments that were replaced by the single payment scheme. To get the amount of this payment we divided for every sector the total amount received by the total area of the farm and we got 235 € ha^{-1}, independently of farmers decisions. This way of estimation was a simplification of the single payments given that the former depend on the historical payment every farm used to get and given the contradiction getting this information beside stakeholders.

In group II, to examine the impact of volumetric water pricing suggested by the WFD (Scenario WFD1) and the incentives provided by the Water Protection Plan of Emilia Romagna to farmers (Scenario WFD2) in order to increase the efficiency in irrigation and the regulation of water deviation to respect a minimum vital outflow MVO (Contini, 2008; PTA, 2006). We hypothesized that farmers could increase the efficiency for their irrigation systems to 80 and 90% respectively for sprinkler and drip irrigation in case they decide to renew the irrigation machinery. Thus, an incentive of reduction in the fixed irrigation costs is provided up to 30% (Scenario WFD2). This scenario includes as well a simulation concerning reduction in water supply in case of drought as required by the WFD (Scenario WFD3). Water quantity decrease is considered up to 20% of the actual availability.

In parallel, water saving in the conservation plan should be also from the RIBs' part that should envisage actions for efficiency improvement of water main and distribution networks (PTA, 2006). Therefore, this set of scenarios will simulate the increase in water quantity at the farm level due to an improvement in the distribution efficiency (Scenario WFD4).

The main changes in group III are the areas occupied by different modalities of water distribution (Scenarios RIB1 till RIB4) that are augmented with different percentages depending on the scenarios maintaining the irrigation efficiency of 65 and 75% respectively for sprinkler and drip irrigation.

The fixed water tariffs are decreased in some simulations and increased in others of about 15% (Scenarios RIB5 and RIB6), the highest values are as follows: 60.6 € ha^{-1} in the case of pressurized system of distribution 30 and 17 € ha^{-1} for gravity distribution and 10 € ha^{-1} in the area not covered by irrigation service, and the lowest values are: 44.8 € ha^{-1} in the case of pressurized system of distribution 22 € ha^{-1} and 12.4 € ha^{-1} for gravity distribution and 0 € ha^{-1} in the area not covered but irrigation service. All these scenarios are also run with different volumetric tariffs for irrigation water (0 € m^{-3}, 0.1 € m^{-3}, 0.5 € m^{-3} and 1 € m^{-3}).

The final set of simulation (Scenario RIB7 and RIB8) is a combination of different simulations of the previous scenarios, in order to have some satisfactory information to improve farmers' income and RIB returns in the presence of different policy measures and local modification in the territory to provide input for decision makers.

CHAPTER VI

6. Results and Discussions

This chapter presents the results of different scenario simulations. Apart from the baseline scenario that reproduces the current situation, each scenario reflects an expected policy and/or technological change to be implemented in the near future. The results described in the following pages can contribute to the decision making process in the water resources management as they shed light on the potential positive and negative economic and ecological implications both on farmers and on the reclamation and irrigation board (RIB), of proposed changes. The main parameters taken into consideration in the analysis of the results will be the following:

- Total land use.
- Arable crop occupation.
- Horticultural occupation.
- Fruit occupation.
- Soil cover.
- Total irrigated area.
- Area served by pressurized delivery system.
- Area served by gravitational delivery system.
- Area occupied by different techniques of irrigation (t0: rain fed technique, t1: complementary irrigation and t2 full or complete irrigation).
- Water use by hectare.
- Net income by hectare.
- Total fixed water tariff.
- Total volumetric water tariff.

6.1. Baseline scenario

The baseline scenario reflects the actual situation of the RIB as it was when the data were collected. The total land occupation is around 119,127.95 ha from which about

68,630 ha are irrigable and only 18,831 ha are irrigated with different irrigation modalities (**Fig. 6.1**): where dp represents irrigation land with pressurized delivery system, dg1 is the irrigation land with continuous gravitational delivery and dg2 the irrigation land with discontinuous gravitational system of delivery. Arable crops, horticultural crops and fruits were cultivated with the following percentages: 67%, 10% and 23% respectively (**Fig. 6.2**).

The baseline scenario refers to the period 2005-2006 the transition phase during which the 2003 CAP reforms where getting into implementation, and has been used to calibrate the model. However, four years from the implementation of the full decoupling in Italy have passed over and therefore, we found appropriate to compare of the different simulated scenarios (paragraphs 6.3 and 6.4) with the full decoupling scenario which is described in paragraph 6.2.

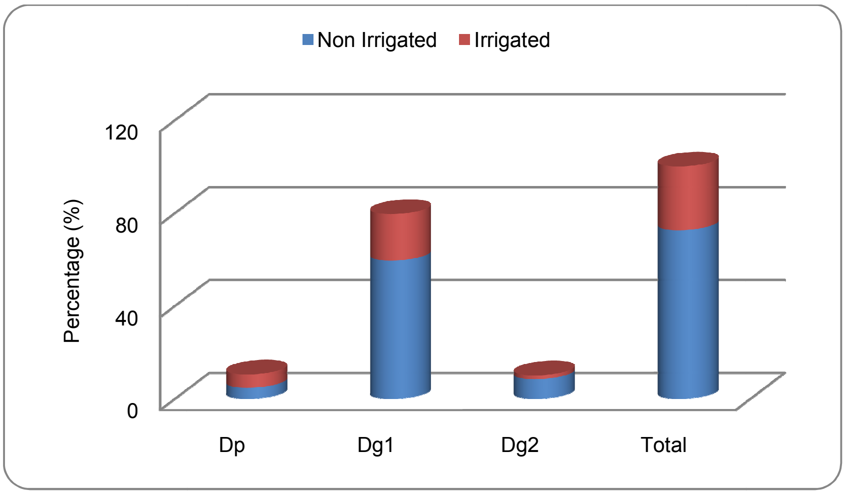


Figure 6.1: Percentage of irrigated/irrigable land served by different delivery systems.

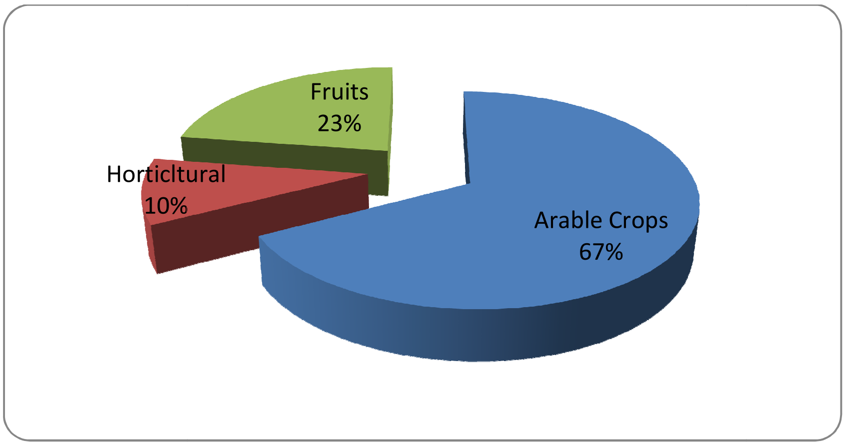


Figure 6.2: Land occupation in the baseline scenario.

A big part of the farms used to practice a complete irrigation technique (85.35%) while only 14.65% practiced the complementary irrigation technique for a total consumption of 33.03 MCM, equivalent to about a mean of 1,754.37 m^3 ha^{-1}.

The rain fed agriculture is mainly concentrated in arable crops production (67.39% of the total land occupation) and 14.93% of the total land occupation for fruits, while horticultural crops are for 1.88% produced without irrigation. Complementary irrigation is only applied on fruits with a percentage of 2.32. Full irrigation techniques are mainly applied on fruit production (**Fig. 6.3**), on 5.37% of the total land occupation and less on horticultural crops (8.12% of the total land occupation).

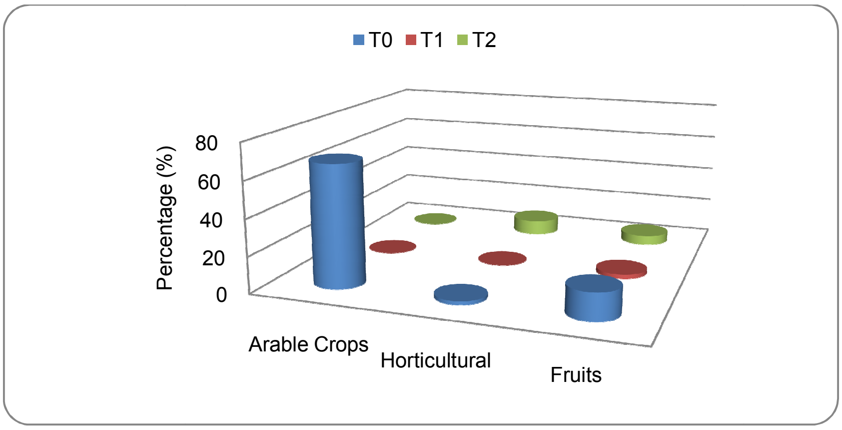


Figure 6.3: Distribution of different irrigation techniques between production blocks.

These numbers could be explained by the fact that in arable crops only maize and sugar beet can be irrigated with complementary or full techniques, while in fruit production except the plum that can be either rain fed or partially irrigated, all crops should be fully irrigated to maximize the production, and in horticulture it is almost unperceivable to produce without irrigation.

Given this situation, the net agricultural product of the area was estimated little bit more than 132.49 M€ that gave a net income return to farmers around 1,112 € ha^{-1}. This income is distributed on set of land use that could in some crops be different from the following crops (**Tab. 6.1**). Finally, returns of the RIB, constituted by the water tariff paid by farmers, in this case they were approximately 1.89 M€.

Table 6.1. Land use by crop and comparison with the mean land use of the survey.

Crops	Mean Farm		Baseline	
	Surface (ha)	**Percentage (%)**	**Surface (ha)**	**Percentage (%)**
Arable Crops Occupation:	82,454.61	69.21	80,275.86	67.39
Maize	9,275.84	7.79	9,273.96	7.78
Bread Wheat	14,964.91	12.56	14,305.38	12.01
Durum Wheat	19,561.28	16.42	18,437.73	15.48
Alfalfa	16,436.76	13.80	16,361.24	13.73
Sorghum	9,027.27	7.58	11,012.85	9.24
Sugar beet	10,816.51	9.08	10,884.69	9.14
Set aside	2,108.44	1.77	-	-
Soybean	515.47	0.43	-	-
Horticulture Occupation:	11,913.62	10.00	11,912.79	10.00
Potatoes	6,362.81	5.13	6,360.33	5.34
Autumn onion	2,404.42	2.02	1,686.86	1.42
Spring onion	3,146.39	2.64	3,865.61	3.24
Fruit Occupation:	24,760.77	20.78	26,939.30	22.61
Peach	9,077.12	7.62	1,589.67	1.33
Pear	10,946.75	9.19	11,531.44	9.68
Plum	1,736.76	1.46	12,881.91	10.81
Grapevine	2,243.71	1.88	-	-
Apple	453.86	0.38	-	-
Apricot	302.57	0.25	936.28	0.79
Total	**119,129**	**100.00**	**119,127.95**	**100.00**

At this point, it is auspicious to mention that variability between the mean farm and the models' results are sometimes due to some decisions farmers take that are not justified economically. This could have two main reasons: either misinformation or even some social and cultural habits earned from previous generations.

A plausible example that concretizes this fact is the presence of peach in the farms notwithstanding its negative contribution to the farm net revenue. Checking out the results near to many farmers we discovered that for many reasons few years ago many farmers used to install peach orchards but now they are gradually proceeding to replace them because they said, they are not economically profitable.

The soil cover indicator, which is the indicator of ecological situation of the territory, is equal to 285 days equivalent to something like 78% of the total days of the year. This value can be considered good as far as the indicator is acceptable above 50% as referred in OECD, (2001).

6.2. Group I: Scenarios of the PAC

The total decoupling of the payments had a significant impact on the land use of the study area; nonetheless, the total cultivated area remains constant and equal to 119,127.95 ha. We saw a fall in arable crops production relative to 12% and an increase in fruit crops while horticultural production remained stable due to soil limitations as explained in the previous chapters (**Fig. 6.4**).

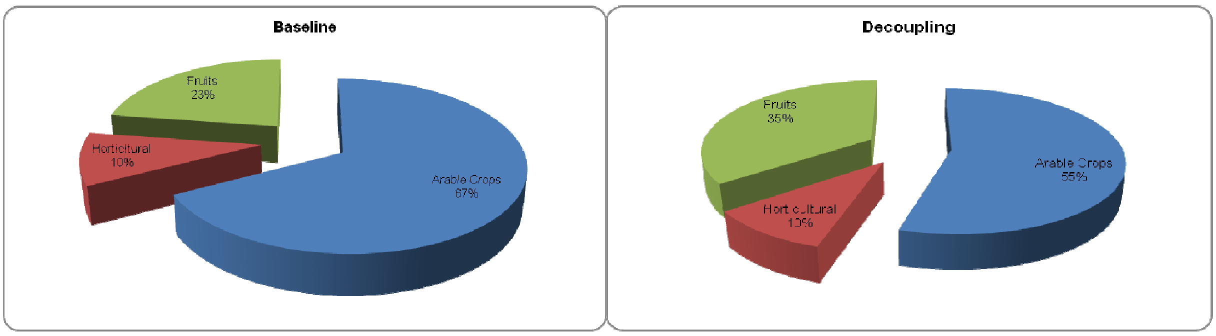


Figure 6.4: Comparative pies of land use.

The expansion in fruit occupation was coupled with slight amplification of irrigated land in the order of 4% (about 784 ha) that happened in the area served by continuous pressurized irrigation system (dp). The impact on the total amount of water used in the

RIB is completely absent, but, contrary to the expected, it showed a slight reduction on water use by hectare (something like 4%), which means that farmers shifted in the irrigation techniques used, indeed the area occupied with complementary irrigation techniques doubled with respect to the baseline scenario (**Fig. 6.5**).

The net agricultural product was estimated in this simulation around 176.82 M€. No changes occurred on water costs given that fixed water tariffs are paid independently from the activity carried out, but an increase in the farmers' income arose due to the substitution of arable crops with fruits this change was about 33.46% and the income by hectare changed form 1,112.56 € ha^{-1} in the baseline to 1,484.27 € ha^{-1}.

Results show a positive environmental impact of the implementation of decoupling in the case study: from one side the soil cover indicator increased something like 2% and it became around 292 days, which means resistance to soil erosion became higher. From another side, water use by hectare was subject to a 4% reduction.

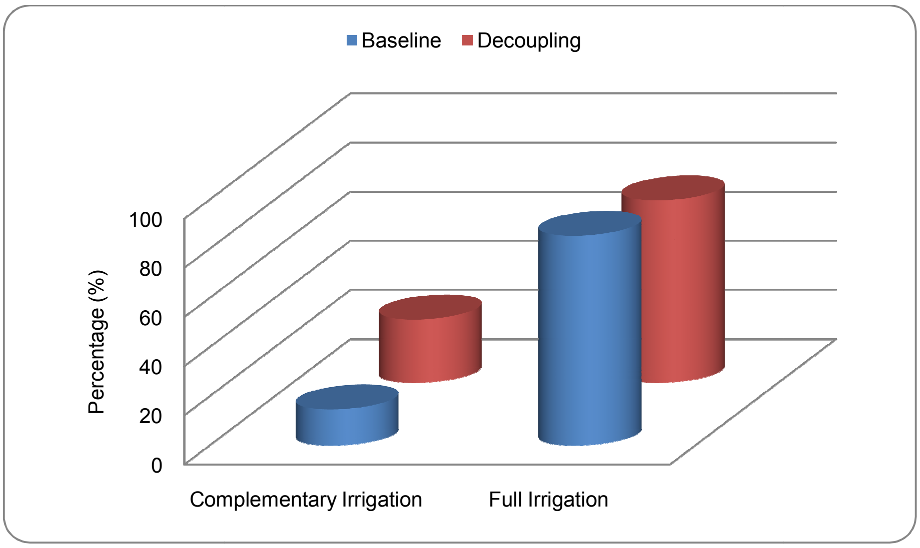


Figure 6.5: Shift in irrigation techniques with respect to the baseline scenario.

These results seem to confirm what many authors found concerning the heterogeneous effects of decoupling depending on farm types and regions (Balkhausen *et al*., 2005). Regarding the land use for example, we have some changes in the distribution of groups of crops, contrary to the results of Varela-Ortega *et al*., (2006) where no change in land use was observed. Different to the conclusions that Blanco Fonseca (2007) arrived at, our results showed that irrigated land increases with decoupling even though slightly, verifying some other studies (Júdez and Piniés 2006).

The simulation results suggest that the agricultural product encounter an increase in total value, different to the decline expected in output and factor in the Scottish and English agriculture (Gelan and Schwarz 2006; Moss *et al*., 2002). The positive impact of decoupling on the welfare of farmers in the RIB verify the conclusions achieved by Butlen and Quirion, (2006) but contrary to the results of Varela-Ortega, (2006) who found negative repercussions of decoupling on farmers' income.

This heterogeneity in the effect of decoupling is mainly determined by local economic and social characteristics of farms and farmers and the resources availability (Piorr *et al*., 2009; Scardigno and Viaggi, 2007). For instance, Júdez and Piniés (2006), worked on cereal farms while for example Blanco Fonseca (2007) and Butlen and Quirion (2006) worked on cotton farms which explains these contradictory results.

6.3. Group II: Scenarios of the WFD

As mentioned previously, for this simulation and all the other scenarios we assumed that decoupling will be the reference scenario for data comparison because as a CAP reform, it has been fully implemented in 2007 for most of the agricultural production.

This group of scenarios is composed of four different simulations regarding measures required by the Water Framework Directive (WFD):

- Cost recovery principle (Scenario WFD1): through the volumetric water pricing.
- Economic incentives to farmers (Scenario WFD2): in order to improve application efficiency in irrigation.
- Water abstraction (Scenario WFD3): to respect the Minimum Vital Outflow of rivers.
- Improve distribution efficiency (Scenario WFD4): Improvement in the channels permeability to reduce losses by percolation.

6.3.1. Scenario WFD1

Within the Water Protection Plan of Emilia Romagna and in line with the WFD's requirements, the measures concerning water quantity protection comprise the "Cost Recovery Principle" to be adopted as the guiding rule for water price setting. In the RIB the implementation of the "Cost Recovery Principle" mean the transformation of the flat water tariff into a volumetric one. For this purpose, we simulated an increasing volumetric tariff in the area going from 0 up to 2.4 € m^{-3}, to analyze the impact of such hypothesis on cropping pattern, farmers' income and RIB's revenue. This simulation is analyzed keeping the flat water tariff fixed at the actual value, but in a subsequent simulation this volumetric water tariff will be simulated with a change of the former.

The implementation and the increasing of volumetric tariff on water have no impact on the total cultivated area that remains constant. Many changes occurred in crop pattern (**Fig. 6.6**): arable crops expand gradually on behalf of a decrease in fruit crops occupation, while horticulture crops endure no changes. Variations are induced also at the level of irrigated land that is reduced from 19,615.22 ha in the absence of volumetric tariff to disappear completely at very high margins of tariff, with a gradual shift in the irrigation technique that becomes mainly supplementary irrigation and then rain fed (**Tab. 6.2**).

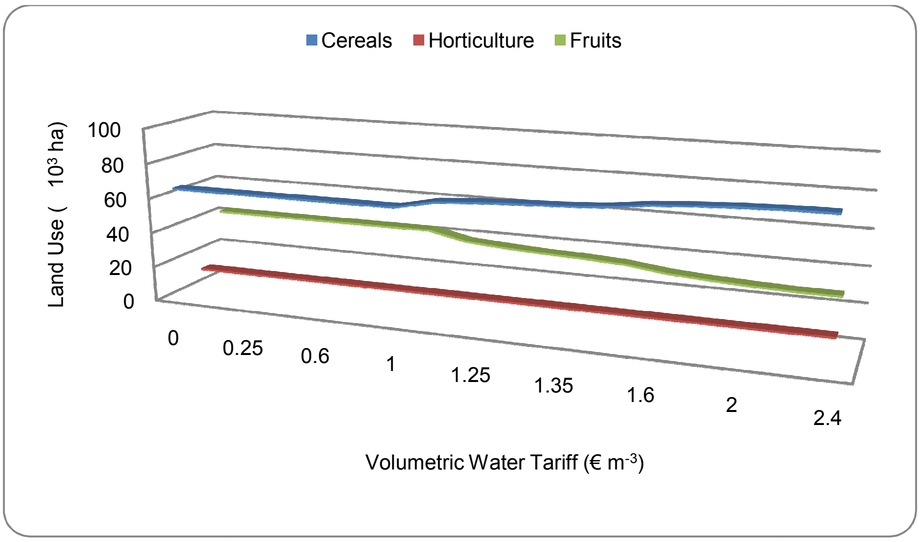


Figure 6.6: Changes in land use due to volumetric tariff implementation.

Table 6.2. Changes induced by implementing a volumetric tariff.

Parameters	Increasing Volumetric Water Tariffs (€ m^{-3})							
	0	**0.2**	**0.8**	**1**	**1.25**	**1.35**	**2.2**	**2.4**
Total area of the RIB	119,127.95							
Arable crops (%)	54.81	54.81	54.81	54.81	59.94	61.48	67.46	67.53
Horticulture (%)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Fruits (%)	35.19	35.19	35.19	35.19	30.06	28.52	22.54	22.47
Total irrigated land (%)	16.47	16.47	16.47	16.47	10.72	8.10	0.17	0
Irrigated land by t1 (%)	4.25	4.25	4.25	4.25	4.60	4.63	0.17	0
Irrigated land by t2 (%)	12.22	12.22	12.22	12.22	6.12	3.47	0	0
Farmer's income (€ ha^{-1})	1,484.27	1,428.81	1,262.41	1,206.95	986.21	929.75	744.51	745.22
RIB's returns (M€)	1.89	8.51	28.33	34.94	25.87	19.66	24.02	1.89
Water use (m^3 ha^{-1})	1,684.27	1,684.27	1,684.27	1,684.27	1,501.45	1,363.35	1,120.00	0
Soil Cover (%)	80.13	80.13	80.13	80.13	79.42	79.30	77.83	77.82

As effect of such a measure farmers modified their choices in order to adapt to new cost implications. The direct consequence is on the income from one side, and on water use from another which are inversely correlated to the volumetric tariff: when the volumetric tariff increases farmers' income drops and the water use as well but with less intensity (**Fig. 6.7**).

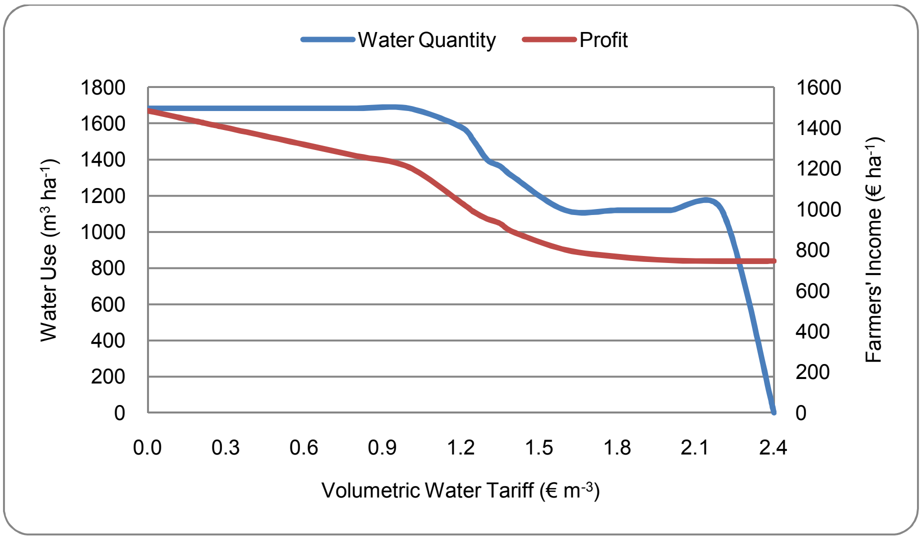


Figure 6.7: Correlation between volumetric tariff, income and water quantity.

As this chart shows, the curve of water use in the RIB has a rigid response to volumetric water tariffs: it remains the same for low tariffs (up to 0.9 € m^{-3}) and begins to decrease slightly above a volumetric tariff equal to 1 € m^{-3}. Once the unit price of water is 1.35 €

m^{-3} a sharp decrease in water use is observed, that can reach 50% of the initial water use. Between 1.4 and 2.2 € m^{-3}, the curve remains flat and the water use represents about 22.45% of the initial water use and for a volumetric tariff above 2.2 € m^{-3}, the water use becomes zero.

On the other hand, contrary to the water use, the income shows more elasticity to slight volumetric tariffs changes. This change is accentuated with further increase of the tariff and above a tariff equivalent to 1.25 € m^{-3}, the curve gets straight and the change in the income is very slight and it gets stabilized above a tariff of 2 € m^{-3}.

Concerning the returns of the RIB, even a slight volumetric water pricing from 0 € m^{-3} to 0.2 € m^{-3} could amplify considerably the RIB's total returns (from 1.10×10^6 € to 8.51×10^6 €), affecting slightly the farmers income that drops of 3.74% by hectare, and without affecting at all the water use per hectare. The reduction in the income is observed also on the net agricultural product that increases of 4.67%.

The maximum return for the RIB (**Fig. 6.8**) could be reached at a volumetric tariff equal to 1 € m^{-3}, up to this level tariff has no impact on the total irrigated land neither on water use, but at this level the income is almost reduced to 20% with respect to the previous scenario of decoupling (around 1,206.95 € ha^{-1} of income and 19,615.22 ha of irrigated land). Beyond this level water use begins to drop as well as irrigated land and in consequence farmers' income and returns of the RIB.

At a volumetric tariff of 2.2 € m^{-3}, no irrigation is practiced any more, horticultural and fruit crops are reduced to the minimum that can be produced in rainfed, income of farmers drops to the half of the initial income as well as the RIB returns. This change is followed by a decrease in the soil cover indicator that goes down approximately 3%.

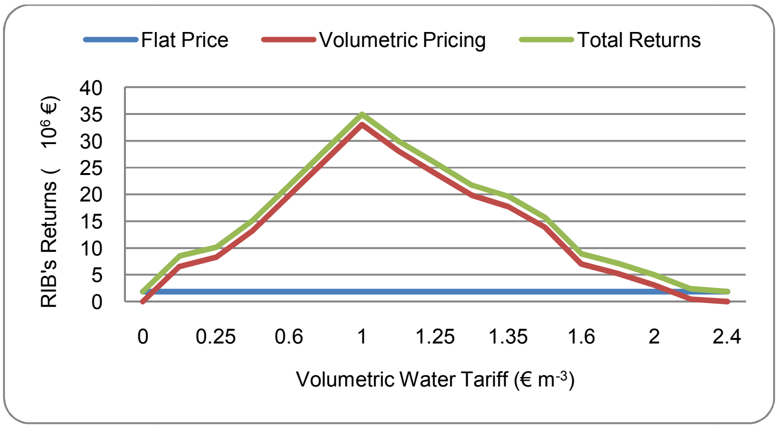


Figure 6.8: RIB's returns from different water pricing.

6.3.2. Scenario WFD2

Within the same regional plan for water protection, for the fulfillment of the objectives of the WFD, some economic incentives are provided to farmers as a participation in the investment's cost of a new irrigation technology in order to improve application efficiency of irrigation water: a reduction in investment costs could reach up to 30% of the irrigation system costs'. The simulation compared to the previous one (decoupling) showed that such measure has no effect on the total agricultural surface that remains equal to the initial one, but it can modify slightly the land use in the RIB; indeed we are in the order of 5% decline in land occupation of arable crops with respect to the decoupling scenario. The change in the different crops is summarized in the following chart (**Fig. 6.9**).

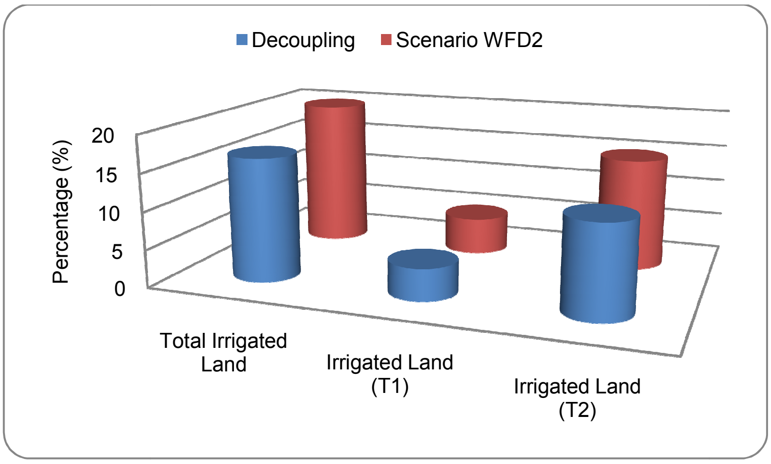


Figure 6.9: Changes in land use with respect to decoupling.

This change is followed by an increase of the total irrigated land of about 12.5%, observed in the area covered by a continuous gravitational irrigation system (dg1). This is followed by a change in the irrigation technique, where complementary irrigation increased for a drop in the full irrigation (**Fig. 6.10**).

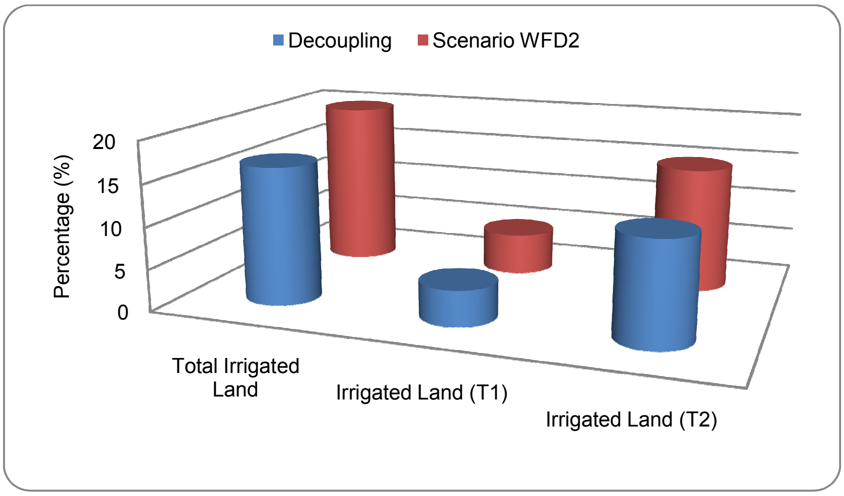


Figure 6.10: Shift in irrigation techniques.

Given that the irrigable land increased while the water quantity distributed by the RIB is invariable, water use per hectare is reduced; this decline was coupled with a change in the land use within each group of crops (**Tab. 6.3**).

Table 6.3. Change in land use by crops.

Crop (%)	Decoupling				Scenario WFD2			
	0 € m^{-3}	1 € m^{-3}	1.5 € m^{-3}	2 € m^{-3}	0 € m^{-3}	1 € m^{-3}	1.5 € m^{-3}	2 € m^{-3}
Bread wheat	9.41	9.41	13.74	15.38	8.13	8.13	12.28	14.44
Durum wheat	12.96	12.96	14.80	15.38	12.39	12.39	13.96	15.05
Maize	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
Alfalfa	11.03	11.03	14.80	15.38	9.55	9.55	13.36	15.05
Sorghum	10.39	10.39	11.04	10.87	10.45	10.45	10.33	11.01
Spring onion	3.04	3.04	3.03	3.13	3.22	3.22	2.69	3.12
Autumn onion	1.00	1.00	0.38	0.44	1.14	1.14	0.75	0.39
Potatoes	5.96	5.96	6.59	6.44	5.65	5.65	6.56	6.49
Sugar beet	3.23	3.23	1.83	2.11	3.64	3.64	2.08	1.91
Peach	2.67	2.67	1.85	1.65	2.88	2.88	2.18	1.77
Pear	15.19	15.19	10.55	8.71	16.53	16.53	12.60	9.84
plum	15.26	15.26	11.84	11.04	16.41	16.41	13.55	11.43
Apricot	2.06	2.06	1.77	1.69	2.24	2.24	1.86	1.72
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

The net agricultural product of the area was around 195.78 M€, little bit less than 11% higher than decoupling scenario and the income of farmers is also as much higher with respect to the previous scenario and is equal to 1,643.44 € ha^{-1}. No changes were observed in the income of the RIB due to this hypothesis, but a slight environmental improvement by a 0.36% raise in the soil cover indicator.

Compared to the literature previously reviewed, local responses to the implementation of the water pricing in some cases confirm what has been studied in the past in different case studies, especially the relation between water pricing, water use and farmers' income (Gallerani *et al*., 2005; Gómez Limón and Riesgo, 2005; Manos *et al*., 2005; Morris *et al*., 2005(a)). They verify some other conclusions about the switch in some water demanding crops to other rain fed crops (Manos *et al*., 2005; Morris *et al*., 2005(a)), but we do not have a radical change in the agriculture of the area, due probably to the typology of the local agriculture very rigid, mainly of arable crops, contrary to the results by Bartolini *et al*., (2007) who analyzed case studies basically dependent on irrigation.

The interesting finding that should be mentioned is the positive impact that eventual incentives could generate to improve the application efficiency in irrigation (**Tab. 6.4**), which partially confirms the results of Huffaker and Whittlesey 2000. In fact, the measure permitted to farmers, with the same initial available water of 33.03 MCM, to expand the irrigated area of 20%, and the full irrigation technique as previously shown in Figure 6.10. This is explained by a drop in water use by hectare of approximately 17%.

Farmers' income rises for more than 10% per hectare (**Tab. 6.4**) and evidently the value of the net agricultural product. But once water price goes up, there is a switch back to complementary irrigation techniques but still, lower in terms of percentage in the case of incentive than without it.

In terms of ecological impact of this policy, no significant results are observed, as far as the soil cover indicator improves only around 0.30%, but could reach a 1% at higher volumetric water tariffs. This partially proves the results obtained on the technological and ecological efficiency of volumetric water pricing (Giannoccaro *et al*., 2008).

Table 6.4. Changes induced by scenario WFD2 on agriculture.

Parameter	Decoupling		Scenario WFD2	
	0 € m^{-3}	**1.5 € m^{-3}**	**0 € m^{-3}**	**1.5 € m^{-3}**
Total area of the RIB	119,127.95	119,127.95	119,127.95	119,127.95
Arable crops (%)	54.81	63.98	51.94	59.80
Horticulture (%)	10.00	10.00	10.00	10.00
Fruits (%)	35.19	26.02	38.06	30.20
Total irrigated land (%)	16.47	4.14	19.85	10.93
Irrigated land by t1 (%)	4.25	3.84	4.92	4.62
Irrigated land by t2 (%)	12.22	0.31	14.93	6.31
Farmer's income (€ ha^{-1})	1,484.27	4.14	1,643.44	991.51
RIB's returns (M€)	1.89	10.50	1.89	26.40
Water use (m^3 ha^{-1})	1,684.27	1162.81	1,397.06	1,254.59
Soil Cover (%)	80.13	78.48	80.49	79.43

6.3.3. Scenario WFD3

In case of drought, and water shortage, and to respect the Minimum Vital Outflow of the rivers required by the communitarian states in the WFD, the RIB will be obliged to cut water for farmers. At this point, it would be interesting to check out how the agriculture of the RIB will be affected and how farmers in the area will react and finally the impacts on RIB's returns and water use when the water availability is reduced to 20% of the initial availability. The new water availability taking into account the probability will be as following (**Tab. 6.5**).

Table 6.5. The reduced on-farm annual water availability (m^3 ha^{-1}).

Probability (%)	Modality of Distribution		
	Pressurized	Gravity continuous	Gravity discontinuous
1/3	640 (m^3 ha^{-1})	640 (m^3 ha^{-1})	640 (m^3 ha^{-1})
1/3	640 (m^3 ha^{-1})	320 (m^3 ha^{-1})	0 (m^3 ha^{-1})
1/3	640 (m^3 ha^{-1})	160 (m^3 ha^{-1})	0 (m^3 ha^{-1})

The response to such reduction in irrigation water can induce reduction in the fruit occupation, and an increase in rain fed agriculture (about 5%), mainly arable crops but the total cultivated area does not change. Irrigated land falls remarkably (**Fig. 5.11**), and inside the irrigated crops there is a shift between irrigation techniques whereas area occupied by complete irrigation technique drops in order of 24% with respect to decoupling, and water use by hectare decreases of approximately 4%. Obviously, diminution in irrigated agriculture causes a 10.24% decline in farmers' income and evidently, this reduction is observed at the level of the net agricultural product. The coupled effect of volumetric water tariff and reduction of water quantity is shown in the following table (**Tab. 6.6**). This change does not save the soil cover indicator that worsens of 2%, which means saving water sometimes could have also negative environmental impacts.

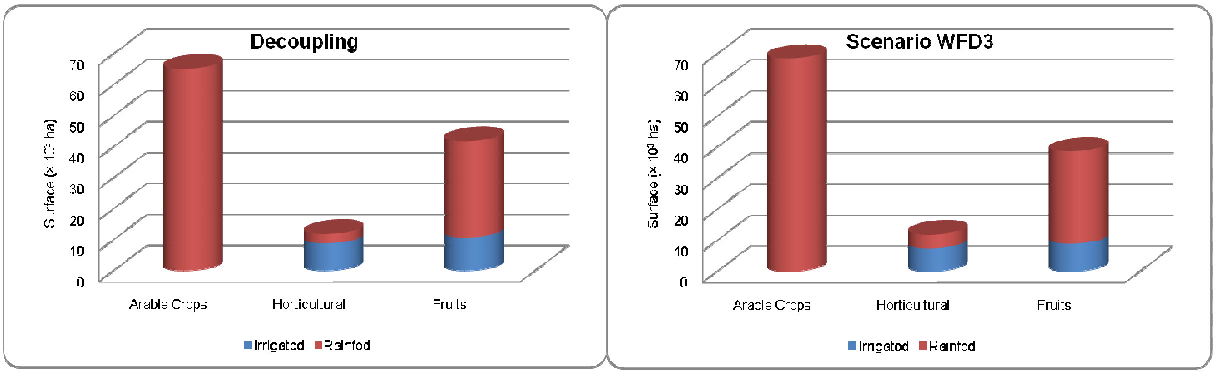


Figure 6.11: Changes in land occupation and irrigated agriculture with water reduction.

Table 6.6. Impact of water pricing in the case of scenario WFD3.

Parameters	**Increasing Volumetric Water Tariffs (€ m^{-3})**			
	0	**1**	**1.5**	**2**
Total area (ha)	119,127.95			
Arable crop occupation (ha)	57.56	57.56	64.06	66.90
Horticultural occupation (ha)	10.00	10.00	10.00	10.00
Fruit occupation (ha)	32.44	32.44	25.94	23.10
Total irrigated land (ha)	13.67	13.67	4.02	1.17
Irrigated land by t1 (ha)	4.33	4.33	3.80	1.17
Irrigated land by t2 (ha)	9.34	9.34	0.22	0
Water use (m^3 ha^{-1})	1,623.02	1,623.02	1,151.92	1120
Farmer's income (€ ha^{-1})	1,332.28	1,110.42	823.93	748.53
RIB's returns (M€)	1.89	28.33	10.17	5.02
Soil Cover (%)	79.72	79.72	78.46	77.97

6.3.4. Scenario WFD4

From the other part, the RIB is supposed to envisage actions to improve efficiency of the distribution networks reducing water losses by percolation, as already explained in the second and fourth chapters. Therefore, this simulation will hypothesize an efficiency improvement and a consequent increase in water availability that becomes 57.75% more of the actual water availability; considering the variability of availability, the distribution between the modalities and the probabilities will be as following (**Tab. 6.7**):

Table 6.7. Augmentation of annual water availability on-farm (m^3 ha^{-1}).

Probability (%)	Modality of Distribution		
	Pressurized	Gravity continuous	Gravity discontinuous
1/3	1,000.00 (m^3 ha^{-1})	1,000.00 (m^3 ha^{-1})	1,000.00 (m^3 ha^{-1})
1/3	1,000.00 (m^3 ha^{-1})	750.00 (m^3 ha^{-1})	500.00 (m^3 ha^{-1})
1/3	1,000.00 (m^3 ha^{-1})	500.00 (m^3 ha^{-1})	0 (m^3 ha^{-1})

Changes in the RIB that could occur in such situation are very significant for the structure of agricultural farms from one side and for the socio-economic improvements that this structural modification could entail for farmers from another. Nonetheless the environmental impacts generated.

Water availability will modify accordingly the land use in the RIB: arable crops will lessen for a higher value crops, in this case fruits given that horticultural cannot be produced above a certain limit (**Fig. 6.12**).

The net agricultural product of the area increases of 31.65% and consequently farmers' income rises up to 1,955 € ha^{-1} (around 31.65%) no impact occurs on the RIB's return unless a volumetric water tariff is applied (**Tab. 6.8**).

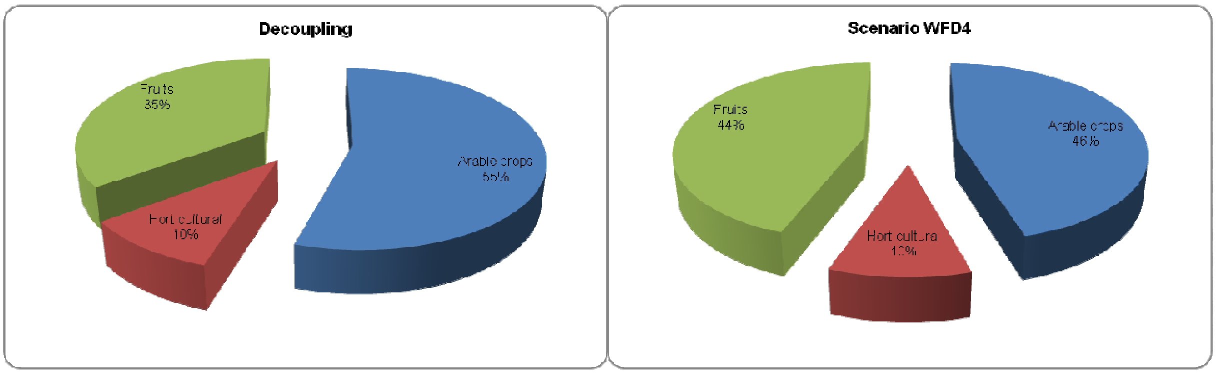


Figure 6.12: Land use in case of a higher water availability.

Table 6.8. Changes induced simulating scenario WFD4.

Parameters	Increasing Volumetric Water Tariffs (€ m^{-3})			
	0	**1**	**1.5**	**2**
Total area (ha)	119,127.95			
Arable crop occupation (ha)	54,289.81	54,903.21	76,044.81	79,692.21
Horticultural occupation (ha)	11,912.79	11,912.79	11,912.79	11,912.79
Fruit occupation (ha)	52,925.35	52,311.95	31,170.35	27,522.95
Total irrigated land (ha)	30,347.58	29,921.33	5,195.68	1,393.04
Land with Partial irrigation (ha)	7,010.99	6,930.16	4,644.79	1,393.04
Land with full irrigation (ha)	23,336.59	22,991.17	550.88	0
Water use (m^3 ha^{-1})	1,698.32	1,695.82	1,181.49	1,120.00
Farmer's income (€ ha^{-1})	1,954.04	1,505.13	831.84	748.53
RIB's returns (M€)	1.89	52.64	11.11	5.02
Soil Cover (%)	81.42	81.34	78.54	77.97

Regarding the environmental impacts, the soil cover due to such efficiency improvement raises around 1.50% equivalent to about 5 more days in which crops cover the soil over the year. Nonetheless, this ecological improvement is accompanied with an augmentation in the total availability of water, consequently an enhancement of irrigation; thus, irrigated land is amplified something like 54% (**Fig. 6.13**); however, water use by hectare is reduced approximately 1% which is a positive environmental impact for the district.

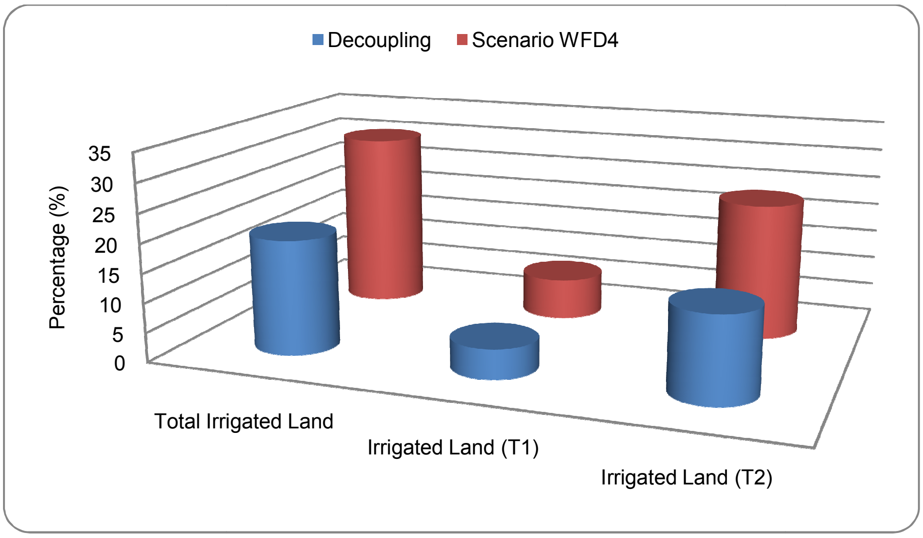


Figure 6.13: Change in irrigated land with respect to total area due to scenario WFD4.

6.4. Group III: Scenarios of water management

Through these simulations we will try to understand how different policies applied by the RIB would impact the future of agriculture in the area, water resources, the net agricultural product and consequently farmers' income that follow the same trend, and returns of the RIB. By this mean we can offer policy analysts some useful information upon which to build their future decisions. These policies are mainly based on modifying water quantity distributed to the farms, the total irrigable area, and the irrigable surface equipped with different delivery systems.

Intuitively, looking at the results of the baseline showing that more than 70% of the irrigable land is not irrigated, it could be said that increasing irrigable land served by different systems for water delivery (dp, dg1 and dg2). The reason is that a big amount of the water distributed by the RIB is lost in the channel systems as already explained. The quantity leftover to farmers is very little; which is an important constraint for irrigated agriculture. Therefore, any policy that the RIB will consider in the future should be implemented after an increase on the efficiency of the channel system in order to reduce water losses by percolation and to augment the quantity of the water distributed.

6.4.1. Scenario RIB1

The first simulation considers the amplification of the land served with continuous gravitational system of water delivery of around 12.5% (from 54,560 ha to 61,460 ha), accompanied with an increase of water availability approximately 66%. This expansion corresponds to the transformation of all the area served by gravitational and discontinuous system for water delivery in a continuous one.

First of all, the total cultivated area does not change but some structural changes are perceived at the level of land occupation given that arable crops will lose more than 20% of land use that will be dedicated for fruit production. These changes would lead to a change in the irrigated land; an amplification of 63.83% of this land is observed, divided between both irrigation techniques as follows: around 70% practicing full irrigation technique and about 45% complementary irrigation technique (**Fig. 6.14**).

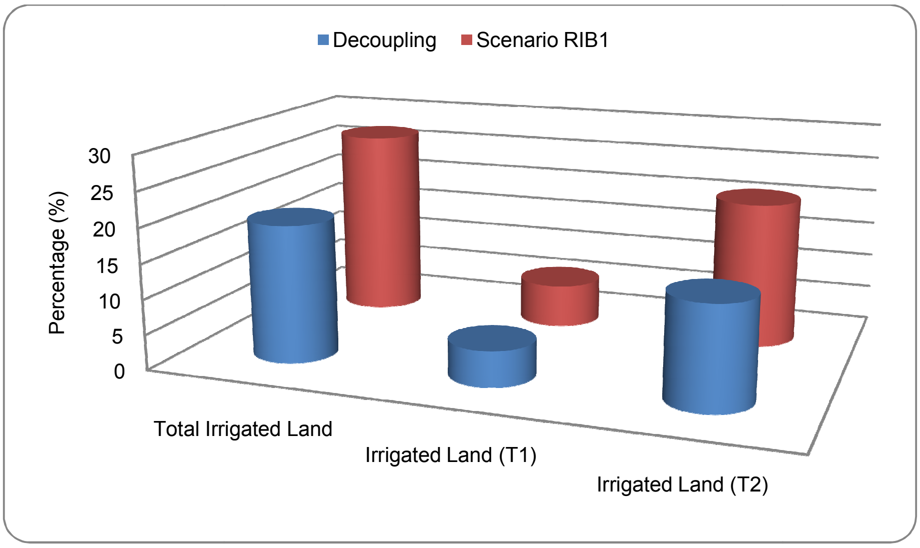


Figure 6.14: Change in irrigated land with respect to total area due to scenario RIB1.

We can detect a highly positive impact, compared to the reference scenario, on farmers' income which increases in the range of 38%, due to the certainty on the territory of water delivery to farmers this augmentation is also observed in the net agricultural product. Idem for the RIB returns which augment of approximately 5%. The combined impact of an increasing volumetric water tariff is detected by a direct decrease in farmers' income and water use, an increase followed by a decrease in the RIB's returns and in fruit occupation (**Tab. 6.9**).

The only negative impact of such a change that could be mentioned, even though not very significant, would be on the water resources where the water use increases from 1,648 m^3 ha^{-1} to 1,708 m^3 ha^{-1}, in terms of percentage it is around 1.44%; while soil cover gains some percentage points (little bit less than 2%).

Table 6.9. Impact of augmentation in irrigable area (scenario RIB1).

Parameters	Increasing Volumetric Water Tariff (€ m^{-3})			
	0	**0.2**	**0.5**	**1**
Total area (ha)	119,127.95			
Arable crop occupation (ha)	51,641.41	54,985.23	76,220.99	79,692.21
Horticultural occupation (ha)	11,912.79	11,912.79	11,912.79	11,912.79
Fruit occupation (ha)	55,573.75	52,229.93	30,994.17	27,522.95
Total irrigated land (ha)	32,135.58	29,860.56	4,932.88	1,393.04
Land with Partial irrigation (ha)	7,343.98	6,903.41	4,568.79	1,393.04
Land with full irrigation (ha)	24,791.60	22,957.15	364.09	0
Water use (m^3 ha^{-1})	1,708.51	1,696.21	1,162.81	1,120.00
Farmer's income (€ ha^{-1})	2,050.85	1,501.26	826.15	747.88
RIB's returns (M€)	1.98	52.63	10.58	5.09
Soil Cover (%)	81.76	81.33	78.48	77.97

6.4.2. Scenario RIB2

The expansion of the land covered by pressurized channel system for water delivery (dp) of the same amount of 12.5% will have almost no impact on land occupation, cropping pattern and water use while it will affect both the RIB's returns and farmers' income (**Tab. 6.10**). In this case, water use rises of 0.87% relative to an increase of the total availability of about 57%. An environmental improvement is observed due to an increase of the ecological indicator of soil cover of around 1.31%.

Table 6.10. Impact of increase in area covered by pressurized system (scenario RIB2).

Parameters	Increasing Volumetric Water Tariff (€ m^{-3})			
	0	**0.2**	**0.5**	**1**
Total area (ha)	119,127.95			
Arable crop occupation (ha)	54,160.01	54,903.24	76,045.04	79,692.28
Horticultural occupation (ha)	11,912.79	11,912.79	11,912.79	11,912.79
Fruit occupation (ha)	53,055.15	52,311.92	31,170.12	27,522.88
Total irrigated land (ha)	30,437.08	29,921.21	5,195.39	1,392.95
Land with Partial irrigation (ha)	7,028.01	6,930.05	4,644.68	1,392.95
Land with full irrigation (ha)	23,409.08	22,991.15	550.70	0
Water use (m^3 ha^{-1})	1,698.84	1,695.83	1,181.48	1,120.00
Farmer's income (€ ha^{-1})	1,958.23	1,504.47	831.55	748.24
RIB's returns (M€)	1.93	52.67	11.14	5.05
Soil Cover (%)	81.43	81.34	78.54	77.97

6.4.3. Scenario RIB3

Doubling land covered by pressurized channel system for water delivery, and raising the total water availability of something like 66% will augment farmers' income and water use per hectare of 1.30% and 1.40% respectively. Irrigable area increases of around 64% and most of this area will be fully irrigated.

The observed impacts are more significant in terms of RIB's returns and land use occupation whereas the RIB's returns will increase approximately 14%, and arable crops occupation will diminish of about 20%. Finally, a slight ecological improvement is observed as far as the soil cover indicator increases around 2% (**Tab. 6.11**).

Transforming the irrigable land to an area totally served by pressurized and continuous water delivery system (dp) could be another policy adopted by the RIB, that will lead to similar improvements in RIB's returns and farmers' income with more or less better percentages. But given the high cost for the implementation of such a system (Giannoccaro *et al.*, 2008) and the small difference in the improvement it could be appropriate to transform a part to pressurized and continuous irrigation system and another part to gravitational and continuous system.

Table 6.11. Impact of doubling the area covered by pressurized system (scenario RIB3).

Parameters	Increasing Volumetric Water Tariff (€ m^{-3})			
	0	0.2	0.5	1
Total area (ha)	119,127.95			
Arable crop occupation (ha)	51,628.24	54,903.44	76,046.55	79,692.73
Horticultural occupation (ha)	11,912.79	11,912.79	11,912.79	11,912.79
Fruit occupation (ha)	55,586.92	52,311.72	31,168.61	27,522.43
Total irrigated land (ha)	32,147.56	29,920.36	5,193.46	1,392.31
Land with Partial irrigation (ha)	7,361.77	6,929.36	4,643.93	1,392.32
Land with full irrigation (ha)	24,785.79	22,991.00	549.53	0
Water use (m^3 ha^{-1})	1,707.88	1,695.85	1,181.37	1,120.00
Farmer's income (€ ha^{-1})	2,051.39	1,503.60	829.59	746.32
RIB's returns (M€)	2.16	52.9	11.36	5.28
Soil Cover (%)	81.76	81.33	78.54	77.96

6.4.4. Scenario RIB4

Therefore, let us observe what the change in all irrigated areas can generate especially in terms of farmers' income, RIB's returns and water use. We assumed that the RIB is able to control the losses in the network and to reduce them up to 20% and modifies all the three areas served with irrigation water (dp, dg1 and dg2) to get the irrigation land covered only by pressurized and continuous gravitational systems of water delivery (dp: 15,000 ha and dg1: 104,129 ha). Results show that this policy could be interesting from different points of view with respect to the baseline scenario. Indeed, farmers' income is increased of about 65% which is the highest income got till now with different simulations, while the water use increased only around 2% and the irrigated land little bit less than 80% (**Tab. 6.12**). Even the ecological indicator for soil erosion is little bit higher than previous simulations which indicate a slight environmental improvement.

Table 6.12. Impact of augmentation in irrigable area (scenario RIB4).

Parameters	Increasing Volumetric Water Tariff (€ m^{-3})			
	0	**0.2**	**0.5**	**1**
Total area (ha)	119,129.00			
Arable crop occupation (ha)	46,887.77	54,968.28	76,045.85	79,693.01
Horticultural occupation (ha)	11,912.90	11,912.90	11,912.90	11,912.90
Fruit occupation (ha)	60,328.33	52,247.82	31,170.26	27,523.09
Total irrigated land (ha)	35,199.93	29,873.57	5,195.25	1,392.89
Land with Partial irrigation (ha)	7,977.03	6,909.00	4,644.66	1,392.89
Land with full irrigation (ha)	27,222.89	22,964.57	550.59	0
Water use (m^3 ha^{-1})	1,721.41	1,696.13	1,181.47	1,120.00
Farmer's income (€ ha^{-1})	2,440.69	1,717.44	1,045.19	961.89
RIB's returns (M€)	3.49	54.17	12.704	6.62
Soil Cover (%)	82.39	81.33	78.54	77.97

6.4.5. Scenarios RIB5 and RIB6

If the RIB decides also to modify the flat water tariff, RIB's returns will significantly change proportionally, given that other changes are not significant. For example, raising the tariff of about 15% of the actual one (Scenario RIB5), RIB's returns will increase of the same amount (15%), while the reduction of farmers' income is very irrelevant and is around 0.16% and land use, irrigated land and water use will remain stable. On the other hand, in Scenario RIB6 reducing water tariff of about 15% will decrease the RIB's returns of 15% and amplify farmers' income approximately 0.16%, but this change will not induce any modification in land use, irrigated land or water use neither a variation in the ecological indicator (**Tab. 6.13**).

For, this modification in water tariff could be a tool used by the RIB in case there is a need to directly increase the returns, without any investment in the actual systems and obviously without affecting farmers' income or even the structure of agriculture in the district. Or even this policy could be a transitional phase; to augment returns in order invest in other works of improvement of the channel systems. While lowering flat water tariffs could be a possible change imposed with the implementation of volumetric water pricing policy.

Table 6.13. Combined effect of modifying flat tariff and volumetric tariff.

Parameters	Increasing flat water tariff (Scenario RIB5)				Decreasing flat water tariff (Scenario RIB6)			
	Increasing Volumetric Water Tariffs (€ m^{-3})							
	0	**0.2**	**0.5**	**1**	**0**	**0.2**	**0.5**	**1**
Total area (ha)	119,127.95				119,127.95			
Arable crop occupation (ha)	65,295.60	65,295.60	76,220.99	79,692.21		65,295.60	76,220.99	79,692.21
Horticultural occupation (ha)	11,912.79	11,912.79	11,912.79	11,912.79	11,912.79	11,912.79	11,912.79	11,912.79
Fruit occupation (ha)	41,919.56	41,919.56	30,994.17	27,522.95	41,919.56	41,919.56	30,994.17	27,522.95
Total irrigated land (ha)	19,615.22	19,615.22	4,932.88	1,393.04	19,615.22	19,615.22	4,932.88	1,393.04
Land with Partial irrigation (ha)	5,059.05	5,059.05	4,568.79	1,393.04	5,059.05	5,059.05	4,568.79	1,393.04
Land with full irrigation (ha)	14,556.17	14,556.17	364.09	0	14,556.17	14,556.17	364.09	0
Water use (m^3 ha^{-1})	1,684.27	1,684.27	1,162.81	1,120.00	1,684.27	1,684.27	1,162.81	1,120.00
Farmer's income (€ ha^{-1})	1,481.83	1,204.51	824.36	746.09	1,486.71	1,209.39	829.25	750.97
RIB's returns (M€)	2.19	35.23	10.79	5.31	1.61	34.64	10.21	4.73
Soil Cover (%)	80.13	80.13	78.48	77.97	80.13	80.13	78.48	77.97

6.4.6. Scenarios RIB7 and RIB8

Finally, to analyze the changes that could generate a simulation with all the single measures studied previously grouped together, on land occupation, farmers' income, RIB's return and water use; we considered the following parameters:

- Change in water quantity.
- Expansion of irrigable land.
- Variation in flat water tariff (increase and decrease).

Given that a higher level of efficiency in distribution must be achieved in order to meet the requirements of WFD, we simulated an augmentation of 80% in water quantity equal to about 60.59 MCM in both scenarios (RIB5 and RIB6). We considered for these scenarios the possible changes in irrigable land as follows: the area covered by pressurized irrigation system raised to 15,000 ha plus 104,129.00 ha for land served continuous gravitational system. The variation in the flat water tariff in scenario RIB7 is an increase of 15% of this tariff, while in scenario RIB8 the tariff is decreased of 15%.

The changes that these simulations can produce are remarkable at the level or RIB's returns, augmented up to two times with respect to the baseline depending on the simulation. In all cases, income is augmented around 65%, fruit crops occupation expanded on behalf of arable crops approximately 28% and finally water use by hectare increased of 2.21%, this is accompanied with an augmentation of irrigated land in the order of 80% most of it done with a full irrigation technique (87%). Further, the simulations showed an environmental improvement as far as the ecological indicator increased something like 2.26%. These results as well as the impact of volumetric water pricing on this simulation are in **Table 6.14**.

Table 6.14. Combined effect of scenarios RIB7, RIB8 and volumetric tariff.

Parameters	Scenario RIB7				Scenario RIB8			
	Increasing Volumetric Water Tariffs (€ m^{-3})							
	0	0.2	0.5	1	0	0.2	0.5	1
Total area (ha)	119,129.00				119,129.00			
Arable crop occupation (ha)	46,887.77	54,968.28	76045.85	79693.01	46,887.77	54,968.28	76045.85	79693.01
Horticultural occupation (ha)	11,912.9	11,912.9	11,912.9	11,912.9	11,912.9	11,912.9	11,912.9	11,912.9
Fruit occupation (ha)	60,328.33	52,247.82	31,170.26	27,523.09	60,328.33	52,247.82	31,170.26	27,523.09
Total irrigated land (ha)	35,199.93	29,873.57	5,195.25	1,392.89	35,199.93	29,873.57	5,195.25	1,392.89
Land with Partial irrigation (ha)	977.03	6,909.00	4,644.66	1,392.89	977.03	6,909.00	4,644.66	1,392.89
Land with full irrigation (ha)	27,222.89	22,964.57	550.59	0	27,222.89	22,964.57	550.59	0
Water use (m^3 ha^{-1})	1,721.41	1,696.13	1,181.47	1,120.00	1,721.41	1,696.13	1,181.47	1,120.00
Farmer's income (€ ha^{-1})	2,445.18	1,721.94	1,049.68	966.38	2,436.20	1,712.95	1,040.70	957.40
RIB's returns (M€)	2.96	53.63	12.17	6.08	4.03	54.70	13.24	7.15
Soil Cover (%)	82.39	81.33	78.54	77.97	82.39	81.33	78.54	77.97

As a conclusion of these policies' changes we can realize that some of them are positive for the RIB and could increase its returns, others could improve farmers' income and others could save in water resources, but sometimes when a policy improves an aspect it could worsen another. Along this chapter we analyzed a lot of possible options the RIB could adopt but the best solution could be taken only by the decision makers who should know the priorities of the territory.

For instance, in different simulations, where there is an amplification of land occupied by a pressurized system of water delivery, there is highest returns for the RIB that could be up to 2 times the actual ones and highest incomes for farmers up to 65% (**Fig. 6.15**), but in the same time this increase could generate highest water uses. Yet, in all simulations changes in land occupation are around 20% which cannot be considered a significant change in the agricultural structure of the district. A comparative table that summarizes all the policies assessed and the major changes induced could help to overview the whole situation (**Tab. 6.15**).

From another side, transforming the irrigable area in a pressurized system of delivery could imply very high initial costs on the RIB for infrastructure. Thus, such a measure before implementation should be analyzed through a cost-benefit analysis to quantify these costs and compare them with returns and benefits that induce.

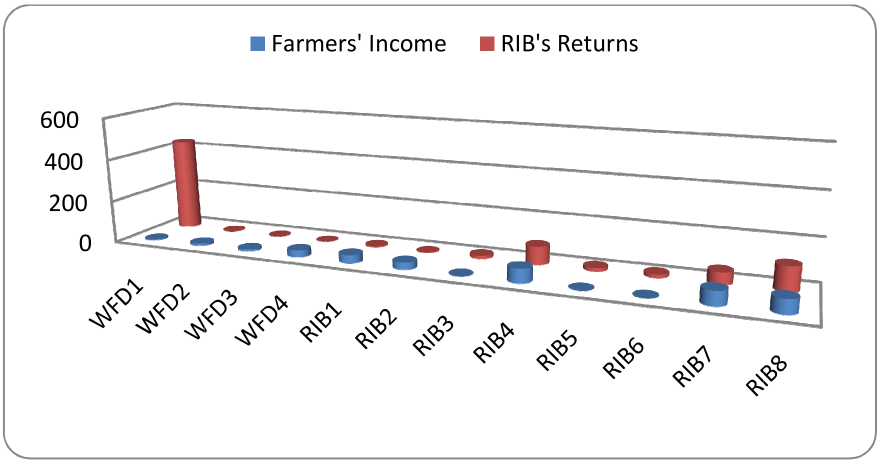


Figure 6.15: Changes implied by different scenarios on farms income and RIB returns.

Table 6.15. Changes between different policies with respect to the baseline.

Scenario[1]	Percentage Change in parameters (%)[2]						
	P1	P2	P3	P4	P5	P6	P7
WFD1	4.67 (↘)	435.19 (↗)	N	N	N	N	N
WFD2	10.72 (↘)	N	17.05 (↗)	N	20.56 (↗)	5.25 (↘)	0.36 (↗)
WFD3	10.24 (↘)	N	3.64 (↘)	20.00(↘)	16.98 (↘)	5.02 (↗)	0.41 (↘)
WFD4	31.65 (↗)	N	0.83 (↗)	56.01 (↗)	54.71 (↗)	16.86 (↘)	1.29 (↗)
RIB1	38.17 (↗)	4.11 (↗)	1.44 (↗)	66.19 (↗)	63.83 (↗)	20.91 (↗)	1.63 (↗)
RIB2	31.93 (↗)	1.82 (↗)	0.87 (↗)	56.51 (↗)	55.17 (↗)	17.05 (↘)	1.31 (↗)
RIB3	1.30 (↗)	13.82 (↗)	1.40 (↗)	66.19 (↗)	63.89 (↗)	20.93 (↘)	1.63 (↗)
RIB4	64.44 (↗)	84.31 (↗)	2.21 (↗)	83.41 (↗)	79.45 (↗)	28.19 (↘)	2.27 (↗)
RIB5	0.16 (↗)	15.32 (↘)	N	N	N	N	N
RIB6	0.16 (↗)	15.32 (↘)	N	N	N	N	N
RIB7	64.74 (↗)	56.12 (↗)	2.21 (↗)	83.41 (↗)	79.45 (↗)	28.19 (↘)	2.27 (↗)
RIB8	64.74 (↗)	112.5 (↗)	2.21 (↗)	83.41 (↗)	79.45 (↗)	28.19 (↘)	2.27 (↗)

(1): For scenarios' name check the previous paragraphs.

(2): The percentage change is observed with respect to the decoupling considered as baseline.

P1: Farm income.

P2: RIB's returns.

P3: Water use.

P4: Water availability.

P5: Irrigated area.

P6: Arable crops.

P7: Soil cover.

↗: Increase.

↘: Reduction.

N: Neutral.

CHAPTER VII

Conclusions

The scope of this dissertation was to analyze irrigation water management issues of the Renana RIB located in Emilia Romagna taking into consideration the quantitative aspects arising in a water scarcity context and some agricultural and water policy measures implemented. The recent reforms of the Common Agricultural Policy removing links between payments and production, the Water Framework Directive entailing qualitative and quantative water resources conservation and safeguarde measures and climate change producing accentuated water shortage are a great challenge for the management board that will have to cope in the future with a higher water demand and a lower availability.

In order to accomplish this task a mathematical stochastic model was designed and implemented using data collected from farms in the area and other local sources. These data were cross-checked and verified with stakeholders and decision makers at different levels. Through the calculation of appropriate indicators, the potential impacts of policy and water management measures have been evaluated in terms of economic results such as farmers' income, cost of water and RIB's revenue, and environmental consequences such as susceptibility to soil erosion and quantity of consumed water.

The first group of simulations concerned the CAP's reforms especially the implementation of the decoupling. Introducing decoupling, the EU removed links between public subsidies and production, changing farmers' incentives and providing a basic income support to farmers, who are further free to produce in response to market demand, instead of having to produce particular products to obtain subsidies. In our case, the direct response to decoupling was an increase in fruits production and consequently irrigated agriculture, but contrary to the expectations water use by hectare does not augment. Farmers' net income increases thus the social situation of local farmer; the ecological status of agricultural land and the environmental status of water resources improve given that water use by hectare decreased while irrigated land expanded.

The second group of simulation related to the reform in the water pricing policy according to the provisions of the WFD. As shown the introduction of a volumetric tariff is an effective tool to control water demand, and it could be very profitable to the RIB which will increases returns up to four times with respect to the current situation. However, imposing a volumetric water tariff will – at a certain threshold – transform agriculture in the district into rain fed dominated by arable crops (around 70%). In this case irrigated area completely disappears and no more water is used for irrigation. This tool is also effective in the case of decoupling. For instance, eventhough decoupling tends to increase irrigated area; implementing water pricing would provoke the opposite effect.

The third group of simulations concerns the measures adopted by the RIB to improve management of resources and services offered to farmers. In order to cope with water shortage affecting the Mediterranean area and to save and improve the status of water resources the RIB have the double role of increasing quantities distributed to farmers by improving the distribution efficiency through the channel system and reducing water quantities in cases of water shortage. Two measures were analized: economic incentives to farmers to improve application efficiency in irrigation and improvements of the distribution efficiency reducing percolation in the channels. Both measures were accompanied with an increase in the total water availability and led to an expansion in the irrigated area between 55.17% and 79.45%, an increase in water availability between 56.51% and 83.41% and in water use by hectare between 0.87% and 2.21%. In consequence, farmers' net income could increase up to 64.74% and the income of the RIB could reach little bit more than the double of the actual value.

Results have shown the advantages of irrigable land expansion and the positive impact that an increased water supply could add to the area. In terms of agricultural production, water could increase agricultural products due to yield response to irrigation especially for high value crops: the net income of farmers augment due to the double effect of yield response and to the shift to high value crops. In environmental terms water could add improvements to the agricultural landscape as the soil cover indicator shows. Besides, the increment in irrigable area has also benefits for the RIB's part that increases returns that could be doubled with respect to the actual returns, e.g. as in scenario RIB8 it reachs four times the actual value of returns in contrast with scenario WFD1. But once the volumetric water pricing is implemented as mentioned previously irrigable area begins to decrease as well as water use by hectare. At this level, the change in land use and crop occupation could have very harmful consequences on the environment the probability of erosion is higher.

Achieved results demonstrate the existence of a trade off between economic and environmental impacts that must be carefully considered. For example applying a volumetric water tariff increases RIB's returns more than four times but reduces farmers' income by 5%. Thus, scenarios RIB7 and RIB8 implying changes in both flat water tariff and irrigable land could be the second best option whereas they lead to an income augmentation of around 65% and returns of the RIB could double and positive ecological outcomes could be generated while the increment in water use is only about 2.20% when in some scenarios it could reach something like 17%.

On the other side, the results highlight that some policy measures could improve both ecological conditions, and farmers' economic welfare in the region. Such "win-win" scenarios were found when for instance farmers get economic incentives to invest in new water saving technologies in irrigation.

In order to cope with policies and to preserve the profitability and the efficiency in the management, the Renana RIB, where water distribution network is mainly based on open canals with a little pressurized area, should increase the distribution efficiency in the system and the potential availability of water by reducing losses. This should be followed by an expansion of the distribution network as it proved to be beneficial from many points of views. Volumetric water tariff could be implemented to control water demand depending on yearly water availability and the increased receipts of the RIB could be used to cover investment costs. However, the combined effects of decoupling and volumetric water tariff could increase the on-farm fixed costs and competitiveness and consequently could lead in the next years to the exclusion of small and marginal farms unable to meet such costs' increments. These farms will be constrained either to do extensive and rain fed crops with a very low profit, either to merge to form bigger farms with higher investment capacity or to stop agricultural activity and switch to other sectors.

While the model served as an appropriate tool for exploring "win-win" options for economic and ecological improvement, some level of uncertainty in the model results remains due to existing data limitations. Higher frequency data would significantly improve the model specifications. Moreover, due to the static nature of the model, it was not possible to include long-term effects of different policy measures and findings were limited to short-term benefits.

Finally, further studies are recommended firstly to understand the dynamic effects of different policy scenarios in the region, and to evaluate impacts their implementation. A follow up study could be useful in order to elicit the cost-benefit value of different measures especially for solutions requiring metering to value if it would be worsen implementing it or it may be costly and not socially profitable.

CHAPTER VIII

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ANNEXES

Annex 1: legislations in Water Resources

Table 1.1. Legislation of Emilia – Romagna region.

Legislation	Description
L.R. nº 35 14/11/1973	Public interventions for reforestation and hydraulic-forestry implementation of the regional territory
L.R. nº 25 06/07/1974	Refinancing of L.R. nº 35, 14/11/1973
L.R. nº 27 06/07/1974	Participation of the Region in hydraulic works in the water channels of Emilia – Romagna
L.R. nº 28 06/07/1974	Financing works in the regional aqueducts modified by L.R. nº 55 20/12/1974
L.R. nº 19 21/03/1975	To control and prevent atmospheric and hydraulic pollution
L.R. nº 26 26/04/1975	To realize depuration systems for discharge treatment
L.R. nº 21 05/06/1976	Financing costs of realization of the programme for optimal utilization and for protection of water resources
L.R. nº 24 01/07/1976	Refinancing L.R. nº 27, 06/08/1974
L.R. nº 7 13/03/1979	To protect Adriatic cost for environmental purposes
L.R. nº 25 06/08/1979	To protect and increase the marine fauna
L.R. nº 39 30/10/1979	Regarding emission of discharges in the sea water of the Adriatic
L.R. nº 6 22/01/1980	New measures to control and prevent atmospheric and hydraulic pollution
L.R. nº 19 24/03/1980	Updating article 2 of L. nº 650 about protecting water from pollution
L.R. nº 22 17/08/1981	Payments for holdings realizing water discharge depuration
L.R. nº 29 04/09/1981	To develop aquaculture
L.R. nº 7 29/01/1983	About public discharges
L.R. nº 9 01/02/1983	Reduction of the territorial and regional plan for water reorganization and protection

(Source: Internet 3, 2007).

Table 1.1. Legislation of Emilia – Romagna region (Continued).

Legislation	Description
L.R. nº 13 23/03/1984	Modifications and integration on L.R. nº 7 , 29/01/1983
L.R. nº 42 02/08/1984	New standards in term of Reclamation and Irrigation Boards
L.R. nº 42 28 /11/1986	Modifications and integration on L.R. nº 7, 29/01/1983
L.R. nº 16 23/04/1987	Integration on L.R. nº 42, 02/08/1984
L.R. nº 32 17/08/1988	Regarding mineral and thermal waters
L.R. nº 34 27/04/1990	Integrative standards on the treatment of urban and special discharges
L.R. nº 25 25/06/1992	Standards for the functioning of the basin authority “del reno”
L.R. nº 11 22/02/1993	Protection and development of the marine fauna
L.R. nº 14 29/03/1993	Institution of the regional basin authorities
L.R. nº 23 13/08/1999	Amending organic administrative Reclamation and Irrigation Boards. Amended by L.R. nº 1 28/01/2003
L.R. nº 25 06/09/1999	Cooperation between local entities for the organization of integrated hydraulic service and the management of urban discharges
L.R. nº 26 07/04/2000	Urgent measures in the organization of the reclamation and irrigation boards activities
L.R. nº 4 06/03/2007	Adjusting environmental standards.

(Source: Internet 3, 2007).

Table 1.2. Italian legislation.

Legislation	Description
R.D. nº 195 22/03/1900	Concerning reclamation matters
R.D. nº 523 25/07/1904	Concerning hydraulic plants of different categories
L. nº 744 13/07/1911	Standards for an Integrated Reclamation Boards
R.D. nº 3256 30/11/1923	Enlargement of the reclamation to irrigation public plants
R.D. nº 1775 11/12/1933	Unify laws about water and electrical plants
R.D. nº 215 13/02/1933	Standards for an Integrated Reclamation Boards
L. nº 230 12/06/1950	Concerning colonization and transformation of funds
L. nº 744 21/10/1950	Concerning colonization and transformation of funds
L. nº 184 19/03/1952	Plan for a systematic regulation of waters
L. nº 11 25/01/1962	Updating the plan for a systematic regulation of waters
L. nº 319 10/06/1976	Standards for prevention of water pollution
D.P.R nº 236 24/05/1988	Actuation of the EEC Directive nº 778 concerning water quality
L. nº 36 05/01/1994	Availability in hydraulic resources matters amended by L. nº 238, 18/02/1999
D.Lgs. nº 152 11/06/1994	To actuate most of the directives concerning water resources
D.Lgs nº 152 11/06/1999	Standards for prevention of water pollution

(Source: INEA, 2007(b)).

Table 1.3. European legislation from 1975 till 1999.

Directive	Description
75/440/EEC	Concerning the quality required of surface water intended for the abstraction of drinking
76/160/EEC	Concerning the Quality of Bathing Water
76/464/EEC	Water pollution by discharges of certain dangerous substances
77/795/EEC	Establishing a common procedure for the exchange of information on the quality of surface fresh water in the Community
78/659/EEC	On the quality of fresh waters needing protection or improvement in order to support fish life
79/923/EEC	On the quality required of shellfish waters
79/869/EEC	Concerning the methods of measurement and frequencies of sampling and analysis of surface water intended for the abstraction of drinking water
80/68/EEC	The protection of groundwater against pollution caused by certain dangerous substances
80/778/EEC	On the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters
82/176/EEC	On limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry
83/513/EEC	On limit values and quality objectives for cadmium discharges
84/156/EEC	On limit values and quality objectives for mercury discharges by sectors other than the chlor-alkali electrolysis industry
84/491/EEC	On limit values and quality objectives for discharges of hexachlorocyclohexane
86/280/EEC	On limit values and quality objectives for discharges of certain dangerous substances included in List I of the Annex to Directive 76/464/EEC, amended by Council Directives 88/347/EEC, 90/415/EEC and 91/692/EEC.
91/271/EEC	Concerning urban waste-water treatment amended by Council Directive 98/15/EC
91/676/EEC	Concerning the protection of waters against pollution caused by nitrates from agricultural sources
91/692/EEC	Standardizing and rationalizing reports on the implementation of certain Directives relating to the environment
92/446/EEC	Concerning questionnaires relating to Directives in the water sector
96/61/EC	Concerning integrated pollution prevention and control amended by Council Directive 2005/87/EC
98/83/EC	Drinking Water Directive (DWD): concerns the quality of water intended for human consumption.

(Source: Internet 2, 2007).

Table 1.4. European legislation from 2000 till the current.

Directive	Description
2000/60/EC	Water Framework directive (WFD) for river basin management
2003/40/EC	establishing the list, concentration limits and labeling requirements for the constituents of natural mineral waters and the conditions for using ozone-enriched air for the treatment of natural mineral waters and spring waters
2005/35/EC	Providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC
2006/7/EC	Concerning the management of bathing water quality
2006/11/EC	On pollution caused by certain dangerous substances discharged into the aquatic environment of the Community
2006/44/EC	On the quality of fresh waters needing protection or improvement in order to support fish life
2006/113/EC	On the quality required of shellfish waters
2006/118/EC	New groundwater directive, complements the Water Framework Directive and establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater.
Under preparation	Floods directive to reduce the risks of floods in Europe

(Source: Internet 2, 2007).

Annex 2: Objectives of Regional Rural Development Program

Table 2.1. Correlation matrix between RPRD – Objectives of Pillar 1, CSO and NSP.

Reg. CE 1698/05 – Objective art. 4 – punto 1.a

Improving the competitiveness of agriculture and forestry by supporting restructuring, development and innovation

RPRD – General objective of Pillar 1

Enforcement of competitiveness of agriculture and forestry system throughout the integration between subjects operating in different sectors, the innovation of products and processes, knowledge transfer, the quality intended as distinct and protected in the market

Common Strategic Orientation (CSO)			RPRD – Specific objectives of Pillar 1	National Strategic Priorities (NSP)			
Modernization, innovation and quality of food industry	Knowledge transfer	Investments in capital and human resource		Promotion of modernization and innovation of farms and integration of sectors	Consolidation and development of the quality of agriculture and forestry production	Increasing potential of infrastructural physical and telecommunication equipment	Improve entrepreneur and professional capacity of those assign to agriculture and forestry and maintain renewing of generation
	×	×	To increase the professionalism of farmers and those involved in the agricultural and forestry activity through integrated actions of formation, information and consulting, to supply support to the acquaintance and the information dissemination	×			×
×		×	To consolidate and stabilize the income of agricultural and forestry sector, improving work conditions, stimulating the modernization and technological innovation	×			
		×	To support the renewing of generations in agriculture sustaining either the settlement of young and professional farmers or the structural adaptation of holdings	×			
×	×	×	To increase and consolidate the degree of integration and innovation of food technology sectors and to promote the aggregation of entreprises	×	×		
×	×	×	To promote the development of new products, processes and technologies as well depending on the necessity, to stimulate the realization of agro energetic systems	×			
×	×		To support farmers' participation to quality systems, to inform consumers and promote the peculiarity of quality production	×	×		
×		×	Sustain rationalization and innovation of processes in the transformation and commercialization segment of agricultural and forestry products to guarantee the increasing of added value	×			
×	×	×	Promote restructuring productive non competitive compartments respecting an internationalized market	×	×		

(Source: RPRD, 2007).

Table 2.2. Correlation matrix between RPRD – Objectives of Pillar 2, CSO and NSP.

Reg. CE 1698/05 – Objective art. 4 – punto 1.b

Improving the environment and the countryside by supporting land management

⇩

RPRD – General objective of Pillar 2

To support a sustainable allocation and management of agriculture and forestry to increase competitiveness and social cohesion of the regional system

⇩

Common Strategic Orientation (CSO): Water regimes	CSO: Biodiversity and protection of agricultural and forestry systems of high natural value and agricultural landscapes	CSO: Climatic changes	**RPRD – Specific objectives of Pillar 2**	National Strategic Priorities (NSP): Biodiversity conservation and protection and diffusion of agro-forestry systems of high natural value	NSP: Qualitative and quantitative protection of ground and surface water resources	NSP: Reduction of greenhouse effect gases	NSP: Protection of the territory
×			Quantitative and qualitative protection of water resource		×		
			To protect soil by blocking hydro geological shortage, erosion and chemical contamination				×
	×		To preserve and value biodiversity of species and habitats of agricultural territory, support a correct management of Nature 2000 areas, to support and develop agricultural and forestry systems of high naturalistic value	×			
	×		To preserve genetic diversity of agriculture	×			
	×		To preserve and value agricultural landscape				×
		×	To contribute at the attenuation of climatic change and the improvement of air quality			×	
			To support methods and conditions of optimal livestock reproduction for animal welfare				
	×		Maintaining sustainable agricultural activity in less favored areas				×

(Source: RPRD, 2007).

Table 2.3. Correlation matrix between RPRD – Objectives of Pillar 3, CSO and NSP.

Reg. CE 1698/05 – Objective art. 4 – punto 1.c

Improving the quality of life in rural areas and encouraging diversification of rural economic activity

⇩

RPRD – General objective of Pillar 3

To maintain a sustainable agricultural and forestry management and utilization of the territory and its natural resources to enhance competitiveness and the social cohesion of the regional system

⇩

Common Strategic Orientation (CSO)			National Strategic Priorities (NSP)	
Creation of job opportunities	Creation of growth environment	**RPRD – Specific objectives of Pillar 3**	Maintenance and/or creation of job opportunities and of revenue in countryside	Improvement of attractiveness for rural population and activities
×	×	Development of competitiveness of farms	×	
	×	Increasing the rural environmental attraction as a center for residence and investments		×
×	×	Valuing and developing the human capital in a vision of projection and organization of strategies for integrated local development		

(Source: RPRD, 2007).

Table 2.4. Correlation matrix between RPRD – Objectives of Pillar 4, CSO and NSP.

Reg. CE 1698/05

Implementation of Leader approach in the mainstream of the rural development program

RPRD – General objective of Pillar 4

To promote a qualitative rural environment and an integrated development strategy that praise the multifunctional rule of agriculture, through the reorganization of productive factors of farms, orienting them to activities complementary to the primary one and enhancing economic, social and environmental functions

Common Strategic Orientation (CSO)			National Strategic Priorities (NSP)	
Improving the governance	Mobilization of endogenous development potential of rural areas	**RPRD – Specific objectives of Pillar 4**	Reinforce the projection and management capacity	Valuing territorial endogenous resources
×		Consolidate a governance for the rural development intervention through the Local Action Groups (LAG), extend and ameliorate the co participatory approach	×	
	×	Increase the entrepreneur participation to develop economic valorization initiatives of the territory and its resources		×
	×	Determining, valuing and mobilization of endogenous potentials beginning from agricultural and natural ones, to improve competitiveness of territorial system of farms, sectors and fields of the countryside at the national and international markets		×
	×	Increasing social participation to development projections finalized to unexpressed resources explication, at the engagement of local communities and the reinforcement of dialogue between civil society and local institution	×	
×		Research and perfection of extra-territorial relations for initiatives exchange as well as to import stimulation of innovation		

(Source: RPRD, 2007).

Annex 3: CAP Pillars

Table 3.1. Summary of measures and actions for the 1st pillar.

Pillar	Measure code	Measure	Action
1st pillar: Improving the competitiveness of agriculture and forestry	111	Vocational training and information actions	1. Training and education for agri-forestry farms 2. Support for technicians for training and education
	112	Setting up of young farmer	
	114	Use of advisory services by farmers and forest holders	
	121	Modernization of agricultural holdings	
	122	Improving the economic value of forests	
	123	Adding value to agricultural and forestry products	1. The processing and/or marketing of products 2. Technological improvement of forestry holdings
	124	Cooperation for development of new products, processes and technologies in the agriculture and food sector and in the forestry sector	
	132	Supporting farmers who participate in food quality schemes	
	133	Supporting producer groups for information and promotion activities for products under food quality schemes	

(Source: RPRD, 2007).

Table 3.2. Summary of measures and actions for the 2nd pillar.

Pillar	Measure code	Measure	Action
2nd pillar: Improving the environment and the countryside	211	Mountain areas Compensatory Allowances Schemes	
	212	Less Favoured Areas Compensatory Allowances Schemes	
	214	Agri-environmental payments	1. Integrated Crop Management Schemes 2. Organic Farming Schemes 3. Grassland management schemes for soil and water protection 4. Maintaining soil organic matter 5. Herbs plantations for energy 6. Soil management 7. Promotion and utilization of effluents in non vulnerable 8. Minimum tillage and extensive grassland farming 9. Restoration and/or conservation of natural and semi-natural spaces and agricultural landscape 10. Withdrawal of seeds from production for environmental scopes 11. Agro biodiversity, protection of genetic characteristics of local animal variety of agricultural interest for the soil
	215	Animal welfare payments	
	216	Support for non-productive investments	1. Public access and faunal management 2. Increasing the public welfare value of high natural value areas
	221	Afforestation of agricultural land	1. Support of permanent forests 2. Supporting arboreal plantations of medium-long rotation cycle 3. Supporting arboreal plantations of short rotation cycle, eco-compatible 4. Supporting arboreal plantations of short rotation cycle for biomass production
	225	Forest environment compensation	
	227	Support to non-productive forestry investments	

(Source: RPRD, 2007).

Table 3.3. Summary of measures and actions for the 3rd pillar.

Pillar	Measure code	Measure	Action
3rd pillar: Improving the quality of life in rural areas and encouraging diversification of rural economy	311	Diversification into non-agricultural activities	1. Restructuring of rural holdings and open spaces, acquisition of machinery designated for agro tourism (including didactic activities) 2. Restructuring of habitable historical or typical rural holdings for tourism hospitality of bed and breakfast 3. Interventions for the faunal management compatible with the objectives of RL 8/94 4. Realization of systems for the production, utilization and selling of energy and/or heat
	313	Encouragement of touristic activities	
	321	Basic services for the economy and rural population	1. Optimization rural aqueduct systems 2. Improving local rural viability 3. Realization of public systems for energy production from local biomass
	322	Village renewal and development	1. Recuperation of rural buildings for collective activities, tourism, cultural activities and for services 2. Recuperation of typical rural holdings for habitation aims for the hospitality of agricultural workers
	323	Conservation and upgrading of the rural heritage	
	331	Training and information for economic operators	
	341	Skills-acquisition and animation measure	

(Source: RPRD, 2007).

Table 3.4. Summary of measures and actions for the 4th pillar.

Pillar	Measure code	Measure	Action
4th pillar: Implementation of Leader approach	411	Competitiveness	1. Activation with Leader of Measure 111; 2. Activation with Leader of Measure 114; 3. Activation with Leader of Measure 121; 4. Activation with Leader of Measure 122; 5. Activation with Leader of Measure 123; 6. Activation with Leader of Measure 132; 7. Performance of integrated and multisectoral strategies
	412	Environmental and territorial qualification	1. Activation with Leader of Measure 214; 2. Activation with Leader of Measure 215; 3. Activation with Leader of Measure 216; 4. Activation with Leader of Measure 221; 5. Activation with Leader of Measure 225; 6. Activation with Leader of Measure 227; 7. Performance of integrated and multisectoral strategies
	413	Improvement of standard living and diversification of economic actitivies	8. Activation with Leader of Measure 311; 9. Activation with Leader of Measure 313; 10. Activation with Leader of Measure 321; 11. Activation with Leader of Measure 322; 12. Activation with Leader of Measure 323; 13. Activation with Leader of Measure 331; 14. Performance of integrated and multisectoral strategies
	421	Implementing transnational and international co-operation projects	
	431	Running the Local Action Group	

(Source: RPRD, 2007).

Annex 4: GVP, land use and production in Emilia Romagna

Crop	Surface			Yield			Collected Prod.			Price			PLV		
	(Ha)			(100 Kg ha^{-1})			(100 Kg)			€ 100.Kg^{-1}			M€		
Cereals	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Bread Wheat	176800	164450	193840	65.1	63.8	49.3	11507780	10494720	9550930	12.00	14.00	23.30	138.09	146.93	222.54
Durum Wheat	22256	32190	46467	66.1	60.4	49.3	1470480	1943800	2292935	13.80	16.50	29.20	20.29	32.07	66.95
Barley	33460	36800	35230	50.7	51.6	45.6	1695960	1899950	1608210	11.40	12.80	21.50	19.33	24.32	34.58
Rice	5813	6495	7405	57.4	55.4	56.3	333938	360030	416803	25.00	29.00	29.20	8.35	10.44	12.17
Maize	109086	109540	101120	86.3	80.5	84.7	9409152	8819673	8566156	11.80	14.50	21.20	111.03	127.89	181.60
Sorghum	19509	24370	18000	65.4	63.4	65.2	1275450	1544650	1173220	11.00	12.80	19.80	14.03	19.77	23.23
Total Cereals	**366924**	**373845**	**402062**				**25692760**	**25062823**	**23608254**				**337.55**	**387.72**	**562.03**
Horticulture	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Potatoes	6665	7018	7716	361.6	356.6	332.0	2410083	2502645	2561679	13.50	22.00	24.00	32.54	55.06	61.48
Common bean	4508	4386	4402	93.3	87.6	93.6	420700	384210	412036	60.50	50.50	55.00	25.45	19.40	22.66
Pea	4170	4128	4023	72.5	78.8	69.5	302304	325300	279678	26.00	25.50	24.50	7.86	8.30	6.85
Industrial tomato	26639	23496	22310	601.8	624.7	655.7	16031480	14677555	14629363	6.70	6.30	7.70	107.41	92.47	112.65
Garlic	276	281	414	110.3	108.3	107.2	30445	30440	44377	130.00	170.00	200.00	3.96	5.17	8.88
Onion	2494	2949	2995	390.7	378.3	352.5	974350	1115720	1055826	11.00	14.00	22.00	10.72	15.62	23.23
Melon	1390	1455	1613	304.3	294.1	295.6	422985	427985	476450	24.00	40.00	35.00	10.15	17.12	16.68
Squirting cucumber	1561	1575	1535	425.6	455.7	438.2	664428	717760	672692	6.00	20.00	13.00	3.99	14.36	8.74
Asparagus	955	917	846	62	58.2	66.3	59243	53381	56117	150.00	165.00	175.00	8.89	8.81	9.82
Strawberry	683	603	594	272.1	258.0	253.0	185850	155597	150290	155.00	140.00	130.00	28.81	21.78	19.54

Zucche & zucchini	1063	1118	1164	228.9	236.7	248.6	243346	264675	289340	54.00	49.00	50.00	13.14	12.97	14.47
Lettuce	1445	1406	1388	308.2	309.5	310.7	445288	435200	431261	33.50	32.00	35.00	14.92	13.93	15.09
Fennel	253	209	200	286.4	285.8	263.5	72460	59740	52690	28.50	30.20	28.20	2.07	1.80	1.49
Total Horticulture	**52102**	**49541**	**49200**				**22262962**	**21150208**	**21111799**				**441.04**	**445.87**	**476.42**
Industrial Crops	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Sugar beet	82762	32414	32906	571.5	546.9	558.1	47298.397	17728048	18366173	3.68	3.81	4.28	173.95	67.54	78.61
Soybean	18722	34610	16978	39.1	24.0	22.7	731626	829420	385970	20.80	20.80	34.30	15.22	17.25	13.24
Sunflower	6423	11230	7038	28.6	25.2	26.8	183404	282500	188660	20.60	19.30	35.00	3.78	5.45	6.60
Total Ind. Crops	**107907**	**78254**	**56922**				**48213427**	**18839968**	**18940803**				**193.06**	**90.36**	**99.16**
Fruit Crops	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Apple	5404	5310	5444	311.1	300.6	288.9	1681405	1596055	1572909	22.00	25.00	35.00	36.99	39.90	55.05
Pear	23383	23451	22974	271.5	267.5	250.8	6347890	6273023	5762454	43.00	40.50	45.00	272.96	254.06	259.31
Peach	10908	10579	10131	223.3	224.9	214.6	2435521	2379290	2174524	22.00	42.00	42.00	53.58	99.93	91.33
Nectarine	13366	13176	13232	238.0	233.0	206.5	3181536	3070462	2732120	21.00	41.00	42.00	66.81	125.89	114.75
Apricot	4377	4293	4226	144.8	166.5	138.6	633977	714851	585631	50.00	60.00	70.00	31.70	42.89	40.99
Cherry	1770	1742	1780	63.8	60.0	68.0	113014	104570	120976	190.00	210.00	220.00	21.47	21.96	26.61
Plum	4174	4163	4121	158.6	157.9	149.6	662122	657265	616598	40.00	52.00	55.00	26.48	34.18	33.91
Kiwi	2783	2754	2789	198.7	207.2	185.6	553050	570739	517551	42.50	40.00	40.00	23.50	22.83	20.70
Persimmon & Kaki	1134	1122	1084	149.9	156.7	142.7	169976	175827	154733	32.50	29.00	38.50	5.52	5.10	5.96
Total Fruit crops	**67299**	**66590**	**65781**				**15778491**	**15542082**	**14237496**				**568.86**	**677.77**	**679.73**