Conservation scenarios for olive farming on sloping land in the Mediterranean

Luuk Fleskens

Promotor: Prof. Dr. Ir. L. Stroosnijder
Hoogleraar Erosie en Bodem & Waterconservering

Co-promotor: Dr. Ir. J. de Graaff
Universitair hoofddocent bij de leerstoelgroep Erosie en Bodem & Waterconservering

Promotiecommissie:	Prof. Dr. Ir. E.H. Bulte	Wageningen Universiteit
	Prof. Dr. Ir. A.P.J. Mol	Wageningen Universiteit
	Dr. Ir. E.E. van Loon	Universiteit van Amsterdam
	Prof. Dr. M.F.R. Duarte	Instituto Superior de Agronomia, Lissabon, Portugal

Dit onderzoek is uitgevoerd binnen de C.T. de Wit onderzoeksschool Production Ecology and Resource Conservation (PE&RC)

Conservation scenarios for olive farming on sloping land in the Mediterranean

Luuk Fleskens

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit
Prof. Dr. M. J. Kropff,
in het openbaar te verdedigen
op vrijdag 7 september 2007
des ochtends te 11:00 uur in de Aula

Fleskens, L., 2007
Conservation scenarios for olive farming on sloping land in the Mediterranean
Doctoral Thesis Wageningen University – with ref. – with summary in English and Dutch

ISBN: 978-90-8504-717-9

Key words: olive, multifunctionality, natural resource conservation, scenario analysis

Acknowledgements

The future is uncertain. In retrospective, this certainly applies to the time prior to embarking upon this PhD research. I had worked on two EU research projects which had finished and we were setting our chances at acquiring EU-funding for a third, more ambitious project. When assembling the work plan, it occurred to us that disciplinary niches were well served by each of the five southern European partners, and the role for the Erosion and Soil & Water Conservation Group of Wageningen University next to being co-ordinator would be supporting research across, and synthesizing results from various disciplines. Puzzled at the qualifications sought in a candidate to do the job I asked my co-promoter, Jan de Graaff, “Who can do the job?” The unexpected answer was: “You for example!”

When the negotiations with the EU turned out favourably and the Olivero project was bound to be kicked off, I accepted the position, taking the intention to develop a PhD thesis on the project for granted as a mere part of the work. My wife Carla, smarter than me, exclaimed “you what?!” She could not believe I took the aim to complete a PhD so lightly – without discussing or even mentioning it beforehand.

Both Jan’s and Carla’s opinion strongly marked my thoughts. My promoter, Leo Stroosnijder, added that it would be a challenge to complete a PhD about multiple disciplines and across multiple research areas. I started to realize I had taken on a major task with uncertain outcome. Bleak and doom scenarios appeared in my imagination, but Olivero’s are adapted to harsh conditions, just like olive trees can tolerate hostile environments. Nevertheless they need to find fertile soil between the rocks and proper care to produce fruits.

The farmers growing the tree, Leo and Jan, had divided the tasks. Leo managed to keep the soil fertile, sometimes by pouring in manure, other times by tilling the land and allowing water and nutrients to reach the roots. Jan closely monitored the tree’s development, regularly taking leaf and fruit samples for analysis – long before maturity. Sometimes, a rough pruning was necessary to keep the tree productive. Leo, your ability to structure work and keeping overview has inspired me very much. You always challenged me and other Olivero’s to make bold statements, without the annoying ‘yes, but’s’ and ‘only if’s’ and I believe this attitude has greatly benefited the Olivero project, and my work in particular. Jan, your untiring support is truly amazing! It has been a true pleasure to work intensively together on the Olivero project, from its conception to its finale (and on the Wahia project and the Impact assessment course). Your creative solutions to administrative and scientific difficulties have oiled the smooth progress of the project and the completion of my thesis.

The Olivero project constituted a stimulating scientific and social environment. From the kick-off meeting on Crete to the final seminar in Lisbon, it has been a rewarding experience. In each country I tasted the ‘best olive oil in the world’ and all competed for the latest dinner time in the evening. While the winner of the latter competition surely was Spain, I will not express any opinion on the quality of olive oil in the different partner countries. I thank the teams led by dr. Ioannis Metzidakis (Crete), prof. Cristos Xiloyannis (Basilicata/Salerno), dr. Armando Martínez Raya (Granada/Jaèn), dr. Elias Fereres and dr. José Gómez (Córdoba) and dr. Filomena Duarte (Tras-os-Montes) for the fruitful collaboration. The financial support by the EU under project number QLK-CT2002-01841 is also gratefully acknowledged.

Apart from the project meetings I undertook working visits to Italy and Portugal. In Italy, Assunta Maria Palese, Guisseppe Celano, Mariafara Favia, Bruno Basso, Mariana Amato, Vito Martielli and others assured productive and pleasant visits, with lots of field trips and interesting discussions. Molto grazie! In Portugal, I would like to thank Inês Mansinho, Madalena Barreira, Nádia Jones, Carla Lúcio, Isabel Ramires, Ana Sá and António Nunes of ISA/DEASR Lisbon, Domingos Amaro, ex-director of the PNDI Natural Park and Fernando Martins, ex-director of DRATM. João Lopes and Francisco Pavão of the latter institution provided much useful information on regional olive growing. Dr. Tomás de Figueiredo of IPB Bragança closely collaborated in erosion field work. Muito obrigado! The farmers Paolo Puciarelli and José de Carvalho Neto generously allowed us to install runoff plots in their groves, respectively at Caggiano, Italy and Mascarenhas, Portugal.

Although much of the work undertaken simultaneously in Tunisia did not make it into this thesis, I am indebted to dr. Habib Snane and dr. Mohammed Mechergui of INAT Tunis for the interest shown in elaborating a joint research proposal. The assistance of CRDA Kairouan is also highly appreciated. Merci beaucoup!

Many MSc students contributed to this thesis by undertaking field research in the different countries. The efforts of Victor Bayona, Rut Aspizua and Mariana Bolaños in Spain, of Sander van Rooij (Utrecht University), Irmgard Eicher and Katelijne Stevens in Portugal, of Veerle van Waesberghe (ISTOM Paris) in Tunisia, of David Verspeek in Italy, of Arnold Brouwer in Portugal and Italy, of Dai Min in The Netherlands and of Ioannis Papanagiotou in Greece are all gratefully acknowledged.

At the Erosion and Soil & Water Conservation Group, first at De Nieuwlanden and later at the Atlas building, I appreciated the very nice atmosphere among colleagues. Leo, Coen, Jan, Geert, Wim, Dirk, Piet, Saskia F, Saskia K, Aad, Michel, Anton, Jakolien, Monique, Helena, Olga, Ferco, Jantiene, Cathelijne, Rina, Tony and Jolanda: I enjoyed working with you very much. My longstanding former roommate Michel deserves a big thanks for his excellent assistance in getting this thesis ready for publishing. The ‘third floor’ at De Nieuwlanden often was completed by many foreign PhD students, all of whom I would like to thank as well, in particular Robert and Elysée from Burkina Faso, Bezayehu from Ethiopia and León from Rwanda who became good friends. The coffee and tea breaks in Atlas yet have to become institutionalized – although I must admit that personally I was often absent during the final stages of completion of this PhD.

At Wageningen University, dr. Justus Wesseler and dr. Rob Schipper provided advice on economics and using GAMS respectively. I also appreciated the courses organized by the PE&RC Graduate School. Particularly the course of prof. Carlos Romero from UCM Madrid on multi-criteria decision making was a real stimulus for developing the scenario simulation model for this research.

Life goes on during a PhD. Many thanks to all friends, nearby and abroad, for their company, lots of games played, or (remote) support. A special word of thanks to my friend and paranymph Etienne, who shared much of the ups and downs arising during a PhD, and in life in general. The support of my family in The Netherlands and Mozambique has been enduring and inspiring. I thank my sister Janneke and brothers and sisters in law Jan, Consolação and Puyer, and my late sister in law Mirela who died much too young. Também agradeço os meus sogros pela confiança em mim ao longo dos anos, e o supporte durante a finalização desta tèse.

My parents, Luud en Agnes, I don't know how I can thank you for raising me the way you did. The curiosity you stimulated in me, and the respect for nature with which you brought me up essentially form the roots of this scientific work. I also acknowledge your more tangible contributions in the form of discussing ideas and checking the Dutch summary.

Finally, my dear wife Carla and children Sara and Robin. You have had to cope with a serious shortage of attention. Carla, the many nights I worked until late, or went to bed only to find out I felt the urge to wake up again and put thoughts on paper or store them in the less volatile digital memory of a computer made you feel very lonely. Sincere but false promises that chapters would be ready in a number of days often drove you to despair. It is not easy to find the right balance between work and family, but I am the first to admit that especially in the final year there has not been a balance at all. Although I know that your answer to the question not asked would have been 'Yes, go ahead!', you deserve a well-earned holidays with me (partially) making up for the time lost. The same applies to Sara and Robin. You rarely complained, but suffered a lack of attention. I will never forget the repeated question: "Papa, wanneer is je artikel klaar?" Although you did not understand what drove your father to be always behind the computer, I dedicate this book to you.

Luuk

Bennekom / Nampula, July 2007

Table of contents

Chapter 1

Introduction

1. Introduction

1.1. Olive cultivation on sloping land

Olive plantation or production systems on sloping and mountainous land in the Mediterranean have both been accredited (e.g. Kosmas et al., 1997; Arhonditsis et al., 2000) and criticised (e.g. Laguna and Giraldéz, 1990; Pastor and Castro, 1995; WWF/Birdlife International, 2001) for their impact on the natural resource base, with an especially ambiguous role reserved for their record on soil erosion. As there exists a wide variety of such systems (Hofmeister, 1971; Beaufoy, 2001) this may not come as a surprise. However, their future is uncertain. While since Roman times, these systems formed a major source of income and employment and olive production was economically and environmentally sustainable, in some regions they are presently affected by emigration of its population and fierce competition from lowland plantations or even from other countries. This comparative disadvantage has led to a decreased interest in farming, ultimately culminating in abandonment (MacDonald et al., 2000). A number of causes can be indicated for this: the steep and often fragmented fields are difficult to mechanise and hand labour is getting both increasingly scarce and more expensive. These regions are often weakly developed and access is difficult. The population is ageing and lacks dynamism. In other areas where conditions are more favourable or where labour is less costly and still amply available, olive cultivation has spread at the cost of forested land or onto steep slopes. In southern Europe this tendency has been exacerbated by EU production subsidies under the Common Agricultural Policy (CAP) regime (de Graaff and Eppink, 1999; Beaufoy, 2000). Continuing expansion of olive growing area in other Mediterranean countries (Tunisia, Syria, Turkey, Morocco) suggests that the move towards marginal areas is omnipresent throughout the Mediterranean.

Both abandonment and expansion processes have been detrimental to the environment in various ways. This fact was recognised and policy changes were proposed in the EU (CEC, 1997), to become effective within a broader strategy envisaged for sustainable rural development (European Economy, 1997), among others through cross-compliance and agri-environmental schemes. However, policy change has only been materialized in 2005; before the change production subsidies occupied the lion share of olive farmer aid (WWF/Birdlife International, 2001). While agri-environmental policy has had an important impact on the landscape of some EU member countries, it has not yet received much attention in Mediterranean member states (Whitby, 2000) and probably even less so in non-EU members (e.g. Turkey: Tunalioglu and Gükçe, 2001). Tunisia has a long record of experience in combating desertification through soil and water conservation and olive orchards have been expanded onto treated areas (DGPA/ONH, 1996), although disregard of traditional soil and water conservation techniques has also been reported (Missaoui, 1996).

Looking at the changes the olive production systems have undergone in the past decades, the questions comes up which functions they (should) perform.

1.2. Addressing multifunctionality

Fundamentally, new policies are based on the recognition that the environment (air, water, soil) fulfils various functions vital to human well-being (either directly or indirectly), and that degradation of the environment leads inevitably and irreversibly to a decreased potential to do so. Two broad models of the relation between agriculture and environment have gained momentum among researchers and policy-makers: the impact model (i.e. negative externalities directly related to agriculture) and the public goods model (i.e. environmental attributes or positive externalities jointly produced alongside with agricultural production) (Lowe and Baldock, 2000). The latter model has received considerable attention in Europe, where it is referred to as the ‘European Model of Agriculture’.

While the multifunctional nature of agriculture has been much debated, an apparent lacuna in the literature is a study operationalising the concept (Brandt and Vejre, 2004). Moreover, the absence of studies advocating analysis of multiple functions in the decision-making process is surprising (e.g. Hall et al., 2004). To assess the multiple functions of agriculture, one should first know what functions can be distinguished and in what way they present value to mankind. De Groot (1992; 2002) developed a framework to relate value to functions of nature, considering 37 environmental functions in four groups. He defined ‘function’ as ‘the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly’. For agro-ecosystems (historically) modified by human beings to provide certain functions, the definition of ‘function’ needs to be broadened to include the socio-economic dimension of such systems in which nature and culture co-evolved. There is an important gain to be obtained from integrated analysis over the conventional approach where the environmental question is broken into specific, seemingly unlinked boxes (Marsden et al., 2001).

Multifunctionality of olive cultivation has already been the topic of research from various angles, such as ecology (Cirio, 1997; Guzmán Álvarez, 1999), history (Marathianou, 2000), landscape planning (Grove and Rackham, 1993; Makhzoumi, 1997), sociology (Alonso Mielgo et al., 2001), organic agriculture (Kabourakis, 1996; 1999) and tourism development (Loumou et al., 2000). Olive trees are closely associated with an extensive tradition of a wide range of soil and water conservation techniques (Baldy, 1997; Missaoui, 1996; de Graaff and Ouessar, 2002). More recently, improved crop management (Tombesi et al., 1996; Rallo Romero, 1998), land husbandry systems (Pastor and Castro, 1995; Gómez et al., 1999; Gómez et al., 2001; Martínez Raya et al., 2002; Mollenhauer et al., 2002) and (supplementary) irrigation systems (Michelakis et al., 1996; Pastor et al., 1998, Fernández and Moreno, 1999; Palomo et al., 2002) in olive cultivation have received considerable attention.

In the Mediterranean, olive oil generates direct income for about 7 million families and indirectly supports 30-35 million families in less favoured areas (Bonazzi, 1997). The uncertain future addressed in Section 1.1 is probably not felt in the same way in the different countries. Olive production in Italy had a hard time competing with especially Greece and Spain (which countries accessed the EU at a later date) due to relatively high wage levels (Leone, 2000). Portugal has a predominance of traditional olive growing systems with low production levels (Beaufoy, 2001; Fleskens and de Graaff, 2001). And Tunisia faces both most unfavourable climatic conditions and trade inequalities with the EU as its major export market, while lacking the funds available under the CAP regime. To overcome their specific problems and take advantage of comparative opportunities, it is clear that functions of specific olive production systems will be valued differently in each of these and other countries. The same also applies at lower aggregation levels within countries. The variety of functions and geography in a context of change is likely to demand different conservation strategies.

1.3. Developing conservation scenarios

Scenario studies provide a suitable tool to assess the effects of autonomous or planned development. Through the last five decades, changes in agriculture and its position in society have been dramatic (Rabbinge and van Diepen, 2000): productivity rise per unit area, labour and input; from empirical and skill driven activity to a more science and understanding based activity with industrial characteristics; recoupling agriculture and societal aims; generic extensification (cropping system level) and specific intensification (per crop) to reach biotechnical and environmental aims. Although somewhat lagging behind progress in arable cropping, these developments are now taking place in olive cultivation as well (Rallo Romero, 1998).

Scenario studies have frequently been applied for exploratory studies of land use changes. Different approaches have been developed for land use scenario modelling (e.g. de Koning et al., 1999; Stoorvogel and Antle, 2001; Roetter et al., 2005). Where multifunctionality is included in the scenarios, stakeholder preference for functions needs to be considered as well. Which functions are important and how to conserve them under various external factors is a pertinent question for many olive groves. In order to develop (conservation) scenarios indicators are needed that can evaluate the performance of different olive production systems on selected functions.

Van der Werf and Petit (2002) have made a comprehensive overview of indicator-based methods in evaluation the environmental impact of agriculture. They divided methods according to the use of *means*-based indicators and *ends*-based indicators. The development of indicators for the assessment of sustainability in agriculture has received much attention in the last decade (e.g. Tisdell, 1996; Lefroy et al., 2000; Von Wirén-Lehr, 2001). Pacini et al. (2003) stress that sustainability indicators pertain to various stakeholders (scientists, farmers, policy makers) with different needs for monitoring; they argue that indicators at the level of agricultural production processes enable the right balance to be found between production economics and environmental goals and provide the link to farm management decision-making that so many indicator systems lack. A set of environmental indicators at the farm level was also developed by Kabourakis (1996) for organic olive farms in Crete. Indicator development has received due attention at the policy level as well (e.g. CEC, 2000; OECD, 2000).

Changing functions of agriculture demands that objectives be reformulated; explorative studies involving interaction and iterative approaches are needed to see what are the consequences of particular choices and preferences, especially at lower aggregation levels (Rabbinge and van Diepen, 2000). Brouwer and Lowe (2000) identified particular agri-environmental research gaps at European level for southern regions, production systems and their typical problems (e.g. soil erosion, flooding, fire hazards) and a lack of research into comparative, integrated studies linking agricultural economic analysis and farming systems/agro-ecology analysis. An attempt was made to fill this research niche, at least for olive production systems facing an uncertain future. They were the topic of a multidisciplinary research project.

1.4. The OLIVERO project

The current research was embedded within the OLIVERO research project (2003-2006). The full title of the project was: “The future of olive plantation systems on sloping and mountainous land; scenarios for production and natural resources conservation”. Its acronym is derived from the combination of the words ‘Olive’ and ‘Erosion’, and possesses a typical Latin sound that would not be misplaced in many Mediterranean vocabularies.

The Olivero project, funded by the European Union under its fifth research framework programme and executed with six partner institutes in five countries[1] (Stroosnijder et al., 2007), addresses the environmental and socio-economic sustainability of Sloping and Mountainous Olive Production Systems (SMOPS). SMOPS represent the oldest tradition in olive growing, as the more fertile lowland areas were historically used for other (annual) crops. On the often shallow and stony soils in the steep areas occupied by the SMOPS, annual crops performed very poorly, rendering olive growing the most profitable land use possible. Despite of this comparative advantage, the remote and poorly accessible regions had limited access to agricultural markets, and

---

[1] The Olivero partners were: Wageningen University (The Netherlands), Instituto de Agricultural Sostenible (Córdoba, Spain), Centro de Investigación y Formación Agraria (Granada, Spain), Università della Basilicata (Potenza, Italy), Institute of Subtropical Plants and Olive Tree (Chania, Greece) and Instituto Superior de Agronomia (Lisbon, Portugal)

the local populations practiced a subsistence-oriented agriculture that led to the creation of typically small-scale diversified mosaic landscapes. In order to make the best use of scarce soil and water resources, terraces and other soil and water conservation techniques were widely applied.

Although remnants of many of these traditional landscapes still exist today, the general trend is different. Demographic changes of the rural population, integration in the market economy with its competitive character, and technological innovation have drastically changed both the local economy, its agricultural production systems and – as a consequence – its environment. Strikingly, olive production systems that have been sustainable for ages have in a relatively short time frame witnessed major changes that led to the question: is there a sustainable future for olive production on sloping land, and if so, what actions should farmers and policy-makers take to achieve it?

In a nutshell this is the rationale for the Olivero project. The question becomes even more pertinent in the light of recent EU policies. Until 2005, these subsidies promoted intensification, and led to an unprecedented expansion of olive cultivation, especially in Spain after joining the EU in 1986 (de Graaff and Eppink, 1999). The policy-driven expansion led to unsustainable farming practices (Beaufoy, 2001). The EU, in recognition of policy failure, and faced with the inherent out-of-control budget requirements, first presented proposals for policy change in 1997 (CEC, 1997). The Olivero project intended to contribute to the identification and development of suitable alternative policies.

1.5. Problem definition and research objectives

Many SMOPS in the Mediterranean are no longer productive or sustainable. However, these mostly traditional land use systems now fulfil other than productive functions only. Of an increasing number of functions, the importance is recognised by stakeholder groups at various levels or by society as a whole. Ultimately, wise use of land and water resources is to be aimed at, if downstream people and infrastructure and future generations are to be respected. The present research project searches to develop an integrated methodology addressing these problems and to assess its performance for different scenarios of SMOPS.

One can imagine that, while SMOPS may (potentially) fulfil various functions, their actual appreciation by society may be subject to many factors. It is an explicit choice to consider some of these factors in the present research by looking at different geographical areas. This may be illustrated by comparing recent developments in three areas: North-Eastern (NE) Portugal, Southern Italy and Central West Tunisia.

Portugal has until recently witnessed a continuously decreasing olive production since the high in the 1950s (Castro et al., 1997). This decline has been attributed to rural depopulation in the 1960s, mounting production costs, poor olive quality and competition from seed oils (domestic per capita olive oil consumption fell from 10.5 kg in 1960 to 3.6 kg in 1980) (Gouveia and Soeiro, 1997). Abandonment rates have been higher in Portugal than in most other Mediterranean countries (Margaris et al., 1996). The government has indicated the olive sector as priority area, and the traditional character of olive cultivation has been used to develop Product Denominations of Origin (PDO’s) (Gouveia and Soeiro, 1997). Moreover, agri-environmental schemes have been introduced at a fairly large scale (Beaufoy, 2001) and productivity of olive orchards is very low. Hence, NE Portugal offers an interesting case study for addressing multifunctionality.

In Southern Italy, olive production contributes substantially to regional agricultural earnings: 24% in Puglia and 19% in Calabria (Cilenti, 1998). While in other regions, Italy has been successful in creating added product value by investing in quality upgrading and PDO’s, the 78% of olive groves that are on hilly and mountainous land in southern Italy are not competitive: relief poses serious restrictions to mechanisation; 85% of olive holdings is tiny (smallholders/part-time farmers) and there are no co-operative or associative schemes, and oil quality is inferior (mix of 250 cultivars!) (Lombardo, 1993; see also Jacoboni et al. (1990) for a specific account of olive growing in Calabria). Leone (2000) adds to these problems the sharp price fluctuations, slow dissemination of cultural innovations and stringent, expensive environmental rules. Unlike in Spain olive growing is not heavily concentrated in a particular area (Andalucia), and labour costs are 30% higher than in Spain, 50% higher than in Greece and very much higher than in Tunisia, Morocco and Turkey. Southern Italy thus presents a case where the productive function of olive orchards is declining, but where a development pathway is yet to be defined.

Central West Tunisia is the second important olive growing area in Tunisia (DGPA/ONH, 1996). Olive cultivation has been advocated as the optimal (and often only) agricultural land use option in the more marginal regions, both in terms of production and for preventing soil degradation. The area under olive trees has extended continuously in recent decades. Tunisia has adopted an export strategy (Bonazzi, 1997), but the processing industry modernised in order to improve oil quality is concentrated in coastal regions (DGPA/ONH, 1996). The social role of olive farming is nicely illustrated by the fact that while olive production accounts for 11% of the total value of agricultural output, it absorbs 24% of the working days in agriculture (Mahbouli, 1971); more recent data suggest increased mechanisation: 10% and 20% respectively (DGPA/ONH, 1996). Problems the olive sector in Tunisia faces include: low productivity, increasing production costs, the strong influence of the climate, lack of technical progress and lack of farmer’s associations. Olive farmers have experienced diminishing returns because of the decrease of property size (through inheritance), the lack of rejuvenation in areas suited to olive growing and the limited returns of new orchards in marginal areas (DGPA/ONH, 1996). While these problems probably affect the SMOPS most, it remains to be seen whether other than productive functions can become the basis for rural development plans.

The above three cases hint at a large diversity of SMOPS, and of issues affecting their development. This led to the formulation of the following for the research project:

I. Making an inventory of SMOPS and their natural resource conservation issues;

II. Developing a function assessment methodology and analyzing the various functions of SMOPS;

III. Taking soil conservation as an example function, exploring the importance of soil erosion in SMOPS and assess how it can be controlled;

IV. Developing scenarios based on a set of core functions identified by stakeholders;

V. Optimizing environmental and social performance of SMOPS in conservation scenarios.

With regard to objective I, first an inventory will be made of those regions where olive cultivation is an important land use and where erosion problems are potentially high (with sloping land being an explicit criterion). Olive production systems (SMOPS) in selected regions will subsequently be further analyzed in order to get a grasp of the variety of systems. A typology of systems based on their functions is to be developed. This functional typology should be more accurate than those developed by Hofmeister (1971) and Beaufoy (2001) in that it should allow for dynamism (trends) instead of static descriptions.

From the research on objective II, an extensive list of functions should result. A function assessment methodology will be developed. Moreover, suitable indicators need to be defined in order to evaluate the performance of SMOPS. This will be done for a group of selected functions. Various surveys were conducted and secondary sources consulted to assess the performance of SMOPS with regard to these functions.

Under objective III the current state of soil and water resources within SMOPS are to be assessed taking into account historical developments and current farming practices. To this aim sites for field research were selected in three research areas: in Portugal, Italy and Spain.

Objective IV subsequently is concerned with scenario development. Stakeholder opinions and expert knowledge will be used for the selection of core functions for each research area. Based on trials and secondary data, the local effectiveness and/or appropriateness of different interventions and policy instruments will be assessed and built into a scenario simulation model.

The fifth and last objective concerns the optimization of conservation scenarios for the respective SMOPS. The function assessment methodology will for this purpose be applied to evaluate scenarios.

The above objectives are in fact cross-cutting issues that require interlinked activities. Some of the inputs required were provided by parallel research within the OLIVERO project.

1.6. Key concepts and definitions

Throughout this thesis some key concepts are used that might need to be defined for a better understanding by the reader.

SMOPS
The Sloping and Mountainous Olive Production System ('SMOPS') is the basic unit of analysis throughout the thesis. It is defined as a production system in which olives are produced using roughly the same technology, under similar agro-ecological and socio-economic conditions. Where olive cultivation is associated with other land use, this is considered as an integral part of the SMOPS. The geographical dimension of SMOPS vary: there are cases of large regions presenting more or less identical characteristics, covering several farms. However, it is also possible that a single farmer uses different technologies on different parcels of the farm (i.e. drip irrigation on a young, densely spaced orchard, while remaining parcels are managed extensively); in such cases a single farm may contain several SMOPS. SMOPS only cover olive production on sloping and mountainous land with an indicative slope of 15% or higher. A typology of SMOPS is presented in Chapter 3.

Agro-ecosystem
The SMOPS are presented as agro-ecosystems because their characteristics are strongly linked to the agro-ecological zones in which they occur. It is important to realize that a broad interpretation of the agro-ecosystem concept has been adopted. They are defined as ecosystems modified by human beings to produce agricultural products, thereby acquiring a socio-economic dimension (Conway, 1987).

Function
A function is defined as the capacity of a SMOPS to generate a specific product that satisfies human needs, either directly or indirectly (cf. de Groot, 1992; Section 1.2). Products can be either goods or services, marketable or public, and could include also (nearly always public) 'bads', irrespective of the question whether they could be classified as unintended side-effects (OECD, 2001). Five groups of functions will be distinguished: ecological, productive, economic, social and cultural functions (Chapter 5). Productive functions refer to the capacity of a SMOPS to generate (marketable) biomass, and should not be confused with the economic concept of production function.

Conservation scenario

A conservation scenario is the outcome of the interplay of external factors and planned activities undertaken to enhance the (multiple) functions of SMOPS and to reduce negative impact. To qualify as a conservation scenario, a scenario has to comply with two linked conditions: i) an attempt should be made to adapt to changes induced by external factors, and ii) such action should be geared towards preservation of positive and mitigation of negative functions of SMOPS.

Mediterranean

The Mediterranean is popular delineated by the limit of olive cultivation around the Mediterranean Sea. This is the naturally ideal definition within the scope of this study as well. The olive tree can grow under various environmental conditions, but it needs a period of cold weather to produce flowers. On the other hand, temperatures below –12°C lead to severe damage to leaves, branches and trunk (Loussert and Brousse, 1978). The actual geographical focus of the research in this thesis varies per chapter, as will be shown in the next section.

1.7. Thesis outline

This study has a wide geographical and multidisciplinary focus. Chapter 2 inventories olive production in major production countries (Spain, Italy, Tunisia, Greece and Portugal), from a regional Mediterranean perspective. It establishes a link between important olive production areas and areas with a vulnerable natural resource base, as witnessed by a high erosion risk. In Chapter 3, olive production in selected research areas (Trás-os-Montes – Portugal, Jaén/Granada and Córdoba – Spain, Basilicata/Salerno – Italy, Western Crete – Greece and Haffouz – Tunisia) is further analysed by the development of a typology of olive plantation systems. The variety of regional olive orchards is given, with a description of their main natural resources management issues, and options to improve management. Chapter 4 deals in more detail with one of the plantation systems distinguished in Chapter 3: the traditional orchards. It should be noted that the so-called “traditional system” on Crete (Greece), as discussed in Chapter 4, has been classified as semi-intensive system in Chapter 3.

Chapter 5 subsequently presents a methodology to assess the functions of olive orchards (or other agro-ecosystems) in a systematic way. Focussing on a case study of NE Portugal, it demonstrates the strengths and weaknesses of the regional olive production system. Chapter 6 reports in detail about one particular environmental function: soil conservation. Presenting data from erosion assessment in Portugal, Italy and Spain, it presents the challenges to come up with suitable indicators for soil erosion. It presents an optimistic prospect for soil conservation options. Chapter 7 presents the prospects and scenarios for olive production systems, especially those in NE Portugal and

Southern Spain. Combining expert opinion and results of a linear programming model simulating ‘farmer economic logic’, this chapter shows that regional developments may vary widely, with olive cultivation abandonment and intensification leading to important social and environmental consequences. Chapter 8 subsequently explores what policies could be implemented to offset the negative social and environmental consequences, or to reverse negative consequences. Finally, Chapter 9 integrates results from all previous chapters and proposes conservation scenarios as a tool for adaptive management.

Chapter 2

Soil conservation options for olive orchards on sloping land

This chapter is a revised and extended version of:

Fleskens L and de Graaff J
In: García-Torres L et al. (eds), 2003. Conservation Agriculture: Environment, Farmers Experiences, Innovations, Socio-Economy, Policy. Kluwer Academic Publishers, Dordrecht, The Netherlands. pp. 381-385

2. Soil conservation options for olive orchards on sloping land

Abstract

Olive production is an important agricultural activity throughout the Mediterranean zone and the production area and volume are on the increase. At the same time, soil erosion is one of the environmental key problems in this zone. Actual erosion in olive production areas is high, in particular on sloping land. Several erosion risk factors are present here: erosivity of rainfall, erodibility of soils, steep slopes and insufficient ground cover because of clean weeding. In addition to on-site production losses, downstream effects of erosion can be severe. In this chapter an inventory is made of the actual situation and trends of olive production and erosion hazards. Subsequently, soil and water conservation options for olive orchards on sloping lands are briefly described, with particular reference to five important production areas: Eastern Andalusia (Spain), North-eastern Portugal, Southern Italy, Crete (Greece) and Central-West Tunisia.

2.1. Introduction

Olive trees have played for ages an important role in rural development in southern Europe, North Africa and the Near East. They have been one of the major sources of income and employment and have helped to reduce the rural exodus in these relatively poor rainfed areas. In the past ten years the olive production has increased, at least partly thanks to EU-subsidies (de Graaff and Eppink, 1999). This expansion has partly taken place on sloping land, where insufficient attention is paid to erosion control.

The Mediterranean area, characterised by high rainfall erosivity and high soil erodibility, is generally susceptible to erosion. In Italy, Spain, Greece and Portugal, respectively 27, 41, 43 and 68% of the total land area has a high potential soil erosion risk (CEC, 1992) and 47% of the total land area of Tunisia (excluding the Southern region) is affected by erosion (Projet PNUD-FAO TUN/86/020, 1992). Erosion risk is particularly high on steep slopes. With time, sloping land has become marginal for agriculture, as with ongoing erosion soil depth decreased and nutrients washed away. Olive production has been empirically developed as one of the few land use alternatives on these marginal lands, with a range of soil and water conservation measures to sustain productivity.

Since the 1970’s, mechanisation was introduced on all but the steepest slopes and olive orchard design was altered to allow tractor passing while maximising orchard production. Frequent soil tillage was introduced in order to get rid of weeds competing for water and to enhance infiltration. Existing terraces and hedges for soil and/or water conservation purposes were removed to facilitate mechanisation. With the introduction of drip irrigation, the use of terraces for water conservation was completely abolished.

Interestingly, olive production continued to be concentrated on sloping land, partly because other crops proved more profitable on better lands and partly because in these marginal areas, there were no alternatives. With increasing economic development, in many areas triggered by the development of tourism, more jobs became available and especially young people abandoned olive production. Labour costs have increased, reducing margins on olive production. Many olive growers now face a difficult choice: invest in further mechanisation to reduce production costs or abandon their olive orchards, neither of which choices seems to present a favourable scenario for soil and water conservation. Nevertheless, for both directions there are suitable options to preserve the soil; these will be explored in this chapter.

2.2. Materials and Methods

An analysis was made of olive production statistics in fourteen countries in the Mediterranean area (Spain, Tunisia, Italy, Greece, Turkey, Morocco, Syria, Portugal, Algeria, Libya, Jordan, Lebanon, Egypt and France). The FAOSTAT (2001) database was consulted on national olive area and yield statistics. Figures from FAOSTAT may differ from other sources, especially because harvested area is considered and not area planted to olive trees. It was found necessary to define area and yield increase over the last decade as the difference between two five-year average periods (1987-1991 and 1996-2000, respectively), in order to rule out the alternate bearing behaviour of the olive tree and the effect of very dry years.

The eight most important producer countries were selected for comparison and subsequently five countries were selected for a literature review of soil erosion problems and soil and water conservation options on sloping land. For these countries, the regional importance of olive growing was assessed, using the percentage of total agricultural land (excluding pastures) under olive trees as a variable. No single data source was found for this purpose; hence national statistics gathered from different sources were used: for Spain and Italy land use data were available at the provincial level in annual agricultural statistics; for Portugal and Greece data was taken from recent agricultural censuses, and for Tunisia relatively aged data were available at regional level. Potential erosion statistics were available from the CORINE soil erosion risk assessment (CEC, 1992) for the southern European countries, and a UNDP-FAO project document provided data on actual erosion at regional level for Tunisia (Projet PNUD-FAO TUN/86/020, 1992).

2.3. Results and Discussion

2.3.1. Olive production in Mediterranean countries

A general characterisation of the importance and trends in olive production was obtained by comparison of cultivated area, yield and production variability of the eight main olive producing countries (Table 2.1). The largest olive area can be found in Spain, followed at distance by Tunisia, Italy and – to a lesser extent – Greece. Yields are highest in Greece and Italy, with Spain and Turkey following at a much lower level. Variation in production is lowest in Greece and highest in Tunisia. Area increase over the last decade has been fastest in Spain, Morocco and Syria, while yield increase has been most evident in Spain, Greece and Syria.

Spain
Spain has the largest production area and the largest production. However, yields are relatively low and show a high variabilility. Lately, production increases have been due both to important area and yield increases.

Tunisia
Tunisia has an extensive olive area, but yields are both very low and very inconsistent. The main reason for this is the unfavourable (dry) climate. Olive area and yield have witnessed slight progression over the last decade.

Italy
Italy's olive area and yield have shown little change over the last decade. Production variability is relatively low. Yield levels are high.

Greece
Greece has a substantially lower area under olive, but it is increasing at a steady pace. Moreover, average yield is very high and still increases. Olive production demonstrates a very stable pattern (low variability).

Table 2.1: State and trends of area and yield of the main olive producer countries (1991 – 2000).

Country	Average area	Area increase*	Average yield	Yield increase*	Variation in production
	(1000 ha)	(1000 ha)	(kg/ha)	(kg/ha)	(ratio lowest/highest)
Spain	2136	129	1665	540	0.29
Tunisia	1393	8	618	193	0.19
Italy	1123	-7	2675	225	0.54
Greece	728	45	2719	505	0.76
Turkey	558	38	1617	341	0.28
Syria	432	92	1148	473	0.29
Morocco	428	116	1209	-149	0.42
Portugal	324	-20	898	118	0.35

Note*: calculated on basis 5-year averages (1987-1991) and (1996-2000)
Source: elaborated from data from FAOSTAT (2001)

Portugal

The Portuguese case is distinct in that its area under olives has declined. Moreover, yields are low which is caused by predominance of little intensified traditional production systems. Yields have shown little improvement in the last decade.

2.3.2. Soil erosion and olive growing areas in Mediterranean countries

Potential soil erosion is high in many regions of the Mediterranean area. Figure 2.1 shows the percentage of land of high potential erosion risk per administrative region for southern Europe and Table 2.2 the percentage of land affected by erosion in Tunisia. In central and northern Portugal and northern and north-western Spain, this risk is mainly associated with climatic erosivity (in northern Spain also with steep slopes), while in southern Spain, some northern coastal areas and southern Italy (Calabria and part of the islands) and south and central Greece, soil erodibility (shallow soils and unfavourable textural characteristics) and steep slopes are the main risk determining factors. In Tunisia, the percentage of land affected by erosion in the north-western region is mainly due to climate erosivity, in the north-eastern region both due to climate erosivity and steep slopes, in the central eastern region due to steep slopes and soil erodibility and in the central western and southern region especially due to soil erodibility. As the Tunisian assessment concerns actual erosion risk, the sparse vegetation cover in the central and southern region also contributes importantly to the percentage of erosion affected land.

As indicated before, sloping land has over the centuries to a great extent been planted to olive trees. If we compare areas with a high degree of olive farming (Figure 2.2 and Table 2.2) with the areas of high potential erosion risk, we notice that they partially coincide (Table 2.3). With the exception of the Central East region in Tunisia, all of these areas are characterised by steep slopes. Puglia is the most notable olive producing area on plain land with negligible erosion risk.

Without soil conservation measures, erosion from olive orchards on sloping land is severe. For Andalucía, 80 ton ha^{-1} yr^{-1} has been mentioned as an average value for olive orchards (López-Cuervo, 1990, cited in Pastor and Castro, 1995); Laguna and Giráldez (1990) found values ranging from 60-100 ton ha^{-1} yr^{-1} in conventionally tilled olive orchards with trees aged 55-100 years and average slopes of 10-33% in Córdoba. In contrast, Kosmas et al. (1997) reported very low erosion (maximum 0.03 ton ha^{-1} yr^{-1}) in an olive grove on a 16-23% slope in Spata, Central Greece. In this case, annual vegetation and plant residues provided about 90% soil cover and no tillage was applied. Arhonditsis et al. (2000) also report negligible sediment losses from terraced olive groves with annual cultivation and undergrowth of annuals on Lesvos, with average slope of run-off plots being 50%. It should be realised that the above data are hard to compare due to differences in methods, scales and field situations.

Table 2.2: Soil erosion and relative olive area in Tunisia, by region.

Region	Affected by soil erosion* (% total area)	Relative olive area** (% cultivated area)
Northeast	29	11
Northwest	60	10
Central East	38	55
Central West	54	31
South	>50	51

Sources: *Projet PNUD-FAO TUN/86/020 (1992); **DGPA/ONH (1996) and DG/PDIA (1995).

Table 2.3: Olive growing areas in relation to erosion risk in selected countries.

Country	Important olive growing areas in high erosion risk areas	Important olive growing areas in low erosion risk areas
Spain	Jáen, Málaga, Granada (Andalucía) Cáceres (Extremadura)	Tarragona (Cataluña)
Tunisia	Central-West and Southern Regions	Central-East Region
Italy	all of Calabria Lucca (Toscana) Genova (Liguria)	Bari, Taranto, Brindisi, Lecce (Puglia) Salerno (Lazio) Firenze (Toscana) Imperia, La Spezia (Liguria)
Greece	Crete, Peloponnese, West Greece, most of Epirus, Central Greece, and Ionian and Aegean islands	Boeotia (Central Greece) Halkidiki, Pella and Imathia (Central Macedonia)
Portugal	Douro, Beira and Pinhal regions (Central and North-Eastern Portugal)	–

2.3.3. Soil and water conservation options for olive orchards on sloping land

Three major groups of soil and water conservation measures may be distinguished: mechanical measures (involving earth movement), tillage measures and soil covering measures (involving live or inert covers, and both area and line interventions). Of each group, a short description is given of their potential for olive orchards.

Mechanical measures

In many parts of the Mediterranean, terraces have historically been established in olive orchards. In Lesvos, for example, large-scale establishment of terraced olive orchards has contributed to soil conservation for centuries (Marathianou et al., 2000). However, in most regions terraces have not been well maintained or have even been removed in order to facilitate mechanisation. Preserving existing terraces is being advocated for the purpose of landscape conservation or habitat diversification (Kabourakis, 1999), but constructing new terraces is not feasible in economic terms.

An exception may be areas with less then 350 mm rainfall, where water conservation is the main purpose of measures. Examples from Tunisia are the *meskat* and *tabia* micro-catchment systems (Missaoui, 1996), which, provided they are sufficiently large, still permit mechanisation. An estimated 200,000 ha of meskats exist in the Central East region of Tunisia (Baldy, 1997).

Tillage measures

Much research has been conducted on tillage systems in olive orchards, especially in Spain. Conventional tillage, consisting of various cultivation treatments amounting to 10 tractor hours of tillage ha^{-1} yr^{-1} (Pastor and Castro, 1995), is still widely applied. Although tillage enhances infiltration, frequent machine passing also results in a dense plough pan and increased erodibility of the top soil.

Several reduced- and no-tillage systems have been developed in advocacy of reducing erosion, while simultaneously curbing production costs, which had risen substantially as influenced by the oil-crisis of the mid 1970’s. The basis of these systems is the application of residual pre-emergence herbicides, mainly Simazine (now banned) and Diuron. Under no tillage, surface crusting is common and the soil is compacted, the effect being more evident in the rows between the trees. Decreased infiltration rates have been observed (Gómez et al., 1999) resulting in higher surface run-off but, due to better soil structure, lower sediment losses. Despite lower infiltration rates, Pastor and Castro (1995) and Gómez et al. (1999) found that in dry years, olive yields under no tillage were higher than under conventional tillage. Possible explanations are (Pastor and Castro, 1995): better soil moisture availability in spring, enhanced temperature regime, more efficient use of the fertile top soil layer and absence of root damage by tillage implements. These encouraging results were initially quickly taken up by farmers (Gómez et al., 1999), but the olive area under no tillage has stagnated at about 40,000 ha in Andalucía (less then 4% of the total area under olives) (Gómez et al., 2001). The no tillage system, while performing better with regard to preventing sheet erosion, promotes the formation of deep gullies, especially on sloping lands. These have a negative visual effect, deteriorate orchard access or may even divide the orchard.

Semi-tillage, consisting in tilling strips between the tree rows, combines beneficial effects of conventional tillage and no-tillage. In some cases where no-tillage reportedly caused surface crusting severely hampering infiltration, semi-tillage was found a solution to both increase infiltration and reduce runoff velocity.

The absence of soil cover is an important factor in causing high erosion rates. As one of the reasons for clean weeding (either by tillage or herbicide application) is to facilitate harvesting of immaturely dropped olives from the ground, it is not to be expected that soil covering measures will be applied underneath the trees. However, the soil beneath the canopy suffers a higher erosion risk as a result of increased erosivity of rainfall by interception (de Luna et al., 2000). Under these circumstances, vegetated or inert contour strips would probably be the best soil conservation option.

Soil covering measures

Inert and live plant covers provide good soil protection, while contributing to favourable hydrological soil properties. Live plant cover (weeds or crops) should have an autumn/winter cycle with an early start of growth and it should be turned into mulch in early spring, either by mowing or application of contact herbicides to prevent competition for water (Tombesi et al., 1996). Soil cover is especially important in traditional olive orchards with lower tree densities, but these generally occur in dry areas, where cover crops may fail frequently, or, when badly managed, compete for water with the olive trees (Pastor and Castro, 1995). Weed cover can be adequate, but is difficult to manage. Barley (*Hordeum vulgare,* L.) in combination with chemical mowing in spring was found to present a suitable cover crop, which produces sufficient biomass on marginal land, even in dry years (Pastor and Castro, 1995). It produces resistant straw, an important characteristic for protecting the soil against the impact of torrential summer rains. Vetch (*Vicia sativa,* L.) is considered a less effective and more expensive alternative, but it has been reported to fix large amounts of N in the soil.

Martínez Raya et al. (2002) have studied the effect of vegetated strips in olive groves on steep slopes (30%). Soil loss over a period of 3 years of the strip cover crop treatment (in spring altered in a mulch layer by applying contact herbicides) was less then 10% of the conventional tillage treatment and about 5% of the no-tillage treatment. In a subsequent trial, Martínez Raya et al. (2002) found that herbaceous shrubs (*Thymus baeticus*) performed better as a strip cover crop than cereals and legumes (respectively 4 and 13 times less aggregate soil loss over 19 rainfall events). Further research is needed into the effects on the water balance of herbaceous strips, as they are perennial plants and might compete for water in summer. However, these shrubs may present an additional economical value.

An effective inert alternative to vegetated strips could be formed by arranging pruned cuttings along contour lines. We have not encountered any mention of such a measure for the particular case of olives, but it is occasionally applied in other tree crops in the Mediterranean.

In a high density orchard, arranging tree lines with an inter-tree spacing of 4m or less along the contours could provide another way of controlling runoff velocity and amount (Gómez et al., 2001), similar to the effect of covered strips. However, such a design would in almost all cases require drip irrigation and the possibility of full-scale mechanisation, conditions that are hard to meet on most marginal sloping lands.

In Italy, a system of maintaining a permanent grass cover over the whole orchard is known as ‘inerbimiento’ (Beaufoy, 1998). It is extremely effective in soil conservation, but requires sufficient rainfall or irrigation to avoid competition for water. It also rules out harvesting of fallen olives, and is therefore particularly adapted to high quality (table) olive production systems, in which only olives from the trees are harvested.

Sheep grazing in olive orchards has a long tradition and is still applied in certain areas (Beaufoy, 1998). In combination with permanent grassland, scope in semi-arid areas is very limited. Sheep grazing of cover crops could be a viable option, provided that stocking rates are not too high. However, grazing of cover crops leaves the soil unprotected vis-à-vis aggressive rainfall events in summer (Pastor and Castro, 1995). Grazing can not be integrated with olive farming if low stem varieties are used. In Greece, excessive grazing pressure in (abandoned) orchards in marginal sloping lands has led to degradation in many areas.

Abandonment of olive orchards often leads to shrub invasion and a gradual succession to natural woodland, presenting a high fire risk. In this case, and where fire risk of cover crops or residues could destroy productive orchards, grazing could be a viable option.

2.4. Conclusions

Olive orchards and high potential erosion risk areas overlap to a great extent. This is especially so, because olive orchards have traditionally been established on marginal sloping land. In the following areas, the overlap is most convincing: East Andalucia (Spain), Calabria (Italy), Peloponnese, Crete and other islands (Greece), Central and North-East Portugal, and Central-West Tunisia. Erosion in olive orchards on sloping land where no soil conservation measures have been undertaken is very high. The most promising soil and water conservation methods for sloping land depend on agro-ecological conditions and orchard characteristics, but include mechanical water harvesting measures for arid regions, permanent grassland (with or without sheep grazing) in the more humid regions and certain soil cover (area or line interventions) in the semi-arid areas. The latter environmental category is by far the most important for olive growing and as criteria for soil conservation options are the most delicate, emphasis should be put on research of alternatives for these zones.

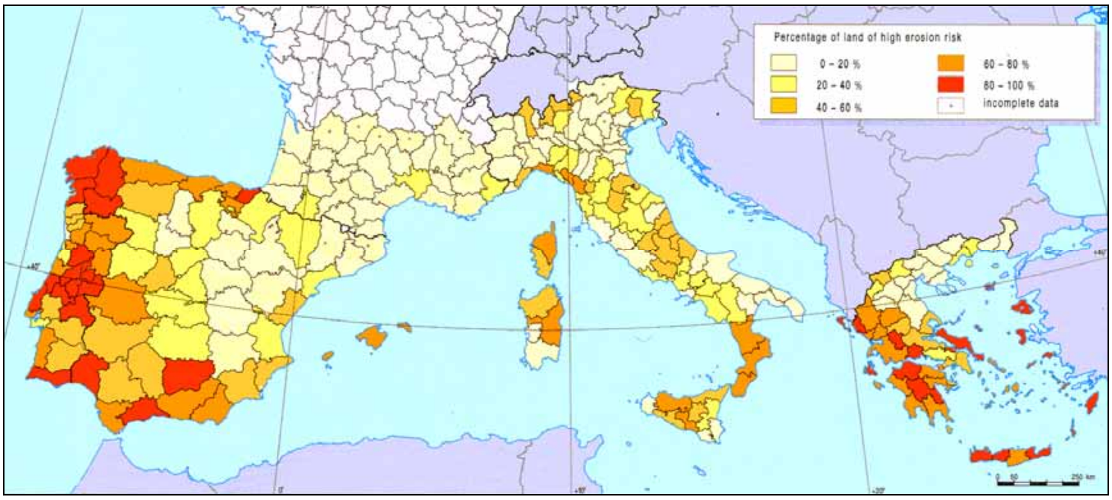


Figure 2.1. High potential soil erosion risk by administrative regions (CEC, 1992).

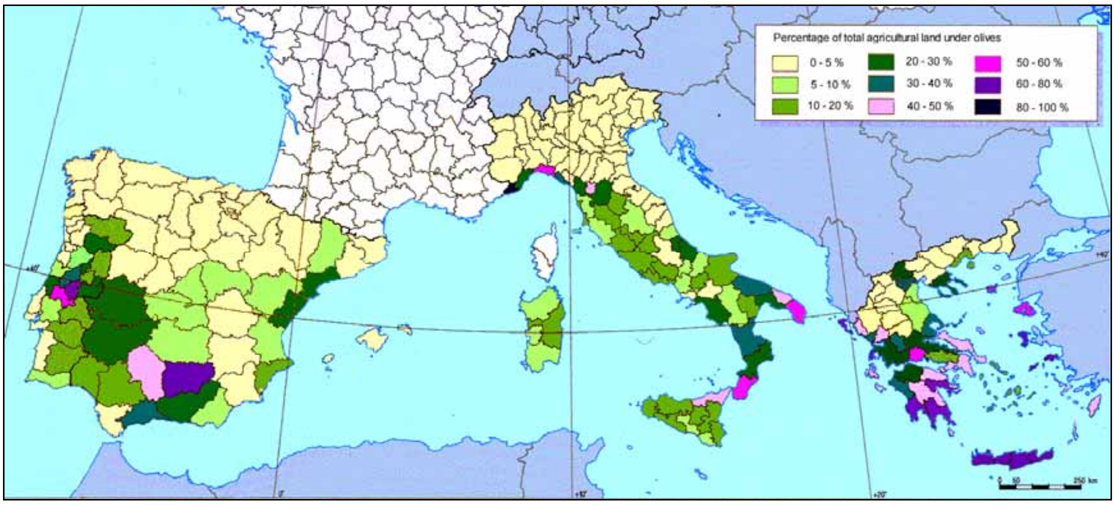


Figure 2.2. Percentage of total agricultural land (excluding pastures) under olive trees by administrative regions (after M.A.P.A., 1999; ISTAT, 2001; NSSG, 2000; RGA, 1999).

Chapter 3

A typology of sloping and mountainous olive plantation systems to address natural resources management

Fleskens L
Agricultural Systems (submitted)

3. A typology of sloping and mountainous olive plantation systems to address natural resources management

Abstract

Olive plantation systems occur in a wide variety throughout the Mediterranean, especially in sloping and mountainous areas. Recent drivers of change, including the widespread introduction of mechanisation, increased use of (chemical) inputs and (drip-)irrigation have considerably added to this diversity. The various systems have very different resource use patterns and environmental and social performances. This chapter attempts to grasp these differences and to link systems characteristics to options for natural resources management in the spirit of contemporary agricultural policies which seek to promote a more sustainable agriculture. Cluster analysis was employed to classify 28 olive plantation systems distinguished by regional typologies developed for six study areas: Trás-os-Montes (Portugal), Córdoba and Granada/Jaén (both in Spain), Haffouz (Tunisia), Basilicata/Salerno (Italy) and West-Crete (Greece). Six types of olive plantation systems resulted: 1) very extensive, 2) traditional extensive, 3) semi-intensive low input, 4) semi-intensive high input, 5) intensive, and 6) organic. Natural resources management options to address soil erosion, low biodiversity, wildfire risk and excessive water use are explored for each of these systems. In the discussion, it becomes eminent that an important quality for a typology lies in its capacity to differentiate likely future development pathways. If options are known, policy-makers can make choices as to what the desired pathway is, and what instruments to design to facilitate it.

3.1. Introduction

Many agricultural products are produced in a wide range of farming systems. These farming systems not only employ different production technologies resulting in variability of qualitative and quantitative aspects of production, but may also have very different resource use patterns and environmental and social performances. In order to take into account this diversity, not in the least for targeting agricultural policies or measuring policy impacts, farming system typologies have been established on various occasions. De Graaff (1996) reviews some of the approaches generally followed, e.g. departing from the main type of agricultural enterprise, farm size, degree of market integration, technology used, and importance of agriculture for farm family income. Andersen et al. (2006) remark that the farm typology used in Europe for several decades, mainly based on the relative distribution of farm income coming from different production sources, was useful when agricultural policies were related to production and economy, but is now less relevant because policy objectives also include the environment, landscape and rural viability.

Approaches relevant for typifying tree cultivation systems are scarce. Withrow-Robinson et al. (1999), in a classification of fruit-based agroforestry systems in northern Thailand, consider the size of planting (number of fruit trees), number of tree species, share of commercial species, presence and purpose of herbaceous intercrops, and patterns of trees and intercrops. Bellon et al. (2001) stress the importance of current management practices to assess environmental risks and design possibilities for improved performance in apple orchards.

Olive cultivation is an important land use throughout the Mediterranean and occurs in a large diversity of systems, shaped by divergent local environmental and social factors, evolved during thousands of years. Despite of this, typologies of olive farming systems are not common in international scientific literature. An early account has been made for the Spanish case by Hofmeister (1971). In *Olivae*, a journal issued by the International Olive Oil Council (IOOC), some other country or regional level classifications have been published (e.g. Jacoboni et al., 1990; Lombardo, 1993; DGPA/ONH, 1996; Castro et al., 1997). A strong driver for studying olive plantation systems came from the enormous expansion of olive growing in the 1990's due to EU production subsidies, most notably in Andalucía, Spain (de Graaff and Eppink, 1999). Alarming reports of widespread soil erosion and biodiversity decline were made, as expansion coincided with mechanisation and intensification of production. This led to the curious situation that olive groves were both viewed as most sustainable Mediterranean land use (Kosmas et al., 1997) and as disastrous: average soil erosion rates >80 t ha yr^{-1} (López-Cuervo (1990) cited in Pastor and Castro, 1995). Beaufoy (2001) attributed these large differences to variations in olive plantation systems. Traditional low intensity orchards, often terraced, were qualified as ecologically beneficial, while new, intensive, drip-irrigated plantations with excessive use of chemicals threatened the environment. A negative environmental impact could also be attributed to semi-intensive orchards, those traditional orchards that – in an attempt to compete with the new intensive plantations – were rejuvenated, restructured and mechanised (Beaufoy, 2001).

Now that the direct incentive to increase production has been replaced with new EU legislation starting in 2005 (the Single Farm Payment Scheme), good agricultural practices are introduced as a concept for cross-compliance. The present study results from a European research project studying the future of olive plantation systems on sloping and mountainous land in southern Europe (acronym 'Olivero') and a comparative research in Tunisia. Its main objectives are:

1. to elaborate a supra-national classification of olive plantation systems from the six study areas that is able to grasp the diversity of orchard structural characteristics and management practices (note that the focus is on sloping and mountainous areas!);

2. to explore the major natural resource management issues in each of the distinguished types of systems and define the scope for (policy incentives for) improvement of environmental performance.

3.2. Materials and methods

3.2.1. Target areas and olive orchard classifications

Characteristics of sloping and mountainous olive plantation systems (abbreviated as 'SMOPS') distinguished in six Mediterranean target areas in five countries were used for the analysis (Figure 3.1). In Portugal (PT), nine municipalities of the Agrarian Region Trás-os-Montes constitute the target area, from hereon further referred to in short as Trás-os-Montes. In Spain, part of the Province of Córdoba (CO) constitutes the first target area, and parts of the Provinces of Granada and Jaén the second (Granada/Jaén - GJ). In Tunisia (TU) the Delegation of Haffouz was selected within the Governorate of Kairouan. The Italian target area (IT) comprises the Provinces of Matera and Potenza – together forming the Basilicata region – and the Province of Salerno of the neighbouring Campania region (short: Basilicata). Finally, in Greece (HE) the Prefectures of Chania and Rethymno were selected, occupying the Western part of Crete (subsequently referred to as West-Crete). The total reference area is approximately 0.9 Mha, about 16% of the area under olives in the countries considered, and 13% of the total area under olive trees in the Mediterranean basin.

Agro-ecological conditions differ both within and between target areas. The driest area is Haffouz (Tunisia) with average annual rainfall of 310 mm and the wettest area is Basilicata (Italy), receiving 800 mm y^{-1}. However, the latter area demonstrates large internal variation, with the Tyrrhenian coast registering values over 1200 mm y^{-1} and the interior of Matera just 600 mm y^{-1}.

In each target area, a classification of the existing olive orchards was made, with exclusive focus on sloping and mountainous zones; lowland plantations were thus not included. These classifications were generally based on agro-socio-economic farm surveys among a total of 81 farmers in Trás-os-Montes, 107 in Córdoba, 223 in Granada/Jaén, 57 in Haffouz, 91 in Basilicata and 70 in West-Crete. In each area, 4 or 5 types of orchards were distinguished (Table 3.1), resulting in a total of 28 SMOPS types, the average parameter values of which served as the basis for the present analysis. Although efforts were made to standardize the surveys and classification criteria in the respective areas, this was only partially achieved; Table 3.2 lists the main criteria used for the classification in each target area.

The classification in Trás-os-Montes was primarily based on orchard structural characteristics and cultural operations, although SMOPS types PT3 and PT4 are concentrated in geographical regions and SMOPS PT5 represents organic plantations.

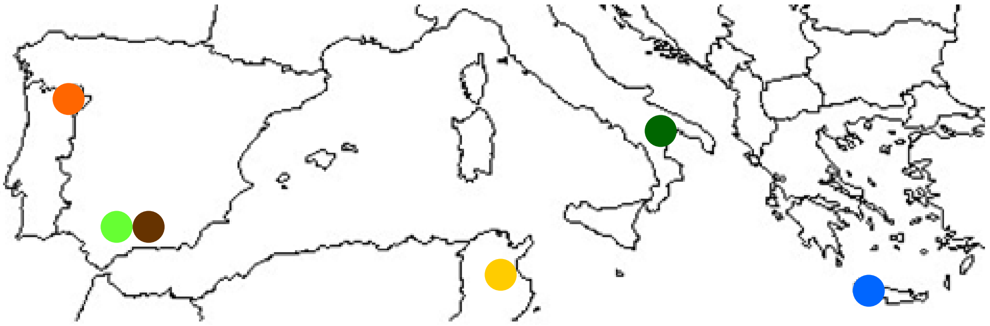


Figure 3.1. Location of study areas. From left to right: Trás-os-Montes (Portugal), Córdoba and Granada/Jaén (Spain), Haffouz (Tunisia), Basilicata (Italy), West-Crete (Greece).

Table 3.1: Characterization of SMOPS types distinguished in the respective target areas.

Target area	SMOPS type				
	1	2	3	4	5
PT	Traditional	Semi-intensive	Semi-intensive (table)	(Risk of) abandonment	Organic
GJ	Traditional rain-fed (Slope 7-15%)	Traditional irrigated (Slope 7-15%)	Traditional rain-fed (Slope 15-30%)	Traditional rain-fed (Slope >30%)	Intensive irrigated
TU	Foot plains, regular	Mountain, SWC	Foot plains, natural	Mountain	
IT	Traditional extensive	Traditional intensive	Modern extensive	Modern intensive	Organic & Integrated
HE	Traditional	Semi-intensive	Intensive	Organic	
CO	Sierra	Sierra (organic)	Sierra	Sierra	Campina

All SMOPS types are for olive oil production, except PT3.

Table 3.2: Relative importance of criteria used to distinguish SMOPS types in the target areas.

Criteria	Target area					
	PT	GJ	TU	IT	HE	CO
Slope	2	1	1	1	1	2
Tree density	1	3	1	2	1	
Cultural operations	2		2	2	2	
Organic	2			2	2	3
Farm size	2			1		2
Irrigation	2	2		2		
Soil characteristics			2		2	3
Olive variety	2		3		2	
Geographical location	3			3		1
Tree age	2				1	
Terraces			2		2	
Secondary products						2

Criteria are ranked on importance: 1 = Major criterion; 2 = Important criterion; 3 = Minor criterion.

The main criteria used to classify plantations in the Granada/Jaén target area were slope, practice of irrigation and low or high tree density. Different combinations of these factors resulted in five SMOPS types (GJ1 – GJ5).

The Tunisian SMOPS were singled out based on slope and orchard characteristics. Plantations in foot plains were separated based on trees planted in regular patterns (TU1) and dispersed natural trees (TU3), plantations in mountains were subdivided in those with (TU2) and without (TU4) soil and water conservation (SWC) structures.

In Basilicata, a more complex approach was followed using productive orientation of the farms (extensive versus intensive) and orchard structural characteristics (traditional versus modern) as main criteria. Plantations under environmental-respectful management (organic or integrated) were classified as IT5.

The Greek plantations were grouped based on slope, presence of terraces, orchard structural characteristics and cultural operations on a gradient from traditional (HE1) to intensive (HE3) plantations; organic SMOPS were also here separated (HE4).

The Córdoba target area classification presents a special case, as the survey was focused on organic farms. Relatively homogeneous olive production zones were distinguished based on geographical location: CO1 – CO4 in the mountainous north of the Province (Sierra), CO5 in the more gently sloping Campina area in the south. The relative importance of organic olive farming is particularly high in the CO2 zone.

3.2.2. Analytical methods

As data collection methodologies in the six target areas differed, 78 of 136 original variables could be retained for the overall classification. These were entered and further analyses were undertaken in SPSS. A distinction was made between interval data (50 variables), ordinal data (3 variables), and nominal data (the remaining 25 variables).

Hierarchical cluster analysis was used to classify the 28 systems. Cluster analysis methods assume homogeneous variable types; thus interval data and nominal data were analysed separately – the 3 ordinal variables were not considered. The analysis of nominal data tended to produce clusters based on geographical location and will not be detailed here. Including all 50 interval variables was not very useful because of the heterogeneity of the data, resulting in either little differentiation or too many clusters, depending on clustering method and measure. As the main purpose of the cluster analysis was to group together comparable SMOPS from different geographical locations, the data was further analysed on local discriminating criteria. Variables that showed no or little variation over the local classification systems were removed, resulting in a reduced set of 32 variables. This reduced set was used for further analysis.

In a next step, factor analysis was employed to extract the variables with the highest influence on the total variance of the dataset. Variables were ranked according to their correlation coefficient with resulting components (‘factors’) and sequentially entered in a hierarchical cluster analysis. Ward’s clustering method was applied with squared Euclidian distance as a measure of distance, and variables were normalized on a 0-1 range. Results of clustering were examined for the classification of several SMOPS of one target area within one group (this was not desired). The largest possible number of variables before such tendency manifested was strived for as optimal clustering. Clustering of organic SMOPS (known to have very different characteristics) was ‘enforced’ by always including the variable ‘percentage of organic farms’ differentiating those systems. This variable was found to exert a strong influence on variation in the factor analysis, albeit lower than other variables that were taken into account.

Clusters were subsequently explored for significance of different means by one-way ANOVA. Levene’s test of homogeneity of variances was applied to decide whether differences in cluster means of individual variables could be tested with a normal F-test, or whether the Welch statistic was required. Although the normal F-test is rather insensitive to unequal variances, the latter test is to be preferred if groups with unequal variance and unequal sample size are compared (de Vocht, 2001). In the case of some variables, the Welch statistic could not be computed because one (or more) clusters had a variance of zero. Where this happened, a non-parametric test of means was applied (Kruskal-Wallis).

The abovementioned tests can only indicate whether cluster means are significantly different, but not *which* cluster means are different from each other. For this purpose further analysis of significance of individual cluster means was undertaken with Bonferroni or Games-Howell tests, respectively when homogeneity of variance could or could not be assumed.

The final clustering was validated with discriminant analysis. Hereto, a stepwise method was employed whereby all 32 originally selected variables were taken into account. At each step, the variable that minimized the sum of unexplained variation for all pairs of groups was entered.

Nominal variables could not be tested for statistical significance using the six clusters distinguished because of the low frequencies in cross-tabulation. Therefore, the six clusters of SMOPS were regrouped into two broad categories, allowing some additional characteristics to be established.

3.3. Results

3.3.1. SMOPS typology

Construction of the SMOPS typology

The factor analysis extracted seven components with eigenvalues >1, cumulatively explaining 86.6% of total variance of the data set. The first component explained 43.3% of total variance and was found to be strongly associated (coefficient >0.5) with 25 of the 32 variables. The second component was similarly associated with 8 (partly overlapping) variables, the third and fourth component with 2 variables, the fifth with 3, the sixth with 1 and the seventh with none. Ten variables in the first component had higher correlation coefficients than the most strongly correlated variable in the other components, in practice meaning that all variables entered in the cluster analysis belonged to the first factor (Table 3.3). This factor could be described by 'level of intensification'.

The variables in Table 3.3 were one by one entered in cluster analysis, together with the variable 'percentage of organic farms'. Each addition not deteriorating the prior result of clustering was maintained. This was possible until inclusion of the eighth variable (olive gross margin); adding the variable 'soil cover by olive trees' started cluttering SMOPS from the same geographical region, a tendency that could not be reversed by entering subsequent variables. Figure 3.2 shows the dendrogram that resulted from the hierarchical cluster analysis.

Table 3.3: Ten variables with highest correlation to components extracted by factor analysis.

Variable (unit)	Correlation coefficient to first component
1. Yield Consistency Index (-)	0.931
2. Olive yield (kg ha^{-1})	0.898
3. Auto-consumption of olive (oil) produced (% of produce)	-0.839
4. Pruning residues grazed/fed to animals (% of residues)	-0.821
5. Fertiliser amount applied (kg ha^{-1} yr^{-1})	0.820
6. Percentage of total UAA mechanized (% of farm UAA)	0.804
7. Phytosanitary product application (% of cases)	0.767
8. Olive gross margin (€ ha^{-1} yr^{-1})	0.763
9. Soil cover by olive trees (%)	0.761
10. Extra virgin olive oil (% of total production)	0.723

A first group of TU1 – TU4 plus PT4 was found to be very different from the other SMOPS. These were later referred to as very extensive SMOPS.

A second spin-off is formed by a group of four SMOPS (PT5, CO2, IT5 and HE4), which were named after their common characteristic: organic SMOPS.

Subsequently, three systems (IT4, GJ5 and HE3) are found to have distinct characteristics. These were later referred to as intensive SMOPS.

The remaining SMOPS types can be divided into two main groups, the first of which is constituted by CO1, CO3, CO4, IT1, GJ4 and PT1. These were later named traditional extensive SMOPS (short: traditional SMOPS).

The last group of 10 SMOPS was found to be too large. Although substantial differences were known to exist between these SMOPS, they were probably clustered together because the differences were relatively small in relation to the variation within the entire sample. To allow further subdivision of this cluster, the 10 SMOPS were separately entered in a subsequent cluster analysis, using the same methodology. Based on the variables 'olive yield' and 'yield consistency', this resulted in two groups of 5 SMOPS each, the first consisting of HE1, PT2, GJ1, GJ3 and IT3 (later to be named semi-intensive low input SMOPS), and the second of HE2, IT2, PT3, GJ2 and CO5 (semi-intensive high input SMOPS) (Figure 3.2).

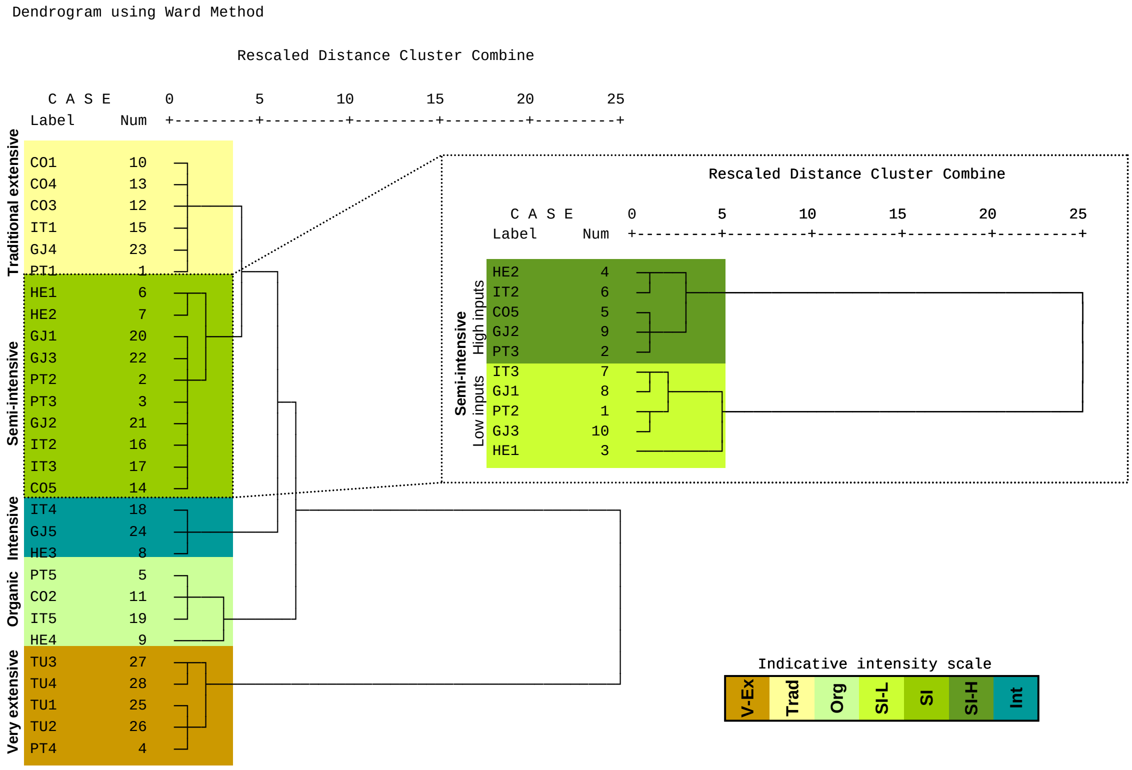


Figure 3.2. Clustering of all SMOPS based on eight variables with highest correlation to factors in factor analysis (+ one variable differentiating organic farms) and sub-classification of semi-intensive SMOPS based on olive yield and yield consistency.

Main characteristics of the respective SMOPS

The final clusters were analysed for their discriminatory capacity with the aid of three statistical methods, depending on homogeneity of variance (Levene's test) as described in Section 3.2.2. Many variables could not be assumed to have similar variance within the clusters distinguished. Differences between clusters were found to be statistically significant by any of the three methods in the case of 29 variables (in 4 cases at $P<0.001$; in 17 cases at $P<0.01$; in the 8 remaining ones at $P<0.05$).

Further analysis of the interval-scaled data was undertaken. Figure 3.3 shows some of the variables that allow us to clearly distinguish the different clusters. The six clusters (overall SMOPS types) were named after careful examination of their characteristics; a description will be given in Table 3.4. Olive yields are significantly different in all SMOPS types except organic ones. Organic SMOPS are rather heterogeneous in this respect, as shown by a large standard deviation.

Yield consistency is clearly lower in very extensive SMOPS than in all other ones. Differences between traditional, semi-intensive high input and intensive SMOPS are also statistically significant, but larger variation in semi-intensive low input and organic SMOPS does not allow a similar conclusion for these systems.

Average tree density is too variable to distinguish between all SMOPS, but semi-intensive high input and intensive orchards count significantly more trees per area unit than very extensive groves.

Application of irrigation is generally absent from very extensive, traditional and semi-intensive low input SMOPS, while it is applied in three-quarter of intensive SMOPS. The other types show a large variation.

No application of phytosanitary products is carried out in very extensive SMOPS. Other types show increasing averages towards intensive SMOPS, although only for traditional and semi-intensive high input systems the difference with very extensive SMOPS was statistically significant. The low number of observations (e.g. of intensive SMOPS) may be debit to this. Phytosanitary control in organic orchards is with organic products.

The pattern of fertiliser application is comparable, including semi-intensive low input systems in the group with significantly higher frequency. (Organic) fertilisation is relatively rare in organic SMOPS.

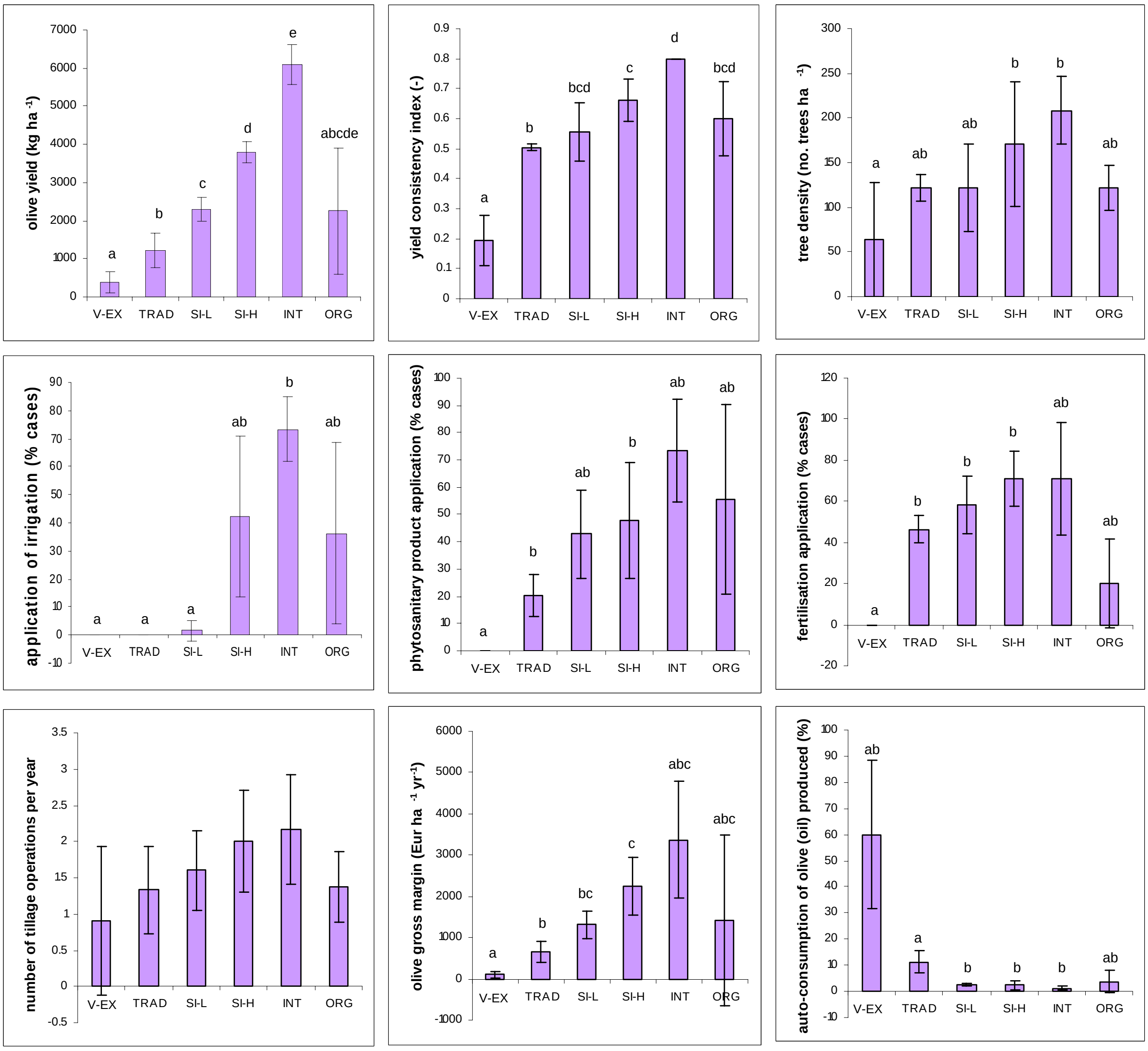


Figure 3.3. Cluster means and standard deviations for nine selected variables. Different letters above bars indicate statistically significant differences between clusters ($P<0.05$). The following clusters of SMOPS are distinguished: V-EX – Very Extensive; TRAD – Traditional; SI-L – Semi-intensive low inputs; SI-H – Semi-intensive high inputs; INT – Intensive; ORG – Organic.

The number of tillage operations is not significantly different between SMOPS types (high standard deviations). Nevertheless, average values clearly show a trend increasing from approximately 1 tillage operation per year in very extensive orchards to more than 2 in intensive orchards.

Gross margin on olive production is invariably low in very extensive systems, significantly higher in traditional orchards and again significantly higher in semi-intensive high input systems. Semi-intensive low input systems are not significantly different from traditional and semi-intensive high input SMOPS, although the average values show an increasing gradient. Intensive and especially organic SMOPS are characterised by a wide range of economic performance.

High rates of auto-consumption are a trait of very extensive and traditional SMOPS, while almost all produce of semi-intensive and intensive SMOPS is marketed. Organic SMOPS occupy an intermediate position.

Relations of two of the three ordinal variables with clusters were found to be statistically significant (Kruskal-Wallis): amount of pruned material (χ^2 16.472, P<0.01) and biodiversity value (χ^2 23.056, P<0.001). Differences in slope classes were not significant.

Table 3.4: Description of overall SMOPS classes.

Type of SMOPS	Description
Very extensive	Plantations are primarily characterized by low productivity (500 kg ha^{-1}) due to biophysical constraints or limited management. No fertilization or phytosanitary treatments are performed. Tillage and pruning are applied at minimal levels, grazing is frequent. Some plantations can be qualified as agro-forestry systems. Produce is predominantly for self-consumption.
Traditional extensive	Low density plantations (100 trees ha^{-1}) of old trees (>50 years), sometimes in an irregular pattern, with low yield levels (1250 kg ha^{-1}), low labour and material inputs and usually manual or semi-mechanised harvesting. Some cultural operations such as tillage and pruning are not performed on a regular basis
Semi-intensive (low input)	Plantations with a tree density from 100-150 trees ha^{-1} with variable tree age, mostly in a regular pattern, with an indicative yield level of 2500 kg ha^{-1}, intermediate labour input but low material inputs. All cultural operations are performed on a regular basis.
Semi-intensive (high input)	Plantations with a variable tree density usually with young, productive trees (indication: 30 years), with an indicative yield level of 3750 kg ha^{-1}, high labour and material inputs, but usually not irrigated (if irrigated, often supplementary irrigation).
Intensive	Plantations with a high tree density (>200 trees ha^{-1}) with young, productive trees (indication: 20 years), with an indicative yield level of 6000 kg ha^{-1}, high labour and very high material inputs, in the majority of cases irrigated (drip-irrigation).
Organic	Plantations with very variable characteristics, but usually low or intermediate tree densities (100-200 trees ha^{-1}), variable yield levels, high labour input and most notably, variable levels of *organic* material inputs. Compost application is typical for this system. Olive (oil) marketing is through certified organic channels.

For statistical analysis of nominal variables, the extensive and traditional SMOPS clusters were combined (n=11), and the remaining four classes were also grouped (n=17). Fisher's Exact Test showed that the first group could be associated with irregular planting (64%) patterns and the second with regular ones (82%) (P=0.020). Similarly, weed control by grazing was found to be practiced in the first group (82%) but less so in the second (35%) (P=0.024). Although in none of the SMOPS of the first group mechanical harvesting was practiced against 35% in the second group, the result of Fisher's Exact Test (P=0.055) was just not significant ($\alpha = 0.05$). All other nominal variables showed no close associations with one of the two broad groups of SMOPS. Presence of grazing and absence of mechanised harvesting are thus characteristic traits of extensive and traditional SMOPS, while modernised orchards are chiefly planted in regular patterns.

The following definitions of SMOPS classes were elaborated (Table 3.4). Although orchards come in wide varieties, Figure 3.4 gives an example of each type of SMOPS.

Validation of the SMOPS typology

The clustering was validated with discriminant analysis. Four canonical discriminant functions (obtained by addition of one variable at a time) were used in the analysis, cumulatively explaining 100% of variance. The first two functions respectively explained 72.8 and 22.3% of variance. Figure 3.5 shows the clusters and group centroids on a factorial plot of these two functions. Function 1 was highly correlated to the variables fertiliser application (0.979), olive production (0.816), and percentage of organic farms (0.809); Function 2 was only highly correlated to the percentage of organic farms (-0.768). Function 3 was highly correlated to a fourth variable, pruning materials grazed/fed to animals (0.742), and to olive production (0.677). The last function was highly correlated to fertiliser application (0.679) and to pruning materials grazed/fed to animals (0.549). This discriminant model was able to classify 100% of SMOPS correctly.

3.3.2. Economics of the respective SMOPS types

As was shown in Figure 3.3, olive gross margin of the SMOPS increases from very extensive towards intensive SMOPS and is highly variable for organic SMOPS. This trend can be partially explained by an increasing gradient of price obtained for olive oil from very extensive to intensive SMOPS (difference not significant). There is a price premium on organic olive oil in the order of €0.70-1.50 liter^{-1} (data from West-Crete and Basilicata), but organic farmers in the Trás-os-Montes and Córdoba target areas often do not succeed in selling their oil at higher prices. The vast majority of farmers in Haffouz sell olives at farm gate to ambulant traders at lower prices than they would receive after oil processing, presumably because of a lack of transport and storage facilities.

Very extensive SMOPS (TU3)

Traditional extensive SMOPS (PT1)

Semi-intensive low input SMOPS (GJ3)

Semi-intensive high input SMOPS (HE2)

Intensive SMOPS (IT4)

Organic SMOPS (CO2)

Figure 3.4. Photos of typical examples of SMOPS types from Haffouz, Tunisia (TU3), Trás-os-Montes, Portugal (PT1), Granada, Spain (GJ3), West-Crete, Greece (HE2), Basilicata, Italy (IT4) and Sierra, Córdoba (CO2).

Labour costs of production consist for all SMOPS for about 70% of harvesting. The total labour input is 116 h ± 39 h ha^{-1} for traditional SMOPS, 163 h ± 78 h ha^{-1} for semi intensive low input SMOPS, 274 h ± 161 h ha^{-1} for semi intensive high input SMOPS, 276 h ± 136 h ha^{-1} for intensive SMOPS, and 233 h ± 165 h ha^{-1} for organic SMOPS. Pruning frequency and type of harvesting (manual, semi-mechanised with branch shakers or mechanised with trunk shakers) can explain much of the variability both between and within overall SMOPS types.

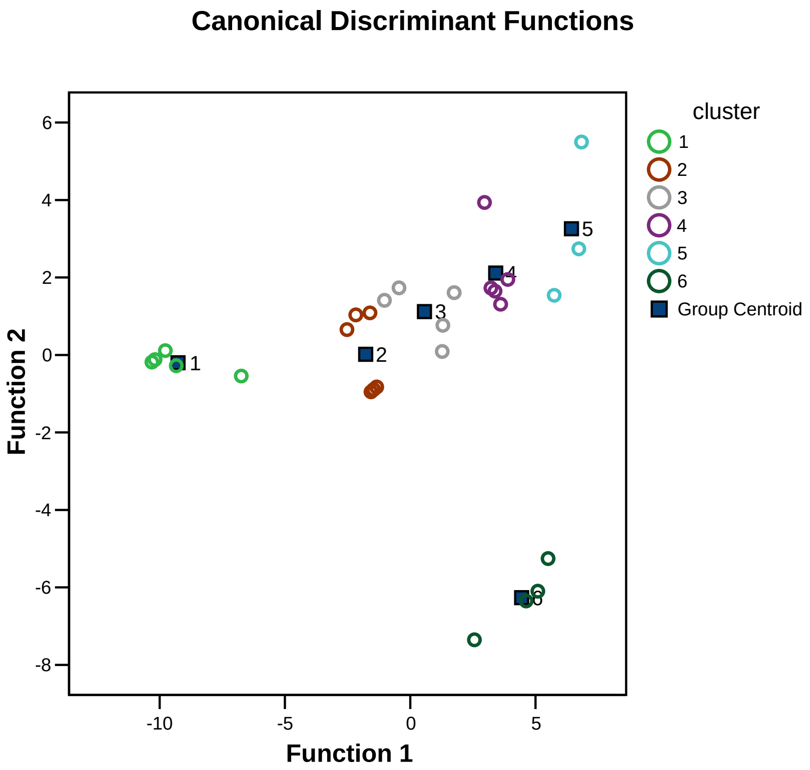


Figure 3.5. Factorial plot of the two most important functions distinguished by discriminant analysis. Clearly visible is the fact that Function 1 enables the discrimation of Cluster 1 (very extensive SMOPS) and – to a lesser extent – Cluster 5 (intensive SMOPS). Function 2 separates Cluster 6 (organic SMOPS) from the other systems. Cluster 2-4 (traditional and semi intensive SMOPS) remain relatively close.

Non-labour production costs amount to €455 ± €170 ha^{-1} for traditional SMOPS, €617 ± €91 ha^{-1} for semi intensive low input SMOPS, €967 ± €347 ha^{-1} for semi intensive high input SMOPS, €1457 ± €592 ha^{-1} for intensive SMOPS and €1051 ± €657 ha^{-1} for organic SMOPS. Costs for traditional SMOPS are relatively high because of higher cost of operation in these often steep areas. Organic SMOPS present high non-labour costs due to the high price of organic inputs.

Table 3.5 presents data on production costs, net revenues and profitability per SMOPS type. Production costs per hectare increase towards intensive SMOPS. Net revenues are better for very extensive than for traditional SMOPS (however, the reduced management may in the long run not be able to sustain yields). Organic systems have high costs but low output, resulting in comparatively low net revenues (despite attracting considerable subsidies). Net profitability is only positive for intensive SMOPS, meaning that these can ‘survive’ without subsidies. Very extensive SMOPS come second with only slightly negative result. Both systems present a relatively high standard deviation: not all individual SMOPS have positive results; for the case of very extensive SMOPS, TU1-4 need to be (and are) profitable because of absence of subsidies in Tunisia.

Per litre of olive oil, very extensive SMOPS present lowest production costs (mainly due to dominance of the Haffouz SMOPS with significantly lower labour costs), followed by intensive, semi intensive high and low input SMOPS. Organic olive oil is the most expensive in terms of production costs. Net revenues are highest for intensive SMOPS, followed by semi intensive high input systems; very extensive SMOPS come third due to absence of subsidies. Organic SMOPS obtain higher average revenues than traditional ones because of higher average olive oil prices and eligibility for additional agri-environmental subsidies. Profit per litre of oil is highest for very extensive SMOPS and most negative for traditional SMOPS.

Looking to production costs per unit of labour, differences between SMOPS types are relatively small (no data available for SMOPS TU1-4). Net revenues, or return to labour show highest values for semi-intensive and intensive SMOPS. Net revenues minus production costs per unit labour are on average only slightly positive in organic SMOPS and negative in traditional SMOPS; this indicates that farmers in traditional SMOPS accept lower return to labour than local market wage rates.

Table 3.5: Economic results of SMOPS types presented per area unit, output unit and labour input unit (± standard deviation).

Economic results	SMOPS type					
	V-EX	TRAD	SI-L	SI-H	INT	ORG
per ha (€ ha^{-1})						
PC	217 ± 392	1127 ± 415	1621 ± 747	2352 ± 942	2683 ± 945	2213 ± 1297
NR	63 ± 43	-64 ± 72	317 ± 429	745 ± 926	1358 ± 853	192 ± 586
NP	-17 ± 158	-428 ± 50	-247 ± 366	-117 ± 769	248 ± 615	-499 ± 350
per litre oil (€ l^{-1})						
PC	1.3 ± 1.5	4.7 ± 0.6	3.3 ± 1.1	3.2 ± 1.9	3.1 ± 1.5	5.4 ± 2.2
NR	0.8 ± 0.1	-0.3 ± 0.3	0.7 ± 0.8	1.0 ± 1.3	1.3 ± 0.7	0.0 ± 1.0
NP	0.4 ± 0.9	-1.9 ± 0.6	-0.5 ± 0.7	-0.1 ± 1.2	0.2 ± 0.6	-1.6 ± 1.1
per labour unit (€ h^{-1})						
PC	Na	5.8 ± 0.7	6.1 ± 1.6	5.3 ± 1.2	4.6 ± 1.1	5.3 ± 1.2
NR	Na	5.2 ± 1.2	9.1 ± 4.2	11.5 ± 9.0	11.3 ± 6.8	5.4 ± 1.5
NP	Na	1.8 ± 1.2	5.0 ± 2.6	6.8 ± 5.5	6.6 ± 4.0	2.2 ± 1.3

Economic results: PC = Production Cost; NR = Net Revenue (incl. subsidies); NP = Net Profitability (excl. subsidies).

3.3.3. *Natural resource management issues and options in SMOPS types*

The environmental issues at stake vary between the different SMOPS types. Moreover, the options for natural resources management depend on the orchards' specific lay-out and productive and socio-economic performance. In sub-sections 3.3.1-3.3.4, issues and options related to soil erosion, biodiversity, wildfire risk and water use will be linked to the SMOPS typology. Moreover, examples of the feasibility of mitigation strategies are presented, all of which are based on data from Martinez Raya et al. (2006).

Soil management options for the mitigation of soil erosion

Very extensive SMOPS. Labour is a major limitation in these systems, either because of a real shortage or because of low labour productivity. The low number of annual tillage operations (Fig. 3) already indicates this. Grazing is frequently applied and constitutes a cheap alternative for weed control. As tree density and soil cover by olive trees are low, a continuous cover (spontaneous vegetation) is the best management practice from a soil conservation perspective.

Traditional SMOPS. Often located on steep slopes, soil erosion control is crucial in these orchards. Due to financial constraints or low expected returns, application of fertiliser is scarce, the annual number of tillage operations is reduced and expenses on crop care are minimized. Maintenance of existing terraces could contribute considerably to control erosion. In cases where soil erosion is severe, its on-site impact could be large and its mitigation could pay off by increased yield levels. For the traditional orchards of the Spanish target areas, it was assessed that soil erosion could be reduced by 37% (±12%) at slightly decreased cost by substituting tillage with a cover crop managed by mowing or herbicide application. Yields would thereby not be affected or even show a modest increase.

Semi-intensive low input SMOPS. These SMOPS are characterised by a high mechanisation rate, but relatively low material and labour inputs. As a consequence, soil erosion is accelerated and resulting nutrient losses are not sufficiently compensated for. As irrigation is in many cases not an option, competition for water between weeds and olive trees is an important issue. Permanent cover crops are less suited to this type of system. Timely killing of the cover is necessary to avoid competition. No-till and reduced till strategies, possibly in combination with herbicide application seem to be the most promising and economical options. Implementing cover crops instead of conventional tillage is thought to reduce erosion by about half, while compromising yields (a loss of about €60 ha^{-1}) and reducing operational cost (€10-15 ha^{-1}) for the GJ1 and GJ3 systems. On the other hand, adopting no-tillage in SMOPS HE1 supposedly leads to savings of €50 ha^{-1} and a yield increase worth €110 ha^{-1}.

Semi-intensive high input SMOPS. These SMOPS have more options due to the possibility of irrigation. The soil erosion problem can be latent because higher levels of chemical inputs may mask soil loss and soil fertility decline. Assessments of improved management practices in four SMOPS (GJ2, CO5, IT2, PT3) showed that substantial reduction of soil erosion is possible without affecting yields while keeping operational costs stable (replacing conventional tillage with cover crop controlled by mowing; CO5), slightly reduced (saving €20-50 ha^{-1}; cover crop with herbicide application; GJ2, PT3), or substantially reduced (saving €120 ha^{-1} by installing a cover crop that is buried annually instead of the conventional 2-3 tillage operations; IT2).

Intensive SMOPS. Intensive SMOPS are not often present on steep slopes and therefore not the most prone to erosion. As with semi-intensive high input SMOPS it should be relatively easy to mitigate erosion risk. In the GJ5 and

HE3 systems, installing cover crops leads to reduction of erosion with 30% while economizing €5-50 ha^{-1} on tillage. The main risk of erosion is pollution of water resources by run-off. More rational and generally reduced amounts of chemical inputs could contribute to minimise this risk.

Organic SMOPS. For this category of SMOPS erosion control is crucial as chemical inputs are not allowed. Compost and manure application not only help maintaining soil fertility but also contribute to better soil structure. Integration with livestock presents an interesting opportunity for low density orchards, where livestock provide these organic inputs and can simultaneously graze permanent cover crops as to minimize competition for water with the olive trees.

Options for biodiversity enhancement

Very extensive SMOPS. Remote location and rare visits to this type of orchards result in elevated biodiversity values, especially where they are part of a diversified mosaic landscape including patches with natural vegetation. No further enhancement needed.

Traditional SMOPS. These systems normally also have high levels of biodiversity. Little disturbance and minimal use of chemicals contribute to this. If present, stone terraces provide a niche for reptiles, birds and insects.

Semi intensive low input SMOPS. In these types of orchards, more intensive management leads to increased physical disturbance. Frequent tillage leads to a lower quantity of weeds, and moreover to a lower number of species. Nevertheless, biodiversity values are usually classified as acceptable. A feasible biodiversity enhancement strategy could be to apply leguminous cover crops instead of mineral fertilization (also leading to reduced erosion and pollution). For the case of GJ1 and GJ3, this could lead to saving about €40 ha^{-1} without affecting olive yield. For IT3 it is estimated that split application of fertilizers adjusted to crop need (N-fertilisation by foliar application) and establishment of a cover crop that is annually buried by tillage may reduce the system's environmental impact, but at an extra cost of €407 ha^{-1}. If this leads to the expected yield increase of 600 kg ha^{-1}, the net gain could be €50 ha^{-1}.

Semi intensive high input SMOPS. High levels of chemical input use further constrain biodiversity. Integrated pest management strategies may benefit biodiversity while economizing on production costs.

Intensive SMOPS. These orchards have the lowest biodiversity value. The widespread use of drip irrigation makes it possible to apply fertilisers more timely and precisely by fertirrigation. General reduction of the level of polluting agents could improve their biodiversity value. The financial consequences of such strategies vary: integrated pest management could save €15 ha^{-1} in HE3, while biological control of pests and diseases in GJ5 leads to additional costs of €209 ha^{-1}.

Organic SMOPS. These SMOPS are comparable to very extensive or traditional SMOPS in terms of biodiversity value, although the most intensively managed orchards may compare to semi intensive low input orchards.

Options to reduce wildfire risk

Very extensive SMOPS. A general lack of pruning and remote location make these orchards prone to wildfires. Incentives to change this may be reduced by the limited economic interest in these plantations. Pruning in small private orchards could be stimulated by linking regular pruning as a condition to subsidy payment, while large areas could be split by (government sponsored) construction of wildfire corridors. Very extensive SMOPS could be relatively less prone to wildfires than other SMOPS because of their usually very low tree density.

Traditional and organic SMOPS. Location and more frequent pruning are factors that make those plantations less critical in wildfire risk, but their higher tree density may neutralise this beneficial effect. The same options as for extensive SMOPS apply, with the difference that farmers may be more motivated to minimize wildfire risk because their plantations represent an important economic asset.

Semi intensive and intensive SMOPS. These orchards with regular pruning and weed management do not usually have high wildfire susceptibility.

Options to reduce water use

Intensive SMOPS. Water resources depletion is a serious problem in some zones where many irrigated orchards exist. By applying deficit irrigation, adjusting water gifts to crop needs, a reduction of water use is possible (of about 20% reported for HE3 and GJ5). This would reduce costs, but also yields. For the Greek case this reduction would be cost neutral, but for the Spanish case, a net loss of €300 ha^{-1} would result.

3.4. Discussion and conclusions

3.4.1. Remarks about the SMOPS classification

A supra-national classification of sloping and mountainous olive plantation systems is presented that successfully distinguishes five different SMOPS types along an intensity gradient (very extensive, traditional extensive, semi-intensive low input, semi-intensive high input and intensive orchards), and organic orchards with variable intensity of production as a sixth type. The classification was based on an aggregate analysis of previous classifications at the target area level.

Due to differences between the target areas, some SMOPS distinguished at the target area level that were at relatively large distance from the overall average situation tended to be clustered together; for instance, the SMOPS TU1-TU4 ended up in the same cluster despite considerable differences between them. In fact, it would be possible to make a subdivision of very extensive SMOPS between regularly managed and occasionally managed systems. The latter could be considered to be agro-forestry systems. This type of system occurs in other Mediterranean countries as well, e.g. Turkey (Tunalioglu and Gokce, 2001).

On the other hand, it proved difficult to classify SMOPS types that were more closely interrelated, i.e. to distinguish between traditional and semi-intensive SMOPS, and more specifically the subdivision of the latter in semi intensive low input and high input SMOPS. These tended to be grouped together in cluster analyses because they were more closely related to each other than to very extensive, intensive and organic SMOPS. This could be resolved by reclassifying them separately. Despite this complication, discriminant analysis proved the validity of the final classification.

3.4.2. Economics of SMOPS types and conservation of natural resources

Very extensive SMOPS can compete with other types by the very reduced use of inputs, including labour. However, this may be symptomatic of an ongoing abandonment process. Where appropriate, extra management efforts could be rewarded, e.g. by policy to reduce wildfire risk.

Intensive SMOPS cause most environmental havoc, while they are also the most profitable systems. Making subsidies conditional to a minimum set of good agricultural practices (known as cross-compliance in European policy documents) could provide enough of an incentive to enhance their environmental performance.

Other SMOPS types occupy intermediate positions. As many systems present negative or only slightly positive net revenues (including subsidies), cross-compliance rules requiring farmers to incur extra costs might not lead to increased uptake of natural resources conservation management practices. Rather, they will risk loosing subsidies. These SMOPS face the choice of increasing production or reducing costs. Policy schemes rewarding them for natural resources management actions beyond expected minimum practice could provide them with welcome incentives.

Better marketing of olive oil might constitute an important driver for improved natural resources management: if e.g. organic olive oil can be sold at a substantially higher price, these systems might become more and more widespread.

3.4.3. Natural resources management and SMOPS types

The typology presented gives some useful general characteristics to recommend natural resources management practices. However, recommendations may not be applicable to each individual SMOPS or every particular local condition.

Soil management options are widely studied in olive orchards. Reduced tillage has generally been found to result in less soil erosion (Pastor and Castro, 1995; Kosmas et al., 1997; Mollenhauer et al., 2002; de la Rosa et al., 2005; Hernandez et al., 2005). However, fields under no-tillage that are kept bare by herbicide application presented the largest erosion rates (Gomez et al., 2003;

Gomez et al., 2004). It is thus not the absence of tillage but the presence of soil cover that can conserve the soil. Many studies in the literature are based on model studies that frequently tend to overestimate soil losses on steep slopes. Effects of stone cover, terraces and orchard soil management, or simply the absence of erodible soil limit erosion in practice. Orchard cover with (strips of) herbaceous species have shown encouraging results (Hernandez et al., 2005; Martínez Raya et al., 2005)

High biodiversity value in very extensive and traditional orchards is not only a characteristic of these systems, but linked to the mosaic landscape in which they usually occur (Siebert, 2004). Substantially enhancing biodiversity in intensive orchards in areas characterized by vast monocultures would thus require much more than applying conservation practices in orchard management. However, as clean weeding – the conventional practice in intensive orchards – was found to lead to impoverishment of ground flora in Crete (Siebert, 2004; Allen et al., 2006), reduced soil management definitely has a positive effect on flora, and on arthropods and birds. Reduction of pesticide use in GJ5 orchards was shown to benefit spider abundance and species richness in tree canopies (Cardenas et al., 2006).

Several studies indicate that a minimum recommendable level of management also exists, and abandonment of orchards leads to a lower diversity of some typical Mediterranean herbaceous species which are intolerant to shade (Siebert, 2004; Allen et al., 2006), including floristic diversity, and as a consequence, diminished provision of pollination services (Potts et al., 2006).

In many low intensity SMOPS the low productivity is a key-problem. There are several options to enhance orchard productivity of those types of orchards without causing negative environmental impact. Generally, fertilisation can be improved by taking into account crop needs (leaf sampling, compensation of nutrients harvested) and distributing applications in time. Leguminous cover crops and mulching are other alternatives. These management practices not only directly but also indirectly benefit productivity by contributing to better soil structural quality and water retention capacity.

Although these management options could also benefit more intensive SMOPS, a frequently mentioned problem here is control of pests and diseases. Regular monitoring is recommended to ensure timely remediation, but at the same time may contribute to reduce amounts of chemicals used. So again, orchard productivity can be enhanced without additional detrimental effect to the environment. Where reductions of chemical inputs do lead to potential yield loss, effects of decreased costs could compensate for reduced return.

Chapter 4

Traditional olive orchards on sloping land: sustainability or abandonment?

Duarte F, Jones N, and Fleskens L.

Journal of Environmental Management (accepted)

4. Traditional olive orchards on sloping land: sustainability or abandonment?

Abstract

Traditional olive orchards account for a large share of the area under olives in the EU, particularly in marginal areas, like those analysed in the OLIVERO project. In general, traditional olive growing can be described as a low-intensity production system, associated with old (sometimes very old) trees, grown at a low density, giving small yields and receiving low inputs of labour and materials. Though such systems are environmentally sustainable, their economic viability has become an issue, since EU policies favour more intensive and competitive systems. Orchards that have not been intensified seem to be threatened by the recent reform of the EU olive and olive oil policy, as income support has been decoupled from production. The main purpose of this chapter is to identify the present constraints to traditional olive growing, and to recommend some private and public interventions to prevent its abandonment. During the OLIVERO project, traditional olive production systems were identified and described in five target areas (Trás-os-Montes – Portugal, Cordoba and Granada/Jaen – Spain, Basilicata/Salerno – Italy, and West Crete – Greece). The causes and consequences of abandonment are discussed, based on the analysis of the costs and returns, which revealed that these systems are barely economically sustainable. Their viability is only assured if reduced opportunity costs for family labour are accepted, and the olive growing is part-time. Based on these results, recommendations are made to prevent the abandonment of traditional olive growing and to preserve its environmental benefits.

4.1. Introduction

The EU olive and olive oil sector is now facing new challenges as a result of its recent integration in the Single Payment Scheme (SPS). The sector is, however, heterogeneous in terms of the structural features of the olive orchards, farming practices and the socio-economic characteristics of the olive farms.

Traditional olive production accounts for a large share of the area under olives, particularly in marginal areas like those analysed in the OLIVERO project. In general, the traditional system can be described as a low-intensity farming system (Beaufoy et al., 1994). It is associated with old or very old trees grown at low densities, giving low yields, receiving low agrochemical inputs, and with a low degree of mechanisation and absence of irrigation.

Awareness of the importance of low-intensity farming systems to the conservation of natural resources conservation has grown gradually (Bignal and

McCracken, 1996). In fact, this type of production system has important environmental and social functions.

The maintenance of traditional olive groves is benign for the environment, as these systems show high levels of biodiversity and low rates of soil erosion (Loumou and Giourga, 2003). The latter is particularly important, given that the groves are frequently on sloping land. According to the latter authors, traditional olive groves have been able to maintain production throughout the centuries on poor erosion-prone Mediterranean soils.

The abandonment of traditional olive groves would have negative environmental consequences beyond a decrease in biodiversity and increase in erosion risk, as it would result in an increased fire risk, and major changes to the traditional Mediterranean landscape. As Angles (1999) notes, the olive tree is the iconic tree of the Mediterranean where, along with vines and cereals, it helps define the most striking features of the agricultural landscape. Where intensive olive monocultures have replaced the traditional mosaic landscape (including traditional olive orchards), biodiversity and landscape values have been substantially reduced (Grove and Rackham, 1993; Santos and Cabral, 2003; Siebert, 2004).

Traditional olive growing also has a significant socio-economic role, as it provides an important source of income and employment, particularly in marginal regions, strongly dependent upon agricultural activities. According to de Graaff and Eppink (1999), over the centuries olive trees have played an important role in the rural development of the Mediterranean’s relatively poor rainfed areas.

Olive orchards have historically been planted on marginal soils. Changes in production and consumption patterns, together with EU policies, have pushed olive production systems towards flatter, more fertile land. Olive growing in marginal areas, mostly relying on traditional production systems, is now strongly disadvantaged due to its lower productivity. However, both the abandonment and the intensification of this low-intensity farming system may be detrimental to the ecological value of the orchards (Bignal and McCracken, 1996; Caraveli, 2000). Despite being environmentally friendly, this type of system seems to be barely economically sustainable.

According to Loumou and Giourga (2003) two main factors threaten traditional olive cultivation, favouring its abandonment: competition from intensive olive groves in flatter and irrigated areas, and cheaper seed oils. EU policy for olives and olive oil has promoted intensification in certain regions, but has to some extent averted the abandonment of small traditional plantations in marginal zones, preserving their environmental and social value (Beaufoy, 1998).

The new Common Agricultural Policy (CAP) rules concerning olives and olive oil will be detailed in Section 4.2.4. However, we can already note that totally integrating the olive oil sector in the SPS, as almost all the main EU producing countries have already done, may lead to increased abandonment of this type of olive growing, as income support for olive growers will be completely decoupled from production.

The purpose of this chapter is to clarify what the traditional olive production system means, to describe its main features as observed in OLIVERO target areas (Trás-os-Montes (Portugal), Cordoba and Granada/Jaen (Spain), Basilicata/Salerno (Italy) and West Crete (Greece) and the constraints to its bio-physical and economic sustainability, and to suggest private and public interventions to prevent the abandonment and collapse of these habitats.

The OLIVERO target areas chosen cover a large proportion of the olive groves on sloping land, which are at greater risk of erosion and abandonment. The main biophysical, climatic and socio-economic characteristics of these regions are detailed by Stroosnijder et al. (2007), who also explain the OLIVERO research framework.

4.2. What is a traditional olive production system?

Of the 24 Sloping and Mountainous Olive Production Systems (SMOPS) identified in the OLIVERO project, seven are considered to be traditional production systems (Table 4.1). The biophysical and socio-economic criteria used to identify them include slope, tree age, tree density, cultural practices, and farm type and size. Also important were local knowledge (e.g. from Ministry of Agriculture, farmers' associations), the results of an agro-socio-economic survey (Duarte, 2005a), and other typologies (Beaufoy, 1998); Mansinho and Henriques, 2000).

Beaufoy (1998) considers three main types of olive-growing system: traditional, semi-intensive and intensive. The traditional system is associated with old or very old orchards, frequently on terraces and grown with few or no agrochemicals. Mansinho and Henriques (2000) consider five systems: traditional, organic, traditional improved, semi-intensive and intensive. The traditional system is defined by a low planting density and small yield, few agrochemicals, no irrigation and manual harvest. OLIVERO traditional production systems display these features. The agro-socio-economic survey, based on a sample of at least 60 farmers in each target area, allowed each farmer to identify and characterise his different olive-growing plots according to the criteria mentioned above, like density of planting, tree age and main cultural practices. The results allowed the different SMOPS to be identified and characterised, associating them with certain socio-economic characteristics of the producer. In the particular case of traditional SMOPS, the most important finding was the association with small and very small farms and with producers whose income came mainly from off-farm activities (Duarte, 2005a).

In the five project target areas, the traditional systems represent around 23 % of the total area under olive orchards (Fleskens, 2005). However, in certain areas, such as Trás-os-Montes in Portugal or Basilicata in Italy, they are by far the most common production system, and are normally associated with small olive growers.

In some target areas, traditional systems are scattered, occurring side by side with semi-intensive, organic or intensive systems. However in others, like Cordoba, they are concentrated in particular locations.

4.2.1 Plantation characteristics and farming practices

All the traditional systems identified have a productive function, though they are less productive when compared to the other systems. The olive orchards show similar structural characteristics (Table 4.1), in terms of orchard age, planting density and plot slope. Despite the slope, the most common method for weed control in these systems seems to be tillage. In some regions, bare soil is even associated with a “clean” and “well cultivated” olive orchard (Metzidakis, 2004). The practice of keeping a cover crop, natural or sown, during the rainy period of the year, in order to prevent erosion is fairly recent. In traditional SMOPS in Granada/Jaèn, plant strips are applied in 21% of the area (Xiloyannis et al., 2006).

Though grazing still remains a common method of weed control in Crete and Cordoba, in Granada and Trás-os-Montes this practice has almost disappeared. Indeed, in many European olive-producing regions, crop cultivation and grazing in olive areas have been progressively abandoned since the 1970s (Beaufoy, 2001).

Table 4.1. Traditional SMOPS orchard characteristics and farming practices.

SMOPS code [1]	HE 1	CO 1,3,4 [2]	GJ 4	IT 1	PT 1
Slope	Moderate – Steep	Moderate	>30%	Moderate – Steep	Moderate – Steep
Structural characteristics					
Tree age (years)	>50	>50	–	>50	>50
Production kg ha^{-1}	1 850	816 – 1 012	1 500	2 100	1 100
Oil yield l kg^{-1}	0.25	0.20	0.24	0.19	0.17
Planting pattern	Irregular	Regular	Regular	Regular	Regular
Planting density Trees / ha	50 – 80	130 - 135	100	100 - 156	100 - 150
Cultural operations					
Pruning	1 every 5 years	1 every 3 years	1 every 3 years	1 every 3 years	1 every 3 years
Tillage	None – 1 every year	2 every year	No tillage	1 – 2 every year	2 every year
Fertilisation	Chemical 1 every year	Chem.+ Organic 3 every year	Leaf Chemical 2 every year	None	Chemical 2 every year
Pest control	Mostly yes	2 every year	2 every year	None	None
Weed control	Chemical – Tillage – Grazing	Tillage + Grazing	Chemical 2 every year	Tillage	Tillage
Harvest	Manual	Manual	Backpack vibrator	Manual	Backpack vibrator

[1] HE :1 West-Crete Traditional System; CO 1,3,4: Cordoba Traditional Systems; GJ 4: Granada–Jaen Traditional System; IT 1: Basilicata–Salerno Traditional System; and PT 1: Trás-os-Montes Traditional System in (Fleskens, 2005), [2] range of the three original Traditional Systems.

Source: adapted from Xiloyannis *et al.* (2004) and Fleskens (2005).

No irrigation, low levels of chemical inputs or none at all, and low annual consistency of yield, are also common features of these systems in the different target areas, and help explain their low productivity. While operations like fertilisation and pruning are done regularly in Trás-os-Montes, in other target areas like West Crete, some traditional systems are seldom tilled or pruned (Metzidakis, 2004).

Harvesting is normally manual or semi-mechanised, as these systems are frequently associated with small or very small farms, and mechanisation is hampered by the structural features of the orchards. All the traditional SMOPS identified are mainly oriented towards olive oil production. However, there are significant differences in olive oil yield, the range being from 0.17 l/kg in Trás-os-Montes to 0.25 l/kg in Crete (Metzidakis, 2004).

The quality of the olive oil quality from the five target areas may generally be considered high, and some traditional producers have been involved in a process of product differentiation, associated, for instance, with the use of Protected Denomination of Origin (PDO) labels (Metzidakis, 2004). These PDO labels have been applied for and have been awarded on a regional basis for typical traditional products, based on the use of specific varieties, production process and/or quality requirements (i.e. Colline Salernitane , Italy – Regione Campania (2006); Azeite de Trás-os-Montes, Portugal – IDRHA (2003)). However, the proportion of olive oil marketed as a PDO product is still small (for Trás-os-Montes 3500 hl in 2001 i.e. 2.7% of regional production, according to Duarte et al., 2006).

4.2.2 Biophysical characteristics

Orchard characteristics and farming practices are closely related to the biophysical characteristics of the different regions, namely the soil and climatic conditions, slope and water availability. On the other hand, the environmental impact of particular practices depends in part on these conditions.

In the OLIVERO project much emphasis was given to slope and its effect on soil erosion. Traditional systems may be present on different types of slope, but as Table 4.1 shows, they tend to be associated with moderate (>15%) and steep slopes (>25%). Figure 4.1 shows the distribution of traditional areas of olive groves in the Portuguese target area, classified by slope, based on Olive GIS information.

For simplification, traditional systems were assumed to have a tree density of less than 150 trees per ha. Despite this simplification it can be confirmed that traditional systems in Trás-os-Montes are mostly on moderate / steep slopes (Duarte et al., 2004) and thus face a higher potential erosion risk than other olive plantation systems that are normally concentrated on shallower slopes. Although slope is an important factor in determining potential erosion risk, actual erosion is also influenced by biophysical characteristics like the soil type and rainfall, and also by farming practices. Much depends on the maintenance of soil cover (Gomez et al., 2003). Where the soil is permanently covered, erosion may be negligible (Kosmas et al., 1997).

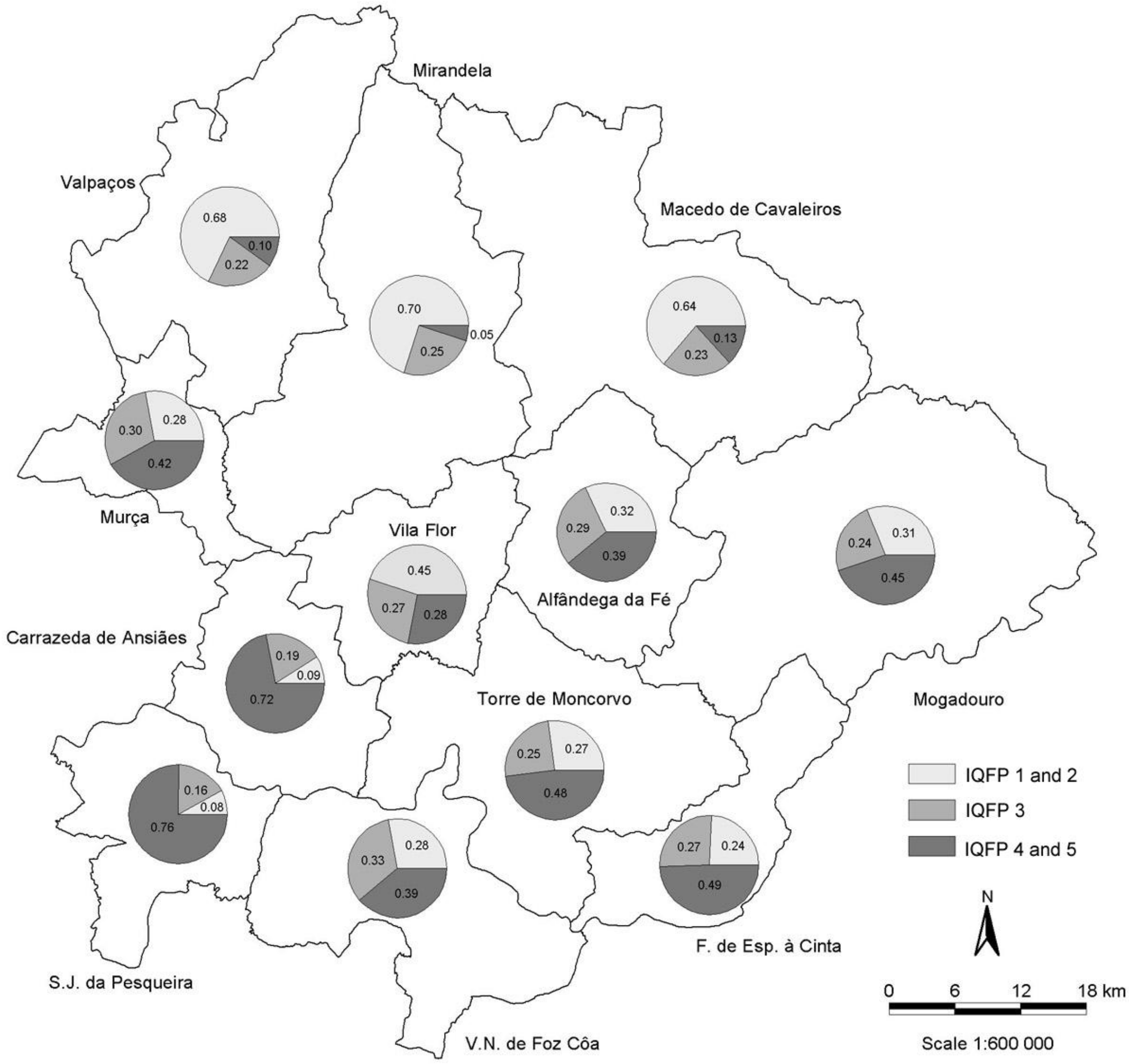


Figure 4.1. Slope categories (IQFP[1]) of plots with olive orchard land use and tree density below 150 trees/ha for the twelve municipalities of the Trás-os-Montes target area, Portugal (SIG-OL and slope database from IFADAP/INGA). Pale grey = slopes < 15%, darker grey = slopes of 15–25%, dark grey = slopes >25%.

Soil depth in the traditional orchards is generally shallow (0.2–0.5 m), and soil fertility low. In response to these conditions, many olive orchards in Trás-os-Montes, as well as in the other target areas, have traditionally featured terraces to conserve soil and water. However as these terraces are very costly to maintain, many of them have been abandoned. While the resulting deterioration of terraces might increase erosion, the ground cover that develops after tillage is ceased could offset such a trend (e.g. Siebert, 2004).

---

[1] IQFP (Índice de Qualidade Fisiográfica da Parcela) is a physiographic index of the parcel. This index is the only information in the Olive GIS database that allows the representation of olive orchard parcels with different slopes. This index has 5 categories: 1 (0–10%), 2 (0–15%), 3 (0–25%), 4 (0–45%), 5 (≥ 45%). The upper limit of the interval means that at least 45% of the slope's value is under that limit. The higher the index the higher the dominant slope. For simplification these five categories have been reduced to three categories that roughly represent slopes up to 15%, between 15 and 25% and over 25%.

The target areas studied have an average annual rainfall of between 400 and 700 mm, except in zones at higher altitudes, where this value can reach 800 or 900 mm. The summer is generally hot and dry (Xiloyannis et al., 2004). Under these climatic conditions, the more relevant constraint is scarcity of water and tillage is seen as a way to improve water penetration and reduce competition from weeds.

The agro-socio-economic survey (Duarte, 2005a) revealed that many farmers in West Crete, Trás-os-Montes and Basilicata do not perceive erosion as a serious risk. None of the farmers interviewed mentioned erosion as a major constraint to olive production – probably because in many of these traditional olive orchards water is scarce and/or there are terraces. It is not only the perception of erosion that is low: the incentive for preventive action on the part of the farmer may also be low, as according to Stoate et al. (2001), the changes in soil are generally slight during the farmer's lifetime and environmental problems associated with erosion are externalised. No information is available on erosion perception in Cordoba, but the erosion assessment led by the Cordoba team in this target area revealed that traditional SMOPS had smaller annual soil losses as a result of the application of certain good agricultural practices, such as natural cover crops controlled by grazing or mowing (Gomez, 2005).

As they are low-input farming systems associated with lower use of chemical herbicides, pesticides and fertilisers, traditional systems have rather positive ecological functions. These functions have been identified and discussed in Metzidakis (2004) and can be summarised as contributing to soil and water conservation, biodiversity, landscape enhancement, and prevention of fire risk.

4.2.3 Socio-economic characteristics

The OLIVERO agro-socio-economic survey data, discussed in detail in Duarte (2005a), allows us to summarise here the main features of traditional olive farmers. In general they are small producers, with less than 10 hectares and often no more than 2 hectares of olive orchard. The average olive orchard in SMOPS HE1 is 1.26 hectares (Duarte, 2005a). The main sources of income for most farmers are off-farm activities (salaries from services) and pensions. The small farm size usually precludes them from obtaining sufficient income from agriculture alone. For these olive producers, olive growing assures them some income.

The farmers of traditional SMOPS are old, generally about 50 years or older (e.g. 50 in Cordoba, but as much as 58 in West Crete: Metzidakis, 2004; Duarte 2005a). Most (over 90%) farmers said they had successors for their farms. This may seem surprising in the light of their weak productivity and generally negative economic returns. However, it must be taken into account that sentimental and cultural reasons are important drivers for many traditional olive farmers, who regard their ability to work in their olive groves as an important aspect of quality of life, if income is secured by other activities (de

Graaff, 2005). This fact is also illustrated by the high proportion of olive groves acquired through inheritance: 92% in SMOPS HE1 for example. Continued inheritance has contributed substantially to the small orchard size and high fragmentation rates (e.g. farms in Trás-os-Montes have on average 24 land parcels: Duarte, 2005a).

In many of the traditional systems identified, olive growing is accompanied by other crops (permanent or annual), or even by animal production. For instance, in Trás-os-Montes only 16% of the olive farms are specialist olive-growing farms (those with a Standard Gross Margin (SGM) from olive growing equal to at least 75% of total SGM). Most of the regional olive farms specialise in permanent crops. This information confirms that these types of farms actually derive agricultural income from different crops and do not depend exclusively on olive growing (Metzidakis, 2004).

Traditional olive farmers do not in general have a close relationship with the market. They process olives in private or cooperative olive mills, retaining an important part for their own domestic use. Informal marketing among farmers' relatives and friends is also important (Duarte, 2005a).

Cooperative membership is high: in SMOPS CO1 it is 88% (Metzidakis, 2004), in Granada/Jaen 90% (Duarte, 2005). In Basilicata/Salerno, all but one of the farmers interviewed was a member of a cooperative, although often the only reason was that this is the only way to be eligible for CAP subsidies (Duarte, 2005a).

Rural depopulation is a common characteristic of all target areas, especially in the less accessible areas where traditional SMOPS are commonly present. It has indirect effects on the liveability of the areas, but also impacts directly on the availability of labour. Seasonal labourers are often employed during olive harvest, albeit less in traditional SMOPS than in other systems.

4.2.4 Policy factors affecting the future of traditional systems

In the scenario studies done for OLIVERO (de Graaff, 2005) the policy environment is assumed to be an external factor, i.e. a factor that despite affecting the future of the different SMOPS cannot be influenced from within. Two other main external factors important for traditional systems – agro-climatic and demographic factors – are detailed in another paper (de Graaff et al., 2007).

The future of SMOPS, particularly of traditional ones, will be affected by the policy framework of the CAP. Recently, support for EU olive growers has changed because the olive and olive oil regime has been integrated into the SPS.

Under the new rules established in Council Regulation (EC) no. 864/2004 partial decoupling has been permitted in order to prevent the abandonment of olive groves in marginal areas (Duarte, 2005b). According to this Regulation, at least 60% of the average of production aid payments during the reference period 1999/2000 – 2002/2003 (100% for holdings with less than 0.3 ha of olive orchard), was supposed to be converted into entitlements under the SPS, meaning that each farmer would then benefit from equivalent income support. The remaining part would be retained by Member States as national envelopes that would be used to grant farmers an aid per olive GIS hectare for the maintenance of the environmental and social value of olive groves (Duarte, 2005b; Duarte et al., 2006).

Each Member State was free to decide the proportion of decoupling: from 60% up to 100%. At the time of writing, all the main producing countries had opted for 100% decoupling, except for Spain (which opted for 95%). By opting for total decoupling, an opportunity to favour particular olive production systems that have environmental and social value has been lost. What made total decoupling attractive was that it is administratively simpler; pressure from producers' associations was also influential. Note that in countries where small and traditional olive growers are in the majority, the possible financial transfer associated with a partial decoupling would result in small subsidies (Duarte, 2005b).

The application of the SPS has been accompanied by the introduction of cross compliance (Council Regulation (EC) no. 1782/2003), which makes Good Agricultural and Environmental Practices mandatory for every farmer receiving EU support. Farmers not complying with these conditions suffer a reduction or a complete exclusion from direct payments (Duarte et al., 2006). The SMOPS identified by OLIVERO can be helpful when defining the most suitable cross-compliance conditions in each region that will support environmentally valuable olive growing. Some recommendations for good agricultural and environmental practices for traditional systems are listed at the end of this article.

Finally, it should be mentioned that one way of supporting environmentally and socially valuable olive growing is by improving agri-environmental measures (AEM) and providing additional financial resources to implement them. The aim of these measures is to support farmers who use environmentally friendly production practices (Duarte et al., 2006). It is up to each Member State to establish an agri-environmental programme, defining the appropriate measures, the farmers' obligations, and the amounts of aid to be awarded. The application of these programmes became mandatory for Member States after the 1992 CAP reform, but farmer participation remains voluntary. The Member States co-finance these programmes. Originally the contribution was 25% in Objective 1 regions (regions with a Gross Domestic Output below 75% of the EU average), and 50% in the remaining regions, but since the 2003 CAP reform these co-financing rates have been 15% and 40%, respectively.

Though AEM are considered to be the main instrument for achieving environmental objectives within the CAP (European Commission, 2003), their adoption by farmers has been disappointing, as noted by Fay (1998), cited in Stoate et al. (2001). The low adoption is attributed to inadequate funding, resistance to long-term obligations, and reluctance to abandon traditional practices. AEM and other rural development aids are currently being redefined within the EU Structural Funding Reform. At the moment, therefore, the policy environment that olive growers will face in the future is still uncertain.

4.3. Major constraints regarding soil and water conservation and socio-economic aspects

In order to develop scenarios, a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was conducted with the participation of the stakeholder platform (representatives of different types of farmers, olive processing units, extension officers and farmers' organisations). This type of analysis, frequently used in marketing research (Haynes, 1999), aimed to identify the major key issues and prospects for the regional SMOPS.

Two major sets of constraints (i.e. weaknesses and threats) are discussed here: those relating to soil and water conservation and those relating to socio-economics. They were identified in close collaboration with project end-users (de Graaff, 2005), represented by the stakeholder platform.

4.3.1 Soil and water conservation constraints

As mentioned before, the most significant threat to traditional SMOPS mentioned by all project partners is abandonment. According to MacDonald et al. (2000) agricultural land is considered to have been abandoned as an economic resource when income flow has ceased and the opportunities for changes in farming practices and structure have been exhausted. Abandonment is a complex phenomenon with a wide range of causes; it has significant consequences for soil and water conservation (e.g. Lasanta et al., 2001). Here we analyse the main causes and consequences of the abandonment of traditional olive growing.

Causes of abandonment of olive growing

According to Baldock et al. (1996), the most important factors that may lead to abandonment are: environmental factors, geographical location, agricultural structures, social factors, economic factors and policy factors. Environmental factors (such as soil, climate, topography, water supply or altitude) have a fundamental influence on the production potential of a particular area. Olive growing in sloping and mountainous areas is limited by handicaps like shallow soils, steep slopes and scanty rainfall; in combination with the great age of the trees, these factors account for the low productivity observed for traditional systems (Gálvez et al., 2004). This low productivity is one of the main causes of the difficult economic sustainability of these systems, as will be shown below. Another factor found to influence abandonment was the existence of terraces with limited accessibility (Bielsa et al., 2005).

Olive growing in sloping and mountainous areas may also be at a disadvantage because of the difficult access to production factors and final markets. Farm structure is also a relevant factor affecting farm's viability. In all the regions examined, the farms associated with traditional SMOPS are small or very small. "Under poor soil fertility and low rainfall, large holdings are required in order for agriculture to be economically viable" (Viana, 2003). The provision of infrastructure such as access roads and watering points are also important factors to ensure the viability of the farms.

All these sloping and mountainous areas are characterised by aged farmers and in many cases by the absence of successors. The lack of social, cultural, and recreational facilities also increases the risk of abandonment, as young people are moving away from these regions. The demographic features of these areas, particularly the declining population, decrease labour supply and contribute to increase production costs, as de Graaff and Eppink (1999) have noted.

Baldock et al. (1996) identify several economic factors that may contribute to abandonment. Summarising, it can be mentioned that olive producers in marginal areas face competition from other production regions that have a comparative advantage that influences their economic sustainability. The low ability of farmers to invest in their holdings is another important factor favouring abandonment.

Finally, but also very important, is the fact that the economic sustainability of olive farms strongly depends on the policy framework. It is feared that the application of the SPS will stimulate abandonment, particularly of the traditional systems. In fact, as will be shown later, the economic results of traditional systems were found to be strongly dependent on production subsidies, as well as on other CAP measures such as less-favoured areas payments and agri-environmental subsidies.

Consequences of olive growing abandonment on soil and water conservation

The environmental effects of abandonment vary greatly and may be complex, as shown by several studies mentioned by Viana (2003). These consequences are site-specific and may be non-uniform, even in a small region. Viana (2003) summarises the main environmental impacts of abandonment as follows:

- on-site (soil degradation, reduction of accessibility, …), and off-site effects of soil erosion (flooding, sedimentation, water quality and quantity,…);
- increased risks of wildfires;
- changes in wildlife communities (flora and fauna);
- changes in landscape;
- changes in future land use;

One major effect of the abandonment of olive groves in Mediterranean regions is the increased risk of wildfires. Abandoned olive plantations have a high fire risk because of the dense growth of trees and spontaneous vegetation and the high oil content of unpicked fruits (Metzidakis, 2006). This risk is exacerbated by the spontaneous establishment of fire-prone pine trees in abandoned areas (Grove and Rackham, 1993). Steep slopes are at greater risk because fire spreads easily upslope and because they are generally less accessible for fire fighters (Eicher, 2005). So, preventing the abandonment of traditional olive groves can be socially relevant for regions like the OLIVERO target areas, where every summer thousands of hectares of forest and crops are destroyed by fire.

According to Baldock et al. (1996) the occurrence of fires is frequently associated with problems of erosion and land degradation, as after fires the slopes are left without vegetation during winter rains. This effect is especially important in the initial stage of abandonment, when a natural soil cover is only starting to develop and its root system has not yet developed (Dunjo et al., 2003). Wildfires delay the natural succession process, perhaps by over 30 years (Bielsa et al., 2005).

Erosion problems may also arise from other reasons as a consequence of abandoning olive growing. In some cases, traditional olive groves are on steep slopes that are otherwise unproductive and are protected by terraces from erosion and loss of nutrients and water. As Beaufoy (2001) mentions, the maintenance of these terraces is labour-intensive and so their abandonment is quite common in marginal areas, leading to landslides and sometimes desertification.

Increased erosion may also be a consequence of the abandonment of olive orchards when the land use changes to pasture and over-grazing reduces the plant cover (Metzidakis, 2006). The off-site effects of erosion from abandoned orchards may be important, as shown by Schoorl and Veldkamp (2001).

The abandonment of olive growing impacts on biodiversity in complex ways that are difficult to generalise. Abandonment is a process with different stages, which may generate different types of ecosystems after several years. It has been found that the biodiversity of olive orchards, specifically the floristic diversity of shade-intolerant herbaceous species, may decline following abandonment, because perennial cover becomes denser (Siebert, 2004; Allen et al., 2006). Moreover, widespread abandonment may result in a loss of the characteristic complex mosaic of land uses, thereby reducing the variety of habitats appreciated by several species (Russo et al., 2002; Santos and Cabral, 2003; Scozzafava and de Sanctis, 2006; Potts et al., 2006).

Baldock et al.(1996) remark that the effects on flora and fauna resulting from changes in agricultural management depend on a multitude of factors, such as the prevailing environmental conditions, the type of agriculture currently practised, the existing pattern of land use in the area, the ongoing change in use and the resulting management system or absence of management. Compared with other, more intensively managed agricultural systems, however, a cultivated traditional olive orchard seems to have a high level of biodiversity (Metzidakis, 2006).

Finally, abandonment has also negative consequences for landscape quality: changing the view and making it more homogeneous (Viana, 2003). This applies both within a single orchard, where the invasion of shrubs leads to the trees becoming visually indistinguishable from undergrowth (Stobbelaar et al., 2000), and at the broader landscape scale, where the characteristic mosaic patches are homogenised (Grove and Rackham, 1993; Bielsa et al., 2005). In the Rio Douro valley in Portugal, the stakeholders interviewed, ranging from village leaders to representatives of nature conservation organisations, pointed out that cultivated olive orchards contributed to the region's attractiveness. A large majority of farmers agreed with this statement (Eicher, 2005).

4.3.2 Socio-economic constraints

Prior to the recent reform, EU policy on the olive oil sector clearly favoured the most intensive and competitive olive production systems (Beaufoy, 1998; de Graaff and Eppink, 1999), particularly after 1998, when subsidies became proportional to the amount of olive oil produced, for all the olive farmers. Before 1998, small farmers (those producing less than 500 kg of olives per annum), received a payment per tree, based on the average historical yields of their district.

As mentioned above, the main causes of abandonment are closely related to farm profitability, the main issue being the low yields of traditional olive groves. The yields from the seven traditional SMOPS ranged from around 1000 kg/ha in the Portuguese and Spanish target areas, up to around 2000 kg/ha in the Greek and Italian ones (Table 4.1). The figures are striking when compared with the average yield obtained by the other SMOPS identified (Fleskens, 2005): 2600 kg/ha for semi-intensive low input, 3800 kg/ha for semi-intensive high input and 4700 kg/ha for intensive plantations, though the figure for the organic SMOPS was only 1000 kg/ha.

The analysis of costs and returns for the 2004/2005 harvest campaign, shows that even with production subsidies all the systems except for the Greek one have negative net revenue (Table 4.2). The factors accounting for the Greek result are a good harvest and the absence of a subsidy cut-off due to quota surpass (since the introduction of the National Guaranteed Quantity in 1998, the subsidy per kg decreases when a particular country's production exceeds the quota). The results for the production cost analysis show that higher outputs are associated with higher costs (Table 4.2), particularly labour costs (Table 4.3). This is the case for HE 1, GJ 4 and IT 1 traditional SMOPS.

Further analysis of the returns to labour reveals that without financial support, none of the traditional systems would sustain the salaries actually paid: see the bottom row of Table 4.3. On the other hand, the analysis of returns to labour when production is subsidised clearly shows that despite favouring more intensive systems, the former CAP aid system was essential to support traditional farmers as well (Table 4.3). It is possible to verify that even with subsidised production, the returns to labour per hour in Cordoba and Trás-os-Montes are much lower than the average regional wage. These systems will only be sustainable if supported by other types of subsidies.

Table 4.2: Costs and results (€ ha^{-1}) for the 2004/05 harvest campaign in traditional SMOPS.

SMOPS code [1]	HE 1	CO1	CO3	CO4	GJ4	IT1	PT1
Output	1 156	392	486	437	824	1 397	423
Production Aid	601	147	182	164	330	359	223
Total costs	1472	914	947	920	1 360	1 887	778
Net Revenues	286	-376	-279	-319	-205	-132	-133
Net Profitability	-315	-523	-461	-483	-535	-491	-355

[1] HE 1: West-Crete Traditional System; CO 1,3,4: Cordoba Traditional Systems; GJ 4: Granada–Jaen Traditional System; IT 1: Basilicata–Salerno Traditional System; and PT 1: Trás-os-Montes Traditional System in Fleskens (2005).

Source: adapted from Fleskens (2005); Metzidakis (2004) and Xiloyannis *et al.* (2004).

Table 4.3: Analysis of labour input in traditional SMOPS.

SMOPS code [1]		HE1	CO1	CO3	CO4	GJ4	IT1	PT1
Labour required [2]	(AWU ha^{-1})	0.107	0.042	0.044	0.042	0.057	0.103	0.060
Labour Costs	(€ ha^{-1})	932	516	537	516	731	1 178	553
Not including any subsidies:								
Returns to labour	(€ / AWU)	7 915	–	1 725	781	4 409	6 626	3 307
Returns to labour / h	(€ h^{-1})	4.12	–	0.90	0.41	2.30	3.45	1.72
Including production subsidies:								
Returns to labour	(€ / AWU)	13 533	3 336	5 868	4 681	10 198	10 112	7 017
Returns to labour / h	(€ h^{-1})	7.05	1.74	3.06	2.44	5.31	5.27	3.65
Average wage [3]	(€ h^{-1})	4.55	5.68	5.70	5.68	6.67	5.95	4.82

[1] HE 1: West-Crete Traditional System; CO 1,3,4: Cordoba Traditional Systems; GJ 4: Granada–Jaen Traditional System; IT 1: Basilicata–Salerno Traditional System; and PT 1: Trás-os-Montes Traditional System in Fleskens (2005), [2] AWU: Annual Working Units (1920 h), [3] Considering skilled and unskilled work.

Source: adapted from Fleskens (2005); Metzidakis (2004); Xiloyannis et al. (2004).

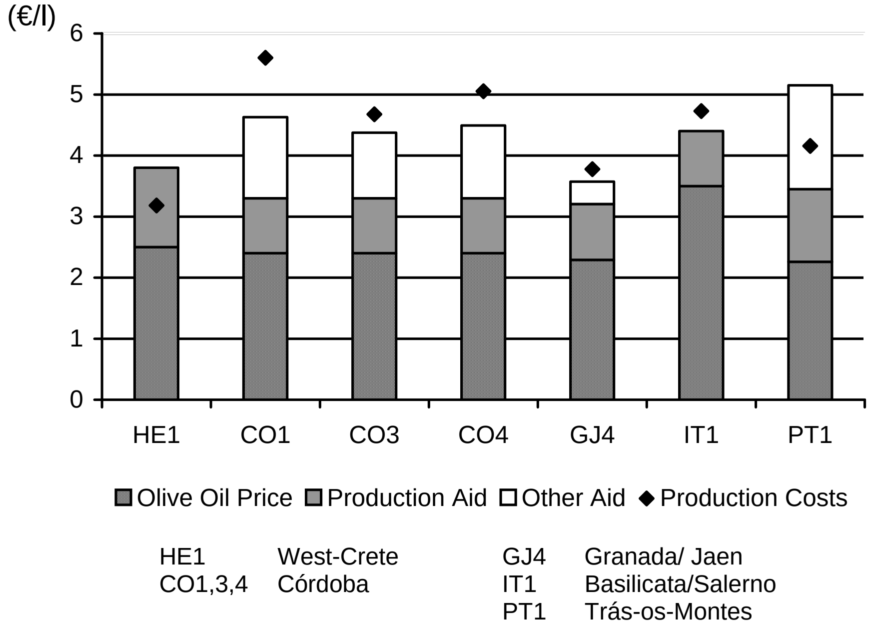


Figure 4.2. Production costs vs. olive oil output (€ lt $^{-1}$) for the 2004/05 harvest campaign for each traditional SMOPS. Other aid comprises compensation payments for less favoured areas and AEM.

Comparing olive oil production costs with the gross revenue per litre of olive oil (Figure 4.2) reveals that other assistance, namely compensatory payments for less favoured regions and AEM – even though these are not enough – greatly help traditional farmers to cope with production costs. Even where the price is higher (Italy), olive growing by itself is not economically worthwhile. The reason traditional growers carry on, even with these results, is that most of the work is done by family members.

The OLIVERO agro-socio-economic survey results show that in the Greek and Portuguese target areas (Duarte, 2005a), more than 70% of labour is provided by the farmer's family. The present costs and returns analysis assumed that labour opportunity cost was equal to the average regional wage. However, this cost may be much lower, as most traditional farmers are pensioners (Duarte, 2005a). This low labour opportunity cost helps assure the current sustainability of traditional systems, as long as these farmers are willing and able to work their olive groves.

To assure the future sustainability of the olive groves, the main challenge is to find ways to encourage other olive farmers to keep these olive groves with minimum management practices, in order to avoid the negative environmental and social effects of their abandonment. In the following two sections, some good agricultural practices and recommendations are listed, in order to address this question.

4.4. Good Agricultural Practices

Cross compliance has been introduced with the SPS. Each Member State will set its own rules in order to guarantee good agricultural and environmental conditions for olive orchards.

As traditional olive orchards are low-intensity production systems, they are generally environmentally friendly. For this type of SMOPS, the main issue to be included in cross compliance should be erosion prevention. This can be achieved by including the obligation to maintain a natural or cultivated cover crop during the rainy period. The feasibility of complying with this requirement has been assessed as good (Martinez Raya et al., 2006): on average, soil erosion could be reduced by almost 40% at no extra cost (Córdoba), or for even less cost than conventional tillage (saving €25–50 ha^{-1} in the case of Granada/Jaèn and West Crete). Moreover, this change in soil management could lead to yield increasing by 5–10% as a result of inherently better conservation of soil fertility and the avoidance of runoff losses.

Various additional good agricultural and environmental practices can be suggested for different options, in order to guarantee a minimum management of traditional orchards that will prevent the negative environmental impacts of abandonment and assure the future of these systems:

Orchards in process of abandonment and abandoned orchards:

Wildfire is the key environmental issue for orchards that have been or are being abandoned. In order to minimise wildfire risk, the following good agricultural practices can be recommended, based on the information given above in Sections 4.2 and 4.3:

- herbaceous soil cover should be eliminated, by tillage, mowing or grazing at the end of spring
- suckers and small shrubs should be removed at least every two years
- olive trees should be pruned enough to prevent the development of a closed canopy that will facilitate the spread of fire. How often this should be done depends on various orchard characteristics
- terraces and stone bunds should be kept free of vegetation to avoid their deterioration and also to prevent wildfire spreading upslope
- combustible dry crop residues and woody debris should be collected from the orchard soil and either chopped into pieces or taken out of the orchard.

Some of these recommendations could be achieved with the incentive of appropriate AEM. Without such an incentive, farmers of orchards with low SPS entitlements might be discouraged from applying for the subsidy because the costs involved in cross compliance are too high (de Graaff et al., 2006).

If the farmer cannot implement these practices and large contiguous areas or small orchards interspersed with natural vegetation are abandoned, the authorities should intervene and apply the following practices (de Graaff, 2005):

- in areas where nature parks are being created, fire corridors should be established and maintained.
- in areas with no new land use designation, some rows of trees should be grubbed out.

Continuation as traditional orchards:

- preservation of terraces and other structures helps to: a) maintain landscape value; b) conserve niches for reptiles and bird species, and c) control erosion
- minimum tillage or alternative soil management maintains: a) a high biodiversity of herbs in the orchards; b) minimises soil erosion, and c) increases landscape value
- pruning trees into traditional shapes and employing traditional harvesting (e.g. using nets) and other management techniques help maintain cultural and landscape value
- use of chemical inputs should be minimised, to maintain high biodiversity.

Adherence to these practices could be exploited in marketing strategies to increase the compensation obtained from the price of the olive oil sold (e.g. by PDOs), or by providing incentives under the AEM programme. In any case, care should be taken to ensure that cross-compliance conditions for traditional orchards are commensurate with the low subsidies involved, in order not to disfavour these comparatively environmentally friendly systems vis-à-vis their more intensively managed counterparts.

Conversion to other orchard types or land use:

If traditional SMOPS follow pathways towards intensification or organic production, the codes of good agricultural practices elaborated by Xiloyannis et al. *(*2007) and Gomez et al.(2007) apply. Note that with these guidelines, intensification should pay off entirely through market incentives, because the more rigid cross-compliance conditions laid down by Xiloyannis et al. (2007) should be respected while the eligibility for subsidy remains at the production level of the pre-intensification reference period. If orchards are replaced by a different land use, care should be taken that the beneficial properties of traditional olive orchards are not lost, or that they are replaced with comparable values.

As mentioned earlier, one of the main constraints to the economic sustainability of these systems is low productivity. Certain agricultural practices can be suggested to help farmers overcome this problem. They will be mentioned in the next section, not as cross-compliance obligations or as additional good agricultural and environmental practices, but as recommendations.

4.5. Conclusions and recommendations

The analysis undertaken has shown that the traditional olive production system has important environmental and social functions, as it contributes to reducing fire risk, enhancing biodiversity, providing employment for the rural population and helping safeguard the income of olive farmers. Despite being generally environmentally friendly, it has been shown that in the selected regions, the system is barely economically sustainable, due to low productivity and reduced economic returns.

A specific target of the OLIVERO project was to generate recommendations for farmers and policy makers on key issues in socio-economics and resource management that would lead to the sustainability of SMOPS.

Farm level

One of the main threats to traditional systems – the risk of abandonment – is largely caused by low productivity. However, it is difficult to improve productivity, since it is determined by structural features of the olive orchards: old trees, low densities, no irrigation, different varieties of olive trees on the same plot of land. However, irrigation, pest control and fertilisation could be improved.

The main intervention to improve productivity would be irrigation, but in many traditional systems this practice is difficult to implement due to the financial investment needed and the lack of irrigation infrastructure. If irrigated, orchards may rapidly (within three years) show enhanced production. Usually, the whole production system will evolve towards semi-intensive or intensive SMOPS.

With regard to fertilisation, farmers could be recommended to apply fertiliser in accordance with the nutrient needs revealed by plant and soil chemical analysis. It appears to be possible to increase olive production by 900 kg ha^{-1}, the equivalent of €345 in SMOPS PT1, by changing fertilisation practices and applying herbicides instead of two tillage operations per year. The extra costs of this improvement would be less than €30 ha^{-1} yr^{-1} (a 4% increase of total costs), plus the additional harvesting costs (Martinez Raya et al., 2006). Although additional harvesting costs were not quantified, these would surely be outweighed by the olive yield. Note that even if the yield increase were less spectacular, the €30 ha^{-1} yr^{-1} extra costs could be recouped fairly quickly.

Integrated protection could be recommended for pest control. Many farmers in the five target areas do already engage in this practice, which in some cases is stimulated by a specific AEM.

Combined improvements in fertilisation and pest control were found to be cost neutral (CO1) or led to slightly better economic performance (CO3 and 4) of the Cordoba SMOPS, assuming a 10% yield increase (Martinez Raya et al., 2006). More rational fertilisation and pest control would not only help improve productivity but would reduce production costs, for example if leaf analysis reveals adequate nutrition status.

Intermediate level

Despite its low productivity, olive growing can generate a high-value product even under adverse circumstances. If marketed as a product with PDO, this high-value product can allow traditional farmers to obtain a better price, improving profitability. According to Ritson (1997) the introduction of a regional label, like a PDO, has the potential to enhance the value of raw material from a region, may ensure that processing occurs within the region, and grants a monopoly advantage to producers and processors within a specific area. However, as van der Lans and van Ittersum (2001) state, two conditions are necessary for marketing products successfully on this basis: first, that a significant proportion of the target market for the regional product is aware of the region, and second, that consumers have strong and favourable associations with it.

Nevertheless, traditional olive farmers are in general not aware of market needs as they are small producers, using a significant part of their own production for their own needs. In order to obtain a better price for their olive oil, marketing skills are needed and in many cases these can only be achieved by collective action. Cooperative mills are an example of farmers' associations playing a significant role in olive oil production in the different OLIVERO target areas. The results of the OLIVERO marketing survey (Duarte, 2005c) of a small sample of olive mills from the different target areas confirmed that the larger olive mills, some of them cooperatives, are in general "Production Oriented", selling bulk olive oil, mainly to intermediaries and refinery industries. So, they should be engaged, together with olive farmers, in the process of product quality improvement and better marketing, to assure the economic sustainability of traditional systems.

Policy level

Arguably, the main way of preventing the abandonment of traditional systems and of enhancing their environmental and social functions is the policy framework. After years of stimulating increased production, the present CAP, with the application of the SPS (Council Regulation (EC) no. 864/2004) to the olive and olive oil sectors, can now help improve olive-growing practices through cross-compliance rules.

In accordance with the 2003 CAP reform, however, Rural Development measures (Council Regulation (EC) no. 1698/2005) are supposed to be reinforced. Some of these measures are particularly relevant for preventing abandonment: Less Favoured Areas payments, agri-environmental subsidies and incentives for the modernisation of farms and processing units.

In face of the recent reform of EU Structural Funds, these measures are now being redefined by the different Member States. Agri-environmental measures can be a very useful policy instrument to enhance the environmental and landscape value of traditional olive-growing systems. They will differ from country to country and in some cases from region to region.

As general recommendation it should be stressed that certain actions have to be developed in order to increase the impact – which has been small to date – in terms of number of farmers and area covered by AEM contracts. For a larger impact, adequate EU and national funds have to be provided, clear environmental objectives and obligations should be defined, and farmers should be stimulated to apply for them through better promotion and reduced bureaucracy.

Finally, incentives to invest in modernising farming and processing facilities should be maintained, as they have a relevant impact on improving the quality of the olive oil produced.

In summary, we can say that in the face of the decoupling of CAP subsidies, the reinforcement of Rural Development measures is essential, if society acknowledges the environmental and social functions of traditional olive production systems, and if prevention of their abandonment is considered a policy objective.

Chapter 5

A conceptual framework for the assessment of multiple functions of agro-ecosystems: a case study of Trás-os-Montes olive groves

Fleskens L, Duarte F, and Eicher I
Ecology and Society (submitted)

5. A conceptual framework for the assessment of multiple functions of agro-ecosystems: a case study of Trás-os-Montes olive groves

Abstract

Multifunctionality in agriculture has in the last decade received a lot of attention from researchers and policy-makers alike, perhaps most notably evidenced by the important changes made to the EU's Common Agricultural Policy. While the concept has been embraced by environmentalists visioning positive impulses for decoupling and a range of local stakeholders recognizing implicit marketing opportunities involved, it has also been criticized as a mere argument in favour of disguised protectionism. Problematic in this discussion is the lack of an operationalising framework for the assessment of multiple functions. In this chapter, we discuss such a framework and the role it can play in the decision-making process. Focusing on a case study about olive farming on sloping and mountainous land in northeastern Portugal, methods are discussed on how to deal with studying multiple functions of agro-ecosystems. Function assessment is presented from a research perspective, but its relevance for stakeholders is also stressed. By using the metaphor of a house, the method could supposedly appeal to a wide range of actors. In the case study, we conclude that olive groves on sloping and mountainous land particularly fall short in supplying ecological functions. They do however contribute significantly to the local economy, generate employment and perform an important cultural role in maintaining the landscape, and are thus a key to regional development and to stop outmigration of the population. Policy-makers could use the function assessment tool to design effective cross-compliance rules and relevant agro-environmental measures to reinforce ecological and social functions, and to communicate ideas to other stakeholders. As such, it provides for an extension of public debate and can reinforce decision-making by visualizing trends, development alternatives or scenarios. The role of research in this method is facilitating dialogue between stakeholder groups and feeding the process with relevant indicators.

5.1. Introduction

The OECD study "Multifunctionality; towards an analytical framework" (OECD, 2001) presents a thorough analysis of the multifunctionality concept from the economist's realm. Afterwards, a number of publications dealing with theoretical economic (Randall, 2002; Harvey, 2003), ethical (Paarlberg et al., 2002; Vatn, 2002) or sociological studies (Knickel and Renting, 2000; Knickel, 2001) have appeared on the topic, and more recently a review integrating concepts from different disciplines (McCarthy, 2005). An apparent lacuna in the literature is a study operationalising the concept (Brandt and Vejre, 2004). Moreover, the absence of studies advocating assessment of multiple functions in the decision-making process is surprising. Hall et al. (2004) come to a similar conclusion with regard to the analysis of societal wishes for the management of the countryside. A major effort to achieve informed decision-making on management of the environment is being undertaken by a global coalition of scientists in the Millenium Ecosystem Assessment (MEA, 2005).

The recognition of multiple functions of land use is in itself not a new issue. Perhaps not surprisingly, the densily populated Netherlands has had a scientific discussion about those functions dating back to the late 1960s, see e.g. Van der Ploeg and Vlijm (1978). However, the entry of the term in policy documents in the 1990's has created another dimension in that it has become linked to the discussion of paying third parties – farmers – for public services and goods that they produce alongside food and fibre (e.g. Potter and Burney, 2002). In this contemporary sense of the word, it seems to have gradually evolved from earlier concepts as 'pluri-activity' dating back to the 1980's (e.g. Fuller, 1990; Reis et al., 1990) and 'post-productivism' (e.g. Wilson, 2001). Evans et al. (2002) quite rightly criticise the use of the latter term, and whether or not the same line of reasoning was followed by scholars introducing the concept of multifunctionality, sure is that the shift of paradigm has followed some 'post-shockwave' behaviour in which initial excitement over other functions *overtaking* agriculture's productive functions has been matured into a neutral word not issuing any value statement as to what extent other functions may gain importance.

The following definition of multifunctionality will be used (adapted from OECD, 2001): "Multifunctionality is a characteristic, either present or not, of agriculture (or any other type of economic activity) *whereby at least two products falling in different function categories and valued by at least two different actors are* – either intentionally or not – co-produced. The value experienced by the second or yet another actor is at least partly transferred to the producer." The products referred to in the definition can be either goods or services, marketable or public, and could include also (nearly always public) 'bads', irrespective of the question whether they could be classified as unintended side-effects (OECD, 2001).

Several classifications of the various functions of (agro-)ecosystems have been made, roughly taking two different approaches:

i) Functions are defined as ecosystem functions with humans (potentially) attaching values to functions (de Groot, 1992; de Groot et al., 2002). This approach is followed by the Millenium Ecosystem Assessment (MEA, 2005), with similar applications relating to landscapes (not necessarily agricultural ones, Brandt and Vejre, 2004) and an Andean 'socio-ecosystem' (Rodriguez et al., 2006). This approach evolves from an ecologist's perspective emphasizing the entity of the natural environment (van der Maarel and Dauvellier, 1978).
ii) Functions are defined taking a broader, human-centred perspective including types of capital other than natural capital (e.g. Bosshard, 2000;

von Wiren-Lehr, 2001; Gómez-Sal et al., 2003). The role of the natural ecosystem in this approach can ultimately be reduced to satisfying the demands from society (for an early account, see Bouma and van der Ploeg, 1975).

Combinations of the above approaches are also possible, by taking an hierarchical approach with ecosystem functions at the basis and other functions as ‘derived’ functions. For example, Van Cauwenbergh et al. (2007) present a hierarchical framework for assessing the sustainability of agricultural systems based on De Groot’s ecosystem functions but including functions in economic and social ‘pillars’.

Function assessment as it is understood here is a method to study the multifunctionality of (parts of) agro-ecosystems, in this case Sloping and Mountainous Olive Plantation Systems (SMOPS) in southern Europe. Agro-ecosystems are ecosystems modified by human beings to produce agricultural products, thereby acquiring a socio-economic dimension (Conway, 1987). SMOPS, as (major components of) agro-ecosystems, have some specific characteristics: they often originate from Roman times and developed on land where other crops would not grow and irrigation was not feasible. In order to adapt to the peculiar Mediterranean climatic conditions a range of soil and water conservation measures has been practiced (Stroosnijder et al., 2007). As SMOPS cannot compete with better endowed plantations in lowland regions in the solely productive sense, the concept of multifunctionality is particularly relevant for their future development.

An important characteristic of different types of functions is that by putting more emphasis on one function, other functions can be affected in variable ways. In a (participatory) planning process, a decision should be made about what mix of functions should be pursued. Crucial in this process is that different stakeholders may value functions differently and that the importance of functions varies across scales of analysis (Hein et al., 2006). Hence, to assess agro-ecosystem functions indicators are needed that are: 1) informative about changes in important processes; 2) sensitive to changes; 3) appropriate at temporal and spatial scales considered; 4) well-understood and based on generally accepted conceptual models; 5) relatively little demanding in data collection; 6) preferentially reliant on existing monitoring systems; and 7) easily understandable by policy-makers (MEA, 2005, p. 50).

Indicators should serve a well-defined purpose. If this is sustainability evaluation, a holistic framework is required (López-Ridaura et al., 2005; van Cauwenbergh et al., 2007). If this is assessing multifunctionality, a selection of indicators that grasps the importance of key functions (those aimed at by stakeholders) suffices. To be useful at multiple scales, indicators should be linkable between relevant assessment levels (Pacini et al., 2003), and preferably be indicators of *objectives* rather than *means* (van der Werf and Petit, 2002). However, when indicators of the first kind are difficult, time-consuming or costly to assess – as often the case in Mediterranean environments – there is a need to define sustainable land management practices as means-based indicators (Zalidis et al., 2002).

The objective of this chapter is to present a conceptual framework for the assessment of multiple functions and to illustrate it with a particular case study at two scales of assessment: region level and farm level, with most emphasis given to the first. The results of the case study are used to discuss the potential of the method. In the remaining part of the chapter, first the function assessment methodology will be described, and the case study area introduced: the Terra Quente zone within the Portuguese Agrarian Region of Trás-os-Montes. Results are thereafter presented and discussed in relation to other approaches, and conclusions with recommendations for future research are drawn.

5.2. Methods

5.2.1. Conceptual framework

The 'House of functions'

'The house of functions' is a tool for assessing the functions of agro-ecosystems (as defined by Conway, 1987). It offers a universal methodology that allows stakeholders to communicate on the multiple functions of agro-ecosystems across scales. We distinguish five groups of agro-ecosystem functions (Gómez-Sal et al., 2003 refer to 'evaluative dimensions'): ecological, productive, economic, social and cultural functions. These functions can in a metaphor be conceived to constitute the five lines of the silhouette of a house (symbolising the living environment). Each set of functions can even be given a specific place in this 'house of functions' (Figure 5.1). Ecological functions form the foundation of the living space, comparable to the concept of ecological footprint. Productive functions depart from the foundation and provide us with products from nature: a standing wall. The second wall of the house represents the cultural functions, and is equipped with a window (the window on life). Culture links ecology to society and production links ecology to economy: the roof of the house is thus constituted by the lines representing economic and social functions, which in turn link at the ridge of the roof. If attention to economy and society is balanced, the ridge is just in the middle, that is to say, if they are balanced with ecology as well: if too much emphasis is put on ecology (a long base line) it leaves a gap in the roof, rendering the house uninhabitable. The opposite (too little attention for ecological functions) results in a hole in the foundation.

While conceptualizing the agro-ecosystem as a house evokes the spirit of responsibility, it also symbolizes the importance of choice. The inhabitants have the option to neglect, sell out, speculate or move. It requires dedication and determination to maintain the house and the functions it fulfils.

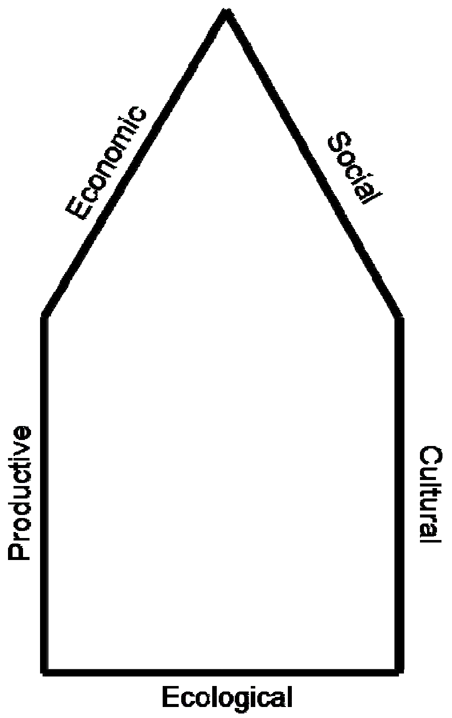


Figure 5.1. The 'house of functions' and its five dimensions; i) Ecology: the fundament to the living space; ii) Production: provides us with products from nature – links ecology to economy; iii) Economy: the revenues of the system; iv) Society: the social dimension of the system; v) Culture: the window on life – links ecology to society.

Construction of the house of functions

For each function, indicators should be elaborated (see Section 5.2.2). The house of functions can be constructed by aggregating indicator scores for each type of function. These aggregated scores should be expressed as an index value (0-1) and presented in a 'house of functions' where all five function groups could obtain a maximum score of 1 (the target value). This means that each indicator should have a range of possible values, the extremes of which need to be normalized to '0' and '1' scores. Indicators should be unambiguous and science-based. However target values will normally be elaborated in a (preferentially informed) decision-making process.

A second possibility for stakeholder interference is attributing weights to each indicator score before aggregration. Weighing is a facultative step in the methodology; if all indicators selected are equally important aggregate scores could be calculated as the arithmetic mean.

There are two ways of constructing the final image of the house, depending on whether it should present a state or a goal. In case the house represents a state, it should be re-arranged in such a way that the least fulfilled function leaves a gap in the house. In case the house represents a goal (or future vision), gaps should be closed (whenever possible) by manipulating the angle between axes, normally resulting in an 'imperfect' house (Figure 5.2). A construction guide is available from the authors.

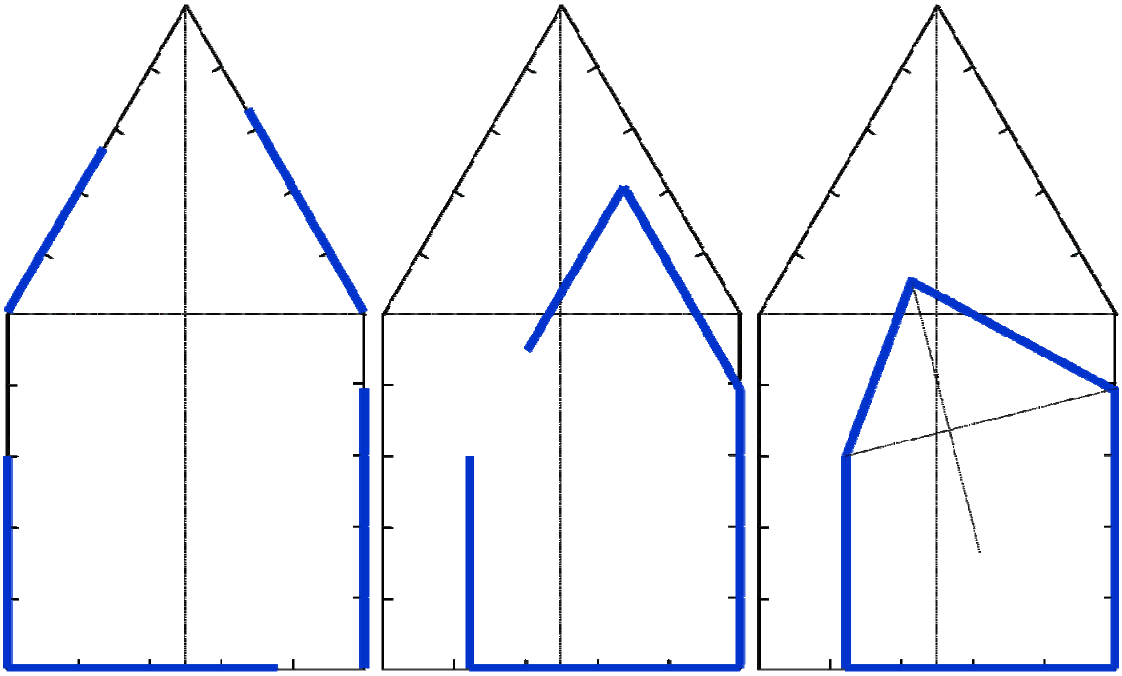


Figure 5.2. Construction of the house of functions: a. indicator values; b. rearranging for descriptive purposes; c. rearranging for normative purposes.

Stakeholders and SMOPS system boundaries

Different stakeholders have different decision-making domains and horizons. However, their preference for certain values may go beyond their control. For instance, a farmer may want to sell his olive oil at a high price, but success may depend on effective marketing of a PDO-label (product of denomination of origin). Vice versa, a regional authority may want to maintain a typical landscape, but will to large extent have to rely on the contributions farmers are willing to make. Hence, two-way traffic along hierarchical decision-making levels should be facilitated by the use of a nested approach. In the present study we distinguish two decision-making levels: farm and regional. A farmer (decision-maker at the farm level) addresses management decisions at parcel level and whole-farm level. For the assessment of functions, the latter was deemed to present a better assessment level, especially with regard to social and economic functions.

At both farm and regional level, the agro-ecosystem is conceived to set the boundary to the function assessment exercise. This means that, while a certain function may have global importance (for the case of SMOPS e.g. contribution of olive tree respiration to the maintenance of atmospheric gas exchange cycles) it has no significant value at the local agro-ecosystem level. As a consequence, SMOPS or land use changes will not affect much the provision of this service. The function 'biodiversity conservation' will similarly only be considered if it has significant local value over neighbouring agro-ecosystems. A function that stands central in the analysis is soil conservation: both because soil erosion is a major concern in SMOPS (Pastor and Castro, 1995; de Graaff and Eppink, 1999; Beaufoy, 2001; Gómez et al., 2003;

WWF/Birdlife International, 2004) and because it normally has significant effects at the local level.

5.2.2. Functions of SMOPS and selected indicators

Productive functions of SMOPS

The SMOPS (like any other agro-ecosystem) by definition bring forth a certain biomass production. In order to separate agronomic from economic issues in the production process, the biomass production is considered under the separate heading of 'productive functions'. Several aspects of biomass production can be considered (see also Table 5.1, where selected indicators at farm and regional level are included):

- Productivity; the olive fruit is normally but not necessarily the main economic objective of olive farming. Apart from olives, associated and secondary products (e.g. almond, vine, cereals, firewood) can be co-produced. Olive groves can also be grazed by animals or support other types of biomass extraction.
- Product quality (notably of the olive oil produced); apart from complete chemical characterisation and organoleptic assessment, olive oil quality is most simply expressed by its grading in acidity level.
- Stability of production; the olive tree has a natural tendency to alternate bearing. This tendency depends on variety, climatic conditions and management practices in SMOPS. A suitable indicator for stability is the Yield Consistency Index (YCI - Fleskens et al., 2005).

Ecological functions of SMOPS

The ecological functions of an agro-ecosystem could be considered to comprise an extensive list of functions also attributed to the natural environment. However, management decisions or land use changes in agro-ecosystems, and specifically in SMOPS, will have no or only a marginal effect on many of the ecological functions they provide. For this illustrative case study we include the following, probably most important ecological functions of SMOPS (Table 5.1), although regulation of the environmental impact of pesticides and water resources conservation may in particular cases (SMOPS 2-3) not be negligible:

- Soil conservation; SMOPS are typically situated on slopes and the Mediterranean climate poses high erosion risk to these systems (Fleskens and de Graaff, 2003), with potentially significant on- and off-site effects. These effects can be minimized by appropriate land management.
- Wildfire control; especially in SMOPS at risk of abandonment, management interventions can play an important role in wildfire prevention.
- Biodiversity conservation; SMOPS may represent important nursery or migrating territories for flora and fauna. Especially when SMOPS provide a habitat for rare species which are absent from neighbouring (agro-) ecosystems, this could be an important function. Biodiversity performs a core ecological function, as shown by Clergue et al. (2005).

Table 5.1: Functions and selected indicators for assessment of multiple functions of SMOPS at farm and regional level.

Function		Regional level indicator (unit)	Farm level indicator[a] (unit)
Productive	Productivity	Total olive production (10^3 ton y^{-1})	Yield (kg ha^{-1} y^{-1})
		Olive oil content (%)	
	Quality	Oil volume < 1° acidity (%)	
	Stability	Yield Consistency Index (–)	
Ecological	Soil conservation	Winter cover (% area)	
		Maintenance of terraces (% terraced area)	
	Wildfire control	Tillage in spring (% area)	
		Abandoned, non-pruned orchard (% area)	Pruning of grove (% area y^{-1})
		Burnt area (ha)	
	Biodiversity	Index value (–)	
Economic	Income	Contribution agricultural production value (%)	Farm income from olives (€)
		Production cost (€ ha^{-1})	
		Olive oil price (€ l^{-1})	
	Food security	n.a.	Value of auto-consumption (€)
	Export	Contribution agricultural exports (%)	n.a.
Social	Employment	Seasonal labour (AWU)	Hired labour input (h ha^{-1})
		Family labour input (AWU)	Return to own labour (€ h^{-1})
	Liveability	Migration rate (%)	
	Safeguard	Dependence on on-farm income (%)	
		Investment in olive orchards (€)	n.a.
Cultural	Landscape value	Index value (–)	
	Recreation	Revenues from tourism (% farm income)	
		Regional products sales (% PDO label)	

[a] If different from regional level indicator

Economic functions of SMOPS

The following economic functions can be distinguished:

- Income generation; the prime objective of economic activities, such as olive cultivation, is normally to provide a source of income.
- Food security; SMOPS contribute to self-sufficiency in products that would otherwise need to be bought at opportunity costs (subsistence production), and/or be dependent on potentially doubtful supply (for a wider perspective, see Losch, 2004).
- Export; the SMOPS can take part in production for an export market, as such contributing to national earnings (possibly in preferred hard currency).

Social functions of SMOPS

Several social functions can be attributed to SMOPS:

- Employment; the SMOPS provide employment, both to the farmers and for contract workers and positions in back- and forwardly linked economic activities.
- Liveability; the existence of the SMOPS may help to secure the liveability of rural areas where otherwise the level of services could drop below a critical level inducing emigration.
- Safeguard function; this function assesses income security for part-time farmers.

Cultural functions

Cultural functions are the hardest to assess, as they relate to more abstract concepts. Note that other classifications group these functions under information functions (de Groot, 1992). Contrary to natural ecosystems, information functions of agro-ecosystems form an intrinsic part of the culture that co-evolved with these systems. We included two cultural functions:

- Landscape value; agro-ecosystems co-shape landscapes which receive very different appreciation from stakeholders. There is a large literature on visual qualities of landscapes (e.g. Kuiper, 2000; Stobbelaar et al., 2000; Tahvanainen et al., 2002). We developed a simple index after Pachaki (2003). This index is assembled from ten scores (range 0–1) addressing seven landscape qualities (see Table 5.5, lateron).
- Recreation; tourism makes an important economic contribution in many Mediterranean areas. However, its geographical distribution is very unequal. In rural areas, landscape, cultural heritage and development of tourism infrastructure and leisure activities are imporant factors in tourism promotion. For SMOPS, directly of interest are tourist expenditure in rural (farm) tourism and regional products sales.

5.2.3. Study area and data collection

The 'Terra Quente' study area

The Portuguese Agrarian Region of Trás-os-Montes (literally: 'Beyond the Mountains') is situated in the extreme North-eastern corner of the country (Figure 5.3). It is up to today characterised by a highly significant primary economic sector, absorbing 46.8% of total regional employment and producing 13.5% of regional GDP in 1995 (GPPAA, 2000). From an agro-ecological point of view, Trás-os-Montes can be divided in five zones differing in climate, altitude and main agricultural systems. One of these zones is the 'Terra Quente' ('Hot Land'), largely coinciding with the extension of olive production (Madureira et al., 1994). Nine municipalities more or less covering the Terra Quente were selected as target area for the function assessment study of SMOPS at the regional level and will subsequently be referred to as Terra Quente area. The Terra Quente area is characterised by hilly topography fluctuating between 300 – 500 m altitude and receives an average annual precipitation of 400 – 600 mm y^{-1}. More than half of all farms in Trás-os-Montes, and 85% of farms in the Terra Quente zone cultivate olives on an average of 1.2 ha and 2.1 ha per farm respectively (INE, 2002).

Data collection

The functions of olive plantations in the Terra Quente area were assessed based on data collected from several sources: an agro-socio-economic survey among a sample of 60 olive producing farmers (excluding SMOPS 4), a specific study of 23 SMOPS 4 farmers, as well as a review of secondary data. Expert knowledge (regional department of agriculture, technicians of farmer associations) was used to complement data. Data availability differed per function category: productive functions could be assessed quantitatively, while for some other functions expert opinion or informed guesses were used. A few functions were not considered due to data shortage. Stakeholder participation in this study was limited to the provision of information, on the basis of which the function assessment exercises were carried out. Target values were thereby constructed based on trend analysis (productive functions), comparisons with other agro-ecosystems, and/or derived from stakeholder information. These approaches may serve as examples of how stakeholders could for themselves arrive at target values. Results are worked out for the regional level function assessment, and a brief comparison is made for two farm-level examples for two types of SMOPS (SMOPS 2 and 4, see below).

The sample of interviewed farmers allowed us to distinguish different types of olive plantation systems (Table 5.2). This typology distinguishes five systems based on differences in tree density, slope, tree age, cultivation practices and olive production. Most orchards in the target area qualify as traditional SMOPS (SMOPS 1), although the area of semi-intensive SMOPS for olive oil production (SMOPS 2) is considerable due to a much larger farm size. SMOPS 3–5 are less widespread. SMOPS 3 has the most intensive management and is usually irrigated, a fact associated with its focus on table olive production. It is specific of a geographical location. SMOPS 4, specific of the very steep hillslopes ('Arribas') of the Douro River and its tributaries, faces severe problems of abandonment. Organic farms are grouped in SMOPS 5 but are of relatively limited importance for the target area.

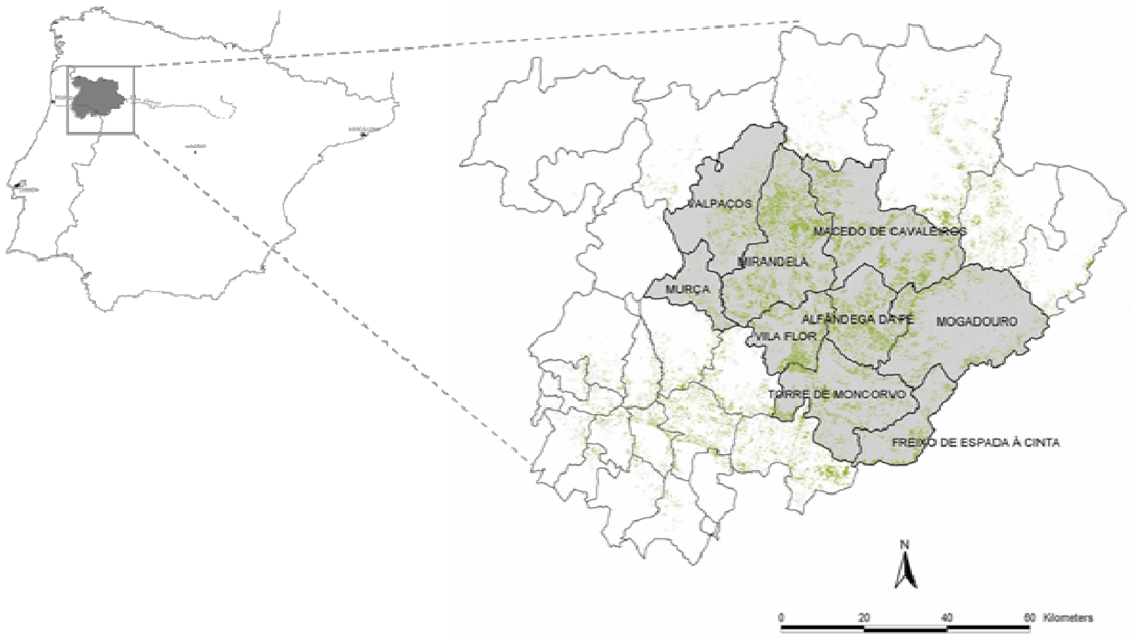


Figure 5.3. Location of the Agrarian Region of Trás-os-Montes in north-eastern Portugal, with land under olives (dotted; source: SIG-OL data IFADAP/INGA) and targeted municipalities constituting the Terra Quente study area.

Table 5.2: Classification of SMOPS for the Terra Quente area.

	SMOPS 1 Traditional	SMOPS 2 Semi-Intensive (Olive Oil)	SMOPS 3 Semi-Intensive (Table Olive)	SMOPS 4 Arribas, in process of abandonment	SMOPS 5 Organic
Number of farms	22800	1300	2250	Na (~4000[c])	220
Olive area (10^3 ha)	30	15	4.8	Na (~7.0[c])	3.2
Tree density (trees ha^{-1})	± 100	± 200	± 280	Irregular	± 100
Slope	Any	Low – Moderate	Strong – Steep	Strong – Steep	Any
Age (y)	Mainly > 50	< 20	Variable	> 50	Mainly > 50
Soil Tillage (no y^{-1})	1–3	1–3	1–3	0–2	1–3
Weed control method	Tillage	Tillage	Tillage	Tillage, grazing	Tillage
Irrigation	No	No	Yes (Drip)	No	No
Fertilisation method	Chemical	Chemical	Chemical	Chemical/Organic, None	Organic
Fitosanitary Treatments (y^{-1})	0 (2[a])	0 (2[a])	4	0	0-2
Pruning frequency (y^{-1})	0.50	0.50	1.0	0–0.5	0.33
Harvesting method	Semi-mechanised	(Semi-)Mech	Manual	Manual/Semi-mechanised, None	(Semi-)Mech
Production (kg ha^{-1})	1000–1200	2000–2500	3500–5000	< 1000	800–1000
Consistency of prod (YCI[b])	Low (0.53)	Low (>0.53)	High (0.76)	Low (<0.53)	Low (>0.53)
Farm size	Small	Medium – Large	Variable	Variable	Medium – Large

[a] if under integrated protection

[b] YCI = Yield Consistency Index; $0 \le YCI \le 1$, with high values indicating stable production – for more details see Fleskens et al. (2005)

[c] figures are estimated as abandoned areas are not registered in agricultural statistics

Sources: Duarte et al. (2004); Eicher (2005).

5.3. Results

5.3.1. *Assessment of SMOPS functions in Terra Quente*

Productive functions of SMOPS in Terra Quente at the regional level

When assessing the productive functions of olive orchards in Trás-os-Montes against national production figures, Trás-os-Montes clearly classifies as an important olive production area with an above average standard of quality of olive oil, i.e. a low acidity level (Table 5.3). The olive area in Trás-os-Montes has expanded 30% over the decade 1990–2000, while the total agricultural area increased only marginally. Average regional olive yield (1990–1998) was 888 kg ha^{-1}, against 763 kg ha^{-1} nationally (INE, 2002). Figure 5.4 shows that the highest regional olive production (slightly over 100,000 tons) was obtained in 1991, corresponding to an average yield of 1625 kg ha^{-1}. We selected these values as targets (Table 5.4). Yield consistency is not very high (average YCI of 0.55 over 1990–2001), although the YCI reached a maximum of 0.89. The volume percentage of olive oil of high quality, expressed as oil with acidity <1°, was 78% in 1999 and 2001 (Figure 5.4). The highest oil content was obtained in 1990: slightly above 19% (Figure 5.4).

Table 5.4 shows the scores on abovementioned indicators for the period 2002-2004. Percentual achievement was assessed on the reference scale constructed from highest and lowest values of Figure 5.4. Considering weights emphasing quantity of production, the aggregate score for the productive function was assessed at 76%.

Table 5.3: Importance of regional and national olive production in 2001.

	National	Trás-os-Montes	% of national
Processed olives (ton)	218 523	74 043	33.9
Olive oil (hl)	349 502	128 676	36.8
- with acidity <1°	148 328	100 705	67.9
- with acidity 1° to 2°	108 128	22 223	20.6
- with acidity >2°	93 050	5 748	6.2
Oil yield (l/100 kg)	16	17	
Table olives (ton)[a]	7 550	2 937	38.9

[a] for the year 2000

Source: INE agricultural statistics in DEASR (2004a)

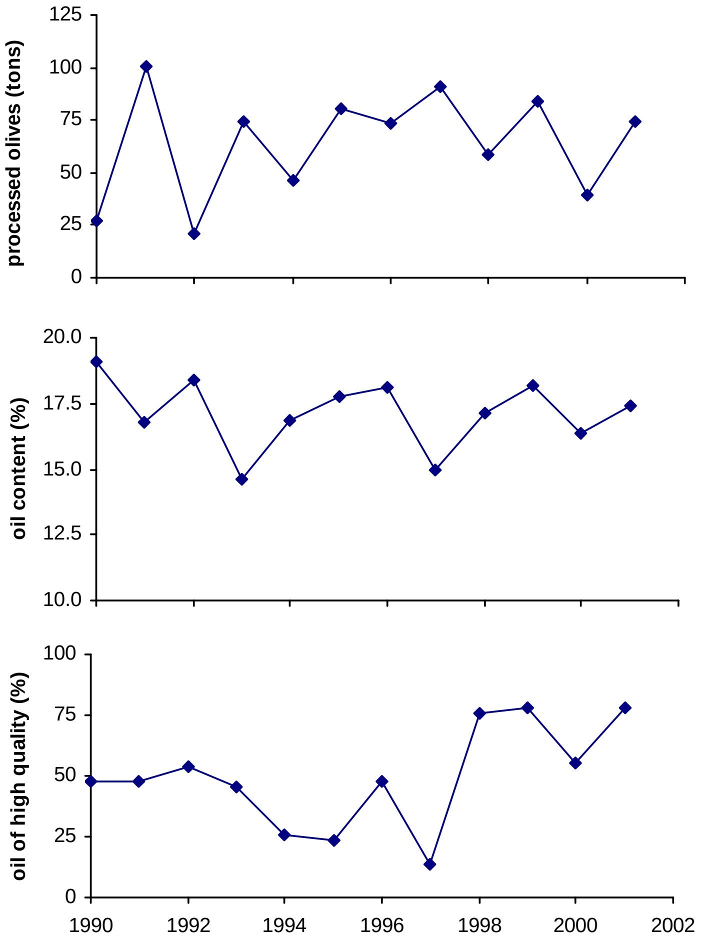


Figure 5.4. Trends of indicators of productive functions of olive growing in Trás-os-Montes, 1990–2001 (data from INE).

Ecological functions of SMOPS in Terra Quente at the regional level

Ninety-five percent of the olive area is on hilly and mountainous land (more than half steeper than 15%, DEASR, 2004b), and 33% is affected by erosion (de Figueiredo et al., 2002). Two soil conservation indicators were selected: 1) the percentage of area protected by a winter cover, and 2) the percentage of terraced area where terraces are well-maintained. Both target levels are set at 100%. Eigthy percent of farmers practice between one and three tillage operations per year. In most cases, this includes a tillage operation in autumn, and low soil cover in winter as a consequence. No regional data were available about terrace maintenance.

Table 5.4: Function assessment of SMOPS in Terra Quente at the regional level: selected functions and indicators, objectives, achievements and weights attributed to arrive at aggregate scores.

Function		Indicator (unit)	Objective	Reference scale	Achievement (2002-2004)	Id., (%)	Weight (%)	Aggregate score (%)
Productive	Productivity	Total olive production (10^3 ton y^{-1})	100	20 – 100	72.7 ± 7.1	66	50	76
		Olive oil content (%)	19	14 – 19	17.5 ± 0.6	70	10	
	Quality	Oil volume < 1° acidity (%)	78	14 – 78	70.4 ± 9.4	88	20	
	Stability	Yield consistency index (–)	0.9	0.1 – 0.9	0.81 ± 0.18	89	20	
Ecological	Soil conservation	Winter cover (% area)	100	0 – 100	20	20	40	45
		Maintenance of terraces (% terraced area)	100	0 – 100	n.a.			
	Wildfire control	Tillage in spring (% area)	100	0 – 100	50	50	20	
		Abandoned, non-pruned orchard (% area)	0	100 – 0	13	87	20	
		Burnt area (ha)	60 (0.075%)	[a]	91 ± 18	48	20	
Economic	Income	Contribution to regional agricultural production value (%)	8.5	0 – 8.5	6.7[b]	79	33	85
		Production cost (€ ha^{-1})	867	[a]	955	90	33	
		Olive oil price (€ l^{-1})	2.62	0 – 2.62	2.26	86	33	
Social	Employment	Total labour input (AWU)	5000		3372	67	50	67
		Seasonal labour input (AWU)	n.a.		n.a.			
	Liveability	Migration rate (% between 1991-2001)	-5.7	[a]	-8.2	56	20	
	Safeguard	Investment in olive orchards (% < 5 y)	10	0 – 10	7.5	75	30	
Cultural	Landscape value	Index value (0-10)	6.4	0 – 6.4	4.9	77	70	70
	Tourism	Revenues from tourism (% farm income)	n.a.		n.a.			
		Regional products sales (% PDO label)	5.0	0 – 5	2.7	54	30	

[a] In absence of a reference scale, a penalty on excess is calculated according to: $1 - ((y - x)/x)$

[b] Value in 2000

Sources: data from agro-socio-economic survey, statistical data from INE, IDRHa & DGRF, and expert consultation (see also main text).

Olive orchards are regarded to be very effective as firebreak. This function is very important, as Portugal has experienced most wildfires of all Southern European countries between 1980 and 2003 (398,682 occasions, 38% of total) (Agronoticias, 2005). Moreover, wildfire problems in Trás-os-Montes strongly increased over this period. Figure 5.5 shows that the number of wildfire outbreaks per area unit is negatively correlated with the share of regional land under olives (Pearson correlation coefficient of –0.394, $P<0.05$), but not with the percentage of total agricultural land in use. These data implicitly show the firebreak effect of olive orchards, especially if one considers that olive cultivation in Trás-os-Montes is confined to the Terra Quente area. This zone has a pronounced hot and dry summer where one would expect higher fire risk (93% of annual burnt area in Portugal occurs during summer months - Pereira et al., 2005). If we estimate the burnt area of olive groves to be 25% of the proportional share of olive orchards of total agricultural land, to account for relatively low fire risk in olive orchards and avoid doublecounting of repeated fire outbreaks in the same area, the average orchard area burnt would be 60 ha y^{-1}. For the years 2002–2004, this indicator value was 91±18 ha y^{-1}. Tillage in spring is a crucial factor in reducing fire risk. We estimate that about 50% of the olive orchard area receives this treatment. Another important management intervention to avoid fires is pruning. According to DEASR (2004a), 13% of the regional olive area is characterised by deficient cultural practices, which usually starts with the neglect of pruning (Eicher, 2005).

The olive plantations are part of diversified agricultural landscapes, next to olives composed of other permanent crops, annual crops and forest. As a consequence they may have a beneficial effect on biodiversity, especially SMOPS 4 and 5. Inappropriate hunting practices have in some instances considerably reduced the population of some birds like thrushes *(Turtidae)* and starlings *(Sturnidae)*. Intensified olive plantations negatively affect pseudo steppe birds of high conservation value (Santos and Cabral, 2004). However, insufficient data was available to include biodiversity conservation in the function assessment study.

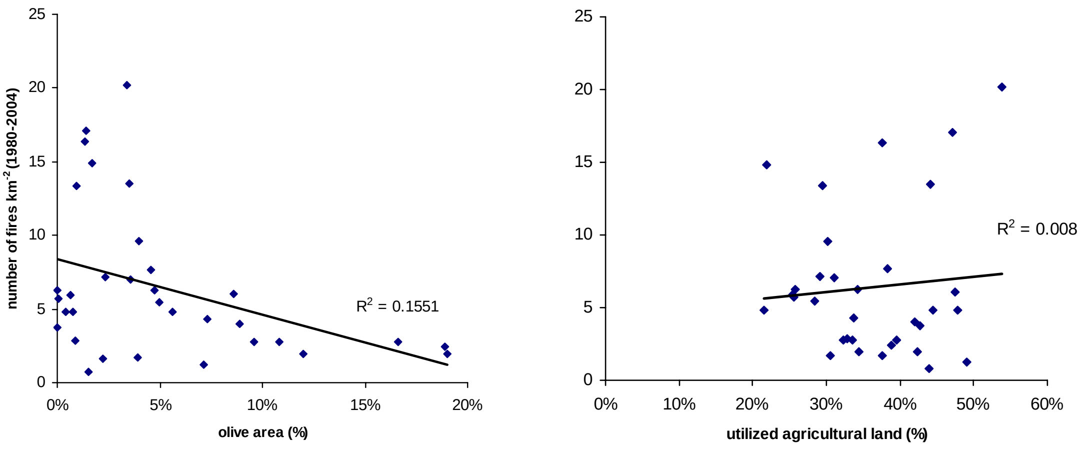


Figure 5.5. Number of wildfires in relation to the percent of the territory of municipalities of Trás-os-Montes covered by olives and total utilized agricultural land. Data obtained from DGRF (2005).

Economic functions of SMOPS in Terra Quente at the regional level

Olive production in Trás-os-Montes contributed on average 8.5% of regional agricultural production value (1995–1999) (INE, 2002). The latest year for which data are available, 2000, the contribution was 6.7%. The importance of back- and forward linkages, especially processing industries, as a source of added value to the regional product could not be quantified.

Production costs of olive oil amount to €955 ha^{-1}, or €3.82 l^{-1}, taking into account labour, equipment, intermediate consumption, processing and other costs. Labour (opportunity) costs of farm family members are thereby valued at market wage rate, which could be an overestimation. The average price of olive oil sold (2004) was €2.26 l^{-1}, while €2.62 l^{-1} (plus the current level of subsidies of €1.20 l^{-1}) would be necessary to cover production costs. Alternatively, production costs should be reduced to €867 ha^{-1} (Fleskens, 2005).

Nation-wide, olive oil comprised €13.9 million (4.3%) of Portuguese agricultural exports, against €73.8 million (4.2%) of agricultural imports (averages over 1997–1999) (GPPAA, 2000). No comprehensive regional data could be found, but assuming that twice the national per capita consumption of olive oil (5.7 kg y^{-1}, IDRHa, 2005) is consumed locally, more than 80% of olive oil production is sold outside of the target area. Figures do exist for about 3% of the olives produced in the target area that are marketed as Product of Denominated Origin (PDO), of which more than 75% is sold outside the production area (IDRHa, 2005).

Of the remaining 20% of olive oil production, three-fifths (12%) is sold locally; about 8% of the regional olive production is used for auto-consumption, and this figure is definitely higher for traditional plantations. For the benefiting families, the value of this share is higher than its economic one, because it contributes to food security at a lower cost than if they would need to buy olive oil from retail shops.

Social functions of SMOPS in Terra Quente at the regional level

Olive production, as a growing agricultural activity, has increased in its importance for regional agricultural employment. Multiplying labour input data per area unit for the different SMOPS types from the farmer survey with the respective areas occupied by each SMOPS gives a total of 3372 Annual Working Units (AWU) in the target area (conservative estimate), 12% of the regional agricultural employment of 29,221 AWU (INE, 2001). Employment generation of the SMOPS is thus in relative terms a more important function than income generation.

The safeguard function, contributing to the security of household incomes by complementing other income sources is also very important, as more than 66% of small producers (those having an olive area under 5ha) and 44% of medium-sized producers (those having between 5 and 25 ha of olive orchards) depend primarily on off-farm income (GPPAA, 2002). For the traditional olive plantation systems these figures are higher, while semi-intensive and organic systems depend to a much higher extent on farm income. In isolation, the importance of on-farm income is not very informative to assess the safeguard function. However, if we assume that olive orchards have an economic life of 50 years, in 5 years 10% of the olive area should be replanted (target value). The investment involved, when made by people not primarily dependent on olive growing, is another indicator of the safeguard function. The actual percentage of orchards younger than 5 year is 7.5%.

The contribution of olive growing to liveability of the area is important considering that the region has a negative migration rate and that the density of industrial and services firms is one of the lowest in the country (0.3 km^{-2}, against 2.8 - 4.7 km^{-2} in other Northern Portuguese regions; GPPAA (2002)). A simple calculation shows that the 158 recognised olive oil mills existing in Trás-os-Montes (12,273 km^{2}) in 2001 directly contributed with more than 4% to this service level index, whereby it should be realized that the bulk of firms is concentrated in the towns and olive oil mills are among few firms in rural areas. The olive sector as a whole, by its importance to regional employment, helps to maintain the level of other (non-commercial) services necessary to ensure agreeable living.

Cultural functions of SMOPS in Terra Quente at the regional level

The aggregate landscape value of SMOPS was derived from individual SMOPS scores (Table 5.5). The target value was assessed in a similar fashion by adjusting partial index scores to the desired level. As such, an average landscape value of 4.9 was obtained while the target value was set at 6.4.

Direct revenues from tourism attributable to olive growing could not be assessed. The importance of regional cultural identity was assessed using the percentage of olive oil sold with PDO label as an indicator. Currently this is 2.7%, while expert-estimated potential market share is 5%.

Table 5.5: Landscape values for SMOPS in the Terra Quente area and for SMOPS types 2 and 4.

Landscape quality [a]	Indicator	Scores (partial scores ranging 0—1)			
		Regional target	Regional average	SMOPS 2	SMOPS 4
1. Merged into natural landscape	- Presence of natural and semi-natural patches	0.5	0.2	0.1	0.8
	- Presence of old, big trees	0.4	0.4	0.2	0.7
2. Spatial and temporal variety	- Frequency of tillage operations	0.8	0.3	0.3	0.8
	- Average plot size	0.6	0.8	0.6	1
3. Richness	- Presence of stone walls/terraces	0.2	0.2	0.1	0.9
4. Smoothness or non-disruption	- Presence of non-managed abandoned area	1	1	1	0.3
5. Special effects	- Special effect bonus (almond, flowers, dramatic landscape features)	0.4	0.4	0.2	1
6. Accessibility	- Accessibility	0.5	0.4	0.6	0.2
7. Environmental soundness	- Presence of signs of erosion	1	0.4	0.3	0.7
	- Presence of areas affected by fire	1	0.7	0.8	0.3
Aggregate landscape value	Index value (sum of all partial scores)	6.4	4.9	4.2	6.7

[a] After Pachaki (2003)

5.3.2. Applying the house of functions concept to Terra Quente SMOPS at regional and farm level

The regional indicator scores of Table 5.4 can be presented in a house of functions (Figure 5.6). Ecological functions appear to be in shortest supply with the set of indicators used. Although a closed house can be constructed, it is highly unstable because the ecological base is too small; improving environmental performance is thus the first priority. After these improvements are made, an inhabitable (closed) house can be constructed, but as social functions are also relatively weak, another imperfect house would result. If this silhouet would be used for normative purposes, the question is whether stakeholders accept the house as it is, or whether they would like to make further improvements, whereby enhancing social functions would have to receive priority.

When regional indicators are replaced by farm level indicators (Table 5.1, scores not shown), individual SMOPS can be compared (Figure 5.7). Taking as an example SMOPS types 2 (semi-intensive) and 4 (in process of abandonment), aggregate scores for productive and economic functions vary largely, while scores for cultural functions differ less. Also scores for ecological functions do not deviate much. This occurs as a result of aggregating indicator scores for soil conservation and wildfire control which show opposite tendencies along an intensity of production gradient.

For SMOPS 4, closing the house silhouet in its present state is possible, although this would result in a house with a flat roof. If this silhouet is used for normative purposes, the question is whether the farmer accepts that this type of orchards performs poorly on economic and social functions (de facto being a hobby farmer), or whether he/she would attempt to enhance these functions. In the first case, economic and social functions would perhaps be transferred to other activities not included within the SMOPS (e.g. receiving a pension to complement farm income).

The overall house of SMOPS 2 resembles the situation of regional SMOPS (Figure 5.6), performing better on most functions except ecological (no difference) and cultural ones. A closed house can be constructed but is highly unstable unless ecological functions are enhanced. Once ecological performance is improved, in second instance priority is required for cultural functions.

Comparing Figures 5.6 and 5.7, we see that farmer and regional level priorities may be very different. While overall regional priority is improving environmental performance of SMOPS, farmers with SMOPS 4 are primarily concerned with economic and social functions. SMOPS 2 farmers could agree on the importance of enhancing ecological functions, but are less concerned with the second regional priority, social functions. Traditional orchards (SMOPS 1) take an intermediate position between SMOPS 2 and 4, and score lowest on economic and ecological functions. This may illustrate that a strategy for effective planning should start with communication between stakeholders.

Ideas on how the house of functions can contribute to this are embarked upon in the discussion.

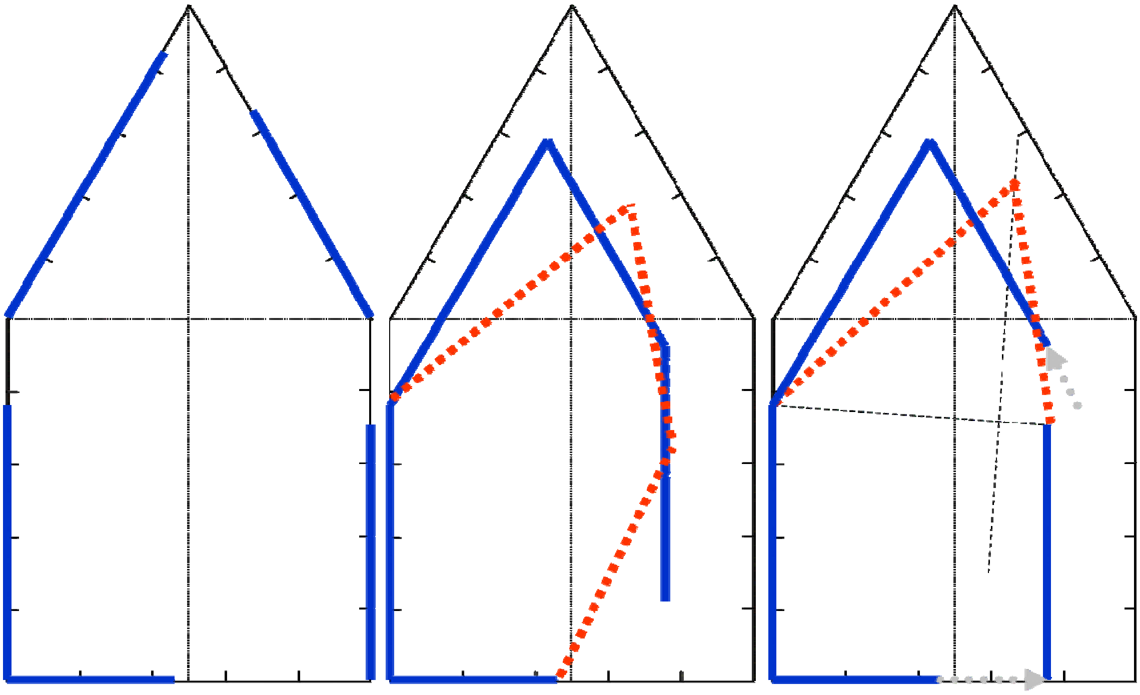


Figure 5.6. The house of functions of regional SMOPS: a. aggregated indicator values; b. rearranged silhouette for descriptive (blue, straight lines) and normative (red, dotted lines) purposes; c. idem after improvement of ecological functions, and suggestion for further improvement to arrive at a possible development vision.

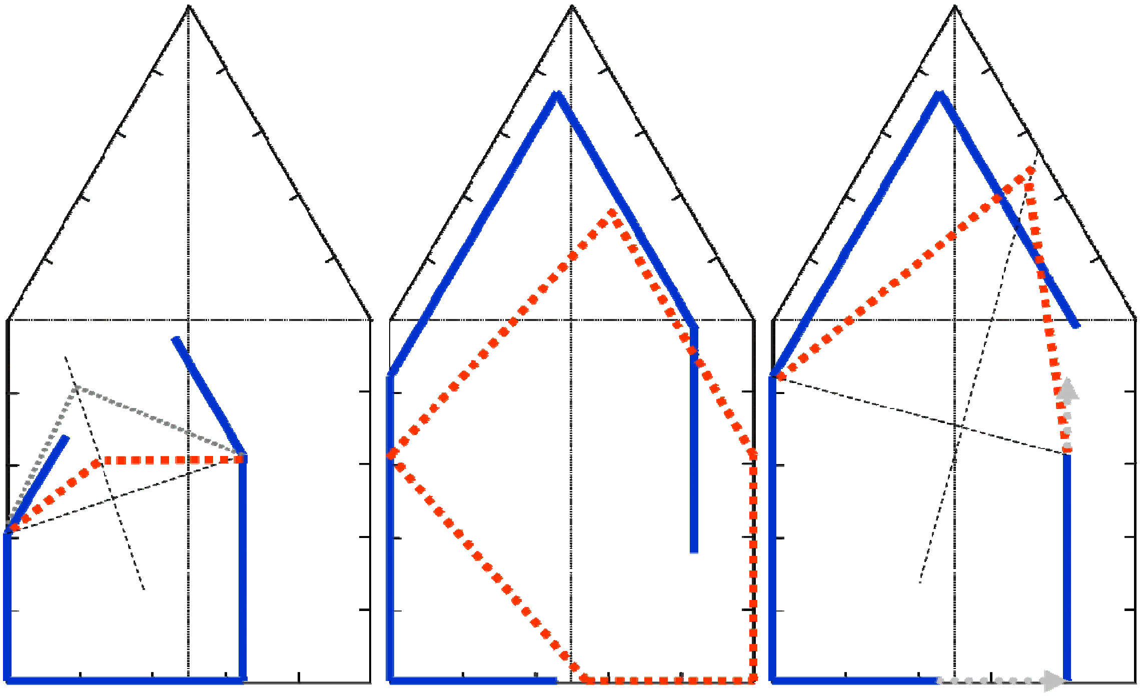


Figure 5.7. Houses of functions: a. SMOPS 4; b-c. SMOPS 2. Blue straight lines represent the descriptive and red dotted lines the normative house silhouette; in Fig. 7a this could be achieved without improvements, or with reinforcement of economic and social functions (grey dotted line); in Fig. 7c the normative house silhouette is shown after improvement of ecological functions; further improvement should be focused on cultural functions.

5.4. Discussion

While Trás-os-Montes is Portugal’s most important olive production area, it must be remarked that in an international context, local olive production systems are predominantly low-productive and traditionally managed (Beaufoy, 2001; Fleskens and de Graaff, 2003). Portuguese agriculture has suffered more important abandonment processes than other Southern European countries (Margaris et al., 1996). In this respect, the drive to value multiple functions maybe more important here than elsewhere, but nevertheless the process is symptomatic of a much more widespread trend. A further impetus is to be expected from the recent (2006) introduction of single farm payment schemes in the CAP regime for olive cultivation. As payments are based on past production in the reference period 1999–2002, plantations which were not or only recently modernised, will not receive additional future subsidy benefits from investment in productive capacity. Investing in diversification could be a viable alternative.

Makhzoumi (1997) emphasizes that olive (and carob) plantations of Cyprus with multiple productive functions are in decline due to economic reasons, while these agro-ecosystems fulfil important social and cultural functions. At a higher abstraction level, Tait (2001) suggests to differentiate a priori between intensive and extensive forms of production requiring different approaches to address multifunctionality. Siebert (2004) reports on the importance of Cretan traditional agriculture (including traditional olive orchards) to conserve biodiversity, and suggests that supporting these systems for this aim may be much more beneficial than subsidizing ‘modern’ agriculture for enhancing biodiversity and landscape value.

The assessment of functions of SMOPS was here undertaken at two scales: regional and farm level. More scales could be added, whereby intermediate stakeholders (such as local governments) should then participate in two adjacent assessment levels and act as communicator between them. López Ridaura (2005) presents such a multi-scale methodology based on attributes of sustainability. Each stakeholder could be characterised by pursuing different goals captured by different system productivity, stability, reliability, resilience and adaptability indicators. In a formal resource allocation model, goals at the lowest decision-making levels act as constraints at higher aggregation levels. While not mutually exclusive approaches, it seems that the function assessment methodology here presented may provide more opportunities for situations in which constraints are imposed upon lower aggregration levels (e.g. cross-compliance regulations).

A report by BBO (1999) discusses experiences with the creation of stakeholder platforms. In many cases, resource conflicts led to their creation, and conflict resolution was their main goal. However, developing partnerships in areas where there is no explicit conflict also poses a challenge, as succesfully developing potential functions requires synergy. Recently, quite some attention is paid in the literature on how to achieve multifunctionality, both at the farmer level, with focus on entreprenurial skills and networks (Clark, 2005; Wortmann et al., 2005), and at the policy level, where strategies should enhance desired functions without negatively affecting farmers' livelihoods (Hodge, 2000; Pretty et al., 2001).

Function assessment and its visualization as the house of functions should be further tested in stakeholder platforms to judge its usefulness in consensus-building and conflict-resolution. Departing from a house representing the current state, stakeholders may note a trend of crumbling down or building up. They may also indicate their desired developments. The methodology thus resembles a SWOT (Strengths–Weaknesses–Opportunities–Threats) analysis, with the difference that it also immediately visualizes viability. As such it provides a potentially powerful tool for the following situations (Figure 5.8):

- Monitoring trends in the fulfilment of functions over time, either as a result of autonomous development or introduction of (environmental) policies;
- Presentation of the results of scenario studies aided by various 'houses', and/or discussing the relative attention that needs to be paid to each function category (axis) in development plans;
- Evaluation of how intervention in one function affects system performance in other functions (trade-offs).

A flaw in the reported application is the aggregation of various functions. For instance, a high soil conservation score and low wildfire control score were averaged out in the process of assigning scores for ecological functions. This could be partially resolved by showing the indexed range of individual function scores or the standard deviation of the aggregated function group value (Figure 5.9). Individual functions could be weighted or a single most important function could be elected to evaluate alternatives. Weighting of individual functions could also be achieved by value expression in uniform units, i.e. monetary valuation (for a state-of-the art, see: Madureira et al., 2007; Randall, 2007).

Notwithstanding these diffulties, the house of functions is probably a more informative tool for decision-making than single aggregate indices, each of which would only serves a narrow field of applicability (Jollands, 2006). Moreover, the concept visualizes trade-offs between functions, and thus allows a discussion of the jointness of production of commodities and non-commodities (Abler, 2001). Another frequently used tool to present indicator scores is the spider diagram. While the spider diagram has its strength in being capable of simultaneously presenting multiple scores with only an implicit limit on the number of indicators, it is not explicit about the importance of various functions. The house of functions can rapidly show the most significant weaknesses of a system: it is immediately obvious that a house with e.g. no foundation cannot be long-lived. The house of functions may thus be used as a rapid assesment tool, while detailed information may be provided as in Figure 5.9 or in spider diagrams (perhaps separately for each function category) .

Contrasting stakeholder views in multifunctional agriculture were also presented by Kaljonen and Rikkonen (2004). While they observed important levels of agreement between stakeholders, they argue that due to the challenging future of agriculture, enhancing self-reflection and dialogue between different stakeholders should be a role of research. A further challenge for research is to develop and test indicators and monitor agro-ecosystem performance to feed the needs of decision-makers.

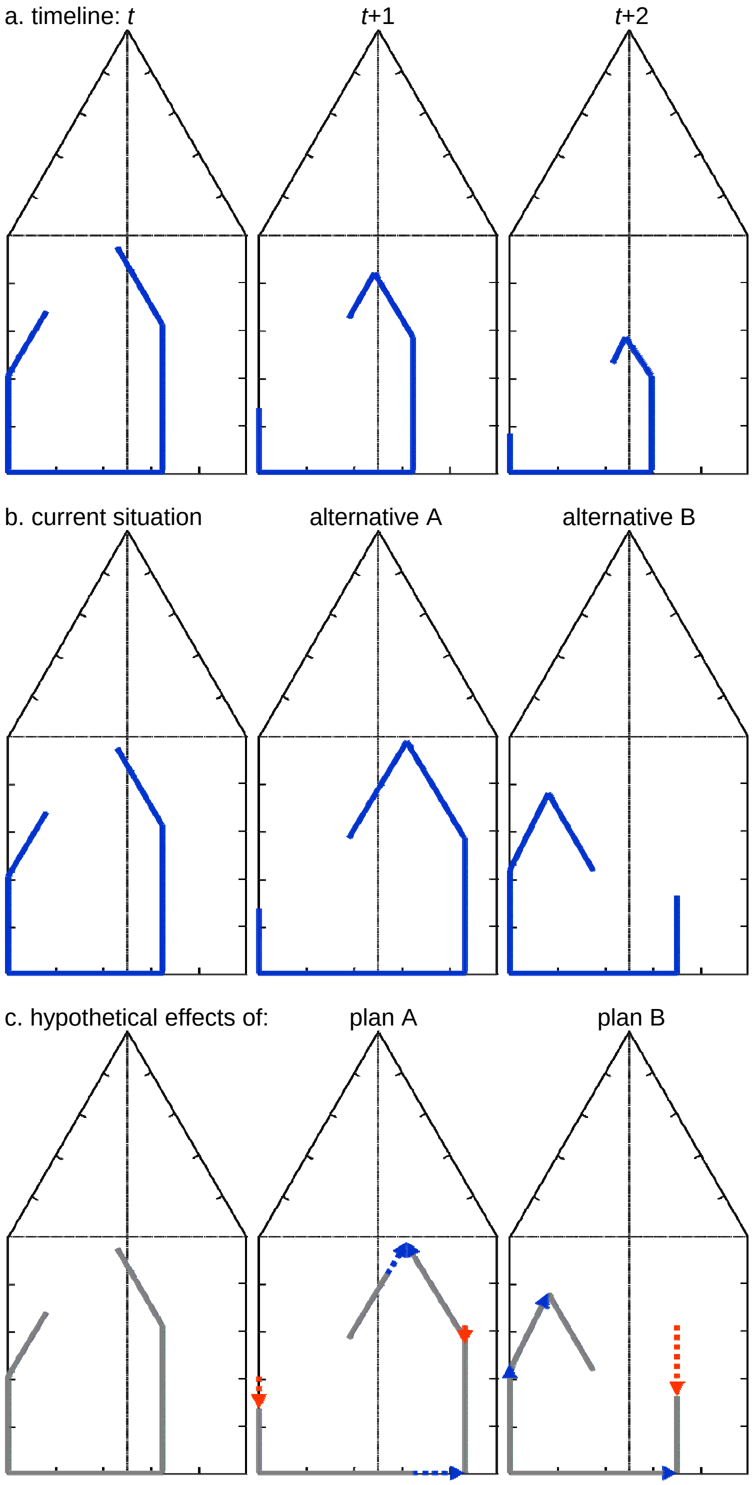


Figure 5.8. Potential uses of the house of functions: a. trend analysis; b. presentation of results of scenario studies or development alternatives; c. trade-off analysis of development alternatives: hypothetical effects of improving environmental performance (plan A) or maintaining the productive function (plan B).

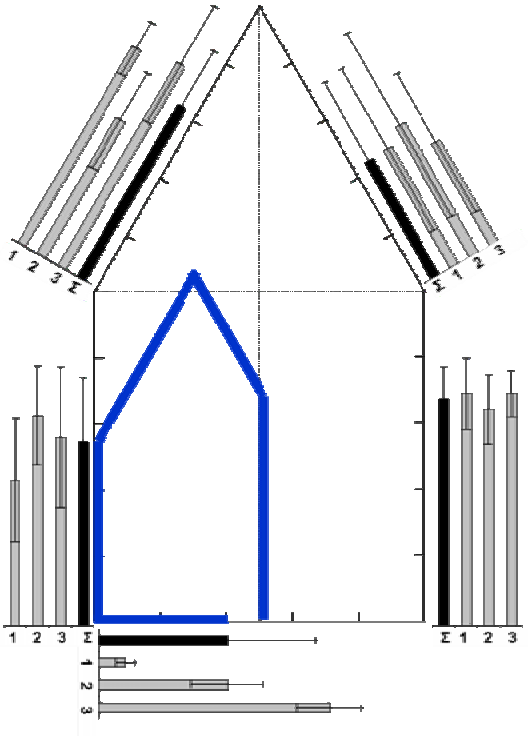


Figure 5.9. An example house of functions with indicator scores and their standard deviations.

5.5. Conclusion

The assessment of functions of olive groves in the Terra Quente study area was able to show that these agro-ecosystems fulfill various functions. The Terra Quente area is home to a diversity of SMOPS. Traditional orchards are the most numerous and perform important ecological and social functions. Semi-intensive SMOPS have been expanding and will progressively strengthen economic functions at the regional level. They may also reveal importance for wildfire control as land under other crops is increasingly being abandoned, although a high degree of mechanisation and frequent tillage can lead to more soil erosion. A well-developed olive oil sector may act as counterweight to ongoing emigration, and may help secure a minimum service level in rural areas. For olive orchards in process of abandonment, the lack of crop care inevitably leads to lower productivity. Minimum maintenance standards of terraces for erosion control and landscape value and of pruning of trees and weeding to avoid wildfires should be established. Farmers have shown interest in agri-environmental contracts and could thus contribute to ecological functions while receiving additional income. The development of tourism should be able to reverse the trend of outmigration by contributing to employment generation (especially during summer, and hence complementary to olive growing), and maintenance of the liveability of the area. Policy-makers may use function assessment as a tool to design appropriate agri-environmental subsidy schemes and cross-compliance rules that are tailored to regional agro-ecosystems and seek to achieve balanced rural development.

Carried out from a research perspective, many different types of indicators were used to illustrate the current performance of these systems. Constructing houses of functions at regional and farm level suggests that the method may have potential for application in participatory decision-making processes. Further testing and refinement is required to judge its usefulness in consensus-building and conflict resolution. However, the following preliminary conclusions can be drawn:

- The function assessment method is flexible; it can be used with either science based (environmental) target values or subjective target values, as long as objective and relatively scale-insensitive indicators are used.
- The function assessment method is descriptive; if objective indicators are used, the analysis can assess (differences in) performance of agro-ecosystems or suggested modifications thereof. It can also be used to show trends over time or tradeoffs between functions.

The metaphor depicted by the house of functions is applicable to all scales of analysis, but ultimately it is *Oikos* that cannot be substituted; multifunctionality is a luxury as much as it is a necessity – it is a matter of careful choices.

Chapter 6

Is soil erosion in olive groves as bad as often claimed?

Fleskens L and Stroosnijder L

Geoderma (accepted)

6. Is soil erosion in olive groves as bad as often claimed?

Abstract

Alarming erosion rates have been reported in olive groves on sloping and mountainous land with some regional averages supposedly as high as 40 – 100 ton ha^{-1} y^{-1}. These figures are based on empirical models that apply a simple multiplication of adverse environmental factors such as steep slopes, erodible soils and low vegetation cover. We present experimental data from rainfall simulations, runoff plot studies and field assessment of erosion symptoms that challenge the alarmist view. We suggest seven factors be taken into account, to achieve more realistic estimates of erosion: 1) increased surface roughness from tillage increases infiltration; 2) a cover of rock fragments protects the soil and reduces the slope effect on erosion; 3) grove undergrowth reduces sediment losses; 4) slope irregularities created by long-term erosion allow runoff to infiltrate locally; 5) vegetative strips hamper rill and gully formation; 6) erosion mainly results from infrequent high intensity rainfall events, and 7) upscaling of experimental results leads to overestimation of erosion. These factors act and/or interact at different scales; although each pertains to a certain scale of analysis only and affects erosion processes differently, taken together the factors provide an argument for indicating more precisely when, where and for whom erosion constitutes a problem.

A literature review (of various types of assessments) yielded erosion rates with upper and lower limits differing more than a factor of 10 000. In some individual experiments, differences between treatments (tillage versus non-tillage or vegetative strips) were still a hundredfold – frequently to the disadvantage of tillage operations.

The results of our own experiments are also presented. In some runoff plots (7.5 x 15 m, previously tilled) the soil loss after cumulative rainfall of 104 mm was 17.3 g m^{-2} for non-tilled against 8.5 g m^{-2} for tilled conditions ($P<0.05$); in another runoff plot experiment (10 x 22 m, previously under a cover crop) tillage initially led to higher soil loss, but differences rapidly disappeared. Field rainfall simulations on soils with plant cover had significantly less soil loss than those without plant cover (recently tilled) (61 g m^{-2} versus 218 g m^{-2}, $P<0.001$); runoff, however, was not significantly different. In consecutive rainfall simulations on soil with or without in situ rock fragments, the runoff, runoff coefficients and soil loss were significantly lower ($P<0.01$) in the case with rock fragments. On non-uniform slopes, runoff and soil loss were spatially different, and tillage led to variable responses, depending on location.

Combining the findings from our individual experiments, we conclude that tillage applied judiciously in selected locations of a grove might reduce erosion. Localised erosion may still be controlled at field level by vegetative

strips. Our results suggest that average soil erosion rates are unlikely to surpass 10 ton ha^{-1} y^{-1}, which is nevertheless still more than the soil renewal by weathering (about 1 ton ha^{-1} y^{-1}). Any recommendations for improved soil management should ideally be tested at the appropriate scale and should capture the climatic (rainfall) conditions under which they are intended to mitigate soil erosion problems.

6.1. Introduction

Soil erosion is a highly variable process in space and time that has intrigued many scientists and worried land managers and authorities, all of whom attach much importance to predicting where it will occur, what impact it will have, and where and how it can be controlled. In attempting to promote more sustainable soil management practices, policy-makers have resorted to simple empirical regression models such as the (Revised) Universal Soil Loss Equation (NRCS-RUSLE2, 2006) in order to design policies. Though these models have often only been validated to a limited extent, they are assumed to be authoritative and their predicted erosion rates are applied uncritically. An illustrative example of this is found in the case of olive groves.

Olive groves are an important land use in the Mediterranean region, especially on sloping and mountainous land prone to soil erosion. Many scientists argue that erosion is the major problem associated with olive (*Olea europeae*) cultivation (Tombesi et al., 1996; Guzmán Álvarez, 1999; Beaufoy, 2001; Pastor et al., 2001). Olive groves have been assessed as having the highest erosion rates in the region (e.g. Pastor and Castro, 1995; Schoorl and Veldkamp, 2001). The frequently cited average soil loss estimate of 80 ton ha^{-1} y^{-1} for Andalusian groves is based on a coarse-scale USLE model estimate by Lopez-Cuervo (1990), but disregarding Lopez-Cuervo's caveat that this estimate does not account for within-field sedimentation (Gómez et al., 2005). Similarly, ICONA (1991) and Kok et al. (1995) report USLE-based average soil erosion estimates of 95 and 40–100 ton ha^{-1} y^{-1} respectively for Spanish olive groves. The fact that olive groves can often be found on steep slopes (Fleskens and de Graaff, 2003) seems to have led to the widespread belief that soil erosion is rife in olive groves. Moreover, trees in rainfed groves on steep slopes are widely spaced and farmers preferentially till intensively to keep the groves' soils weed-free (de Graaff and Eppink, 1999; Zobisch and Masri, 2000).

It seems too simplistic to develop policies on soil management based on the above generalities. Olive groves vary greatly, with those on the steepest slopes often under better land husbandry practices, such as terracing (Fleskens, submitted). In fact, some olive groves on steep slopes are recognised as sustainably managed (Kosmas et al., 1997; Loumou and Giourga, 2003). On the other hand, groves on gentle slopes have been reported to suffer substantial erosion, i.e. exceeding a tolerable soil loss of 11.4 ton ha^{-1} y^{-1} on a 3.4% slope (Gómez et al., 2003). What is more, as already touched upon while discussing

Lopez-Cuervo's 80 ton ha^{-1} y^{-1} soil loss estimate, there is an important scale effect in measuring erosion, as erosion involves processes of detachment, entrainment, transport and sedimentation that are best assessed at scales of less than one square metre to several tens of hectares or even square kilometres, respectively (Stroosnijder, 2005). Consequently, high within-field soil loss rates do not necessarily create important off-site problems at the catchment level. The question of whether the soil erosion record of olive groves is 'bad' thus includes a reference issue, a scale problem and an evaluative dimension.

The purpose of this chapter is threefold: to provide a context for available soil erosion estimates for olive groves; to present reasons why soil erosion rates might be lower than often claimed (addressing the abovementioned reference issue and scale problem); and to discuss the implications for soil conservation practices and policies (addressing the evaluative dimension). The first objective sets the stage and will be embarked upon in the remainder of this introduction. In the next section, field research methods are described. Results are presented grouped according to the possible causes of the overestimation of erosion. Concluding remarks on the implications of these findings complete the chapter.

Table 6.1 summarizes data on erosion rates measured in olive groves. A few caveats are in order: a) some data refer to simulated single events, others to average annual values calculated from multi-year experiments; b) although soil loss data are expressed in g m^{-2} as the most appropriate unit for the majority of experiments (and of those to be presented in this chapter), methods vary widely and in principle the results are not comparable; c) though differences between treatments can be compared, possible scale differences should be taken into account.

Given the above limitations, it is easy to see why reported soil loss rates may differ by a factor of 10 000. The influence of slope, vegetative cover, rock fragment cover, soil type, presence and state of soil and water conservation measures, and amount and intensity of precipitation certainly play a role, but cannot account for differences this large: differences between treatments (aggregated under the headings conventional tillage – CT; no-tillage – NT; and cover crop strips – CS) usually do not differ more than a factor 100. The 'unexplained' differences (also a factor of 100) support the suggestion that the assessment of soil erosion rates will always be biased, depending on the methods and scales of analysis employed (Stroosnijder, 2005).

Theocharopoulos et al. (2003), who assessed erosion rates with ^{137}Cs at catchment level, estimated that the net soil loss from the catchment amounted to 18–22 ton ha^{-1} y^{-1}, while soil erosion rates measured at various points within the catchment varied between 4.5–96 ton ha^{-1} y^{-1}. They ascribed this difference to sedimentation, which ranged from 1–189 ton ha^{-1} y^{-1} at different points in the catchment. Failure to take into account sedimentation is just one of the shortcomings of erosion prediction approaches. Gómez et al. (2003) mention that over-simplistic soil cover (C-factor) estimates are a second reason why USLE-based studies overestimate erosion. Their suggested remedy is to evaluate the soil cover at 15-day intervals. They show that soil management systems greatly influence soil erosion rates: from a minimum of 15 ton ha^{-1} y^{-1}

for a barley (*Hordeum vulgare*) cover crop to a maximum of 80 ton ha^{-1} y^{-1} for a no-till bare soil situation in an olive grove on a 70 m long 20% slope. According to Gómez et al. (2005), the overestimates can be reduced even more by taking into account the protective effect of rock cover (Poesen et al., 1994), as such cover is a feature of many Mediterranean slopes.

Concentrating on the plot (<225 m^2) and field (2500 m^2) scales, we present experimental results that allow us to distinguish seven factors that account for why erosion rates in olive groves are often exaggerated:

1. Tillage increases surface roughness and infiltration
2. Rock fragment cover protects the soil and reduces the slope effect on erosion
3. Olive grove undergrowth reduces sediment losses
4. Long-term erosion creates a non-uniform slope that allows local infiltration of runoff
5. Vegetative strips hamper the formation of rills and gullies
6. Erosion mainly results from infrequent high intensity rainfall events
7. The upscaling of experimental results leads to overestimation of erosion

6.2. Materials and methods

6.2.1. Study areas

Our field research focused on three areas: Trás-os-Montes (north-eastern Portugal), Granada (southern Spain), and Basilicata/Salerno (southern Italy). Trás-os-Montes has a continental climate caused by mountain ranges in the West and South that exclude Atlantic influences. Of the 72 288 ha under olives in the region (6% of total area), 60% receives less than 600 mm y^{-1} and 90% less than 800 mm y^{-1}(de Figueiredo et al., 2002). At Mirandela (41º29’ N, 7º11’W), in the centre of the olive growing region where olives occupy 19% of all land, average annual precipitation is 520 mm. Summer is usually dry. Average annual temperature is 14.1 ºC (January 6.1 ºC, July 23.6 ºC). Soils are less than 0.5 m deep in 76% of olive groves, and a similar share of the groves’ soils has a stoniness of over 30% (de Figueiredo et al., 2002).

In Granada, the study area was confined to the agrarian region of Iznalloz (37º23’ N, 3º31’W). Iznalloz has 24 500 ha of olive groves, occupying 30% of its total surface. It is crossed by the Subbetica mountain chain, and the territory of Iznalloz is at an altitude of 800–1400 m a.s.l. The soils in the study area are mainly moderately deep Inceptisols and Aridisols with accumulation of calcareous and gypseous materials and low organic matter content, along with shallow Entisols (Xerorthents) in the steepest areas and, less frequently, deep Alfisols with high organic matter content (Aspizua, 2003). Average annual precipitation is between 500–600 mm, falling predominantly in March/April and November/December. Mean temperature is 12.3 ºC (December 5 ºC, July 22 ºC) (Aspizua, 2003).

Table 6.1: List of erosion assessments carried out in olive groves with different methods, specified according to soil management (CT = Conventional tillage; NT = No-tillage; CS = Cover strips).

			Tree		Spatial scale		Temporal scale		Erosion		
Location [reference]	Soil type (Clay-Silt-Sand %)	Slope (%)	-density (ha^{-1})	-age (y)	Dimensions (m)	Trees (no.)	Duration	Precipitation (mm)	CT (g m^{-2})	NT (g m^{-2})	CS (g m^{-2})
1. Rainfall simulations											
Cordoba, ES [1]	Colluvial slope (17-16-67)	20	333	15	10 x 12	4	2254s	21.4	121		
		20	333	15	10 x 12	4	1035s	11.6		27	
		20	–	–	0.20 x 0.36		30 min	75	1681; 2099	147; 290	
		20	–	–	0.20 x 0.36		30 min	83	265[a]; 1300[b]	74[a]; 284[b]	
Cordoba, ES [2]	Typic Xerofluvent (s. cl-loam)	7	278	5	8 x18	3	0.79 h	34; 31	30		4
	id.	7	278	5	8 x 18	3	1 h	45; 48			3; 12
Mação, PT [3]	Lithic Xerorthent				1 x 1				23–48	0–75[c]	
2. Field surveys & radio nuclide tracer studies (^{137}Cs)											
Cordoba, ES [4]	Typic Pelloxererts (clay)	13		65	30; 85	10–20[d]			10500; 6000		
	id.	10		55	40	id.			6500		
	Typic Xerorthent	33		65	25; 70	id.			7000; 8000		
	Typic Xerochrept (high Ca)	17		100	60	id.			7000		
	Typic Pelloxererts (43-41-16)	13		65	220[e]				8440 (0–22300)		
3. Runoff plot studies											
Lesvos, HE [5]	?	50			10 m^2		2 y		0.056	0.024[f]	
Athens, HE [6]	Typic or Calcic Xerochrept	16–23			3 x 10		5 y	496 (349–575)		0–3[g]	
Cordoba, ES [7]	Typic Chromoxerert (49-47-4)	13.4	278	7	6 x 12	2	3 y	665 (594–744)	400	850	120
Cordoba?, ES [8]	?	30					2 y			2510	740; 1030
Cordoba, ES [9]	?	13					1 y		5000		50
		4					1 y		300		20
Calabria, IT [10]	?	?					2 y		4100	36[h]	
Sevilla, ES [11]	Typic Xerochrept (29-29-42)	6	204		1 x 8	0	2 months	204	4.6		0.3
	Typic Calcixerept (19-9-72)	5	204		1 x 8	0	2 months	204	0.4		
	Aquic Haploxerept (31-17-52)	7	204		1 x 8	0	2 months	180[i]	8.2[i]		
Granada, ES [12]	Typic Xerochrept	30		25			>1 y	571	1010	4250	340
Granada, ES [13]	Typic Xerorthent (19-27-54)	30	156	30	8 x 24	3	2 y	270; 460	100; 1040	1050; 4070	170; 240
Lesvos, HE [14]	(clay or clay-loam)	25; 40			10		2 y	481		1; 5	
Aleppo, SY [15]	Lithic Xerorthent (25-40-35)	24		80			4 y	400–650	1190–8100	20–1410	

References: [1] Giráldez et al. (1990); [2] Castro et al. (in press); [3] Coelho et al. (2001) cited in Carvalho et al. (2002); [4] Laguna & Giráldez (1990); [5] Arhonditsis et al. (2000); [6] Kosmas et al. (1997); [7] Gómez et al. (2004); [8] Arroyo (2004) cited in Gómez et al. (2005); [9] Gómez et al., unpublished (Gómez et al., 2005) ; [10] Raglione (1999) cited in Gómez et al. (2004); [11] De la Rosa et al. (2005) ; [12] Francia Martínez et al. (2000); [13] Francia Martínez et al. (2006); [14] Koulouri & Giourga (2006) ; [15] Bruggeman et al. (2005). Notes: [a] Under canopy; [b] Open field; [c] Treebase measurements; [d] ^{137}Cs study; [e] Soil cover range 10–60%; [f] Abandoned field; [g] Soil cover 90%; [h] Permanent cover crop; [i] Same series of events as in other soil types, except for one missing event.

Two research sites were selected in the Italian study area: Caggiano (40º34’ N, 15º30’E, elevation 450 m a.s.l.) and Ferrandina (40º31’ N, 16º26’E, elevation ca. 400 m a.s.l.). The two locations are separated by the Lucanian Apennines, causing Caggiano to have a distinctly more humid climate than Ferrandina (average annual precipitation of 866 mm against 676 mm, which is moreover distributed more evenly over the year). Average annual temperatures are 19.3 ºC and 13.9 ºC respectively (January: 10.8 ºC vs. 5.5 ºC, August 30.1 ºC vs. 23.4 ºC) (Xiloyannis et al., 2004). The soils around Caggiano are derived from Appenine rock sediments and have sandy–clay to clayey–sand texture. Topsoil (0–15 cm) texture from a sample of olive groves was 39% sand, 20% silt and 41% clay, with a soil organic matter (SOM) content of 2.1%. At the Ferrandina site, fluvial sandy conglomeratic soils predominate (average texture of the olive grove’s soil sample: 44% sand, 22% silt, 34% clay; SOM content 1.2%). Active $CaCO_3$ content is rather high at 7.4% by weight (Xiloyannis et al., 2004). In the Basilicata/Salerno area there are 72 600 ha of olive groves (7%). In the area around Caggiano olive groves are more prevalent, while in the Ferrandina region, annual crops dominate.

6.2.2. Rainfall simulations

A total of 160 rainfall simulations were performed with a mobile rainfall simulator (Kamphorst, 1987) in the Italian and Portuguese study areas. The rainfall simulator covers a square surface area of 6.25 10^{-2} m^2. The following types of simulations were done in a temporal sequence (simulations of type 3 and 4 were only performed in Portugal):

1. Simulations under ambient conditions (variable initial soil moisture content and rock fragment cover (n = 63);
2. Simulations under pre-wetted conditions (5–10 minutes after simulation type 1); initial soil moisture content is assumed to be saturation (n = 62);
3. Simulations approximately 30 minutes after simulation type 2, performed after removal of coarse (> 2 cm) rock fragments (n = 21);
4. Simulations performed after simulation type 3; generally, the removal of rock fragments exposed dry soil underneath, and also led to the creation of artificial roughness (craters); by the end of simulation type 3, these anomalies had disappeared (n = 14).

The simulations were run for 180 seconds. The time to first runoff (TTFR) was recorded and the amount of simulated rainfall and the volume of collected runoff were recorded. The mass of eroded sediment was determined after drying (105 ºC, 24 h).

6.2.3. Runoff plots

Runoff plots were installed at Caggiano (Italy) and Mascarenhas (Portugal): 41º33’03”N, 7º08’39”W, 350 m a.s.l. At Caggiano, two delimited plots of 225 m^2 (ca. 10 x 22 m) were constructed on a south-facing slope of 32%. To mimic the olive grove's situation, each plot incorporated four olive trees with varying canopy diameter (1–4 m; smaller trees of younger age had been planted in between the older trees). The trees were in a rectangular pattern, planted 5 m apart in rows 10 m apart, giving a tree density of 200 trees ha^{-1}. At the moment of installation (October 2004), a permanent cover crop (CC) consisting of different types of clovers (*Trifolium* spp.) and herbs had been developing for four years on both plots. The farmer controlled the cover by mowing several times per year for cattle fodder. For the experiment, in order to evaluate differences in runoff and erosion the cover crop on one plot was eliminated by ploughing to 0.25 m depth; this plot is henceforth referred to as CC-T (cover crop – tillage).

A trough installed at the lower side of the plot collected runoff water and suspended sediment, which flowed to a drum with a storage capacity of 0.5 m^3. This drum was connected to a second drum of the same capacity which received 20% of overflow from the first drum. With this set-up it was possible to collect up to 3 m^3 of runoff (the equivalent of about 13 mm of overland flow). From November 2004 until February 2005, runoff was measured after each heavy rainfall event or after a few minor rain events. After calibrating the drums, the volume of runoff was determined directly from the depth of water in the drums (regression equation $r^2 > 0.99$). Eroded sediment was determined by sampling the water from different depths in the drums, after stirring. Suspended sediment in the samples was filtered and oven-dried, after which its mass was determined. This method has been applied successfully elsewhere (de la Rosa et al., 2005). Rainfall, temperature and relative air humidity data were measured every 2 minutes on site by a fully automated meteorological station.

In Mascarenhas (Portugal), four runoff plots of 7.5 x 15 m were constructed (July 2004) in an olive grove with a stony soil under conventional tillage (two ploughing operations per year to 0.15 m depth). The slope of the plots was 18% and the soil depth less than 0.2 m. Rock fragments cover 56% (n = 12, range 46–68% - see Section 2.5 for method) of the soil on the plots. The soil texture was found to be 61% sand, 32% silt and 7% clay. The olive trees in this grove are about 50 years old, planted more or less in rows along the contours at a density of 100 trees ha^{-1}. The entire olive grove had been tilled in March 2004. On 22 November 2004, two plots were tilled, as customary under conventional tillage (CT); the other two plots were not tilled and a natural cover crop was allowed to establish on them (CT-N, in which N signifies the natural cover crop). Runoff was collected in reservoirs dug out directly below each plot. Each reservoir was lined with plastic, with a straw layer underneath to protect the plastic from puncturing. After calibrating each reservoir individually (regression equations $r^2 > 0.99$), runoff volume could be determined by recording the depth of water. The experimental set-up required some additional calculations: a) subtraction of the amount of rainfall collected directly by the reservoirs; b) if water volumes were not instantly determined a correction for evaporation was needed. It was more difficult to determine the amount of sediment; several hours after a rainfall event, most sediment had settled at the bottom of the reservoir. Water was then siphoned out of the reservoirs and the remaining sediment was left to dry as much as the weather allowed. Air-dried sediment was collected with a broom and stored in sealed plastic bags. These were later oven-dried and weighed in the laboratory.

Rainfall was collected at the research site with a tipping bucket rain gauge (0.2 mm tip^{-1}) and recorded at intervals of one hour. Additional climatic data needed in order to calculate potential evapotranspiration (Penman-Monteith method: Allen et al., 1998) were taken from Mirandela meteorological station (distance 7 km).

6.2.4. *Runoff detectors*

In total 74 runoff detection devices (Figure 6.1) were placed at different points on an undulating hillslope at Ferrandina, Basicilata (Italy). Each T-shaped detector, made from PVC tube of 50 mm diameter had openings through which runoff could enter the horizontal catch tube along a length of 16 cm. The runoff detectors were installed with the incised side facing upslope and aligned across the expected path of overland flow, in order to catch runoff and suspended sediment. The water captured by the device was subsequently led to the vertical tube (the storage tube) for later observation. While installing the tubes, care was taken to: a) avoid runoff seeping under the catch tube; and b) to incline the catch tube slightly, so the collected runoff would flow to the storage tube by gravity. Similar runoff detectors have been used successfully elsewhere to collect information on the occurrence of overland flow (Vigiak et al., 2006). In our research we determined the height of the water column in the storage tube as an indicator of runoff and assessed the amount of sediment using three levels of magnitude (none/low, half-full, full).

After the first rainfall event, the devices were checked for their position and any settling, and were repositioned if necessary. In the period from October to December 2004 there were three rainfall events after which measurements were taken.

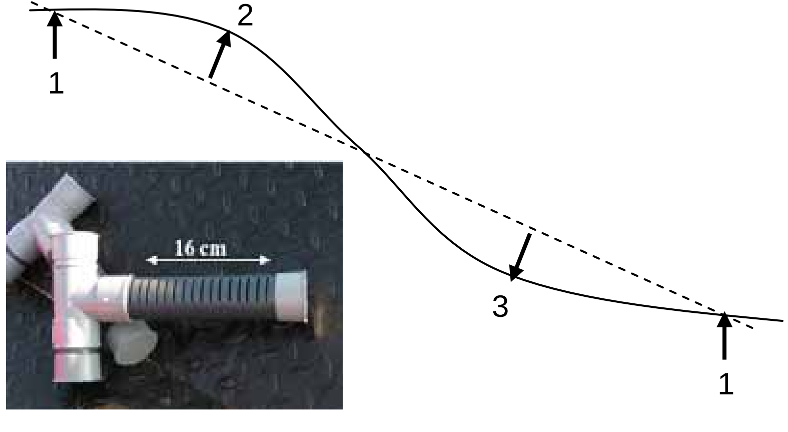


Figure 6.1. Runoff detectors and schematic overview of their positions (1–3) along a convex-concave hillslope.

6.2.5. Field assessment of erosion features and additional field measurements

In Iznalloz, Granada (Spain) 25 fields of 0.25 ha (50 m long and 50 m wide) were selected for visual assessment of erosion using the ACED (Assessment of Current Erosion Damage) method (Herweg, 1996). The method involves the identification of biophysical factors influencing erosion (e.g. slope characteristics, vegetation, land management), erosion symptoms (paths of overland flow, rill and interrill erosion) and, most importantly, an estimation of rill and gully erosion by measuring the length, depth and width of rills and gullies. Fields were selected according to a strategy allowing the inclusion of: a) areas of different potential erosion risk determined as a function of vegetation, soil and topography, and b) different soil management systems: bare soil (BAR, $n = 9$; conventional or reduced tillage and no-tillage with recent herbicide application), covered soil (COV, $n = 8$; cover created by manually distributed stones or by natural vegetation; includes no-till systems prior to herbicide application and semi-abandoned groves), and vegetative strips of natural vegetation, 1–3 m wide, more or less following contour lines (VEG, $n = 8$).

In one runoff plot, Mascarenhas, Portugal, rills were measured at two points in time.

Soil roughness was measured on the site of the Portuguese runoff plots at two moments: the first after tillage of two of the four plots, the second at the end of the measurement campaign (June 2005). The chain method (Saleh, 1993) was used to measure surface roughness in any direction relative to plough furrows but in the direction of the hillslope (subsequently referred to as C_r).

The vegetation cover and rock fragment cover of fields and runoff plots were assessed on sample plots of 1 m^2 with a minimum of three replications. For rainfall simulations, a photograph was taken of the ground frame ($6.25\ 10^{-2}$ m^2) and then the stone surface cover was determined with the aid of image-processing software.

6.2. Results and discussion

6.3.1. Factor 1: tillage increases surface roughness and infiltration

Eroded soil collected from runoff plots in Mascarenhas, Portugal is shown in Figure 6.2a. The average annual soil erosion (2004–2005) was 60 g m^{-2} y^{-1} with a standard error (SE) of 9 g m^{-2} y^{-1}. A disaggregation of CT and CT-N treatments was possible from the moment two of the four runoff plots were ploughed: late November 2004 (Figure 6.2b). Surprisingly, the erosion measured in the CT-N treatment was higher than in the CT treatment: an average soil loss of 17.3 g m^{-2} (SE 0.5) versus 8.5 g m^{-2} (SE 0.8) (difference significant at $P < 0.05$, *t*-test – equal variances not assumed; $t = 9.52$, $df = 1.67$). We attribute this difference to surface roughness being increased by tilling along the contour. Soil roughness measurements made immediately after tillage to compare the freshly tilled with the non-tilled treatment resulted in a significant difference (*t*-test; t = 2.48, df = 23, $P < 0.05$): C_r of 21.1 (SE 1.9) and 15.1 (SE 1.5) respectively. This difference was still present at the end of the season (*t*-test – equal variances not assumed; t = 3.59, df = 13.52, $P < 0.01$): C_r of 13.9 (SE 0.5) and 12.1 (SE 0.2). We attribute this unexpected result to the absence of high intensity rainfall (a maximum of 4.3 mm h^{-1} was recorded in between the two soil roughness measurements) and the low cumulative rainfall of only 104 mm. However, after 294 mm of rainfall in a similar time span, Lampurlanes and Cantero-Martinez (2006) still found significantly higher soil roughness in tilled fields compared to untilled fields. In any case, under our circumstances, the micro-relief was able to persist, reducing runoff and consequently erosion.

That roughness created by tillage also creates a risk of erosion can be illustrated by the data of plots B and D in Figure 6.2a–d. Until the moment of tillage, runoff from the latter plot was substantially higher than from the other plots (Figure 6.2c), leading to the standard errors of cumulative runoff becoming larger with each observation (Figure 6.2d). In plot B, during a moderately intense rain shower the runoff accumulated in the furrow depressions and finally broke through the plough ridge. This triggered the formation of a rill. Rill volume was assessed twice (August and November) and appeared to have decreased slightly (by 1%) over this period. In plot D, the lower part of the plot had been tilled in the direction of the slope prior to conducting the experiment. A non-parametric test showed that differences between plots in runoff, runoff coefficient and erosion were statistically significant at $P < 0.05$ in the order D > B > A > C. The differences between plots B and D might indicate that runoff from plots ploughed in the direction of the slope drains excess water with a low sediment concentration, while the breaching of ridges created by contour tillage might lead to important erosion. The current experiments do not provide sufficient data to test this hypothesis. Furthermore, greater runoff could negatively affect the grove's soil water content and hence olive grove productivity.

Tillage delayed the development of a vegetative ground cover, but the differences between CT and CT-N plots (20% and 29% plant cover by the end of winter) were not significant. It is possible that the stoniness of the plots prevented a continuous vegetative soil cover from developing, thus severely reducing the role of plant cover in controlling soil erosion.

In these experiments no attention was paid to tillage erosion, a process that could lead to considerable relocation of soil (e.g. Govers et al., 1994; Van Oost et al., 2006).

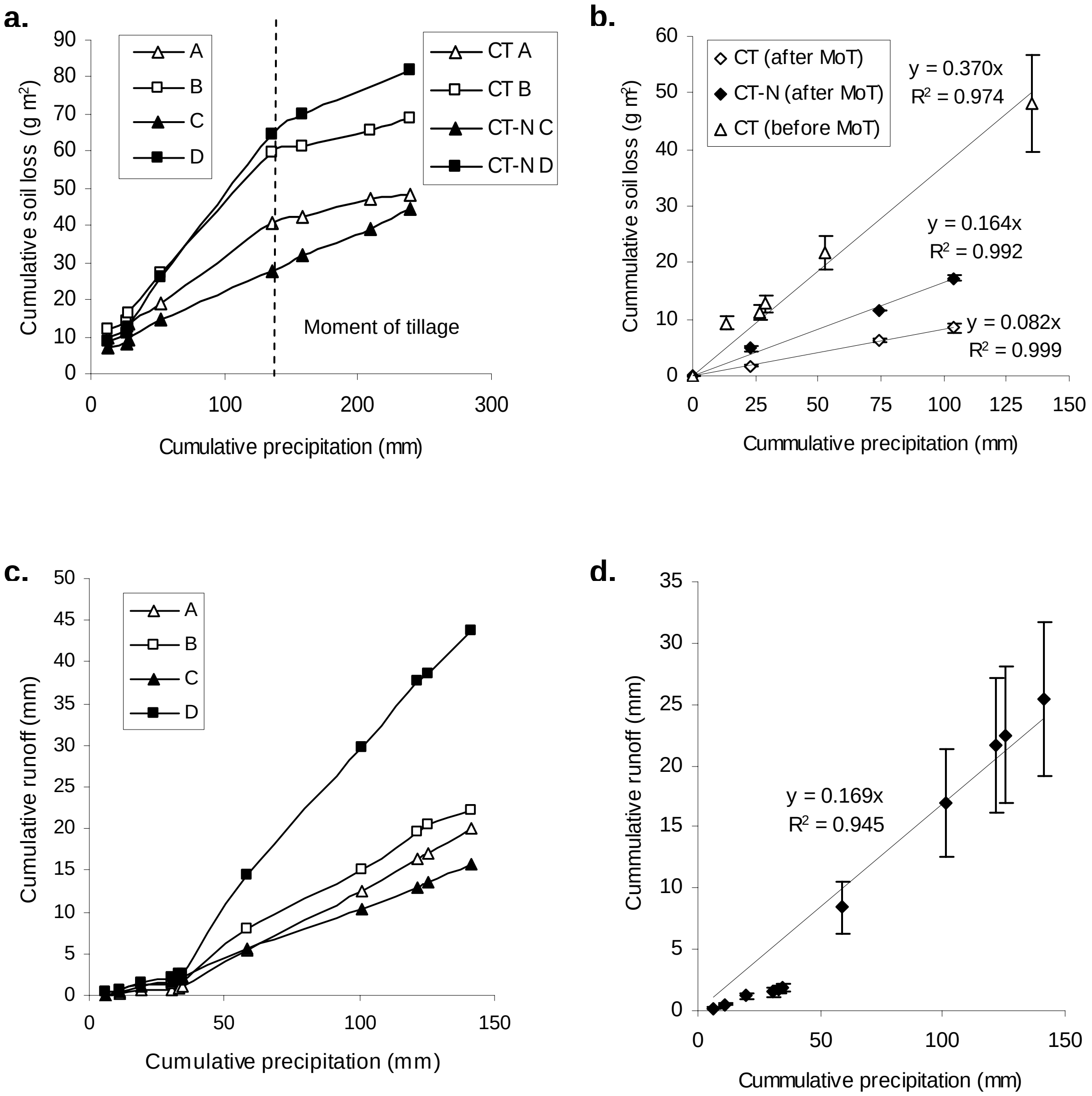


Figure 6.2. a) Relationship between cumulative precipitation and soil loss for four runoff plots (Mascarenhas, Portugal); note that tillage (CT) of plots A and B led to a remarkable reduction of the soil loss rate compared to non-tilled plots C and D where a natural cover crop was allowed to establish (CT-N); b) Idem, aggregated for CT and CT-N plots after the Moment of Tillage (MoT), and for all plots before MoT; c) Relationship between cumulative precipitation and cumulative runoff for the individual runoff plots until the MoT; d) Idem, aggregated for all plots. Vertical bars (b and d) represent standard error of means.

6.3.2. Factor 2: A cover of rock fragments protects the soil and reduces the slope effect on erosion.

Rainfall simulation plots were selected to evaluate the effect of slope. No significant relationship could be found between soil loss and slope gradient. However, there was a very significant correlation (Pearson correlation coefficient 0.415, $P < 0.001$) between slope gradient and rock fragment cover.

This is in agreement with other findings (e.g. Simanton and Toy, 1994; Poesen et al., 1998).

The protective effect of rock fragment cover was investigated using rainfall simulations (runs 2 vs. 4) (n = 12; slope = 24% (SE 3.2%); original rock cover 25% (SE 3.8%)). Runoff, runoff coefficients and soil loss were found to be significantly higher if rock fragments had been removed (Wilcoxon Signed Ranks test, $P < 0.01$; Table 6.2). Cerdà (2001) and Mandal et al. (2005) come to similar conclusions. The TTFR was decreased after removal of the stones, though not significantly. The stones probably create extra surface roughness, increasing the possibilities for ponding, and this effect is stronger than that of raindrops which, if they land on stones, cannot infiltrate.

The fact that steeper slopes tend to have more rock fragment cover, which may or may not be the result of past erosion, could thus explain – at least partly – why slope is not the dramatic factor in causing soil loss that is often projected in results from erosion modelling.

6.3.3. Factor 3: Olive grove undergrowth reduces sediment losses.

The runoff plots in Caggiano, Italy were designed to evaluate the effect of soil cover. The CC-T plot initially showed erosion rates four times higher than in the CC plot (Figure 6.3). However, as the experimental season continued, plant cover gradually increased on the CC-T plot, reaching 20% in December and 80% in February. It was probably this spread of plant cover that led to the disappearance of the difference in erosion between the treatments. This is in agreement with results obtained by Snelder and Bryan (1995), who noted a rapid increase of erosion rates when plant cover was below a critical threshold of 55%. In our study, differences in runoff coefficient were less marked, but seemed to remain higher under CC-T than in CC, even after plant cover had established.

Rainfall simulations showed that plant cover was highly effective in controlling soil loss (Pearson correlation coefficient –0.345, n = 48, $P < 0.05$; see Figure 6.4). Differences in plant cover between fields tilled recently (less than two months previously) and untilled fields were very significant (Table 6.3). Plant cover was significantly correlated with soil moisture content (Pearson correlation coefficient 0.438, n = 43, $P < 0.01$). As measurements started in August and continued up to February, this correlation illustrates the development of vegetation.

If we compare runoff and soil loss from rainfall simulations (run 2) on untilled (n = 31) and tilled (n = 34) soil, we observe a non-significant difference for runoff but a significantly lower amount of eroded sediment on untilled soil (t-test – equal variances not assumed; t = 4.04, df =47.737, $P < 0.001$). Thus, under these conditions, with simulated high intensity rainfall and pre-wetted soil, tillage cannot reduce runoff. However, the average soil loss from tilled (218 g m^{-2}, SE 35 g m^{-2}) versus untilled experiments (61 g m^{-2}, SE 17 g m^{-2}) can be ascribed to difference in plant cover.

Table 6.2: Wilcoxon signed ranks statistics of paired rainfall simulations with and without rock fragments (runs 2 vs. 4, Portuguese research area) (*n* = 12).

	Runoff (l m^{-2})		Runoff coefficient (%)		Soil loss (g m^{-2})		TTFR (s)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
With rock	7.7	1.4	47	8.1	39.0	7.3	36.2	7.6
Without rock	10.9	1.1	69	6.4	70.1	12.6	22.9	5.3
Z	–2.667		–2.667		–2.589		–0.969	
Significance	0.008		0.008		0.010		0.333	

Table 6.3: Mann-Whitney statistics of rainfall simulations (run 2) on tilled and non-tilled soil (Portuguese and Italian research areas).

	Plant cover (%)		Runoff (litre m^{-2})		Runoff coefficient (%)		Soil loss (g m^{-2})		Sediment concentration (g l^{-1})	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Tilled	1	0.4	9.4	0.8	48	4.1	218	35	24.0	5.0
	(*n* = 28)		(*n* = 35)		(*n* = 35)		(*n* = 34)		(*n* = 34)	
Non-tilled	45	8.7	8.0	1.0	44	5.6	61	17	6.7	1.4
	(*n* = 21)		(*n* = 31)		(*n* = 31)		(*n* = 31)		(*n* = 29)	
Z	–5.202		–1.111		–0.657		–3.955		–4.662	
Significance	0.000		0.266		0.511		0.000		0.000	

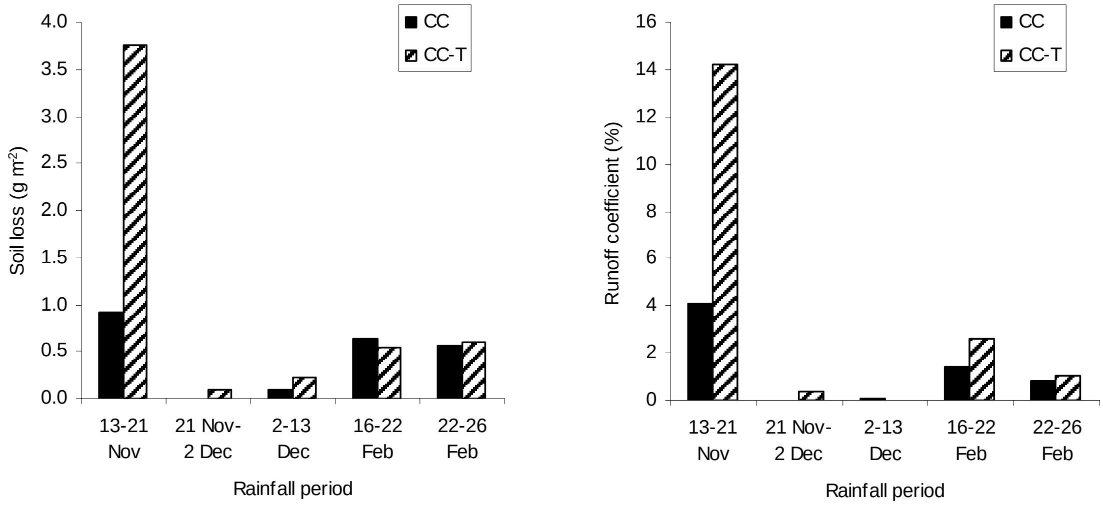


Figure 6.3. Soil loss and runoff coefficients measured at runoff plots under permanent cover (CC) or after a single tillage operation (CC-T), Caggiano, Italy.

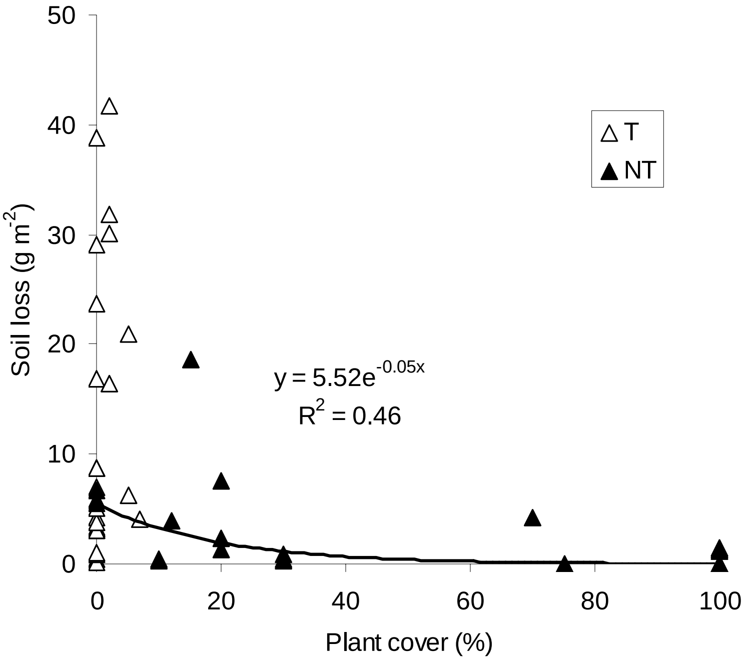


Figure 6.4. Relation between plant cover and soil loss as recorded in rainfall simulations (runs 2, Italian and Portuguese research areas). NT = Non-tilled; T = Tilled microplots.

6.3.4. Factor 4: long term erosion creates an irregular slope that allows local infiltration of runoff.

The slopes in old groves are often made up of a sequence of alternating convex and concave segments (Figure 6.1). At the research site at Ferrandina, Italy, the slopes determined at the transition point from concave to convex (1), the point of maximum convexity (2) and the point of maximum concavity (3) were 11%, 38% and 36% respectively (Table 6.4). The slopes at position 1 were significantly different from those in positions 2 and 3. Rock fragment cover was significantly higher at point 3. Plant cover was high on position 1, high but highly variable in position 2 and low in position 3.

The results from runoff detectors indicated that runoff accumulates along the slope from position 2, through position 3 to position 1, after which it apparently infiltrates (Table 6.4). We expected infiltration to occur earlier, between positions 3 and 1. A possible explanation for this finding is that the flatter parts of the slope at position 1 had previously received large amounts of fine-textured sediments, which formed a dense layer in or on the topsoil (Verspeek, pers. comm.). At position 1, despite the much lower slope gradient, the runoff coefficients were of the same order of magnitude as those observed at positions 2 and 3. However, when the field was tilled, this changed: the runoff coefficient decreased from 46% to 32% (Table 6.4). Tillage did not lead to reductions of the runoff coefficients at positions 2 and 3. On the contrary, no-tillage was beneficial for infiltration at position 3 (runoff coefficient decreased from 47% to 23%). This might be associated with erosion/deposition patterns along the slope.

Table 6.4: Data of runoff detectors and rainfall simulations (all, untilled and tilled) on irregular slopes in Ferrandina.

	Hillslope position		
	1	2	3
Runoff detectors			
Number of registrations	88	6	112
Water depth in detector (cm)	8.7 a	2.0 b	7.9 c
Sediment count of half-full	2	0	5
Sediment count of full	2	0	9
Rainfall simulations			
Number of experiments	10	14	18
Runoff (l m^{-2})	9.4	10.6	10.1
Runoff coefficient (%)	45.9	52.1	47.2
Soil loss (g m^{-2})	98 a	336 b	253 b
Slope (%)	11.3 a	38.4 b	35.8 b
Rock fragment cover (%)	22.7 a	38.3 a	86.7 b
Plant cover (%)	13.5 a	24.3 ab	2.3 b
Untilled			
Number of experiments	8	6	4
Runoff (l m^{-2})	10.1	10.0	8.4
Runoff coefficient (%)	49.4	50.0	23.3
Soil loss (g m^{-2})	107	194	82
Slope (%)	12.8 a	39.1 b	27.2 c
Rock fragment cover (%)	22.7	15.0	–
Plant cover (%)	15.7	45	–
Tilled			
Number of experiments	2	8	13
Runoff (l m^{-2})	6.4	11.0	10.7
Runoff coefficient (%)	31.8	53.6	52.7
Soil loss (g m^{-2})	54	445	304
Slope (%)	5.4 a	37.8 b	38.3 b
Rock fragment cover (%)	–	50.0	86.7
Plant cover (%)	7.0 a	3.5 ab	2.3 b

Values followed by different letters are significantly different at $P < 0.05$ (Bonferroni-adjusted)

The amount of soil loss in rainfall simulations followed a different pattern. Although runoff was considerable at position 1, significantly less soil was eroded here. Possible reasons for this are the gentler slope and crust formation. Tillage at this position increased soil roughness and led to even less soil loss. At position 2, under all circumstances more soil was detached and lost in the rainfall simulations. However, as the runoff detectors at this position captured low amounts of runoff and never filled with sediment, it seems likely that soil loss was transport-limited here. Soil loss at position 3 was importantly influenced by tillage. Runoff detectors at this position were most frequently found to have filled with sediment, from which we infer that most soil is deposited between points 3 and 1, when runoff velocity is reduced. That means that under non-tilled conditions, this position experiences a net outflux of sediment, leaving little erodible soil available. However, soil displacement by tillage is thought to lead to soil accumulation in this position, thereby increasing the availability of erodible soil (Govers et al., 2006).

6.3.5. Factor 5: vegetative strips hamper the formation of rills and gullies.

An important form of erosion in olive groves is rill erosion, but at our microplots (rainfall simulations) and runoff plot scales, this was not observable. However, a field survey of rills carried out in Iznalloz, Spain (Aspizua, 2003) allows us to make some important observations. The survey showed that plant cover at the field scale varied between 5% and 95% (average 47%). Observed soil loss was only weakly correlated with plant cover ($r^2 = 0.18$). Figure 6.5 shows the importance of the distribution of soil cover by plants as influenced by the soil management applied (BAR, COV, VEG). The number of rills observed is significantly different (Kruskall-Wallis, $\chi^2 = 11.6$, 2 df, $P < 0.01$), although differences between individual categories are not. The figure also shows the average length of rills. The differences between treatments are significant (Kruskall-Wallis, $\chi^2 = 8.0$, 2 df, $P < 0.05$). Rills in the VEG treatment are significantly shorter than in the BAR treatment. The resulting differences in average soil loss are also significant (Kruskall-Wallis, $\chi^2 = 10.2$, 2 df, $P < 0.01$). Soil losses in BAR, although highly variable, are much higher than in COV and VEG as a result of the cumulative differences in the number of rills, average rill length and, moreover, the average rill depth and width (not shown). Clearly, vegetative strips are highly effective in controlling soil loss, mainly by reducing the dimensions (especially length) of rills.

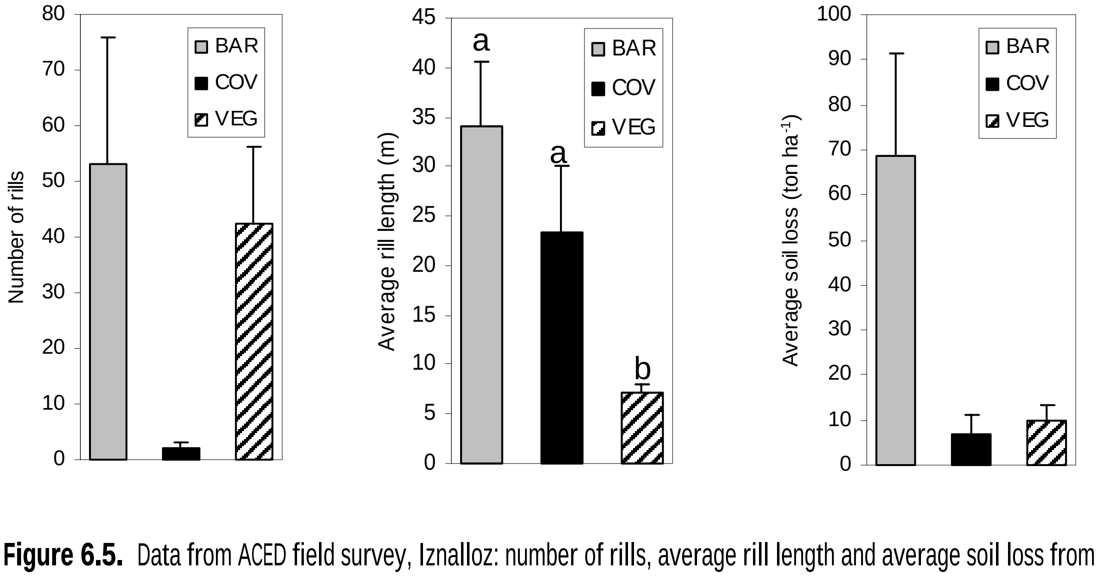


Figure 6.5. Data from ACED field survey, Iznalloz: number of rills, average rill length and average soil loss from rill erosion. Bars indicate standard errors. Different letters indicate statistical significance (Games-Howell, $P <$ 0.05).

6.3.6. Factor 6: erosion mainly results from infrequent high intensity rainfall events.

It should be noted that for all erosion measurements other than simulations, whether or not high intensity long duration events are captured is largely a matter of luck. Our runoff plot results from Mascarenhas, Portugal show that the single most erosive rainfall event that generated eroded sediments that were recorded in isolation accounted for only 10% of total rainfall in the experimental period, but generated 15% of the total quantity of sediment collected. Francia Martínez et al. (2000) report much extremer results: the single most erosive rainstorm (of the 18 recorded) accounted for 46% of the total erosion of a cover crop (CC) treatment, 66% of the total erosion of a no-till (NT) treatment, and 90% of the total erosion of a conventional tillage (CT) treatment. If this event had not been captured, the cumulative erosion for the treatments would only have been 14.4 ton ha^{-1} for NT, 1.8 ton ha^{-1} (13% of NT) for CC and 1.0 ton ha^{-1} (7% of NT) for CT. The conclusions would have been very different than the actual ones of 42.5 ton ha^{-1} for NT, 3.4 ton ha^{-1} (8% of NT) for CC and 10.1 ton ha^{-1} (24% of NT) for CT. Not only would the absolute values have differed by up to a factor 10, but CC would not have been recommended as the best soil conservation method. The implication is that any soil management option can only be recommended unequivocally after it has been shown to perform well under extreme conditions.

3.7. Factor 7: the upscaling of experimental results leads to overestimated erosion.

Extrapolating the results from experimental erosion research to larger areas is a very precarious process. We have reported results from rainfall simulations, runoff plots and visual erosion assessment (ACED) fields. The spatial scales ranged from 6.25 10^{-2} m^2, via 114 m^2 and 225 m^2 (runoff plots) to 2500 m^2. The temporal scales in the same order of magnitude should be expressed in minutes, days and months. To be able to compare the results, we should express them in the same units, e.g. g m^{-2} mm^{-1} rainfall (actual or simulated). In addition, we assume that the symptoms of erosion observed in ACED plots were created in one year or less. To be on the safe side, we left out three fields where gullies (rills deeper than 25 cm) were recorded. Aggregating all measurements, it can be concluded that methods at different scales lead to significantly different results (Welch F-asymptotical 36.1, df1:3, df2: 59.5, $P <$ 0.001). The distribution of data differs per method (Figure 6.6): for example, the data from rainfall simulations contain outliers and extreme values and the data from ACED fields are very scattered. Whereas rainfall simulations measure interrill erosion, runoff plots measure rill- and interrill erosion, and ACED fields measure only rill erosion, it is rather striking that the method capable of measuring both types of erosion led to the lowest estimates. One reason is that the rainfall intensity was very high in the rainfall simulation experiments but the rainfall intensity captured during the duration of runoff experiments was fairly low.

That further upscaling (to ACED fields) produces a jump in soil loss estimates might be caused by the fact that this method does not consider relocation of sediment within the field. This problem, which is inherent to many methods (see for instance the previously mentioned example of Theocharopoulos et al. 2003), suggests the need to verify erosion estimates at the outlet of the catchment or subcatchment – especially if the erosion estimates are to be used to assess potential off-site effects.

Assuming annual rainfall of 1000 mm (higher than in any of the research sites), the average soil loss from our experiments would be 4.4, 3.3, 0.2 and 44 ton ha^{-1} yr^{-1} respectively for rainfall simulations, two types of runoff plots and ACED field assessment. Median soil loss in the same order would be much lower at 2.2, 2.3, 0.1 and 13 ton ha^{-1} yr^{-1}, respectively. Given that soil losses from ACED fields are probably overestimated, the erosion rates in our study are far below the average values of 40 – 100 ton ha^{-1} yr^{-1} derived from simulation modelling studies. However, only small soil losses are tolerable on steep slopes with shallow soils, and if they exceed 1 ton ha^{-1} yr^{-1} they could be considered irreversible within a time span of 50 – 100 years (Van-Camp et al., 2004).

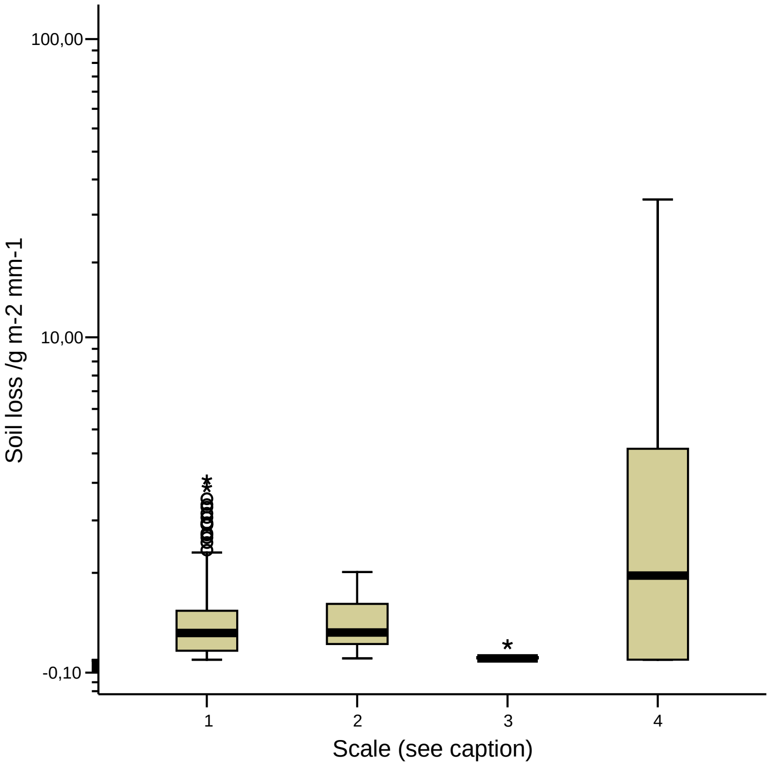


Figure 6.6. Box plot of soil loss as a function of experiment (1 = rainfall simulations, *n* = 160; 2 = runoff plots Portugal, *n* = 32; 3 = runoff plots Italy, *n* = 10; 4 = ACED fields, *n* = 25). Different letters indicate significant difference ($P < 0.05$).

6.3. Conclusions

Our findings demonstrate that slope is a less important factor in determining soil erosion in olive groves than it appears to be from model studies. A first reason for this could be rock fragment cover. There are more rock fragments on steeper groves; they protect the soil from the erosive impact of raindrops and reduce the speed of overland flow. A second reason is that in olive groves on steep slopes, natural terraces tend to form, with the result that the steep hillside is not a continuous slope but a sequence of sections, with zones of runoff generation and erosion alternating with zones of infiltration and sedimentation.

A second conclusion is that tillage is not inevitably an adverse soil management strategy. We have shown that under low intensity rainfall conditions and not too steep slopes, tilled fields allow more infiltration and lead to less runoff and erosion. Second, in fields tilled at the appropriate moment, natural plant cover may develop quickly and so by the time the winter rains start (contributing 30–40 % of total average annual precipitation in the areas we studied), the field is well protected against erosion. The period in which the field remains bare or sparsely covered is short.

This leads to three recommendations:

1. Given that tillage can be a useful practice in controlling erosion, it should be applied judiciously in designated zones, i.e. at the point of transition from convexity to concavity in non-uniform slopes, to enhance infiltration.
2. Although the use of cover crops is widely advocated because of their efficacy under normal circumstances, in order to assess their real benefit research should be done on their capacity for soil conservation under extreme conditions as most of the erosion in Mediterranean environments is caused by infrequent high intensity rainstorms.
3. Additionally, soil management options should be evaluated on aspects other than erosion. Their effects on the olive grove’s water balance and olive tree productivity should be assessed simultaneously. Other issues, such as reduction of wildfire risk by tillage and biodiversity conservation by means of natural plant cover also need to be integrated into the assessment.

Chapter 7

Olive production systems on sloping land: prospects and scenarios

de Graaff J, Duran Zuazo VH, Jones N, and Fleskens L.
Journal of Environmental Management (accepted)

7. Olive production systems on sloping land: prospects and scenarios

Abstract

The ultimate objective of the EU Olivero project was to improve the quality of life of the rural population and to assure the sustainable use of the natural resources of land and water in the sloping and mountainous olive production systems (SMOPS) areas in Southern Europe. One specific objective was to develop, with end-users, alternative future scenarios for olive orchards in the five Olivero target areas. This chapter discusses the development of these scenarios, and their socio-economic and environmental effects. After presenting the different production systems (SMOPS) and their strengths, weaknesses, opportunities and threats, a general overview is given of the medium- and long-term prospects. These have been validated by experts from the olive sector and foresee changes towards abandonment, intensification and organic production. On balance, the changes could lead to lower production of some target areas in future. An analysis of major external factors affecting the future development of SMOPS indicates there will be labour shortages and increased wage rates, reduced subsidies and constant or rising olive oil prices. On the basis of these assumptions, four future scenarios are developed for the five target areas, with the help of a Linear Programming simulation model. The results are presented for two target areas. For the Trás-os-Montes target area in Portugal, three of the four tested scenarios point to a high level of abandonment, while in the most positive scenario the areas under semi-intensive low input and organic SMOPS increase. In the Granada and Jaen target area in Spain, all scenarios hint at intensification, and only the orchards on the steepest slopes are likely to be abandoned. The direction and extent of environmental effects (erosion, fire risk, pollution, water use and biodiversity) differ per scenario, as do the extent of cross-compliance and agri-environmental measures.

7.1. Introduction

The cultivation of olive trees in the Mediterranean basin goes back to ancient times. Most of the plantations are rainfed and occupy extensive hilly and mountainous areas that are susceptible to water erosion (Gomez et al., 2003; Francia Martínez et al., 2006). Nevertheless, olive farming constitutes a major source of employment in the Mediterranean rural areas. Therefore the ultimate objective of the EU Olivero project (2003–2006) was to improve both the quality of life of the rural population and the use of the natural resources land

and water in the sloping and mountainous areas in Southern Europe currently under olive orchards.

Based on an inventory of olive orchard areas, with their socio-economic and ecological functions (Metzidakis, 2004), different types of Sloping and Mountainous Olive Production Systems (SMOPS) were distinguished in each of the five target areas. A SMOPS type constitutes a more or less homogenous olive plantation on the sloping land of specialised or mixed farms. It is possible for more than one SMOPS type to be represented on one farm. Following detailed physical, agronomic and socio-economic research (Xiloyannis et al., 2004; Stroosnijder et al., 2007) and in conjunction with end-users, the project team assessed the outlook for these different systems.

This chapter discusses the development of the prospects and alternative scenarios with their socio-economic and environmental implications. After presenting the different SMOPS types, with their strengths, weaknesses, opportunities and threats, a general overview is given of their medium and long-term prospects. Thereafter some of the major external factors that affect the future development of these SMOPS are analysed and on the basis of this analysis, four future scenarios are developed with the help of a Linear Programming simulation model. The four alternative scenarios are presented for two of the five target areas, indicating the major trends in terms of SMOPS changes and abandonment. Subsequently the socio-economic and environmental implications are shown, and some conclusions are drawn.

7.2. The performance of olive production systems on sloping land

7.2.1 SMOPS by target area

Initially, four to six SMOPS types were identified in the target areas. These were reduced to four general types (Table 7.1). A cluster analysis was then undertaken using 32 variables, the most dominant ones of which related to cropping intensity. The analysis revealed that the largest category (the semi-intensive olive orchards) could better be split into two categories on the basis of low and high use of inputs (Fleskens, 2005; 2007).

7.2.2 SMOPS: strengths, weaknesses, opportunities and threats

The internal factors influencing the development of SMOPS were assessed using the SWOT methodology (Strengths, Weaknesses, Opportunities, Threats), in relation to the functions of the orchards (productive, ecological, economic and social). In each target area primary stakeholders participated in a SWOT analysis. The most important weaknesses and threats were considered as key issues; problem trees were drawn up for these issues, in order to analyse the best solutions and to find which opportunities were feasible. The detailed results of the SWOT analysis are discussed in Brouwer (2005) and de Graaff (2005). The general key issues and opportunities are shown in Table 7.2.

The detailed analysis showed that the internal factors influencing olive cultivation on sloping and mountainous land vary considerably within and between the five SMOPS categories and five target areas (de Graaff, 2005). However, some general conclusions could be drawn (Table 7.2). It was found that low productivity, lack of a successor and abandonment are major problems for the traditional and semi-intensive low-input orchards, and that soil erosion and pest control are important issues in semi-intensive high-input and intensive SMOPS. All the orchard types present opportunities for the improvement of their productive, ecological, economic and social functions.

Table 7.1: Occurrence of different types of SMOPS, by target area.

SMOPS types	Target areas					
	W. Crete Greece	Basilicata Italy[a]	Cordoba[b] Spain	Granada & Jaen Spain	Trás-os-Montes Portugal	All Areas
	Number of types occurring:					
Traditional	1	1	3[b]	1	2[c]	8
Semi-intensive:						
Low input	1	1		2	1	5
High input		1	1[b]	1	1	4
Intensive (irrigated)	1	1		1		3
Organic	1	2[d]	1[b]		1	5
Total by target area:	4	6	5	5	5	25

[a] Also including Salerno area in Campania province;
[b] In Cordoba the focus was on organic farms;
[c] One local type in process of abandonment;
[d] Including "integrated protection" and organic

Table 7.2: Summary of general key issues and opportunities, by type of SMOPS.

SMOPS type	General key issues	General opportunities
1. Traditional	No successor / abandonment Low productivity / quality Soil erosion & wildfire risk Weak marketing	Promotion of cultural heritage Agro-eco-tourism (parks) Agri-environmental support Organic cultivation
2. Semi-intensive, low input	Labour shortage / costs Low productivity Wildfire / other constraints High age; no successor	Intensification / mechanisation Farm expansion Better infrastructure / regulation
3. Semi-intensive, high input	Pests & diseases Soil erosion Marketing & social networks	Farm consolidation + irrigation Soil & water conservation Improving rural infrastructure
4. Intensive (irrigated)	Excessive use of water Water pollution by chemicals Soil erosion	Improved irrigation systems Integrated Pest Management (IPM) Soil & water conservation
5. Organic	Marketing Reduced productivity Pest and diseases	Promotion of organic products Higher price / eco-tourism Organic & IPM subsidies

7.2.3 Production costs

Following a review of the financial farm management (Duarte, 2005) a detailed analysis was undertaken of the production costs of the different types of SMOPS in the respective project target areas (Fleskens, 2005). Table 7.3 shows the major performance indicators of the SMOPS. The net return excludes subsidies (see Section 7.4.3). It should be realised that these calculations are based on average prices and costs, which do not reflect the wide variability between sub-regions, farm size, soil type, olive variety, etc.

It can be seen from Table 7.3 that all traditional SMOPS have a negative net return, which is not compensated for by the production subsidy in 2004 (0.90–1.30 € L^{-1}). The two types of semi-intensive SMOPS give a rather mixed picture: some are financially attractive even without the production subsidies, but most have a negative net return, which the production subsidy barely covers. The intensive SMOPS have only a small negative return, while the organic plantations, which benefit from slightly higher prices and special subsidies, show either small or large negative net returns.

Table 7.3: Performance indicators of different types of SMOPS, by target area[a].

SMOPS Type	Indicators	Target area				
		West-Crete	Basilicata & Salerno	Cordoba	Granada & Jaen	Trás-os-Montes
Traditional	Trees per ha	70	100	135	122	100
	Yield: kg ha^{-1}	1850	2100	910	1500	1100
	Production costs: € L^{-1}	3.21	4.71	5.03	4.00	4.14
	Net Return € L^{-1}	- 0.71	- 1.21	- 2.38	- 1.28	- 1.88
Semi-intensive Low input [b]	Trees per ha	130	125		107 / 114	200
	Yield: kg ha^{-1}	3937	2700		2000/2500	2250
	Production costs: € L^{-1}	3.11	5.18		2.84 / 2.35	2.99
	Net Return € L^{-1}	- 0.51	- 1.38		- 0.12 /0.37	- 0.73
Semi-intensive High input [c]	Trees per ha		200	128	110	280
	Yield: kg ha^{-1}		3600	3968	4000	4250
	Production costs: € L^{-1}		5.86	1.51	2.28	0.50 [c]
	Net Return: € L^{-1}		- 1.66	1.14	0.43	- 0.10
Intensive	Trees per ha	250	250		175	
	Yield: kg ha^{-1}	6500	3200		4500	
	Production costs: € L^{-1}	2.90	4.67		1.75	
	Net Return: € L^{-1}	- 0.20	- 0.17		0.97	
Organic [d]	Trees per ha	170	varies	136		100
	Yield: kg ha^{-1}	4800	3000	1088		900
	Production costs: € L^{-1}	3.53	5.79	4.20		4.46
	Net Return: € L^{-1}	- 0.23	-1.29	- 1.55		-2.20

[a] Situation in 2004; all labour valued at market wage rate, and net return excludes subsidies;
[b] Two SMOPS in Granada–Jaen area;
[c] Table olive production system in Trás-os-Montes area: the production costs are expressed in € kg^{-1} olives, while the price was 0.40 € kg $^{-1}$;
[d] No price differential considered.

7.3. Prospects for olive production systems on sloping land

7.3.1 Prospects for SMOPS

On the basis of the SWOT analysis, selected key issues, further discussions with stakeholders and the physical and financial analysis, the prospects for the respective SMOPS were drawn up for the medium (2010) and the long term (2030). They are discussed briefly below.

Traditional SMOPS

For traditional SMOPS, discussed in Duarte et al. (2007), with their small orchards, old trees, low density (100 trees ha^{-1}), low productivity, lack of successors, remoteness and limited market orientation, there is a high risk of abandonment, particularly if subsidies are reduced. This will make them even more vulnerable to wildfire, and subsequently to soil erosion.

In the medium term some improvements could be made with regard to pruning, semi-mechanised harvesting, better fertilisation and phyto-sanitary treatments. In the long term, abandonment could be reduced by improving local living conditions and marketing, by combining olive cultivation with other activities (e.g. livestock, agro-tourism) and/or by improving prices following a change towards organic production and PDO (Protected Designation of Origin) labelling.

Semi-intensive, low input, SMOPS

The semi-intensive orchards are discussed in Xiloyannis et al. (2007). The low input type also has old trees, a relative low density (120 trees ha^{-1}) and a low productivity, and because of labour scarcity is already making more use of mechanisation. The use of fertilisers, pest and disease control, and soil and water conservation measures is still restricted.

In the medium term it will be important to give more emphasis to better pruning, increased mechanisation and to extension and training, in particular to young farmers. The intensification and expansion of this type of SMOPS will be hampered by their low profitability in the past, which in the coming period will result in relatively low fixed subsidy payments (see under EU policy changes below). It could move towards organic farming and benefit from better prices and other subsidies.

Improvements that could help overcome the present negative prospects are to increase the area under olives (retaining the semi-intensive cultivation) by acquiring small neighbouring plantations that are being abandoned, and to introduce irrigation. This will require financial support (grants for farm consolidation).

Semi-intensive, high input SMOPS

This high-input type generally consists of plantations with a medium plant density (150 trees ha^{-1}), and more intensive management. Despite the steep slopes, much tillage is applied and trees receive adequate fertilisation. Productivity is therefore reasonable, but there are problems with erosion, pest and diseases, and with marketing. Pruning is done annually, and because of the slope and small size of the orchards, the harvesting is still often manual.

Sometimes irrigation is applied; in the Portuguese target area the focus is on table olives.

In the medium term, efforts should focus on stabilising production, by controlling pests and diseases and reducing soil erosion. In the long term, improvements to water infrastructure (e.g. small dams) may increase irrigation. Specialised extension support may reduce pest and diseases (e.g. Integrated Pest Management: IPM) and improve erosion control, through vegetative strips, cover crops, compost, etc. Mechanisation may reduce the costs of pruning and harvesting.

Another important strategy may be to promote the gradual expansion of these orchards, by acquiring and upgrading otherwise abandoned traditional plantations.

Intensive SMOPS

This type of SMOPS, discussed by Metzidakis et al. (2007), consists mainly of relatively young plantations, with high density (over 200 trees ha^{-1}), drip irrigation and a high degree of fertilisation and mechanisation, resulting in highly productive olive orchards. However, because of the relatively high soil moisture, low biodiversity and high productivity, the trees are very prone to pests and diseases. As a result of the heavy applications of agro-chemicals there is soil degradation and water pollution. And the often intensive and inappropriate tillage (clean weeding) reduces soil organic matter content, promotes soil erosion and increases the risk of flooding. Another negative effect of this system might be the depletion of aquifers and salinisation problems as a result of irrigation practices.

In the medium term there should be more focus on a balanced fertilisation, pest management (e.g. IPM), appropriate tillage and soil and water conservation measures. In the long term, a better organisation of processing (including bottling) and marketing, including labelling, may contribute to overall higher returns, in order to compete successfully with orchards in the plains.

Organic SMOPS

In most countries, organic olive production, discussed by Gomez et al. (2007), accounts for only a minor share of total production, but this share is increasing every year. Since both old traditional and recently established plantations have become involved in organic farming, this SMOPS is rather heterogeneous in terms of age, farm size, productivity, etc.

In general, organic farmers find that production levels are rather low, although better prices may compensate for this. Management is hampered among other things by having to find adequate and not too costly organic inputs. Orchards often do not receive enough compost and manure and are not sufficiently protected against pests and diseases. In some areas, where olive farming is combined with livestock, grazing controls weeds. While the traditional organic SMOPS have a very positive environmental impact (e.g. biodiversity, landscape value), this is less so for the more recent plantations.

In the medium term, farmers should receive more information about new technologies and adequate inputs, and in both the medium and long term much attention should be given to increasing consumer awareness of and confidence in organic olive oil.

7.3.2 Expert views on prospects for SMOPS

Thirty-four experts from the olive sector in the respective target areas were surveyed to ascertain their views of the prospects for the different SMOPS. They were asked to fill in a form, indicating the type and extent of changes they anticipated in the medium and long term, and the activities and policies that would be required to accommodate these changes.

In the medium term, the experts assume that about half of the SMOPS will not change, that some 15 % of the traditional SMOPS will be abandoned, and that other SMOPS may to some extent turn into more intensive or organic orchards. Table 7.4 shows that the experts foresee many changes in SMOPS in the long-term (by 2030). The calculations used the estimated area under each SMOPS type (Stroosnijder et al., 2007). The experts believe that by 2030 many (almost 30 %) traditional orchards will have been abandoned, and that many semi-intensive and intensive SMOPS will either have intensified or have switched to organic production. The change towards organic production may be exaggerated, since this was emphasised by experts in the Granada–Jaen target area, which is considerably larger than the other areas.

There are some differences in expert opinions between the target areas. In Trás-os-Montes, Basilicata and Cordoba, experts fear considerable abandonment, while their counterparts in Granada–Jaen expect a trend towards organic production and those on Crete expect a further intensification.

On the basis of the experts' opinions about future changes of SMOPS, it can be anticipated that there will be considerable decreases of production in Basilicata, Trás-os-Montes and Cordoba, a slight decrease in West Crete, and an overall decrease of 7%. Production in Granada and Jaen would remain unchanged. Calculations are provided in Fleskens and de Graaff (2006). This estimation does not take into account technological improvements and expansion of SMOPS, but it indicates that experts fear that production may decline in most of these sloping and mountainous target areas.

Table 7.4: Changes of present types of SMOPS (% area) in the long term, according to experts.

SMOPS types	Abandon-ment	Natural Park	Less intensive	Continu-ation	Expansion	Organic Production	Intensi-fication	Other
Traditional	29	2	9	21	0	11	4	14
Semi-int. low	7	0	8	15	1	36	16	16
Semi-int. high	15	0	10	50	1	3	19	2
Intensive	0	3	2	37	13	24	18	2
Organic	22	0	12	49	1	0	16	0
All SMOPS	12	2	8	26	3	23	15	11

7.3.3 Possible interventions to bolster prospects: the experts' view

The extent of changes will depend on internal and external factors – particularly on the type of interventions by farmers and on the amount of support available in the future. The experts mentioned several interventions for each type of change. These were classified as:

a) Agronomic measures, such as: interplanting new trees, using drip irrigation, planting cover crops, mulching, more effective fertilisation and pest control.
b) Physical environmental measures, including corridors for wildfire protection, afforestation, and a wide range of erosion control (EC) measures (e.g. preservation of terraces, vegetative strips),
c) Policy measures: the agri-environmental measures (AEM), different types of credit (e.g. for purchasing abandoned orchards), public rural facilities, infrastructural development (e.g. access roads), measures to improve marketing and prices (e.g. with PDO labelling) and activities to promote tourism.

The public management of abandoned plantations, interplanting of forest trees and fire corridors are among the measures suggested by the olive sector experts. If former olive-growing areas are turned into nature parks, the emphasis should be on preserving biodiversity, on local products and on promoting tourism.

The experts also suggested making the market for land market more dynamic, in order to allow remaining orchards to expand. All these interventions require more extension training, research and development (R&D), rural facilities, marketing services and a lower certification cost for organic olive oil. For intensive plantations they recommend setting cross-compliance criteria with regard to the use of water and agro-chemicals.

7.4. External factors affecting the development of SMOPS

During the group interviews for the SWOT analysis, the farmers as primary stakeholders also indicated the most common external factors affecting the future development of SMOPS. They emphasised the following five factors, which are further investigated in this section:

1. The great climatic variability;
2. The reduced accessibility in these sloping and mountainous areas;
3. The demographic situation as a result of migration, etc.
4. The fear of adverse changes in EU policies
5. The market price for olive oil

7.4.1 Climatic factors

In the past decade there have been many studies on the effects of long-term climate change on land use. Rounsevell (1999) found that climate change will have important effects (by 2050), but that there are many interrelated factors influencing land use changes. Schröter et al. (2005) show that decreasing precipitation in southern Europe will affect land use, but that socio-economic factors may have a greater effect on land use than climatic drivers. It remains difficult to predict the effects of medium- and long-term climate change on future land use.

The influence of annual, or short-term, climatic variability can be assessed on the basis of historical climate and production data. The annual variability is larger in the countries with drier olive production areas (e.g. Tunisia, Spain and Syria), where coefficients of variation area as high as 35–58 % (FAO, 2006). Fortunately, the climatic conditions in the Mediterranean basin are such that bad rainfall years in one part of the basin are often compensated by better years in other areas. In the year in which world olive production peaked (2003), the only bumper crops were in Spain and Tunisia. Annual climatic variability has therefore not yet dramatically influenced prices (or consumption).

Annual variability of rainfall and production is a factor that cannot be influenced, and can only be mitigated by having adequate irrigation infrastructure, in order to secure water for the long dry summer period. Since the latter would require detailed local water supply studies, the climate factor was not considered in this scenario study.

7.4.2 Accessibility and demographic factors

Many of the SMOPS, and in particular the traditional one, are located in rather remote and sparsely populated mountainous areas, making it difficult to market and transport inputs and olive oil. Unless there are options for alternative income-earning activities, such as tourism and certain industries, countries are unlikely to invest much in roads and rural facilities in such areas.

Most of the project target areas currently have a population density of 40–70 persons per km^2, but in the more mountainous zones the density is only 25–50 persons per km^2. While the overall annual population growth in 1991–2001 was still positive in Spain and in Portugal thanks to immigration, projections for 2050 show a declining population in all the four countries (FAO, 2006). In the project target areas the population growth has been negative for some time: it ranged between - 2 % and - 8 % in the period 1991–2001 (de Graaff, 2005).

As elsewhere in Europe, the population in the four countries is ageing rapidly. While in 1950 only 7–8 % of the population was over 65 years of age, this is expected to reach about 36 % by 2050. In agriculture the situation is worse, and the four countries have on average the oldest farmers in Europe. In 2001 more than 30 % of farmers in these four countries were over 65 years of age (FAO, 2006). In the project target areas the situation is even more pronounced. But only if the agricultural sector is viable will younger people remain in these rural areas. In Trás-os-Montes area, for example, 21 % of employment is in agriculture, compared with 10 % at national level (Metzidakis, 2004).

Given that population density is already rather low, that in most target areas the population is decreasing and that the average age of farmers is very high, one can expect that labour will become scarcer in these areas in the next 25 years, unless major new road and development projects are initiated. In all cases this will have the effect of increasing wage rates.

7.4.3 EU policy changes

Under the previous Common Agricultural Policies (CAP) olive oil subsidy regime, eligibility was based on the amount of olive oil produced (EU, 2003). The consequences included:

- EU Olive oil production increased on average by 5% per year in the 1990s, compared with only 0.6 % in the 1980s.
- Intensification of production had negative environmental effects (e.g. erosion, decreased biodiversity, high water use and pollution).
- The large farms on flat land with intensive production systems benefited from much higher support than traditional SMOPS (Beaufoy, 2001), so there was little social impact.
- Within most SMOPS little attention is paid to environmental issues, which are only addressed through additional subsidies (e.g. agri-environmental measures).
- All SMOPS have become dependent on subsidies.
- Traditional SMOPS often show negative returns, even with production aid.

These farmers apparently accept a low opportunity cost of labour. The changes announced in the CAP since 1997 have clearly created a sense of insecurity amongst farmers, who fear they will get fewer subsidies in the future. In 2004 the Single Payment Scheme (SPS) or “Decoupled Aid” was introduced, whereby at least 60 % or more of entitlements received during the four-year reference period 2000–2003, is to be paid directly to farmers, with the remainder to be used as national envelopes for social and environmental purposes (EU, 2005). However, under pressure from the farming lobby, the olive-producing countries opted for a high level of decoupling of 90 % and more. In countries where traditional orchards predominate (e.g. Portugal), another reason for this was that the financial transfer from high- to low-productive orchards cannot be very significant.

The SPS in force from 2006–2013 will probably have the following effects:

- “Decoupled aid” will not stimulate intensification as much as its predecessor “Production aid”. Thus production will increase less than in the 1990s.

- It will still benefit most the high-producing farms on flat land and the intensive SMOPS which intensified in time (before 2000).
- Traditional and Low input Semi-intensive SMOPS will receive rather low subsidies in SPS (up to 2013), and will therefore be unable to invest much in orchard improvements (including environmental measures).
- The more intensive SMOPS, with guaranteed SPS income in coming years, may switch their attention and labour use to other farm activities.

The special national envelopes could have had various social and environmental benefits: e.g. helping avoid unemployment in remote areas, olive orchard abandonment, excessive water use and pollution and landscape destruction. These can now only be achieved through the, now obligatory, cross-compliance requirements and the agri-environmental measures (AEM: Duarte et al., 2007).

7.4.4 The olive oil market

Olive oil is more expensive than other oils because olive trees take a long time to mature, the harvesting costs are high and advanced technology is required for processing. In the period 1999–2001 the producer price for high quality olive oil (virgin) was about 2 US$ kg^{-1}, while the price for palm, groundnut and sunflower oils was no more than about 0.5 US$ kg^{-1} (UNCTAD, 2006).

The area under olives in the world increased from about 8.1 million ha in 1981 to 10.7 million ha in 2004. As a result, world production increased from about 1.8 million MT in the early 1990s to about 2.8 million MT in the early 2000s (FAO, 2006). In the meantime, consumption increased at a similar pace, among others thanks to the vigorous marketing campaigns for olive oil.

Figure 7.1 shows the world production and consumption over the period 1991–2005. It shows that since the end of the 1990s, olive oil production in the EU has exceeded EU consumption, whereas the reverse is true for areas outside the EU.

It may turn out that the change in subsidy regime in the EU will slow down the production increase, and in that case have a certain effect on prices. The four EU olive- producing countries involved in the project still dominate the market to such extent that in the medium term other producers are unlikely to fill a shortfall in production. The greatest increases in production and exports are likely to come from Spain, Tunisia, Morocco, Turkey and Syria, although there are also many newcomers on the market, such as Argentina and Australia (Mili and Zúñiga, 2001).

The analysis of the only long-term producer price series for olives, provided by FAO (2006), indicates that for the period 1990–2003 there was an increase in prices in 1994–1996 in Spain and Portugal, as a result of the low production. In Italy, prices were highest in 1996 and have fallen slightly since, while in Greece, prices rose gradually, peaking in 2001 and 2002. According to the IOOC (2006) the prices of olive oil in the period 2002–2004 were around 2.3–2.6 € kg^{-1} (in Italy higher), but in 2005, after a 13 % decrease of production compared to 2004, there was a sharp rise to about 3.7 € kg^{-1}. This would indicate a high price elasticity, which may also be affected by a lack of real substitutes. With a slow-down of production increases in the medium and long term, due to the revised subsidy scheme, the prices are more likely to rise than to fall.

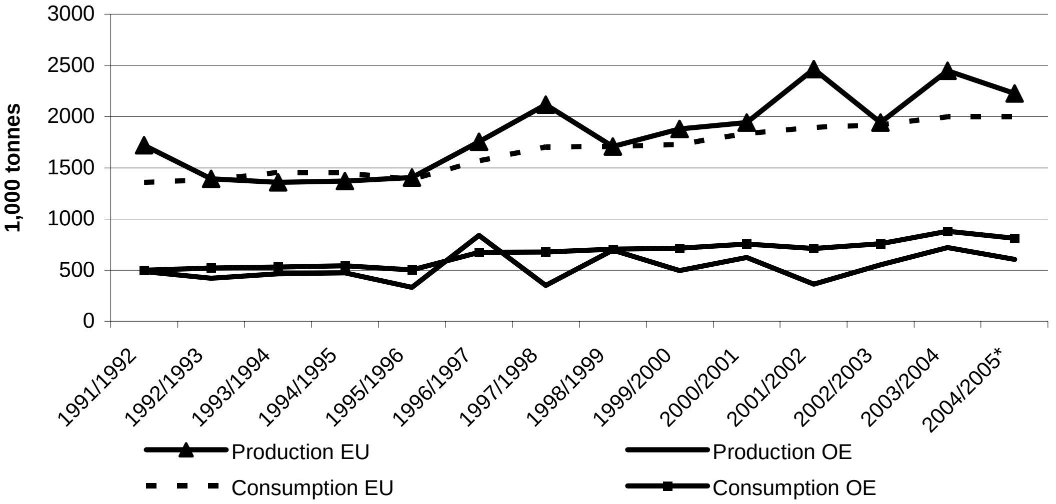


Figure 7.1. World olive oil production and consumption (1000 MT).
Legend: * - Provisional figures; EU – European Union; OE – Outside Europe
Source: IOOC, 2006.

7.5. Future scenarios according to the linear programming simulation model

7.5.1 Alternative scenarios

The analysis of external factors in Section 7.4 was used to develop several alternative scenarios. The climatic variability was not considered, and the reduced accessibility was linked to the demographic and labour force trends, with their effects on wage rates. These were considered to remain constant or to increase at 2 % per year. The EU policy changes are assumed to lead to subsidy reductions after 2013 of either 2 % per year (moderate) or 4 % per year (strong). And market prices are assumed to remain constant or to increase by 2 % per year.

Of the eight possible different combinations, four options were selected and given appropriate names (Table 7.5).

Table 7.5: Scenario options on the basis of future annual percentage changes in subsidies (as from 2013), wage rates and olive oil prices.

Scenario	Reduction of subsidies		Wage rates		Olive oil prices	
		Yearly		Yearly		Yearly
A. Stable	Moderate	- 2 %	Constant		Constant	
B. Bright	Moderate	- 2 %	Constant		Increasing	+ 2 %
C. Doom	Strong	- 4 %	Increasing	+ 2 %	Constant	
D. Bleak	Strong	- 4 %	Increasing	+ 2 %	Increasing	+ 2 %

7.5.2 The simulation model

Using GAMS (Brooke et al., 1998), a linear programming simulation model was developed to assess the various socio-economic and environmental effects of changes from one type of SMOPS to another, including abandonment. While aiming at the highest possible annual net returns from olive production over the period 2005–2030, the model includes no less than 35 constraints, such as constant total area, limited family labour and hired labour supply, minimum return to labour (varying per target area, from 4.50 to 6.80 € h^{-1}), annual amount of finance for investment, time lap for production changes, subsidy levels, annual budget for agri-environmental measures, etc. For convenience, the model consists of a hypothetical area of 10 units (ha or 1000s of ha), at the start showing the 2005 distribution of SMOPS as existing in the respective target areas. The influencing variables are the level of subsidies after 2013, the labour cost and olive oil prices. The model includes various environmental indicators affected by the changes to the SMOPS, such as soil loss, wildfire risk, biodiversity, pollution and water use. Some are expressed in physical units and others on the basis of index values (Table 7.8).

The model was run for all five target areas. Details on the model and its results are presented in Fleskens and de Graaff (2006).

7.5.3 Effects of scenarios on SMOPS distribution

Based on the different structural features and production costs of the SMOPS, the model reallocates the olive orchard area, both by abandonment and change, to other SMOPS.

Table 7.6 gives an example of changes that are likely to take place between 2005–2030 under the four scenarios in the Trás-os-Montes region in Portugal. It is important to note that olive oil yields in this region are relatively low, among other reasons due to the shallow soils and to the rather low oil content of about 16–18 % (Castro et al., 1997).

Table 7.6 shows first, under A, the likely changes, assuming that farmers want to obtain a return to labour at least equal to actual wage rates. This assumption is released under B. The first part (A) shows that only under the Bright market scenario is the minimum return to labour achieved, with the best option being the semi-intensive low input system (PT2). Under the other scenarios, an extremely high abandonment (PT0) is projected (80 % or more). In the Doom market scenario, when low subsidies and low olive oil prices are coupled with high labour prices, there will even be total (100%) abandonment. These very pessimistic projections are due to the minimum return to labour constraint.

Part B in Table 7.6 shows the results of the analysis if this constraint is relaxed, assuming that farmers do not mind receiving a low return for their own labour. In the present situation (2005), this is in fact on average already the case. Under that assumption, abandonment remains important (20–30 %) for all but the Bright market scenario. Under the Stable and Doom scenarios, some of the traditional orchards will become organic orchards; in the Bright scenario, the traditional orchards will change into the intensive orchards and in the Bleak scenario they will change into semi-intensive low-input orchards.

Though the various scenarios show quite different results for the Trás-os-Montes area, this is less the case in the Granada–Jaen area (Table 7.7). In this table the minimum return to labour constraint is retained: farmers in Granada–Jaen generally have a return to labour exceeding the wage rate. Intensification is a common trend in all four scenarios, and there is not much abandonment. The semi-intensive low-input orchards (GJ3 and GJ1) will gradually turn into semi-intensive high-input (GJ2) and intensive orchards (GJ5) by 2030. The traditional orchards on very steep slopes (GJ4) that cannot change into other SMOPS will either remain or be abandoned.

In order to see what would happen under a worse situation, an additional fifth "Disaster" scenario was added, in which wage rates would increase by 4 % per year. In that scenario, drastic changes would occur, resulting in abandonment of 84 % of the orchards. Only the intensive system will withstand these very adverse market forces.

Table 7.6: Changes in SMOPS area in Trás-os-Montes target area, according to scenarios simulated with linear programming model.

Scenarios and Year	Traditional PT1	Semi-low PT2	Semi-high PT3	Intensive PT9	Organic PT5	Aband. PT0
In 2005	59	29	6	0	6	0
A. considering a minimum return to labour						
Stable 2030	12	0	6	2	0	80
Bright 2030	0	87	1	12	0	0
Doom 2030	0	0	0	0	0	100
Bleak 2030	1	1	0	19	0	80
B. without the minimum return to labour constraint						
Stable 2030	24	00	6	0	38	32
Bright 2030	0	16	0	84	0	0
Doom 2030	13	0	6	3	49	28
Bleak 2030	0	76	0	0	0	24

Table 7.7: Changes in SMOPS area in Granada–Jaen target area, according to scenarios, simulated with linear programming model.

Scenarios and Year	Traditional GJ4-very st.	Semi-low GJ3-steep	Semi-low GJ1	Semi-high GJ2 + irr.	Intensive GJ5	Aband. GJ0
In 2005	7	27	38	12	16	0
Stable 2030	3	0	10	40	43	4
Bright 2030	7	0	3	46	45	0
Doom 2030	0	0	26	16	51	7
Bleak 2030	7	0	2	46	45	0
Disaster 2030	0	0	0	0	16	84

In the other target areas, the results are somewhere in between those discussed above. The Cordoba target area is composed of two sub-areas: the SMOPS in the Sierra (rather remote, mountainous areas north of Cordoba) will move further towards organic and the orchards in the Campiña area (south of Cordoba) will shift towards intensive orchards.

In the Basilicata target area, the traditional, semi-intensive high-input and “integrated protection” orchards disappear in almost all scenarios, making way for semi-intensive low-input, intensive and to a lesser extent organic plantations. Abandonment is considerable, except in the Bright market scenario.

In West Crete target area the price premium for organic olive oil is currently so high that all orchards would become organic, except in the Doom market scenario, when 71 % will be abandoned. When a lower price for organic olive oil (3 € per litre) is assumed, all intensive orchards remain, except in the Doom market scenario, when many will be abandoned or become semi-intensive low input orchards.

7.5.4 Effects of scenarios on income and employment, and on the environment.

Table 7.8 provides information about the various effects of the market changes on income, employment and environmental factors for the Trás-os-Montes and Granada–Jaen target areas, without and with the minimum return to labour constraint. The 2005 base data for the socio-economic factors and water use have been derived from the agro-socio-economic surveys undertaken by the project in the target areas (Duarte, 2005), and the base data for the other environmental factors have been derived from various sources (e.g. Gomez, 2005).

In Trás-os-Montes, the scenarios show very different effects. The Bright (B) and to a lesser extent the Bleak (D) scenario have a positive effect on income and on return to labour, with the Bright scenario requiring more hired labour. Under the Doom (C) and Stable (A) scenarios, production will decline and profits will remain negative.

In Granada–Jaen, production will increase in all scenarios by about 10–20 % (except in the Disaster scenario, not shown here), and due to the subsidy and price changes the income will double under the Bright (B) and Bleak (D) market scenarios.

Thanks to the more intensive production, the net profit and the return to labour are, on average, much higher in Granada–Jaen than in Trás-os-Montes However this more intensive production has important environmental effects. In 2005 the erosion, pollution and water use in Granada–Jaen were already much higher than in Trás-os-Montes. In both target areas, the water requirements are higher under the Bright market scenario, which is also the scenario with the lowest fire risk. Whether or not this fast increase in water requirements can actually be met deserves careful investigation. It was not possible to put a realistic limit to water use in the model.

Partly thanks to the fact that the efforts for cross-compliance measures in the Granada-Jaen area do pay off under all scenarios, the risks of erosion and fire will diminish. However, the increasing production also increases pollution and water use, and reduces biodiversity.

Despite the costs involved, the model suggests that most farmers (85–93%) will respect the cross-compliance requirements, even after abandonment (in Trás-os-Montes area), since farmers will then still be eligible for subsidies. The effects on income, employment and environment in the other three target areas will not be elaborated on here (See in Fleskens and de Graaff, 2006). In the Cordoba area, income will increase with an increasing demand for water, higher erosion rates and declining biodiversity in almost all scenarios. In the other two areas, the effects vary too much per scenario, and it is not possible to generalise.

The authors realise that some of the assumptions underlying the respective scenarios may be rather simplistic: for example, when continuous price increases lead to considerable increases in production, as in the Bright market scenario, price increases are unlikely to continue over the period considered.

Table 7.8: Effects of subsidy, wage and price changes on socio-economic and environmental factors in Trás-os-Montes and Granada–Jaen target areas[a], as simulated with linear programming model.

Factors	Scenarios Trás-os-Montes (2030)					Scenarios Granada-Jaen (2030)				
	2005	A-pt	B-pt	C-pt	D-pt	2005	A-gj	B-gj	C-gj	D-gj
Socio-economic factors										
Income € ha^{-1}	313	317	1018	252	665	1523	1830	3400	1685	3257
Net profit € ha^{-1}	-465	-354	282	-633	-235	144	591	2182	44	1625
Labour h yr^{-1}	1323	891	1917	910	950	1242	1305	1419	1220	1419
- Hired h yr^{-1}	383	0	870	0	6	5	53	102	11	102
Labour return € h^{-1}	3.3	3.5	9.7	2.8	7.0	12.3	14.6	26.7	13.9	25.6
Environmental factors										
Erosion t ha^{-1} yr^{-1}	3.1	0.4	2.4	0.5	3.2	36.7	17.5	22.8	15.8	21.5
Fire risk[b] % yr^{-1}	0.09	0.11	0.03	0.11	0.11	0.06	0.04	0.04	0.05	0.04
Pollution (index)	2.6	4.0	5.1	5.2	3.9	16.2	21.3	22.2	20.2	22.2
Water[c] m^3 ha^{-1}yr^{-1}	90	91	1679	158	0	496	1428	1552	1321	1552
Biodiversity[d]	10.1	10.8	6.0	10.1	7.8	7.8	6.6	6.5	6.6	6.5
Cross-compl. %	100	88	88	85	85	100	91	91	93	90

Notes: A-D pt and A-Dgj stand for four scenarios in respectively Portugal and Granada–Jaen

[a] Without and with minimum return to labour constraint for Trás-os-Montes and Granada–Jaen respectively;

[b] Percentage of area burnt per year;

[c] i.e. water use;

[d] on basis of index values.

Sources: Duarte, 2005; Gomez, 2005.

7.6. Conclusions

The analysis of prospects and scenarios for sloping and mountainous olive production systems (SMOPS) shows that there is more or less unanimity about the direction of change that is triggered by reduced support and future market conditions. The farmers, the experts in the olive sector and the LP simulation model, all point out that in some target areas there will be widespread abandonment of orchards, whereas in other areas and under other conditions, a shift can be expected towards more intensive plantations and in some areas towards organic production systems. While it is not clear how much scope there will be for organic production, the trends towards abandonment and more intensive orchards may have considerable social and environmental effects. Abandonment may accelerate further emigration and increase wildfire and soil erosion risk, and a shift towards more intensive plantations may lead to more pollution and intensify pressure on scarce water resources. It is questionable whether cross-compliance regulations will be able to mitigate these adverse environmental effects without greatly affecting production and income levels.

Chapter 8

Conserving natural resources in olive orchards on sloping land

Alternative goal programming approaches towards effective design of cross-compliance and agri-environmental measures

Fleskens L and de Graaff J

Ecological Economics (submitted)

8. Conserving natural resources in olive orchards on sloping land: alternative goal programming approaches towards effective design of cross-compliance and agri-environmental measures

Abstract

Olive farming on sloping land is facing multiple challenges: competition with better endowed lowland plantations, a shortage of labour in these often remote areas with a declining and ageing population, uncertain income from production and subsidies while expected to meet high environmental standards. The future of olive farming under those conditions is highly uncertain. It is reasonable to believe that farmers will make shifts in production, leading to the likely abandonment of some systems and intensification or change to organic production of other systems. The impact of those shifts on environment and society can be either positive or negative, depending on how they are realized. The issues at stake surpass financial farm viability and two EU policy instruments – cross-compliance and agri-environmental measures – are available to address environmental objectives. Meeting policy objectives however, requires the cooperation of olive farmers, and unattractive instruments may lead to higher abandonment rates with often negative environmental impacts. This chapter presents alternative goal programming models that takes into account all these aspects and offers an integrated approach to policy design.

8.1. Introduction

The European paradigm of agriculture is that it is inherently multifunctional and supplies services or amenities next to producing marketable food and fibre. Recent agricultural policies recognize that many of such services are not valued in markets, and with these policies attempts have been introduced to remunerate farmers for the provision of these public goods and services. Sloping and mountainous olive production systems (‘SMOPS’) present an interesting case for the operationalisation of the paradigm:

1. A large variety of production systems exists (Fleskens, 2007), with variable degrees of productivity and provision of public goods and services;
2. These systems are facing several challenges: they can not produce as efficiently as better endowed lowland plantations and are often situated in

remote regions with difficult access and declining and ageing rural population leading to increased labour scarcity and prices;

3. The number of land use alternatives is very limited, and both abandonment and intensification processes in various degrees are presently noticeable. These processes have a large impact on the functions of these systems;
4. The majority of production systems are situated in environmentally sensitive regions which moreover are characterized by relatively low levels of development, stressing the need for sustainable development pathways.

For olive farmers on sloping land, subsidies have become a substantial part of their revenues. Until the year 2005, these subsidies were linked to production and provided an incentive for intensification (de Graaff and Eppink, 1999), with negative effects for the environment, especially soil erosion (Beaufoy, 2001). Commencing 2006, olives have been included under the single farm payment scheme (EU Council Resolution No. 1972/2003), meaning that olive farmers will be paid a fixed amount per hectare based on olive oil production in the reference period 1999-2002, resulting in so-called decoupling of subsidies from production. According to the regulation, the single farm payment subsidies should be made conditional to minimum requirements of good agricultural practice, to be established under cross-compliance regulations. While these regulations should provide an incentive for the application of environmentally benign practices, they could easily prove ineffective if:

1. Cross-compliance conditions are too strictly defined and farmers will not abide by them – normally resulting in their disqualification for the single farm payment (however, if control is not effective and/or penalization low, more or less widespread abuse of the subsidies may persist);
2. Cross-compliance conditions are set too low and almost all farmers can easily comply, providing no incentive for improving environmental performance;
3. Cross-compliance conditions are defined on a limited number of criteria differentiating chances of different types of olive orchards to comply with them, resulting in respectively the first and second shortcoming mentioned above.

Next to the cross-compliance regulations, farmers may choose to participate in agri-environmental measures (AEM) schemes which establish possibilities to reward agricultural practices beyond the minimally required ‘good’ agricultural practices. Agri-environmental measures fall under rural development policy, the so-called second pillar of agricultural support. EC member countries or autonomous regions are free to design the agri-environmental programmes. After their introduction in 1992 they have had varying degrees of success in the different areas and depending on the aspects evaluated (Tahvanainen et al., 2002; Kleijn and Sutherland, 2003; Carey et al., 2005; Kleijn et al., 2006). Nevertheless, their role in the reformed agricultural policy has grown: rural development policy is perceived to gradually become the major ‘pillar’ of subsidies. However, the AEM schemes potentially run similar risks as mentioned above for the cross-compliance regulations, namely that either they may receive major uptake by farmers if easily implemented, or receive hardly any attention if too difficult to implement.

Given the critical aspects involved in the formulation of conditions of both types of subsidy schemes, scenario modelling provides a tool to evaluate the effects of current and potential future policies. Scenario studies have frequently been applied for exploratory studies of land use changes. Exploratory studies are characterised by their attempt to answer a “what if?” question typical of a situation with a high level of uncertainty and a good deal of causality (van Ittersum et al., 1998). Different approaches have been developed for land use scenario modelling (e.g. de Koning et al., 1999; Stoorvogel and Antle, 2001; Roetter et al., 2005). For the assessment of decisions at farm level that are influenced by external factors such as the policy environment and technological innovations, use is frequently made of approaches based on Linear Programming (LP). Simple LP models optimize a single goal, in the context of farm decision-making models frequently assessed through a simple measure of profit maximization (Janssen and van Ittersum, 2007). We opted for a multiple goal decision making model as the problem under scrutiny is equipped with many different aspects, all of which need to be considered by the decision-taker. For all these aspects goals can be defined, which will usually (partly) conflict with each other. The multiple criteria decision making paradigm offers an array of methods to deal with such conflicts (Romero and Rehman, 2003), among which is (Multiple-Objective) Goal Programming (MGP, or simply GP) (Tamiz et al., 1998). It has been extensively applied in land use (policy) analysis (e.g. de Wit et al., 1988; Schipper, 1996; Nhantumbo et al., 2001; Nidumolu et al., 2007)

The objective of this chapter is to explore the options of a scenario simulation model taking into account SMOPS performance on multiple functions (criteria) to contribute to policy design. Four variations of the simulation model will be presented. In the simplest form, the scenarios can be formulated as a LP optimization model, in which the farming community seeks to maximize income from olive farming given certain constraints. These constraints are governed by intrinsic as well as external (policy) factors. The problem could also be formulated as a GP model. Two variations of the GP model are used: Weighted GP (WGP) and MINMAX GP. By introducing weights, a farmer (F) perspective and societal (S) perspective can be simulated. After determining the type of model that bests meets the criteria, scenario studies are undertaken to explore the effects of policy choices on farm income and environmental indicators.

The chapter is structured as follows: first, the context of olive farming on sloping land is sketched and indicators are introduced. Subsequently, the LP model is described and its results are presented. Thereafter, different versions of the MGP model are described together with their results. All model descriptions in the main text are kept simple; full versions are provided as supplementary material. Finally, the results are discussed and thereafter conclusions are drawn.

8.2. The context of olive farming on sloping land

8.2.1. Characteristics of olive production systems on sloping land, with special reference to NE Portugal

Olive orchards occupy an important share of Mediterranean land. Within the European Union, they cover over 4 million ha (Fleskens and de Graaff, 2003). In Trás-os-Montes (NE Portugal), the focus area of this chapter, 72,000 ha of land is covered by olive trees, the majority of which is confined to the so-called Terra Quente area where olive groves cover almost 30% of the utilized agricultural land (Fleskens et al., 2007). Ninety-five percent of orchards are located on sloping and mountainous land, hence almost all orchards can be considered SMOPS. Different types of SMOPS can be distinguished (Duarte et al., 2004; Fleskens, 2007); Table 8.1 gives some details of each SMOPS type, including share of orchards in each category (situation 2005), and indicators of social and environmental performance.

All SMOPS types have concerns relating to social and environmental key-issues. Traditional SMOPS (PT1) present high wildfire risk and low productivity. Semi-intensive SMOPS for olive oil production (PT2) suffer high soil erosion risk and have low levels of biodiversity. Semi-intensive SMOPS for table olive production (PT3) receive high amounts of chemical inputs and water. Organic SMOPS (PT5), although generally environment friendly, use high amounts of copper compounds for pest control and produce low yields. Intensive SMOPS (PT9) besides using many inputs have a comparatively low landscape value. At the other end of the spectrum abandoned SMOPS (PT0) present highest risk to wildfire.

The economic indicators of SMOPS were taken from Fleskens (2005) and Martinez Raya et al. (2006), as were labour input data. All these values were derived from an agro-socio-economic farm survey among 60 farmers in Trás-os-Montes (Duarte, 2005a). Amounts of subsidies and eligibility criteria under respectively the single farm payment scheme and agro-environmental measures were taken from Duarte (2005b) and IDRHa (2004).

For the assessment of environmental performance of different SMOPS in the present study various data sources were used. Soil erosion estimates were taken from de Figueiredo et al. (2002) and field experiments reported in Fleskens and Stroosnijder (2007). Wildfire risk was determined from analysis of regional statistics (Fleskens et al., 2007). As a proxy-indicator for biodiversity use was made of an index scale ranging from 0-10, based on floral diversity assessments in olive orchards (Siebert, 2004; Xiloyannis et al., 2004; Allen et al., 2006). Rates of water use and nitrogen application were taken from interviews with farmers and experts (Fleskens, 2005; Martinez Raya et al., 2006). The same data sources were also used for information on pesticide use per SMOPS. The Environmental Impact Quotient (EIQ) field use rating of each pesticide was calculated following Kovach et al. (1992). The EIQ gives a single score based on toxicity of pesticide active ingredients for farm workers, consumers and the environment (leaching and toxicity to different ecological strata); the EIQ of dimetoate is 74, cuprics 33.3 and glyphosate 15.3. EIQ scores are then multiplied by the number of pesticide applications and amount of pesticide active ingredients per application to arrive at a total EIQ field use rating. Landscape value was assessed according to a simplified application of the idea postulated by Pachaki (2003) – see Fleskens et al. (2007) for more details.

Table 8.1: Characteristics of SMOPS types.

Characteristics	SMOPS type[a]					
	PT0	PT1	PT2	PT3	PT5	PT9
Initial SMOPS distribution normalized for 10 ha	0	5.9	2.9	0.6	0.6	0
Yield (kg ha^{-1})	0	1100	2250	4000	900	3500
Olive oil price (€ liter^{-1})	2.26	2.26	2.26	0.40	2.26	2.26
Olive oil content (%)	0	17	17	100	17	17
Single farm payment subsidy (initial situation) (€ ha^{-1})	-	223	455	645	182	-
Subsidies inherent to SMOPS type besides SFP scheme (€ ha^{-1})	0	0	0	0	80	0
Intermediate consumption of inputs (€ ha^{-1})	0	61.0	257.3	300.6	127.1	277.2
Olive oil processing costs (€ liter^{-1})	0	0.32	0.32	0	0.32	0.32
Equipment variable costs (€ ha^{-1})	0	55.3	115.7	87.5	100.8	121.7
Equipment fixed costs (€ ha^{-1})	0	40.3	95.5	36.6	61.9	109.8
Depreciation on plantation investment (€ ha^{-1})	0	0	67.9	112.7	0	67.9
Annual labour input requirements (h)	0	127	148	375	108	234
Average annual soil erosion (ton ha^{-1})	2	5	5	4	1	3
Annual irrigation water requirements (m^3 ha^{-1})	0	0	0	1500	0	2000
Wildfire risk (% SMOPS affected in 10 years)	2	1	0.8	0.2	0.8	0.2
Biodiversity value index (scale 0-10)	7	7	5	3	7	4
Input use (N-application) (kg ha^{-1})	0	75	128	128	10	128
Input use (dimetoate) (kg active ingredients ha^{-1})	0	0	0.32	0.40	0	0.32
Input use (cuprics) (kg active ingredients ha^{-1})	0	0	1.75	2.25	4.50	1.75
Landscape value index (scale 0-10)	5.3	5.1	4.2	5.4	5.5	3.2

[a] PT0 = Abandoned; PT1 = Traditional; PT2 = Semi-intensive (olive oil); PT3 = Semi-intensive (Table olive); PT5 = Organic; PT9 = Intensive.

8.2.2. Policies affecting olive groves on sloping land, with special reference to NE Portugal

Olive farms throughout the EU are integrated into the single farm payment scheme since 2006. Flat rate single farm payment entitlements are calculated based on the reference yield in the period 1999-2002. For the study area in NE Portugal, this means that traditional SMOPS may on average receive €223 ha^{-1} while semi-intensive SMOPS for table olives receive €645 ha^{-1} (Table 8.1). Organic SMOPS, even less productive in the reference period, receive lower amounts and semi intensive SMOPS for olive oil production occupy an intermediate position. No intensive SMOPS existed in 2005. Automatically, olive groves that were abandoned and not harvested in the reference period are not eligible for the single farm payment subsidy; those are excluded from further analysis in this chapter.

In order to actually receive the single farm payment olive orchards should meet cross compliance conditions. These conditions include: a) weed control in late spring to minimize the risk of wildfires (in the model only applicable to abandoned SMOPS as all other systems receive this treatment standard); b) soil cover in winter to reduce erosion risk; c) pruning to reduce fire risk (also only applicable to SMOPS PT0); and d) terrace maintenance in orchards where they are present (variable percentages of orchards in all SMOPS except PT9). In the different SMOPS, costs to comply with these conditions vary, as do the beneficial effects on functions performed.

Three agri-environmental measures were included in the simulation model. These are: a) the growing of a cover crop, (surprisingly) only eligible for irrigated orchards (SMOPS PT3 and PT9); b) preservation of traditional olive orchards (applicable to SMOPS PT1 and PT5); and c) integrated pest management (IPM, applicable to all productive SMOPS except organic orchards). Implicitly, a fourth AEM was considered: organic production. As registration of orchards with a producers association is mandatory to market olive oil as organic, in the model the subsidy is automatically linked with SMOPS PT5. The agri-environmental subsidies vary between €63 ha^{-1} for cover crops and €147 ha^{-1} for integrated pest management in SMOPS PT1 (AEM payments are in reality only implicitly linked to SMOPS types, but related to farm size).

Besides affecting subsidy payment, cross compliance and agri-environmental measures require additional labour input and modified variable and intermediate consumption costs. Moreover, yields maybe affected (e.g. through increased competition between olive trees and cover crops).

The above data (Table 8.1) and methods were used in different goal programming models: linear programming (LP, Section 8.3), weighted goal programming (WGP) and minmax or Chebyshev goal programming (MINMAX GP), both introduced in Section 4.

8.3. LP Model descriptions and results

The LP model considers for each area the alternative SMOPS types *i* for a time frame of 25 years, represented by set *j*, starting 2005 and ending 2030. Each year *j* is divided in four seasons *k* (winter, spring, summer, autumn) over which some model variables are defined. Furthermore, two types of labour *l* are considered, hired labour (*l* =1) and family labour (*l* =2). The set *a* contains agri-environmental measures. Set *c* concerns cross-compliance and includes two options: *c* =1 and *c* =0, respectively meeting and not meeting the requirements. For *c* =1, cross-compliance requirements are specified by the elements of the set of cross-compliance measures *m*.

The LP model's objective function Z_1 is assumed to represent the farmer's economic interest of maximizing income (gross margin including hired labour costs but excluding a return to own labour) from olive farming (Eq. 8.1):

$$\begin{aligned} Z_1 = \max \sum_i \sum_j P_{ij} \cdot p_{ij} + \sum_i \sum_j X_{ij} \cdot m_i + \sum_j S_j + \sum_a \sum_i \sum_j A_{aij} \cdot g_{ai} \\ - \sum_j \sum_k \sum_{l=1} L_{ijk} \cdot w_{jk} - \sum_i \sum_{i'} \sum_j Yp_{ii'j} \cdot n_{ii'} - \sum_c \sum_m \sum_i \sum_j C_{cij} \cdot c_{cim} \end{aligned} \tag{8.1}$$

where:

P_{ij} = production of olive oil of SMOPS type *i* in year *j* (kg)
p_{ij} = price of olive oil produced in SMOPS type *i* in year *j* (€ kg^{-1})
X_{ij} = area devoted to SMOPS type *i* in year *j* (ha)
m_i = miscellaneous subsidies minus all variable production costs except labour for SMOPS type *i* (€)
S_j = single farm payment subsidy received in year *j* (€)
A_{aij} = area of SMOPS *i* under agri-environmental measure *a* in year *j* (ha)
g_{ai} = agri-environmental subsidy minus all additional variable production costs for agri-environmental measure *a* practiced in SMOPS type *i* (€)
L_{ijk} = labour use of SMOPS type *i* in year *j* and season *k* (h)
w_{jk} = wage rate of hired labour in year *j* and season *k* (€ h^{-1})
$Yp_{ii'j}$ = positive area change from SMOPS *i* to SMOPS *i'* in year *j* (ha)
$n_{ii'}$ = investment cost of change from SMOPS type *i* to SMOPS type *i'* (€)
C_{cij} = area of SMOPS type *i* meeting (*c*=1) or not meeting (*c*=0) cross-compliance conditions in year *j* (ha)
c_{cim} = additional variable costs to comply with cross-compliance condition *c* for SMOPS type *i* requiring measure *m*

The LP model is subject to several constraints (Eq. A1–30, See Appendix A) grouped into five categories:

- Constraints related to area accounting and changes between SMOPS types
- Constraints related to the use and remuneration of labour (facultative)
- Constraints related to olive production
- Constraints related to subsidies
- Income constraint

Four scenarios were defined for the model based on an analysis of external factors (de Graaff et al., 2007): a) the Stable scenario (single farm payment subsidies are reduced with 2% per year after 2013); b) the Bright scenario (idem, but olive oil prices rise with 2% per year); c) the Doom scenario (SPS payments reduced with 4% per year after 2013 and labour costs increase with 2% per year); d) the Bleak scenario (idem, but additionally olive oil prices rise with 2% per year). For comparison of the different models, only the results of the stable scenario will be shown in this chapter. However, the scenarios are essential to evaluate the impact of the two policy options cross-compliance and agri-environmental measures.

Figure 8.1 shows the results of the LP simulation over 25 years. Organic SMOPS (PT5) and intensive irrigated SMOPS (PT9) will expand at the expense of the traditional and semi-intensive systems (PT1 and PT2 respectively). Moreover, an important part of the olive area will be abandoned (PT0). Note that important changes in the final 2-3 years relate to opportunistic effects due to proximity to the end of the simulation period; these effects are further ignored in the description of results. Total olive production will decrease sharply initially and remain fairly stable thereafter, with PT9 making the highest contribution. All of the area will comply with cross-compliance except the final years (caused by the very low penalties of 5% subsidy loss in the first two years of non-compliance). Agri-environmental measures will be implemented at about half of the area, mainly in the AEM scheme ‘preservation of traditional olive orchards’. Income initially sharply increases by eradication of hired labour and concentration of effort on intensive olive production, and is quite stable over the years thereafter. Total labour use will initially decrease sharply as a result of the complete disappearance of hired labour. Return to labour is clearly below the market wage in the current situation, but develops similarly as income. Relating to environmental performance, especially the increase of water use and pesticide environmental impact associated with intensive olive production (PT9) stand out, while erosion is completely controlled by conversion of SMOPS PT1 to SMOPS PT5 and abandonment (PT0) and of SMOPS PT2 to SMOPS PT5 and PT9 (all with good soil cover; moreover, cross-compliance conditions and participation in AEM further reduce soil erosion). Biodiversity value increases first and decreases thereafter. Wildfire risk remains stable and also the landscape value is maintained.

8.4. WGP and MINMAX GP Model descriptions and results

Model Z_1 can be transformed into a multiple goal model in order to allow the simultaneous consideration of several (soft) goals instead of rigid constraints (Eq. A7, A8 and A11, see Appendix A). The remaining constraints are system constraints or balance equations that will remain unaltered in the transformed model: Eq. A1-6, A9-10, and A13-30 (Appendix A). The return to labour constraint (Eq. A12) is optional. Two MGP approaches were taken, WGP and MINMAX GP. In both models, the following 12 goals were considered as indicators for important functions that SMOPS provide (see Fleskens et al., 2007):

Productive function

- Primary produce – Maximization of olive production

Economic functions

- Income generation – Maximization of gross margin (cf. objective function Z_1, Eq. 8.1)

- Cost efficiency – Minimization of investment
- Redistribution of wealth – Optimization of eligibility for subsidies

Social functions

- Employment & Liveability – Maximization of total labour input
- Employment – Maximization of hired labour input

Cultural functions

- Recreation – Maximization of landscape value

Ecological functions

- Water regulation – Minimization of water use
- Soil conservation – Minimization of soil erosion
- Wildfire control – Minimization of (risk of) burnt area
- Biodiversity conservation – Maximization of biodiversity value
- Pollution control – Minimization of pollution (pesticides and nitrogen application)

Note that some goals were previously included as constraints in the LP model, and that all goals are defined over the entire simulation period. Both the WGP and MINMAX GP models were adapted to a societal (S) and farmer (F) perspective by attributing weights to each goal. This will from now on be indicated by inclusion of the (S) or (F) behind the model name, e.g. WGP (S).

First, goals are defined from a societal perspective. This is achieved implicitly by considering all goals to be equally important, i.e. supporting economic functions without jeopardizing social, cultural and ecological functions of SMOPS. This is accomplished by maximization and minimization of respective goals. For the eligibility for subsidies, optimization rather than minimization or maximization is aimed at; as such, an optimal contribution to public policy social and environmental objectives can be achieved without compromising available funding (in other words: policy-makers, guardians of the societal perspective, dislike both over- and under expenditure).

A pay-off matrix was constructed to assess the degree of conflict between these goals by maximizing, minimizing, or optimizing them one by one (Table 8.2). When income is maximized, production is reduced to one third of its ideal value, total labour input is more than halved, hired labour input reduced to less than 1% and pollution reaches its anti-ideal value. Similarly, maximizing production leads to negative income, maximum erosion and minimum biodiversity. Surprising is that not only goals of different types of functions conflict, but also goals within the same group. For instance, minimizing fire risk leads to high soil erosion, high pollution, low biodiversity and very high (anti-ideal point) water use. Two important conclusions can be drawn from this: a) there is considerable scope to improve environmental and social performance of the single objective LP model Z_1; and b) it will be impossible to generate a solution that will satisfy all (environmental) goals.

Table 8.2: Pay-off matrix of single objective optimized solutions and their resulting values for all model parameters considered as objectives.

	tot prod kg	tot inc Euro	tot inv Euro	tot lab hours	tot hir lab hours	tot subs Euro	tot water m3	tot erosion ton/ha	tot burnt ha	avg biodiv -	avg pollut -	avg N-app kg/ha	avg landsc -
MAX income	292955	**104227**	2553	25821	366	81375	8390	11.90	2.66	8.02	79.38	32.55	6.27
MAX production	**698318**	49625	21775	8390	16820	71681	23706	77.43	1.40	5.79	75.93	121.26	4.96
MIN investment	29778	18091	**0**	23706	366	13731	**90**	53.76	5.01	7.05	2.92	5.30	5.36
MAX total labour	629427	31465	25000	**50685**	20999	**81829**	30940	66.47	1.29	6.57	43.81	99.45	5.09
MAX hired labour	671917	-19708	21727	30940	**33058**	79356	31170	66.48	1.29	6.43	57.40	105.40	5.10
MAX subsidies	270313	80667	1355	31170	6783	**81829**	**90**	75.11	2.68	8.80	11.90	57.57	6.57
MIN water use	31187	18135	273	2333	366	13971	**90**	53.34	4.98	7.06	3.90	5.19	5.36
MIN erosion	247910	74392	940	24643	366	**81829**	**90**	**-13.27**	2.09	8.62	145.59	11.95	6.26
MIN area burnt	638304	48124	22365	43917	15140	71720	31248	34.78	**1.15**	6.23	103.09	86.62	4.78
MAX biodiversity	100392	82772	31	31248	366	**81829**	**90**	17.62	3.59	**8.99**	**1.50**	23.97	7.44
MIN pesticide EIQ	26990	17994	**0**	2188	366	13622	**90**	54.21	5.01	7.07	**1.50**	5.18	5.37
MIN N application	23822	16910	78	1909	366	13284	**90**	53.53	5.04	7.06	1.95	**4.07**	5.35
MAX landscape value	93674	80496	92	14830	366	**81829**	**90**	17.62	3.59	**8.99**	**1.50**	23.97	**7.44**

Note: ideal values in bold; anti-ideal values underlined

Table 8.3: Target values for goals based on current levels.

Goal	Unit	Current level	Target level*	
		yr^{-1}	yr^{-1}	simulation period
Income	Euro	3000	6000	150 000
Olive production	kg ha^{-1}	1600	2400	60 000
Investment	Euro	na	400	10 000
Total labour input	h	1400	1200	30 000
Hired labour input	h	400	320	8000
Subsidies	Euro	3200	2400	60 000
Water use	m^3 ha^{-1}	9	20	500
Erosion	ton ha^{-1}	3	2	50
Area burnt	%	0.09	0.08	2
Biodiversity index value	-	10	8	200
Pesticide environmental impact	EIQ	40	40	1000
Nitrogen application rate	kg N ha^{-1}	85	60	1500
Landscape index value	-	6	7	175

*Note: In the MGP models, targets are defined over the whole simulation period only.

In order to explore the playing field, goal programming can thus make a contribution. There is a fundamental difference between the WGP and MINMAX GP models. In the WGP approach, the sum of unwanted deviational variables is minimized (Objective function Z_2, Eq. 8.2). In the MINMAX GP approach, the largest deviation (D) between achieved values and target values is minimized (Objective function Z_3, Eq. 8.3). Note that in both models deviation variables are normalized by division through the respective target values (Table 8.3).

$$Z_2 = \min\left(\frac{n_1}{150000} + \frac{n_2}{600000} + \frac{p_3}{10000} + \frac{n_4}{30000} + \frac{n_5}{8000} + \frac{(n_6 + p_6)}{60000}\right.$$
$$\left. + \frac{p_7}{5000} + \frac{p_8}{25} + \frac{p_9}{2} - \frac{n_{10}}{200} + \frac{p_{11}}{1000} + \frac{p_{12}}{1500} - \frac{n_{13}}{175}\right) \qquad (8.2)$$

where $n_1 \ldots n_i \ldots n_{13}$ and $p_1 \ldots p_i \ldots p_{13}$ are negative and positive deviational variables respectively connected with the goals of Eq. A31-43 (Appendix A).

Model Z_2 is subject to the constraints of Eq. A1-7, A9-10, A12 (optional), A13-30 and the goals of Eq. A31-43 (Appendix A).

$$Z_3 = \min D \qquad (8.3)$$

where D = normalized distance between achieved value and target value for each of the goals of Eq. A31-43 (Appendix A).

Model Z_3 is subject to the constraints of Eq. A1-7, A9-10, A12 (optional), A13-30, and the goals of Eq. A31-43, and additional constraints of Eq. A44-56 (Appendix A).

Figures 8.2 and 8.3 show the results of the WGP (S) and MINMAX GP (S) model runs respectively.

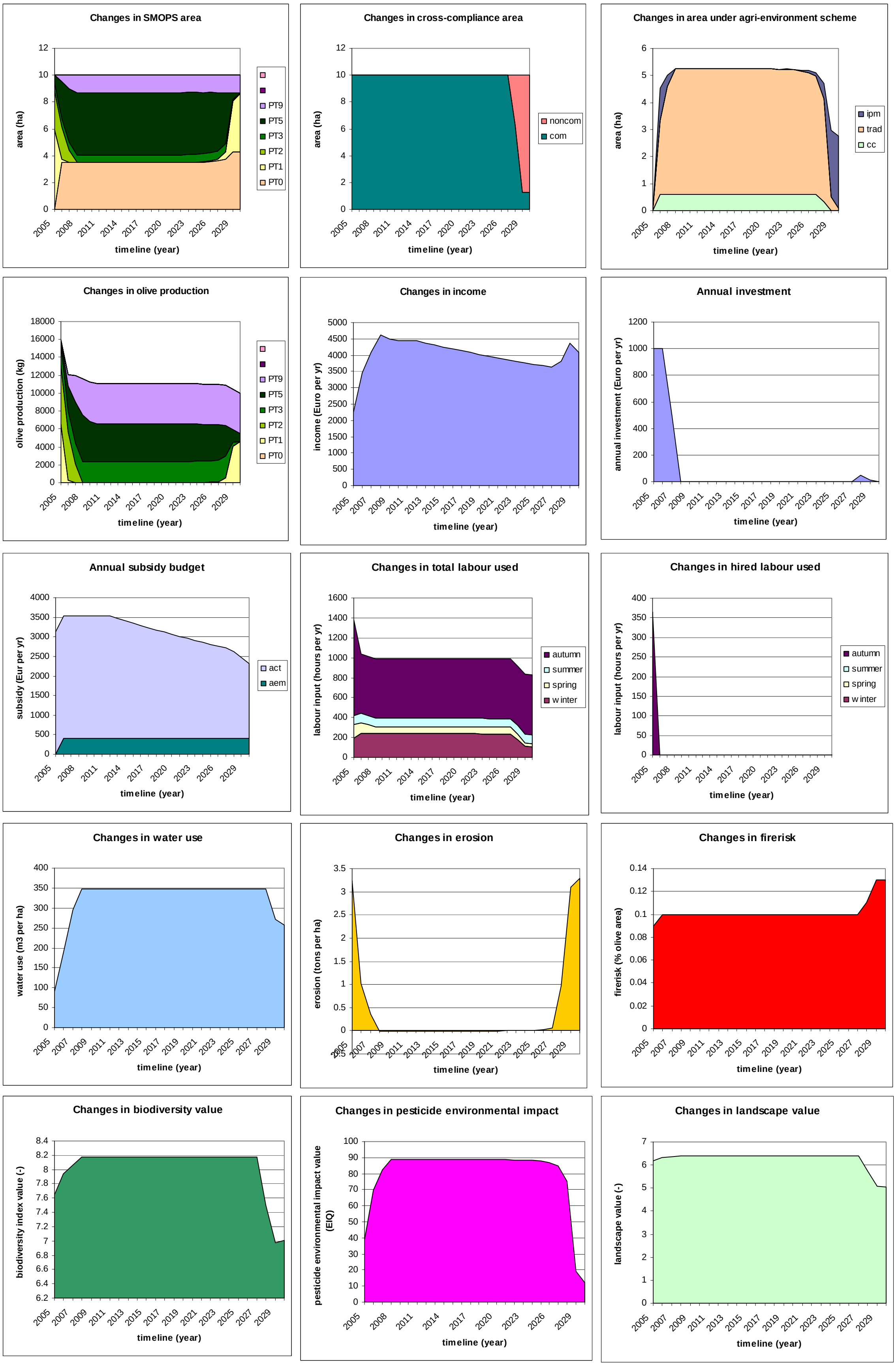


Figure 8.1. Simulation results of LP model under the Stable scenario on 3 policy indicators and 12 goals.

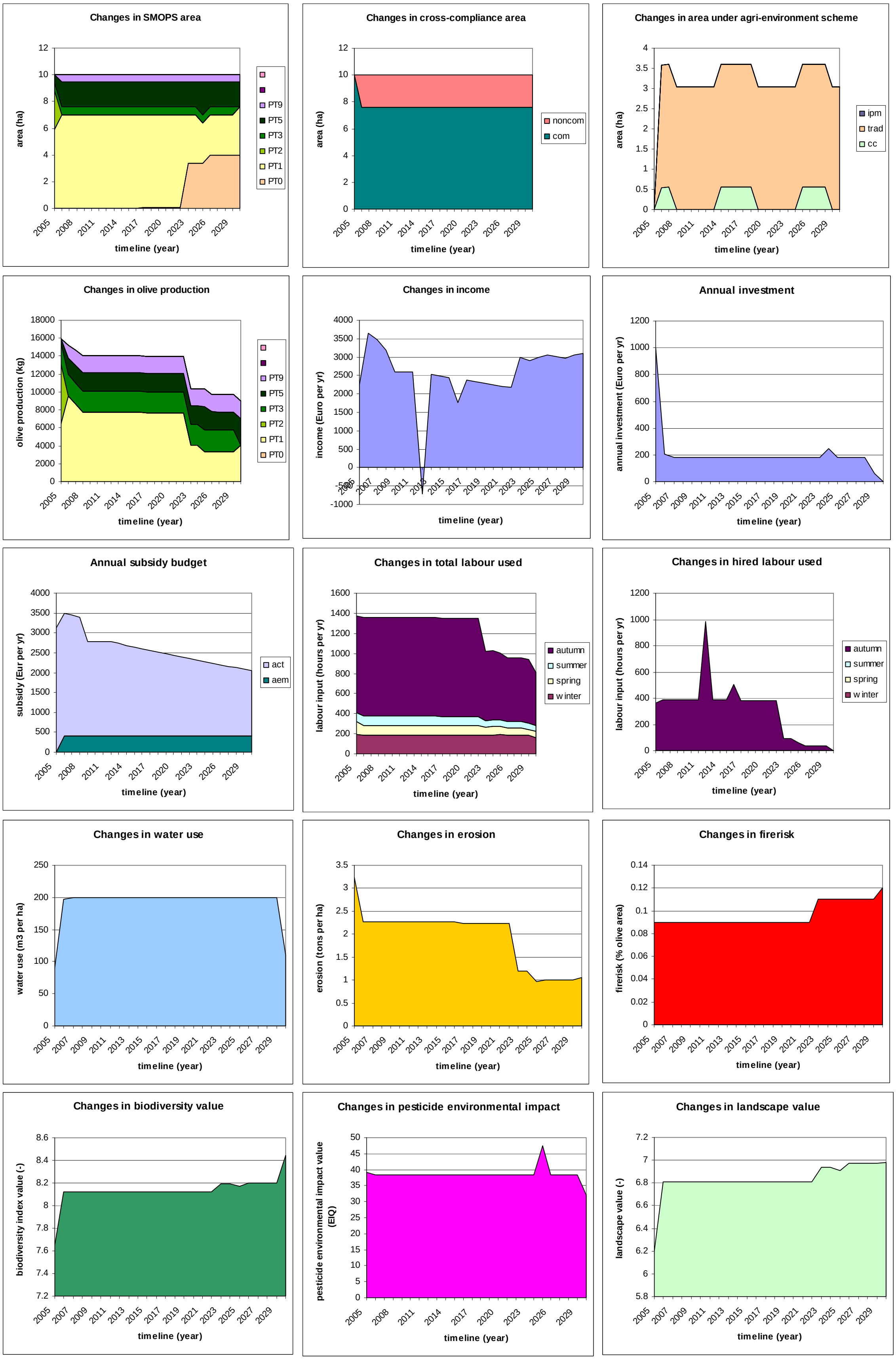


Figure 8.2. Simulation results of WGP (S) model under the Stable scenario on 3 policy indicators and 12 goals.

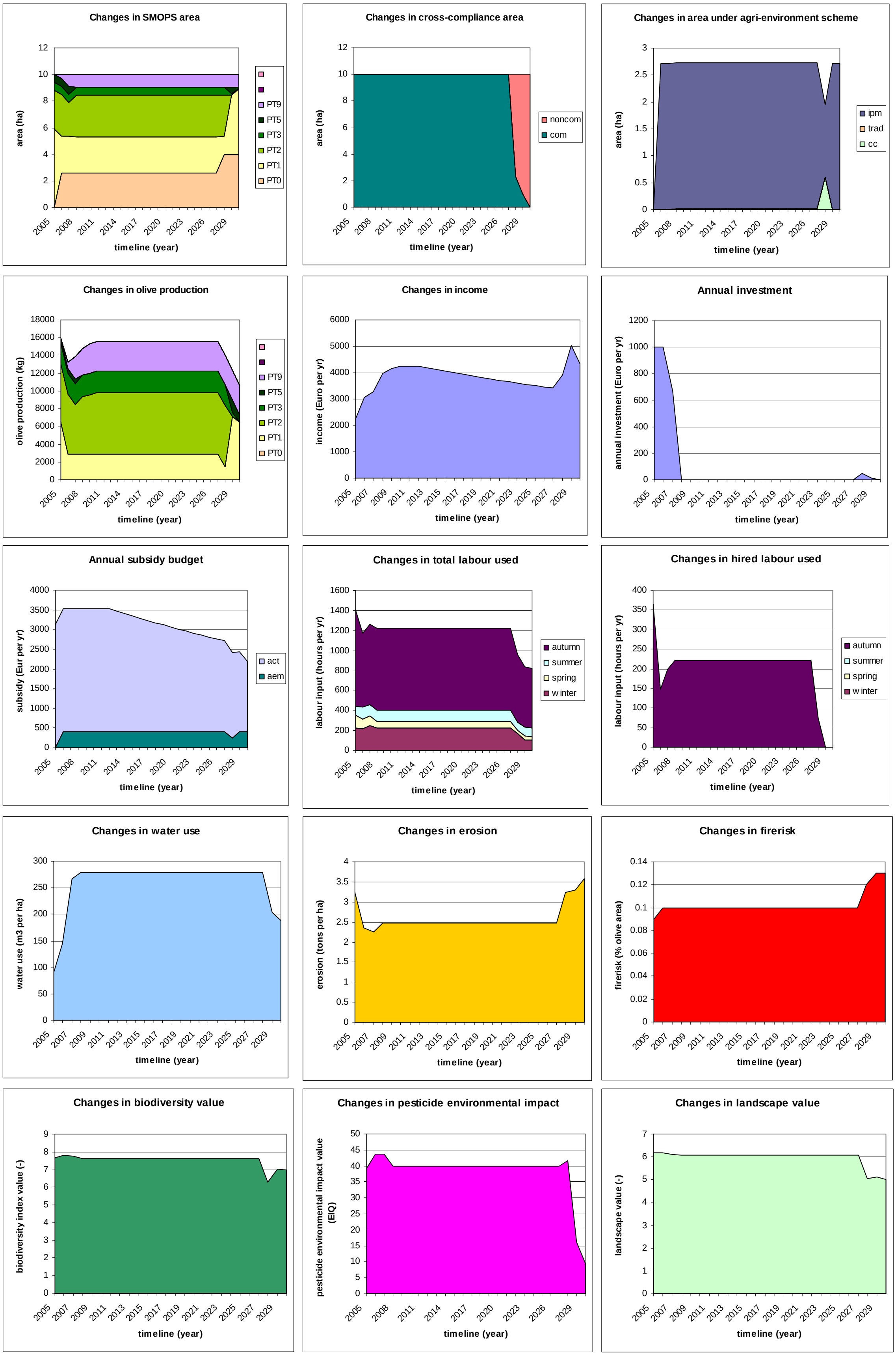


Figure 8.3. Simulation results of MINMAX GP (S) model under the Stable scenario on 3 policy indicators and 12 goals.

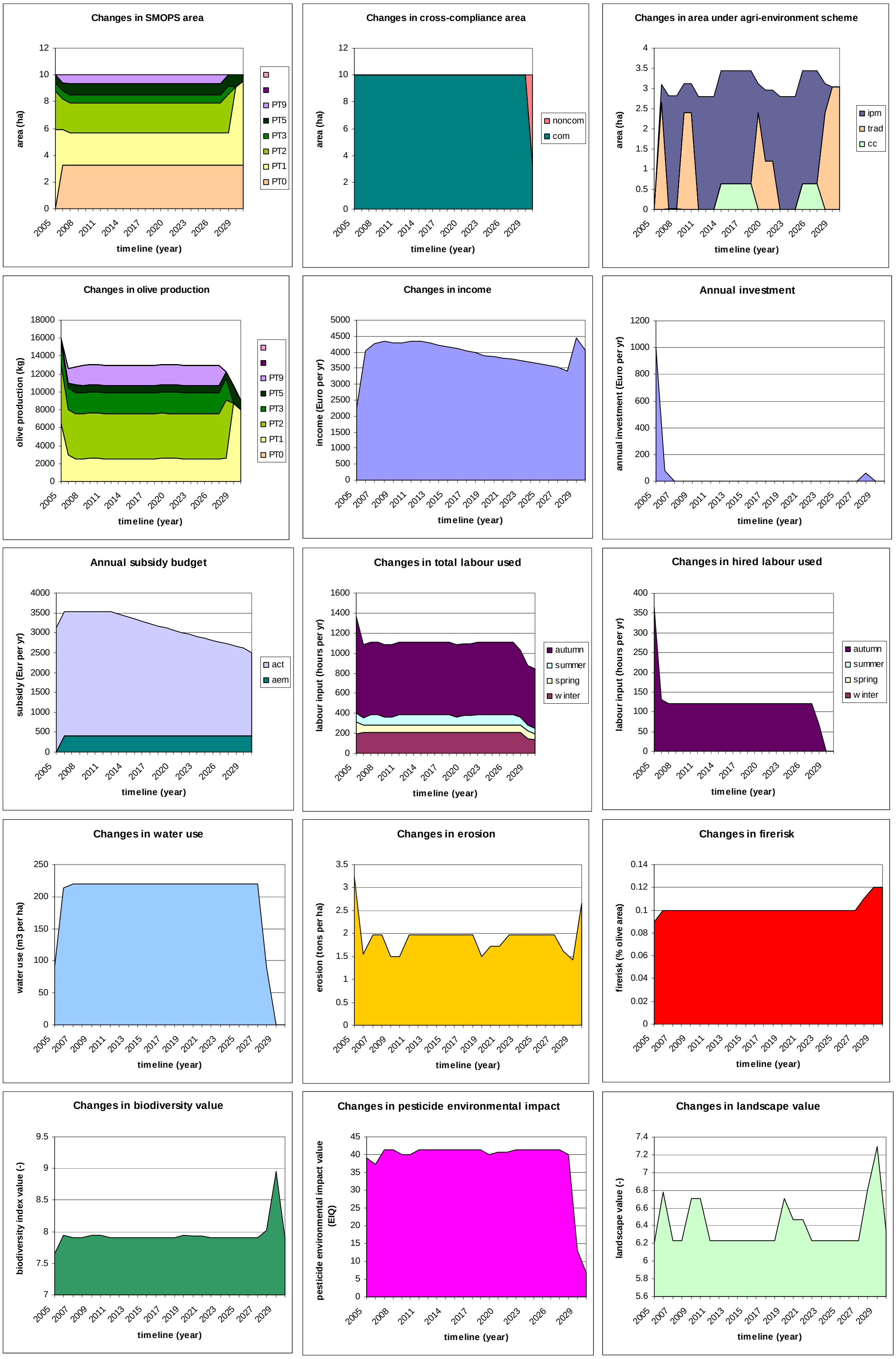


Figure 8.4. Simulation results of WGP (F) model under the Stable scenario on 3 policy indicators and 12 goals.

Turning first to the WGP (S) model in Figure 8.2, the area distribution of SMOPS shows two important developments: the disappearance of semi-intensive SMOPS for oil production (PT2) to the benefit of traditional (PT1), organic (PT5) and intensive irrigated SMOPS (PT9), and the abandonment of more than half of the area under traditional SMOPS (PT1) in the final decade. Total production first decreases slightly and experiences a major drop after abandonment. About 20% of the area looses eligibility for subsidies due to non-compliance, while the area under agri-environmental measures is about one third of the total area, mainly in the ‘preservation of traditional olive orchards’ scheme. Income is not stable but is roughly maintained, with the exception of one year when a peak in hired labour leads to negative income. This peak, apparently triggered by the onset of subsidy decline, is actually nothing more than a one-time substitution of hired for family labour to increase performance on the hired labour goal. Investment after the initial year does not lead to SMOPS changes, suggesting that this goal is met by switching of equal areas between SMOPS types. Total labour use is stable until the moment of abandonment, when the use of hired labour is practically abolished. The annual subsidy budget decreases sharply initially (with some delay) as a result of non-compliance of part of the area with the conditions of the single farm payment scheme. Water use and biodiversity and landscape values increase while erosion reduces. Wildfire risk increases after abandonment, while pesticide environmental impact changes little.

The MINMAX GP (S) model shows a different pattern for SMOPS, with abandonment (PT0) of an important share of the traditional SMOPS area (PT1), and appearance of intensive irrigated SMOPS (PT9) and extension of semi-intensive SMOPS for oil production (PT2) at the expense of organic SMOPS (PT5) and a fraction of traditional SMOPS (PT1). Olive production is maintained apart from a small initial dip and final change associated with a change of PT2 to PT1 and abandonment. The whole area complies with cross-compliance rules, except in the final years. More than one quarter of the area participates in agri-environmental schemes, almost exclusively under IPM. Income first increases at a steady pace, to decline with reduced subsidies afterwards. Total labour input reduces somewhat, at the expense of hired labour. Water use increases and erosion reduces slightly, but other environmental performance indicators show very little variation.

The WGP (S) and MINMAX GP (S) model simulations show that there is room to enhance environmental performance. However, how much is viable from a farmer perspective depends on importance attached to the economic function: income generation. While the WGP (S) and MINMAX GP (S) models were normalized without eliciting preferences for certain goals (implicitly attributing equal importance to all goals), a second run was made with the following weights (total = 1): income 0.5, erosion and biodiversity 0.025, and the nine other goals 0.05 each. This could reflect the viewpoint of a farmer. Inclusion of these weights yielded two additional models: WGP (F) and MINMAX GP (F). As the MINMAX GP approach is especially useful for balanced achievement of goals, it is less pertinent to the farmer perspective, and the MINMAX GP (F) model solution is therefore not shown; it is however included in the discussion of all models below. Results for the WGP (F) model are shown in Figure 8.4.

Figure 8.4 shows a solution combining stable income with good environmental and social performance. More than half of SMOPS PT1 is rapidly abandoned (PT0), but intensification also takes place (especially from SMOPS PT 2 to PT9). In terms of production semi-intensive olive cultivation for olive oil (PT2) is most important. Total production is reduced as a consequence of the net effect of abandonment being larger than that of intensification processes. The entire orchard area complies with cross-compliance conditions until the final year of simulation. Participation in all three AEM schemes occurs, with IPM assuming most interest. Investments are minimal and limited to the first year. Labour input reduces, all at the expense of hired labour. Water use doubles, but is reduced to zero from the moment that SMOPS PT3 and PT9 are reverted to traditional SMOPS. Erosion decreases substantially, while performance of most other environmental functions only alters in the final years.

In Figure 8.5 the model solutions are assessed against the target values (target values are normalized to 1) for all scenarios. Under the stable scenario none of the models is able to meet the ambitious income target, but the WGP (S) model solution is clearly worse than the others. However, the WGP (S) model scores best on most other indicators. The LP model solution shows very low achievement of the hired labour and pesticide environmental impact targets and also total water use is far from the target level. The MINMAX GP (S) model solution is more equilibrated with intermediate scores between the LP and WGP (S) model scores. When weights are included in the models, the WGP (F) solution almost achieves the LP total income level. This significant improvement relative to the WGP (S) solution is reached at the cost of strongly reduced hired labour input, larger deviation from the total targeted amount of subsidy payment, and smaller reductions in the achievement of total area burnt, average landscape value and total labour input. Similarly the MINMAX GP (F) solution has increased total income at the expense of very strongly reduced hired labour input and also reduced performance on total labour input, total water use, total area burnt and total production. However, besides improved income, improvements are also realized with regard to the target levels of total erosion, average biodiversity value, total N-application and average landscape value.

While hitherto we have focussed on the Stable scenario, we will now also look at model achievements under other scenarios. In the Bright scenario, all models perform much better on the income criterion. Hired labour input is also substantially higher. It becomes harder to meet the average pollution (pesticide environmental impact) and erosion target levels. Model performance in the Doom scenario is roughly similar to the Stable scenario, but income is more constrained. In the Bleak scenario, the LP model performs better than under other scenarios. Generally, model performances are in between the Stable and Bright scenarios.

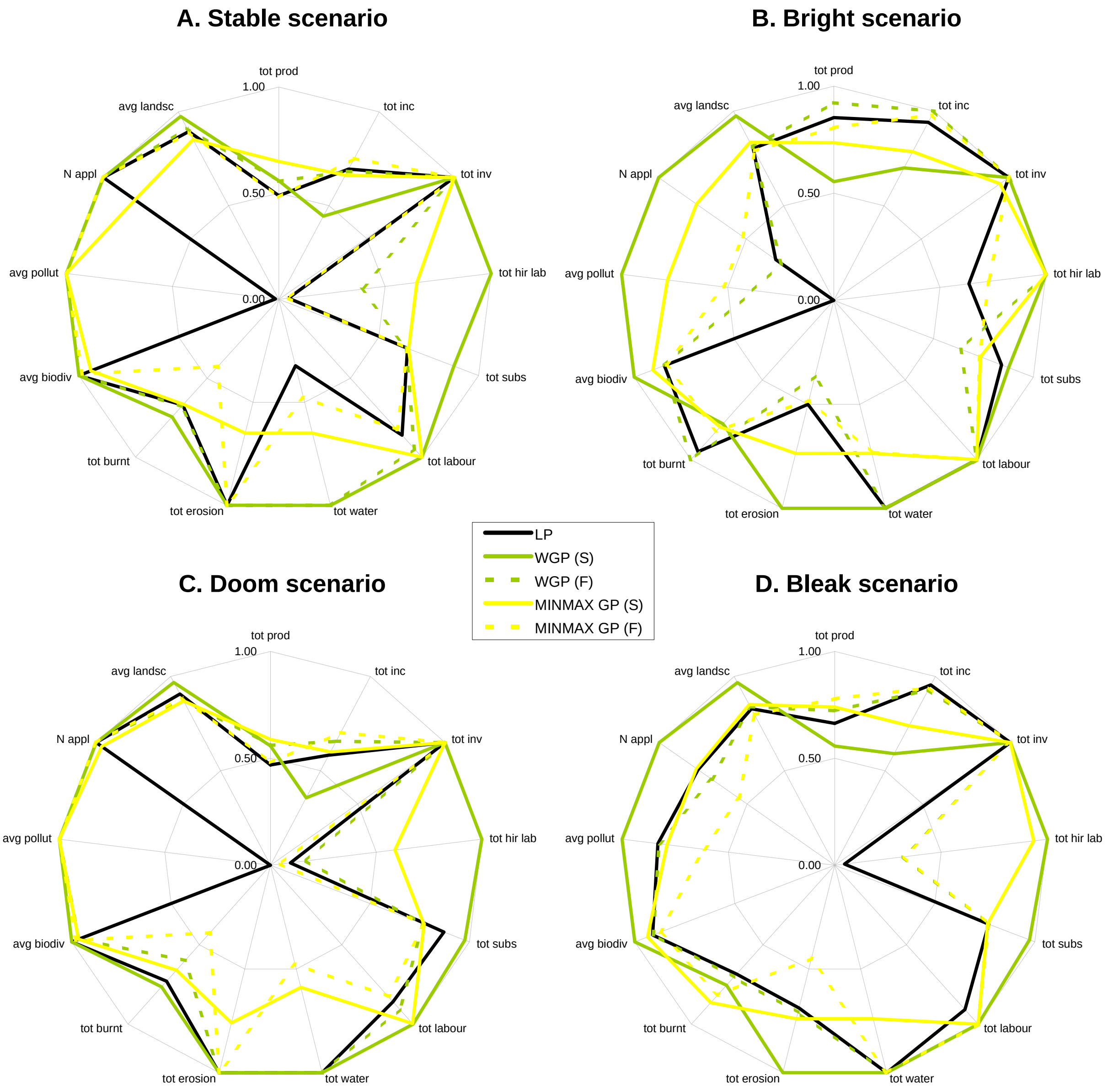


Figure 8.5. Indexed goals (full achievement or overachievement = 1, complete non-achievement = 0) for the five models under four scenarios.

Taking into account all goals simultaneously, model performance is evaluated in Table 8.4. The WGP (S) and WGP (F) model solutions rank highest if goals are respectively not weighted (government perspective) and weighted (farmer perspective).

Table 8.4: Aggregate score for achievement of target values for goals.

Scenario	Model	Aggregate score			
		Goals are not weighted		Goals are weighted	
		Score	Rank*	Score	Rank*
Stable	LP	0.66	5	0.68	5
	WGP (S)	0.90	**1**	0.69	4
	MINMAX GP (S)	0.78	3	0.73	3
	WGP (F)	0.83	2	0.76	**1**
	MINMAX GP (F)	0.73	4	0.73	2
Bright	LP	0.75	5	0.86	3
	WGP (S)	0.91	**1**	0.81	5
	MINMAX GP (S)	0.83	2	0.82	4
	WGP (F)	0.77	4	0.91	**1**
	MINMAX GP (F)	0.79	3	0.88	2
Doom	LP	0.73	5	0.67	4
	WGP (S)	0.89	**1**	0.65	5
	MINMAX GP (S)	0.80	3	0.70	3
	WGP (F)	0.81	2	0.73	**1**
	MINMAX GP (F)	0.74	4	0.71	2
Bleak	LP	0.77	4	0.86	2
	WGP (S)	0.91	**1**	0.76	5
	MINMAX GP (S)	0.84	2	0.80	4
	WGP (F)	0.80	3	0.87	**1**
	MINMAX GP (F)	0.76	5	0.86	3

*Note: ranking: scale 1-5 with 1 being most preferred and 5 least preferred.

8.5. Effectiveness of cross-compliance and agri-enviromental measures

Opting for the WGP (F) model that best achieves the multiple goals from the farmer point of view, we made an analysis of the effectiveness of policy options under different scenarios (Figure 8.6). Six options were distinguished, based on two cross-compliance options (yes or no) and three levels of subsidies allocated to agri-environmental measures (budgetary constraints). These levels include €0 (no AEM budget), €400 (approximately equivalent to the actual current AEM budget), and €800 (doubling of the current AEM budget). The total amount of subsidies includes SPS as well as AEM payments, whereby SPS payments are adjusted for possible non-compliance. Note that the AEM budget constraints are for 10 ha annually, and that the total amount of subsidies is summed over 25 years. The maximum amount available for AEM subsidies during the entire simulation period thus ranges from €0 - €20,000 depending on the budget constraint. Two perspectives are included, that of the farmer (left-hand side) and society (right-hand side). Goal achievement (0 – 1) under these perspectives is calculated as the weighted average of the achievement on each individual goal.

When assessing average goal achievement, it is good to keep in mind that the scenarios have an important influence on SMOPS distribution. The doom scenario leads to important abandonment, while the bright scenario stimulates intensification. The stable and bleak scenarios occupy an intermediate position. The weighted goal achievement thus averages the scores on individual functions as presented in Figure 8.5. For example, a low score on average pesticide pollution risk and a high score on hired labour input under the bright scenario are reversed in the doom scenario, when the pesticide pollution risk is negligible, but the hired labour input is far below the target level.

Figure 8.6 shows that from a farmer perspective the SMOPS performance is hardly influenced by any of the options, except in the bright scenario, where cross-compliance improves goal achievement. There is also a slight increase with the total amount of subsidies allocated, but this tendency is weakest in the doom scenario. The difference between the lowest and highest total amount of subsidies reveals that farmers are not participating to the maximum extent possible in AEM schemes, or – if they do – they do not comply equally well to cross-compliance as in the absence of AEM subsidies so that they face a reduction in eligibility for the SPS payments. As a consequence, the net effect of the AEM budget does not appear to help farmers substantially in achieving their goals, and this failure is stronger under the already difficult conditions of unfavourable scenarios. The scenarios themselves are much more important factors in determining the fulfilment of farmer objectives, biased towards income generation.

The societal perspective shows interesting differences. Firstly, the implementation of cross-compliance clearly increases the fulfilment of goals compared to absence of this policy (it should be remarked that the transaction costs of ensuring policy adherence were not taken into account). Secondly, the budget allocated to agri-environmental measures if accompanied with cross-compliance does not lead to substantial improvements under the doom scenario, but its added value increases with better prospects in general. Thirdly, in absence of cross-compliance, the budget allocated to agri-environmental measures is generally more effective than when combined with this policy instrument. There appears to be considerable overlap between the two instruments. Finally, the range of goal achievement does not vary widely between the four scenarios. This means that the policy instruments contribute importantly to better performance of SMOPS, whether under adverse or bright conditions

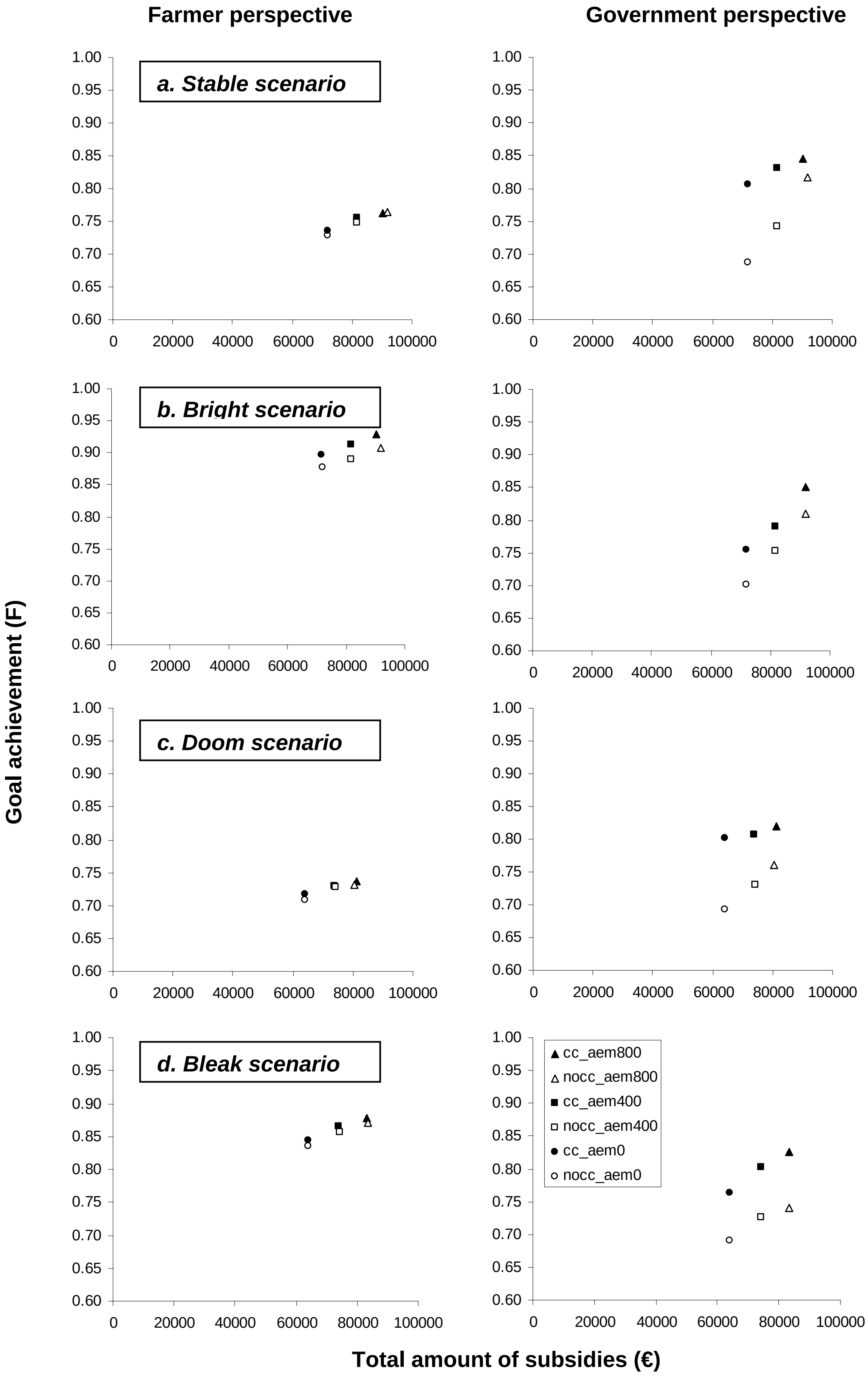


Figure 8.6. Effects of different combinations of cross-compliance (yes: CC; no: NOCC) and agri-environmental budgets (AEM0, AEM400 and AEM800) on SMOPS performance under four scenarios.

8.6. Discussion and conclusions

The olive production systems in NE Portugal vary widely in the functions they perform. As a consequence, evolutions of one type of production system to another result in important changes on a range of indicators. Scenario studies can shed light on possible future developments under various circumstances. (Multiple) goal programming was applied to study changes under various scenarios and to assess the effects of two policy instruments: cross-compliance and agri-environmental measures. Two perspectives were taken: the perspective of a farmer and the perspective of the society at large. The two perspectives represent hierarchical levels mutually dependent on each other to achieve best performance of the olive production systems from their perspective.

By comparing scores on farm income, MGP and LP modelling approaches can give a hint at the cost of achievement of environmental and social objectives. This cost differs under the various scenarios. It is hence important to consider in policy design whether the financial risk will be with the service provider (olive farmer) or whether the risk of underachievement of targets in the public domain is to be taken for granted. Apart from taking a purely societal or utilitarian perspective, hybrid modelling approaches such as the WGP (F) and MINMAX GP (F) model can come up with alternatives that result in similar levels of income, but with considerable improvement on environmental and social performance. The WGP (F) model, in which income represents half of the total weight of criteria, was most successful in achieving this under all scenarios.

While the return to labour constraint was mentioned as an optional constraint (Eq. A12, Appendix A), it was not used in any of the analyses in this chapter. The reason for this omission is that in the Trás-os-Montes area, the actual situation is one in which the shadow price of labour is much below the going wage rate. Given this situation, the gloomy future prospects for olive farming that results when putting a value on labour opportunity costs is clearly not realistic. We have documented the effect of activating this constraint elsewhere (Fleskens and de Graaff, 2006; de Graaff et al., 2007).

It should be kept in mind that the target values attached to individual goals also influence the outcomes of simulations and act as weighting factors themselves. Comparing for example Tables 8.2 and 8.3, it becomes clear that the income target is far more ambitious than targets for many of the other goals. This has contributed to the fact that the WGP and MINMAX GP models performed differently than when target values would have been set to their ideal values. Only in the latter case, the WGP (S) model would truly have attributed no preference to goals. However, target values were not determined for the situation under the Stable scenario only (cf. Table 8.2). Under for example the Bright scenario, the income target can be actually achieved.

Further analysis using the WGP (F) model showed that from a farmer perspective current cross-compliance and AEM hardly contribute to SMOPS performance (in which farm income plays a major role). This is especially so under adverse conditions, such as the doom scenario in our study. In the doom scenario, there is thus hardly an incentive to adhere to voluntary agri-environmental schemes or to comply with cross-compliance conditions: in both cases the subsidies only marginally outweigh the costs incurred. In the bright scenario, these policy measures do make a difference for the farmer: apparently, current measures give more incentives to reduce the negative environmental impact of (intensive) farming than to enhance the positive functions of traditional agriculture or reduce the negative effects of abandonment.

From a societal perspective, a similar trend was noted. Cross-compliance has the largest effect in the doom (and stable) scenario, or – put differently – cross-compliance conditions are especially targeted to areas under extensive olive farming and abandoned olive groves that prevail under adverse conditions. Contrastingly, AEM lead especially to better SMOPS performance under the bright scenario: voluntary measures are designed to reduce negative effects of intensification rather than valorise positive functions of traditional SMOPS. This means that SMOPS under more constrained and disadvantaged positions are burdened with additional policy requirements, while those with intensification potential (under favourable conditions) are not and may opt to participate in attractive AEM schemes.

While from a farmer perspective scenarios have an important effect on SMOPS performance (the doom scenario leads to an average fulfilment of farmer objectives of only 70-75%, against 88-95% under the bright scenario), the environmental and social functions valued from a societal perspective are rather insensitive to them (in all scenarios between 70-85%). The policy instruments assessed can be improved by: a) removing substantial overlap between them; b) shifting focus of cross-compliance conditions more to intensive SMOPS, e.g. by the inclusion of IPM, or design additional conditions for them; c) shifting focus of agri-environmental measures more to extensive SMOPS or design additional measures for them, e.g. by inclusion of biodiversity aims; and d) increase incentives for farmers to adhere to or comply with the policies, for example by giving awards to ‘good’ farmers.

Chapter 9

Synthesis

9. Synthesis

9.1. The changed policy environment

In recent years, profound changes have occurred in the EU policies affecting olive farming. Production aid has been abolished and the Single Farm Payment Scheme (SPS) was introduced, effective as of 1 January 2006. The previous policy provided a strong incentive to intensify production, with negative environmental effects (Beaufoy, 2001) and unfair distribution of subsidies (Duarte et al., 2005b). Under the SPS a fixed amount per year will be paid based on olive (oil) production in the four-year reference period 1999 – 2002 (decoupling from current production). At least 60 % of entitlements would be paid directly to farmers, while the SPS provided an opportunity to reserve the remaining part of (up to) 40% of the total subsidy budget to sustain a maximum of five categories of olive orchards with important environmental or social functions in the so-called ‘national envelopes’ (EC Regulation 865/2004).

Although the EC Regulation 865/2004 thus provided an excellent opportunity to transfer part of the subsidies from intensive olive orchards (on flat and sloping land, and profitable without subsidy anyway – Metzidakis et al., 2007) to traditional SMOPS providing multiple (environmental) services, all major producing countries have decided in favour of 100% decoupling (except Spain with 95%). As a consequence all entitlements will be directly paid to farmers, and the olive support is fully integrated in the SPS. According to de Graaff et al. (2006), the partial decoupling could have contributed, among others, to the following social and environmental purposes:

- To avoid environmental harm to abandoned plantations
- To assure that traditional farmers in remote areas, with few employment opportunities, could stay in (the olive) business.
- To avoid massive abandonment and/or social isolation in such areas.
- To maintain some standards of bio-diversity and landscape management.
- To establish cost-effective soil erosion control measures on steep slopes
- To control pollution and efficient water use on irrigated SMOPS.To focus to Integrated Pest Management (IPM), and integrated systems.

Because of the choice made for total decoupling some of these purposes, in particular the environmentally oriented, can now only be achieved through agri-environmental measures or through cross-compliance requirements.

With the integration of the olive sector in the SPS, cross-compliance has become obligatory. Farmers will only receive payments provided that they comply with certain rules of good agricultural and environmental practices. In particular, cross-compliance intends to ensure that they maintain their land in good agricultural condition and comply with the standards on public health, animal and plant health, the environment and animal welfare (EC Regulation

1782/2003). If a farmer fails to comply with these rules through negligence, direct payments may be reduced by 5 – 15 %, and in case of deliberate non-compliance, payments may be reduced by at least 20 % and eventually up to 100 % (Martinez Raya, 2006). Cross compliance rules for olive orchards vary per member state or autonomous region, but include conditions on the application of tillage and irrigation, the establishment of a vegetative soil cover or strips, maintenance of terraces, prohibition of unauthorized grubbing out of trees (e.g. Andalucia: Consejería de Agricultura y Pesca, 2005 and Boja No. 1330; Basilicata: Legge Regionale No. 13 Art. 9 and Decreto 15-12-2005 No. 4432; Portugal: Despacho Normativo No. 7/2005). While direct subsidies can distort price signals and negatively affect the environment, the combination of subsidies with cross-compliance rules for conservation could be beneficial for both welfare and the environment.

Apart from recent reforms in the Common Agricultural Policy (CAP), the EU is increasingly stressing the need for sustainable development in all its facets, most recently extending its attention towards a thematic strategy for soil protection, which was adopted in 2006 (CEC, 2002; 2006). This may be illustrative of an increased awareness of environmental problems, and the role human interference in general and agriculture in particular play in exacerbating these problems.

The Olivero project’s initial intention was to contribute to a more environmentally sustainable and socially equitable policy. With the incorporation of the common market organization for olive oil in the SPS (EC Regulation 865/2004), a new policy effective until at least 2013 was a fact. Where the new regulation left scope for national governments to develop measures to tackle environmental and social issues, all countries opted for (almost) total decoupling of subsidies. Hence, the project’s ambitions had to be adjusted, and now mainly concern recommendations on how to accomplish cross-compliance (i.e. the minimum set of good agricultural practices that farmers need to adhere to in order to be eligible for the single farm payment subsidies), and what additional measures beyond good agricultural practices (known as agri-environmental measures) could be developed or continued.

In spite of these changes in the policy context, the Olivero project managed to deliver the expected outcome. The key-results of the project are to be presented in a Special Issue of the Journal of Environmental Management (Fleskens and de Graaff, 2007). Many of the projects’ deliverables are available for download from its web-site: www.olivero.info, where also references to other published materials can be found, along with further information on the project, its methodologies and its participants.

With regard to the objectives of this thesis (Section 1.5) the policy environment plays an enabling role. Conceptually, the changed context is not important, but it does influence the capacity of SMOPS to fulfil multiple functions, and stakeholder preferences for each type of function.

9.2. What functions of olive orchards are worth conserving?

Olive production systems on sloping land occur in a wide variety. These systems have different characteristics. In Chapter 3, a selection of these characteristics was used to classify SMOPS according to an intensity of production gradient. Some characteristics are structural features (i.e. tree density, terraces) while others are management practices (i.e. land husbandry and crop management). Changing of structural features often requires an investment (or disinvestment), and may result in a gradual shift from one SMOPS type to another. Management practices can generally be altered more easily, although some require investment as well (mechanisation, irrigation). Without accompanying investments, alteration of management practices rarely results in a shift from one SMOPS to another.

The whole of structural features and management practices determines the SMOPS' resource use patterns and performances on multiple criteria. In Chapter 5, resource use patterns and performances are reshuffled into multiple functions, with functions defined as the capacity of SMOPS to produce goods and services, taking into account negative (environmentally harmful) aspects as well (OECD, 2001). Defining SMOPS as (parts of) agro-ecosystems in a broad sense, i.e. including the socio-economic dimension (sensu Conway, 1987) – five function categories can be distinguished: ecological, productive, economic, social and cultural functions, each of which may contain multiple functions itself.

The valuation of functions is a question of the decision-makers interests. The perspective of the decision-maker is in turn influenced by the context in which he/she operates. Prioritisation of functions is therefore dependent on the context. A brief conceptual history of the recent past shows that from the 1950's to the 1970's, an increasing specialisation of agricultural production took place. A strong preference for productive functions was evident, as witnessed by agronomical research to augment productivity, the search for economies of scale and the incorporation of farming in production columns. In this rat race, few won and many lost. For the case of olive cultivation, the disadvantaged position of many SMOPS became apparent starting in the 1980's. For those SMOPS operating in the margin, a need to diversify income generating activities emerged. Economic functions were at the forefront. It was simultaneously more and more realised that the sole focus on production led to associated environmental problems. As a consequence of this awareness, the post-productivism paradigm evolved (Wilson, 2001), with increased attention to ecological functions, more in particular witnessed by an effort to reduce the negative externalities of agricultural production. Renewed interest in rural areas contributed to redefining the role of agriculture as inherently multifunctional. In this paradigm, objectives are not confined to reducing negative externalities, but also to enhance positive contributions of agriculture to public goods and services, including social and cultural functions.

To answer the question what functions of SMOPS are worth conserving, we need to take a broad perspective. Several factors play a role:

- The type of SMOPS; traditional SMOPS have other qualities than intensive SMOPS. Chapter 4 shows that traditional SMOPS have a high biodiversity and, considering that they are at risk of abandonment, help to control wildfire risk and provide social and cultural functions, such as employment.
- The regional environment; Chapter 5 includes a case study on functions of SMOPS in the Trás-os-Montes region, Portugal. Other regions surely present different situations, as briefly sketched in Chapter 1.
- The driving forces; where the context of olive farming is changing rapidly, there may be a high threat to qualities of certain systems and/or to further deteriorating SMOPS performance. For example, both when traditional SMOPS will be intensified or abandoned, the specific characteristics of these systems (e.g. high biodiversity) are worth conserving.
- The possibility to respond to these changes; the opportunity to conserve functions depends on the direction of development: wildfire control of traditional SMOPS can obviously more easily be conserved when intensifying or maintaining production, but is harder to maintain when traditional SMOPS will be abandoned. Vice versa, biodiversity and soil conservation are more easily achieved when olive cultivation is discontinued than when it is intensified.
- The decision maker; each decision-maker has certain preferences and is bound by preconditions set by stakeholders at different hierarchical levels. Regional and national policies require decision-makers at the local level to take certain measures (e.g. for wildfire control or soil conservation), but vice versa, there are also objectives set at higher hierarchical levels that require the cooperation of farmers (landscape value).

Whether functions are worth conserving is to large extent dependent on stakeholder preferences. However, scientific insights in the ecological processes that occur in olive groves may help establish minimum sustainability criteria for SMOPS. A second role of science is facilitating the monitoring of functions of olive orchards by developing useful indicators. Chapter 6 demonstrates that this is not a trivial task: the soil conservation function of olive groves varies across temporal and spatial scales. This variability is impossible to capture by a single indicator. An additional potential role of science is analyzing performance of SMOPS under various circumstances, and to assist decision-makers in making the right choices for conserving the functions of SMOPS facing an uncertain future.

9.3. Defining conservation scenarios

The functions of SMOPS (and other agro-ecosystems) are not static characteristics: they tend to change with their context. Scenario studies are a suitable tool to explore possible trends under variable circumstances (i.e. van Ittersum et al., 1998; Rabbinge and van Diepen, 2000). In Chapters 7 and 8, scenario simulation modelling was applied to assess the influence of wage rates, olive oil market prices and subsidy levels on SMOPS distribution and selected indicators of SMOPS performance. Chapter 7 thereby explored the effects of various combinations of these external factors – from the perspective of the olive producer named the Stable, Bright, Doom and Bleak market scenario respectively. For some olive producing areas, the effects of these combinations of external factors are huge (e.g. Trás-os-Montes), while for others they are relatively unimportant (e.g. Granada/Jaèn).

When we introduce in the scenarios elements of choice to deliberately enhance positive non-productive functions and/or reduce negative impact, we can speak of an attempt to arrive at conservation scenarios. This approach was used in Chapter 8, where the effects of different combinations of cross-compliance and agri-environmental measures were explored. Both policy measures have environmental aims. The question is however, when a scenario can truly be called a conservation scenario. The 'action' scenario should thereto be compared to the scenario without intervention. An 'action' scenario reaching substantially better performance on environmental, social and cultural criteria while not (importantly) compromising economic performance is then clearly to be preferred above non-intervention. However, this should not be the case for just one scenario (combination of external factors), but for all. The reason is that external factors are beyond the decision-maker's control, and providing for variable changes to the context will serve as a sensitivity analysis for the decision-maker's instruments being evaluated.

A good way to define conservation scenarios is to resort to the House of Functions of Chapter 5. In Figure 9.1, three management options are compared on their fulfilment of the various functions (sides of the houses) under the four scenarios distinguished. The larger a (side of a) house, the better a function is realized. Position of the houses to the left or right indicates relative importance between productive and cultural functions. Gaps occur when there are important discrepancies in fulfilment of different functions. If we compare the three management options, we may notice the following:

- "Laissez faire" (management option 1) results in an average fulfilment of functions that varies with the scenarios. Although in most scenarios functions are more or less equilibrated, in the bright scenario productive and economic functions improve greatly but ecological performance is very poor. "Laissez faire" represents the case without specific intervention for the conservation or enhancement of ecological, social and cultural functions; perhaps, it involves measures stimulating production. Economic functions seem to be coupled to productive functions.
- "Strict environmental compliance" (management option 2) stands out for its good performance on ecological functions. However, it fails to provide economic functions. This option is thereby especially successful in improving ecological functions in the doom scenario, but a large gap in the roof results from the low score on economic functions. Only in the

bright scenario the economic functions are more balanced with performance of other functions. While this option enhances ecological and – to a lesser extent – social and cultural functions, it cannot sustain performance of economic functions and can therefore not be considered a conservation scenario.

- "Stimulating multifunctionality" (management option 3) overall results in the most balanced functions, leaving the smallest gaps in respective houses. Besides the most equilibrated performance per scenario, it also results in the least differences between individual functions under the different scenarios. Compared to the case without intervention, the third option enhances ecological and social (and productive) functions, while not having important repercussions on the fulfilment of economic and cultural functions. It is therefore an example of a conservation scenario.

The visual exercise detailed above can also be analyzed with different formulations of the decision-making problem, as was shown in Chapter 8. The "laissez faire" management option would then result from an optimization of economic functions. An LP or WGP model with weights emphasizing economic functions would be suitable. The "strict environmental compliance" management option results from maximizing total achievement, with all functions (here: function categories) considered equally important. This can be simulated with a WGP model with (implicit) equal weights to all functions. In this particular case, it appears that chances that economic functions will be sufficiently developed are small: apparently there are important trade-offs between economic and ecological functions. The third management option ("stimulating multifunctionality") can be simulated with a MINMAX GP model minimizing the largest deviation from the desired performance (or with a WGP model if trade-offs are less important than in this example).

The success of defining conservation scenarios depends on the quality of indicators used. If for example soil conservation is assessed by the indicator 'percentage soil cover during winter months' (being a means-based indicator following van der Werf and Petit, 2002), soil conservation methods based on judicious use of tillage as suggested in Chapter 6 will not lead to improved ecological performance and will – as a consequence – not be adopted. While this thesis did not intend to develop indicators, it does provide a strong argument to be very careful with the use of means-based indicators, as it may obscure potential solutions that are equally effective or even better than the prescribed one.

Conservation scenarios should appeal to, or at least be acceptable to, stakeholders at all levels. While the final choices will clearly be the result of a political decision-making process, the scenario approach and its presentation in easy to understand houses of functions is potentially an appealing method to delineate the room for negotiations. Thereby, it can be reiterated time and time again if the context changes, when new scientific insights are gained, or when stakeholder objectives alter.

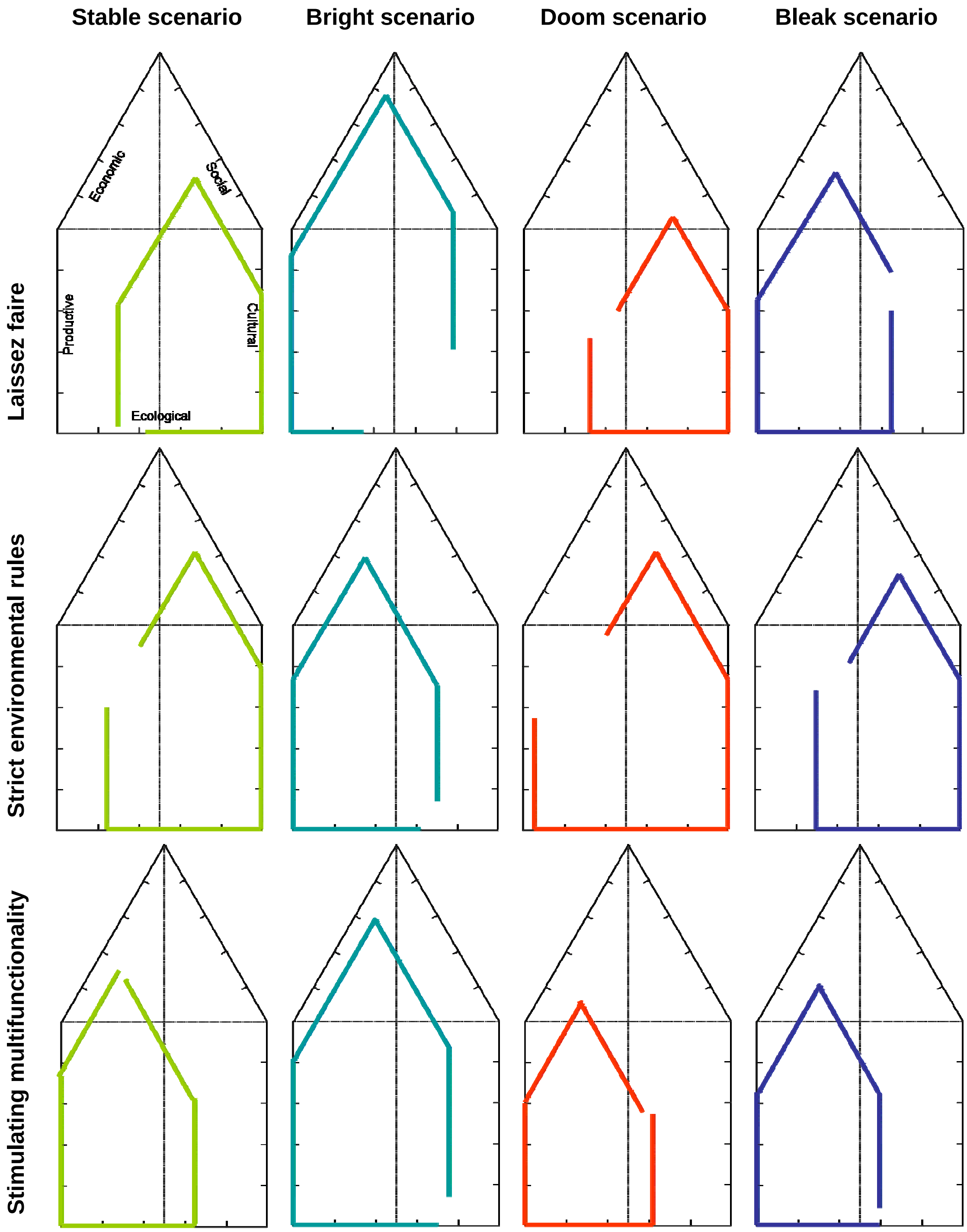


Figure 9.1. A comparison of the performance of SMOPS under three (hypothetical) management options and four scenarios.

9.4. Conservation scenarios as an adaptive management strategy

In the previous section, I showed how conservation scenarios can be a powerful tool in planning environmental management, or – in a broader context – the preservation or promotion of multifunctional agriculture. The external factors taken into account in this thesis were limited to prices of labour and olive oil, and subsidies under the SPS. By increasing the number of external factors, SMOPS' sensitivity and management strategies can be assessed in a wider perspective. In Chapter 7 several external factors were mentioned; they are also expressed in more detail in Fleskens and de Graaff (2006). Climatic change is one of those external factors that could in the long run have significant effects. Schröter et al. (2006) foresee important consequences for Mediterranean areas. Combined effects of rising temperatures and decreasing rainfall could lead to higher wildfire risk and increased threats to biodiversity. Rainfall erosivity could increase, which – when falling on orchard soils less well covered due to generally drier conditions – could exacerbate land degradation problems. Water resources could become scarcer, rendering irrigation more difficult. The ecological functions of SMOPS would, under such circumstances, become more constrained.

In the approach taken, climate change could be included in the assessment. If 3 – 4 climate change scenarios would be developed and juxtaposed on the four market scenarios, 12 – 16 new combined market/climate scenarios would result. This number could in turn be reduced to 4 – 6 (being more convenient for scenario analysis, while allowing for the elimination of scenarios that lead to very similar outcomes). By assessing which kinds of management alternatives best safeguard the performance of SMOPS under the respective market/climate scenarios, we can select those resulting in conservation scenarios as the best management options.

Fully acknowledging that decisions need to be made in a rapidly changing context that is not perfectly understood and with highly dynamic stakeholder objectives, conservation scenarios offer a tool to integrate the newest scientific findings, technological innovations and political decision-making issues. In this way, conservation scenarios may be a tool for adaptive management (Holling, 1978).

While demonstrated for the case of olive farming on sloping land, conservation scenarios could be applied to many areas where preferentially informed decisions need to be made. As long as *Oikos* is our home and we do not intend to move, we better build on a solid foundation of knowledge, under a roof of economic welfare and social protection, using building blocks produced with innovative power, while nourishing what's worth conserving and keeping a window of opportunity open for the future.

References

Abler D. 2001. A synthesis of country reports on jointness between commodity and non-commodity outputs in OECD agriculture. Workshop on multifunctionality. Paris, 2-3 July 2001. OECD, Paris.

Agronoticias. 2005. UE / Incêndios : Portugal é o país com mais incêndios nos últimos 25 anos. http://www.agroportal.pt/x/agronoticias/2005/01/25e.htm.

Allen HD, Randall RE, Amable GS, Devereux, BJ. 2006. The impact of changing olive cultivation practices on the ground flora of olive groves in the Messara and Psiloritis regions, Crete, Greece. *Land Degradation & Development* **17**: 249-273.

Allen RG, Pereira LS, Raes D, Smith M. 1998. Crop evapotranspiration - Guidelines for computing crop water requirements. *FAO Irrigation and drainage paper* ***56***. FAO, Rome.

Alonso Mielgo AM, Sevilla Guzmán E, Jiménez Romera M, Gúzman Casado G. 2001. Rural development and ecological management of endogenous resources: the case of mountain olive groves in Los Pedroches comarca (Spain). *Journal of Environmental Policy and Planning* **3**: 163-175.

Andersen E, Verhoog AD, Elbersen BS, Godeschalk FE, Koole B. 2006. A multidimensional farming systems typology. SEAMLESS Report No. 12. Wageningen University, Wageningen. Available from http://www.seamless-ip.org/Reports.htm.

Angles S. 1999. The changes in the olive-growing geography of Andalusia. *Olivae* **78**: 12-22.

Arhonditsis G, Giourga C, Loumou A. 2000. Ecological patterns and comparative nutrient dynamics of natural and agricultural Mediterranean-type ecosystems. *Environmental Management* **26**: 527-537.

Aspizua R. 2003. Erosion assessment and conservation measures in sloping and mountainous olive production systems in Andalucía. MSc Thesis Wageningen University. Olivero Student Report Series No. 2. Available from http://www.olivero.info

Baldock D, Beaufoy G, Brouwer F, Godeschalk F. 1996. Farming at the margins: abandonment or redeployment of agricultural land in Europe. Institute for European Environmental Policy, London / Agricultural Economics Research Institute, The Hague.

Baldy C. 1997. Systèmes traditionnels d'arboriculture et conservation des sols dans le bassin méditerranéen. *Cahiers Agricultures* **6**: 31-44.

BBO. 1999. New functions, new partnerships. Searching for common ground in land use negotiations; A vision from NGO's on the multifunctional character of land and agriculture. Report to be presented at the FAO Conference on the Multifunctional Character of Land and Agriculture, Maastricht, 12-17 September 1999. Bureau Beleidsvorming Ontwikkelingssamenwerking, The Hague, Netherlands.

Beaufoy G, Baldock D, Clark J. 1994. The nature of farming: low-intensity farming systems in nine European countries. Institute for European Environmental Policy, London.

Beaufoy G. 1998. La Reforma del Régimen Olivarero de la PAC. Qué implica para el Medio Ambiente? European Forum on Nature Conservation and Pastoralism, Peterborough, UK. Occasional Publication Number 14 (Es).

Beaufoy G. 2000. The olive oil regime. In: Brouwer F, Lowe P (Eds), CAP regimes and the European countryside. CABI Publishing, Wallingford. pp 155-178.

Beaufoy G. 2001. The environmental impact of olive oil production in the European Union: practical options for improving the environmental impact. European Forum on Nature Conservation and Pastoralism / Asociación para el Análisis y Reforma de la Política Agro-rural, Peterborough, UK.

Bellon S, Lescourret F, Calmet JP. 2001. Characterisation of apple orchard management systems in a French Mediterranean Vulnerable Zone. *Agronomie* **21**: 203-213.

Bielsa I, Pons X, Bunce B. 2005. Agricultural abandonment in the North Eastern Iberian Peninsula: the use of basic landscape metrics to support planning. *Journal of Environmental Planning and Management* **48**: 85-102.

Bignal E, McCracken D. 1996. Low-intensity farming systems in the conservation of the countryside. *Journal of Applied Ecology* **33**: 413-424.

Bonazzi M. 1997. Euro-Mediterranean policies and olive oil: competition vs. job-sharing. *Olivae* **65**: 16-20.

Bosshard A. 2000. A methodology and terminology of sustainability assessment and its perspectives for rural planning. *Agriculture, Ecosystems & Environment* **77**: 29-41.

Bouma F, van der Ploeg SWF. 1975. Functies van de natuur: een economisch-oecologische analyse. Instituut voor Milieuvraagstukken, Vrije Universiteit, Amsterdam.

Brandt J, Vejre H. 2004. Multifunctional landscapes - motives, concepts and perspectives. In: Brandt J, Vejre H (Eds), Multifunctional Landscapes Vol. I: Theory, Values and History. WIT Press, Southampton / Boston. pp. 3-31.

Brooke A, Kendrick D, Meeraus A, Raman R. 1998. GAMS: a user’s guide. GAMS Development Corporation, Washington.

Brouwer A. 2005. Towards scenarios for Sloping and Mountainous Olive Plantation Systems (SMOPS); examples from Italy and Portugal. MSc Thesis Wageningen University.

Brouwer F, Lowe P. 2000. CAP and the environment: policy development and the state of research. In: Brouwer F, Lowe P (Eds), CAP regimes and the European countryside. CABI Publishing, Wallingford. pp. 1-14.

Bruggeman A, Masri Z, Turkelboom F. 2005. Strategies to sustain productivity of olive groves on steep slopes in the northwest of the Syrian Arab Republic. In: Benites J, Pisante M, Stagnari F (Eds), Integrated soil and water management for orchard development; role and importance. *FAO Land and Water Bulletin* **10**. FAO, Rome, Italy, pp. 75-87.

Caraveli H. 2000. A comparative analysis on intensification and extensification in mediterranean agriculture: dilemmas for LFAs policy. *Journal of Rural Studies* **16**: 231-242.

Cardenas M, Ruano F, Garcia P, Pascual F, Campos M. 2006. Impact of agricultural management on spider populations in the canopy of olive trees. *Biological Control* **38**: 188-195.

Carey PD, Manchester SJ, Firbank LG. 2005. Performance of two agri-environment schemes in England: a comparison of ecological and multi-disciplinary evaluations. *Agriculture, Ecosystems & Environment* **108**: 178-188.

Carvalho TMM, Coelho COA, Ferreira AJD, Charlton CA. 2002. Land degradation processes in Portugal: farmers' perceptions of the application of European agroforestry programmes. *Land Degradation & Development* **13**: 177-188.

Castro C, Guerreiro M, Caldeira F, Pinto P. 1997. The olive oil sector in Portugal: general aspects. *Olivae* **66**: 12-19.

Castro G, Romero P, Gómez JA, Fereres E. 2006. Rainfall redistribution beneath an olive orchard. *Agricultural Water Management* **86**: 249-258.

van Cauwenbergh N, Biala K, Bielders C, Brouckaert V, Franchois L, Garcia Cidad V, Hermy M, Mathijs E, Muys B, Reijnders J. 2007. SAFE – A hierarchical framework for assessing the sustainability of agricultural systems. *Agriculture, Ecosystems & Environment* **120**: 229-242.

CEC. 1992. CORINE soil erosion risk and important land resources in the southern regions of the European Community: an assessment to evaluate and map the distribution of land quality and soil erosion risk. Office for Official Publications of the European Communities, Luxembourg.

CEC. 1997. Note to the council of ministers and to the European parliament on the olive and olive oil sector (including economic, cultural and social and environmental aspects), the current common market organisation, the need for a reform and the alternatives envisaged. COM (97) 57 final. Commission of the European Communities, Brussels.

CEC. 2000. Indicators for the integration of environmental concerns into the Common Agricultural Policy. COM (2000) 20 final. Commission of the European Communities, Brussels.

CEC. 2002. Towards a thematic strategy for soil protection. COM (2002) 179 final. Commission of the European Communities, Brussels.

CEC. 2006. Communication from the commission to the council, the European parliament, the European Economic and Social Committee and the committee of the regions. Thematic Strategy for Soil Protection. COM (2006) 231 final. Commission of the European Communities, Brussels.

Cerdà A. 2001. Effects of rock fragment cover on soil infiltration, interrill runoff and erosion. *European Journal of Soil Science* **52**: 59-68.

Cilenti . 1998. The olive oil sector in Italy: how it looks. *Olivae* **73**: 12-15.

Cirio U. 1997. Agrichemicals and environmental impact in olive farming. *Olivae* **65**: 32-39.

Clark JRA. 2005. The 'New Associationalism' in agriculture: agro-food diversification and multifunctional production logics. *Journal of Economic Geography* **5**: 475-498.

Clergue B, Amiaud B, Pervanchon F, Lasserre-Joulin F, Plantureux S. 2005. Biodiversity: function and assessment in agricultural areas. A review. *Agronomy for Sustainable Development* **25**: 1-15.

Conway GR. 1987. The properties of agroecosystems. *Agricultural Systems* **24**: 95-117.

Council Regulation (EC) nº 1698/2005 of 20 September 2005. *Official Journal of the European Union* nº **L 277** of 21 October 2005, 0001-0040.

Council Regulation (EC) nº 1782/2003 of 29 September 2003. *Official Journal of the European Union* nº **L 270** of 21 October 2003, 0001-0069.

Council Regulation (EC) nº 864/2004 of 29 April 2004. *Official Journal of the European Union* nº **L 161** of 30 April 2004, 0048-0096.

DEASR. 2004a. Contribution to deliverable no. 7: overview of productive, ecological, economic and social functions of different types of olive orchards. In: Metzidakis IE (Ed.), An overview of productive, ecological, and socio-economic functions of SMOPS. Olivero Project Communication No. 2. Chania. pp. 61-77.

DEASR. 2004b. Contribution to deliverable no. 6: maps of different types of SMOPS in major production countries in southern Europe. In: Metzidakis IE (Ed.), Maps of different types of SMOPS in major production countries in southern Europe. Olivero Project Communication No. 1. Chania. pp. 35-53.

DG/PDIA. 1995. Annuaire des statistiques agricoles 1993. Ministère de l'agriculture, Tunis.

DGPA/ONH. 1996. Olive farming in Tunisia. *Olivae* **61**: 12-20.

DGRF. 2005. Estatísticas nacionais de incêndios florestais. Totais por Concelho (1980 - 2004). Direcção Geral de Recursos Florestais, MADER, Lisbon. Available from : *http://www.dgrf.min-agricultura.pt/v4/dgf/pub.php?ndx=1467*

Duarte F (Ed.). 2005a. Overview of financial farm management data in project areas by farm type and zone. Olivero Working Paper nº 2.

Duarte F (Ed.). 2005b. Review of the effects of alternative subsidies and other policy measures. Olivero Project Communication nº 8. Available from *http://www.olivero.info*

Duarte F (Ed.). 2005c. Overview of olive oil marketing and processing and olive sector organisation. Olivero Project Communication nº 7. Available from http://www.olivero.info

Duarte F, Jones N, Fleskens L. 2007. Traditional olive orchards on sloping land: sustainability or abandonment. *Journal of Environmental Management* (in press)

Duarte F, Jones N, Lúcio C, Nunes A. 2006. The reform of the olive oil regime and its impacts on the olive and olive oil sector: a case study in Northern Portugal – Trás-os-Montes. *New Medit* **2**: 4-15.

Duarte F, Jones N, Lúcio C. 2004. Tipologia e Funções dos Sistemas de Produção Olivícola em Trás-os-Montes. In: Proceedings of IV Congresso Nacional de Economistas Agrícolas, Faro.

Dunjó G, Pardini G, Gispert M. 2003. Land use change effects on abandoned terraced soils in a Mediterranean catchment, NE Spain. *Catena* **52**: 23-37.

Eicher I. 2005. Olive cultivation and nature conservation in the Rio Douro valley – future options for traditional olive plantation systems on steep slopes in the International Douro Nature Park, Portugal. MSc Thesis Wageningen University. Olivero Student Report Series nº 5. Available from *http://www.olivero.info*

European Commission. 2003. Agriculture DG VI Fact Sheets: Agriculture and Environment. Available from *http://ec.europa.eu/agriculture/publi/fact/envir/2003_en.pdf*

European Economy. 1997. Towards a Common Agricultural and Rural Policy for Europe. Reports and Studies Vol. 5. Directorate-General for Economic and Financial Affairs, Brussels.

European Union. 2003. The olive oil sector in the European Union. Available from *http://europa.eu.int/comm/agriculture/publi/fact/oliveoil/2003_en.pdf*

European Union. 2005. The Single Payment Scheme (SPS); the olive oil and table olives sector. Available from *http://europa.eu.int/comm/agriculture/capreform/infosheets/olive_en.pdf*

Evans N, Morris C, Winter M. 2002. Conceptualizing agriculture: a critique of post-productivism as the new orthodoxy. *Progress in Human Geography* **26**: 313-332.

FAO, 2006. FAOSTAT, Agricultural statistics. FAO, Rome. *http://www.fao.org*

FAOSTAT. 2001. FAO Statistical Databases. *http://www.fao.org*

Fernández JE, Moreno F. 1999. Water use by the olive tree. In: Kirkham MB (Ed.), Water use in crop production. The Haworth Press, Binghamton NY. pp 101-162.

de Figueiredo T, Almeida A, Araujo J, Martelli GP. 2002. Edaphic characteristics of olive-tree areas in the Tras-os-Montes Region (Portugal): a map-based approach. In: Vitagliano C (Ed.), Proceedings of the 4th International Symposium on Olive Growing, 25-30 September, 2000. Valenzano, Italy. pp. 151-154.

Fleskens L, de Graaff J (Eds). 2007. A sustainable future for olive production on sloping land? *Journal of Environmental Management* (in press)

Fleskens L, de Graaff J. 2001. Soil conservation options for olive orchards on sloping land. In: L Garcia-Torres L, Benites J, Martinez-Vilela A (Eds), Conservation Agriculture, a worldwide challenge; I World Congress on Conservation Agriculture (Vol. II). XUL, Cordoba. pp. 231-235.

Fleskens L, de Graaff J. 2003. Soil conservation options for olive orchards on sloping land. In: Garcia Torres L, Benites J, Martinez Vilela A, Holgado-Cabrera A (Eds), Conservation Agriculture: Environment, Farmers Experiences, Innovations, Socio-Economy, Policy. Kluwer Academic Publishers, Dordrecht. pp. 381-385.

Fleskens L, de Graaff J. 2006. Future scenarios for olive production systems on sloping land: stakeholder and expert opinions and results from a LP simulation model. Olivero Project Communication nº 13. Available from http://www.olivero.info

Fleskens L, Duarte F, Eicher I. 2007. A conceptual framework for the assessment of multiple functions of agro-ecosystems: a case study of Trás-os-Montes olive groves. *Ecology and Society* (submitted).

Fleskens L, Stroosnijder L, Ouessar M, de Graaff J. 2005. Evaluation of the on-site impact of water harvesting in southern Tunisia. *Journal of Arid Environments* **62**: 613-630.

Fleskens L, Stroosnijder L. 2007. Is soil erosion in olive groves as bad as often claimed? *Geoderma* (in press).

Fleskens L. 2005. Overview of production costs for Sloping and Mountainous Olive Plantation Systems (SMOPS) under different circumstances. Olivero Working Paper No. 3. Wageningen.

Fleskens L. 2007. A typology of sloping and mountainous olive plantation systems to address natural resource management. *Agricultural Systems* (submitted).

Francia Martínez JR, Durán Zuazo VH, Martínez Raya A. 2006. Environmental impact from mountainous olive orchards under different soil-management systems (SE Spain). *Science of The Total Environment* **358**: 46-60.

Francia Martínez JR, Martínez Raya A, Ruiz Gutiérrez S. 2000. Erosión en suelos de olivar en fuertes pendientes. Comportamiento de distintos manejos de suelo. *Edafología* **7**: 147-155.

Fuller AM. 1990. From part-time farming to pluriactivity: a decade of change in Rural Europe. *Journal of Rural Studies* **6**: 361-373.

Gálvez M, Parra MA, Navarro C. 2004. Relating tree vigour to the soil and landscape characteristics of an olive orchard in a marly area of southern Spain. *Scientia Horticulturae* **101**: 291-303.

Giráldez JV, Carrasco C, Otten A, Ietswaart H, Laguna A, Pastor M. 1990. The control of soil erosion in olive orchards under reduced tillage. In: Coutinho MA, Tomás PP (Eds), Proceedings of the seminar on the interaction between agricultural systems and soil conservation in the Mediterranean belt, September 4-8, 1990. European Society for Soil Conservation, Oeiras, Portugal.

Gómez JA (Ed.). 2005. Assessment of land degradation in project olive areas, with on- and off-site effects. Olivero Project Communication nº 6. Available from http://www.olivero.info

Gómez JA, Amato M, Celano G, Koubouris G. 2007. Organic olive orchards on sloping land: more than a specialty niche? *Journal of Environmental Management* (in press).

Gómez JA, Battany M, Renschler CS, Fereres E. 2003. Evaluating the impact of soil management on soil loss in olive orchards. *Soil Use and Management* **19**: 127-134.

Gómez JA, Giráldez JV, Fereres E. 2001. Analysis of infiltration and runoff in an olive orchard under no-till. *Soil Science Society of America Journal* **65**: 291-299.

Gómez JA, Giráldez JV, Fereres E. 2003. Impact on runoff and soil erosion of soil management in olive orchards in Southern Spain. In: Gabriels D, Cornelis W. (Eds), 25 years of assessment of erosion. Ghent University, Ghent. pp. 505-510.

Gómez JA, Giráldez JV, Fereres E. 2005. Water erosion in olive orchards in Andalusia (Southern Spain): a review. *Geophysical Research Abstracts* **7**, 08406.

Gómez JA, Giráldez JV, Pastor M, Fereres E. 1999. Effects of tillage method on soil physical properties, infiltration and yield in an olive orchard. *Soil & Tillage Research* **52**: 167-175.

Gómez JA, Romero P, Giráldez JV, Fereres E. 2004. Experimental assessment of runoff and soil erosion in an olive grove on a Vertic soil in southern Spain as affected by soil management. *Soil Use and Management* **20**: 426-431.

Gómez-Sal A, Belmontes JA, Nicolau JM. 2003. Assessing landscape values: a proposal for a multidimensional conceptual model. *Ecological Modelling* 168: 319-341.

Gouveia J M B, Soeira A. 1997. Protected designations of origin for olive oils in Portugal. *Olivae* **66**: 25-27.

Govers G, van Oost K, Poesen J. 2006. Responses of a semi-arid landscape to human disturbance: A simulation study of the interaction between rock fragment cover, soil erosion and land use change. *Geoderma* **133**: 19-31.

Govers G, Vandaele K, Desmet P, Poesen J, Bunte K. 1994. The role of tillage in soil redistribution on hillslopes. *European Journal of Soil Science* **45**: 469-478.

GPPAA. 2000. Portugal - Panorama Agricultura 1999. Gabinete de Planeamento e Política Agro-Alimentar, Lisbon.

GPPAA. 2002. Portugal Rural: Territórios e Dinâmicas. Gabinete de Planeamento e Pólitica Agro-Alimentar, Lisbon.

de Graaff J (Ed.). 2005. Perspectives of different types of Sloping and Mountainous Olives Plantation Systems (SMOPS). Olivero Working Paper nº 4. Available from *http://www.olivero.info*.

de Graaff J, Duarte F, Fleskens L, de Figueiredo T. 2006. Cross-compliance for erosion control in olive orchards on sloping land. In: de Graaff J, Kessler CA, Riksen M (Eds), Farm level adoption of soil and water conservation measures and policy implications in Europe. COST 634 Meeting, 1-3 October 2006, Wageningen, The Netherlands.

de Graaff J, Durán Zuazo VH, Jones N, Fleskens L. 2007. Olive production systems on sloping land: prospects and scenarios. *Journal of Environmental Management* (in press).

de Graaff J, Eppink LAAJ. 1999. Olive oil production and soil conservation in southern Spain in relation to EU subsidy policies. *Land Use Policy* **16**: 259-267.

de Graaff J, Ouessar M (Eds). 2002. Water harvesting in Mediterranean zones: an impact assessment and economic evaluation; proceedings from EU WAHIA project final seminar in Lanzarote. *Tropical Resource Management Papers* No. **40**. Wageningen University, Wageningen.

de Graaff J. 1996. The price of soil erosion: an economic evaluation of soil conservation and watershed development. Doctoral Thesis Wageningen Agricultural University.

de Groot RS, Wilson MA, Boumans RMJ. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* **41**: 393-408.

de Groot RS. 1992. Functions of nature; evaluation of nature in planning, management and decision making. Wolters-Noordhoff, Groningen.

Grove AT, Rackham O. 1993. Threatened landscapes in the Mediterranean: examples from Crete. *Landscape and Urban Planning* **24**: 279-292.

Guzmán Álvarez JR. 1999. Olive cultivation and ecology: the situation in Spain. *Olivae* **78**: 41-49.

Hall C, McVittie A, Moran D. 2004. What does the public want from agriculture and the countryside? A review of evidence and methods. *Journal of Rural Studies* **20**: 211-225.

Harvey DR. 2003. Agri-environmental relationships and multi-functionality: further considerations. *World Economy* **26**: 705-725.

Haynes M. 1999. Marketing for Farm and Rural Enterprise. Farming Press, Ipswich, UK.

Hein L, van Koppen K, de Groot RS, van Ierland EC. 2006. Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics* **57**: 209-228.

Hernandez AJ, Lacasta C, Pastor J. 2005. Effects of different management practices on soil conservation and soil water in a rainfed olive orchard. *Agricultural Water Management* **77**: 232-248.

Herweg K. 1996. Field manual for assessment of current erosion damage. Soil Conservation Research Programme, Ethiopia / Centre for Development and Environment, University of Berne, Berne, Switzerland.

Hodge I. 2000. Agri-environmental relationships and the choice of policy mechanism. *World Economy* **23**: 257-273.

Hofmeister B. 1971. Four types of agriculture with predominant olive growing in southern Spain – a case study. *Geoforum* **8**: 15-30.

Holling CS (Editor). 1978. Adaptive environmental assessment and management. John Wiley & Sons, Chichester, UK.

ICONA. 1991. La erosión en España. Síntesis. Ministerio de Agricultura, Pesca y Alimentacíon, Madrid.

IDRHa. 2003. Azeite de Trás-os-Montes: Denominação de Origem Protegida. Avaliable from http://www.idrha.min-agricultura.pt/produtos_tradicionais/azeites/azeite_de_tm.htm

IDRHa. 2004. Medidas agro-ambientais. Instituto de Desenvolvimento Rural e Hidraúlica, Lisbon.

IDRHa. 2005. Produtos tradicionais com nomes protegidos; apresentação de dados sobre produção, preços e comercialização 2002. Instituto de Desenvolvimento Rural e Hidráulica, Lisbon.

INE. 2001. Recenseamento Geral da Agricultura 1999. Principais Resultados Tras-os-Montes. Instituto Nacional da Estatística Portugal, Lisbon. Available from *http://www.ine.pt*.

INE. 2001. Recenseamento Geral da Agricultura 1999; Principais resultados por região agraria. Available at *http://www.ine.pt/prodserv/Rga/index_rga.asp*

INE. 2002. Contas Éconornicas da Agricultura 2002. Instituto Nacional da Estatística Portugal, Lisbon. http://www.ine.pt.

IOOC. 2006. International Olive Oil Council. http://www.internationaloliveoil.org/

ISTAT. 2001. Dati congiunturali sulle coltivazioni. Available from http://www.istat.it/Primpag/datiagri/ anno2000.htm

van Ittersum MK, Rabbinge R, van Latesteijn HC. 1998. Exploratory land use studies and their role in strategic policy making. *Agricultural Systems* **58**: 309-330.

Jacoboni A, Acciardi A, Rufini E. 1990. Some aspects of olive growing in Calabria. *Olivae* **30**: 28-37.

Janssen S, van Ittersum MK. 2007. Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems* (in press).

Jollands N. 2006. How to aggregate sustainable development indicators: a proposed framework and its application. *International Journal of Agricultural Resource Governance and Ecology* **5**: 18-34.

Kabourakis E. 1996. Prototyping and dissemination of ecological olive production systems; a methodology for designing and a first step towards validation and dissemination of prototype ecological olive production systems (EOPS) in Crete. PhD dissertation Wageningen Agricultural University.

Kabourakis E. 1999. Code of practices for ecological olive production systems in Crete. *Olivae* **77**: 35-45.

Kaljonen M, Rikkonen P. 2004. Divergent images of multifunctional agriculture: a comparative study of the future images between farmers and agri-food experts in Finland. *International Journal of Agricultural Sustainability* **2**: 190-204.

Kamphorst A. 1987. A small rainfall simulator for the determination of soil erodibility. *Netherlands Journal of Agricultural Science* **35**: 407-414.

Kleijn D, Baquero RA, Clough Y, Diaz M, Esteban J, Fernandez F, Gabriel D, Herzog F, Holzschuh A, Johl R, Knop E, Kruess A, Marshall EJP, Steffan-Dewenter I, Tscharntke T, Verhulst J, West TM, Yela JL. 2006. Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecology Letters* **9**: 243-254.

Kleijn D, Sutherland WJ, 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology* **40**: 947-969.

Knickel K, Renting H. 2000. Methodological and Conceptual Issues in the Study of Multifunctionality and Rural Development. *Sociologia Ruralis* **40**: 512-528.

Knickel K. 2001. The marketing of Rhöngold milk: an example of the reconfiguration of natural relations with agricultural production and consumption. *Journal of Environmental Policy and Planning* **3**: 123-136.

Kok K, Clavaux MBW, Heerebout WM, Bronsveld K. 1995. Land degradation and land cover change detection using low-resolution satellite images and the CORINE database: a case study in Spain. *ITC Journal* **3**: 217-228.

de Koning GHJ, Verburg PH, Veldkamp A, Fresco LO. 1999. Multi-scale modelling of land use change dynamics in Ecuador. *Agricultural Systems* **61**: 77-93.

Kosmas C, Danalatos N, Cammeraat LH, Chabart M, Diamantopoulos J, Farand R, Gutierrez L, Jacob A, Marques H, Martinez-Fernandez J, Mizara A, Moustakas N, Nicolau JM, Oliveros C, Pinna G, Puddu R, Puigdefabregas J, Roxo M, Simão A, Stamou G, Tomasi N, Usai D, Vacca A. 1997. The effect of land use on runoff and soil erosion rates under Mediterranean conditions. *Catena* **29**: 45-59.

Koulouri M, Giourga C. 2007. Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands. *Catena* **69**: 274-281.

Kovach J, Petzoldt C, Degni J, Tette J. 1992. A method to measure the environmental impact of pesticides. Available from http://www.nysipm.cornell.edu/publications/EIQ.

Kuiper J. 2000. A checklist approach to evaluate the contribution of organic farms to landscape quality. *Agriculture, Ecosystems & Environment* **77**: 143-156.

Laguna A, Giráldez JV. 1990. Soil erosion under conventional management systems of olive tree culture. In: Ferreira AG, Coutinho MA, Tomás PP (Eds), Proceedings of the seminar on interaction between agricultural systems and soil conservation in the Mediterranean belt, September 4-8, 1990. European Society for Soil Conservation, Oeiras. pp. 94-101.

Lampurlanes J, Cantero-Martinez C. 2006. Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions. *Soil and Tillage Research* **85**: 13-26.

van der Lans I, van Ittersum K. 2001. The role of the region of origin and EU certificates of origin in consumer evaluation of food products. *European Review of Agricultural Economics* **28**: 451-477.

Lasanta T, Arnãez J, Oserín M, Ortigosa LM. 2001. Marginal lands and erosion in terraced fields in the Mediterranean mountains; a case study in the Camero Viejo (Northwestern Iberian System, Spain*). Mountain Research and Development* **21**: 69-76.

Lefroy RDB, Bechstedt HD, Rais M. 2000. Indicators for sustainable land management based on farmer surveys in Vietnam, Indonesia, and Thailand. *Agriculture, Ecosystems & Environment* **81**: 137-146.

Leone. 2000. The globalisation of the olive oil market and the competitive position of the secotr in Italy: an international comparison. *Olivae* **83**: 10-14.

Lombardo. 1993. Olive farming in Italy: conditions, problems and outlook. *Olivae* **47**: 9-14.

López-Ridaura S, van Keulen H, van Ittersum MK, Leffelaar PA. 2005. Multiscale methodological framework to derive criteria and indicators for sustainability evaluation of peasant natural resource management systems. *Environment, Development & Sustainability* **7**: 51-69.

López-Ridaura S. 2005. Multi-scale sustainability evaluation: a framework for the derivation and quantification of indicators for natural resource management systems. *Tropical Resource Management Papers* **68**. Wageningen University, Wageningen.

Losch B. 2004. Debating the multifunctionality of agriculture: from trade negotiations to development policies by the South. *Journal of Agrarian Change* **4**: 336-360.

Loumou A, Giourga C, Dimitrakopoulos P, Koukoulas S. 2000. Tourism contribution to agro-ecosystems conservation: the case of Lesbos island, Greece. *Environmental Management* **26-4**: 363-370.

Loumou A, Giourga C. 2003. Olive groves: "the life and identity of the Mediterranean". *Agriculture and Human Values* **20**: 87-95.

Loussert R, Brousse G. 1978. L’olivier. Maisonneuve et Larose, Paris.

Lowe P, Baldock D. 2000. Integration of environmental objectives into agricultural policy making. In: Brouwer F, Lowe P (Eds), CAP regimes and the European countryside. CABI Publishing, Wallingford. pp. 31-52.

de Luna E, Laguna A, Giráldez J V. 2000. The role of olive trees in rainfall erosivity and runoff and sediment yield in the soil beneath. *Hydrology and Earth System Sciences* **4**: 141-153.

van der Maarel E, Dauvellier PL. 1978. Naar een globaal ecologisch model voor de ruimtelijke ontwikkeling. Ministerie van Volkshuisvesting en Ruimtelijke Ordening, The Hague.

MacDonald D, Crabtree JR, Wiesinger G, Dax T, Stamou N, Fleury P, Gutierrez Lazpita J, Gibon A. 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. *Journal of Environmental Management* **59**: 47-69.

Madureira L, Rambonilaza T, Karpinski I. 2007. Review of methods and evidence for economic valuation of agricultural non-commodity outputs and suggestions to facilitate its application to broader decisional contexts. *Agriculture, Ecosystems & Environment* **120**: 5-20.

Madureira L, Rebelo J, Ferreira P. 1994. A olivicultura e sector do azeite em Trás-os-Montes e Alto Douro: situação actual e perspectivas. Universidade de Trás-os-Montes e Alto Douro, Vila Real.

Mahbouli A. 1971. Role de l'olivier dans la vie economique et sociale du Tunisien. *Informations Oléicoles Internationales* **54/55**: 63-70.

Makhzoumi JM. 1997. The changing role of rural landscapes: olive and carob multi-use tree plantations in the semiarid Mediterranean. *Landscape and Urban Planning* **37**: 115-122.

Mandal UK, Rao KV, Mishra PK, Vittal KPR, Sharma KL, Narsimlu B, Venkanna K. 2005. Soil infiltration, runoff and sediment yield from a shallow soil with varied stone cover and intensity of rain. *European Journal of Soil Science* **56**: 435-443.

Mansinho MI, Henriques P. 2000. Subsidiar os Sistemas de Agricultura Pouco Intensivos: o olival tradicional e o olival biológico em Portugal. In: APDEA, A Agricultura Portuguesa numa Economia Globalizada, 3º Congresso Nacional de Economistas Agrícolas, Lisboa.

MAPA. 1999. Anuario de Estadística Agroalimentaria 1999. Available from http://www.mapya.es/

Marathianou M, Kosmas C, Gerontidis S, Detsis V. 2000. Land-use evolution and degradation in Lesvos (Greece): a historical approach. *Land Degradation & Development* **11**: 63-73.

Margaris NS, Koutsidou E, Giourga C. 1996. Changes in traditional Mediterranean land-use systems. In: Brandt CJ, Thornes JB (Eds), Mediterranean desertification and land use. Wiley, Chichester. pp. 29-42.

Marsden T, Banks J, Renting H, van der Ploeg JD. 2001. The road towards sustainable rural development: issues of theory, policy and research practice. *Journal of Environmental Policy and Planning* **3**: 75-83.

Martínez Raya A, Durán Zuazo VH, Francia Martínez JR. 2005. Soil erosion and runoff response to plant-cover strips on semiarid slopes (SE Spain). *Land Degradation & Development* **17**: 1-11.

Martínez Raya A, Francia Martínez JR, Martínez Vilela A, Ruiz S. 2002. Soil conservation techniques in the cultivation of perennials on steep slopes in semi-arid ecosystems. In: Rubio JL, Morgan RPC, Asins S, Andreu V (Eds), Proceedings of the Third International Congress Man and Soil at the Third Millennium, Logroño, Spain, March 2000. European Society for Soil Conservation, Valencia. pp. 779–786.

Martínez Raya A, García Bolaños M, Cárceles Rodríguez B, Francia Martínez JR, Martínez Vilela A, Durán Zuazo V (Eds). 2006. Good agricultural practices and cross compliance for olive production systems on sloping land. Olivero Project Communication No. 12. Available from http://www.olivero.info

McCarthy J. 2005. Rural geography: multifunctional rural geographies - reactionary or radical? *Progress in Human Geography* **29**: 773-782.

MEA. 2005. Millenium Ecosystem Assessment, Ecosystems and human well-being: Current state and trends. Island Press, Washington D.C.

Metzidakis I (Ed.). 2004. An overview of productive, ecological and socio-economic functions of SMOPS. Olivero Project Communication nº 2. Available from *http://www.olivero.info*

Metzidakis I (Ed.). 2006. Recommendations for olive orchards that will be abandoned. Olivero Project Communication nº 9. Available from *http://www.olivero.info*

Metzidakis I, Castro Nieto G, Martinez Vilela A, Basso B. 2007. Intensive olive orchards on sloping land: requiring good water and pest management. *Journal of Environmental Management* (in press).

Michelakis N, Vouyoukalou E, Clapaki G. 1996. Water use and soil moisture depletion by olive trees under different irrigation conditions. *Agricultural Water Management* **29**: 315-325.

Mili S, Zúñiga MR. 2001. Exploring future developments in international olive oil trade and marketing: a Spanish perspective. *Agribusiness: an international journal* **17**: 397-415.

Missaoui H. 1996. Soil and water conservation in Tunisia. In: Pereira LS et al. (Eds), Sustainability of irrigated agriculture. Kluwer Academic Publishers, Dordrecht. pp. 121-135.

Mollenhauer K, Taysun A, Frede H G. 2002. C-Factors of the Universal Soil Loss Equation for olive plantations in western Anatolia (central Ege region). *Journal of Plant Nutrition and Soil Science* **165**: 313-319.

National Statistical Service of Greece (NSSG). 2000. Agriculture and livestock census 2000. *http://www.statistics.gr/eng_tables/VIII5.htm*

Nhantumbo I, Dent JB, Kowero G. 2001. Goal programming: Application in the management of the miombo woodland in Mozambique. *European Journal of Operational Research* **133**: 310-322.

Nidumolu UB, van Keulen H, Lubbers M, Mapfumo A. 2007. Combining interactive multiple goal linear programming with an inter-stakeholder communication matrix to generate land use options. *Environmental Modelling & Software* **22**: 73-83.

NRCS-RUSLE2. 2006. Revised Universal Soil Loss Equation, Version 2 (RUSLE2). Available from *http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm*.

OECD. 2000. Environmental indicators for agriculture: methods and results (executive summary). OECD Publications, Paris.

OECD. 2001. Multifunctionality; towards an analytical framework. OECD Publications, Paris.

van Oost K, Govers G, de Alba S, Quine TA. 2006. Tillage erosion: a review of controlling factors and implications for soil quality. *Progress in Physical Geography* **30**: 443-466.

Paarlberg PL, Bredahl M, Lee JG. 2002. Multifunctionality and agricultural trade negotiations. *Review of Agricultural Economics* **24**: 322-335.

Pachaki C. 2003. Agricultural landscape indicators: a suggested approach for the scenic value. In: NIJOS/OECD Expert Meeting - Agricultural landscape indicators. NIJOS rapport 7/2003. NIJOS, Oslo. pp. 247-257.

Pacini C, Wossink A, Giesen G, Vazzana C, Huirne R. 2003. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* **95**: 273-288.

Palomo MJ, Moreno F, Fernández JE, Díaz-Espejo A, Girón IF. 2002. Determining water consumption in olive orchards using the water balance approach. *Agricultural Water Management* **55**: 15-35.

Pastor M, Castro J, Humanes MD, Muñoz J. 2001. Sistemas de manejo del suelo en olivar de Andalucía. *Edafología* **8**: 75-98.

Pastor M, Castro J. 1995. Soil management systems and erosion. *Olivae* **59**: 64-74.

Pastor M, Hidalgo J, Vega V, Castro J. 1998. Olive irrigation in the district of La Loma in the province of Jaén (Spain). *Olivae* **71**: 39-49.

Pereira MG, Trigo RM, da Camara CC, Pereira JMC, Leite SM. 2005. Synoptic patterns associated with large summer forest fires in Portugal. *Agricultural & Forest Meteorology* **129**: 11-25.

van der Ploeg SWF, Vlijm L. 1978. Ecological evaluation, nature conservation and land use planning with particular reference to methods used in the Netherlands. *Biological Conservation* **14**: 197-221.

Poesen JW, Torri D, Bunte K. 1994. Effects of rock fragments on soil erosion by water at different spatial scales: a review. *Catena* **23**: 141-166.

Poesen JW, van Wesemael B, Bunte K, Benet AS. 1998. Variation of rock fragment cover and size along semiarid hillslopes: a case-study from southeast Spain. *Geomorphology* **23**: 323-335.

Potter C, Burney J. 2002. Agricultural multifunctionality in the WTO – legitimate non-trade concern or disguised protectionism? *Journal of Rural Studies* **18**: 35-47.

Potts SG, Petanidou T, Roberts S, O’Toole C, Hulbert A, Willmer P. 2006. Plant-pollinator biodiversity and pollination services in a complex Mediterranean landscape. *Biological conservation* **129**: 519-529.

Pretty J, Brett C, Gee D, Hine R, Mason C, Morison J, Rayment M, van der Bijl G, Dobbs T. 2001. Policy challenges and priorities for internalizing the externalities of modern agriculture. *Journal of Environmental Planning and Management* **44**: 263-283.

Projet PNUD-FAO TUN/86/020. 1992. Journée sur la mise en oeuvre de la strategie nationale de la conservation des eaux et du sol: la conservation des eaux et du sol en Tunesie – bilan et perspectives. Ministère de l’agriculture, Direction de la C.E.S, Sidi Thabet.

Rabbinge R, van Diepen CA. 2000. Changes in agriculture and land use in Europe. *European Journal of Agronomy* **13**: 85-100.

Rallo Romero L. 1998. Olive farming in the age of science and innovation. *Olivae* **72**: 42-51.

Randall A. 2002. Valuing the outputs of multifunctional agriculture. *European Review of Agricultural Economics* **29**: 289-307.

Randall A. 2007. A consistent valuation and pricing framework for non-commodity outputs: Progress and prospects. *Agriculture, Ecosystems & Environment* **120**: 21-30.

Regione Campania. 2006. I Prodotti tipici della Campania: Colline Salernitane (Olio extravergine di Oliva) DOP. *http://www.sito.regione.campania.it/AGRICOLTURA/Tipici/oliosale-new.html*.

Reis J, Hespanha P, Pires AR, Jacinto R. 1990. How 'rural' is agricultural pluriactivity? *Journal of Rural Studies* **6**: 395-399.

Ritson C. 1997. Food Marketing and Agricultural Marketing: the scope of the subject of agro-food marketing. In: Padberg D, Ritson C, Albisu L (Eds), Agro-food Marketing. CAB International, Oxon, UK.

Rodriguez LC, Pascual U, Niemeyer HM. 2006. Local identification and valuation of ecosystem goods and services from Opuntia scrublands of Ayacucho, Peru. *Ecological Economics* **57**: 30-44.

Roetter RP, Hoanh CT, Laborte AG, van Keulen H, van Ittersum MK, Dreiser C, van Diepen CA, de Ridder N, van Laar HH. 2005. Integration of Systems Network (SysNet) tools for regional land use scenario analysis in Asia. *Environmental Modelling & Software* **20**: 291-307.

Romero C, Rehman T. 2003. Multiple Criteria Analysis for Agricultural Decisions. Elsevier, Amsterdam.

de la Rosa D, Diaz-Pereira E, Mayol F, Czyz EA, Dexter AR, Dumitru E, Enache R, Fleige H, Horn R, Rajkay K, Simota C. 2005. SIDASS project: Part 2. Soil erosion as a function of soil type and agricultural management in a Sevilla olive area, southern Spain. *Soil and Tillage Research* **82**: 19-28.

Rounsevell MDA (Ed.). 1999. Spatial modelling of the response and adaptation of soils and land use systems to climate change – an integrated model to predict European land use (IMPEL). Louvain-la-Neuve, Belgium.

Russo D, Jones G, Migliozzi A. 2002. Habitat selection by the Mediterranean horseshoe bat, *Rhinolophus euryale* (Chiroptera: Rhinolophidae) in a rural area of southern Italy and implications for conservation. *Biological Conservation* **107**: 71-81.

Saleh A. 1993. Soil roughness measurement: chain method. *Journal of Soil and Water Conservation* **48**: 527-529.

Santos M, Cabral JA. 2004. Development of a stochastic dynamic model for ecological indicators' prediction in changed Mediterranean agroecosystems of north-eastern Portugal. *Ecological Indicators* **3**: 285-303.

Schipper RA. 1996. Farming in a fragile future: economics of land use with applications in the Atlantic Zone of Costa Rica. PhD Thesis Wageningen Agricultural University.

Schoorl J, Veldkamp A. 2001. Linking land use and landscape process modeling: a case study for the Alora region (south Spain). *Agriculture, Ecosystems & Environment* **85**: 281-292.

Schröter D, Cramer W, Leemans R, Prentice CI, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, de la Vega-Leinert AC, Erhard M, Ewert F, Glendining M, House JI, Kankaanpää S, Klein RJT, Lavorel S, Lindner M, Metzger MJ, Meyer J, Mitchell TD, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, Zierl B. 2005. Ecosystem service supply and vulnerability to global change in Europe. *Science* **310**: 1333-1337.

Scozzafava S, de Sanctis A. 2006. Exploring the effects of land abandonment on habitat structures and on habitat suitability for three passerine species in a highland area of Central Italy. *Landscape and Urban Planning* **75**: 23-33.

Siebert SF. 2004. Traditional agriculture and the conservation of biological diversity in Crete, Greece. *International Journal of Agricultural Sustainability* **2**: 109-117.

Simanton JR, Toy TJ. 1994. The relation between surface rock-fragment cover and semiarid hillslope profile morphology. *Catena* **23**: 213-225.

Snelder DJ, Bryan RB. 1995. The use of rainfall simulation tests to assess the influence of vegetation density on soil loss on degraded rangelands in the Baringo District, Kenya. *Catena* **25**: 105-116.

Squires VR, Badora A. 1999. Carbon sequestration in Mediterranean basin drylands: prospects and challenges. *Desertification Control Bulletin* **35**: 14-20.

Stoate C, Boatman N, Borralho R, Carvalho C, de Snoo G, Eden P. 2001. Ecological impacts of arable intensification in Europe. *Journal of Environmental Management* **63**: 337-365.

Stobbelaar DJ, Kuiper J, van Mansvelt JD, Kabourakis E. 2000. Landscape quality on organic farms in the Messara valley, Crete; organic farms as components in the landscape. *Agriculture, Ecosystems & Environment* **77**: 79-93.

Stoorvogel JJ, Antle JM. 2001. Regional land use analysis: the development of operational tools. *Agricultural Systems* **70**: 623-640.

Stroosnijder L, Mansinho I, Palese AM. 2007. OLIVERO: the project analysing the future of olive production systems on sloping land. *Journal of Environmental Management* (in press).

Stroosnijder L. 2005. Measurement of erosion: Is it possible? *Catena* 64: 162-173.

Tahvanainen L, Ihalainen M, Hietala Koivu R, Kolehmainen O, Tyrvainen L, Nousiainen I, Helenius J. 2002. Measures of the EU Agri-Environmental Protection Scheme (GAEPS) and their impacts on the visual acceptability of Finnish agricultural landscapes. *Journal of Environmental Management* **66**: 213-227.

Tait J. 2001. Science, governance and multifunctionality of European agriculture. *Outlook on Agriculture* **30**: 91-95.

Tamiz M, Jones D, Romero C. 1998. Goal programming for decision making: An overview of the current state-of-the-art. *European Journal of Operational Research* **111**: 569-581.

Theocharopoulos SP, Florou H, Walling DE, Kalantzakos H, Christou M, Tountas P, Nikolaou T. 2003. Soil erosion and deposition rates in a cultivated catchment area in central Greece, estimated using the 137Cs technique. *Soil and Tillage Research* **69**: 153-162.

Tisdell C. 1996. Economic indicators to assess the sustainability of conservation farming projects: an evaluation. *Agriculture, Ecosystems & Environment* **57**: 117-131.

Tombesi A, Michelakis N, Pastor M. 1996. Recommendations of the working group on olive farming production techniques and productivity. *Olivae* **63**: 38-51.

Tunalioglu R, Gökçe O. 2001. A specific problem of olive growing in Turkey. *Olivae* **85**: 16-18.

UNCTAD, 2006. Market information in the commodities area. *http://r0.unctad.org/infocomm*

Van-Camp L, Bujarrabal B, Gentile AR, Jones RJA, Montanarella L, Olazabal C, Selvaradjou SK. 2004. Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume - II: Erosion. EUR 21319 EN/2. Office for Official Publications of the European Communities, Luxembourg.

Vatn A. 2002. Multifunctional agriculture: some consequences for international trade regimes. *European Review of Agricultural Economics* **29**: 309-327.

Viana V. 2003. Causes and consequences of abandonment of mountainous olive groves and the options for natural resource conservation. Olivero Student Report Series nº 1. Available from *http://www.olivero.info*

Vigiak O, van Dijck SJE, van Loon EE, Stroosnijder L. 2006. Matching hydrologic response to measured effective hydraulic conductivity. *Hydrological Processes* **20**: 487-504.

de Vocht A. 2001. Basishandboek SPSS 10 Voor Windows 98/ME/2000. Bijleveld Press, Utrecht.

Von Wirén-Lehr S. 2001. Sustainability in agriculture – an evaluation of principal goal-oriented concepts to close the gap between theory and practice. *Agriculture, Ecosystems & Environment* **84**: 115-129.

van der Werf H M G, Petit J. 2002. Evaluation of the environmental impact of agriculture at the farm level: a comparison and analysis of 12 indicator-based methods. *Agriculture, Ecosystems and Environment* **93**: 131-145.

de Wit CT, van Keulen H, Seligman NG, Spharim I. 1988. Application of interactive multiple goal programming techniques for analysis and planning of regional agricultural development. *Agricultural Systems* **26**: 211-230.

Whitby M. 2000. Reflections on the costs and benefits of agri-environment schemes. *Landscape Research* **25-3**: 365-374.

Wilson GA. 2001. From productivism to post-productivism and back again? Exploring the (un)changed natural and mental landscapes of European agriculture. *Transactions of the Institute of British Geographers* **26**: 77-102.

Withrow-Robinson B, Hibbs DE, Gypmantasiri P, Thomas D. 1999. A preliminary classification of fruit-based agroforestry in a highland area of northern Thailand. *Agroforestry Systems* **42**: 195-205.

Wortmann CS, Christiansen AP, Glewen KL, Hejny TA, Mulliken J, Peterson JM, Varner DL, Wortmann S, Zoubek GL. 2005. Farmer research: conventional experiences and guidelines for alternative agriculture and multi-functional agro-ecosystems. *Renewable Agriculture and Food Systems* **20**: 243-251.

WWF/Birdlife International. 2001. EU policies for olive farming: unsustainable on all counts. WWF Europe / Birdlife International, Brussels.

WWF/Birdlife International. 2004. EU policies for olive farming – towards sustainable production in Europe. WWF Europe / Birdlife International, Brussels.

Xiloyannis C, Celano G, Amato M, Palese AM (Eds). 2004. An overview of crop management, land husbandry and soil and water conservation measures within the project areas. Olivero Project Communication nº 3. Available from *http://www.olivero.info*

Xiloyannis C, Celano G, Amato M, Palese AM (Eds). 2006. Evaluation of tillage and organic matter management in Sloping and Mountainous Olive Plantation Systems (SMOPS). Olivero Project Communication nº 10. Available from *http://www.olivero.info*

Xiloyannis C, Martinez Raya A, Kosmas C, Favia MF. 2007. Semi-intensive olive orchards on sloping land: requiring good land husbandry for future development. *Journal of Environmental Management* (in press).

Zalidis G, Stamatiadis S, Takavakoglou V, Eskridge K, Misopolinos N. 2002. Impacts of agricultural practices on soil and water quality in the Mediterranean region and proposed assessment methodology. *Agriculture, Ecosystems & Environment* **88**: 137-146.

Zobisch M, Masri Z. 2000. Halting the olive's downward slip. *ICARDA Caravan* **12**: 21-23.

Appendix A. LP and MGP model descriptions

Contents:

A: LP Model description
B: WGP Model description
C: MINMAX GP Model description

A: LP Model description

Objective function:

$$Z_1 = \max \sum_i \sum_j P_{ij} \cdot p_{ij} + \sum_i \sum_j X_{ij} \cdot m_i + \sum_j S_j + \sum_a \sum_i \sum_j A_{aij} \cdot g_{ai} - \sum_j \sum_k \sum_{l=1} L_{ijk} \cdot w_{jk}$$
$$- \sum_i \sum_{i'} \sum_j Yp_{ii'j} \cdot n_{ii'} - \sum_c \sum_m \sum_i \sum_j C_{cij} \cdot c_{cim}$$

where:
P_{ij} = production of olive oil of SMOPS type i in year j (kg)
p_{ij} = price of olive oil produced in SMOPS type i in year j (€ kg^{-1})
X_{ij} = area devoted to SMOPS type i in year j (ha)
m_i = miscellaneous subsidies minus all variable production costs except labour for SMOPS type i (€)
S_j = single farm payment subsidy received in year j (€)
A_{aij} = area of SMOPS type i under agri-environmental measure a in year j (ha)
g_{ai} = agri-environmental subsidy minus all additional variable production costs for agri-environmental measure a practiced in SMOPS type i (€)
L_{ijk} = labour use of SMOPS type i in year j and season k (h)
w_{jk} = wage rate of hired labour in year j and season k (€ h^{-1})
$Yp_{ii'j}$ = positive area change from SMOPS type i to SMOPS type i' in year j (ha)
$n_{ii'}$ = investment cost of change from SMOPS type i to SMOPS type i' (€)
C_{cij} = area of SMOPS type i meeting (c=1) or not meeting (c=0) cross-compliance conditions in year j (ha)
c_{cim} = additional variable costs to comply with cross-compliance condition c for SMOPS type i requiring measure m

Z_1 is subject to the following constraints (Eq. S1-S30, whereby Eq. S12 is optional):

(A1) areaconstraint$_j$

$$\sum_i X_{ij} = a$$

The sum of the areas occupied by each SMOPS i in year j is equal to the total area a

(A2) areabalance$_{i,j+1}$

$$X_{i,j+1} = X_{ij} + \sum_{i'} \left(Yp_{ii'j} + Yn_{ii'j} \right)$$

where:
$Yn_{ii'j}$ = negative area change from SMOPS type i' to SMOPS type i in year j (ha)

(A3) changeconstraint$_{ij}$

$$X_{ij} + \sum_{i'} Yn_{i'ij} > 0$$

Not more than the current area of SMOPS type *i* can be converted to SMOPS type *i'*

(A4) initialarea$_{i,j=2005}$

$$X_{i,j=2005} = a_{ij}$$

where:

a_{ij} = initial area of SMOPS type *i* (ha)

(A5) changebalance$_{ii'j}$

$$Yn_{i'ij} + Yp_{ii'j} = 0$$

A decrease of SMOPS type *i* to the benefit of SMOPS type *i'* is reciprocal to the increase of SMOPS type *i'* at the expense of SMOPS type *i*

(A6) finalposchange$_{ii'j=2030}$

$$Yp^{f}_{ii'j} = Yn^{f}_{i'ij} = 0$$

where:

$Yp^{f}_{ii'}$ = positive area change from SMOPS type *i* to SMOPS *i'* in final year *j* (ha)

$Yn^{f}_{i'i}$ = negative area change from SMOPS type *i* to SMOPS *i'* in final year *j* (ha)

This constraint prevents SMOPS changes in the final simulated year.

(A7) investmentconstraint$_{j}$

$$\sum_{i}\sum_{i'} Yp_{ii'j} \cdot n_{ii'} < f$$

The cost of all SMOPS changes in year *j* should not exceed the financial reserve *f*

(A8) labourconstraint$_{jk}$

$$\sum_{i} X_{ij} \cdot q_{ik} + \sum_{i}\sum_{i'} Yp_{ii'j} \cdot o_{ii'k} + \sum_{c}\sum_{m}\sum_{i} C_{cij} \cdot t_{cikm} + \sum_{a}\sum_{i} A_{aij} \cdot u_{aik} < lf_{jk} + lh_{jk}$$

where:

q_{ik} = labour requirements of cultural operations of SMOPS *i* in season *k* (h)

$o_{ii'k}$ = labour investment requirements of changing from SMOPS type *i* to SMOPS type *i'* in season *k* (h)

t_{cikm} = additional labour required to comply with cross-compliance condition *c* for SMOPS type *i* in season *k* for measure *m* (h)

u_{aik} = additional labour required for agri-environmental measure *a* in SMOPS type *i* in season *k* (h)

lf_{jk} = available family labour in year *j* and season *k* (h)

lh_{jk} = available hired labour in year *j* and season *k* (h)

(A9) labourbalance$_{jk}$

$$\sum_{l} L_{jkl} = \sum_{i} X_{ij} \cdot q_{ik} + \sum_{i}\sum_{i'} Yp_{ii'j} \cdot o_{ii'j} + \sum_{c}\sum_{m}\sum_{i} C_{cij} \cdot t_{cikm} + \sum_{a}\sum_{i} A_{aij} \cdot u_{aik}$$

The sum of the actual amount of labour of all types *l* used in season *k* of year *j* is equal to the labour requirements of cultural operations for the current SMOPS areas, changes of SMOPS types and the additional labour requirements to meet cross-compliance conditions and to participate in agri-environmental schemes.

(A10) famlabconstraint$_{jk}$

$$\sum_{l=2} L_{jkl} < lf_{jk}$$

Family labour employed in season *k* of year *j* should not surpass the maximum available family labour

(A11) hiredlabconstraint$_{jk}$

$$\sum_{l=1} L_{jkl} < lh_{jk}$$

Hired labour employed in season *k* of year *j* should not surpass the maximum available amount of hired labour

(A12) returntolabourconstraint$_{j}$

$$\sum_{i} P_{ij} \cdot p_{ij} + \sum_{i} X_{ij} \cdot m_{i} + S_{j} + \sum_{a}\sum_{i}\sum_{j} A_{aij} \cdot g_{ai} - \sum_{k}\sum_{l=1} L_{jkl} \cdot w_{jk} - \sum_{i}\sum_{i'} Yp_{ii'j} \cdot n_{ii'}$$
$$- \sum_{c}\sum_{m}\sum_{i}\sum_{j} C_{cij} \cdot c_{cim} > \sum_{k}\sum_{l=2} L_{jkl} \cdot v_{jk}$$

where:
v_{jk} = labour opportunity costs of family labour in year *j* and season *k* (€ h^{-1})

This constraint defines that the return to family labour for olive cultivation should always be higher than the family could have earned if it would have shifted the same amount of labour elsewhere where it is valued at the indicated seasonal opportunity cost. This constraint is optional (see main text).

(A13) oliveprodbalance$_{i,j+1}$

$$Pu_{i,\,j+1} = Pu_{ij} + \sum_{i'} \left(Yn_{i'ij} \cdot y_{i} + Yp_{i'ij} \cdot y_{i'} + \sum_{j-9}^{j} Yp_{i'ij} \cdot dy_{i'i}^{j} \right)$$

where:
Pu_{ij} = olive yield of SMOPS *i* in year *j* (kg ha^{-1}), uncorrected for the effect of agri-environmental measures

y_i = olive yield of SMOPS i (kg ha^{-1})

$dy^j_{ii'}$ = linear annual yield change factor whereby j determines how many years it takes before the yield level of SMOPS i reaches that of SMOPS i' after a SMOPS change (kg ha^{-1}) ($1 \leq j \leq 9$)

This equation takes into account that changing from one SMOPS to another requires time before the production is adapted to the new circumstances.

(A14) initialprod$_{i,j=2005}$

$$P_{i,j=2005} = a_{ij} \cdot y_i$$

(A15) oliveprodaem$_{ij}$

$$P_{ij} = Pu_{ij} + \sum_a A_{aij} \cdot dy_{ai}$$

where:

dy_{ai} = yield difference for SMOPS type i between the situation with and without agri-environmental measure a (kg ha^{-1})

This equation incorporates the possibility to adjust yields to situations where farmers apply agri-environmental measures that can influence the yield directly (e.g. integrated pest management)

(A16) initialsubsidy$_{i,j=2005}$

$$S_{j=2005} = \sum_i s_{ij}$$

where:

s_{ij} = initial subsidy under the single farm payment scheme (€)

(A17) subsidybalance$_j$

$$S_j = \sum_{c=1} \sum_i \frac{C_{cij}}{a} \cdot s_j + \sum_{c=0} \sum_i 0.05 s_j \cdot \frac{C_{cij} - C_{ci,j-1}}{a} + \sum_{c=0} \sum_i 0.10 s_j \cdot \frac{C_{cij} - C_{ci,j-2}}{a} + \sum_{c=0} \sum_i 0.80 s_j \cdot \frac{C_{cij} - C_{ci,j-3}}{a}$$

where:

s_j = level of single farm payment subsidy in year j (€)

This equation determines the total annual eligibility for the single farm payment. There is a penalty of 5% for areas not compliant with cross-compliance rules, and additional penalties of 10% and 5% for respectively second year and third year non-compliant areas. Any area with a non-compliance history of more than three years is considered not eligible for subsidies under the single farm payment scheme.

(A18) crosscomplianceconstraint$_{ij}$

$$\sum_c C_{cij} = X_{ij}$$

The sum of the shares of SMOPS area *i* that are respectively compliant and non-compliant with cross-compliance rules is equal to the total area

(A19) crosscompliancebalance1$_{ci,j+1}$

$$C_{ci,j+1} = C_{cij} + dCp_{cij} + dCn_{cij}$$

where:
dCp_{cij} = positive change of area under cross-compliance condition *c* and SMOPS *i* in year *j* (ha)
dCn_{cij} = negative change of area under cross-compliance condition *c* and SMOPS *i* in year *j* (ha)

(A20) crosscompliancebalance2$_{j+1}$

$$\sum_{c=0}\sum_i C_{ci,j+1} > \sum_{c=0}\sum_i C_{cij}$$

This equation defines that once an area has been non-compliant, it will not be considered fully eligible for the single farm payment subsidy again.

(A21) initialcrosscompliance$_{ci,j=2005}$

$$C_{ci,j=2005} = ci_{cij}$$

where:
ci_{cij} = initial area under cross-compliance condition *c* of SMOPS type *i* (ha)

(A22) dcombalance$_j$

$$\sum_c\sum_i dCp_{cij} = -\sum_c\sum_i dCn_{cij}$$

The sum of the positive changes of the area under cross-compliance *c* and SMOPS type *i* is reciprocal to the sum of the negative changes in year *j*

(A23) dcomconstraint$_{cij}$

$$C_{cij} + dCn_{cij} > 0$$

Not more than the current area under cross-compliance condition *c* of SMOPS type *i* can be converted

(A24) aemconstraint$_{ij}$

$$\sum_a A_{aij} \cdot ai_{ai} = X_{ij}$$

where:
ai_{ai} = vector of possible agri-environmental measures *a* per SMOPS type *i*

The sum of the shares of SMOPS area *i* under each possible agri-environmental measure is equal to the total area

(A25) aembudgetconstraint$_j$

$$\sum_a \sum_i A_{aij} \cdot as_{ai} < at$$

where:
as_{ai} = subsidy for area under agri-environmental measure *a* of SMOPS type *i* (€)
at = total annual budget for subsidies under the agri-environment scheme (€)

The area participating in agri-environment schemes may not exceed the subsidy available for payment of implemented measures

(A26) initialaem$_{ci,j=2005}$

$$A_{ci,j=2005} = ai_{aij}$$

where:
ai_{aij} = initial area under agri-environmental measure *a* of SMOPS type *i* (ha)

(A27) aembalance$_{ai,j+1}$

$$A_{ai,j+1} = A_{aij} + dAp_{aij} + dAn_{aij}$$

where:
dAp_{aij} = positive change of area under agri-environmental measure *a* and SMOPS *i* in year *j* (ha)
dAn_{aij} = negative change of area under agri-environmental measure *a* and SMOPS *i* in year *j* (ha)

(A28) daembalance$_j$

$$\sum_a \sum_i dAp_{aij} = -\sum_a \sum_i dAn_{aij}$$

The sum of the positive changes of the area under agri-environmental measure *a* and SMOPS type *i* is reciprocal to the sum of the negative changes in year *j*

(A29) daemconstraint$_{aij}$

$$A_{aij} + dAn_{aij} > 0$$

Not more than the current area under agri-environmental measure *a* of SMOPS type *i* can be converted

(A30) incomeconstraint$_{j}$

$$\sum_{j-2}^{j} S_j + \sum_{i}\sum_{j-2}^{j} P_{ij}\cdot p_{ij} + \sum_{i}\sum_{j-2}^{j} X_{ij}\cdot m_i + \sum_{a}\sum_{i}\sum_{j-2}^{j} A_{aij}\cdot g_{ai} - \sum_{j-2}^{j}\sum_{k}\sum_{l=1} L_{jkl}\cdot w_{jk} - \sum_{c}\sum_{m}\sum_{i}\sum_{j-2}^{j} C_{cij}\cdot c_{cim} > 0$$

The income constraint establishes that the net income over three consecutive years should always be positive (excluding investment costs).

B: WGP Model description

Objective function:

$$Z_2 = \min\left(\frac{n_1}{150000} + \frac{n_2}{600000} + \frac{p_3}{10000} + \frac{n_4}{30000} + \frac{n_5}{8000} + \frac{(n_6 + p_6)}{60000} + \frac{p_7}{5000} + \frac{p_8}{25} + \frac{p_9}{2} - \frac{n_{10}}{200} + \frac{p_{11}}{1000} + \frac{p_{12}}{1500} - \frac{n_{13}}{175}\right)$$

where $n_1 \ldots n_i \ldots n_{13}$ and $p_1 \ldots p_i \ldots p_{13}$ are negative and positive deviational variables respectively relating to goals 31-42 (below).

Model Z_2 is subject to constraints Eq. S1-S6, S9-S10, S12 (optional), S13-S30 and goals S31-S43:

(A31) income goal (cf. objective function Z_1)

$$\sum_{i}\sum_{j} P_{ij}\cdot p_{ij} + \sum_{i}\sum_{j} X_{ij}\cdot m_i + \sum_{j} S_j + \sum_{a}\sum_{i}\sum_{j} A_{aij}\cdot g_{ai} - \sum_{j}\sum_{k}\sum_{l=1} L_{ijk}\cdot w_{jk} - \sum_{i}\sum_{i'}\sum_{j} Yp_{ii'j}\cdot n_{ii'} - \sum_{c}\sum_{m}\sum_{i}\sum_{j} C_{cij}\cdot c_{cim} + n_1 - p_1 = 150000$$

(A32) production goal

$$\sum_{i}\sum_{j} P_{ij} + n_2 - p_2 = 600000$$

(A33) investment goal (cf. investment constraint, Eq. S6)

$$\sum_{i}\sum_{i'}\sum_{j} Yp_{ii'j}\cdot n_{ii'} + n_3 - p_3 = 10000$$

(A34) total labour input goal (cf. labour constraint, Eq. S8)

$$\sum_{j}\sum_{k}\sum_{l}L_{jkl}+n_4-p_4=30000$$

(A35) hired labour input goal (cf. hired labour constraint, Eq. S11)

$$\sum_{j}\sum_{k}\sum_{l=1}L_{jkl}+n_5-p_5=8000$$

(A36) eligibility for subsidy goal

$$\sum_{j}S_j+\sum_{a}\sum_{i}\sum_{j}A_{aij}\cdot as_{ai}-n_6+p_6=60000$$

(A37) water use goal

$$\sum_{i}\sum_{j}\left(X_{ij}\cdot r_i\right)\Big/a-n_7+p_7=5000$$

where:

r_i = average annual irrigation water requirement of SMOPS *i* (m^3 ha^{-1} yr^{-1})

rm = maximum average annual irrigation water availability (m^3 ha^{-1} yr^{-1}) (Table 2)

Water available for irrigation may be in short supply. This goal limits the maximum amount of water that can be used.

(A38) erosion goal

$$\left(\sum_{i}\sum_{j}X_{ij}\cdot e_i+\sum_{a}\sum_{i}\sum_{j}A_{aij}\cdot de_{ai}+\sum_{c}\sum_{m}\sum_{i}\sum_{j}C_{cij}\cdot de_{cim}\right)\Big/a-n_8+p_8=25$$

where:

e_i = average annual erosion rate of SMOPS type *i* (ton ha^{-1} yr^{-1})

de_{ai} = change in erosion rate of area under agri-environmental measure *a* as compared to the original rate for SMOPS type *i* (ton ha^{-1} yr^{-1})

de_{cim} = change in erosion rate of area under cross-compliance condition *c* and measure *m* as compared to the original rate for SMOPS type *i* (ton ha^{-1} yr^{-1})

et = tolerable annual average soil loss (ton ha^{-1} yr^{-1})

(A39) fire risk goal

$$\left(\sum_{i}\sum_{j}X_{ij}\cdot 0.1f_i+\sum_{a}\sum_{i}\sum_{j}A_{aij}\cdot 0.1df_{ai}+\sum_{c}\sum_{m}\sum_{i}\sum_{j}C_{cij}\cdot 0.1df_{cim}\right)\Big/a+n_9-p_9=2$$

where:

f_i = average annual fire risk of SMOPS *i* expressed as fraction of SMOPS area burnt (ha yr^{-1})

df_{ai} = difference in fire risk between area under agri-environmental measure *a* as compared to original fire risk in SMOPS *i*, expressed as fraction of SMOPS area burnt (ha yr^{-1})

df_{cim} = difference in fire risk between area under cross-compliance condition c and measure m as compared to original fire risk in SMOPS i, expressed as fraction of SMOPS area burnt (ha yr^{-1})
ft = tolerable fire risk expressed as fraction of area burnt (ha yr^{-1})

(A40) biodiversity goal

$$\left(\sum_{i}\sum_{j} X_{ij}\cdot b_i + \sum_{a}\sum_{i}\sum_{j} A_{aij}\cdot db_{ai} + \sum_{c}\sum_{m}\sum_{i}\sum_{j} C_{cij}\cdot db_{cim}\right)\Big/ a + n_{10} - p_{10} = 200$$

where:
b_i = biodiversity index value of SMOPS i (-) ($1\leq b_i \leq 10$)
db_{ai} = difference in biodiversity value between area under agri-environmental measure a as compared to the original biodiversity value in SMOPS type i (-)
db_{cijm} = difference in biodiversity value between area under cross-compliance condition c and measure m as compared to the biodiversity value in SMOPS type i (-)
bt = biodiversity index target value (-)

(A41) pollution goal (pesticide environmental impact)

$$\sum_{j}\sum_{n=1}^{n=3}\left(\sum_{i} X_{ij}\cdot n_{in} + \sum_{a}\sum_{i} A_{aij}\cdot dn_{ain} + \sum_{c}\sum_{m}\sum_{i} C_{cij}\cdot dn_{cimn}\right)\cdot h_n\big)/a + n_{11} - p_{11} = 1000$$

where:
n_{in} = input use of type n in SMOPS type i (variable units)
dn_{ain} = difference in input use of type n between area under agri-environmental measure a as compared to the original input use in SMOPS type i (variable units)
dn_{cimn} = difference in input use of type n between area under cross-compliance condition c and measure m as compared to the original input use in SMOPS type i (variable units)
h_n = pollution factor of one unit of input type n (EIQ impact of pesticide application) (-)
ht = maximum tolerable pollution index value (-)

(A42) nitrogen application goal

$$\sum_{j}\sum_{n=0}\left(\sum_{i} X_{ij}\cdot n_{in} + \sum_{a}\sum_{i} A_{aij}\cdot dn_{ain} + \sum_{c}\sum_{m}\sum_{i} C_{cij}\cdot dn_{cimn}\right)\Big/ a + n_{12} - p_{12} = 1500$$

(A43) landscape value goal

$$\left(\sum_{i}\sum_{j} X_{ij}\cdot l_i + \sum_{a}\sum_{i}\sum_{j} A_{aij}\cdot dl_{ai} + \sum_{c}\sum_{m}\sum_{i}\sum_{j} C_{cij}\cdot dl_{cim}\right)\Big/ a + n_{13} - p_{13} = 175$$

where:
l_i = landscape value of SMOPS i (-)($1\leq l_i \leq 10$)
dl_{ai} = difference in landscape value between area under agri-environmental measure a as compared to the original landscape value of SMOPS type i (-)
dl_{cim} = difference in landscape value between area under cross-compliance condition c and measure m as compared to the original landscape value of SMOPS type i (-)
lt = landscape index target value (-)

C: MINMAX GP Model description

Objective function:

$$Z_3 = \min D$$

where D = normalized distance between achieved value and target value for each of the goals Eq. S36-47.

Model Z_3 is subject to constraints Eq. S1-6, S9-10, S12 (optional), S13-30, goals S31-43, and additional constraints Eq. S44-56:

(A44) $n_1/150000 \leq D$

(A45) $n_2/600000 \leq D$

(A46) $p_3/10000 \leq D$

(A47) $n_4/30000 \leq D$

(A48) $n_5/8000 \leq D$

(A49) $(n_6 + p_6)/60000 \leq D$

(A50) $p_7/5000 \leq D$

(A51) $p_8/25 \leq D$

(A52) $p_9/2 \leq D$

(A53) $n_{10}/200 \leq D$

(A54) $p_{11}/1000 \leq D$

(A55) $n_{12}/1500 \leq D$

(A56) $n_{13}/175 \leq D$

Table A1: Definition of sets.

Set	Description	Elements
a	agri-environmental measures	none; covercrop; traditional orchards; IPM
c	cross-compliance condition	non-compliance (0); compliance (1)
$i; i'$	SMOPS type	abandoned (0); traditional (1); semi-intensive (olive oil) (2); semi-intensive (table olives) (3); organic (5); intensive (9)
j	year	2005…2030
k	season	winter; spring; summer; autumn
l	labour	hired labour (1); family labour (2)
m	cross-compliance measure	weed control; winter cover; pruning; terrace maintenance
n	inputs	N-application (0); dimetoate (1); cuprics (2); glyphosate (3)

Table A2: Definition of parameters.

Parameter	Description	Unit
a	Total area	ha
a_{ij}	Initial area of SMOPS type i	ha
ai_{ai}	Vector of possible agri-environmental measures a per SMOPS type i	–
ai_{aij}	Initial area under agri-environmental measure a of SMOPS type i	ha
as_{ai}	Subsidy for area under agri-environmental measure a of SMOPS type i	€
at	Total annual budget for subsidies under the agri-environmental scheme	€
b_i	Biodiversity index value of SMOPS i ($1 \leq b_i \leq 10$)	–
bt	Biodiversity index target value	–
c_{cim}	Additional variable costs to comply with cross-compliance condition c for SMOPS type i requiring measure m	€
ci_{cij}	Initial area under cross-compliance condition c of SMOPS type i	ha
db_{ai}	Difference in biodiversity value between area under agri-environmental measure a as compared to the original biodiversity value in SMOPS type i	–
db_{cim}	Difference in biodiversity value between area under cross-compliance condition c and measure m as compared to the original biodiversity value in SMOPS type i	–
de_{ai}	Change in erosion rate of area under agri-environmental measure a as compared to the original rate for SMOPS type i	ton $ha^{-1}y^{-1}$
de_{cim}	Change in erosion rate of area under cross-compliance condition c and measure m as compared to the original rate for SMOPS type i	ton $ha^{-1}y^{-1}$
df_{ai}	Difference in fire risk between area under agri-environmental measure a as compared to the original fire risk in SMOPS type i, expressed as fraction of SMOPS area burnt	ha y^{-1}
df_{cim}	Difference in fire risk between area under cross-compliance condition c and measure m as compared to the original fire risk in SMOPS type i, expressed as fraction of SMOPS area burnt	ha y^{-1}
dl_{ai}	Difference in landscape value between area under agri-environmental measure a as compared to the original landscape value in SMOPS type i	–
dl_{cim}	Difference in landscape value between area under cross-compliance condition c and measure m as compared to the original landscape value in SMOPS type i	–
dn_{ai}	Difference in input use of type n between area under agri-environmental measure a as compared to the original input use in SMOPS type i	variable
dn_{cim}	Difference in input use of type n between area under cross-compliance condition c and measure m as compared to the original input use in SMOPS type i	variable
dy_{ai}	Yield difference for SMOPS type i between the situation with and without agri-environmental measure a	kg ha^{-1}
$dyj_{ii'}$	Linear annual yield change factor whereby j determines how many years it takes before the yield level of SMOPS i reaches that of SMOPS i' after a SMOPS change ($1 \leq j \leq 9$)	kg ha^{-1}
e_i	Average annual erosion rate of SMOPS type i	ton $ha^{-1}y^{-1}$
et	Tolerable annual average soil loss	ton $ha^{-1}y^{-1}$
f	Financial reserve annually available for investment	€
f_i	Average annual fire risk of SMOPS i expressed as fraction of SMOPS area burnt	ha y^{-1}
ft	Tolerable fire risk expressed as fraction of area burnt	ha y^{-1}
g_{ai}	Margin of agri-environmental subsidy minus all additional variable production costs for agri-environmental measure a practiced in SMOPS type i	€
h_n	Pollution factor of one unit of input type n (EIQ impact of pesticide application)	–
ht	Maximum tolerable pollution index value (EIQ impact of pesticide application)	–

Table A2 Continued…

Parameter	Description	Unit
l_i	Landscape value of SMOPS i ($1 \leq b_i \leq 10$)	–
lt	Landscape index target value	–
lf_{jk}	Available family labour in year j and season k	h
lh_{jk}	Available hired labour in year j and season k	h
m_i	Margin of miscellaneous subsidies minus all variable production costs except labour for SMOPS i	€
$n_{ii'}$	Investment cost of change from SMOPS type i to SMOPS type i'	€
n_{in}	Input use of type n in SMOPS type i	variable
$o_{ii'k}$	Labour investment requirements for changing from SMOPS type i to SMOPS type i' in season k	h
p_{ij}	Price of olive oil produced in SMOPS type i in year j	€ kg^{-1}
q_{ik}	Labour requirements of cultural operations of SMOPS i in season k	h
r_i	Average annual irrigation water requirement of SMOPS i	m^3 ha^{-1} y^{-1}
rm	Maximum average annual irrigation water availability	m^3 ha^{-1} y^{-1}
s_{ij}	Initial subsidy under the single farm payment scheme	€
s_j	Level of single farm payment subsidy in year j	€
t_{cikm}	Additional labour required to comply with cross-compliance condition c for SMOPS type i in season k for measure m	h
u_{aik}	Additional labour required for agri-environmental measure a in SMOPS type i in season k	h
v_{jk}	Labour opportunity costs of family labour in year j and season k	€ h^{-1}
w_{jk}	Wage rate of hired labour in year j and season k	€ h^{-1}
y_i	Olive yield of SMOPS i	kg ha^{-1}

Table A3: Definition of variables.

Variable	Description	Unit
A_{aij}	Area of SMOPS type i under agri-environmental measure a in year j	ha
C_{cij}	Area of SMOPS type i meeting (c=1) or not meeting (c=0) cross-compliance conditions in year j	ha
D	Normalized distance between achieved value and target value for each of the goals (MINMAX GP)	–
dAn_{cij}	Negative change of area under agri-environmental measure a and SMOPS type i in year j	ha
dAp_{cij}	Positive change of area under agri-environmental measure a and SMOPS type i in year j	ha
dCn_{cij}	Negative change of area under cross-compliance condition c and SMOPS type i in year j	ha
dCp_{cij}	Positive change of area under cross-compliance condition c and SMOPS type i in year j	ha
L_{jk}	Labour use of SMOPS type i in year j and season k	h
$n_1 \ldots n_{13}$	Negative deviational variables (WGP and MINMAX GP)	–
$p_1 \ldots p_{13}$	Positive deviational variables (WGP and MINMAX GP)	–
P_{ij}	Production of olive oil of SMOPS type i in year j	kg
Pu_{ij}	Olive yield of SMOPS i in year j, uncorrected for the effect of agri-environmental measures	kg ha^{-1}
S_j	Single farm payment subsidy received in year j	€
X_{ij}	Area devoted to SMOPS type i in year j	ha
$Yn_{ii'j}$	Negative area change from SMOPS type i' to SMOPS type i in year j	ha
$Yp_{ii'j}$	Positive area change from SMOPS type i to SMOPS type i' in year j	ha
$Z_1 \ldots Z_3$	Objective functions	variable

Table A4: Seasonal labour input requirements.

Seasonal labour input requirements (hours/ha)	PT0	PT1	PT2	PT3	PT5	PT9
winter	0	12	29.9	41.3	24	29.9
spring	0	5.9	2.6	0	5.5	2.6
summer	0	7	10	17.1	10.5	11.5
autumn	0	89.9	76	275.6	43.8	160.3

Table A5: Labour availability and price.

available family and hired labour (hours/season) and respective prices	winter	spring	summer	autumn
Family labour	600	600	600	600
Hired labour	9999	9999	9999	9999
Price of family labour (opportunity cost, in Euro/hour)	5.5	5.5	5.5	4.5
Price of hired labour (Euro/hour)	5.5	5.5	5.5	5.5

Table A6: Possible SMOPS changes.

Possible SMOPS changes	PT0	PT1	PT2	PT3	PT5	PT9
PT0	0	1	0	0	1	0
PT1	1	0	1	0	1	0
PT2	0	1	0	0	1	1
PT3	1	0	1	0	1	1
PT5	0	1	1	0	0	1
PT9	0	0	1	0	1	0

Note: read changes from horizontal to vertical SMOPS

Table A7: Investment requirements of possible SMOPS changes.

Investment requirement (Euro/ha)	PT0	PT1	PT2	PT3	PT5	PT9
PT0	0	10	0	0	110	0
PT1	0	0	1000	0	100	0
PT2	0	0	0	0	100	1625
PT3	0	0	0	0	100	0
PT5	0	0	1000	0	0	2625
PT9	0	0	0	0	0	0

Note: read investment requirements from horizontal to vertical SMOPS

Table A8: Labour required for investment in SMOPS changes, specified per season.

Labour investment requirement (hours/ha/season)	PT0	PT1	PT2	PT3	PT5	PT9
PT0						
winter	0	24	0	0	24	0
spring	0	0	0	0	0	0
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0
PT1						
winter	0	0	50	0	0	0
spring	0	0	50	0	10	0
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0
PT2						
winter	0	0	0	0	0	0
spring	0	0	0	0	10	50
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0
PT3						
winter	0	0	0	0	0	0
spring	0	0	0	0	0	0
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0
PT5						
winter	0	0	50	0	0	50
spring	0	0	50	0	0	100
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0
PT9						
winter	0	0	0	0	0	0
spring	0	0	0	0	0	0
summer	0	0	0	0	0	0
autumn	0	0	0	0	0	0

Note: read labour investment requirements from horizontal to vertical SMOPS

Table A9: Time it takes before investment results in full benefits of new SMOPS.

Benefit lag (years)	PT0	PT1	PT2	PT3	PT5	PT9
PT0	1	3	1	1	3	1
PT1	1	1	3	1	3	1
PT2	1	3	1	1	3	3
PT3	1	1	1	1	3	1
PT5	1	1	3	1	1	3
PT9	1	1	1	1	1	1

Table A10: Cross-compliance regulations applicable to each SMOPS.

Cross compliance concerning:	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	1	0	0	0	0	0
Winter soil cover	1	1	1	1	1	1
Pruning	1	0	0	0	0	0
Terrace maintenance	1	1	1	1	1	0

Table A11: Additional labour required for cross-compliance per SMOPS.

Labour requirement (hours/ha/season)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control						
Winter	0	0	0	0	0	0
Spring	0	0	0	0	0	0
Summer	0	0	0	0	0	0
Autumn	0	0	0	0	0	0
Winter soil cover						
Winter	0	0	0	0	0	0
Spring	4	4	4	4	4	4
Summer	0	0	0	0	0	0
Autumn	0	0	0	0	0	0
Pruning						
Winter	12	0	0	0	0	0
Spring	0	0	0	0	0	0
Summer	0	0	0	0	0	0
Autumn	0	0	0	0	0	0
Terrace maintenance						
Winter	0	0	0	0	0	0
Spring	0	0	0	0	0	0
Summer	0	0	0	0	0	0
Autumn	4	3	1	3	2	0

Table A12: Additional variable costs for cross-compliance regulations per SMOPS.

Additional variable costs (EUR/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	0	0	0	0	0	0
Winter soil cover	20	10	10	10	10	10
Pruning	7	0	0	0	0	0
Terrace maintenance	32	24	8	24	16	0

Table A13: Changes of average erosion rates of SMOPS under certain cross-compliance regulations.

Changes of erosion rate (ton/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	0	0	0	0	0	0
Winter soil cover	-1	-1	-1	-1	-1	-1
Pruning	0	0	0	0	0	0
Terrace maintenance	-0.8	-0.6	-0.2	-0.6	-0.4	0

Table A14: Changes in average fire risk of SMOPS under certain cross-compliance regulations.

Changes in fire risk (fraction of area burnt per 10 ha)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	-0.01	0	0	0	0	0
Winter soil cover	0	0	0	0	0	0
Pruning	-0.03	-0.01	0	0	0	0
Terrace maintenance	0	0	0	0	0	0

Table A15: Changes in biodiversity value of SMOPS under certain cross-compliance regulations.

Changes in biodiversity value (-)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	0	0	0	0	0	0
Winter soil cover	1	1	1	1	1	1
Pruning	0	0	0	0	0	0
Terrace maintenance	0.8	0.6	0.2	0.6	0.4	0

Table A16: Changes in landscape value of SMOPS under certain cross-compliance regulations.

Changes in landscape value (-)	PT0	PT1	PT2	PT3	PT5	PT9
Weed control	0.2	0	0	0	0	0
Winter soil cover	0	1.2	1.1	0.7	0.4	0.8
Pruning	1.4	0	0	0	0	0
Terrace maintenance	0.1	0.3	0.1	0.3	0.1	0

Table A17: Changes in input use under certain cross-compliance regulations.

Changes in input use	PT0	PT1	PT2	PT3	PT5	PT9
Weed control						
N-application	0	0	0	0	0	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	0	0	0
Winter soil cover						
N-application	0	0	0	0	0	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	0	0	0
Pruning						
N-application	0	0	0	0	0	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	0	0	0
Terrace maintenance						
N-application	0	-5	-2	-5	-1	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	0	0	0

Table A18: Potential agri-environmental measures for each SMOPS.

Agri-environmental measures	PT0	PT1	PT2	PT3	PT5	PT9
None	1	1	1	1	1	1
Cover crop	0	0	0	1	0	0
Preservation of traditional orchards	0	1	0	0	1	0
Integrated pest management (IPM)	0	1	1	1	0	1

Table A19: Agri-environmental subsidies.

Agri-environmental subsidies (EUR/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	63	0	0
Preservation of traditional orchards	0	131	0	0	78	0
Integrated pest management (IPM)	0	147	118	118	0	118

Table A20: Additional labour required for agri-environmental measures per SMOPS.

Labour requirement (hours/ha/season)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop						
Winter	0	0	0	4	0	0
Spring	0	0	0	2	0	0
Summer	0	0	0	0	0	0
Autumn	0	0	0	0	0	0
Preservation of traditional orchards						
Winter	0	4	0	0	4	0
Spring	0	0	0	0	0	0
Summer	0	2	0	0	2	0
Autumn	0	0	0	0	0	0
Integrated pest management (IPM)						
Winter	0	4	4	4	0	4
Spring	0	0	0	0	0	0
Summer	0	16	16	16	0	16
Autumn	0	0	3	3	0	3

Table A21: Change of variable costs of SMOPS under agri-environment scheme.

Change of variable costs (EUR/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	3	0	0
Preservation of traditional orchards	0	24	0	0	12	0
Integrated pest management (IPM)	0	8	8	8	0	8

Table A22: Change of intermediate consumption of SMOPS under agri-environment scheme.

Change of intermediate consumption (EUR/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	3	0	0
Preservation of traditional orchards	0	24	0	0	12	0
Integrated pest management (IPM)	0	8	8	8	0	8

Table A23: Change of orchard productivity of SMOPS under agri-environment scheme.

Change of orchard productivity (kg/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	-50	0	0
Preservation of traditional orchards	0	0	0	0	0	0
Integrated pest management (IPM)	0	-50	-113	-500	0	-500

Table A24: Change of average erosion rates of SMOPS under agri-environment scheme.

Change of erosion rate (ton/ha)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	-1	0	0
Preservation of traditional orchards	0	-2	0	0	-0.5	0
Integrated pest management (IPM)	0	0	0	0	0	0

Table A25: Change of landscape value of SMOPS under agri-environment scheme.

Change of landscape value (-)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	1	0	0
Preservation of traditional orchards	0	2	0	0	0.5	0
Integrated pest management (IPM)	0	0	0	0	0	0

Table A26: Change of biodiversity value of SMOPS under agri-environment scheme.

Change of biodiversity value (-)	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop	0	0	0	1	0	0
Preservation of traditional orchards	0	1	0	0	0.5	0
Integrated pest management (IPM)	0	1	1	1	0	1

Table A27: Changes in input use of SMOPS under agri-environmental schemes.

Changes in input use	PT0	PT1	PT2	PT3	PT5	PT9
Cover crop						
N-application	0	0	0	0	0	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	2.52	0	0
Preservation of traditional orchards						
N-application	0	0	0	0	0	0
Dimetoate	0	0	0	0	0	0
Cuprics	0	0	0	0	0	0
Glyphosate	0	0	0	0	0	0
Integrated pest management (IPM)						
N-application	0	-15	-30	-20	0	-25
Dimetoate	0	0	-0.16	-0.2	0	-0.16
Cuprics	0	0	-0.88	-1.13	0	-0.88
Glyphosate	0	0	0	0	0	0

Summary

Summary

The future of olive farming on sloping land in the Mediterranean is uncertain. Sloping and Mountainous Olive Production Systems (SMOPS) that have been sustainable for ages have in a relatively short time frame witnessed major changes. Although remnants of many of these traditional landscapes still exist today, the general trend is different. Demographic changes of the rural population, integration in the market economy with its competitive character, and technological innovation have drastically changed both the local economy, its agricultural production systems and – as a consequence – its environment.

As a result of differential developments, there is now a stratification of SMOPS. While some production systems can continue to compete on global markets, other mostly traditional olive groves will need to rely on other than productive functions only. Of an increasing number of functions, the importance is recognised by stakeholder groups at various levels or by society as a whole. This awareness also extends to those systems that continue to be economical, but which need special attention to conserve functions that could get lost in the process of intensification.

The present research project searches to develop an integrated methodology addressing these problems and to assess its performance for different scenarios of SMOPS. It addresses the following objectives:

1. Making an inventory of SMOPS and their natural resource conservation issues;
2. Developing a function assessment methodology and analyzing the various functions of SMOPS;
3. Taking soil conservation as an example function, exploring the importance of soil erosion in SMOPS and assess how it can be controlled;
4. Developing scenarios based on a set of core functions identified by stakeholders;
5. Optimizing environmental and social performance of SMOPS in conservation scenarios

The first objective is embarked upon in Chapters 2 and 3. While olive production is an important agricultural activity throughout the Mediterranean, soil erosion is one of the environmental key problems in this zone. Due to their location on sloping land, erosive rainfall patterns, erodible soils and deficient ground cover, erosion risk in olive production areas is high. Chapter 2 identifies those areas where olive cultivation can be considered to be SMOPS, and inventories soil and water conservation options for olive orchards with particular reference to five important production areas: Eastern Andalusia (Spain), North-eastern Portugal, Southern Italy, Crete (Greece) and Central-West Tunisia.

Chapter 3 analyses the link between SMOPS and natural resource management issues in more detail. It starts off with the notion that a wide variety of olive plantation systems exists throughout the Mediterranean, especially in sloping and mountainous areas. Recent drivers of change, including the widespread introduction of mechanisation, increased use of (chemical) inputs and (drip-)irrigation have still augmented this variety. It is postulated that the various systems have very different resource use patterns and environmental and social performances. Based on a comprehensive case study in six study areas: Trás-os-Montes (Portugal), Córdoba and Granada/Jaén (both in Spain), Haffouz (Tunisia), Basilicata/Salerno (Italy) and West-Crete (Greece), a cluster analysis is applied to classify 28 SMOPS distinguished regionally. This analysis resulted in the classification of 6 types of SMOPS along an intensity of production gradient: 1) very extensive, 2) traditional extensive, 3) semi-intensive low input, 4) semi-intensive high input, 5) intensive, and 6) organic. Natural resources management options to address soil erosion, low biodiversity, wildfire risk and excessive water use are explored for each of these systems.

Chapter 4 presents one of the distinguished SMOPS types in detail: traditional extensive (or simply: traditional) olive orchards account for a large share of the area under olives in the Mediterranean, particularly in marginal areas. Traditional SMOPS are characterised as a low-intensity production system, associated with old (sometimes very old) trees, grown at a low density, giving small yields and receiving low inputs of labour and materials. During the OLIVERO project, traditional olive production systems were identified and described in five target areas: Trás-os-Montes (Portugal), Córdoba and Granada/Jaén (Spain), Basilicata/Salerno (Italy), and West-Crete (Greece); the latter of which was in a supra-regional classification later reclassified as a semi-intensive low input SMOPS (Chapter 3).

Though traditional SMOPS provide multiple environmental services, their economic viability has become an issue, especially in southern Europe where EU policies favour more intensive and competitive systems. Orchards that have not been intensified seem to be threatened by the recent reform of the EU olive and olive oil policy, as income support, now decoupled from production, is based on past production in a four-year reference period. As a consequence, traditional olive growing is at risk of abandonment. Chapter 4 concludes that the viability of these systems is only assured if reduced opportunity costs for family labour are accepted and the olive growing is part-time, and recommends some private and public interventions to prevent its abandonment.

While Chapter 4 anticipates on the functions of traditional olive groves, a framework for the analysis of the multiple functions of SMOPS (Objective 2) is presented in Chapter 5. Multifunctionality in agriculture has in the last decade received a lot of attention from researchers and policy-makers. Focusing on a case study about SMOPS in north-eastern Portugal, methods are discussed on how to deal with studying multiple functions of agro-ecosystems. The “House of Functions” is presented as a function assessment method. By depicting performance of ecological, productive, economic, social and cultural functions on axes together forming the silhouette of a house, the method could supposedly appeal to a wide range of actors. In the case study, we conclude that regional SMOPS particularly fall short in supplying ecological functions. They do however contribute significantly to the local economy, generate employment and perform an important cultural role in maintaining the landscape, and are thus a key to regional development and to stop outmigration of the population. Policy-makers could use the function assessment tool to design effective cross-compliance rules and relevant agri-environmental measures (AEM) to enhance ecological and social functions, and to communicate ideas to other stakeholders. As such, it can reinforce decision-making by visualizing trends, development alternatives or scenarios. The role of research in this method is facilitating dialogue between stakeholder groups and feeding the process with relevant indicators.

Chapter 6 subsequently focuses on a single function: soil conservation, and explores how well olive groves perform this function (Objective 3). A literature review provides a pessimistic view of the capacity of SMOPS to conserve the soil, with some average regional soil loss values supposedly as high as 40 – 100 ton ha^{-1} y^{-1}. These figures are based on empirical models that apply a simple multiplication of adverse environmental factors such as steep slopes, erodible soils and low vegetation cover. We present experimental data from rainfall simulations, runoff plot studies and field assessment of erosion symptoms that challenge this view. We point at the effects of surface roughness from tillage, rock fragment cover on steep slopes, orchard undergrowth, slope irregularities, vegetative strips, and of erosion resulting mainly from infrequent high intensity rainfall events, and (erroneous) upscaling of experimental results. Although these factors act and/or interact at different scales, taken together they provide an argument for indicating more precisely when, where and for whom erosion constitutes a problem.

Combining the findings from our individual experiments, Chapter 6 concludes that tillage applied judiciously in selected locations of an orchard might reduce erosion. Localised erosion may still be controlled at field level by vegetative strips. Our results suggest that average soil erosion rates are unlikely to surpass 10 ton ha^{-1} y^{-1}, which is nevertheless still more than the soil renewal by weathering (about 1 ton ha^{-1} y^{-1}). Any recommendations for improved soil management should ideally be tested at the appropriate scale and should capture the climatic (rainfall) conditions under which they are intended to mitigate soil erosion problems.

This brings us to Chapter 7, which concentrates on scenario development with stakeholders for olive orchards in the five Olivero target areas (Objective 4). The first step in scenario development is in fact the establishment of a typology of SMOPS (Chapter 3), as their future perspectives differ. The next step is to perform a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. Departing from the SWOT, a general overview is given of the medium- and long-term prospects. These have been validated by experts from the olive sector and foresee changes towards abandonment, intensification and organic production. On balance, the changes could lead to lower production of some target areas in future. An analysis of major external factors affecting the future development of SMOPS indicates there will be labour shortages and increased wage rates, reduced subsidies and constant or rising olive oil prices. On the basis of these assumptions, four future scenarios are developed for the five target areas, with the help of a Linear Programming (LP) simulation model. The results are presented for two target areas. For the Trás-os-Montes target area in Portugal, three of the four tested scenarios point to a high level of abandonment, while in the most positive scenario the areas under semi-intensive low input and organic SMOPS increase. In the Granada/Jaén target area in Spain, all scenarios hint at intensification, and only the orchards on the steepest slopes are likely to be abandoned. The direction and extent of environmental effects (erosion, fire risk, pollution, water use and biodiversity) differ per scenario, as do the extent of cross-compliance and AEM.

In Chapter 8, the LP model and scenarios of Chapter 7 are taken as a point of departure for a further methodological development and optimization of environmental and social performance of SMOPS (Objective 5). It presents alternative (multiple) goal programming (GP) models that take into account two perspectives: a farmer's and that of the society at large. The two perspectives represent hierarchical levels mutually dependent on each other to achieve best performance of the SMOPS from their perspective. A weighted GP model from a farmer's perspective – in short WGP (F), in which income represents half of the total weight of criteria, scored best on income and environmental and social objectives under all scenarios.

Further analysis using the WGP (F) model showed that the scenarios have an important effect on SMOPS performance from a farmer's, but not from a societal perspective. Current cross-compliance conditions and AEM give more incentives to reduce the negative environmental impact of (intensive) farming than to enhance the positive functions of traditional agriculture or reduce the negative effects of abandonment. SMOPS under more constrained and disadvantaged positions are burdened with additional policy requirements, while those with intensification potential (under favourable conditions) are not and may opt to participate in attractive AEM schemes.

The effectiveness of cross-compliance and AEM can be improved by: a) removing substantial overlap between them; b) shifting focus of cross-compliance conditions more to intensive SMOPS, e.g. by the inclusion of IPM, or design additional conditions for them; c) shifting focus of AEM more to extensive SMOPS or design additional measures for them, e.g. by inclusion of biodiversity aims; and d) increase incentives for farmers to adhere to or comply with the policies, for example by giving awards to 'good' farmers.

Chapter 9 recapitalizes the findings from previous chapters. It argues that with the full integration of the olive sector in the single farm payment scheme, an opportunity has been missed to promote low intensity olive farming. What functions are valued is context-dependent and science plays a facilitating role. The concept of conservation scenario is coined as an iterative learning process to facilitate adaptation to factors beyond decision-makers' control. After all, we better build a house on a solid foundation of knowledge…

Samenvatting

De olijventeelt op hellingen in het Middellandse Zeegebied heeft een onzekere toekomst. Olijfproductiesystemen in steile en bergachtige gebieden (‘SMOPS’, naar het Engelse acroniem) die eeuwenlang duurzaam waren, hebben in een relatief kort tijdsbestek grote veranderingen doorgemaakt. Hoewel er tegenwoordig nog steeds overblijfselen van deze traditionele landschappen te vinden zijn, is de algemene trend anders. Demografische veranderingen in de rurale bevolking, integratie in de markteconomie met haar competitieve karakter en technologische innovatie hebben de lokale economie, haar productiesystemen en daardoor het natuurlijke milieu drastisch veranderd.

Ten gevolge van de verscheidenheid aan ontwikkelingen is er nu een stratificatie opgetreden binnen de SMOPS. Terwijl sommige productiesystemen kunnen blijven concurreren op de wereldmarkt, zullen andere veelal traditionele olijfboomgaarden meerdere functies naast productieve moeten gaan vervullen. Van een groeiend aantal functies wordt het belang ingezien door belangengroepen op verschillende niveaus, of zelfs de samenleving als geheel. Dit bewustzijn geldt ook voor die systemen die economisch wel rendabel zijn gebleven, maar welke speciale aandacht behoeven om functies te behouden die verloren zouden kunnen gaan in het intensiveringproces.

Het huidige onderzoeksproject heeft als doel een geïntegreerde methodologie te ontwikkelen die deze problemen analyseert en om de toepassing van deze methodologie te evalueren voor verschillende scenario’s voor de SMOPS. Het project heeft de volgende doelstellingen:

1. een inventarisatie maken van SMOPS en hun aandachtspunten op het gebied van het beheer van natuurlijke hulpbronnen;
2. een functie evaluatiemethode ontwikkelen en de verschillende functies van SMOPS analyseren;
3. bodemconservering als een voorbeeldfunctie nemen en onderzoeken hoe belangrijk bodemerosie is in SMOPS en hoe dit probleem gecontroleerd kan worden;
4. scenario’s ontwikkelen gebaseerd op een verzameling kernfuncties geïdentificeerd door belanghebbenden;
5. milieu- en sociale prestaties van SMOPS optimaliseren in conserveringsscenario’s.

De eerste doelstelling wordt behandeld in de hoofdstukken 2 en 3. Hoewel de olijventeelt een belangrijke landbouwactiviteit is in het gehele Middellandse Zeegebied, is bodemerosie een van de grote milieuproblemen in deze zone. Het erosierisico in olijfproductiegebieden is hoog door de ligging van boomgaarden op (steile) hellingen, erosieve regenvalpatronen, erosiegevoelige bodems en onvoldoende bodembedekking. Hoofdstuk 2 identificeert die gebieden waar de olijventeelt als SMOPS gekenmerkt kan worden en verkent opties voor bodem- en waterconservering in olijfboomgaarden, met name die in vijf belangrijke productiegebieden: Oost Andalusië (Spanje), Noordoost Portugal, Zuid Italië, Kreta (Griekenland) en Centraal-West Tunesië.

Hoofdstuk 3 analyseert de relatie tussen SMOPS en aandachtspunten met betrekking tot het beheer van natuurlijke hulpbronnen meer in detail. Het begint met het inzicht dat er in het Middellandse Zeegebied een grote verscheidenheid aan olijfboomgaarden bestaat, met name in gebieden met steile hellingen. Recente aanjagers van veranderingsprocessen zoals de algemene introductie van mechanisatie, het toegenomen gebruik van (chemische) inputs en (druppel-)irrigatiesystemen hebben deze verscheidenheid nog verder vergroot. Er wordt geopperd dat de verschillende systemen zeer verschillende patronen in het gebruik van hulpbronnen hebben en dientengevolge verschillende milieu- en sociale prestaties. Gebaseerd op een uitgebreide studie in zes onderzoeksgebieden: Trás-os-Montes (Portugal), Córdoba en Granada/Jaén (beide in Spanje), Haffouz (Tunesië), Basilicata/Salerno (Italië) en West Kreta (Griekenland), werd een clusteranalyse uitgevoerd om 28 regionaal onderscheiden SMOPS te classificeren. Deze analyse resulteerde in de classificatie van 6 SMOPS typen op een gradiënt van productie-intensiteit: 1) zeer extensief, 2) traditioneel extensief, 3) semi-intensief met laag gebruik van inputs, 4) semi-intensief met hoog gebruik van inputs, 5) intensief en 6) biologisch. De opties met betrekking tot het beheer van natuurlijke hulpbronnen zoals het bestrijden van bodemerosie, lage biodiversiteit, bosbrandgevaar en excessief watergebruik worden verkend voor elk van deze typen.

Hoofdstuk 4 presenteert een van de onderscheiden SMOPS typen in detail: traditioneel extensieve (of simpeler: traditionele) olijfboomgaarden nemen een groot deel van de oppervlakte onder olijfbomen in het Middellandse Zeegebied voor hun rekening en zijn vooral talrijk in marginale gebieden. Traditionele SMOPS worden gekarakteriseerd als een laagintensief productiesysteem, geassocieerd met oude (soms zeer oude) bomen, gecultiveerd in lage dichtheden, met lage opbrengsten en ook lage inputs van arbeid en materialen. Gedurende het OLIVERO project zijn traditionele olijfboomgaarden onderscheiden en beschreven in vijf doelgebieden: Trás-os-Montes (Portugal), Córdoba en Granada/Jaén (beide in Spanje), Basilicata/Salerno (Italië) en West Kreta (Griekenland); de laatste van dit rijtje werd in een latere overkoepelende classificatie heringedeeld als een semi-intensief systeem met laag gebruik van inputs (hoofdstuk 3).

Hoewel traditionele SMOPS meerdere milieudiensten verschaffen, is hun economische levensvatbaarheid een belangrijk punt van aandacht geworden, zeker in Zuid Europa waar EU beleidsmaatregelen intensievere en meer concurrerende systemen bevoordelen. Boomgaarden die niet geïntensiveerd zijn geworden lijken te worden bedreigd door de recente hervorming van het EU olijven- en olijfoliebeleid, doordat inkomensondersteuning na loskoppeling van productie is gebaseerd op productie in een vierjarige referentieperiode in het verleden. Daardoor loopt de traditionele olijventeelt het risico te worden verlaten. Hoofdstuk 4 concludeert dat de levensvatbaarheid van deze systemen slechts dan gegarandeerd kan worden wanneer genoegen wordt genomen met een lagere remuneratie voor familiearbeid dan elders verdiend zou kunnen worden en wanneer de olijventeelt plaatsvindt als een parttime activiteit. Verschillende private en publieke interventies worden aanbevolen om verwaarlozing tegen te gaan.

Waar hoofdstuk 4 vooruitloopt op de functies van traditionele olijfboomgaarden, wordt in hoofdstuk 5 een raamwerk voor de analyse van de verschillende functies van SMOPS (doelstelling 2) gepresenteerd. Multifunctionaliteit in de landbouw heeft in de afgelopen tien jaar veel aandacht gekregen van onderzoekers en beleidsmakers. Concentrerend op een casus over SMOPS in Noordoost Portugal, worden methoden beschreven om de verscheidenheid aan functies van landbouwecosystemen te bestuderen. Het “Huis van Functies” wordt gepresenteerd als een methode voor de evaluatie van functies. Door het voorstellen van de prestaties op het gebied van ecologische, productieve, economische, sociale en culturele functies op assen die tezamen het silhouet van een huis vormen kan deze methode wellicht in de smaak vallen bij een grote verscheidenheid aan actoren. In de casus concluderen we dat de regionale SMOPS vooral tekortschieten in het voorzien van ecologische functies. Wél dragen ze significant bij aan de lokale economie, creëren ze werkgelegenheid en vervullen ze een belangrijke culturele rol in het beheer van het landschap, waardoor ze een sleutelpositie innemen voor regionale ontwikkeling en het tegengaan van emigratie van de bevolking. Beleidsmakers zouden de functie-evaluatiemethode kunnen gebruiken om effectieve randvoorwaarden en relevante agromilieumaatregelen te ontwerpen om ecologische en sociale functies te versterken en om ideeën te communiceren naar andere belanghebbenden. In deze zin kan de methode beleidsplanning verbeteren door het visualiseren van trends, ontwikkelingsalternatieven of scenario’s. De rol van wetenschap in deze methode is het faciliteren van de dialoog tussen groepen belanghebbenden en het voeden van het proces met relevante indicatoren.

Hoofdstuk 6 verdiept vervolgens één specifieke functie: bodemconservering en verkent hoe goed olijfboomgaarden deze functie vervullen (doelstelling 3). Een literatuurstudie geeft een pessimistische kijk op de capaciteit van SMOPS om de bodem te conserveren en laat sommige regionale gemiddelde bodemverlieswaarden van 40 – 100 ton ha^{-1} jaar^{-1} zien. Deze waarden zijn gebaseerd op empirische modellen die een simpele vermenigvuldiging toepassen van nadelige milieufactoren zoals steile hellingen, erosiegevoelige bodems en lage bodembedekking door vegetatie. Wij presenteren experimentele data van regenvalsimulaties, studies van afstromingspercelen en een veldevaluatie van erosiesymptomen die deze visie betwisten. Wij wijzen op de effecten van het vergroten van de oppervlakteruwheid van de bodem door ploegen, de hoge bedekkingsgraad van steile hellingen met stenen, ondergroei in de boomgaarden, onregelmatigheden in de helling, strips met plantenbedekking en op het feit dat erosie voornamelijk wordt veroorzaakt door zeldzame regenbuien met hoge intensiteit en het (abusievelijk) opschalen van experimentele resultaten. Hoewel deze factoren (in samenspel) optreden op verschillende schalen, vormen zij bij elkaar genomen een argument om preciezer aan te duiden wanneer, waar en voor wie erosie een probleem vormt.

Aan de hand van de resultaten van onze individuele experimenten leidt Hoofdstuk 6 tot de conclusie dat verstandig ploegen in daartoe aangewezen gebieden van een olijfboomgaard bodemerosie kan tegengaan. Lokale bodemerosie kan eventueel op veldniveau worden ingedamd door strips met plantenbedekking. Onze resultaten suggereren dat het onwaarschijnlijk is dat gemiddelde bodemverliezen boven de 10 ton ha^{-1} jaar^{-1} uitkomen, wat overigens nog altijd meer is dan de nieuwe bodemvorming door verwering (ongeveer 1 ton ha^{-1} jaar^{-1}). Elke aanbeveling voor beter bodembeheer zou idealiter getest moeten worden op de relevante schaal en zou de klimatologische (regenval) condities moeten meenemen onder welke ze geacht worden bodemerosieproblemen het hoofd te bieden.

Dat brengt ons bij hoofdstuk 7, dat zich richt op het met belanghebbenden ontwikkelen van scenario’s voor de olijfboomgaarden in de vijf Olivero doelgebieden (doelstelling 4). De eerste stap in het ontwikkelen van scenario’s is in feite de vaststelling van een typologie van SMOPS (hoofdstuk 3), omdat toekomstperspectieven per SMOPS verschillen. De volgende stap is het maken van een zogenaamde SWOT analyse (naar het acroniem van het Engelse equivalent van sterke punten (strengths), zwakke punten (weaknesses), mogelijkheden (opportunities) en bedreigingen (threats)). Door de SWOT analyse als uitgangspunt te nemen kan een globaal overzicht gegeven worden van vooruitzichten op de middellange en lange termijn. Deze vooruitzichten zijn bevestigd door olijfsector experts en omvatten b.v. het verlaten, intensiveren en omschakelen naar biologische landbouw. Bij elkaar genomen kunnen deze veranderingen in de toekomst leiden tot lagere productie in sommige doelgebieden. Een analyse van de belangrijkste externe factoren die de toekomstige ontwikkeling van SMOPS beïnvloeden wijst op een tekort aan arbeid en hogere lonen, gereduceerde subsidies en constante of stijgende prijzen van olijfolie. Op basis van deze aannames worden vier toekomstscenario’s ontwikkeld voor de vijf doelgebieden, met behulp van een simulatiemodel op basis van lineaire programmering (LP). De resultaten van twee doelgebieden worden gepresenteerd. Voor het doelgebied Trás-os-Montes in Portugal leiden drie van de vier geteste scenario’s tot een hoog percentage van verwaarlozing, terwijl in het meest positieve scenario de gebieden onder semi-intensieve boomgaarden met laag gebruik van inputs en biologische boomgaarden in belang toenemen. In het doelgebied Granada/Jaén in Spanje leiden alle scenario’s naar intensivering en alleen olijfboomgaarden op de steilste hellingen zullen waarschijnlijk verwaarloosd worden. De richting en grootte van milieueffecten (erosie, bosbrandgevaar, vervuiling, watergebruik en biodiversiteit) verschillen per scenario, net als het respecteren van randvoorwaarden en participatie in agromilieumaatregelen.

In hoofdstuk 8 worden het LP model en de scenario’s uit hoofdstuk 7 als uitgangspunt genomen voor een verdere methodologische ontwikkeling en optimalisering van de milieu- en sociale prestaties van SMOPS (doelstelling 5). Verschillende alternatieve (multiple) goal programmeringsmodellen (GP) worden gepresenteerd die twee perspectieven als uitgangspunt nemen: dat van een boer en dat van de samenleving als geheel. De twee perspectieven representeren hiërarchische niveaus die over en weer afhankelijk van elkaar zijn om vanuit hun eigen invalshoek de beste prestaties voor SMOPS te behalen. Een gewogen GP model vanuit boerenperspectief – kort aangeduid met WGP (F), waarin het inkomen de helft van het totale gewicht van criteria voor haar rekening neemt, scoort onder alle scenario’s het best op inkomen en milieu- en sociale doelen.

Verdere analyse op basis van het WGP (F) model laat zien dat de scenario’s een belangrijk effect hebben op de prestaties van SMOPS vanuit boerenoogpunt, maar niet vanuit het perspectief van de samenleving als geheel. De huidige randvoorwaarden voor het verkrijgen van subsidie en agromilieumaatregelen stimuleren meer tot het verminderen van de negatieve impact van (intensieve) landbouw dan tot het versterken van de positieve functies van de traditionele landbouw of het reduceren van de negatieve effecten van verwaarlozing. SMOPS met meer beperkingen en in nadelige posities worden geconfronteerd met extra randvoorwaarden om in aanmerking te komen voor subsidies, terwijl die met een intensiveringspotentieel (onder voordelige omstandigheden) dat niet worden en bovendien kunnen participeren in attractieve agromilieumaatregelen.

De effectiviteit van randvoorwaarden en agromilieumaatregelen kan worden verhoogd door: a) het verwijderen van substantiële overlap; b) het verleggen van het zwaartepunt van randvoorwaarden naar de meer intensieve SMOPS, zoals b.v. door het betrekken van eisen op het gebied van geïntegreerde gewasbescherming, of extra voorwaarden te creëren; c) het verleggen van het zwaartepunt van agromilieumaatregelen naar de meer extensieve SMOPS of extra maatregelen te creëren, b.v. door het betrekken van biodiversiteitsdoelen; en d) het verhogen van de stimulans voor boeren te participeren in agromilieumaatregelen en om randvoorwaarden te respecteren, b.v. door het toekennen van prijzen aan ‘goede’ boeren.

Hoofdstuk 9 recapituleert de bevindingen van de vorige hoofdstukken. Er wordt gesteld dat er met de volledige integratie van de olijfsector in het programma voor inkomenssteun een kans gemist is om laagproductieve olijventeelt te promoten. Welke functies gewaardeerd worden hangt af van de context en wetenschap speelt daarbij een faciliterende rol. Het concept van conserveringsscenario’s wordt opgeworpen als een iteratief leerproces om aanpassing aan allerhande factoren buiten de controle van de beslisser te vergemakkelijken. Tenslotte is het beter om een huis te bouwen op een solide fundering van kennis…

PE&RC PhD Education Certificate

The C.T. De Wit
Graduate School
PE&RC
PRODUCTION
ECOLOGY
& RESOURCE
CONSERVATION

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of Literature (3 credits)

- Assessment of multi-functionality of olive production systems on sloping land (2002/2003)

Writing of Project Proposal (3 credits)

- Valuation of conservation scenarios for olive farming on sloping and mountainous land (2002/2003)

Laboratory Training and Working Visits (4.3 credits)

- Multiple functions of olive orchards in Trás-os-Montes; Instituto Superior de Agronomia (Lisbon, Portugal) (2003)
- Assessment of soil erosion in olive orchards; University of Basilicata (Potenza, Italy) (2004)

Post-Graduate Courses (5 credits)

- Wind and water erosion: modelling and measurement; WUR & Ghent University (2003)
- Multi-criteria decision making; MGS (Prof. C. Romero) (2005)

Deficiency, Refresh, Brush-up and General Courses (6 credits)

- Multifunctional land use; WU-SIL (2003)
- Time and project management ; PE&RC – STOAS (2003)
- Basiscursus didaktiek; WU – Onderwijsondersteuning (2006)

Discussion Groups / Local Seminars and other Scientific Meetings (4 credits)

- Sustainable land use and resource management (2003/2005)
- Advanced in land use management (seminar series at the ESW group) (2004/2005)

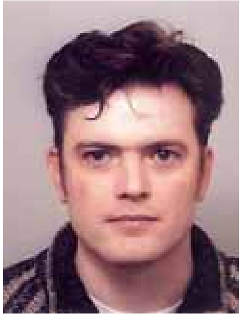
PE&RC Annual Meetings, Seminars and the PE&RC Weekend (0.75 credits)

- Annual meeting 2004: “Biological disaster” (2004)
- Meeting “How to manage change in rural areas in desired directions?” (2005)
- Meeting “10 Years anniversary” (2005)

International Symposia, Workshops and Conferences (3 credits)

- Ist World congress conservation agriculture; FAO/ECAF, Madrid, Spain (2001)
- Int’l Symposium olive tree and environment; NAGREF/MAICH, Chania, Greece (2003)
- COST 634 meeting; COST634, Rouen, France (2005)

Curriculum Vitae



Luuk Fleskens was born on 1 February 1974 in Eindhoven, the Netherlands. He grew up in Paramaribo, Suriname where he had the privilege to visit the country's pristine rainforests on numerous trips and expeditions. This experience marked his interest in geography and ecology. After attending secondary school, he studied Tropical Land Use at Wageningen University (WU). He combined a practical period on soil nutrient balances and a thesis research on erosion and its perception by farmers in Nampula, Mozambique (1996). He conducted a second thesis on modelling nitrogen fixation in tropical forests and graduated in the specialization Management of Natural Resources in 1997.

After his first job as assistant to the post-graduate course Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS), he returned to Nampula to combine living with his Mozambican girlfriend (later his wife) and setting up a private consultancy business. From 1998 to 2000 he provided services to many (inter-)national (N)GO's including CARE, SDC, World Vision, Movimondo, and Dutch bilateral development projects. One activity that stands out from this period is the work as umbrella programme coordinator with CARE for a sunflower promotion project.

In 2000, he returned to Wageningen to work as project officer on two EU-funded research projects on water harvesting for the Erosion and Soil & Water Conservation group at WU. These projects brought him to Turkmenistan, Morocco and Tunisia, where he became interested in olive cultivation. Upon ending of these projects, he was contracted as assistant professor to lecture courses, most notably Impact Assessment of Land and Water Management, supervise students and for project acquisition. He co-wrote the OLIVERO project proposal that was selected for funding by the EU (€1.5 million) and formed the smooth transition to a position as researcher (2003-2007). He was involved in the daily coordination of the project and developed many of the ideas that led to the present PhD thesis. Meanwhile he continued lecturing, and supervised final theses of a total of 11 MSc students.

Besides this thesis, Luuk authored a total of 6 journal articles, 4 book chapters and 50+ research and consultancy reports, and acted as guest editor for a special issue of the Journal of Environmental Management on the future of olive production systems on sloping land.

Recently, he was contracted as consultant by IFDC, an International Center for Soil Fertility and Agricultural Development, to prioritize rural public works interventions for agricultural intensification in the African Great Lakes region (Rwanda, Burundi and Eastern Congo DRC).

He currently lives with his wife and two children in Bennekom and can be contacted at luukcarla@orange.nl.