AGFORWARD
Agroforestry for Europe

Environmental and socio-economic framework conditions of agroforestry in different regions in Europe

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Authors	Mercedes Rois Díaz, Natasa Lovric, Marko Lovric, Michael den Herder, Anil Graves, Andrea Pisanelli, Rosa Mosquera Losada, Nuria Ferreiro Rodríguez, Silvestre Garcia De Jalon, Andrea Vityi, Anna Varga, Paul J Burgess
Contributors	Norbert Lamersdorf, Joana Amaral, Béla Marosvölgyi, Jaconette Mirck, Penka Tsonkova, Anastasia Pantera, Konstantinos Mantzanas, Pablo Fernandez Paradela, Mikko Kurtila, Jari Miina, Gerardo Moreno, Matthew Upson, Nina Malignier, Frances Ward, Catherine Gerrard, Jo Smith, Francesca Camilli
Contact	mercedes.rois@efi.int
Approved	Felix Herzog Paul Burgess (10 April 2017)

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1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the first objective by analysing which environmental and socio-economic characteristics are most significant in the successful adoption of agroforestry. These characteristic may vary with agroforestry system and with region.

After this introduction, the report comprises four sections. Section 2 comprises a background review of the agricultural sector in Europe, and Section 3 provides a brief review of the socio-economic and environmental factors affecting the adoption of agroforestry. Section 4 comprises the use of grounded theory and qualitative interviews with farmers. The objective of this section is to examine the driving forces determining the implementation of agroforestry by farmers across Europe. Section 5 describes the development of five Analytic Network Process (ANP) models, based on questionnaires with experts. The objective of this section is to identify the key criteria that determine whether farmers will adopt agroforestry in each of the five main biogeographical regions (Atlantic, Boreal, Continental, Mediterranean and Pannonian) of Europe.

2 Background on the agricultural sector in Europe

Europe is characterized by a predominantly rural landscape (Figure 2.1) with particularly large rural areas in France, Northern Europe and Eastern Europe (Eurostat 2016). The Farm Structure Survey (FSS) carried out by Eurostat provides some basic statistical information of the agricultural and forestry sector in Europe. In 2013, there were 10.8 million farms across the EU-28 working 174.4 million hectares of land (Utilised Agricultural Area or UAA). This equals 40% of the total land area of the EU-28, while the forested area of the EU is slowly increasing and covers a slightly greater proportion of the land than is used for agriculture, 42%.

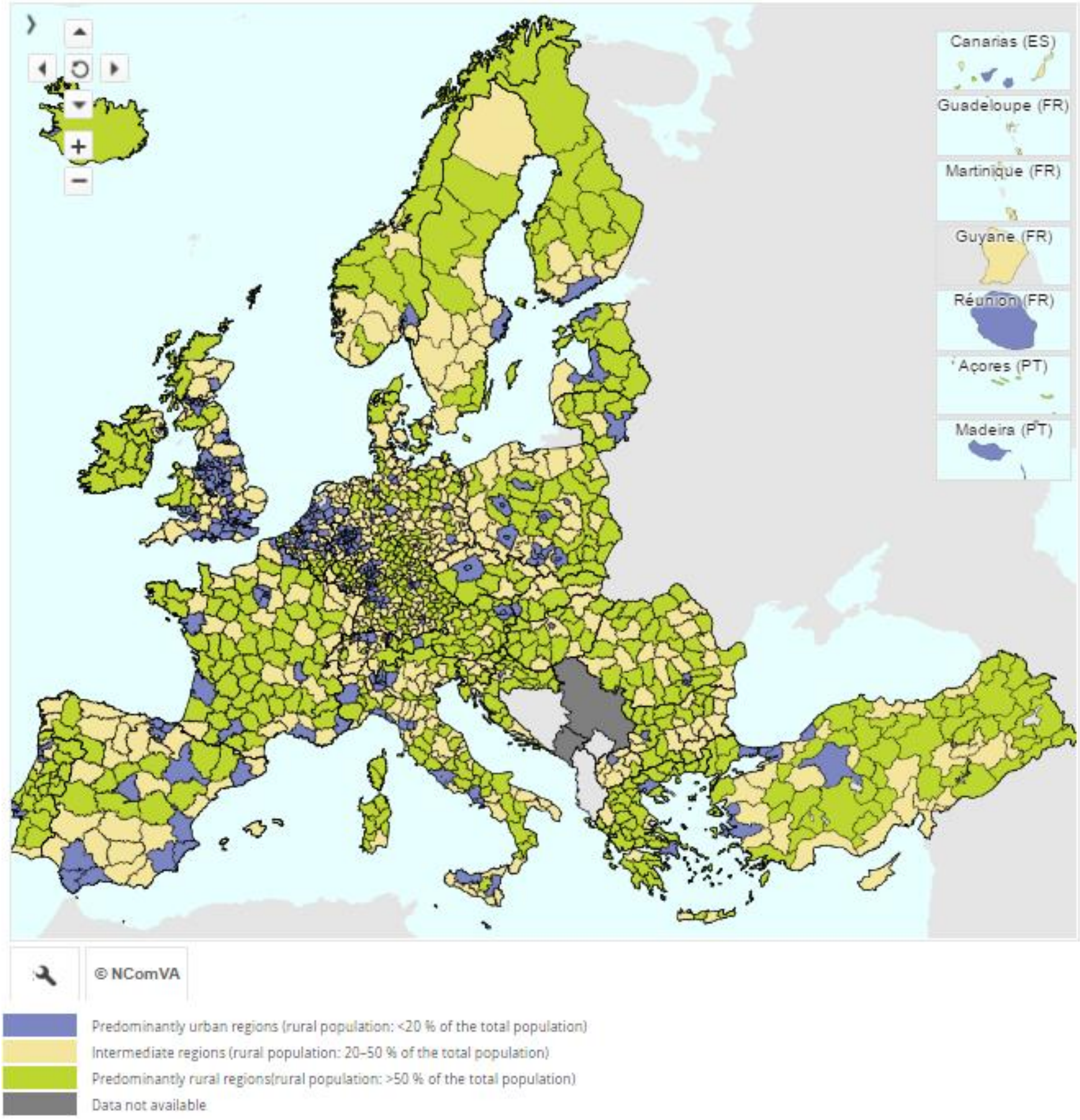


Figure 2.1. Urban-rural typology based on NUTS 3 regions (Eurostat 2016)

The average size of a European farm is about 16 hectares. However the distribution is skewed with almost half of all farms being less than 2 hectares (occupying only 2.5% of the UAA), whilst a small proportion (3.1%) of very large farms cover over 100 hectares and farm about 50% of the UAA (EU 2016). This variation is also observed in the economic size of the holdings. Almost 40% of the farms had a standard output below €2000 and were responsible for only 1.0% of total agricultural economic output in 2013. By contrast, 2.4% of holdings that had a standard output in excess of €250,000 accounted for more than half (51.7 %) of all agricultural economic output (EU 2016).

Three fifths (59.8%) of the utilised agricultural area in the EU-28 was used as arable land in 2013, a majority being used for cereal production. A further third (34.2%) was permanent grassland and meadow. Permanent crops, such as vineyards, olive trees and orchards, accounted for a 5.9% share and kitchen gardens around 0.2%. The proportion of utilised agricultural area occupied by permanent crops was relatively high in some of the Mediterranean countries, the highest shares (a little over 19%) being in Cyprus, Greece and Portugal (EU 2016).

In 2013, just under a third (29.6%) of EU-28 farms were holdings specialised in field crops (for example, cereals, oilseeds and vegetables). A further 17.4% of farms were specialist permanent crop holdings (for example, vineyards, olive groves or orchards). Specialist grazing livestock holdings (dairy cows, cattle, sheep and other ruminants), pigs and poultry, mixed livestock holdings and mixed crop-livestock holdings together accounted for over two fifths (44.7%) of all agricultural holdings in the EU-28. The 'EU-28's livestock herd' was 130.3 million LSU in 2013; about one half (48.3%) were cattle, 26.1% were pigs and 15.3% were poultry (EU 2016).

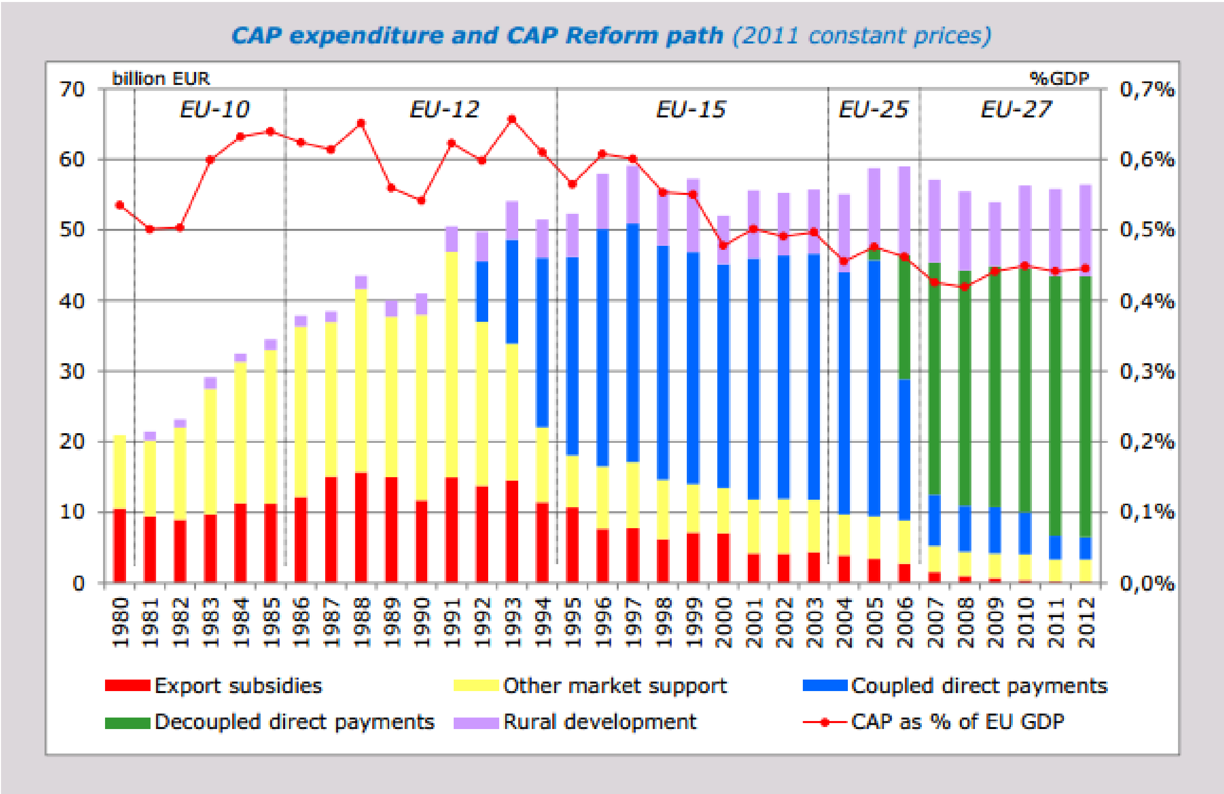
According to the EU's labour force survey (LFS), people employed in agriculture, forestry and fishing activities represented 5.4% of all employment in 2013. Farming was predominantly a family activity in the EU-28; about three quarters (76.5%) of the labour input in agriculture came from the holder or members of his/her family in 2013 (EU 2016).

Of the 10.8 million farm managers in the EU-28 agricultural sector in 2013, there were relatively few young farm managers. On average, across all EU Member States, managers younger than 35 years accounted for only 6% of the total. On the other hand, more than half of the farm managers, (some 6 million farm managers, or 55.8%) were aged 55 or above and thus close to or beyond the regular retirement age (EU 2016).

The vast majority of the EU's farms are relatively small, family-run holdings. Often, these holdings draw on family members to provide labour (in addition to the farm holder). Agriculture is also characterised by seasonal labour peaks (for example those linked to harvesting) with high numbers of workers hired for relatively short periods of time. Otherwise, some farmers are occupied on a part-time basis (and they may have alternative, sometimes important sources of income) so while there are a large number of people providing labour within agriculture, many of these will have their main employment elsewhere. The EU-28 agricultural labour input was estimated at 9.8 million annual work units (AWUs) (the equivalent of 9.8 million people working full-time) in 2014. Agricultural labour input declined over the period 2010–14 (–5.6%). Actually, since the early 1980s, there has been a steady downward trend in the number of livestock on agricultural holdings across the EU (EU 2016).

The agricultural sector is much dependent on the Common Agriculture Policy (CAP). CAP expenditure (as a proportion of the EU budget) has decreased over the past 25 years from 73% in 1985 to 41% in 2012. The expenditure on the CAP has remained relative constant in real terms since 1996 (Figure

2.2) despite EU enlargement due to CAP reform and EU budget restrictions.



Sources: *CAP expenditure: European Commission, DG Agriculture and Rural Development (Financial Report).GDP: Eurostat. Annual expenditure in 2011 constant prices.*

Figure 2.2. CAP expenditure and CAP reform path (EC 2016)

With the Agenda 2000 the reform of the CAP continued and rural development policy was introduced as a second pillar. With the 2003 reform most direct payments were decoupled from current production as they were based on the farmer's historical receipts. Rural development expenditure has tended to increase.

Despite its numerous benefits, agroforestry was only recognised in 2005 in the CAP. There was no policy in place at a European Union level to promote this kind of land system management on a widespread scale until 15 September 2005, when a Council Regulation on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) was released. According to EU Regulation 1698/2005 the establishment of agroforestry systems should be encouraged due to their “high ecological and social value”. This established that “measures targeting the sustainable use of forestry land through the establishment of agroforestry systems on agricultural land” should be taken (Rigueiro et al. 2009). Under the former Rural Development Programmes, 2007-2013, 19 programmes supported the establishment of agroforestry systems allocating about 15 million Euros to implement the measure 222. Nevertheless, the effective uptake of the measure was very poor: only about 6.4% of those resources were designated to create new agroforestry systems, namely in Belgium, France, Hungary, Italy and Portugal (Pisanelli et al. 2014). Although few farmers have used these funds, there is room for improvement in the current programming period, 2014-2020. According to the EU Regulation 1305/2013 agroforestry is defined in the Article 23 as “land use systems in which trees are grown in combination with agriculture on the same land”. The main instrument for establishing new agroforestry systems on agricultural land is the sub-measure 8.2 that has been activated in 35 regions in France, Spain, Italy, Portugal, the United Kingdom, Belgium, Hungary and Greece (Lawson et al. 2016).

Europe has been facing several issues of concern for the last years. There has been a clear rural land abandonment and migration of people from rural to urban areas as consequence of the agriculture getting less attractive as an economic activity. The number of farmers in Europe is declining and their average age is increasing. Only 5.4% of EU's population works on farms whilst the farming sector was responsible for 1.6% of the GDP of the EU in 2005. The number of European farmers is typically decreasing by 2% annually (EC 2011).

The major factor for such depopulation where agriculture and forestry are the main economic activities is the lack of agricultural competitiveness but can result also from a lack of rural finance, a lack of public infrastructure, the overall economic context of a country (territorial competitiveness), and a negative social image of agriculture, and the ageing European population (FAO 2006).

Maintaining agricultural activities, particularly in low-productive areas, becomes difficult. Some agricultural land is being abandoned and this could have consequences beyond the local economy for areas where farming activities actually help preserve nature. To stop abandonment, farmers in marginal areas need enhanced support and increased public support for agriculture's role in the provision of public goods. Revitalization implies defining and implementing incentives that will convince the economic actors in rural areas, such as farmers and forest managers, to invest and to produce (FAO 2006). Incentives may be market-based incentives or public-goods based incentives.

By managing a large part of the European Union's territory, agriculture ensures food production, manages some important natural resources (including a wide range of valuable habitats) and supports socio-economic development of rural areas. The continuation of appropriate agricultural land management is essential to ensure these primary functions. This is why avoidance of farmland abandonment is an important rationale for the CAP (Terres et al. 2013).

On the other hand, there is the problem of intensification to obtain higher yields per unit of land through practices that can damage ecosystems such as intense mechanization, drainage, irrigation and application of fertilizers and pesticides. These practices have been associated with decreasing biodiversity, loss of genetic resources and pollution of soil and water bodies (EEA 2013).

Europe, as is the case in most parts of the world, is facing major societal challenges like climate change, food, water and energy security, rural decline and biodiversity loss. These challenges require a decoupling of economic growth from environmental degradation and new approaches to manage agricultural and forest land.

3 Existing knowledge on the drivers of agroforestry vs. conventional agriculture or forestry

In this document, the term conventional agriculture refers to any kind of agriculture that does not involve agroforestry practices. Hence in the context of this report “conventional” agriculture could include both organic and intensive agricultural practices. Likewise whilst some agroforestry practices are traditional, and thus understood as conventional by some participants, in the context of this report they are referred to as agroforestry.

3.1 Socio-economic factors

There are some socio-economic barriers limiting agroforestry. Agroforestry practices can result in extra costs compared to conventional agriculture: e.g. trees must be protected in early stages in silvopastoral systems, or they may increase labour and machinery inputs per unit area in silvoarable systems (Graves et al. 2009). Recent surveys carried out within the SAFE and AGFORWARD projects have highlighted that farmer perceived the complexity of management as one of the main constraints limiting the adoption of agroforestry (Graves et al. 2009; Burgess et al. 2016; Camilli et al. 2016).

On the other hand, there can sometimes be economic benefits. For example grazing an orchard may reduce the need for mechanised mowing whilst providing an additional source of income. Providing shelter and/or shade to livestock can reduce stress and increased feed conversion efficiency and thus increase revenue. In some systems, agroforestry practices may increase pollination rates potentially resulting in a higher yield of seeds and fruits and hence revenue. Graves et al. (2007) demonstrated that under typical management, integrating crops and trees on the same area of land can increase yield productivity per unit area compare to growing them separately.

Whilst conventional agriculture can provide greater margins for an individual crop or product than agroforestry, the societal value of agroforestry can be high because of its beneficial effect on environmental services (e.g. nutrient recycling, water quality, soil quality, pollination, biological control, air quality, windbreak, and carbon storage). Knowing this, society working through government subsidies may provide support to encourage farmers to adopt agroforestry systems (Alam et al. 2014).

3.2 Environmental factors

In Northern Europe, farmers identified that the key benefits of silvoarable agroforestry were primarily social and environmental, rather than economic (Graves et al. 2009). The main acknowledged benefits included farmer image, biodiversity, landscape, farm diversification, soil conservation and timber production, namely high quality timber. Some farmers who want to establish trees may consider that maintaining annual revenues from pasture or crop production is a benefit compared to forestry (Graves et al. 2009).

During the 20th century, many farmers removed trees from their fields to facilitate mechanization and to maximise the eligible area for CAP subsidies. However, isolated trees in field and trees in hedges or in groups can now be classified as landscape features supported by European agri-environmental measures. In many regions, there are regulations that prohibit the removal of trees.

According to den Herder et al. (2017) the total area under agroforestry in the EU 27 is about 15.4 million ha which is equivalent to about 3.6% of the territorial area or 8.8% of the Utilised Agricultural Area. The same authors report that Mediterranean countries (Spain, France, Italy, Greece and Portugal) have the largest absolute areas of agroforestry.

Reisner et al. (2007) highlighted that, even considering only five tree species, 40% of European arable land was suitable for introducing novel silvoarable agroforestry systems and could benefit from either reductions in soil erosion and nitrate leaching or increases in landscape diversity.

3.3 Innovations

A fundamental challenge in developing a new farming practice is to have it adopted and maintained by farmers. Widespread adoption is more difficult if the new farming system is complex and/or radically different to current farming practice. Pannell (1999) highlighted four conditions to adopt an innovative farming system: 1) awareness of the innovation, 2) perception that it is feasible to test the innovations, 3) perception that the innovation is worth testing, and 4) perception that the innovation promotes the farmer´s objectives.

Domínguez and Shannon (2011) report that forest owners can manage their land considering four axes: i) economic expectations of the land, ii) ethical behaviour, iii) how the forest should be, and iv) the behaviour in relation to natural hazards. Land owners typically appreciate the technical advice and solutions suggested by the technicians and extension services are an influential agent on the opinion of the owner towards alternative management options e.g. subsidies, programmes, innovative management practices (Primmer and Karppinen 2010; Van Gossum et al. 2005), especially in cases of high uncertainty (e.g. prices fluctuation, climate change) and complexity (technological advances) (Schlüter and Koch 2009).

4 Driving forces for the implementation of agroforestry systems by the farmers

Authors: Mercedes Rois[1], Nataša Lovrić[1], Marko Lovrić[1], Michael den Herder[1], Rosa Mosquera[2], Nuria Ferreiro[2,] Paul Burgess[3]

[1] European Forest Institute, Finland
[2] University of Santiago de Compostela, Spain
[3] Cranfield University, UK

4.1 Introduction

The intention of the qualitative interviews carried out across Europe was to perform a theoretical sampling to the level of a 'newly-built' theory on the research question we aim to address, that is **'Why is agroforestry accepted or not?'** Eight research questions were formulated to clarify this.

4.2 Material and methods

As a research approach, grounded theory is appropriate for identifying and explaining social processes (Bowen 2006). It originated as the discovery of theory from data (Glaser & Strauss 1967). Grounded theory is accepted to be holistic, naturalistic and inductive (Egan 2002) and is a practical approach to help researchers understand complex social processes (Suddaby 2006). The goal of grounded theory research is to explain how social circumstances could account for the behaviour and interactions of people being studied (Benoliel 1996). In grounded theory there is no clear break between collecting and analyzing the data. In fact, data must be collected until no new evidence appears, i.e. category saturation (Suddaby 2006). Suddaby (2006) argues that a combination of qualitative and quantitative methods should be encouraged.

Interpretative analyses attempt to describe, explain and understand the lived experiences of a group of people (Charmaz 1995). The early analytic work while collecting data leads the researcher subsequently to collect more data around emerging themes and questions.

In grounded theory, the analysis begins as soon as the first data are collected and directs the next interviews and observations (Corbin and Strauss 1990). Given the flexibility of grounded theory research, ongoing sampling adjustments are possible and expected (Egan 2002). The raw data are given conceptual labels. Each code or concept is constantly compared to all other codes to identify similarities, differences and general patterns. Themes or categories gradually emerge and move from a low level of abstraction to become major themes, which when related one to another could form a theory. When theoretical saturation occurred, i.e., when additional data failed to uncover any new ideas about the developing theory, the coding process is ended (Bowen 2006).

Assessments considering the triple bottom line approach are necessary to assess the development, wealth, and long-term welfare of any system. Economic and social factors are as essential as environmental components in sustainability assessments (Santiago-Brown et al. 2015).

4.2.1 Sampling

The intention of the qualitative interviews was to use research questions to develop a 'newly-built' theory and sampling continued until theoretical saturation occurred. Theoretical saturation meant that the answers started to repeat themselves, and additional interviews would provide no new explanations. Theoretical saturation often does not occur on the level of an individual question in the interview, but at the level of the research question that the research tries to answer instead, which is 'Why is agroforestry accepted or not?'

The selection of the respondents was as random as possible, after the stratification in two groups: farmers practicing conventional agriculture (A), and farmers practicing agroforestry (AF). The farmers not using agroforestry were selected from a similar production sector in the same region. The level of generalization had also a geographical reference, and it was related to the population of farmers in that area. As a starting point, a list of all the farmers (e.g. from associations or extension services) was used. If a list was available, then each farmer was chosen randomly, and then the next random farmer from the list was chosen, and so forth. If the selected farmer was not available, the next one from the list was chosen instead.

The analysis of interviews was carried out in parallel with the interviews i.e. listening to the interviews to 'learn' to get an overview of the answers and then to continue on with the further interviews. In some interviews, when considered appropriate, the list of questions evolved with the answers i.e. if some respondents kept directing the interview toward a (important) topic not addressed by the protocol, then this was added as a question in the subsequent interviews.

4.3 Performing the interview

Interviews were performed either face-to-face or by telephone, in both situations they were asked for a permission to record it. The interviews were performed, and recorded when possible, in their respective languages and then translated into English language for their analysis. The recordings will be kept until the end of the project in December 2017. The interviews were performed with the person from the household within the list of respondents/farmers. If that person was not available someone else from the household could answer the questions instead. The interview protocol including ethical considerations was explained to the interviewee at the beginning of each interview.

The interviews were performed with almost no intervention from the interviewer. Only in the main questions with no or very little detail in the answers, 'suggestions' were posed. The column 'comments' in the protocol was used just for the interviewer. The interviewer took notes during the interview. In this way the respondent perceived heightened importance of his/her answers. These notes were used later on in the analysis of the interview, and they also made the respondent more engaged in the interview. The main analysis came from the recordings.

Several partners from the AGFORWARD project performed, in total, 183 qualitative interviews with identified farmers which are implementing or not implementing agroforestry, grouped by different systems across Europe (Table 4.1). The agroforestry systems used follow the different categories selected in the AGFORWARD project, i.e. i) high nature and cultural value agroforestry, ii) agroforestry with high value trees, iii) agroforestry for arable systems and (iv) agroforestry for livestock systems. Data collection was done by partners in Spain, Italy, Greece, Portugal, France, Germany, Hungary and the UK. Once the data were collected and submitted, the analysis was performed by staff from the European Forest Institute (EFI) and the University of Santiago de Compostela (USC).

Table 4.1. Distribution of the sampling for performing the qualitative interviews to farmers across Europe. AF: agroforestry, A: conventional agriculture

Agroforestry system	Partner	Country	Country	Number of AF interviews	Number of A interviews
WP2 High Nature and Cultural Value	TEI	Greece	EL	8	8
	ISA	Portugal	PT	8	8
	UNEX	Spain	ES	9	8
	BTU	Germany	DE	8	8
WP3 High value trees	CRAN	UK	UK	5	0
	AFBI	UK	UK	1	10
	USC	Spain	ES	4	7
WP4 Silvoarable	ORC	UK	UK	9	4
	TEI	Greece	EL	8	8
	BTU	Germany	DE	8	8
	AFAF	France	FR	8	9
WP5 Silvopasture	USC	Spain	ES	9	7
	NYME	Hungary	HU	7	0
	CNR	Italy	IT	6	0
		TOTAL (183)		98	85

For details on the interviews carried out, see Annex I Protocol, Annex II Guidance document for the interviews and Annex III Qualitative analysis of the interviews.

4.4 Analysis of the interviews

There were two types of questions in the interviews: 'simple', or closed format questions, and 'complex' or open format questions. Simple questions require the researcher just to note/write down the answers, or to categorize them. Examples are 'Which land type?' and 'Size of the farm?' and were regarded as independent variables appropriate for quantitative analysis. The 'complex' questions were the ones through which the theoretical saturation was sought, recorded for individual opinions and appropriate for qualitative analysis.

The analysis was completed in English. The analysis ran inductively from the data to the research question, i.e. from the data the researcher 'built' codes and categories which are increasingly abstract, until the point they become concepts directly related to the research question (e.g. a category of reasons why is agroforestry implemented or not, or hurdle rate which stops the adaptation of agroforestry in a certain region). Researchers applied these techniques before using appropriate software for qualitative analysis (MaxQDA), while others just used Microsoft Word while listening to the recording. The analysis proceeds by the researcher listening the recording, and marking a time frame with words that describe that period of conversation. Several elements were used simultaneously to describe a segment of the interview. This was the initial coding phase. After the entire interview was coded in such manner the researcher tried to systematize the codes by producing 'categories' of codes. Each 'category' contained its explanation, called a ‘memo’. This memo explained what the code is about. If applicable, then the researcher tried to systematize them further in even more abstract and general groups of codes. In this study there were only few 'general' codes which were directly related to the explanation of the research question.

The memos contained all the relevant information to describe the code. The texts and the memos were kept short. The groups of codes found did not precisely relate to the questions within the interview protocol. They were also related to any possible factors that bring about some understanding of the research question (i.e. why is agroforestry accepted or not). Some of them had multiple levels of codes. This number was kept theoretically manageable. Three types of coding were performed on the data: initial, in-vivo, and pattern coding.

4.4.1 In-vivo coding

Direct quotations for either particularly typical or unique aspects (e.g. definitions and causalities) were collated for each question during the other two coding approaches. The original text was kept safe (with MAXQDA it is possible to add layers of coding on the same text without altering the original text).

4.4.2 Initial coding

"Initial coding" refers only to condensing the data to more manageable (shorter) units that can be listed and categorized more easily in the later phases. The essence of the ideas was captured with a few words, and the transcribed text was condensed. This was purely inductive research (applying grounded theory methods); there were no hypotheses to test but rather just an iterative process of using the data to identify new findings. In other words, there were no predefined categories.

4.4.3 Pattern coding

"Pattern coding" is an iterative process of categorizing the initial codes (i.e. the shortened text fragments) into relevant meta-codes and sub-codes. It identifies patterns from the condensed data: by copy-pasting the single pieces of text to more cohesive wholes, which ultimately leads to a system of sub-codes to develop a set of main headlines, and related sub-headlines. Specifically, original quotations were added at the end of each subcategory (or a separate document, but with clear indication to which interviewees are they referred to). The researchers who analysed the data applied their judgement and additional categorizations were performed where needed. Some categories were overlapping, but in all the cases there were categorized as meta-codes in general headlines and sub-codes in sub-headlines. Categorization of the variables was performed in the end.

Some of the 'answers' to questions were found under some other topics that are not covered by the interview protocol as they were asked in questions in the subsequent interviews. Those questions were defined by each interviewer. These new questions were general, and were constructed in a manner in which they could not 'lead' the interviewees to a certain answer, i.e. they were let to speak freely. In some cases, the interviewers re-directed the interviewees if the topic had totally gone "off-track". All the changes done in the interview protocol were reported. There was no theoretical/substantive overlap between the codes, i.e. each of them was unique. The definitions of codes and of their memos evolved during the analysis. Overlapping definitions of two codes were either change one by one or both were adjusted, and the associated parts of the interview were also re-coded.

4.5 Results

Suddaby (2006) encourages the combination of qualitative and quantitative methods. The aim of this study was to identify the environmental and socio-economic factors framing agroforestry development in Europe, and hence the socio-economic overview of the interviewed farmers was analyzed quantitatively, while the open responses were analyzed qualitatively with the support of the MAXQDA 11.0 software.

4.5.1 Quantitative results

The sample consists of 183 farmers interviewed across Europe. Though the sample and qualitative analysis of the answers has no statistical significance to draw general conclusions, it was used to support the findings in the interviews.

A large proportion of the sampled interviewees (86%) were male; the remaining 14% were female (Figure 4.1). Over half of the farmers (62%) considered themselves as farmers or farm managers, 7% as livestock breeders, 6% as farmers with a second occupation, e.g. researcher, teacher, technical advisor, consultant, businessperson, forest company, 5% as fruit growers, and the remaining 20% had other occupations as main source of income, e.g. civil servant, carpenter, consultant, metal worker, shepherd, teacher, or veterinary worker (Figure 4.2).

In relation to their level of education, surprisingly half (53%) of the interviewees held university degrees, mainly in agricultural sciences. About 19% held a high school degree and another 17% had received only elementary studies. A small sample (3%) was educated in a vocational school, while a similar number (3%) do not have any formal academic qualification. A few farmers were reluctant to share their level of education (5%) (Figure 4.3).

The mean age of the interviewees was 48 years old, while the age range was 23 to 80 years (Table 4.2). The number of descendants varied between none and seven, with a mean value of 1.5 children (Table 4.2).

When we take into account the whole sample, we observe a big variation between the farms, from very small (0.1 ha) to very large (11000 ha), from farmers that do not apply for any subsidy to others that get subsidies for the whole farm area (Table 4.3).

The parameter 'Eligibility CAP 2007-2013' refers to the comparison of the eligible CAP area to the actual size of the farm. The size of some farms was greater than the total area claimed (Table 4.3). As for the parameter 'Change to CAP 2014-2020', most of the farmers claimed or are planning to claim a similar area, with a trend to increase slightly the area under subsidies.

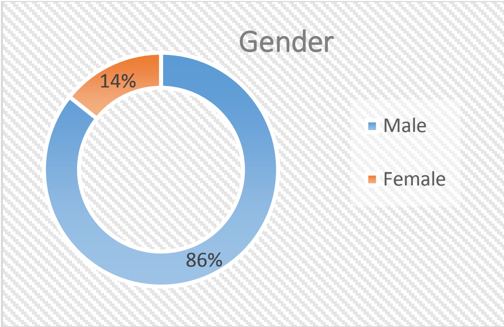


Figure 4.1. Gender of the interviewed farmers

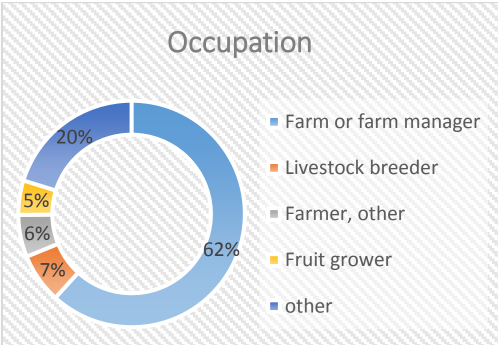


Figure 4.2. Occupation of the interviewed farmers

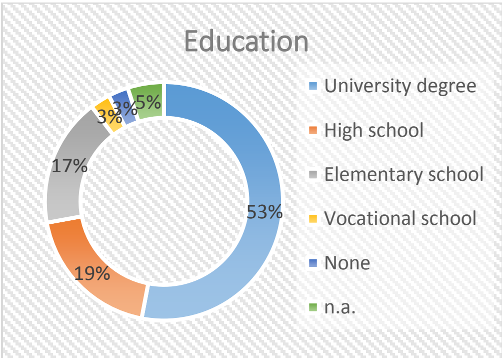


Figure 4.3. Education of the interviewed farmers

Table 4.2. Age and number of descendants of the interviewed farmers.

	Age of interviewee (years)	Number of descendants
Mean	48	1.5
Minimum	23	0
Maximum	80	7
Standard deviation	11.5	
Mode	48	

Table 4.3. Size of the farms of the interviewed farmers.

	Size of the farm (ha)	CAP eligible size (2007-2013) (ha)	CAP eligible size (2014-2020) (ha)	Difference between farm size and CAP eligibility (2007-13) (ha)	Change to CAP (2014-2020)
Mean	363	242	263	128.3	3.5
Minimum	0.1	0.0	0	0	-70
Maximum	11000	6612	6612	4388	320
Standard deviation	994	674	697	448.3	33.4
Mode	20	0	0	33.4	0

4.5.2 Qualitative results

In order to understand 'Why is agroforestry accepted or not?' eight Research Questions (RQ) were formulated. In this section the results of the data analysis are conceptualized for each of the Research Questions we aimed to explain.

1. What do the farmers understand by agroforestry?
2. Why do the farmers start implementing agroforestry?
3. Have trees been removed from the farms and why?
4. What are the agroforestry practices implemented?
5. What are the main problems that the farmers face when implementing agroforestry?
6. What are the positive perceptions from the farmers on the agroforestry systems?
7. What are the negative perceptions from the farmers on agroforestry systems?
8. Do farmers see a need for the labelling of agroforestry systems?

Illustrative in-vivo quotations are included and are shown between quotation marks and in an italic font, followed by the country and partner recording it. When elaborating the theory on the questions, the acronyms used in Table 4.1 were used, i.e. country, partner, type of farming practice (A/AF) and work package (WP).

1. What do farmers understand by agroforestry?

The most common definition by the farmers across Europe, for both agroforestry and non-agroforestry farmers, is a **combination of trees and other crops or animals**, without giving any major details, though existing small variations between their definitions: trees integrated with arable land or livestock, trees in the fields, forest and agricultural productions in the same land, combination of forests and livestock, etc. Agroforestry was understood this way by interviewees in the UK (A/AF), Greece (A/AF), Germany (A/AF), Spain (A/AF), France (A), and Hungary (AF)

> *'Agroforestry is a system for growing trees in arable fields or the integration of trees with growing agricultural crops.' (UK_ORC_ AF_WP4)*

Nevertheless, some farmers showed a more **comprehensive knowledge of agroforestry**, giving more details on the concepts, e.g. including woody vegetation as one of the components, not only trees but also shrubs, in combination with agriculture (grasslands/pastures) and livestock (e.g. dehesa). Some remarked on obtaining revenues from different sources or products (e.g. cattle, sheep, goat milk and meat, fruit trees, timber, biomass, crops), at least one from the understory. Some highlighted the percentage that the trees occupy and some to the number of trees (e.g. a minimum density of 50 trees/ha without a maximum). Some referred to the same land and others to different land but combined management at the same time. This detailed knowledge on agroforestry systems was observed in agroforestry farmers from Spain, France, Portugal and the UK, and some conventional farmers in Portugal and Germany.

> *'In society, agroforestry is a new word for something extremely old and large. For example, hedgerows in this country, but there are systems even older than that. They have seen evidence of stone-age hill systems in Devon, UK which resemble alley cropping - Devon hedges 12 m apart going up a hill side. People do not recognize the extent of agroforestry at the moment e.g. reindeer farming on 10's of million ha.' (UK_ORC_AF_WP4)*
>
> *'I have a eucalyptus plantation where my cows like to go for shade. That area gives me wood, shade for the animals and it is a hunting area. So for me that is an agroforestry area.' (PT_ISA_AF_WP2)*

The definition of agroforestry was **limited or unclear** to many farmers that do not practice agroforestry. Some farmers (e.g. conventional farmers in Greece, Spain and the UK and agroforestry farmers in Hungary) limited the definition to just growing trees or the promotion of trees in agriculture. Other farmers referred only to a single agroforestry practice that was familiar to them. Some UK agroforestry farmers and German conventional farmers limited agroforestry to trees planted in strips. Some conventional farmers in Spain and Germany considered agroforestry as a plantation for biofuels or short rotation coppice. In Italy an agroforestry farmer identified agroforestry as the cultivation of forest trees to produce fruits, e.g. chestnuts.

> *'Perhaps it is a kind of planted forest, what you manage as an arable field and harvest like corn or wheat? But you ask this question, so I think is more related to grazed forest and wood pastures?' (HU_NYME_AF_WP5)*
>
> *'Alleys of trees separated by areas of growing crops.' (UK_ORC_AF_WP4)*

In addition to the above many conventional farmers (especially in France, Spain and Greece) **had not heard of agroforestry**. Oddly enough, many of the farmers implementing agroforestry showed a **lack of awareness** of the term or concept of agroforestry, despite implementing the practice on their own farms. This was particularly common in Spain, Italy, Greece, Hungary and Germany.

2. Why do farmers start implementing agroforestry?

In order to find answer to the main question of our research, the question of why farmers do what they do was introduced to both conventional farmers and agroforestry farmers.

2.1 Reasons to continue conventional farming

Based on the responses, three major drivers for continuing conventional farming are tradition, the lack of knowledge on agroforestry, and easier management. In total conventional farmers gave up to ten different reasons, although there were links between some reasons.

Tradition (either in terms of inherited practices or what is common in a region) was the main reason cited for continuing conventional farming practices, for example in France, Germany, Spain, and the UK. They know that it works.

Besides this, some farmers do not know of other farming options beyond those that they practice. In some cases they **lack knowledge** about agroforestry: what it is, how to implement it, the technical design, and its economic viability. This was found in Spain, UK, Portugal, Germany, and the UK. In relation to the lack of knowledge, most of the farmers did not consider agroforestry as an **economically viable option**, requiring a high investment for establishment and maintenance. Furthermore, they do not see any added value from agroforestry and agricultural production would be reduced if trees are present, perhaps due to shade and changes in the associated microclimate. Some farmers considered that there was no market demand for agroforestry products. Such reasons were offered in Germany, Spain, Greece, Portugal, and the UK.

> *'Trees modify the microclimate with shade, more humidity and less wind and this promotes the mildew in the vegetables.' (PT_ISA_A_WP2)*

Actually, farmers opt preferably for practices that receive some subsidies, and they are not aware of the **subsidies for agroforestry**, which are very limited in any case (UK, Greece).

Conventional agriculture was considered to be **easier to manage**, and better known. Some of the farmers they also consider that having animals makes it more complicated e.g. finding feed for the animals during winter. Others indicated that trees complicate mechanization and sometimes incompatible with grazing. These reasons were given in: Greece, France, Portugal, and the UK.

> *'Mechanization was the main reason not to put trees.' (FR_AFAF_A_WP4)*

Farmers in Spain and Greece consider that agroforestry needs **more time dedication**, there is more work to be done and they lack the time and human resources to work on the farm. Training people every year to work on the farm is not sustainable.

> *'A farmer complained that he cannot find help for his farm. Usually he employs foreigners who stay only a year and then leave for their country and he has to train another all over again.' (EL_TEI_A_WP2)*

If the **plots are small** farmers do not consider other farming options as profitable (UK, Spain, Germany, Greece). On the other hand, **high quality land is a scarce resource to be maximized**, thus many farmers having a very productive soil prefer to maximize its production and use it only for agriculture. They consider trees occupying valuable land have a high opportunity cost (Germany, Portugal).

> *'Land is a very valuable scarce resource, for which the production must be maximized, especially if it is a high-quality soil, or if the plots are small.' (DE_BTU_A_WP2)*

Another driving factor, observed in Spain, influencing in the type of farming is the **age**. Farmers who were close to retirement were not interested in new types of farming and preferred to keep doing what they have done their whole life.

In Germany, **ownership** of the land is also a limitation, as farmers that are renting the land cannot plant trees as the owners do not usually want to plant any trees.

Interestingly, many farmers were interested in the agroforestry practices introduced by the interviewers and considered to give it a try after the interviews. This reflects the interest but the lack of knowledge the farmers have on such farming options. They would need to see examples of profitable practice and other advantages before deciding on whether to invest. Some would implement agroforestry if there was economic support, management was simple, there were no difficulties with the landowner, and if soil fertility was low. Countries where this driver was manifested are France, Greece, Germany, Spain, and Portugal. Several farmers in Spain, though, considered that conventional farming works well for them and do not consider a change into agroforestry; some because of their age, others because there would be a reduction in productivity.

2.2 Reasons to implement agroforestry

When asking agroforestry farmers, 16 different reasons were identified. The three major reasons were tradition, the diversification of the products, and learning from others.

The **tradition** in the family or in the region influences the decision of most of the farmers to continue with the existing systems. This is because of cultural reasons and acknowledgment of the benefit of the synergies between the different components. This reason seems to be the main reason across Europe, in Greece, Spain, Hungary, Italy, Germany and Portugal.

> *'We wanted to do extensive sheep farming. We did not know it is an agroforestry system. We had this area near our village, so we did not have real choice. But without trees you could not do a proper extensive sheep farm.' (HU_NYME_AF_WP5)*
>
> *'Giving continuity to the farm as inherited. After the 2003 fire we became concerned about the economic viability of the farm that was mainly based on the forest… also the quality of the cork and the quantity is decreasing… so in order to overcome this and to diminish the risk in the future, I am planning to increase the number of animals…' (PT_ISA_AF_WP2)*

Agroforestry provides a **diversification of products** (wood, fodder, meat, milk, crops), which contributes to increase the production and the profitability of the farm with several lines of income, maximizing revenues and reduces some costs e.g. associated to land clearing. Agroforestry allows animals to have fodder in winter time and creates pasture instead of unused dense shrubs. Furthermore, products obtained in agroforestry are identified as high quality products. Countries where participants manifested this reasoning were UK, Spain, Germany, Hungary and Portugal. Furthermore, farmers in Portugal remarked that the diversification of the products and the beneficial synergies among the components (trees, animals and crops) **decreases the risks** in crop production due to weather events or market changes.

> *'Pastures without trees are more vulnerable to weather conditions.' (PT_ISA_AF_WP2)*

Learning from others and seeing the benefits was an encouraging driver to implement agroforestry practices in UK, Germany and Spain. Sources of learning were varied: attending a meeting and considering the future for agriculture, working abroad and seeing the benefits, colleagues or other farmer experiences, and the internet.

Where non-productive soils prevent economic crop production, or where there are small fields in difficult areas that are hard to manage, agroforestry becomes an **alternative in marginal lands**, which at the same time improves the soil condition (fertility) and increases the biomass production (Italy, Germany and France).

> *'The silvopastoral system was introduced because arable crops are not convenient (poor production) in marginal lands.' (IT_CNR_AF_WP5)*
>
> *'Increase soil fertility increase biomass production.' (FR_AFAF_AF_WP4)*

Agroforestry **improves the environment** around the farm, hedgerows protect from wind and water erosion, animals decrease the risk of forest fires (with associated cost reduction for land clearing), provides shelter for animals and birds, is good for the environment and nature conservation in general, including a solution for the pollination of trees. This driver was manifested in Germany, Spain, Hungary and Portugal.

> *'Some of them wanted to have a farm, so they could produce healthy and organic food and at the same time to do something for nature conservation as well.' (HU_NYME_AF_WP3)*
>
> *'Most of the farmers started to combine apple trees with bees to increase pollination because the trees had pollination problems.' (ES_USC_AF_WP3)*

Conscientious farmers in France and Germany want to be **coherent at farm and landscape level**. Curiosity and interest in the topic of agroforestry may lead to some farmers to implement agroforestry practices.

Agroforestry has a high **aesthetics value**; it is considered to contribute to a desirable landscape and is part of the cultural heritage. This results in more tourism in the area and more rural employment, thus motivating farmers in UK, Hungary, Germany and Portugal.

In UK and Spain, some farmers prioritised **animal welfare** (less stress, better quality feed), e.g. poultry grow in their natural environment and lambs receive shelter in their first days.

> *'The orchard is very sheltered and is a good place to send lambs in the first few days after lambing.' (UK_CRAN_AF_WP3)*

Some farmers in UK considered it useful to have some grazing in the plots already **fenced** to protect trees from wild fauna.

> *'We have to fence the plots to protect trees from wild fauna, so, it is a pity not to have some grazing in.' (UK_CRAN_AF_WP3)*

In Spain, some farmers indicated that agroforestry systems contribute to **improving the quality of life** of the farmers.

Also **research purposes** can lead to new agroforestry farms, as farmers are contacted for research purposes and use their farms as a demonstration plot, as for example in UK and Germany.

In UK and Portugal farmers refer to agroforestry as being a complex system that provides a more efficient management of the resources and results in **sustainable eco-intensification**. While in Germany, sustainable production is given priority over conventional agriculture when it is a **second occupation**, and not the primary source of income, given that it might not be as productive as conventional farming.

> *'If farming is a primary source of income, then there is a pressure to make profit. If it is a secondary occupation, then sustainable production is more important than financial profit.' (DE_BTU_AF_WP2)*

Subsidies are also an incentive to apply agroforestry, to ensure the farms are profitable. This was mentioned in UK and Spain.

Different laws and **regulations**, e.g. on hedgerows in Germany, might impose restrictions on applying other practices rather than the existing ones.

> *'The hedgerows were already established and it was not allowed that they were removed. The system is historical. It was established by the King of Denmark in the 18th century. In northern Germany the farmers had to plant hedgerows on their land. The hedgerows were already established 300 years ago and are protected by the law. It is not allowed that they were removed. I am an agricultural farmer and if I could I would remove them.' (DE_BTU_AF_WP2)*

3. Have trees been removed from the farms and why?

Agroforestry farmers do not see any problem having trees on grassland, but the main reason for removing trees and shrubs was to **facilitate management** e.g. having wood pasture instead of dense shrub land. This was mentioned in Spain, Portugal and Hungary. Tree can create difficulties e.g. when using tractors or machines close to trees when managing pastures, and the presence of animals can reduce tree regeneration. Some farmers in Greece have removed fruit trees growing on farm boundaries because they were an impediment for farm machinery, but not for eligibility. At the same time, some farmers in Portugal considered the trees as a focus of diseases, and attracting birds that eat the seeds.

> *'In order to protect cork oak roots I am not able to use disc harrow and instead have to use mounted knifes or chains. This last equipment is more restricted when wanting to renew the pastures.' (PT_ISA_AF_WP2)*

Surprisingly, only a few Spanish farmers mentioned **subsidy eligibility** as the main reason to remove trees from their land, to avoid the reduction of the funded area.

> *'The farmers have never removed trees to increase the eligible size of utilized agricultural area: the increased subsides would be very limited. The presence of trees is not negative, and oaks are considered beautiful. However, it should be important to limit the spread of spontaneous vegetation in abandoned land. In the last CAP the presence of four olive trees in the arable field reduced the Single Farm Payment of about*

50 euro. CAP mechanism is too complicated and affected by great bureaucracy complexity.' (IT_CNR_AF_WP5)

Trees have also removed from the fields as part of **tradition**. In Portugal, for instance, agricultural land has been cleared of trees for many centuries. In France and the UK, farmers indicated that previous generations had removed trees. In the UK there is the practice of removing shrubs.

'That is way you have cork oak montado in high land, a few km from the river, and agricultural land close to the river with no trees. Many centuries ago families divided their land creating stripes perpendicular to the river. This would give each child a few area of land close to the river (for agriculture), and a few land far from the river (for forest activities, or agroforestry in the specific case of cork oak).' (PT_ISA_AF_WP2)

In Spain there is sometimes the practice to remove trees **to establish a new crop**, e.g. olive trees. In Portugal some farmers opted for facilitating the management of the land for more profitable crops.

Regulations limit the removal of trees. In some cases, e.g. in Greece it is illegal to remove trees in state-owned forests; the forest service generally does not allow intervention and rarely permits any tree removal. In any case they do not receive any CAP subsidy. A similar situation was claimed by the conventional farmers in the land they used, particular in protected areas. None of the conventional farmers in Greece have removed trees, either because they are needed as it is a family farm or because it is illegal to remove any trees without permission by the forest service. In Germany the hedgerows cannot be removed either.

In most of the interviews in UK, Greece, Germany, Italy, Spain and Portugal, both agroforestry and non-agroforestry farmers, reported that they had **not removed any trees** of their farms on a voluntary basis. Some of them did not understand the question, as they planted them and because they had olives or permanent crops, subsidy eligibility was not an issue.

4. What are the agroforestry practices implemented?

Several practices were described by the interviewed agroforestry farmers. It should be noted that these are not all of the existing practices in Europe, but the ones present in this study.

Grazing farms in oak protected areas, categorized as **High Nature and Cultural Value**, were found on agroforestry farms in Greece and Germany, in addition to the dehesas and montados in Spain and Portugal referred to below. Agroforestry farmers in Greece have mature valonia oak (*Quercus macrolepis*) stands at low density, approximately 70-80 trees/ha. In many cases also prickly juniper (*Juniperus oxycedrus*) is present. The areas are grazed by sheep and/or goats and/or cattle all year to produce meat and milk. There are usually restrictions from the forest service e.g. no change in land use, not removing the trees, and restrictions on the number of animals. These and other farms, e.g. in Hungary, are extensively managed and do not necessarily have ancient grassland and/or ancient forest. Some are not protected, whilst some are protected under Natura 2000 or designated as an Area of Outstanding Natural Beauty (AONB). Some livestock farms in Germany were in protected areas.

'I would categorize our land as High Nature and Cultural Value area. I can see that we have more flower and birds now. I think it is the result of our nature-friendly extensive

grazing. No protected land nor Nature 2000.' (HU_NYME_AF_WP5)

In Germany some farmers have **hedgerows** which vary in species, age and use. In some cases, hedgerows are composed of acacia, poplar and linden. They are used for self-consumption and local marketing of fruits, honey, juices, and distilled spirits. Other hedgerows are composed of hornbeam, ash, cherry, maple, hazelnut, whitethorn and blackthorn harvested for firewood at a young age (7-13 years) and others of oak, maple, birch, beech and larch harvested for construction at a later stage (60 years). On the other hand, some farmers in UK use 'architectural corridors' for aesthetic reasons.

Other farmers in Germany practicing agroforestry have **grasslands with scattered trees**, e.g. poplar, pine, alder, willow, and maple. Some systems combine an industrial use with recreational purposes whilst others are meant for nature protection and wind protection in a nature reserve.

'**Montado'** appears in Portugal. A mixture of cork oak (*Quercus suber*) and *Pinus pinea*, at various ages, at low tree densities (40-250 trees/ha) and not harvested for timber. The main products are non-wood forest products: cork and pine nuts. Some agroforesters do not harvest timber, while others do. Another non-wood forest product (NWFP) might be resin. Many of the farmers also have small patches of maritime pine (*Pinus pinaster*) and eucalyptus (*Eucalyptus globulus*). Areas occupied by Maritime pine are being converted to stone pine (*Pinus pinea*) stands due to the health of the forest and the lower timber value. The eucalyptus area in Portugal has increased since the 1970s. It is frequent to have montado areas where tree decline is severe and where the installation of new cork oak trees is not viable or has low rates of success (natural regeneration or plantation). Some of these areas are being planted with eucalyptus and more recently with stone pine (usually with agroforestry practices). Eucalyptus plantations do not comprise a majority of the farm areas, but it is frequent for farmers to have some area of that species. Cork oak area is being maintained in the country, mainly due to forestation of agricultural land with cork oak plantations.

> *'If we want to protect cork oak we must agree on the plantation of eucalyptus. Because it will give me money from areas were cork oak is naturally disappearing, and I will invest some of that money in my cork oak agroforestry stands for my children.' (PT_ISA_AF_WP2)*

In Spain, many farms are '**dehesa'**, areas of holm oak (*Quercus ilex*), combined with a minor proportion of cork oak (*Q. suber*), Pyrenean oak (*Q. pyrenaica*) and Portuguese oak (*Q. faginea*). Only one of the farms had a small area (5%) of eucalyptus (*Eucaliptus globulus*). Trees are usually older than 100 years, ranging from 80 to 200 years. Tree density is very low ranging from 15-20 to 40-50 trees per ha. Many farms use grazing all year round, with the rest grazing six to nine months outside and using preserved grass in winter. Most of the farmers have cows grazing for producing beef, many have sheep for lamb meat and wool, and a few have also goats and pigs. One farmer producing cork had cattle, swine, goats, and sheep for milk and meat. Another produces ecological olive oil, olives, cork, wood, meat and calves, olives and benefits from ecotourism. One raises bulls for bull fighting, producing also pistachios and having a museum.

Orchard meadows occur in UK, Spain and Germany comprising a single or multiple tree species with various combinations with cereals, vegetables and/or animals. In Germany, some comprise mixed fruit trees (apple, pear, cherry, plums and nuts) whilst others include existing broadleaved trees like willow, oak, poplar, and alder. The trees in pasture occur at a low density up to 100 trees/ha, with a typical age of up to 80-100 years. Others are composed of cherry, pear, apple, and mirabelle plum, with ages up to 60 years. The key values of the orchard meadows are aesthetic, cultural (keeping traditions) and nature conservation. The fruit trees are sometimes used for commercial purposes or small-scale local supply, but the principal use is for self-consumption or if a visitor comes, he/she is allowed to pick their own fruit. In some cases the fruit are used to produce juices or liquor of high quality. The grazed animals include cattle, pigs, poultry and horses.

In the UK they use apple trees at a density between 250 to 700 trees per hectare, between 3 and 60 years old, with a production of 75-125 tonnes of apples per hectare, often used for cider production where there is sheep grazing.

In Spain apple trees are combined with bees for honey production, with kiwis, or with horses, sheep or goats. Other species used are chestnuts, combined with sheep and/or goats. In UK and Spain some farmers have beehives in the orchard, producing an extra income of up to €5700 per hectare.

In Greece one of the interviewed farmers had grazed olives orchards at 10 m x 10 m spacing with the olive used for direct sale and oil production. Part of the farm had *Platanus* and *Juglans*. The farm had approximately 100 sheep grazing all year round for meat and dairy production under the olive trees.

Wood pasture systems were identified in Hungary.

> *'Our aim was to have a wood pastures system, therefore we had to remove the dense shrub and trees from the grassland. We left ancient trees and shrub patches to maintain natural wood pasture dynamics. Of course the subsidies are important, but ancient trees are much more important for us.' (HU_NYME_AF_WP5)*

In Spain, some farmers have horse **grazing in dense forests** of pine and eucalyptus.

5. What are the main problems that farmers face when implementing agroforestry?

When interviewing the agroforestry farmers, three major problems in implementing agroforestry were highlighted: problems with farm management, regulation problems and lack of knowledge.

Many see some difficulties in the **management**, as agroforestry is more difficult compared with the conventional agriculture, but do not consider this as a major problem.

One management problem is that it is hard work to start an agroforestry farm and renew an abandoned area. It usually costs a lot of money and time as well. Management costs of the animals are higher, it is difficult to find a good shepherd, bureaucracy becomes a burden (e.g. land and animal registrations and land delimitation), and there is a need to fence out wild animals. There is also decay of cork oaks, problems with natural regeneration (although this can be addressed by tree protectors), the need to use other machinery (mounted knifes or chains instead of disc harrows), the potential requirement to reduce the number of cows, and the high investments for improved pastures. Other problems concern the quality of the pastures where the cows feed as climate fluctuation makes it difficult to provide feed only from pastures and they frequently have to buy additional food in the summer to feed the cows. It can also be hard to look after animals in orchards. These problems were described in Portugal, Greece, UK, Germany, Spain and Hungary.

Several limitations from different **regulations** were identified as limiting the implementation of agroforestry practices. Hedgerows, known as 'knicks' in Germany, are subject to regulations in some provinces; they cannot be managed and used by the farmer who has to protect them from the animals and prevent their use as shelter. In the past, the hedgerows were planted by farmers and were used for supplying firewood which supported the sustainable management and proper maintenance of the hedgerows. In Greece there are usually restrictions from the forest service preventing a change in land use and the removal of trees and restricting the number of animals. In Hungary, abandoned wood pasture after a period of time can be registered as forest. The farmers having this type of land are not allowed to graze or clean it because of very strict forest laws. Woodland grazing is not allowed either in Germany where special permission is needed.

Property rights can be also a problem. In areas of previous community pastureland in Hungary, it was noted that it can take a lot of time to time to identify owners and buy the small parcels. The cleaning process afterwards is also complicated, because they were abandoned areas.

In Italy **wild animals** (wolf, wild boar) represent a key management problem. The problem, connected to the abandonment of farmland, is becoming unsustainable for farmers. The interviewees highlighted many lambs were killed last year, stressing sheep and reducing production. Due to the frequent attacks, sheep are housed during the night, but there is still damage from wild animals. Previously when wild fauna was not a problem, sheep were continuously left in the open field. These farmers considered that preventive selection and monitoring of wolf presence should be carried out by local public institutions.

> *'The problem came out heavily in the last 10-15 years. Before that, all farms used to have sheep and in the area about 12600 sheep were managed. All these farms were useful for water regulation and control of roads accessing to farms. Farmers used to keep sheep in open field for all time, thus the quality of milk was good with low expenses. Wild fauna problems started in 2000, with wolves and hybrids and stray dogs. Actually only about 2800 sheep are present. Wild predators pushed small farms to retire and stop the livestock activity because working conditions became un-sustainable with wolves attacking also during the day. The milk quality and production was reduced and is not enough to satisfy the cheese industry demand. The closure of several livestock farms determined also an increment of unemployment rate. If the situation will not change, more farms will be forced to stop the livestock activity.' (IT_CNR_AF_WP5)*

Another problem indicated by some agroforestry farmers in UK, Hungary and France is the strong **lack of knowledge** that exists on how to put in practice agroforestry.

> *'First 10 years was very hard. We were doing everything alone. We did not have experience before and also we did not have any childhood memory of farming. To be a farmer needs time and learning. One of the hardest was to get the knowledge of agroforestry management.' (HU_NYME_AF_WP5)*

In Spain farmers complain on the **bureaucracy** and slow answering from the administration to allow the system establishment and on the CAP limitations and complexity. The significant administrative burden and complexity was also recognised by agroforestry practitioners in France.

Some farmers in Spain, UK and Greece mention the **low profitability** and the product price fluctuations, low demand due to recent financial crises, together with the high costs of establishment (fencing, protectors), changing to breeds more compatible with the trees, and the long time period required term for returns (e.g. 15 years for good fruit production from apple trees). While in the UK farmers face additional expenses if they need to swap between sheep breeds for less damaging ones to trees (e.g. LLeyn to Shropshire), as they do not want additional burden of running two flocks.

By contrast to the above, many farmers in Spain, France, UK, Germany and Portugal reported no problem in managing their agroforestry farms.

6. What are the positive perceptions from farmers of agroforestry systems?

The agroforestry and non-agroforestry interviewees were asked about the positive perceptions that they had on the sustainability of agroforestry systems. Their perceptions were grouped under production, environment and social aspects. At the same time, once the farmers indicated their perceptions, the interviewers provided detailed information on the agroforestry, and asked again if new perceptions arose.

6.1 Production

Animal welfare is one of the aspects most highlighted by farmers as agroforestry can favour animal welfare compared to intensive systems, for example providing shade and shelter for chickens and young lambs. This can improve the quality of products and reduce the risk of illness. This aspect was identified across Europe in France (A), UK (A/AF), Greece (A/AF), Spain (A/AF), Germany (AF), Hungary (AF).

> *'Keeping animals out in the open area in natural conditions is better than keeping them in a stable/stall. It is animal keeping in natural conditions. It´s very positive in the farm that for example the calves can be close to their mother until they become independent and after that they can enjoy their life in the pasture areas at their farm.' (DE_BTU_AF_WP2)*

Farmers all over Europe, UK (A/AF), Greece (A/AF), Spain A/AF, Hungary (AF), Germany (A/AF), Portugal (AF), Italy (AF), acknowledge also that agroforestry practices lead to a **diversification of products** (e.g. firewood, timber, fruits, mushrooms, livestock, reuse of manure). In UK and Portugal they remarked explicitly that the diversification leads to having several lines for income benefits, giving resilience to the system and business. In France (A) and Spain (AF) farmers indicate that agroforestry provides at the same time **additional food for livestock**, which helps saving some money on regular feed.

> *'Production is diversified: meat from lamb and beef are the main products, chestnut fruits are also sold or used to feed pigs (fruits that are not commercially valuable). Extra virgin olive oil represents also an important product, especially in relation to rural tourism activity, but last year the production was very limited because of climate*

adversity and pathogen infestation. Animals fed with chestnut and oaks fruits are stronger than those fed only with grass.' (IT_CNR_AF_WP5)

'With agroforestry the farmer has more frequent income due to the increased number of products: meat, cork, versus only meat or only cork. If you go from agriculture to agroforestry you have the same periodicity and more income. If you go from forestry to agroforestry you decrease the periodicity of the income.' (PT_ISA_AF_WP2)

Several farmers in UK (AF) and Portugal (AF) identified the agroforestry systems as a **profitable land use** and the annual revenues as the main positive production aspect. Even some conventional farmers in Portugal do not see agroforestry as an expensive system. UK farmers (A/AF) consider that the agroforestry practices contribute to a reduction in costs for diesel and fertilizers and sprays to the trees. At the same time, farmers in the UK (AF), Greece (A/AF) and Spain (AF) believed that the higher quality of the products leads to a higher price in the market.

'It offers higher quality products (meat) in a semi-natural environment feeding on natural pastures unprocessed. The animals do more exercise with a healthy and balanced diet. Trees provide also fruits (acorns) that are used as animal feed, with high protein and nutritional value.' (ES_UNEX_AF_WP2)

Farmers in UK (AF) and Germany (AF) acknowledge an **increase in biomass production**, both for crop yield and timber production. One of the reasons is that livestock manure contributes to the fertilization for the trees.

'In agroforestry the yield is higher than in the conventional agriculture.' (DE_BTU_AF_WP4)

'It is especially interesting for those areas with very high difficulties to replace the sward, and is not highly productive in the respect, but the combination of the poor sward and trees is more productive together than it would be apart.' (UK_CRAN_AF_WP3)

Agroforestry systems are considered **resilient to climate change** in UK (AF) and France (AF). Farmers use, for instance, walnut varieties from Southern France. It usually generates a positive change of seasonal grass productivity, low in spring and high in the autumn extending the grazing season. Some conventional farmers in Portugal (A) are aware that trees create a border effect and help in the prevention of wind, preserving more humidity in the above ground layer. This might help crops in very dry years. There are synergies between trees and crops that increase the production and growth.

A farmer in Portugal (AF) defended agroforestry as the most efficient way of managing resources in areas characterized by low production. It was **suitable for marginal areas** not very productive for arable crops, while some farmers in Portugal (A) considered that agroforestry provided a **natural refuge for hunting animals**.

As a consequence of the previous benefits, many farmers, namely in UK (A), Greece (A), Spain (A/AF), Hungary (AF), Germany (AF) recognize that agroforestry **increases the land value**.

'Another main benefit is that the value of the land increases due to soil conservation and

diversification, not only for the farmers and local people but also for the tourists.' (DE_BTU_AF_WP2)

Farmers in UK (AF) agree that agroforestry practices work as an **integrated pest and disease management** for arable crops, thus the need for chemicals is reduced. Trees attract beneficial insects and there is an improved pest/predator balance. Further, livestock can eat weeds and keep them under control. There is also a reduction of diseases of trees.

> *'Lots of benefits from helping animals, e.g. like a beetle bank, helps with crop protection and slug control.' (UK_ORC_AF_WP4)*

Some farmers in UK (AF) and Spain (AF) consider that agroforestry systems require **less labour** than intensive agriculture, i.e. zero effort and zero input system with less labour requirements.

> *'The farmer saves the time to take food to their animals. They also save money in animal feed.' (ES_UNEX_AF_WP2)*

Only a few farmers identified no production benefit, for example in Greece (AF) and Germany (A).

After further explanations on the benefits of agroforestry systems provided by the interviewers, some farmers gave their **new perceptions** as follows, matching in some cases with benefits indicated initially by other farmers.

Several farmers in Greece (A), Spain (A/AF), UK (AF) and Hungary (AF) consider that agroforestry systems provide higher **animal welfare** than intensive systems, e.g. providing shade during the summer.

> *'I am very happy about that EU is going to support agroforestry systems, because our originally plan and our work in the last couple of years was to develop agroforestry systems for our livestock. But until now we did not get any support, even it was forbidden in a way.' (HU_NYME_AF_WP5)*

Many farmers in Greece (A), Portugal (AF) and Spain (A) and Germany (AF) see the benefit of agroforestry for the **diversification of products**, thus increasing the market niches and income diversification, reducing the risk if one component fails. At the same time, some farmers in Hungary (AF) and Spain (A) identify agroforestry as the best practice to produce healthy food and **higher quality products**. A farmer in Portugal (AF) remarks that the **periodicity of revenues** is reduced when comparing to pure forest management.

> *'I see that establishing an orchard meadow may increase the products in the farm.' (DE_BTU_AF_WP2)*

A few farmers in Spain (A) considered that agroforestry had a **similar administrative burden** as conventional agriculture.

A farmer in Spain (A) claimed that with agroforestry the **production would be higher for the same land area**. One of the reasons for higher productivity is that trees contribute to the water availability, saving water, and improving irrigation efficiency. Farmers in Portugal (A) and the UK (A) noted that in areas prone to wind, trees act as a protecting barrier and increase productivity.

Some farmers in UK (A) identified agroforestry as encouraging the presence of **beneficial insects**.

Some farmers in Hungary (AF) and Greece (A) considered that agroforestry **increases land value**. Some farmers in the UK (A) and Spain (A) identified obtaining **wood fuel** as one of the benefits.

6.2 Environmental

Agroforestry practices increase the sustainability and **ecological value of the farm**, improving microclimate and the habitat quality also for wildlife. This aspect was mentioned in UK (A/AF), Portugal (AF), Spain (AF), Hungary (AF) and Germany (A).

> *'Very high natural value and biodiversity are being more appreciated every day.' (HU_NYME_AF_WP5)*

In relation to this, a farmer in Portugal (AF) stated that agroforestry systems are providers of **environmental services** in general. Environmental services were mentioned explicitly by many other farmers and are examined below in terms of increasing biodiversity, addressing climate change, favouring soil conservation, and improving water quality and quantity.

Among the benefits from agroforestry, the farmers in UK (A/AF), Greece (A/AF), Spain (A/AF) and Hungary (AF) highlighted its contribution to **address climate change**. Farmers in UK (AF), Germany (AF), Spain (AF) and Portugal (A) claimed that trees act as carbon (C) sinks and fix more C than conventional agriculture.

> *'It fosters resilience to climate change. For instance, in UK we are using walnut varieties from the south of France.' (UK_ORC_AF_WP4)*

Many farmers in France (AF), UK (AF), Italy (AF) and Germany (AF) indicated that agroforestry systems **improve the landscape** due to the presence of trees and/or grazing animals and the diversification of the landscape.

> *'The presence of grazing animals in the open field is really appreciated for its aesthetic value.' (IT_CNR_AF)*

Most of the farmers acknowledged the **increased biodiversity** in agroforestry compared to agricultural systems. Countries that recognized this benefit are France (A), UK (A/AF), Greece (A/AF), Germany (A/AF), Spain (AF), Hungary (AF), Italy (AF) and Portugal (A/AF).

> *'Have a huge range of birds - the system is attractive to both lowland and woodland birds which improves the diversity. They have barn owls, buzzards and kestrels indicating there is an intact food system all the way down.' (UK_ORC_AF_WP4)*

Most of the farmers, namely in France (A), UK (A/AF), Greece (A/AF), Germany (A/AF), Spain (AF), Hungary (AF), Italy (AF) and Portugal (A), acknowledged the benefit of **soil conservation** or reduction of soil erosion, benefiting soil mycorrhizas and other soil organisms and improving soil quality thanks to the tree canopy and roots, adding organic matter.

> *'Agroforestry increases soil fertility, physical properties (i.e. permeability), better root development, increase of OM, reduction of evapotranspiration at the end of the season, increase biodiversity and soil improvement.' (FR_AFAF_AF_WP4)*

Agroforestry was appreciated for the land or **environment conservation** in Spain (A/AF) and Greece (A/AF). While a few farmers in Germany (A) and UK (AF) recognized the benefit of **not using chemicals** (herbicides, pesticides or fertilizers).

> *'No need to use herbicides. No need to apply nitrogen, sheep fertilise the trees.' (UK_CRAN_AF_WP3)*

Most of the farmers also acknowledged the benefit on **water quality and quantity**, reducing runoff, namely in France (A), UK (A/AF), Greece (A/AF), Germany (A/AF) and Spain (A/AF).

> *'Most of the farmers agree that trees filter excessive summer solar radiation, reducing runoff and favoring water retention and quality.' (ES_UNEX_AF_WP2)*

In agroforestry systems, farmers in Portugal (A/AF) and Italy (AF) acknowledged that grazing animals contribute to the control of understory vegetation and **reduce the intensity or the occurrence of forest fires**.

> *'If forest fires occur, the intensity might be lower than in pure forests due to the discontinuity of the tree cover.' (PT_ISA_A_WP2)*

In Germany (AF) some farmers recognized the benefit of trees for providing **shelter**.

> *'Trees are shelter for livestock, birds and wild animals (e.g. from sun, wind).' (DE_BTU_AF_WP2)*

After further explanations on the benefits of agroforestry systems provided by the interviewers, some farmers gave their **new perceptions** as follows, matching in all cases with benefits indicated initially by other farmers.

For some farmers in Greece (A), UK (A) and Spain (A) identified that agroforestry helps to **address climate change**. Agroforestry favouring **biodiversity**, e.g. offering habitat for more nesting birds, was heard in Greece (A), UK (A), Portugal (AF) and Spain (AF). One farmer in Greece (A) indicated that agroforestry is **good for the environment** in general, and a couple of farmers in Germany (AF) and UK (AF) indicated that it provides structures in the **landscape** and creates interesting habitats, fostering wildlife. Farmers in Greece (A), Portugal (A) and Spain (A/AF) identified that agroforestry contributes to improve water infiltration and quality and **regulating the water cycling**. Several farmers in UK (A/AF), Greece (A), Germany (A), Spain (A/AF) and Portugal (A/AF) mentioned that agroforestry **reduces soil erosion** and supports river margin stabilization. Some farmers also mentioned protection against wind erosion.

6.3 Social

Agroforestry systems were identified as preserving **cultural heritage** and family traditions, as indicated in Spain (A) on the 'dehesas' and Germany (AF) on the 'knicks'.

> *'The dehesa is a system with higher cultural values preserved over the centuries, representing our culture heritage and habits.' (ES_UNEX_AF_WP2)*

Many farmers in UK (A/AF), Germany (AF), Hungary (AF), Portugal (A) and Spain (AF) recognized that agroforestry **improve landscape aesthetics**, which results in tourists visits for the pleasure of the people.

> *'Orchards can be extremely attractive...when the blossom is blossoming.'*

(UK_CRAN_AF_WP3)

'Given the landscape aesthetics, the beautiful landscape is suitable for recreation and walkers can also enjoy picking a fresh fruit from the trees.' (DE_BTU_AF_WP2)

More than the landscape value per se, many farmers acknowledged directly that agroforestry contributes to **increase the tourism** in the area. This was reflected in Germany (A/AF), Spain (A/AF), UK (A/AF) and Portugal (A). In this sense, a couple of farmers in UK (AF) indicated that agroforestry helps people to connect with nature and the source of their food. Trees can also enhance **well-being**, as supported by many farm visitors and by medical research.

'Positive social aspect is first of all the increased recreational value of the land due to the combination of pasture and animals. It is a rare system that has higher appreciation. It adds value especially when there is a large city close by.' (DE_BTU_AF_WP2)

In UK (AF) agroforestry is seen as a **good marketing tool**, improving amenity and facilitating the sale of the products. Farmers in France (AF) consider that agroforestry **improves the farmer image** towards the consumers. Actually, most of the farmers, e.g. in UK (A/AF), Spain (A/AF), Greece (A/AF), Portugal (AF) and Germany (A) identify as social benefit the increasing **rural employment**, providing stable jobs, e.g. in winter there is also work in the forest, that allow a decent income and a better quality of life in the villages comparing to the cities or the village prior to agroforestry farming development, preventing the rural abandonment, and due to the human presence a decrease in robberies and abuses.

'Most of the Anavra people used to live in cities and then moved to Anavra to raise organic livestock, taking advantage of relevant subsidies. Their life quality improved and the village, from a typical rural-poor village turned to a modern village with cultural events, gym, infrastructures etc. Even tourism increased as many people visit to witness the "miracle" village where farmers gain a respectful income out of livestock. Yet, in the Greek society, even if someone gets a respectful income, the fact that he is raising livestock prevents him from a wide social acceptance.' (EL_TEI_AF_WP2)

After further explanations on the benefits of agroforestry systems provided by the interviewers, some farmers gave their **new perceptions** as follows, matching in many cases with benefits indicated initially by other farmers.

A few farmers in Germany (A), Spain (A) and Portugal (AF) considered that agroforestry contributes to **increase rural employment**.

'Agroforestry will provide more employment as the systems have longer rotations (long-term persistence).' (ES_UNEX_A_WP2)

Many farmers in UK (A), Germany (A), Portugal (A/AF) and Spain (AF) appreciated the benefit of increasing **landscape aesthetics**, in particular at large scales and not just a plot level. Thus many farmers saw the benefit of increasing the public interest and the **tourism**, especially by the youth. This came up also in Germany (A), UK (A) and Spain (A/AF).

Some farmers in Hungary (A), Greece (AF) and Spain (AF) saw agroforestry as improving the **quality of life**. Some families are happy to be farmers and live together with their families and livestock on an agroforest area. They perceive themselves as a good example, that it is possible to live such a hard and beautiful silvopastoral farmer life, having a better quality of life in the villages compared to the cities or the same village prior to agroforestry farming development. Some farm owners in Hungary perceive, thus, agroforestry as a **lifestyle**, rather than a profession.

Actually, many farmers in UK (AF) and Germany (AF) considered that agroforestry offers wider **community involvement**, more interaction with the public through the educational programs in schools and kindergartens, having planting days with children in association with 'one tree per child' movement, interacting socially with each other because of the need for the liaison with other farmers, improving relationships in the village.

> *'Offers an opportunity for wider community involvement, helping people connect back to nature and where their food comes from, have planting days with local children in association with one tree per child movement.' (UK_ORC_AF_WP4)*

Only a few farmers in France (A) and Greece (A/AF) did not mention any social benefit.

6.4 No change in perceptions

For most of the farmers, namely in France (A/AF), UK (AF), Greece (A/AF), Germany (A/AF), Spain (A/AF), Italy (AF), Greece (A/AF) and Portugal (A/AF), the positive perceptions remained the same after the explanation provided by the interviewer.

7. What are the negative perceptions from farmers of agroforestry systems?

The agroforestry and non-agroforestry interviewees gave their negative perceptions of the sustainability of agroforestry systems. For this, their perceptions were grouped under production, environment and social aspects. At the same time, once the farmers indicated their perceptions, the interviewers provided detailed information about agroforestry, and asked again if new perceptions arose.

7.1 Production

Many farmers (Spain (A/AF), Hungary (AF), Italy (AF)) claimed that agroforestry resulted in **lower productivity** and higher costs than other more specialized farming practices. Since productive land is a scarce resource, this must be maximized with more productive practices (Portugal (A)). The low profitability obliges the farmers to request subsidies (Spain (AF)). Although some farmer may indicate that is still profitable, German farmers indicated that these systems are less profitable than conventional agricultural systems (Germany (A)).

The lower productivity is claimed to be due to the competition for water and nutrients between trees and crops, shade generated by trees, trees taking space from crop production, increase of disease risk (e.g. by manure of animals, mildew and pests due to increasing shade and humidity while decreasing wind) (Germany (A), Portugal (A), UK (A)). Several farmers identified crop reduction under adult trees (UK (AF), Spain (A), Germany (A), Portugal (A)). Lower production of the system could also result because animals may damage the trees and lead to high mortality rate of trees (Spain (A), Germany (AF)).

> *'No doubt that agroforestry system is less productive than non-agroforestry alternatives on the same land unit, but it works and it is profitable.' (UK_CRAN_AF_WP3)*

Famers mentioned that a negative aspect of agroforestry is the **extra costs** associated to them, namely fencing for the animals and trees (Spain (A), Germany (AF)), beekeeping (Spain (AF)), the complexity of the work (Italy (AF)), hiring more employees due to the complexity having several productions (Portugal AF)), or the high capital costs for the establishment (fencing, buying livestock, tree protectors, animal robbery, equipment) (UK (A/AF), Portugal (AF), Hungary (AF)). There is a poor remuneration of the derived products to compensate the production costs (Italy (AF)). Also in relation to profitability, farmers claimed that agroforestry requires them to spend more management time in the field, and it primarily provides a **long-term financial return** when the tree harvest occurs (Germany (A/AF), Portugal (AF), UK (A/AF)).

> *'Time, effort and upfront capital on which a return would not be seen for some considerable time.' (UK_CRAN_AF_WP3)*

Several farmers in Italy (AF), Greece (AF), Portugal (A) indicated that the agroforestry products are of better quality and thus have a higher price, but it is difficult to find a market for them, as the consumers affected by recent financial crises choose cheaper products from conventional agriculture and that there was a **low willingness from consumers to pay a higher price**. Actually many people are not aware of the high quality of these products, e.g. lamb meat (Italy (AF), Hungary (AF)).

> *'Meat produced in silvopastoral systems is sold for a higher price. But in this period of economic crisis people buy cheapest products.' (IT_CNR_AF_WP5)*

> *'We do not know why, but the people prefer normal lamb instead of grazed, extensive lamb. It is true that the tastes are different, but grazed lamb tastes good as well and much healthier.' (HU_NYME_AF_WP5)*

Many farmers referred to **management difficulties**: competition for nutrients and light, compatibility of using animals with spraying activities or natural tree regeneration, replacing sward if not very productive, complexity of labour, increased labour, mechanization (tractor operations) becomes more difficult with trees in the fields (France (A), UK (A/AF), Italy (AF), Germany (A/AF), Greece (A), Portugal (A/AF), Spain (A/AF)).

> *'Agroforestry implies more intense and professional management (e.g. how to combine cattle and natural regeneration or how to make compatible the different components of the system).' (PT_ISA_AF_WP2)*

> *'In small fields, trees are a big obstacle for the needed production to maintain the family' (DE_BTU_A_WP2)*

> *'One problem associated with livestock is overgrazing or shrub invasion due to rural exodus, it is a complex equilibrium. But this fact is related to incorrect management. The same applies to damage affecting the regeneration of trees.' (ES_UNEX_AF_WP2)*

Farmers considered agroforestry increases the farmers' **workload** with no free time available, e.g. while looking after the sheep (Germany (AF), UK (A/AF), Greece (A/AF)).

> *'Agroforestry when using sheep requires a day to day care. More time involved in looking after the sheep than in conventional mowing, more spread out and on the labor requirement is probably more.' (UK_CRAN_AF_WP3)*

Bureaucracy associated to agroforestry systems is usually considered very high in Germany (A/AF) and Spain (A/AF).

The **lack of knowledge** on the systems seems to be a constraint in France (AF) and UK (AF).

Several farmers seem to be concerned with the trees, as the trees would **limit the future use of the land**, with difficulties to get back the plot to the original use legally and as the roots remaining in the soil limit the future growth of conventional crops, for instance in UK (A/AF) and Germany (A).

> *'Once trees are planted, land is tied.' (UK_AFBI_A_WP3)*

Further, the **land tenure** might be an issue. If the land is rented, the owners usually hesitate or forbid to plant any trees (UK (A/AF), Portugal (A)).

After further explanations on the possible constraints of agroforestry systems provided by the interviewers, some farmers gave their **new perceptions** as follows, matching in many cases with constraints indicated initially by other farmers.

Implementing new agroforestry systems might imply hiring more people, meaning higher costs, while the new income might not be enough to compensate those efforts. Farmers in Portugal (AF) and Spain (A) claimed that **extra efforts are not compensated economically**. With agroforestry the production would be lower and the land is not maximized as the trees take the space of crops. Also farmers in Germany (A), UK (AF) considered that **management** is more difficult (e.g. fruit orchards with mushrooms, working around trees, mechanization, and higher workload).

At the same time agroforestry has been associated to a high **bureaucracy** in UK (AF) and Spain (A/AF).

> *'A downside is the bureaucracy and strict requirements to be met to commercialize the product on the market and to obtain subsidies.' (ES_UNEX_AF_WP2)*

A farmer in Portugal (AF) suggested that knowledge on new techniques should be acquired.

7.2 Environmental

There are very few negative perceptions on environmental aspects. Only one farmer in Portugal (AF) mentioned the **decrease of natural regeneration**. Another farmer in Portugal (A) mentioned that fire risk will be increased when compared to agriculture. Only one farmer in Germany (A) remarked on **soil acidification** after 3-4 years because of trees. One farmer in Germany (A) mentioned habitat loss in agroforestry systems when the trees are harvested. A farmer in Spain (A) remarked that the landscape had less aesthetic value because of the excess of trees. Most of the farmers did not mention any negative aspect in relation to the environment in France (A/AF), Greece (A), Germany (A), Spain (A/AF), UK (A/AF), Hungary (AF), Italy (AF).

After further explanations on the possible constraints of agroforestry systems provided by the interviewers, a few farmers gave their **new perceptions** as follows.

Animals are problematic, both domestic and wild, in the forest e.g. in terms of health, predators, and feed (UK (A), Germany (A)).

> *'Wild animals are very problematic. Animal overload with for example wild pigs or other wild animals. Hunting is not much practiced anymore, forestry managers don't take care of this problem, and in the end the agricultural farmer is not compensated for the damages made by these animals.' (UK_AFBI_A_WP3)*

7.3 Social

As in the case of environmental aspects, few farmers had negative perceptions on social aspects. Several farmers in Portugal (AF), France (AF), Greece (AF) and Spain (AF) claimed that agroforestry lacks recognition by society, there is not an acknowledgement of the benefits and synergies generated by agroforestry, and agro-foresters are sometimes criticized and not accepted.

Several farmers in Germany (A/AF) and Spain (A/AF) believe that agroforestry **does not create rural employment**, it is more of a family business.

> *'Given the productivity, the most intensive systems can support a greater burden of employment as an effective means of economic development locally.' (ES_UNEX_A_WP2)*
>
> *'Several farmers remark that the low production and profitability leads to a lack of rural employment, agroforestry generating less jobs than other systems.' (ES_UNEX_AF_WP2)*

Many farmers do not identify negative aspects of agroforestry from a social point of view (Greece (A), Spain (A/AF), UK (AF)).

After further explanations on the possible constraints of agroforestry systems provided by the interviewers, also few farmers gave their **new perceptions** as follows. A farmer in Spain (A) indicated that intensive systems offers more rural employment.

> *'The intensive systems generate more employment than an agroforestry system.' (ES_UNEX_A_WP2)*

7.4 No negative perceptions at all

Only a few farmers in Greece (AF) did not have any negative perceptions of agroforestry at all.

7.5 No change in perceptions

In many cases, there were no changes in the negative perceptions towards agroforestry. The perceptions remained the same after the explanation provided by the interviewer with farmers in France (A/AF), UK (A/AF), Greece (A/AF), Germany (A/AF), Spain (A/AF), NYME (AF), and Portugal (A).

8. Do farmers see a need for the labelling of agroforestry products?

Both agroforestry and non-agroforestry farmers were asked whether they see a need for the labelling of agroforestry products. Below, the reasons for their support or lack of support are presented.

8.1 Support for a label on agroforestry

A good number of farmers (A/AF) would **support** the creation of a label for agroforestry products, in particular in Germany, but also UK, Hungary, Greece, Spain, because the production from agroforestry is natural, unique and with a high quality.

> *'There is a need for a specific label to offer high quality products elaborated in the best condition, different from other, increasing the profitability of the product. Increased product quality increases the price per product offering more market opportunities. And allowing consumers to know what they consume.' (ES_UNEX_AF_WP2)*

Increasing the quality and certifying it **increases the price**, value and profitability of the product, and it is justified and beneficial (Germany AF, Portugal A, Spain A/AF, Hungary AF). German farmers (AF) suggested that the labelling could also be designed for the provision of environmental benefits as it creates habitats for different species, promotes C sequestration, biodiversity, water regulation. There are some farmers in Portugal (AF), who considered than a label could lead to a higher price for the product, e.g. cork.

> *'A label would be useful, as this would turn into a higher price for the products, and sell them better with more market opportunities, offering a quality product with a certification of origin.' (ES_UNEX_A_WP2)*

A farmer in Italy (AF) indicated that a label would favour a higher income and thus compensate the higher labour and management costs .

> *'An agroforestry label could be favoring a higher income and compensate the higher labor costs.' (IT_CNR_AF_WP5)*

Some farmers considered that there is an increased sensitivity towards the agro-food system, thus consumers are more selective and **willing to pay for high quality products**. A farmer in Italy (AF) indicated that the economic crisis will not affect the demand, and a farmer in Hungary (AF) thought that foreign consumers are willing to pay for the products, e.g. at local markets in tourist areas.

> *'The economic crisis doesn't affect the demands of my lambs because consumers look for this product.' (IT_CNR_AF_WP5)*

Farmers from Germany (A/AF), Hungary (AF), Spain (AF) perceived the labels beneficial for **raising awareness on agroforestry** and the quality of its products among the consumers, informing them of where and how the products are grown, to know what they are consuming. Traceability should also be guaranteed for consumer assurance (Italy (AF))

> *'The label could imply that agroforestry is best known among the people.' (DE_BTU_AF_WP2)*
>
> *'Perhaps we could have more consumer and higher acknowledgment as well, because they will know about our hard and important farming practice.' (HU_NYME_AF_WP5)*

A label would make the products more visible and would in turn **increase the demand** and offer more market opportunities offering a quality product with a certification of origin, despite the financial crisis having reduced the demand for these products (Greece (AF) and Spain (A/AF)).

A farmer in Italy (AF) considered that a label could **modify the patterns of the consumers** who are diligent in their ethical decisions, explaining that some vegetarians do not eat meat for ethical reasons due to the difficult conditions of livestock on intensive farms.

> *'A certification of lamb obtained using extensive methods would be attractive also for consumers who are vegetarian for ethical reasons (because animals are usually managed adopting an intensive approach).' (IT_CNR_AF_WP5)*

Some farmers saw the need for the label only if this would give an added-value and mean an increase in the income and profitability of the farm. That was observed in UK (A/AF), and Italy (AF).

Many farmers from France (A), UK (A/AF), Spain (A/AF) and Greece (A/AF) did not have an opinion on the labelling issue.

8.2 Labeling not supported by farmers

Several farmers in UK (A/AF), Greece (A/AF), Germany (A), Portugal (A/AF) and Spain (A/AF) did not consider it useful to have an agroforestry label.

A couple of conventional farmers in Spain (A) and in Portugal (A) considered it might be useful but **doubted** whether consumers would pay a higher price for the products. In Italy (AF) and Portugal (A) farmers discussed how the **economic crisis was influencing the consumer behaviour**, giving priority to price over quality. Some German farmers (A) thought that the label would imply an increase in the products price and not increase the volume of sales.

> *'The economic crisis forces consumers to look more at the price than on how the product is obtained.' (IT_CNR_AF_WP5)*

> *''This is like the case of biological agriculture. In some countries consumers pay more for biological products but here consumers still go for the lower price, and more nowadays with the crisis.' (PT_ISA_A_WP2)*

Farmers in UK (AF), Hungary (AF) and Germany (A) indicated that **lack of awareness was another driver for consumer behaviour**; consumers are not aware of the way how the products are obtained and the impacts and thus are not willing to pay higher prices.

> *'There is a need for rising awareness of agroforestry among the population and inform consumers on where and how the products are grown, but doubt that the people is willing to pay for higher prices.' (DE_BTU_A_WP2)*

> *'Label system could help the agroforestry farmers. They are scared that people would not understand it at all. They are also scared that people would not buy the lamb from the pastureland and that they would pay less for the lamb from the pastureland because the taste is different. The lamb from the pastureland is often found to be muscly because it is drier, than soya feed lamb.' (HY_NYME_AF_WP5)*

A farmer in Portugal (AF) considered that labels are not giving any extra benefits for farmers but **administrative burden** and restrictions, at the same time German (AF) farmers said that labels are just an extra cost.

> *'The increase in the product price does not reach the farmer, who only gets an increase in bureaucracy.' (PT_ISA_AF_WP2)*

Conventional farmers in Portugal (A) considered that labelling will not give an added-value, since the **products obtained are not different to products from conventional agriculture**.

> *'Two farmers are convinced there is no need because the products from conventional agriculture and agroforestry are equal.' (PT_ISA_A_WP2)*

Farmers from Italy (AF), Germany (AF), Portugal (AF) and France (AF) considered that there are **too many labels in the market** nowadays, meaning too much competition, and consumers are overwhelmed with those and probably not paying attention any more to them. Some remarked that so many labels may lead to fraud.

> *'There is an existing label for cork and other products like biological lamb meat.' (PT_ISA_AF_WP2)*

> *'The increase in the price of the product does not compensate the price of the label. Actually the increase in the price of the product might promote fraudulent labelling.' (DE_BTU_AF_WP2)*

Some farmers in Germany (A/AF) suggested that the higher costs that this type of products require should be **paid by the state** instead of the consumers that are not always willing to pay a premium price for a quality product.

> *'There should be subsidies instead of a label. The higher costs should be paid by the state via subsidies. Our soil quality is for example very low and if we have to pay by ourselves for a label it wouldn't be economic. People don't want to pay much either, they want to have good products that are cheap. If the site conditions were more appropriate, maybe it was possible to plant agroforestry.' (DE_BTU_A_WP2)*

> *'Instead of labelling, the products should be subsidized with appropriate policies. The increase in price should not be paid by the consumer, but financed in another way, for example subsidies.' (DE_BTU_AF_WP2)*

4.6 Discussion and implications

There are not many studies on the driving forces behind farmer behaviour at European level, except within particular socio-economic environments (Graves et al., 2009; Sereke et al. 2016). The aim of this study is to identify the drivers affecting the uptake by farmers of agroforestry on their land.

4.6.1 Understanding of agroforestry

This study has shown that, in general, farmers understand that agroforestry is basically a combination of crops and/or animals with trees. Some farmers seem to have a more advanced knowledge than others. However many conventional farmers have not heard the term or do not know what it is. More curious is that some farmers who manage agroforestry are not aware of what agroforestry is.

Several practices were described by the agroforestry farmers interviewed. Whilst the study does not cover all existing practice in Europe, many of the key systems were examined. This includes agroforestry systems of "high nature and culture value" such as hedgerows, grasslands with scattered trees, montado, dehesa, orchard meadows, grazing in dense forest, and wooded pastures. In some cases, the grazing takes place only for a few months in the year, while in many cases they practice grazing holistic grazing all year round. This practice is supported by Savory (2013) and Butterfield et al. (2006) who argue that with holistic planned grazing, the livestock mimics nature and can generate resilient landscapes.

4.6.2 Uptake of agroforestry

Domínguez and Shannon (2011) state that land owners manage their lands in relation to four axes: economic expectations on the property, ethical reasons, how the forest or land should look like, and the natural risks. The socio-psychological factors (e.g. cultural, demographic, economic, and social variables including ancestors, peers and education) and how people make decisions in practicing agroforestry are inseparable, and must be considered if policy makers, extension agents, and agricultural educators hope to influence and improve landowners' agroforestry management (Saha et al. 2011).

Based on the responses in this study, the three major drivers for continuing conventional farming and not taking up agroforestry are tradition, lack of knowledge about agroforestry and easier management. Other identified drivers are the economic viability, existence of subsidies, time availability, quality of soil, the age of the farmer, and the ownership of the land. In broad terms, the results in this study are in line with Saha et al. (2011) who indicate that farmers' decision making processes were most influenced by factors such as ancestors and education, followed by peers, financial condition, and economic importance of the agroforestry land holding.

One of the reasons for not planting agroforestry given by the farmers is that when planting trees, the land would be tied up for future uses. Flexen et al. (2014) also identified this as the most important factor in a survey of attitudes of farmers in Northern Ireland to agri-environment schemes and woodland creation.

Interestingly, many farmers interviewed in this study showed interested in the agroforestry practices explained and considered trying it after the interviews. This highlights the interest but the lack of knowledge the farmers have on agroforestry, although investment was dependent on seeing the profitability and other advantages of such systems in practice. Some would implement agroforestry if there were economic supporting measures, the management was simple, if it was acceptable to the landowner and/or the soil was poor. Flexen et al. (2014) also reports that, in Northern Ireland, both agroforesters and non-agroforesters would consider planting trees in their plots if there were greater financial incentives or if they had land that was poor or unsuitable for farming. This is similar to the attitude found amongst many farmers in our study that agricultural land was too good to plant trees on and that they would only plant trees on marginal land where farming was difficult or not profitable.

From the responses of agroforestry farmers, tradition and learning from other experiences were key reasons for implementing agroforestry. The diversification of products, which reduces the risk in the production, was also another relevant aspect. These drivers contrast with those of farmers reported by Sereke et al. (2016) in Switzerland, where the primary motivations were habitat function, both for biodiversity conservation and shade for livestock. Nevertheless, animal welfare is also mentioned as important driver among the interviewed farmers.

In Estonia, Roellig et al. (2015) identified that almost all the interviewed farmers depended on financial support to manage or restore their wood-pasture and would probably not have started to restore their wood-pasture without it. On the other hand, most farmers were reported to have a clear passion for managing their land and were proud of maintaining their wood-pastures following local traditions. Animal health and biodiversity also played a role in the motivations. Most farmers believed their animals thrive better in a more “natural” environment requiring less medication (Roellig et al. 2015). In Flexen’s study in Ireland most of the agroforestry farmers rated landscape improvement and environmental factors as very important/important factors and more than half rated provision of shelter for livestock as very important. A small proportion of those that had planted woodland said that economic factors were very important/important in their decision. Inheritance value and sporting/recreation reasons were generally not indicated as important in the decision to plant woodland (Flexen et al. 2014).

The farmers in the current study considered agroforestry as a good option for marginal lands of low productivity. Improving the environment, aesthetic value and quality of life are other reasons for implementing agroforestry. Sereke et al. (2015) in Switzerland identified that the motivation to conserve cultural landscapes was higher among adopters of agroforestry compared to non-adopters. Other studies in France have revealed that difficulties in accessing land and the ability to reduce agricultural inputs through functional biodiversity and diversification have motivated smaller farmers to combine annual plants and fruits to increase their plot performance on a multifunctional basis. The number of such plots has significantly in the last years (EURAF 2015).

A review of studies of attitudes in UK found that landscape and conservation were ranked highest when asked reasons for planting, with production and profit ranked low (Lawrence et al. 2010). This matches the study in Ireland, where landscape improvement and environmental factors were more important reasons for planting woodland than economic factors for most farmers (Flexen et al. 2014). Furthermore, Lawrence et al. (2010) reports that the availability of grants appears to influence those who are already interested in planting trees on the fields rather than those that who are not. Other drivers in this study are research purposes, sustainable eco-intensification, while managing a farm as a second occupation leads the farmer to focus more on sustainability than on profits.

By contrast, regulations can limit the use of some agroforestry structures (e.g. hedges). Sereke at al. (2016) reports that whereas farmers feel free to decide whether to practise agroforestry or not, they often believe that regulations hinder adoption (Sereke et al. 2016). Environmental regulation was not a motivation, then, for both adopters and non-adopters.

4.6.3 Awareness of agroforestry

In order to encourage farmers to uptake agroforestry, there is a clear need for raising awareness among farmers about the benefits of these practices, showing them examples of successful farms. Farmer-led projects have greater credibility in the eyes of other farmers (the peer-to-peer effect), thus one channel for such raising of awareness is to update the extension services with latest developments and findings for further knowledge transfer. Primmer and Karppinen (2010) showed that technical solutions suggested by technicians from extension services are used by owners into their decision-making. Technicians are key influencing agents in determining whether an owner will try different management alternatives, in particular in cases with high uncertainty and complexity, e.g. price fluctuations and climate change (Schlüter and Koch 2009).

Hesitating farmers are open to implement agroforestry on their farms if it is profitable. This may require subsidies within the CAP that favour agroforestry together with thorough explanation and encouragement from extension services to increase the awareness of grants available. Sereke et al. (2016) also justify subsidies for ecological production and local and authocthonous agricultural products. Public support to land management can be justified where it results in public goods, e.g. environmental or social benefits such as rural vitality (EBCD 2012), that would otherwise not be provided.

There is also a clear need for raising awareness among consumers, for them to identify the higher value of agroforestry-derived products which in turn becomes an incentive for farmers. Duesberg et al. (2014) recommended that, in addition to monetary incentives, policy tools such as image and information campaigns should be employed. A broader knowledge about ecosystem services needs to be made available to society to increase recognition of local ecological solutions (Sereke et al. 2016).

4.6.4 Tree removal

Contrary to what was expected, this study showed that most of the farmers have not removed trees from their land on a voluntary basis. For those that decided to remove some of the trees, the main driver has been the simplification of the management of their grasslands to avoid problems with machinery. Only a few farmers had removed trees to maximise eligibility for CAP subsidies.

However a tradition to remove trees was claimed by some interviewed farmers as reason to maintain the practice, as well as the decision to replace the trees with more profitable crops (including permanent crops). In some cases, farmers responded that they would opt to remove the trees, but they are limited in their interventions by different regulations. To motivate farmers to manage more complex agroecosystems that are fundamentally different to their current simplified systems is challenging (Pannell 1999). Once trees have been eliminated from the landscape they require time to be restored, bio-physically, economically and socio-culturally.

4.6.5 Challenges with agroforestry

There are many problems and challenges found in this study that farmers are facing in real life. Many agroforestry farmers experience some management difficulties. Although it is not always a problem, for many agroforestry management is more difficult than that for conventional agriculture.

Several regulations across Europe limit the implementation of agroforestry, as several laws limit or prevent the use of certain hedgerows, the removal of some trees for pastures, or grazing in forests. That challenge was also observed by Sereke et al. (2016) in Switzerland, where farmers would opt for forest grazing, but as this is not allowed, they graze their forest illegally.

Some of the findings show that property rights, wildlife attacks, low profitability, bureaucracy burden, and lack of knowledge are other examples of the problems that agroforestry farmers face. Despite this, many of the farmers did not see major problems implementing agroforestry practices.

4.6.6 Positive aspects

When looking at the positive perceptions from the farmers on agroforestry systems the main benefits were related to environmental aspects. All farmers identified some environmental benefits, whilst a high proportion acknowledged production and social benefits. Many of the identified benefits have been studied by scientists, and it is rewarding to observe that these are identified on the ground by land managers.

The interviews sought to identify whether there was a change in the perceptions of non-practitioners when informed about agroforestry. Farmers, who were not familiar with agroforestry, were generally able to identify additional benefits when agroforestry was explained. By contrast farmers who were already aware of agroforestry tended to highlight the same benefits of agroforestry at the end of the interview as they had described at the beginning.

Among the production issues, the main benefits identified relate to animal welfare, diversification of products and increasing land value. Farmers also identified increases in production and profitability, resilience to climate change, suitability to marginal lands, integrated pest management, and lower labour input.

Among environmental issues, mitigation of climate change, carbon sequestration, soil conservation, improvement of water quality and quantity, together with increasing biodiversity, improving landscape and the ecological value of the farm are widely acknowledged. The reduced risk and intensity of fires was infrequently mentioned in the farmers' perceptions, despite a relevant issue in the Mediterranean regions. In these regions there have been excellent examples of grazing agreements between public administration and shepherds for biomass reduction, reducing wildfire probability and severity, and social innovation involving society in tackling fire problems (Varela and Gorriz 2015).

Most of the interviewed farmers highlighted social benefits from the agroforestry systems, especially the improvement of the landscape aesthetics. This can improve the recreational value of the region, enhance human well-being and contribute to cultural heritage. Farmers usually argue that agroforestry increases rural employment, improves the farmer image and is a good marketing tool.

4.6.7 Negative aspects

Farmers were also asked about negative perceptions of agroforestry. Many claimed lower production levels than intensive systems, but they diverge on whether agroforestry was still profitable or not. A similar perception was observed by Sereke et al. (2016), where agroforestry was seen as less productive compared to monoculture, with non-adopters having a significantly more negative attitude regarding productivity. By contrast published studies (Sereke et al. 2015; Graves et al. 2007) indicate that agroforestry practices can be economically competitive compared to arable and grassland monocultures, and that there can be innovative marketing of the fruits or payments for ecosystem service. Successful projects based on payments for biodiversity results, e.g. the Burren Programme, that are funded via the Pillar II of the CAP, could be replicated in more areas in Europe.

Extra management costs and long-term financial return were identified as some of the main constraints in managing a complex agroforestry system. In order to make the system more convenient, farmers were open to the idea of an agroforestry label to compensate these costs, although they perceived a low willingness to pay by consumers. Another common negative aspect was management (e.g. mechanization) as observed by Flexen et al. (2014) in Ireland. Other factors relate to a higher workload, higher administrative burden and lack of knowledge. Planting trees would also tie up the land for future use, discouraging farmers from planting trees in the fields; the same issue was also perceived by Flexen et al. (2014).

As expected, there are very few farmers indicating negative environmental issues related to agroforestry systems, and some of them are biased by the lack of knowledge on the management or misconceptions, e.g. lack of natural regeneration, increased of fire risk compared to agriculture, soil acidification, habitat loss when harvesting trees, lower aesthetic value, and the impact of wild animals.

Very few negative issues were also identified on social aspects. Some farmers claimed that there exists a lack of recognition by society, not acknowledging the benefits and synergies generated by agroforestry, and agro-foresters are sometimes criticized and not accepted by colleagues and society. A similar perception was recognized by Sereke et al. (2016), where non-adopters, in contrast to adopters, concluded that adoption would not have a positive effect on their reputation. Non-adopters' behaviour seems to be more oriented towards the opinion of their colleagues than towards the opinion of society and environmentalists who could be more favourable to agroforestry. Most farmers who had not planted woodland considered that having trees and woodland on their farm would benefit the wider rural community (Flexen et al. 2014). Further on the social issues, some farmers consider that agroforestry does not create as much rural employment as intensive systems.

4.6.8 Labelling

Many of the interviewed farmers in this study supported the labelling of agroforestry products because the products can be natural, unique and of high quality. Thus an increase of the price of the product is justified and beneficial for the profitability of the farm. Many farmers see product labelling as a useful tool for rising awareness among the consumers and opening new market opportunities. However many farmers were also against the labelling as they doubt the consumers would be willing to pay a higher price because of the current economic crisis, giving preference to price over quality. They were also concerned about a lack of awareness among the consumers about agroforestry, the presence of too many eco-labels, and risks of fraud. For some farmers, labels mean only extra cost and administrative burden without financial benefits. As alternative to labels, a few farmers suggested that governments should cover the extra costs associated with agroforestry because of the additional environmental services provided to the society. This could be related to schemes such as Payments for Environmental Services.

4.7 Conclusions

The main drivers for the choice of agricultural practice by both conventional and agroforestry farmers were the tradition in the family or the region and knowledge on existing successful practices.

Most farmers indicated that they did not want to remove the trees on their farm. The farmers who removed the trees, generally took the decision in order to facilitate the mechanization of the land; only a few of them claimed that they did so to maximise eligibility for CAP subsidies.

The interviews aimed to identify whether there was a significant change in farmer perceptions after being informed about agroforestry. Farmers with little knowledge on agroforestry became aware of some of the some benefits, already identified by other farmers. However most farmers, especially those more familiar with agroforestry, did not change their general perception about agroforestry after receiving more information. Many farmers would be open to implement agroforestry if they had more local examples of successful systems, run by farmers, and additional support provided by local extension staff regarding the technical and administrative aspects and grant-eligibility of agroforestry systems.

5 Application of analytic network process for five Europe's biogeographical regions

Authors: Marko Lovrić[1], Michael den Herder[1], Mercedes Rois[1], Anil Graves[2], Andrea Pisanelli[3], Nataša Lovrić[1], Silvestre Garcia De Jalon[2], Andrea Vityi[4], Anna Varga[4], Paul Burgess[2]
[1] European Forest Institute, Finland
[2] Cranfield University, UK
[3] Institute of Agro-environmental and Forest Biology, Italy
[4] Institute of Forest and Environmental Techniques, University of West Hungary, Hungary

5.1 Summary

In order to shed light on the factors which frame agroforestry practices in Europe, a total of five Analytic Network Process (ANP) models have been designed to reflect farm management scenarios for European biogeographical regions (Atlantic, Boreal, Continental, Mediterranean and Pannonian), in which a farm 'typical' for that region could improve its management by implementing different agroforestry practices. This corresponds to five management alternatives: *Implement high natural and cultural value agroforestry system, Implement high value tree systems*, *Implement agroforestry for arable systems*, *Implement agroforestry for livestock systems, and Do not implement agroforestry system*.

Models were developed in a participatory manner through a series of questionnaires and two workshops with a total of 18 decision makers. Each of the models hosts separate "benefits", "costs", "opportunities" and "risks" sub-networks, with a total of 40 criteria. An additive negative formula was used for synthetizing the overall results,

Results show that ANP model for Atlantic region differs from the other ones, with a very low priority of *high value tree and arable agroforestry systems*. In general, *high natural and cultural value agroforestry systems* were the preferred management alternative, whereas *livestock agroforestry systems* were preferred in the model for the Pannonian region. In the context of results obtained by the additive negative formulae, which can be interpreted as providing best long-term results, *no agroforestry* alternative was a viable option in the models representing the Atlantic and Boreal regions.

5.2 Introduction

Agroforestry, concisely defined as the integration of trees with farming, is a historic and common European land use practice. However during the twentieth century, increased specialisation in many areas favoured more intensive monoculture agriculture or forestry. Over the last few decades, agroforestry as a sustainable land use practice has been drawing increasing attention again and there have been initiatives to support its use (Smith 2010). Nevertheless, although there are some successful examples in some European regions, the formal uptake of new agroforestry practices has remained quite limited (Pisanelli et al. 2014, Luske et al. 2016). The decision of a farmer whether or not to practice agroforestry on his or her farm depends on many socio-economic and environmental factors (see Sections 3 and 4 of this report for a detailed overview of these factors).

The aim of this study was to determine the most relevant criteria which could affect a farmer’s choice in implementing different farm management alternatives. This was done by applying a series of surveys to experts in the field of agroforestry and related fields and analysing the results using the Analytic Network Process (ANP). The criteria for the uptake or waiver of agroforestry practices were studied using a separate ANP model for five European biogeographical regions (Atlantic, Boreal, Continental, Mediterranean and Pannonian) (Figure 5.1). These models were used to examine how a farm ‘typical’ for that region could improve its management system by implementing one of five agroforestry management options. These were: i) high natural and cultural value agroforestry systems, ii) agroforestry with high value trees, iii) agroforestry for arable systems, iv) agroforestry for livestock systems and v) no agroforestry system. Each model comprised separate “benefits”, “costs”, “opportunities” and “risks” sub-networks, with a total of 40 criteria.

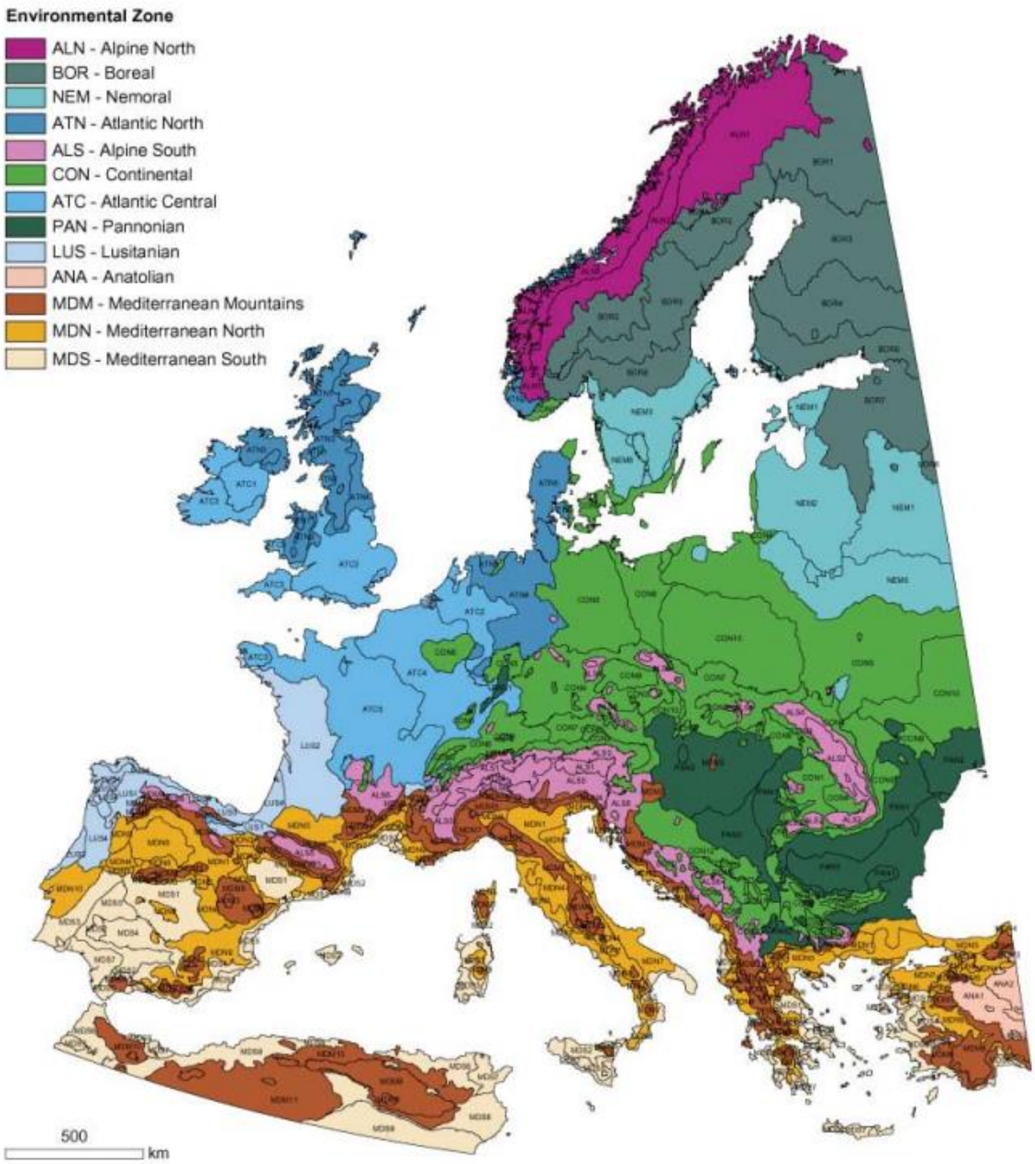


Figure 5.1. The study focused on five environment zones: Atlantic (mainly indicated in blue), Mediterranean (mainly indicated in browns), Boreal (indicated in grey), Continental (mainly indicated in light green) and Pannonian (indicated in dark green) (Metzger et al. 2005).

5.3 Reasons behind uptake of agroforestry practices across Europe

5.3.1 Atlantic region

The area of agroforestry in the Atlantic area of Europe is relatively small compared with Mediterranean areas of Europe. In a recent study using European land use and land cover data, (den Herder et al. 2016) found that many countries typically considered to lie in the Atlantic zone, such as the UK (3.3%), Netherlands (1.5%), Belgium (3.2%) Denmark (0.6%), and Germany (1.6%), France (5.6%) were reported to have a relatively low proportion of their utilised agricultural area taken up with agroforestry in comparison with the European average (8.8%). Nevertheless, a range of agroforestry systems exist, although these tend to be characterised by a lower level of tree species diversity than in Mediterranean agroforestry, and are primarily silvopastoral systems with grazing livestock (den Herder et al. 2016; Eichhorn et al. 2006).

In the Atlantic zone, there are agroforestry systems with livestock production, crop production, and high value tree products. In most cases, these also produce a range of environmental benefits such as biodiversity provision, carbon sequestration and pollution control. Some systems have high nature and cultural value, for example, wood pasture and parkland systems. In some cases, a single area of land may be classified into different groups over time, particularly as the system evolves, for example, if an area grown with crops in the first years of tree growth is then laid to pasture and grazed when the crops are no longer viable.

Agroforestry combining livestock dominates the Atlantic zone. Such systems include livestock agroforestry systems, where the trees provide fodder, fruit or nuts, and shelter for the animals from the rain and cold temperatures, and occasionally shade from heat. In the UK, substantial areas of land are covered with widely spaced trees and pasture which are typically used for sheltering and grazing cattle and sheep (Smith 2010). Some of these systems are ancient and remnant wood-pasture systems in England contain some of the oldest and largest trees in Europe and are associated with high biodiversity, historic and cultural significance (Butler 2006; Isted 2005).

Den Herder et al. (2016) identified relatively large areas of grazed orchard systems with fruit trees such as apples, particularly in the UK and France. Eichhorn et al. (2006) describe such systems, specifically selected for dual purpose fruit and wood production using walnut, pear, and apple trees grown at low density in meadows (*pre-vergers* systems) and describe how in some areas, these systems may be intercropped in the initial years, for example in the Dordogne in the western France, and then grazed once intercropping is no longer viable. These systems are similar to those in central European countries such as southern Germany, Austria or Switzerland, where they are called "*Streuobst*", which are divided into "*Streuobstäcker*" (silvoarable) and "*Streuobstwiesen*" (silvopastoral) systems, making use of apple, pear, plum, and cherry trees (Herzog 1998).

During the 1950s in England, Bryant & May Forestry Ltd established agroforestry systems with poplar grown for match production, where the intercrop area were cropped for the first few years, and then sown to grass and grazed till pasture growth stopped as the tree canopy closed (Beaton 1987; Dupraz and Newman 1997). These systems have since been abandoned although some similar experimental sites have been implemented in the Netherlands and England (Edelenbosch and Dik 1995; Beaton et al. 1999; Burgess et al. 2005).

In some areas of the Atlantic zone, particularly northern Europe, trees are pollarded to collect fodder or wood (Smith 2010). The area beneath the trees might then be cut for hay or grazed (Reed 2006; Austad and Hauge 2006; Dagley 2006). Whilst pollarding used to be widespread in northern Europe, the practice has declined in the Atlantic zone and those that remain are gradually being abandoned (Smith 2010).

Smaller areas of agroforestry systems also exist in Northern Ireland, the UK, France, the Netherlands and Denmark, where chickens for example, might be grazed under fruit, willow, walnut and Christmas trees (Smith et al. 2016; Bestman 2015; Kongsted and Hermansen 2015). Such systems are considered to be important for animal welfare providing a more natural environment for the animals. The trees in some cases may provide environmental benefits, such as carbon sequestration and reduced nitrate and phosphorus pollution flows to water bodies.

Another widespread system that may be viewed as agroforestry includes scattered trees and hedgerows. In the Atlantic zone, France (598,000 hectares) is considered to have the greatest area of hedgerows followed by the UK (240,000 hectares) (den Herder et al. 2016). In Brittany, in western France, some hedgerows are jointly managed by land owner and tenant farmers, in which the owner is entitled to the tree bole of pollarded trees, whilst the farmer is entitled to harvest the side branches, typically for fuelwood. The process of agricultural intensification has led to a decrease in hedgerows, but there is support for their re-establishment for their high historical and cultural value and environmental benefits such as regulating nitrate and phosphorus flows to water bodies in Brittany (Aviron et al. 2016).

5.3.2 Boreal region

In the boreal region, agroforestry is not practiced on a wide scale and currently about 624,000 ha (Finland 158,000 ha or 6.9% of UAA, Sweden 466,000 ha or 15% of UAA) are under agroforestry, mainly as high natural and cultural value agroforestry and livestock agroforestry (den Herder at al. 2017). However, if we would consider reindeer husbandry as a form of agroforestry (Vanhanen and Peltola 2015), agroforestry in the boreal region would cover the largest extent in whole Europe as the reindeer husbandry area covers about 41 million hectares (Jernsletten and Klokov 2002).

The profitability of silvoarable agroforestry in the boreal region is constrained because such systems are not eligible for financial support (Koivula 2012, Agency for Rural Affairs 2016). However, both Sweden and Finland support landscape management of traditional rural biotopes (such as Scandinavian wood pastures) and landscape biodiversity with specific agri-environmental subsidies (Eriksson 2008, Agency for Rural Affairs 2016).

Literature on the reasons behind the uptake of agroforestry in the boreal region is very scarce. In a survey sent to farmers managing traditional rural biotopes in Finland (Laanti 2013), the main challenges were the amount of work, possible sanctions which could lead to a loss of financial support, ban on supplementary feeding, ban on fencing traditional biotopes and the application process for financial support. The main reasons to stop the management of traditional biotopes where the farmer gives up farming (or even the whole farm) were bureaucracy and too much work (Laanti 2013). The most common suggestions for improvement were increase of financial support, moderation of the terms for financial support, easing of management, simplification of application documents and improved guidance by extension services (Laanti 2013). Another survey by Koivu (2014) confirmed that farmers may not be aware of the rules and the content of EU agri-environmental schemes and national subsidies. Farmers were concerned for the future of agriculture in Finland and were hoping for the simplification of support systems. In a study on the future possibilities for alley cropping in Finland, Koivula (2012) acknowledged that agroforestry is more complicated than mono-crop farming and that practices which work in central and southern Europe are unlikely to be successful if they are just copied and transferred to more northern areas with very different biophysical conditions. She noted that in addition to support from extension services, farmers would also need a network of like-minded farmers before starting an agroforestry practice.

5.3.3 Mediterranean region

The warm temperatures in Mediterranean areas mean that, providing there is adequate water, it is possible to grow a wider range of tree species and crops than at higher latitudes. In fact in some locations high temperatures can be damaging to crop and grass production and hence shade provided by trees can be beneficial. Trees, due to the deep roots, can maintain photosynthesis during the summer droughts present in the Mediterranean area. Portugal, Spain, Italy and Greece have the largest absolute extent of agroforestry in Europe (den Herder et al. 2017).

The distinctive character of Mediterranean agroforestry systems is the complex assemblage of different land covers resulting from many millennia of man-made modifications (Antrop 2004). Traditional agroforestry systems are still common in many rural areas where intensive agricultural practices cannot be adopted. In these marginal areas, quality of land is poor and this prevent the adoption of intensive agricultural practices (monocultures) and farmers believe that agroforestry is the most appropriate land use system for such kind of marginal lands.

In these areas, trees have traditionally served several purposes in the agrarian economy such as the production of fruits, fodder and wood for fuel, litter or timber. In addition, they have amenity value, providing shade and shelter for labourers and livestock, and combating erosion by wind and water. In recent decades the traditional composition and arrangement of Mediterranean landscapes have been significantly changed by urbanization, industrialization, logging, the common agricultural policy (CAP) and climate change effects (Simoniello et al. 2015).

Typical traditional agroforestry systems include high natural and cultural value agroforestry like dehesas in Spain, montados in Portugal, and in wood pastures of Sardinia, Italy. There is also agroforestry for high value tree systems like olive orchards managed at various level of complexity in Italy and Greece (olive trees are typically planted in rows, although they may also be irregularly scattered when groves have been thinned). Oaks, carob, walnut, almond and other fruit trees often form a minor mixed component (Eichhorn et al. 2006).

Mediterranean farmers usually demonstrate awareness concerning agroforestry especially in terms of environmental benefits (biodiversity conservation, carbon sequestration, soil erosion control, landscape improvement) and productive potentiality (income diversity, product quality, business opportunities). However at the same time, they still perceive the complexity of management (higher level of labour compared with monoculture and difficulty of mechanization) as main constraints to their adoption (Camilli et al. 2016). Farmers usually affirm that economic subsides are needed to compensate the complexity of work.

Farmers also complain about the complexity of EU policy supporting agroforestry systems: the lack of knowledge and bureaucracy. The conflict between Pillar I and II of the Common Agricultural Policy often discourage framers to apply for grants. In the 2007-2013 Common Agricultural Policy, trees, trees in rows and hedges reduced the Single Farm Payment because they reduced the eligible farm size (Pisanelli et al. 2014). In the current program (2014-2020), there is a discussion concerning the maximum number of trees that are allowed in order to keep the direct payment eligibility.

Moreover, farmers and stakeholders perceive that the problem due to wild fauna (especially wolves) is becoming a large problem in Mediterranean area since farmers are forced to limit the free-grazing time (especially sheep) to avoid animal attacks. Consequently the production of meat and cheese, both in quantitative and qualitative terms, is reduced. In order to compensate the high cost of producing some agroforestry products a kind of label or certification would be appropriate.

Mediterranean farmers are aware that their farms are often located in a fragile environment and in recent years, severe damage has occurred because of heavy rain (flooding and landslides). Agroforestry systems could play an important role in preventing natural disasters due to extreme events.

5.3.4 Continental region

The continental agroecological zone in Europe is characterised by lower annual amounts of rainfall and wider extremes in temperature than the Atlantic region. Compared to the Mediterranean region, the effect of drought on plant growth is less critical (although there are certain areas such as eastern Germany where the annual precipitation is generally low). In the continental region, the availability of solar radiation is likely to be a more critical determinant of yield than in Mediterranean areas. Thus, trees with large light adsorbing canopies can be seen as “competitors” to crop yield. Nonetheless, there are scattered trees around farmland such as hedges and windbreaks in northern Germany (“*Knicks*”, “*Wallhecke*”). There are also low density orchard system with fruit trees (apple, pear, plum and cherry tree) and pasture close to villages, called “*Streuobstwiesen*” and occurring in the central European area (for further details see also Herzog 1998 and Bergmeier et al. 2010).

In general, there is a long history and tradition with different agroforestry applications in the Continental environmental zone in Europe. The tree species and management techniques are adapted to local conditions, but there are some common traits. Due to their historical roots, these systems are i) of high natural and cultural value, e.g. for hosting hot spots of biodiversity or delivering specific services, iii) they are multi-functional, and iii) the original core functions such as fencing for animals, property enclosure, wind breaking, erosion protection, provision of fire wood or fruits are more or less still active (Eichhorn et al. 2006). However some systems are being marginalised by modern developments such as the decline of small family farms, pooling and consolidation of farmland, and less financial support for maintenance measures.

There is a clear need for new agroforestry practices in continental Europe where it can help address climate change (e.g. the need of more protection against heat), enhanced erosion control, and the loss of rural biodiversity (Sereke et al 2015, 2016). In the USA to minimise wind erosion, windbreaks, alley cropping systems and riparian strips have been established. In contrast, such systems are still quite rare in central Europe. Despite efforts to promote such agroforestry practices in some central European countries, most have remained at an experimental stage. The reasons for the low implementation of modern agroforestry in continental Europe are i) the lack of favourable regulation by the EU CAP, national and regional authorities, ii) the general fear of farmers to see their subsidies reduced, and iii) the concern of losing independence of management decisions (e.g. harvesting wood in a riparian buffer strips, once installed as an erosion barrier and including a certain management regime, but later then designated as a high values nature protection area with respective management restrictions). Some of these conflicts are exacerbated by the single focus of some interest groups. A rediscovery of the benefits of agroforestry combined with the experience of local farmers and new scientific insights and practical applications might provide a key to the successful future development of agroforestry systems in central Europe.

5.3.5 Pannonian region

The Pannonian environmental region is exemplified by Hungary. In the Pannonian area silvopastoral systems as wood pastures and grazed forest, wood meadows and protective tree systems - shelterbelts and buffer strips on farmsteads or between arable lands - have been common practice over recent centuries. However their extent is currently declining (Varga and Bölöni 2009, Vityi 2014, Varga et al. 2016c). Traditional small-scale agroforestry vineyards and orchards were common and are still practiced in some regions of Hungary. There are mainly historical or practical description of those fruit based agroforestry systems (Andrásfalvy 2001, Sipka and Külkedi 2012).

The economic and social value of silvopastoral systems is hinted by the name "*Glandifera Pannonia*" (meaning 'acorn bearing Pannonia') to denominate Transdanubia in the Roman Age. The significance and operation of silvopastoral systems declined substantially in the past 100 years, and common ownership of pastures in forested areas has vanished almost entirely (Saláta et al. 2009 a,b, Varga and Bölöni 2009, Varga et al. 2016c) . It is estimated that there is currently only around 5500 ha of used or abandoned wood pasture with ancient trees in Hungary; with a third in a protected area (Bölöni et al. 2008, 2014; Varga and Molnár 2014). There are many younger wood pastures or grazed forests that were not mapped by Bölöni et al. (2008). Grazing in forests is prohibited in areas officially qualified as forests, despite of the farmer and nature conservation need and practice of forest grazing (Varga et al. 2016a, 2016b, 2016c). Traditional herding occurs in some of the remaining wood pastures, but this practice is threatened. Increasing formal recognition of the cultural and ecological value of wood-pastures has resulted in new types of managers and the emergence of new types of knowledge in the remaining wood pastures (Varga and Molnár 2014, Molnár et al. 2016). In recent years, agri-environment subsidies, nature conservation management practices, and the rising demand for organic food mean that some formerly abandoned areas are now farmed again as wood pastures. However, in places this change is hindered by legal impediments such as complicated legal ownership structures. Benefits of silvopastoral systems can include high quality food products and the preservation and maintenance of high natural and cultural values (Varga 2014).

The total area of windbreaks and shelterbelts is about 16000 ha (Frank and Takács 2012). Data on the extent of other types of agroforestry systems – such as grazed orchards, silvoarable or agro-silvopastoral systems – are not known. Modern alley cropping systems seem limited to small farms or newly established pilot systems. (Vityi 2015) Because of the relatively high ratio of agro-environmentally sensitive and risky areas - affected by floods, droughts, inland excess waters - in the Hungarian Great Plain (Láng et al. 2007) there is strong need for development in climate-adaptive agro-technologies. The more extent use of arable agroforestry systems or re-adaptation of traditional ones could become a new pathway for realising more resilient and sustainable production systems. (Vityi and Marosvölgyi 2013).

Although there is significant interest in the benefits of agroforestry, there is a lack of basic knowledge about these systems. Further barriers for this transition have also been identified: the legal implication and technical aspects of developing agroforestry are the main challenges, and even though several types of agroforestry are traditional land use type in Hungary, emphasis was not granted to the assessment of biocultural and economical values, or to the possibilities of this management until quite recently (Varga and Bölöni 2009).

5.4 Material and methods

Analytic Network Process (ANP) is a multi-criteria decision making model. It is based on pairwise comparisons of its elements, where any element of the model can be related to any other part of the model. A full ANP model has separate 'sub-models' (sub-matrices) for "benefits", "opportunities", "costs" and "risks" (BOCR). Benefits and costs are usually considered internal to the system, and opportunities and risks are usually considered as external factors focused on the future developments. The decisions are based on a defined description of a situation, and must entail a limited set of discrete alternative decisions. ANP is a generalization of Analytic Hierarchy Process (AHP), and is designed for decision problems which cannot be characterized hierarchically (i.e. which entail two-way interactions between its elements, regardless of the hierarchy of their relations. ANP was first presented in Saaty (1980), fully described in Saaty (1996), amended in 2001 to include full BOCR sub-networks, and amended again in 2005, where negative priorities and different formulas for overall synthesis of priorities were introduced.

Mathematically, the model is presented in the form of different matrices, which contains all elements of the model both as rows and columns. The first and basic mathematical representation of the model is the 'unweighted supermatrix', in which the columns are the 'senders', and the rows are 'receivers' of the influence relation in the comparison of the model's elements. All the pairwise comparisons are made with respect to a single 'parent' node, and are presented in the unweighted supermatrix as columns (Saaty and Vargas 2006; Saaty 2008)

The 'parent' node can also be called the control criterion, and relative priorities of other 'children nodes' (i.e. their relative weights gained through pairwise comparison) with respect to the 'parent' node are called priority vectors, and are positioned in the unweighted supermatrix as column vectors. If we move beyond the direct influence relations, nodes/elements in the model can be categorized source nodes (which are always the source and never a destination of influence/importance path), sink nodes (which are always the destination and never a destination source of influence/importance path) and intermediary nodes, which lie between the source and the sink nodes (Saaty and Vargas 2006).

Although the terminology used to describe the elements of the model can be confusing, what is of paramount importance is the understanding of the mathematical relations between the elements of the supermatrices. Figure 5.2 provides an example of such relations. This example model has only two alternatives – implement agroforestry practices (AF), and do not implement agroforestry practices (NO AF), and two criteria – Improvement of Biodiversity (BD) and Economic Performance (EP). In this model the supermatrices have four rows and four columns (i.e. two criteria and two alternatives). As ANP allows for feedback loops, we can compare the alternatives AF and NO AF with respect to criteria BD and EP, and also prevalence of BD and EP for each alternative.

		ALTERNATIVES		CRITERIA	
		AF – implementation of agroforestry	NO AF – no agroforestry	BD - Improvement of biodiversity	EP– Economic performance
ALTERNATIVES	AF – implementation of agroforestry	0	0	0.8750	0.33333
	NO AF – no agroforestry	0	0	0.1250	0.66667
CRITERIA	BD - Improvement of biodiversity	0.857143	0.1	0	0
	EP– Economic performance	0.142857	0.9	0	0

Relative priorities of AF and NO AF on HR (fulfilment of EP criteria by AF and NO AF)

Relative priorities of BD and EP for AF (characteristics of AF alternative)

Figure 5.2. Unweighted supermatrix of a demonstration model

Using the example in Figure 5.2, the dominant characteristics of AF alternative is that it has much more pronounced BD than EP (first column, rows 3 and 4), whereas the opposite is true for NO AF alternative (second column, rows 3 and 4). If we look at how do the alternatives meet the (decision maker's) criteria of "Improvement of biodiversity" – it can be seen that for BD, the AF alternative is much more important than NO AF (third column, rows 1 and 2). By contrast if the criterion is economic performance (fourth column, rows 1 and 2), it can be seen the preference for the NO AF alternative (but to a lesser degree than what was the case of dominance of AF over NO AF with respect to the improvement of biodiversity). In the case of the first column, the question that can be asked is: 'Which criterion is better satisfied by AF alternative, BD or EP?' In the case of fourth column, the question that can be asked is 'Which alternative better satisfies criterion EP, AF or NO AF?' The reason for 'double' questions (i.e. both from the perspective of alternatives and criteria, as presented in unweighted supermatrix) is the fact that characteristics of alternatives may differ from their level of fulfilment of a given criteria. To elaborate, in Figure 5.2 (an unweighted supermatrix) both alternatives partially fulfil the criteria of economic performance (fourth column), whereas only AF alternative really fulfils the BD criterion. When we look at the characteristics of individual alternatives (first two columns in Figure 5.2), it can be seen that BD is the dominant characteristics of the AF alternative, while the opposite is true for NO AF alternative. It can be argued that because NO AF has 'excess' of economic performance (i.e. it is nine-times more dominant characteristic of NO AF than BD) and low level of BD, AF is the preferred alternative. These values can be normalized by cluster, where the sum of priorities in a single cluster is 1, or Ideal, where the largest priority within a cluster is assigned with value 1 (i.e. values are obtained by dividing the raw priorities with the value of the highest priority – this format of priorities is used in the presentation of results of our ANP models).

The basic elements of the supermatrices are components – blocks in the matrix defined by cluster names at the left and at the top (in the demo model we have four components, defined by two clusters – Alternatives and Criteria). A weighted supermatrix is obtained by multiplying the elements of the component by its appropriate cluster weights. As the demo model is very simple and has no cluster weights, its unweighted and weighted supermatrices are the same. The final matrix is the limit supermatrix, which is reached by multiplying the weighted supermatrix by itself multiple times, until all columns are the same. Table 5.1 shows the corresponding version of Figure 5.2 in the limit supermatrix for the demo model.

Table 5.1. Example of a part of the limit supermatrix of the demo model

		ALTERNATIVES		CRITERIA	
		AF – implementation of agroforestry	NO AF – no agroforestry	BD - Improvement of biodiversity	EP– Economic performance
ALTERNATIVES	AF – implementation of agroforestry	0.328456	0.328456	0.328456	0.328456
	NO AF – no agroforestry	0.171544	0.171544	0.171544	0.171544
CRITERIA	BD - Improvement of biodiversity	0.295688	0.295688	0.295688	0.295688
	EP– Economic performance	0.201312	0.201312	0.201312	0.201312

The column-sum of priorities of all elements in the limit supermatrix is 1. These 'raw' priorities for alternatives (AF and NO AF) are present in the first top-two entries in the matrix (0.328456 and 0.171544). This shows that AF alternative is preferred to the NO AF alternative.

In the case that we had more than one criteria cluster (e.g. three clusters – Environmental, Social and Economic criteria – just like we do in our real ANP models), then we would again use pairwise comparison (but this time between the clusters) to assign their appropriate component weights. If there is a comparison within a component (as in our demo model), such relations are called inner dependence. In the case comparisons are made between components (e.g. two criteria from one cluster are compared with respect to a criteria from another cluster), such relations are called outer dependence. In the case we had more alternatives (e.g. we have five alternatives in our real ANP models), cluster alternatives could also have inner dependence – i.e. one alternative would serve as the parent node, and two or more other alternatives would serve as the children nodes. In a case that the goal of the model is economic farm performance and there are three management alternatives (e.g. *No agroforestry*, *Agroforestry for livestock system* and *Agroforestry for arable system*), we could do pairwise comparison between *Agroforestry for livestock system* and *Agroforestry for arable system* with respect to the *No agroforestry* alternative. The real meaning of such a comparison would be: Who is the stronger 'competitor' of *No agroforestry*, *Agroforestry for livestock system* or *Agroforestry for arable system*?

When the judgments (i.e. pairwise comparisons) are made, they are stated in a form of a question. A classical form of a question would be: What is the relative importance/influence of the elements *A* and *B* ('children' nodes) on element *C* ('parent' node)? The answers would classically be presented in a textual form matching to the Saaty's Fundamental scale (Table 5.2), and then transformed into corresponding numerical values (reciprocals values are used for inverse comparisons).

Table 5.2. Saaty's Fundamental scale.

Numerical value	Textual equivalent
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,2,8	Intermediate values

If the judgment in a pairwise comparison is that its elements are of equal importance, then the selection would be value of 1, where both elements would be assigned with priority 0.5. If one element is extremely more important than the other (as it is the case in the second column of the demo model), than the selection would be 9 in favour of the dominant element. Their assigned priorities would be 0.9 for the dominant element, and 0.1 for the other one. Saaty discourages the usage on values greater than 9 on the Fundamental scale.

In the Super Decisions software (http://www.superdecisions.com) used for ANP, pairwise comparisons can be done '**graphically**' (i.e. a pie chart in which one can modify the value priority values of elements within the comparison), '**verbally**' (column corresponding to Saaty's Fundamental scale), in form of a **matrix** (where direction and values from Saaty's Fundamental scale and assigned), in a form of a **questionnaire** (double 1-9 scale), and '**directly**', where priorities of elements are directly assigned (i.e. their corresponding values in the unweighted supermatrix – this is what was used in the preparation of our ANP models). The number of pairwise comparisons greatly increases with the number of elements under consideration; as with two children nodes there is only one comparison, with three nodes there are three comparisons, with four nodes there are six comparisons, with five there are ten comparisons, and with six nodes there are fifteen pairwise comparisons. The benefit of pairwise comparisons is that adequate attention is given to each relation, whereas the negative aspects are the respondent fatigue and possibility of inconsistent answers between the judgments. This possible inconsistency is presented as inconsistency ratio when the final priorities are computed (values below 0.1 are recommended).

The benefit of the ‘direct’ method is that the judgment procedure is far shorter than in other methods, whereas the negative side is a possibility that inadequate attention is paid to the relations between the values under consideration of the unweighted supermatrix (we tried to deal with this issue by adding dynamic visual analogue scales and dynamic pie charts next to the numerical representation of judgments).

As stated above, the second mathematical representation is the ‘weighted supermatrix’. The weighted supermatrix is obtained by multiplying all the elements in a component of the unweighted supermatrix by the corresponding cluster weight. The matrix is column stochastic, i.e. sum of each column is 1. The final mathematical representation of ANP is the ‘limit supermatrix’. The limit supermatrix is reached by multiplying the weighed supermatrix by itself (W^k k = 1, 2, ….) until limit of the sum of all the powers of the matrix is reached (Cesaro sum, i.e. $\lim_{k\to\infty} \frac{1}{N}\sum_{k=1}^{N} W^k$) – i.e. until all the columns are the same. If the model has no sub-networks, the final priorities of alternatives are located in the corresponding rows of the limit supermatrix. If the model has sub-networks, this procedure is done separately for each of the BOCR, and the overall priorities are calculated by relaying the respective BOCR priorities through a single formula. There are many ways to do it, and based on literature review we have used four different formulas to calculate overall priorities. These formulas are:

1. Multiplicative formula: B*O/C*R, Where B, O, C and R represent priorities of different alternatives in the “benefits”, “opportunities”, “costs” and “risks” sub-networks. In this formula the relative importance of BOCR elements is the same.
2. Additive negative formula: *w**B + *w**O - *w**C - *w**R, where *w* represents weights of their respective BOCR elements.
3. Multiplicative with weights as powers: (B^w *O^w)/ (C^w*R^w)
4. Additive with weights as coefficients: *w**B + *w**O + *w**1/C + *w**1/R, where values of 1/C and 1/R are normalized to a 0-1 range.

5.4.1 Applications of ANP

ANP has been frequently used in wide range of decision-making situations, many of which are presented in the Encyclicon (Saaty and Ozdemir 2005). Some notable applications are:

- research and development project selection (Meade and Presley 2002; Mohanty et al. 2005);
- construction project selection (Cheng and Li 2005);
- enterprise information system project selection with regard to BOCR (Liang and Li 2008),
- selection of logistics service provider (Jharkharia and Shankar 2007),
- contractor selection (Cheng and Li 2004)
- purchasing decisions (Demirtas and Ustun 2009),
- policy planning (Ulutas 2005)
- market and logistics (Agarwal et al. 2006)

From the topics which are ‘close’ to our (decision on uptake of agroforestry practices by the farmer, with economic, social and environmental considerations), Aragonés-Beltrán et al. (2015) have used ANP for the selection of best location for the construction of municipal solid waste plant in the Metropolitan area of Valencia. In the agricultural and forestry sector, Jaafari et al. (2015) used ANP to select the best wood extraction method for forests in Northern Iran, García-Melón et al (2008) used

it for farmland appraisal in Eastern Spain, Razavi –Toosi and Samani (2012) were evaluating water transfer projects in the Karun River (Iran), and Wolfslehner et al. (2005) and Wolfslehner and Vacik (2008) were assessing management / silvicultural strategies for forest management in Austria. The use of ANP has also been implemented in combination with other research approaches in the literature. For instance, Tran et al. (2004) combined ANP with a principal component analysis approach to methodically rank potentially threatened watersheds in the Mid-Atlantic Region of the United States. Some studies combined ANP with Strengths, Weaknesses, Opportunities and Threats (SWOT) to assess further development of biomass-based energy production (e.g. Catron et al. 2013) and to analyze potential strategies for mining (e.g. Azimi et al. 2011). One novel contribution of this study to the literature is the use of ANP for the selection of agroforestry systems (Palma et al. 2007).
The number of decision makers engaged in the design of the model is often unspecified (Bottero et al. 2011; Razavi –Toosi and Samani 2012; Gencer and Gürpinar 2007; Lee and Kim 2000, Jharkhariaa and Shankar 2007), and ranges from 2 (Aragones-Beltran et al. 2015) to 41 (see Wolfslehner et al. 2003 for Wolfslehner and Vacik 2008).

ANP can be modified with fuzzy logic in order to better capture the value judgments of decision makers (Ayağ and Özdemir 2009 and 2011; Promentilla et al. 2008; Dağdevirena and Yükselb 2010; Liu and Wang 2010). It also can be combined with data envelopment analysis (Lin 2010, Kuo and Lin 2012) and multi-objective programming (Wu et al. 2009). Some authors combine ANP with AHP, where they state that the complexity of problems under consideration can be captured more appropriately with ANP than with AHP (Aragonés-Beltrán et al. 2015; Bottero et al. 2011; Chung et al. 2005).

Results of ANP models are often compared to well-known real life decision situations (Whitaker 2007, Saaty and Vargas 2006; Saaty 2001, Saaty 2005), where the two have shown compatible prioritizations, which validate the use of ANP.

5.4.2 Design of ANP models

The development of this study began in spring 2014, when three researchers from European Forest Institute assessed that the application of ANP models would be suitable to fulfilling the Task 1.4 of the AGFORWARD project ('Analysis of environmental and socio-economic factors framing agroforestry development in Europe'). They decided that a separate model be made for each of the biogeographical regions, that the decision scenario should be based on the description of a farm typical for that biogeographical region, where there are five decision alternatives which reflect different farm management scenarios, covering main types of agroforestry practices, and an alternative in which there is no uptake of agroforestry practices. A literature review was completed in order to describe environmental and socio-economic factors which frame agroforestry development in Europe, which resulted in an initial set of criteria which was added to all the ANP models. During 2014, senior experts/scientists in agroforestry were asked to describe typical farm and farm management scenarios from their regions, which became the basis for the decision making models. The following step was a development of the questionnaire sent to 10 senior agroforestry experts, in which they have defined a list of criteria separately for each model / biogeographical region.

On 3 June 2014, a current model design was presented in an AGFORWARD workshop in Cottbus, Germany. There a total of 22 participants (agroforestry experts) discussed the current status of the models and filled-in another questionnaire in which they further improved the list of criteria and designated the relations between them. A 'master' model was presented, which summed-up all the previously identified criteria and influences. That model consisted of 59 elements (counting criteria and alternatives) and 357 direct ties / (direct) influences. The main feedback from the participants was that the model was too complex and that it should be simplified, and that separate models should be designed for each region. The reasoning had been that many ties were identified only by a single respondent and that the size of the resulting questionnaire (focused on pairwise comparisons) was too large. It was agreed that the relations in which there are many "senders" (e.g. 7 or more) to one "receiver" should be revised to minimise the number of pairwise comparisons and respondent fatigue. Participants were then asked to comment on the importance of each criterion. Their feedback was collected in a form of a questionnaire, where each element was assessed through a visual analogue scale, ranging from 0 to 1. The histogram below (Figure 5.3) presents the distribution of importance of all criteria after questionnaire in summer 2014.

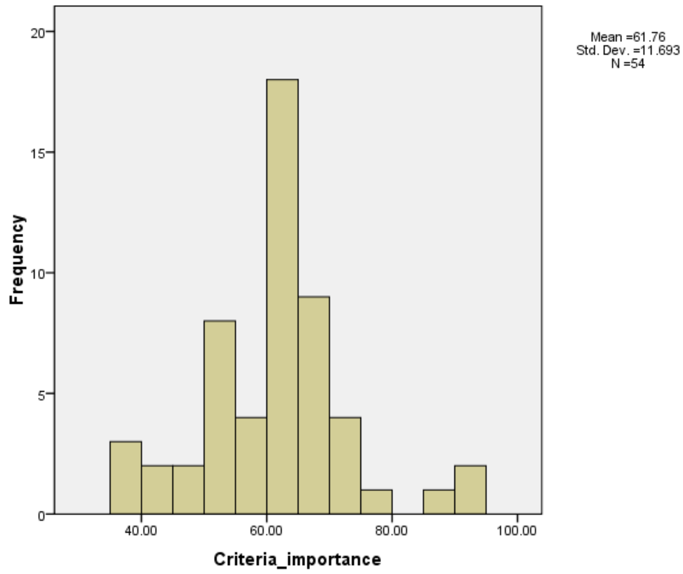


Figure 5.3. Distribution of importance of all criteria after questionnaire in summer 2014

Seven criteria with score below 50 were removed together with those that had been nominated by just one participant, all which had just one tie, and all which had just one tie within a cluster (which makes comparisons impossible) (Figure 5.4). This led to a decrease in the number of criteria from 54 to 40. Hence 40 was the final number of criteria, present in ANP models for all biogeographical regions. Participants commented on which relations should be present in the 'general model', and which relations were not relevant for the regional models. Relations which had only one nomination were re-evaluated once more by EFI members, and if not deemed important, were discarded.

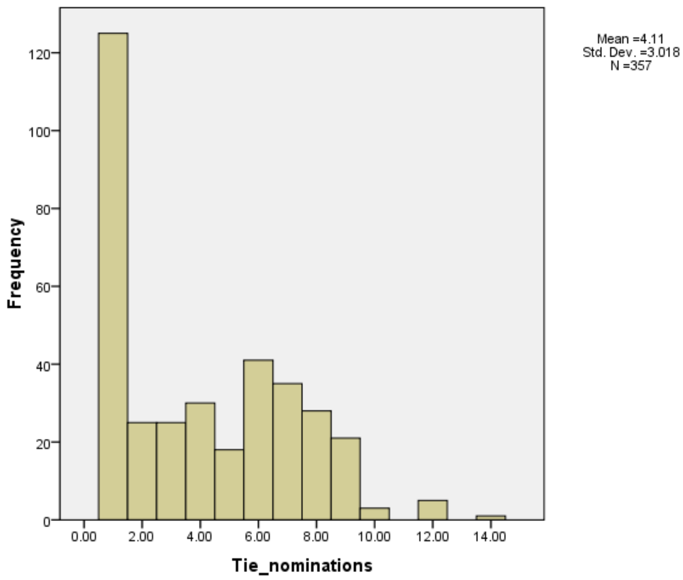


Figure 5.4. Frequency of tie nominations in the creation of the models

Following deletion of certain criteria (described above), all relations connected to them were deleted as well. There were also instances in which there was a single sender of the relation to a receiver within a given component. As such relations are inadequate for a pairwise comparison, they were deleted. All relations were also tested for logical consistency, and if deemed as illogical/unlikely, they were deleted as well. This procedure diminished the number of influence relations. The number of influence relation/ties were 281 for the Atlantic region, 306 for the Boreal region, 327 for the Mediterranean region, 330 for the Continental region, and 326 for the Pannonian region.

In the first months of 2015, another questionnaire was sent to the same group, in which they defined the strength of relations between the elements of the models (i.e. pairwise comparisons). A total of 18 responses were collected. These results were analysed, preliminary priorities of the alternatives were calculated, and a preliminary sensitivity analysis was conducted. Although the models were discussed in workshops and there was a larger number of respondents in other questionnaires, the extent of the required feedback in these questionnaires was smaller, and the number of respondents in this instance was the smallest. For this reason, it is prudent to state that the number of decision makers corresponds to the number of respondents which have filled-in the questionnaire focused on defining the strength of relation between the elements of the ANP models. For Atlantic region model there were three responses, for Boreal three, for Continental two, for Mediterranean eight, and for Pannonian two (total of 18).

Questions were posed in a form where the influence of ‘children’ nodes on the ‘parent’ was assessed (general form - ‘What is the importance of the following elements with respect to X?’). As models have on average 273 influence relations, the assessment of all pairwise comparison stemming from these models would cause strong respondent fatigue. For that reason, the questionnaire was not focused on individual pairwise comparisons, but rather on a set of relations (termed direct comparisons in the Super Decisions software) within a single component for a single parent node. On an example of the ANP model for Continental biogeographical region - the model itself has 330 influence relations, but the weights of all relations in the model have been defined through 73 direct comparisons. Figure 5.5 shows an example of such a direct comparison from the questionnaire, which was accompanied by detailed explanation.

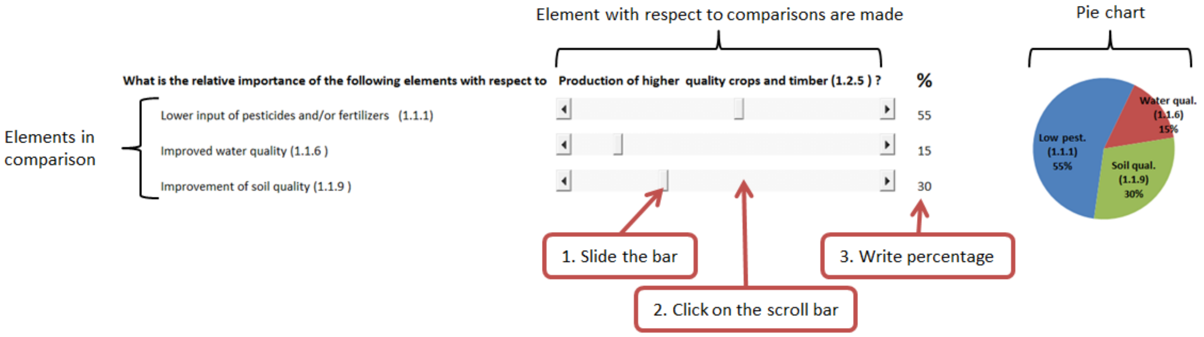


Figure 5.5. Example of direct comparisons from the questionnaire

In order to ease the filling-in of the questionnaire, the respondents could use visual-analogue scales in different ways, where the numerical values of the direct comparisons and the accompanying pie chart were dynamically updated with each new input. Respondents were also asked to take special care in determining the ratio of weight given to the elements in the comparison.

The next step was to design single values for each judgment. The first step was to determine how the opinions of decision makers differ one from another. Figure 5.6 shows the distribution of standard deviations from all respondents.

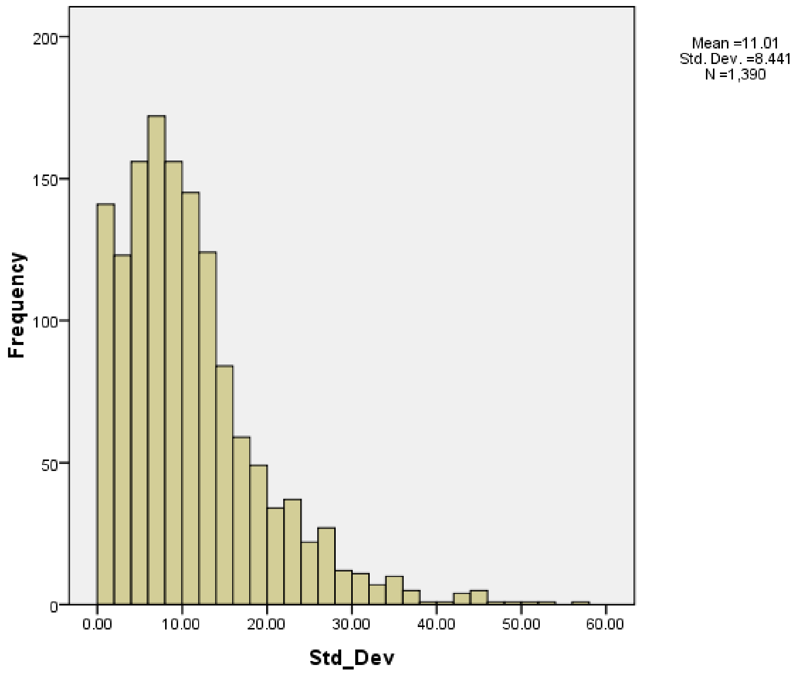


Figure 5.6. Distribution of standard deviations for individual judgments across and all respondents

Preliminary results were presented and discussed in another AGFORWARD workshop, held on June 2015 in Chania, Crete. Another questionnaire was distributed in which respondents had to re-evaluate the pairwise comparisons for relations where respondent opinions from the previous questionnaire differed significantly. Decisions were re-evaluated for all judgments in which opinions differed by more than 0.194 (or 19.4% of the priority vector- i.e. mean + one standard deviation of the distribution of standard deviations). Table 5.3 shows an example of such difference in judgments from the Mediterranean model, where values assigned to *Do not implement agroforestry system* (D5) differ from one another above the threshold.

Table 5.3. Example of differences in judgements in the Mediterranean model

What is the relative importance of the following alternatives with respect to Lower labor cost (1.2.2) ?	Respondent no.									SD	Mean
	1	2	3	4	5	6	7	8	9		
Implement High nature and cultural value agroforestry system (D1)	23	14	13	12	9	11	30	2	20	8.27	15
Implement High value tree systems (D2)	23	36	15	16	11	24	20	2	15	9.51	18
Implement Agroforestry for arable systems (D3)	23	22	16	30	13	24	20	2	10	8.46	18
Implement Agroforestry for livestock systems (D4)	23	22	39	31	14	24	20	2	10	11.11	21
Do not implement agroforestry system (D5)	8	5	18	11	54	16	10	92	45	29.24	29

Due to this high standard deviation, all the judgments of such direct comparisons were evaluated again in a subsequent questionnaire, which was equivalent to the second step of the Delphi method. In this questionnaire the mean value of all judgments was written aside, and the respondents had an opportunity to input new values of their judgments. Table 5.4 below shows frequencies of these critical judgments and direct comparisons

Table 5.4. Number of re-evaluated judgments and direct comparisons

	Atlantic region model	Boreal region model	Continental region model	Mediterranean region model	Pannonian region model
Number of critical judgments	64	48	24	31	26
Number of critical direct comparisons	39	31	16	26	18

After this questionnaire, there were no further 'critical' judgments and the design of the models was finalized. At this point calculation of final priorities and sensitivity analysis was done. A summary of this analysis was given back to the respondents / decision makers, and they were asked to provide their feedback, describing and commenting (both qualitatively and quantitatively on an ordinal scale) to what extent are the presented results an adequate representation of a real-life situation.

5.4.3 Description of the models

In total, five ANP models were made, one for each of the biogeographical regions (Atlantic, Boreal, Continental, Mediterranean and Pannonian). Each model is based on a farm description which is aimed to reflect a typical farm in that region, and of five decision alternatives (1. Implement high natural and cultural value agroforestry system; 2. Implement high value tree systems; 3. Implement agroforestry for arable systems; 4. Implement agroforestry for livestock systems and 5. Do not implement agroforestry system). All models are complete BOCR models. There is a total of 20 criteria nodes in Benefits sub-network (separated into three clusters – Environmental benefits with 11 criteria, Economic benefits with 6 criteria, and Social benefits with 3 criteria), three criteria nodes in the Costs sub-network, 8 in Opportunities, and 4 criteria nodes in the Risks sub-network (Figure 5.7). Continental, Mediterranean and Pannonian model have 20 benefits, while Boreal has 18 and Atlantic has 16.

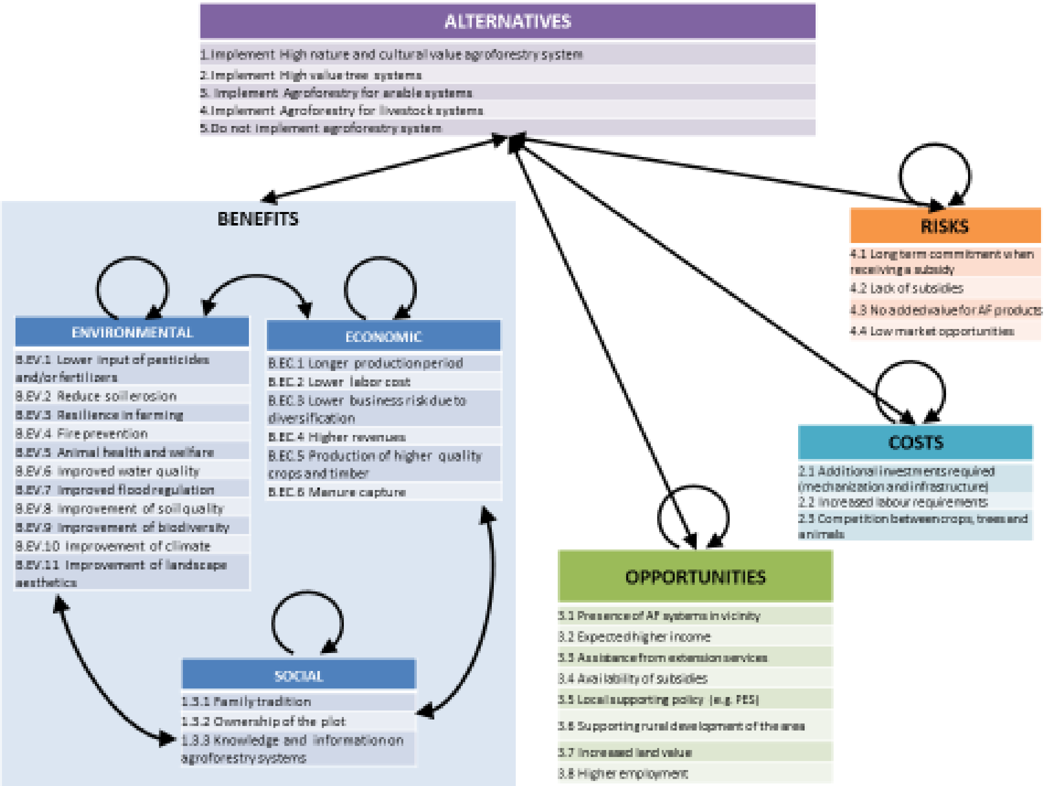


Figure 5.7. Overview of the ANP models

Farm management scenarios, along with the description of management alternatives, are presented in Annex IV, while Table 5.5 provides a summary of these scenarios.

Table 5.5. Overview of farm management scenarios used for ANP models.

Description	Farm description	Decision alternatives				
Region		Implement High natural and cultural value agroforestry system (D1)	Implement High value tree systems (D2)	Implement Agroforestry for arable systems (D3)	Implement Agroforestry for livestock systems (D4)	Do not implement agroforestry system (D5)
Atlantic	Altitude 50 m, farm size 190 ha (70 ha rented), Precipitation 700 mm/year, average annual temperature is 11°C. Flat and windy. 100 ha of cereals, 50 ha other protein oilseed crops, 20 ha forage. 3 ha of forests	35 ha of crop area to forest, grazing with purchased beef cattle, fencing the area	35 ha of crop area to fruit trees, grazing of purchased sheep, fencing the area	35 ha of crop area to fast growing forest, decline in crop profitability.	35 ha of crop area to mix fodder and shade trees, establishing beef and sheep system	No changes to the current regime.

Boreal	Altitude 93 m, farm size 70 ha, Precipitation 650 mm/year, average annual temperature is 9°C. Moraine soil with barley, oats and rapeseed, meadows for hay making, 34 ha of pine forest	Purchase of cattle, 8 ha of meadows to pastures, forest for cattle grazing, low intensity of forest management, reconstruction of animal shelters, replanting hedgerows	Introduction of grazing in apple orchards, purchase of sheep meat, building new stables	Planting berry bushes and planting peas, need for seasonal workers	Meat, firewood and timber production	No changes to the current regime.
Continental	Altitude 100, farm size 45 ha. Precipitation 550 mm/year, average annual temperature is 7.5°C. Cambisol with meadows (30 ha) and rye crop (10 ha), 5ha of forest	Planting of loose treebelts, non-management of forest	Half of the crop area to low-density wild cherry	Crop area to cropping for woody biomass, planting poplar intercropped with rye	Planting poplar for fodder to cattle, planting 10 ha of meadows with berries, free-range poultry	No changes to the current regime.
Mediterranean	Altitude average 300 m, farm size 200 ha, flat area. Precipitation 600 mm/year, average annual temperature is 11 C°. barley, wheat and alfalfa, 15 ha of Quercus ilex forest	Planting of *Quercus ilex* and *Juniperus thurifera* in hedgerows and forest strips	Planting of cherry and walnut trees in low density, forest management plan with objective to optimize high quality timber production	Planting low density poplar forest and tree rows as well	Combining meat (lamb and beef) with arable and forage crops. Planting hedges of mulberry, cattle in the evergreen oak forest, area fencing	No changes to the current regime.
Pannonian	Altitude 150 m, farm size 300 ha, 235 ha arable land. Precipitation 500 mm/year, average annual temperature is 10.5°C	Extensive pig grazing, cattle, planting wild fruit trees, restoration of animal shelters,	Introduction of meat, wool (cattle and sheep) and wood production. Planting of wild fruit trees, poplar and Paulownia. Renewal of animal shelters	Planting maize, wheat and lucerne. Establishment of shelterbelts and wild fruit trees. Usage of wood and non-wood forest products. Need for seasonal workers	Producing meat, wool, firewood and timber. Purchase of 200 cattle, 1000 sheep, 2000 pigs and 500 goats. Planting maize, lucerne and wheat. Planting willows as fodder for sheep and goats.	No changes to the current regime.

5.5 Results

The basic elements of ANP calculations, as well as procedural design elements were elaborated at the workshops in Cottbus and in Chania. As for assessment of relations between the BOCR sub-networks, additive negative formula (*w**B + *w**O - *w**C - *w**R, where *w* represents weights of their respective BOCR elements) was used. This decision was based on the fact that '…additive synthesis with properly weighted factor priorities based on relative magnitudes will produce sound results' (Wijnmalen 2007) and it is frequently used in the literature (e.g. Bottero et al. 2011, Jaafari et al. 2015, Erdoğmuşa et al. 2006.). The participants at the workshops who filled-in the questionnaire and listened to the presentations understood that the assigned weights/priorities will be addressed in such a manner within the calculation of overall priorities, and that the usage additive formula is frequently interpreted as providing best long-term results (Saaty and Sagir 2015). The basic calculations were done in Super Decisions software, whereas additional calculations (synthesis through other formulas, calculations based on beta centrality and network visualizations) were done in R and UCINET software. Ideal overall priorities are used in the following figures, where the alternative with priority is assigned with value of 1.

5.5.1 Results – Atlantic region

In the model for Atlantic region (Figure 5.8), the highest priority is attributed to *Implementation of high natural and cultural value agroforestry systems* (D1; 1), followed by *Do not implement agroforestry system* (D5 or NO AF; 0.29) and *Implement Agroforestry for livestock systems* (D4; 0.28), whereas for *High value tree systems* (D2; -0.002) and *Agroforestry for arable systems* (D3; -0.16) costs and risks outweigh its benefits and opportunities.

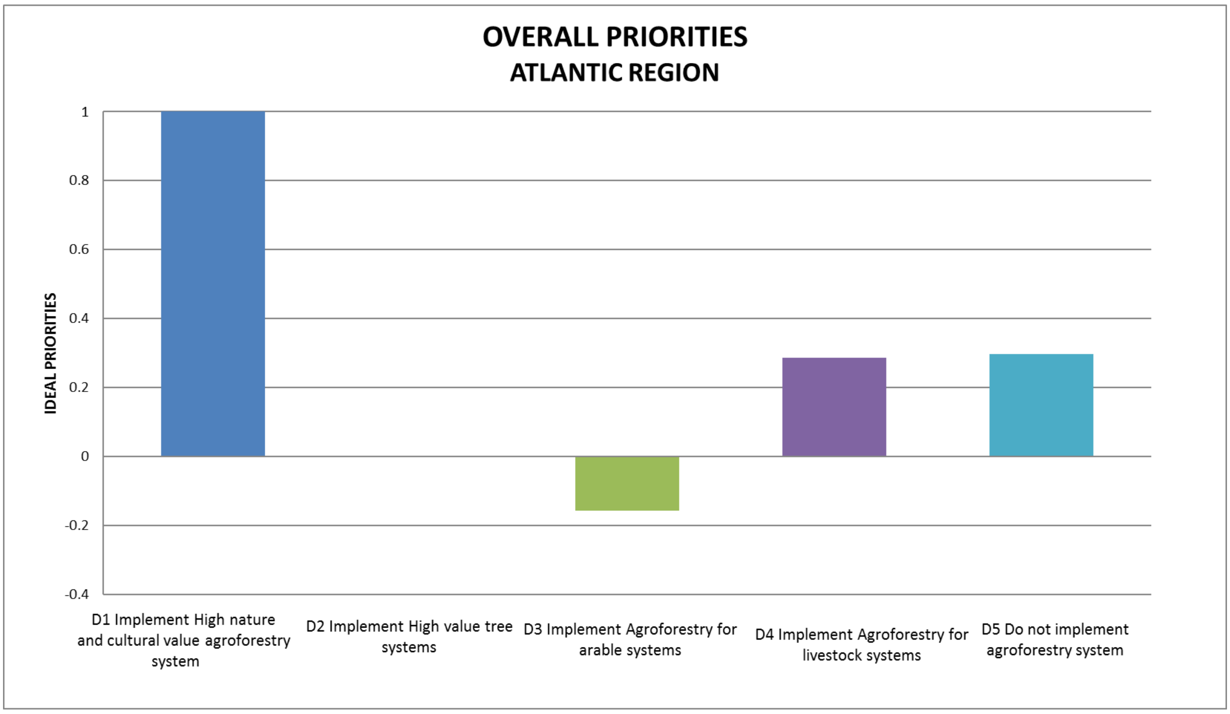


Figure 5.8. Overall ideal priorities for the Atlantic region model

Figure 5.9 shows that all management alternatives which entail implementation of agroforestry practices (D1- D4) have relatively low opportunities and somewhat smaller risks than *Implementation of no agroforestry*. D1 is the only agroforestry management alternative which has low costs and it has the highest benefits. D5 is different; as the effects of its high opportunities and risks 'cancel' each other out, the overall positive priority of D5 is caused by its relatively high benefits (0.58) and lower costs (0.41).

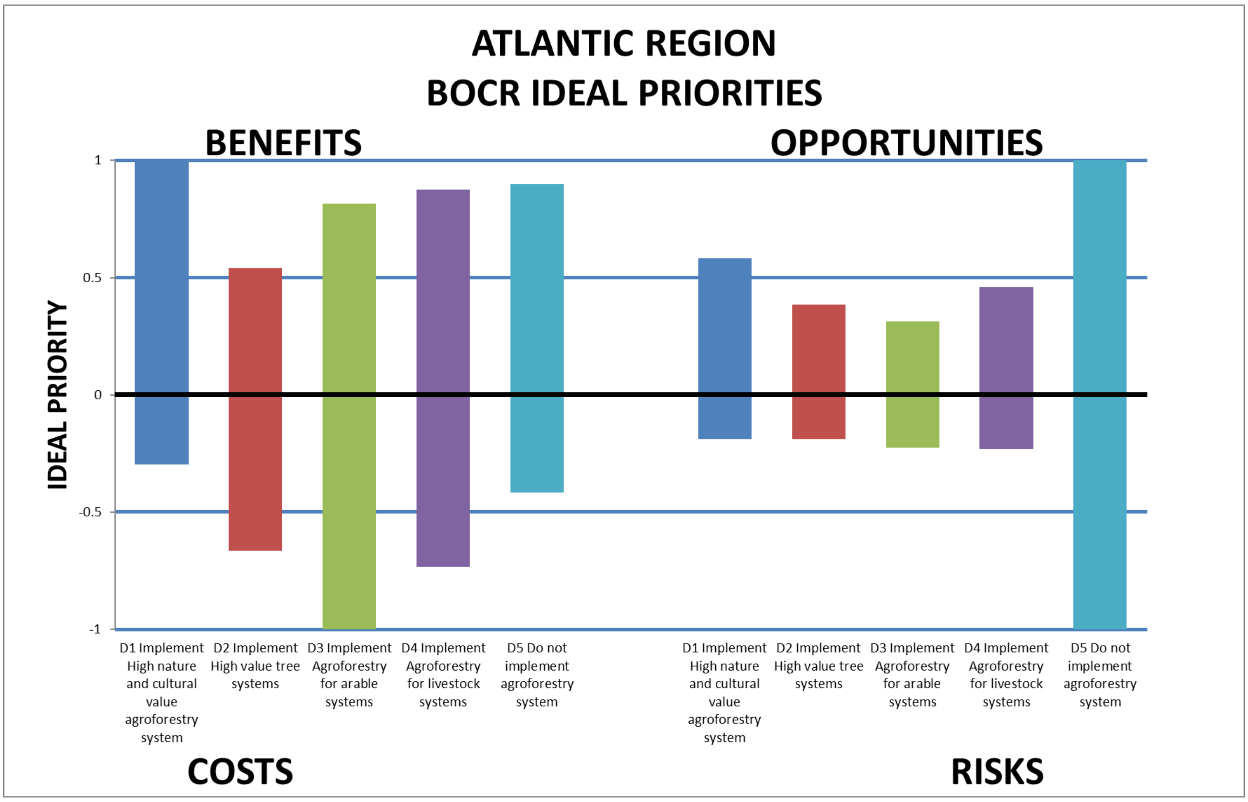


Figure 5.9. BOCR priorities for the Atlantic region model.

5.5.1.1 Sensitivity analysis of BOCR sub-networks

Figure 5.10 shows that that none of the alternatives have an overall positive priority when the role of benefits is very low. The current weight given to Benefits (0.26) is very close to the high point of the dominance of D1. With the increase of importance of Benefits, the only rank reversal which occurs is that D3 raises from fifth to the fourth rank.

High natural and cultural value agroforestry (D1) always had the highest overall priority (Figure 5.10), regardless how much importance was allocated to the costs. With increasing importance of the cost criteria (Figure 5.11), *arable agroforestry* (D3) became the management alternative with the lowest overall priority.

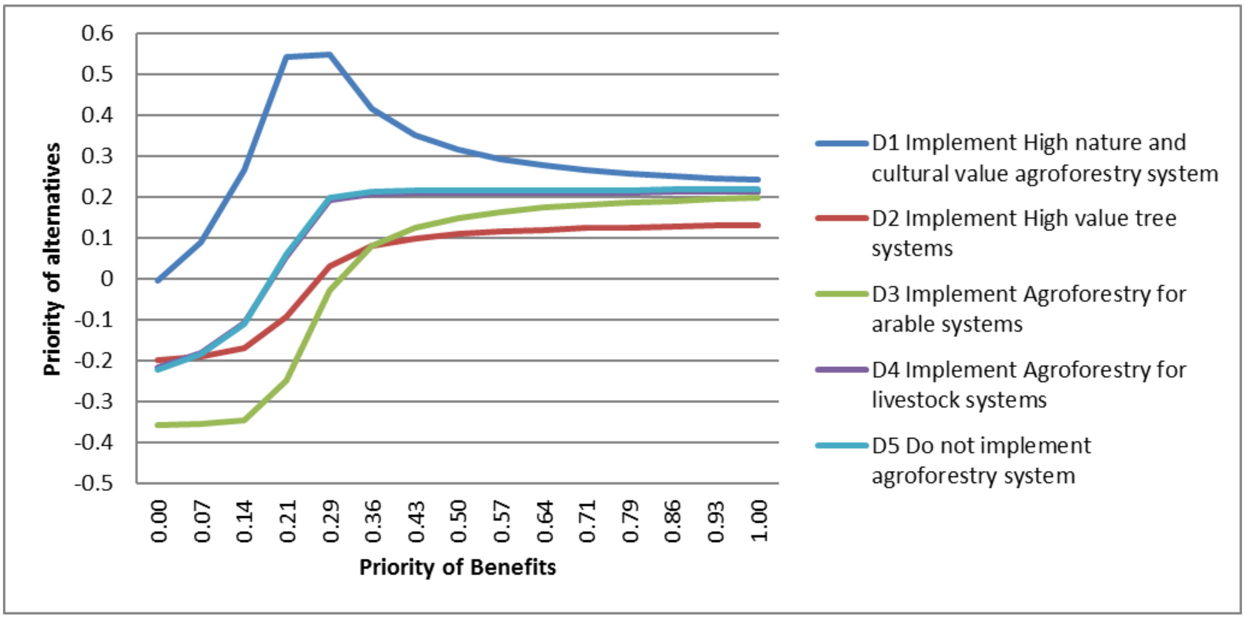


Figure 5.10. Sensitivity analysis of Benefits sub-network for the Atlantic region model

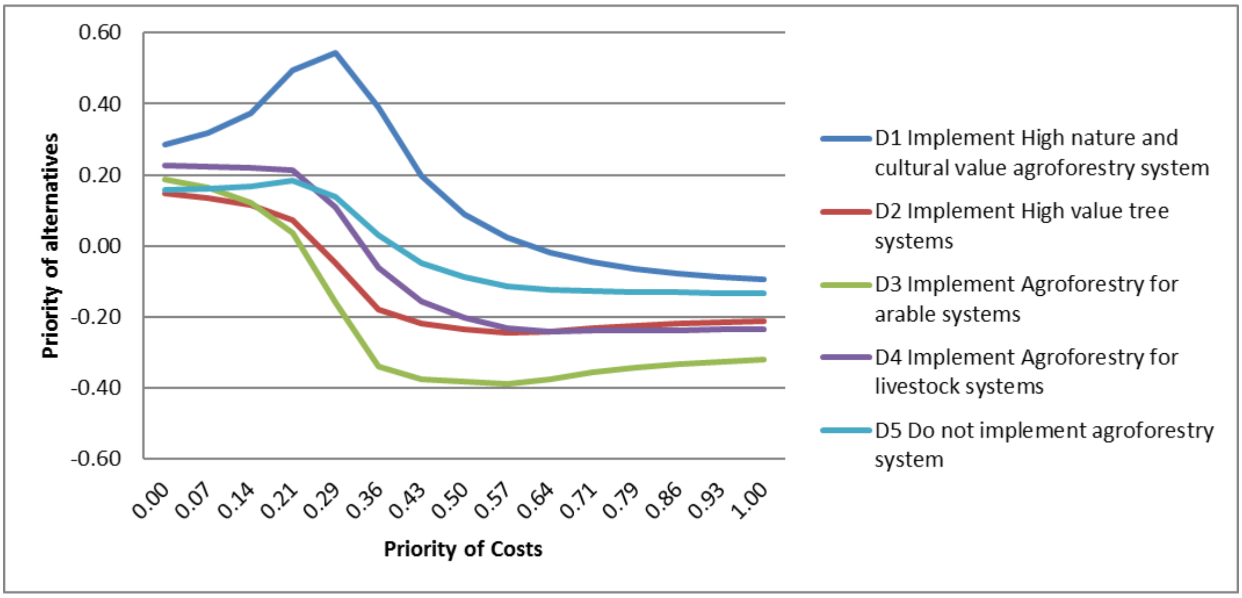


Figure 5.11. Sensitivity analysis of Costs sub-network for the Atlantic region model.

When low to medium importance was given to the opportunities, *Implement high natural and cultural value agroforestry* (D1) had the highest overall priority (Figure 5.12). However, the management alternative *Do not implement agroforestry* (D5) reached the highest overall priority, with increasing importance allocated to the opportunities.

High natural and cultural value agroforestry (D1) had the highest overall priority no matter how much weight was assigned to the risks (Figure 5.13). With increasing importance of the risk, *Do not implement agroforestry* (D5) had the lowest overall priority.

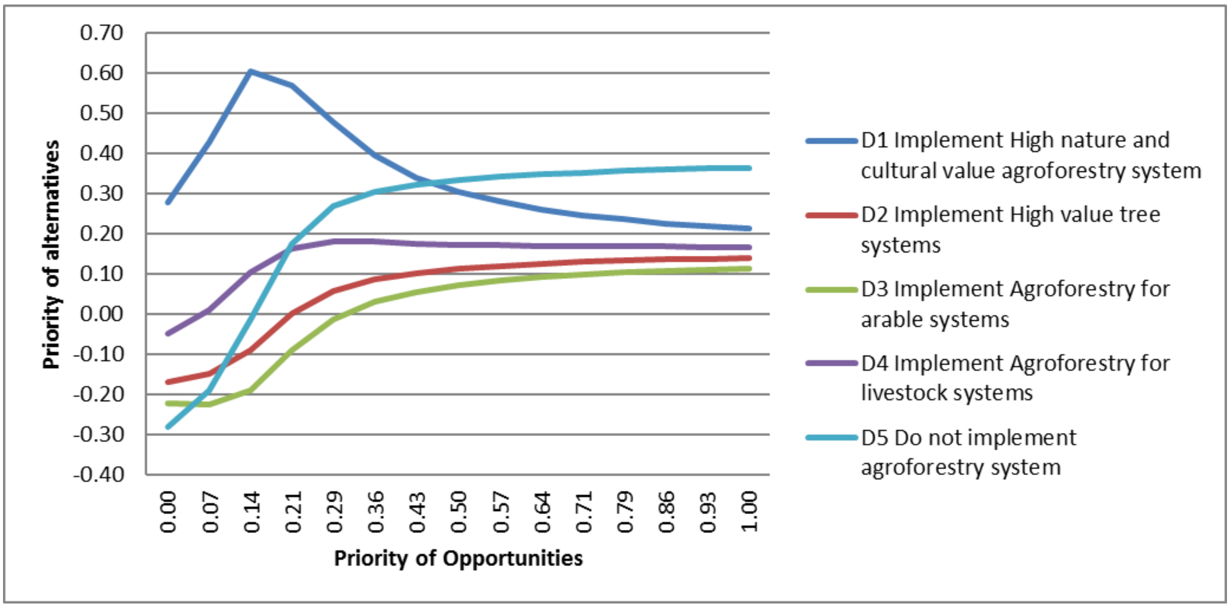


Figure 5.12. Sensitivity analysis of Opportunities sub-network for the Atlantic region model.

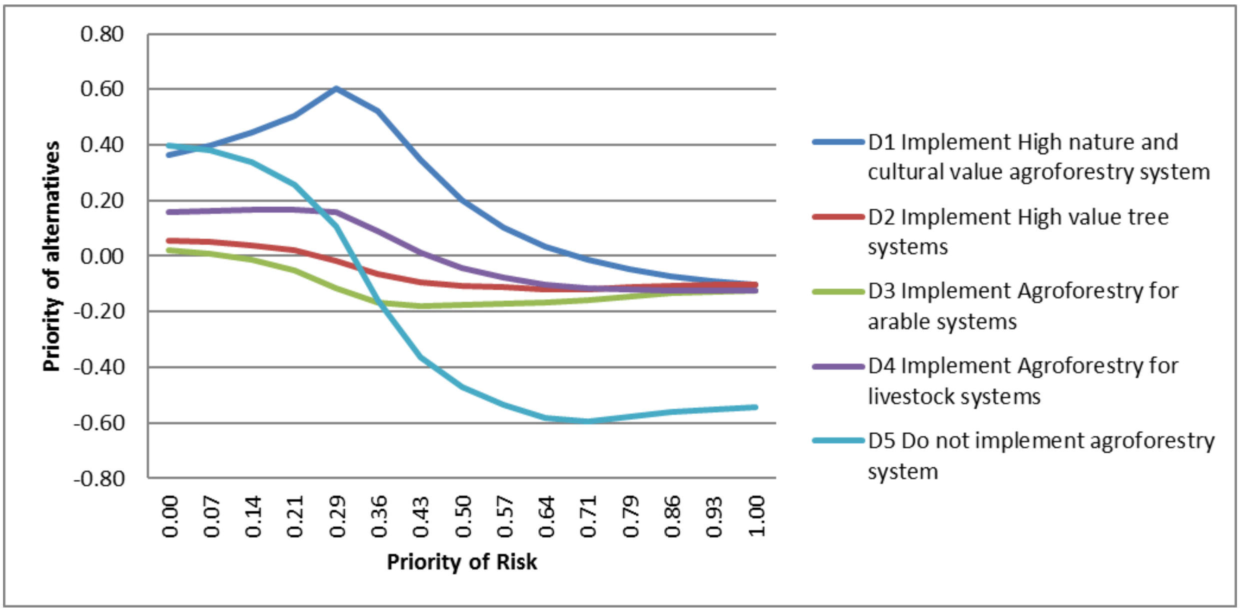


Figure 5.13. Sensitivity analysis of Risks sub-network for the Atlantic region model.

In the Atlantic region, *lower input of pesticides* and *improved water quality* were perceived as the most important environmental benefits by the experts (Table 5.6). *Lower labour cost* and *Lower business risk due to diversification* were seen as the most important economic benefit, and *knowledge and information on agroforestry systems* and *family tradition* as the most important social benefits. According to the experts, *Increased labour requirements* and *competition between crops, trees and animals* involved the highest costs. *Availability of subsidies* and *assistance from extension services* created the greatest opportunities. *Low market opportunities* and *lack of subsidies* were seen by the experts as the greatest risks.

Table 5.6. Priorities of criteria normalized by cluster for the Atlantic region model. Criteria with highest priority in cluster are shaded green, and the criteria with second highest priority are shaded orange.

Environmental Benefits (B.EV.)	Priority normalised by cluster	Economic benefits (B.EC,)	Priority normalised by cluster	Costs	Priority normalised by cluster
1 Lower input of pesticides and/or fertilizers	0.43129	1 Longer production period	0.05078	1 Additional investments required (mechanization and infrastructure)	0
2 Reduce soil erosion	0.05826	2 Lower labor cost	0.49846	2 Increased labor requirements	0.56871
3 Resilience in farming	0.00048	3 Lower business risk due to diversification	0.44407	3 Competition between crops, trees and animals	0.43129
4 Fire prevention	0.27187	4 Higher revenues	0.00669	**Opportunities (O.)**	
5 Animal health and welfare	0.21554			1 Presence of AF systems in vicinity	0.04732
6 Improved water quality	0.01815			2 Expected higher income	0
7 Improved flood regulation	0.00441			3 Assistance from extension services	0.30528
B.EV.8 Improvement of soil quality	0			4 Availability of subsidies	0.41968
9 Improvement of biodiversity	0			5 Local supporting policy (e.g. PES)	0.03985
10 Improvement of climate	0.43129	**Social Benefits (B.S.)**		6 Supporting rural development of the area	0
11 Improvement of landscape aesthetics	0.05826	1 Family tradition	0.43534	7 Increased land value	0
		2. Ownership of the plot	0.04025	8 Higher employment	0.17734
		3. Knowledge and information on agroforestry systems	0.5244	**Risks (R.)**	
				1 Long term commitment when receiving a subsidy	0
				2 Lack of subsidies	0.3554
				3 No added value for AF products	0
				4 Low market opportunities	0.6446

Another way to look at the importance of individual criteria in the model is to make a 'node sensitivity'. Similar to BOCR sensitivity, node sensitivity on Y axis has priority of alternatives in the respective BOCR sub-network, and the x-axis represents the priority of the criteria under consideration (scaled from 0 to 1), where value 0.5 represents original importance of the criteria as stated by the model.

An example of such analysis in the Super Decision software for Criteria "B.S.3 Knowledge and information on agroforestry systems" is presented in Figure 5.14. It can be seen that changes in the value of B.S.3, changes the prioritization of the alternatives in the benefits sub-network. The benefits decision alternative 5 (*No agroforestry*) strongly decreases with the increase on knowledge on AF systems, whereas the opposite is true for D1 (HNCVAF) and D4 (AFLS). However, for vast majority of criteria, the change in the value of parameters does not change priorities of alternatives in their respective sub-networks. Criteria such as B.S.3. in the Atlantic model may be regarded as a **'key'** criterion.

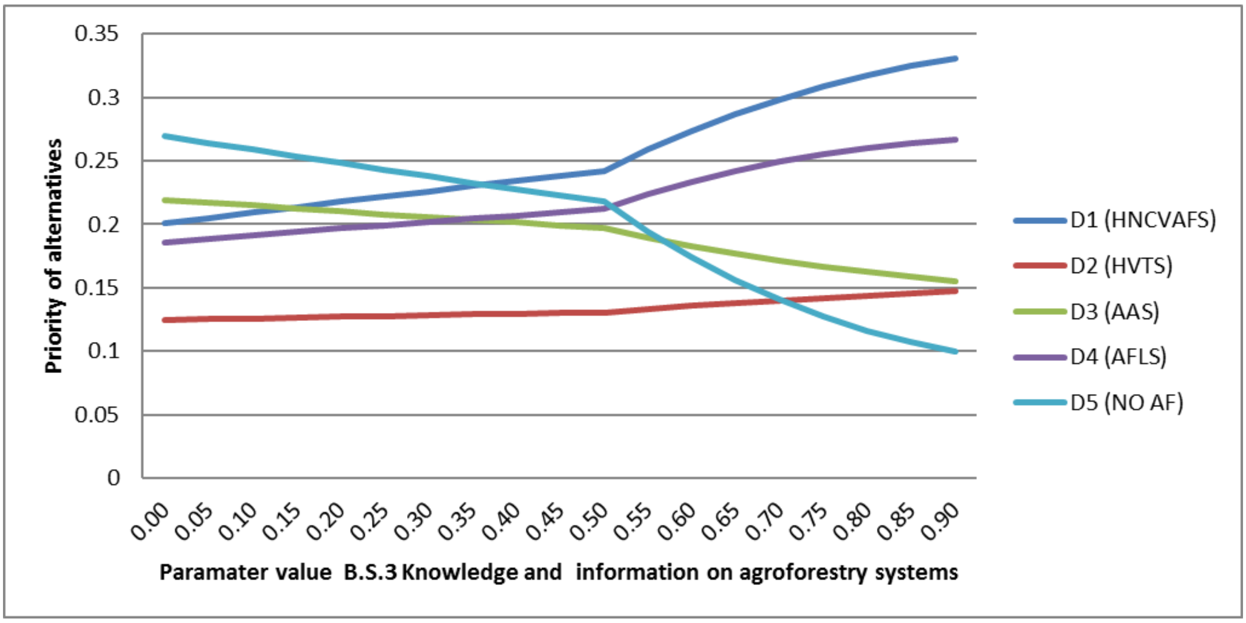


Figure 5.14. Node sensitivity for the criteria "B.S.3 Knowledge and information on agroforestry systems" in the benefits sub-network of the Atlantic model.

5.5.2 *Results – Boreal region*

In the model for the Boreal region, the highest priority is attributed to *Implementation of High natural and cultural value agroforestry systems* (D1) (Figure 5.15). This was followed by *Implementation of* agroforestry *for livestock systems* (D4) and of *Do not implement agroforestry system* (D5). The priories for *implementing Agroforestry for arable systems* (D3) were much lower and those for *High value tree systems* (D2) were close to zero.

According to the experts, *high natural and cultural value agroforestry* (D1) and *livestock agroforestry* (D4) are associated with high benefits and opportunities, but also with high costs (Figure 5.16). However, the risks are only moderate which resulted in a positive overall priority of these two management alternatives (Figure 5.16). *Do not implement agroforestry* (D5), has moderate benefits and opportunities. Furthermore, the costs and risks of *Do not implement agroforestry* (D5) were perceived as low which resulted in a positive overall priority. The relative high overall priority for *Do not implement agroforestry* (D5) can be explained by the fact that farmers probably want to avoid taking risks as most farms in the Boreal region are already struggling with high costs and harsh climatic conditions. Farmers in the boreal region might want to avoid changes which can put the economic profitability of their farm at risk. *High value tree agroforestry* (D2) and *arable agroforestry* (D3) were associated with high risks and had therefore low overall priority.

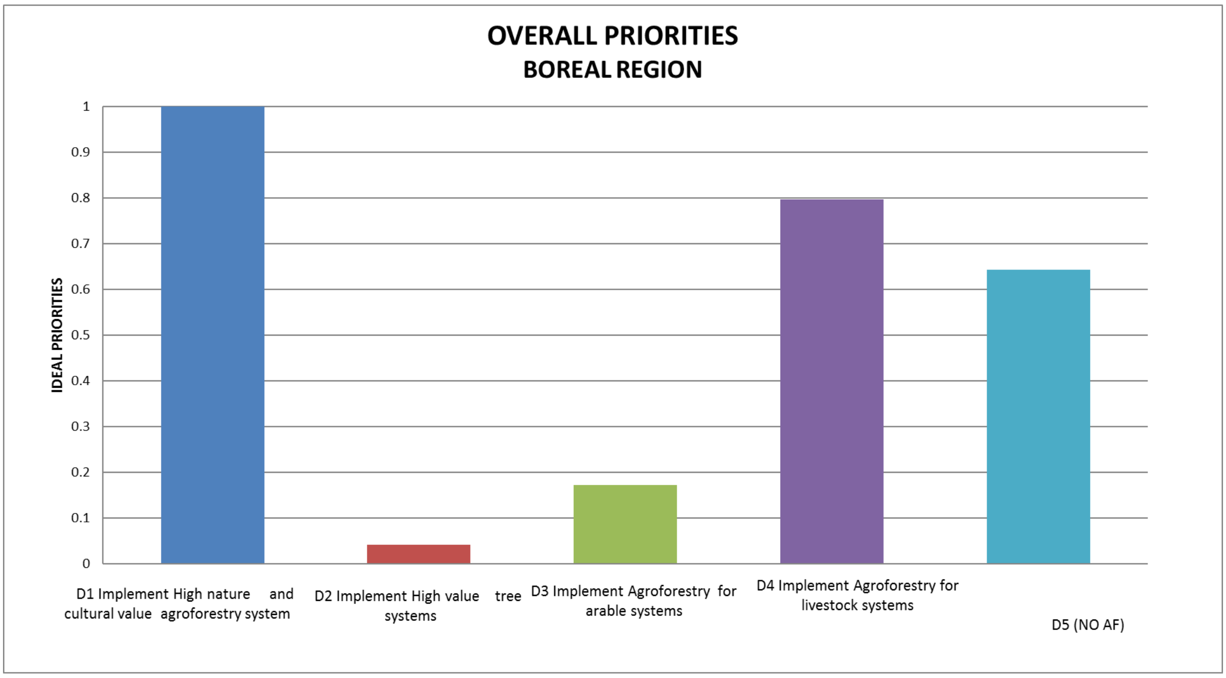


Figure 5.15. Overall ideal priorities for the Boreal region model

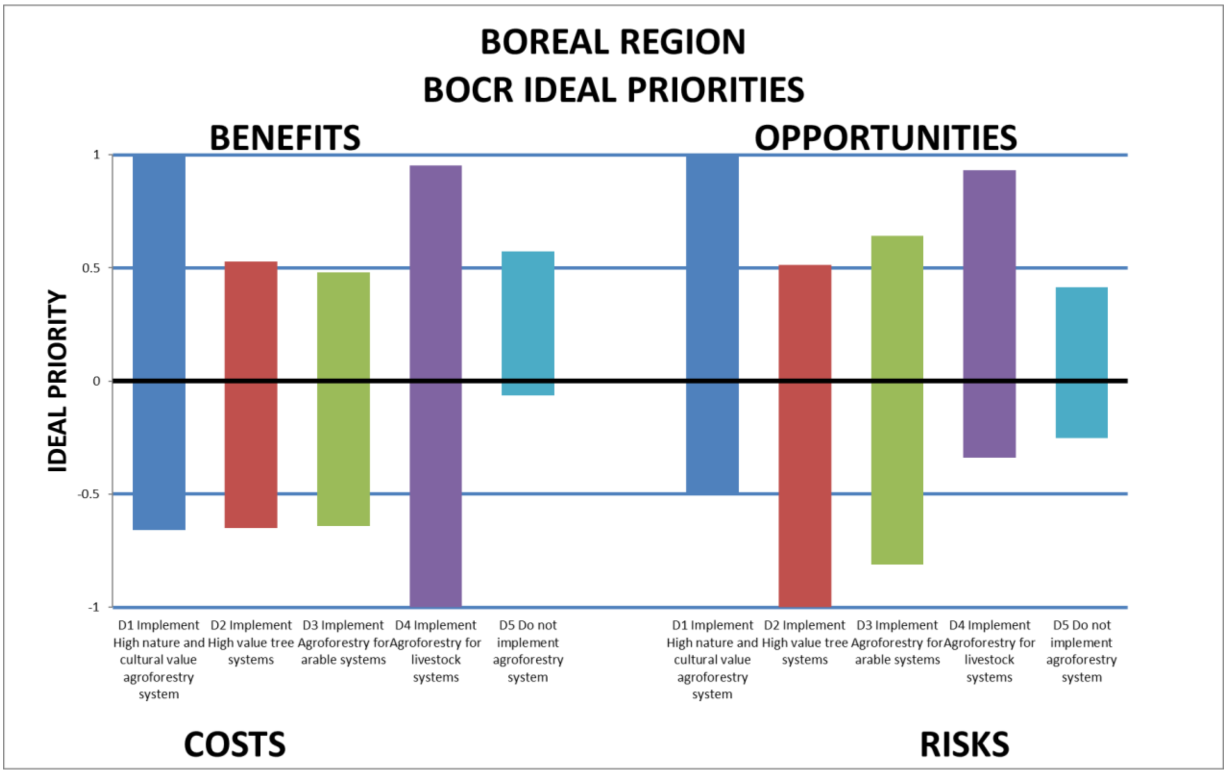


Figure 5.16. BOCR priorities for the Boreal region model

The criteria on which to base the decision whether or not to establish an agroforestry system in the Boreal region, were very similar to the criteria used in the Atlantic region. In the Boreal region, *lower input of pesticides*, *improved water quality*, *production of higher quality crops and timber*, *lower business risk due to diversification*, *knowledge and information on agroforestry systems*, *family tradition*, *increased labour requirements*, *competition between crops, trees and animals*, *higher* *employment*, *availability of subsidies*, *low market opportunities* and *lack of subsidies* were seen by the experts as the most important criteria on which farmers base their decision which management regime to apply (Table 5.7).

Table 5.7. Priorities of criteria normalized by cluster for the Boreal region model. Criteria with highest priority in cluster are shaded green and the criteria with second highest priority are shaded orange.

Environmental Benefits (B.EV.)	Priority normalised by cluster	Economic Benefits (B.EC.)	Priority normalised by cluster	Costs (C)	Priority normalised by cluster
1 Lower input of pesticides and/or fertilizers	0.45197	1 Longer production period	0.02812	1 Additional investments required (mechanization and infrastructure)	0
2 Reduce soil erosion	0.1038	2 Lower labor cost	0.01424	2 Increased labor requirements	0.53615
3 Resilience in farming	0.05382	3 Lower business risk due to diversification	0.43011	3 Competition between crops, trees and animals	0.46385
4 Fire prevention	0.00004	4 Higher revenues	0.00165	**Opportunities (O.)**	
5 Animal health and welfare	0.01238	5 Production of higher quality crops and timber	0.51169	1 Presence of AF systems in vicinity	0.03803
6 Improved water quality	0.3765	6 Manure capture	0.01419	2 Expected higher income	0
7 Improved flood regulation	0.00031			3 Assistance from extension services	0.28167
B.EV.8 Improvement of soil quality	0			4 Availability of subsidies	0.29924
9 Improvement of biodiversity	0.00117			5 Local supporting policy (e.g. PES)	0.03985
10 Improvement of climate	0.45197	**Social Benefits (B.S.)**		6 Supporting rural development of the area	0
11 Improvement of landscape aesthetics	0.1038	1 Family tradition	0.52424	7 Increased land value	0
		2. Ownership of the plot	0.01865	8 Higher employment	0.31347
		3. Knowledge and information on agroforestry systems	0.45711	**Risks (R.)**	
				1 Long term commitment when receiving a subsidy	0
				2 Lack of subsidies	0.46024
				3 No added value for AF products	0
				4 Low market opportunities	0.53976

The management alternative *High natural and cultural value agroforestry systems* (D1) nearly always had the highest overall priority, no matter how much weight was allocated to the benefits (Figure 5.17). The overall priority of all four agroforestry systems (D1-D4) increased when more weight was allocated to the benefits. This was not the case for *Do not implement agroforestry* (D5), whose priority remained more are less at the same level with increasing weight of the benefits and as a consequence this alternative reduced in ranking.

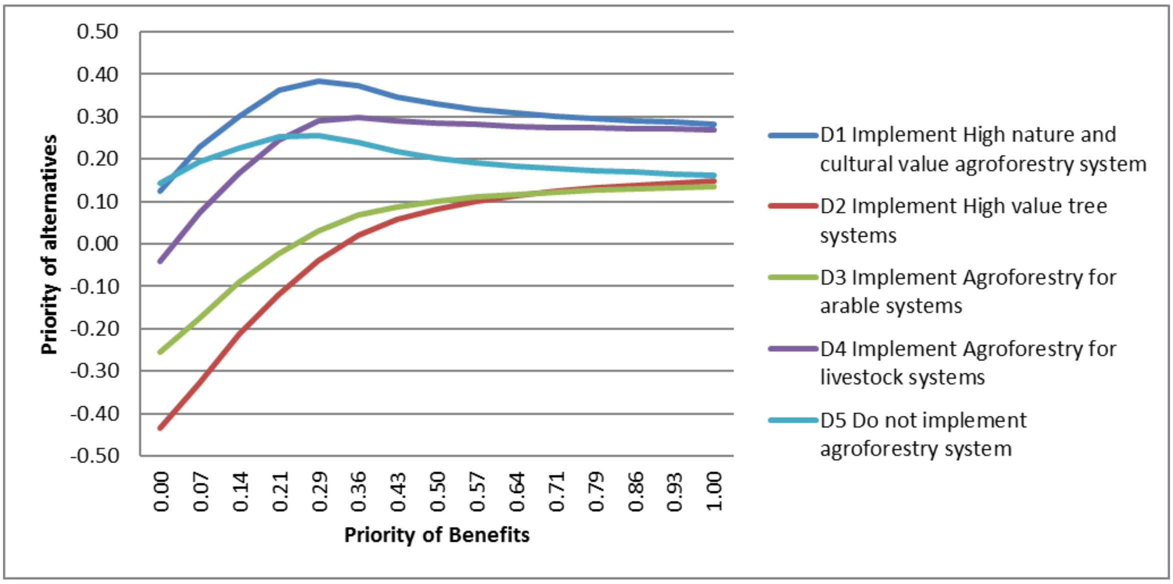


Figure 5.17. Sensitivity analysis of Benefits sub-network for the Boreal region model

When very low weight was allocated to the costs, *high natural and cultural value agroforestry* (D1) and *livestock agroforestry* (D4) ranked highest (Figure 5.18). However, with increasing importance of the cost criteria, management alternative *Do not implement agroforestry* (D5) ranked highest.

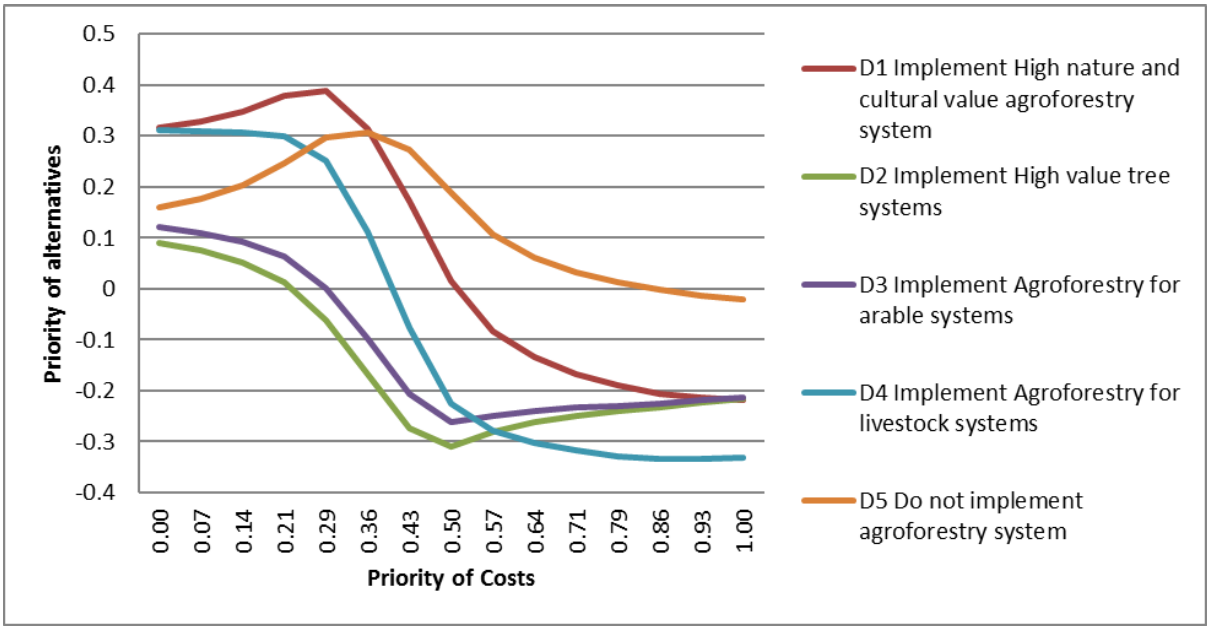


Figure 5.18. Sensitivity analysis of Costs sub-network for the Boreal region model.

With increasing weight on the opportunities, *high natural and cultural value agroforestry* (D1) and *livestock agroforestry* (D4) reached the highest overall priority (Figure 5.19). At the same time, *Do not implement agroforestry* (D5) lost priority and was ranked last when full weight was allocated to the opportunities.

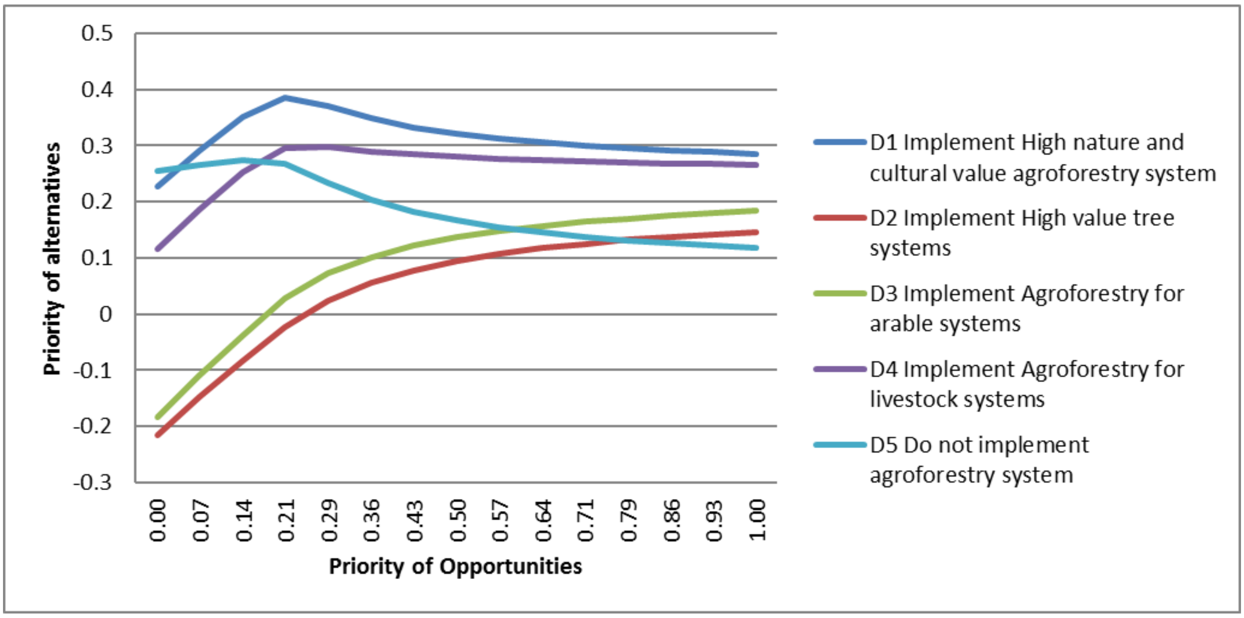


Figure 5.19. Sensitivity analysis of Opportunities sub-network for the Boreal region model.

High natural and cultural value agroforestry (D1) and *livestock agroforestry* (D4) had the highest overall priority when low weight was assigned to the risks (Figure 5.20). However, with increasing emphasis placed risk, *Do not implement agroforestry* (D5) reached the highest overall priority. *High value tree agroforestry* (D2) and *arable agroforestry* (D3) always had a low ranking, no matter how much weight was assigned to the risks.

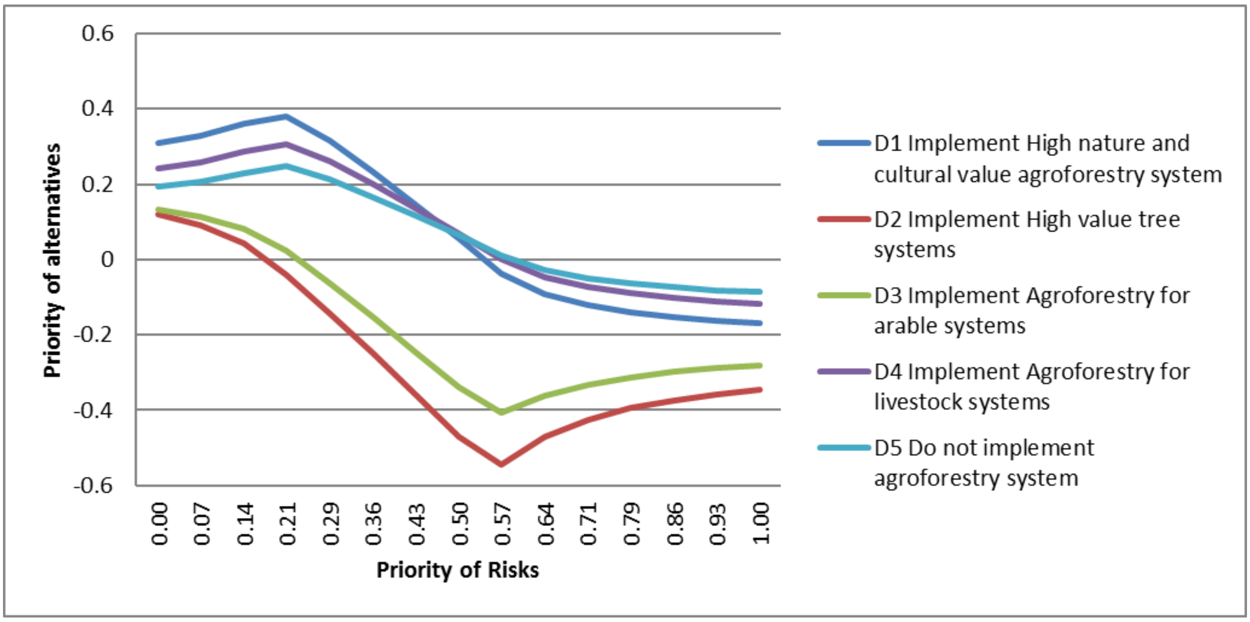


Figure 5.20. Sensitivity analysis of Risks sub-network for the Boreal region model.

5.5.3 Results – Mediterranean region

For the Mediterranean region, the highest priority was attributed to implementation of *High natural and cultural value agroforestry systems* (D1) (Figure 5.21). The priories for implementing *High value tree* (D2) and *livestock agroforestry* (D4) were much lower and for *arable agroforestry* (D3) it was slightly negative. *Do not implement agroforestry* (D5) had a clearly negative overall priority. In general, according to the experts, all Mediterranean agroforestry systems (D1-D4) were associated with high benefits and opportunities, but also with high costs and high risks (Figure 5.22). The greatest benefits however, were attributed to *High natural and cultural value agroforestry systems* (D1), which led to the highest overall priority of this system. Do not implement agroforestry had only moderate benefits and opportunities, relatively low costs but also high risks which led to a negative overall priority.

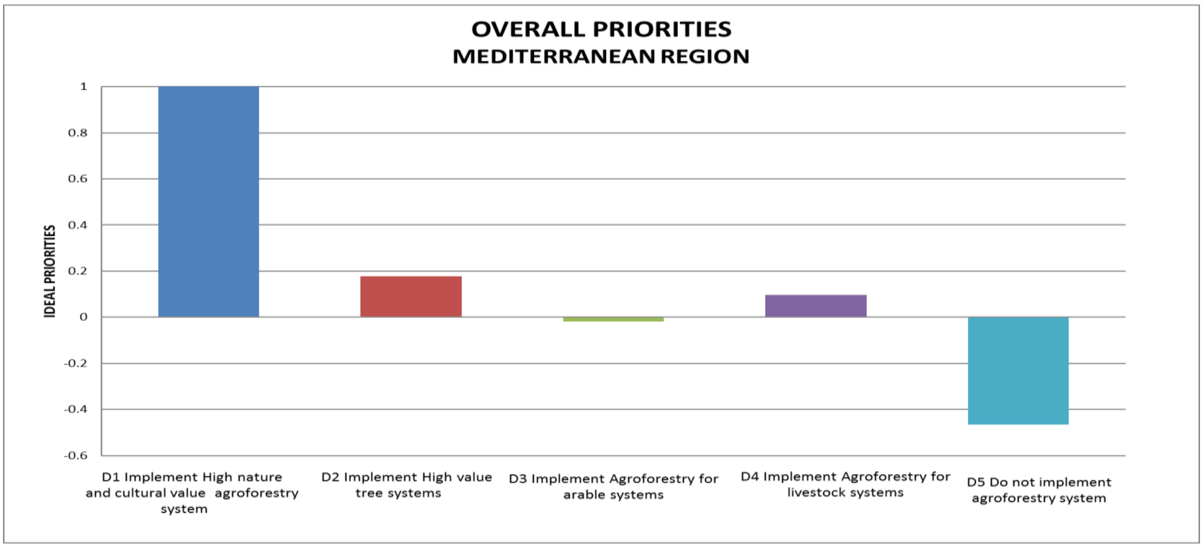


Figure 5.21. Overall ideal priorities for the Mediterranean region model

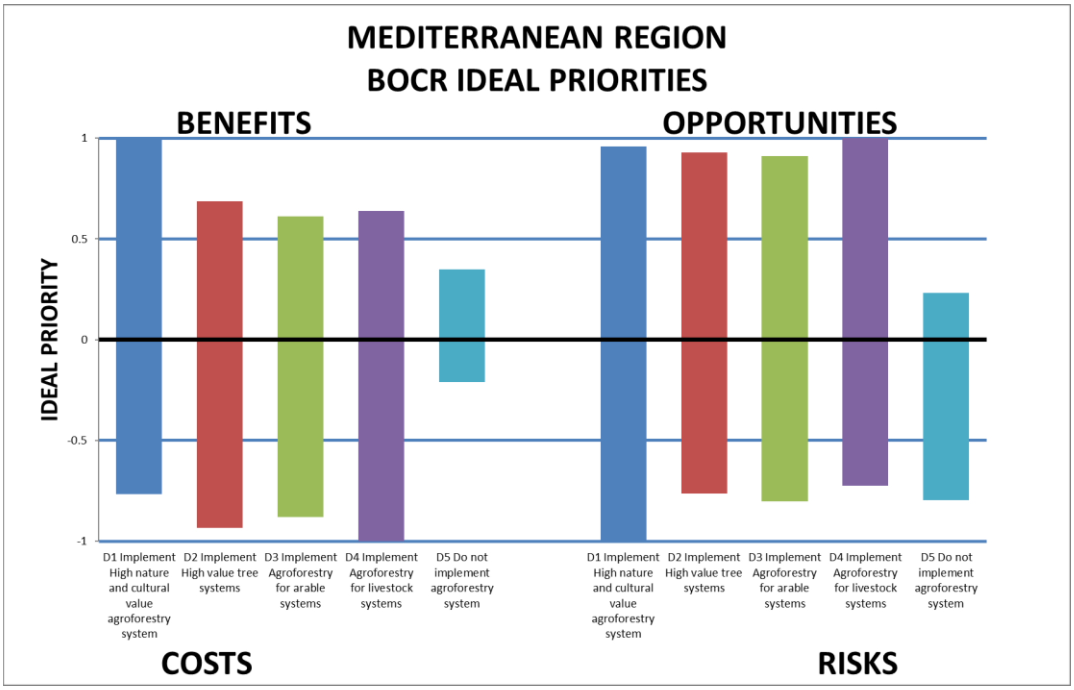


Figure 5.22. BOCR priorities for the Mediterranean region model

For the Mediterranean region, the main criteria for making the decision to establishing an agroforestry system showed a striking similarity with the Atlantic and Boreal regions. *Lower input of pesticides*, *improved water quality*, *production of higher quality crops and timber*, *lower business risk due to diversification*, *knowledge and information on agroforestry systems*, *family tradition*, *increased labour requirements*, *competition between crops, trees and animals*, *higher employment*, *availability of subsidies*, *low market opportunities* and *lack of subsidies* were seen by the experts as the most important criteria (Table 5.8).

Table 5.8. Priorities of criteria normalized by cluster for the Mediterranean region model. Criteria with highest priority in cluster are shaded green, and the criteria with second highest priority are shaded orange

Environmental benefit (B.EV.) criteria	Priority normalised by cluster	Social Benefits (B.S.)	Priority normalised by cluster
1 Lower input of pesticides and/or fertilizers	0.31847	1 Family tradition	0.42313
2 Reduce soil erosion	0.05886	2. Ownership of the plot	0.02462
3 Resilience in farming	0.04556	3. Knowledge & information on agroforestry systems	0.55225
4 Fire prevention	0.0013	**Cost (C) criteria**	
5 Animal health and welfare	0.00407	1 Investments needed (mechanization/ infrastructure)	0
6 Improved water quality	0.24617	2 Increased labor requirements	0.53054
7 Improved flood regulation	0.23578	3 Competition between crops, trees and animals	0.46946
8 Improvement of soil quality	0.07561	**Opportunities (O.)**	
9 Improvement of biodiversity	0.01418	1 Presence of AF systems in vicinity	0.0283
10 Improvement of climate	0	2 Expected higher income	0
11 Improvement of landscape aesthetics	0	3 Assistance from extension services	0.2412
		4 Availability of subsidies	0.37882
		5 Local supporting policy (e.g. PES)	0.03985
Economic benefit (B.EC) criteria		6 Supporting rural development of the area	0
1 Longer production period	0.04521	7 Increased land value	0
2 Lower labor cost	0.02531	8 Higher employment	0.31106
3 Lower business risk due to diversification	0.45218	**Risks (R.)**	
4 Higher revenues	0.00305	1 Long term commitment when receiving a subsidy	0
5 Production of higher quality crops and timber	0.45532	2 Lack of subsidies	0.45305
6 Manure capture	0.01893	3 No added value for AF products	0
		4 Low market opportunities	0.54695

The overall priority of all four agroforestry systems (D1-D4) increased when more weight was allocated to the benefits (Figure 5.23). Similar as in the Boreal region, the management alternative *High natural and cultural value agroforestry systems* (D1) nearly always had the highest overall priority, except when little weight was allocated to the benefits. *Do not implement agroforestry* (D5) nearly always had low priority, except when very low weight was given to the benefits.

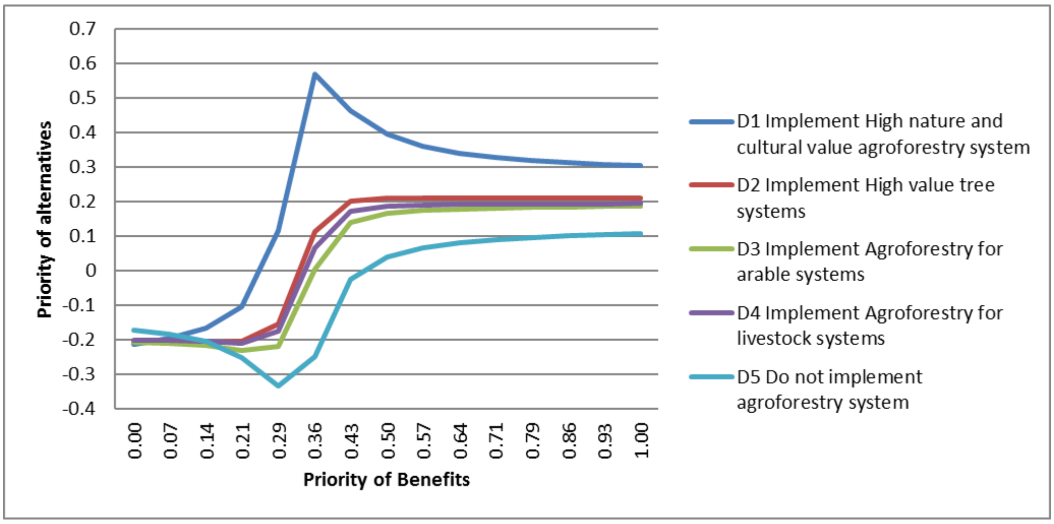


Figure 5.23. Sensitivity analysis of Benefits sub-network for the Mediterranean region model

High natural and cultural value agroforestry (D1) had the highest overall priority (Figure 5.24), when low importance was allocated to the costs. With increasing importance of the cost criteria, all agroforestry systems (D1-D4) lost their overall priority and *do not implement agroforestry* (D5) became the management alternative with the highest priority.

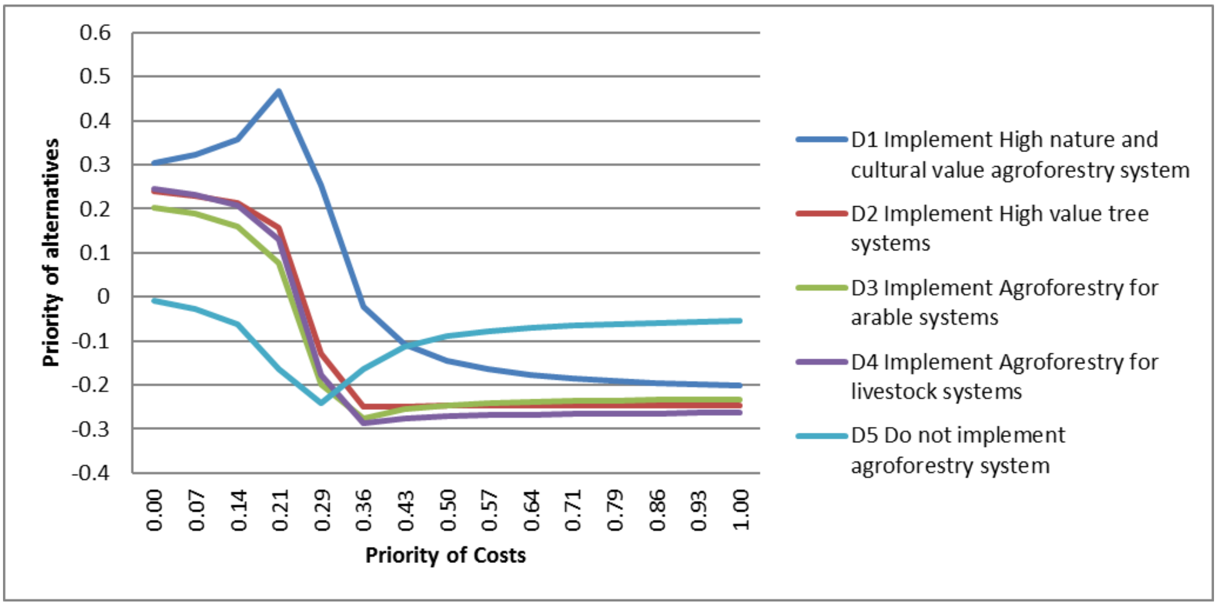


Figure 5.24. Sensitivity analysis of Costs sub-network for the Mediterranean region model.

When low to medium importance was given to the opportunities, *high natural and cultural value agroforestry* (D1) had the highest overall priority (Figure 5.25) but with increasing importance of the opportunities, all the agroforestry systems (D1-D4) reached a high overall level of priority. In most cases, the lowest overall priority was for *Do not implement agroforestry* (D5).

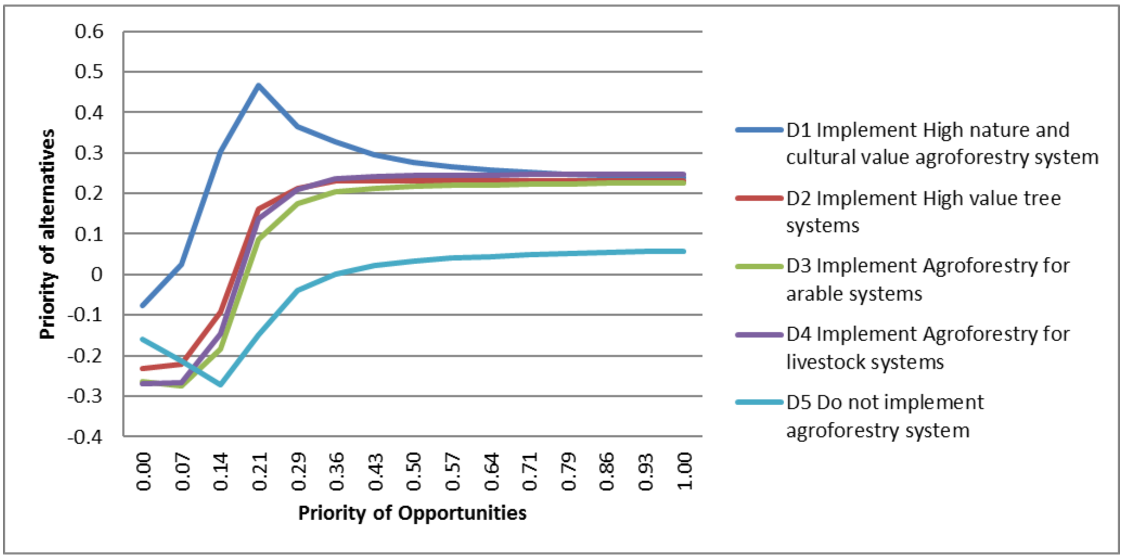


Figure 5.25. Sensitivity analysis of Opportunities sub-network for the Mediterranean region model.

High natural and cultural value agroforestry (D1) had the highest overall priority when low importance was assigned to the risks (Figure 5.26). With increasing importance of the risks, the overall priority decreased and equalized for all management alternatives (D1-D5).

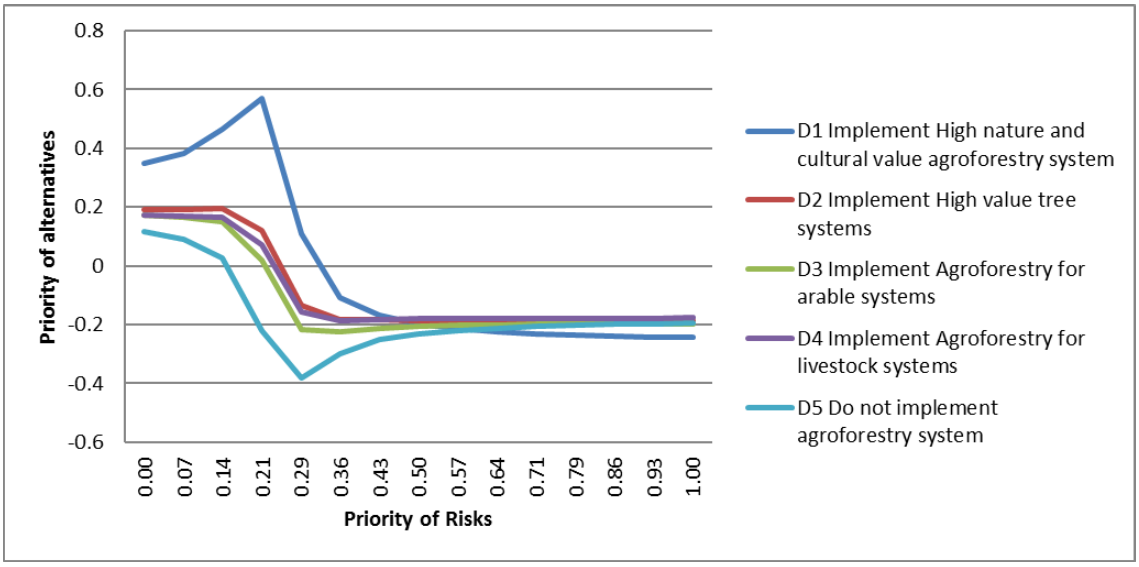


Figure 5.26. Sensitivity analysis of Risks sub-network for the Mediterranean region model

5.5.4 Results - Continental region

For the Continental region, all management alternatives (D1-D5) received a positive overall priority (Figure 5.27). *High natural and cultural value agroforestry systems* (D1) gained the highest overall priority and *Do not implement agroforestry* (D5) the lowest.

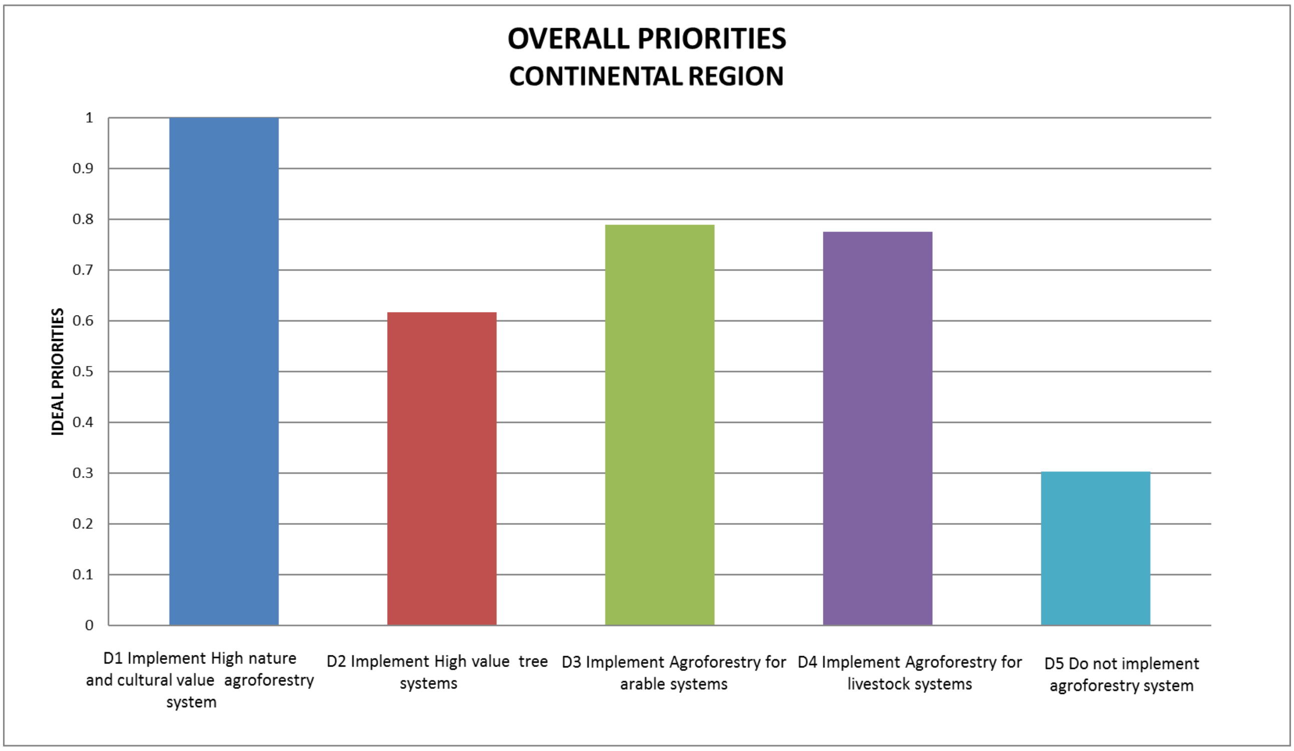


Figure 5.27. Overall priorities for the Continental region model.

For the Continental region, all agroforestry systems (D1-D4) were associated with moderate to high benefits and opportunities, but also with moderate to high costs and risks (Figure 5.28). *High natural and cultural value agroforestry systems* (D1) had the highest benefits according to the experts, and in addition relatively low costs and risks which led to the highest overall priority. *Do not implement agroforestry* (D5) had only moderate benefits and opportunities, as well as moderate costs and risks which led to a moderate overall priority and was therefore ranked lowest.

In the Continental region, the most important criteria on which to base the decision to establish an agroforestry system were very similar as those in the Atlantic, Boreal and Mediterranean regions (Table 5.9). *Lower input of pesticides*, *improved flood regulation*, *lower business risk due to diversification, production of higher quality crops and timber, knowledge and information on agroforestry systems, family tradition, competition between crops, trees and animals, increased labour requirements,* the *availability of subsidies, higher employment, low market opportunities* and *lack of subsidies* were seen by the experts as the decisive criteria for the farmers.

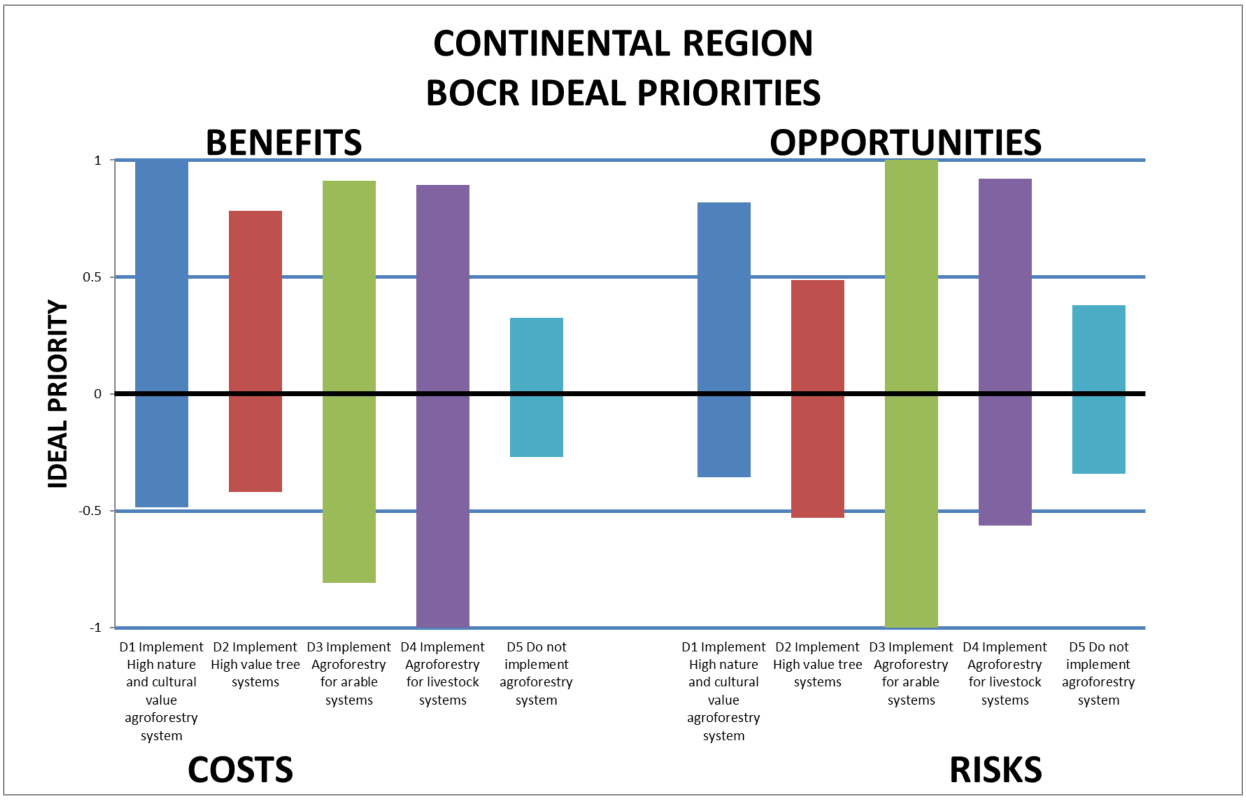


Figure 5.28. BOCR priorities for the Continental region model.

Table 5.9. Priorities of criteria normalized by cluster for the Continental region model. Criteria with highest priority in cluster are shaded green, and the criteria with second highest priority are shaded orange.

Environmental benefit (B.EV.) criteria	**Priority normalised by cluster**	**Social Benefits (B.S.)**	**Priority normalised by cluster**
1 Lower input of pesticides and/or fertilizers	0.34356	1 Family tradition	0.42033
2 Reduce soil erosion	0.05405	2. Ownership of the plot	0.02766
3 Resilience in farming	0.0439	3. Knowledge and information on agroforestry systems	0.55201
4 Fire prevention	0.00159	**Cost (C) criteria**	
5 Animal health and welfare	0.00343	1 Additional investments required (mechanization and infrastructure)	0
6 Improved water quality	0.21285	2 Increased labor requirements	0.47472
7 Improved flood regulation	0.27994	3 Competition between crops, trees and animals	0.52528
8 Improvement of soil quality	0.04756	**Opportunities (O.)**	
9 Improvement of biodiversity	0.01212	1 Presence of AF systems in vicinity	0.03068
10 Improvement of climate	0	2 Expected higher income	0
11 Improvement of landscape aesthetics	0.001	3 Assistance from extension services	0.29218
		4 Availability of subsidies	0.35583
		5 Local supporting policy (e.g. PES)	0.03985
Economic benefit (B.EC) criteria		6 Supporting rural development of the area	0
1 Longer production period	0.0244	7 Increased land value	0
2 Lower labor cost	0.0192	8 Higher employment	0.26725
3 Lower business risk due to diversification	0.4713	**Risks (R.)**	
4 Higher revenues	0.00198	1 Long term commitment when receiving a subsidy	0
5 Production of higher quality crops and timber	0.45756	2 Lack of subsidies	0.60311
6 Manure capture	0.02556	3 No added value for AF products	0
		4 Low market opportunities	0.39689

The management alternative *High natural and cultural value agroforestry systems* (D1) had the highest overall priority, no matter how much weight was allocated to the benefits (Figure 5.29). The overall priority of all four agroforestry systems (D1-D4) equalized when more weight was allocated to the benefits. *Do not implement agroforestry* (D5) generally had the lowest priority.

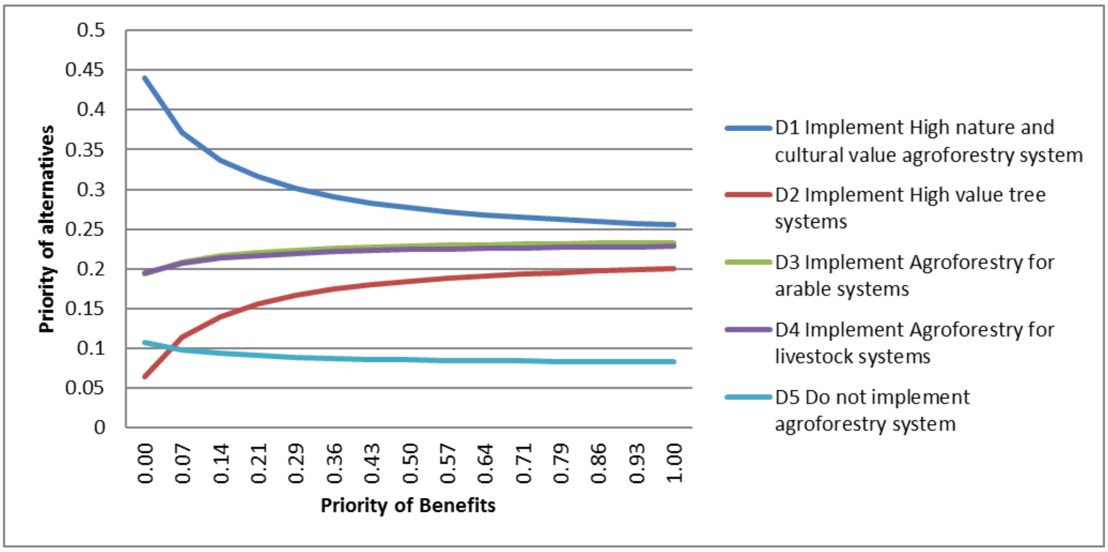


Figure 5.29. Sensitivity analysis of Benefits sub-network for the Continental region model

High natural and cultural value agroforestry (D1) had the highest overall priority (Figure 5.30) when low to medium importance was allocated to the costs. With increasing importance of the cost criteria, all agroforestry systems (D1-D4) declined in priority. *Do not implement agroforestry* (D5) also lost priority with increasing costs but nevertheless it gained the highest priority when full weight was assigned to the costs criteria.

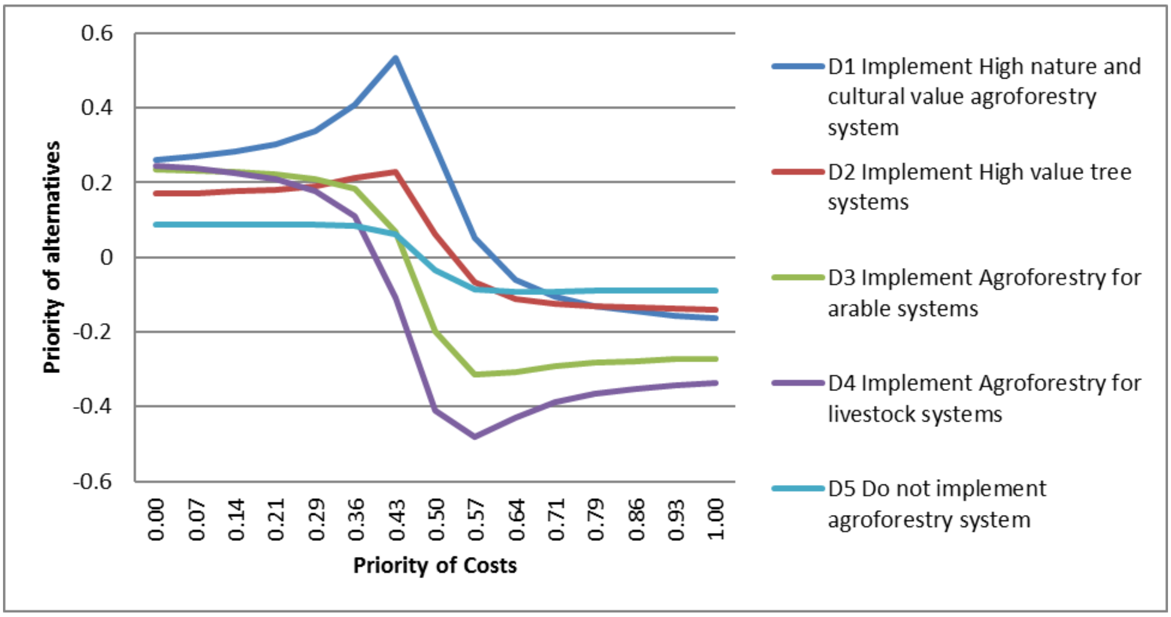


Figure 5.30. Sensitivity analysis of Costs sub-network for the Continental region model

When low to medium importance was given to the opportunities, *high natural and cultural value agroforestry* (D1) had the highest overall priority (Figure 5.31) but with increasing importance of the opportunities, *arable agroforestry* (D3) reached the highest overall priority. *Do not implement agroforestry* (D5) always had the lowest priority indicating that this management alternative provide low opportunities.

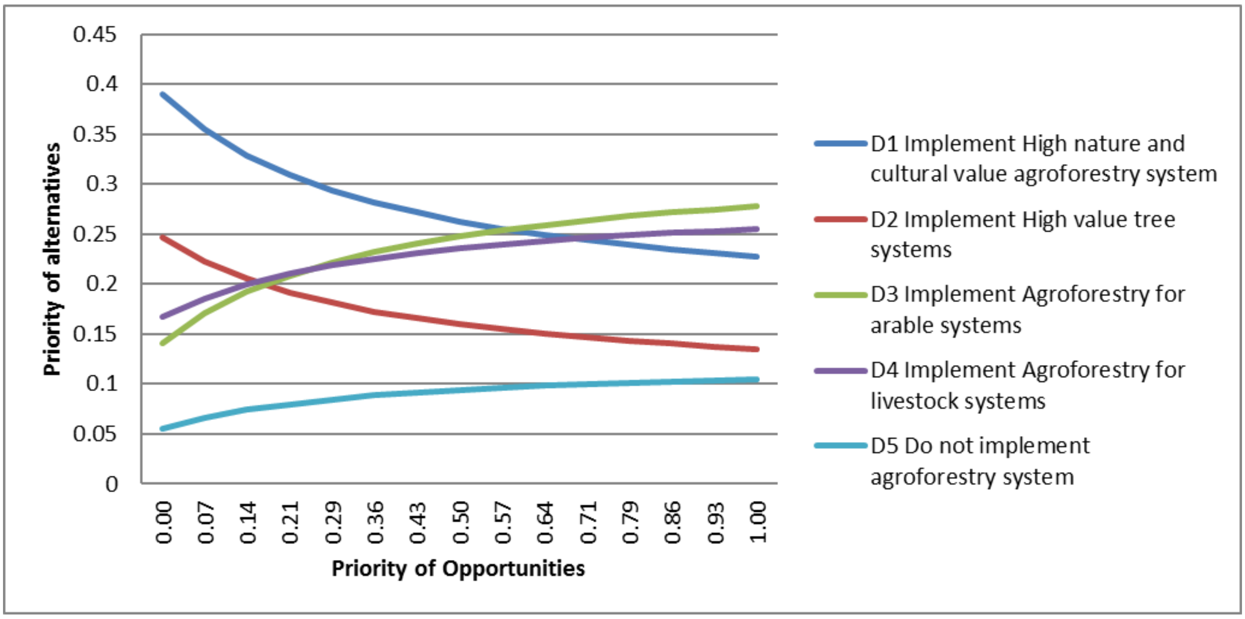


Figure 5.31. Sensitivity analysis of Opportunities sub-network for the Continental region model

High natural and cultural value agroforestry (D1) had the highest overall priority regardless the importance attributed to the risks (Figure 5.32). *Arable agroforestry* (D3) had the lowest overall priority with increasing importance of the risks.

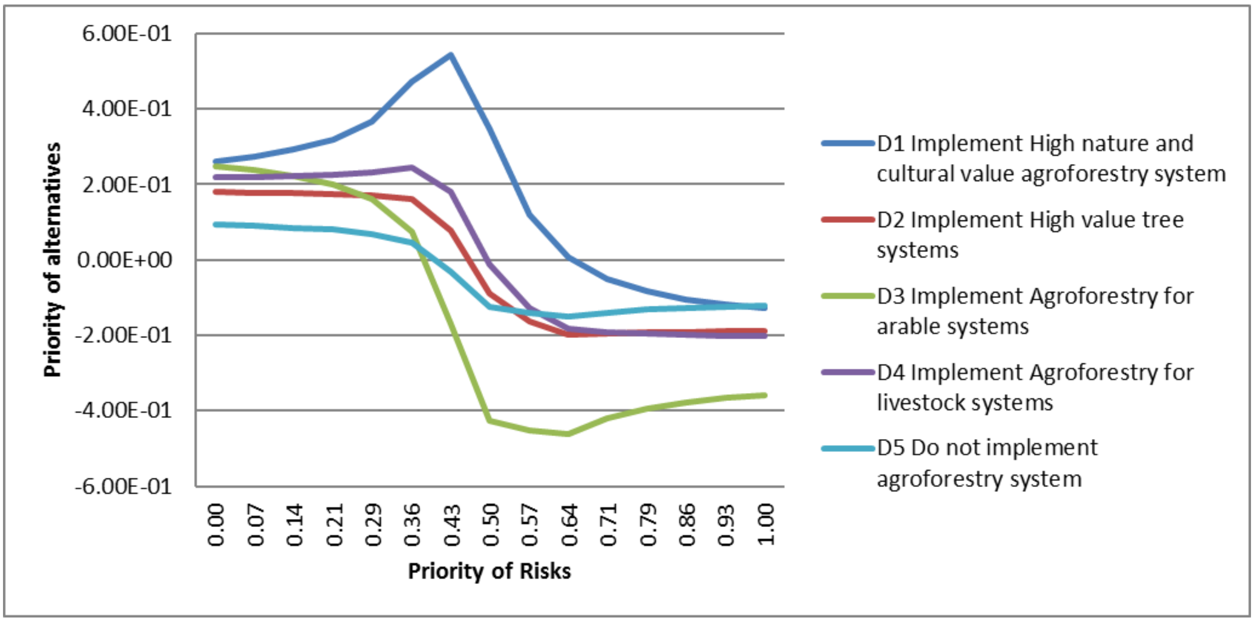


Figure 5.32. Sensitivity analysis of Risks sub-network for the Continental region model.

5.5.5 Results – Pannonian region

In the model for the Pannonian region, the highest priority was attributed to implementation of *High natural and cultural value agroforestry systems* (D1), followed by *Agroforestry for livestock systems* (D4) and *High value tree agroforestry* (D2) (Figure 5.33). The priories for implementing *Agroforestry for arable systems* (D3) and *Do not implement agroforestry* (D5) were the lowest. For the Pannonian region, all agroforestry systems (D1-D4) were associated with high benefits and opportunities, but also with high risks (Figure 5.34). In addition, arable agroforestry (D3) and livestock agroforestry were also associated with high costs. Do not implement agroforestry (D5) had only moderate benefits and opportunities, the lowest costs but high risks which led to a low overall priority.

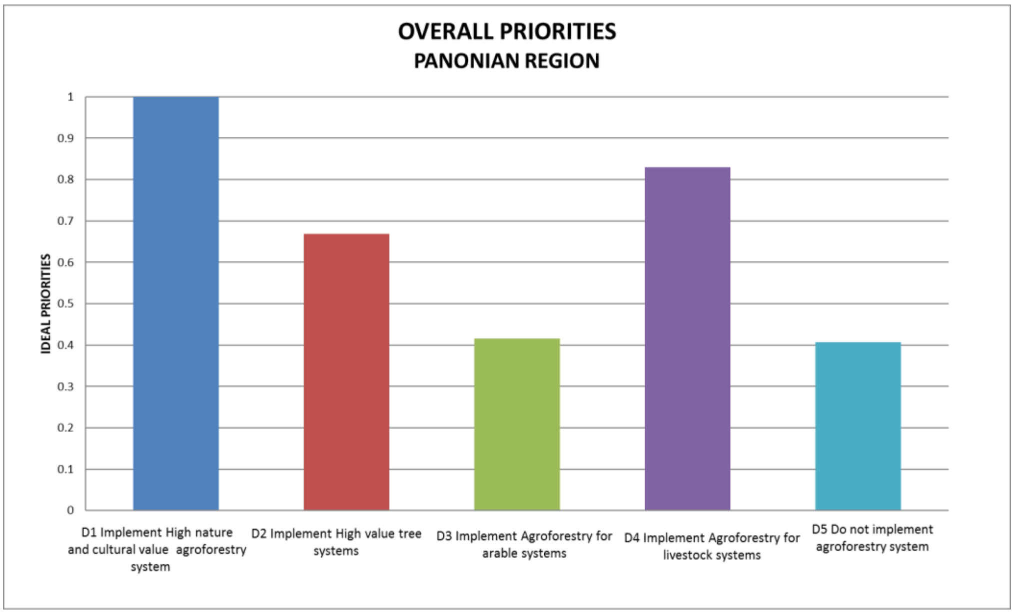


Figure 5.33. Overall priorities for the Pannonian region model

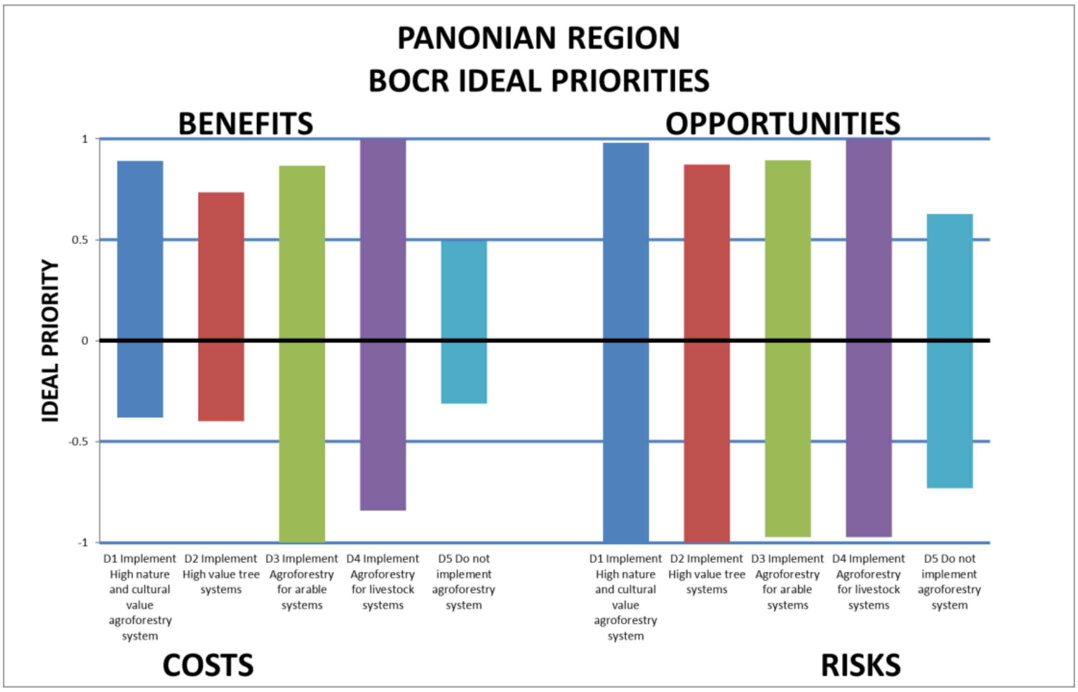


Figure 5.34. BOCR priorities for the Pannonian region model

In the Pannonian region, similar criteria were found important as in the other regions (Table 5.10): *Lower input of pesticides, improved flood regulation, lower business risk due to diversification, production of higher quality crops and timber, knowledge and information on agroforestry systems, family tradition, competition between crops, trees and animals, increased labour requirements,* the *availability of subsidies, higher employment, low market opportunities* and *lack of subsidies* were regarded by the experts as the most important criteria for farmers to decide which management alternative to apply on their farm.

Table 5.10. Priorities of criteria normalized by cluster for the Pannonian region model. Criteria with highest priority in cluster are shaded green, and the criteria with second highest priority are shaded orange.

Environmental benefit (B.EV.) criteria	Priority normalised by cluster	Social Benefits (B.S.)	Priority normalised by cluster
1 Lower input of pesticides and/or fertilizers	0.4128	1 Family tradition	0.34681
2 Reduce soil erosion	0.03201	2. Ownership of the plot	0.04069
3 Resilience in farming	0.07912	3. Knowledge and information on agroforestry systems	0.61249
4 Fire prevention	0.00074	**Cost (C) criteria**	
5 Animal health and welfare	0.00523	1 Additional investments required (mechanization and infrastructure)	0
6 Improved water quality	0.16165	2 Increased labor requirements	0.32805
7 Improved flood regulation	0.24228	3 Competition between crops, trees and animals	0.67195
B.EV.8 Improvement of soil quality	0.05318	**Opportunities (O.)**	
9 Improvement of biodiversity	0.01264	1 Presence of AF systems in vicinity	0.03472
10 Improvement of climate	0	2 Expected higher income	0
11 Improvement of landscape aesthetics	0.00035	3 Assistance from extension services	0.15623
		4 Availability of subsidies	0.53276
		5 Local supporting policy (e.g. PES)	0.03985
Economic benefit (B.EC) criteria		6 Supporting rural development of the area	0
1 Longer production period	0.02644	7 Increased land value	0
2 Lower labor cost	0.01319	8 Higher employment	0.26051
3 Lower business risk due to diversification	0.50727	**Risks (R.)**	
4 Higher revenues	0.0027	1 Long term commitment when receiving a subsidy	0
5 Production of higher quality crops and timber	0.43281	2 Lack of subsidies	0.56786
6 Manure capture	0.01759	3 No added value for AF products	0
		4 Low market opportunities	0.43214

The management alternative *High natural and cultural value agroforestry* (D1) had the highest, and *arable agroforestry* (D3) the lowest overall priority, when low importance was given to the benefits (Figure 5.35). The overall priority of all five management alternatives (D1-D5) levelled off to a similar level when more weight was allocated to the benefits.

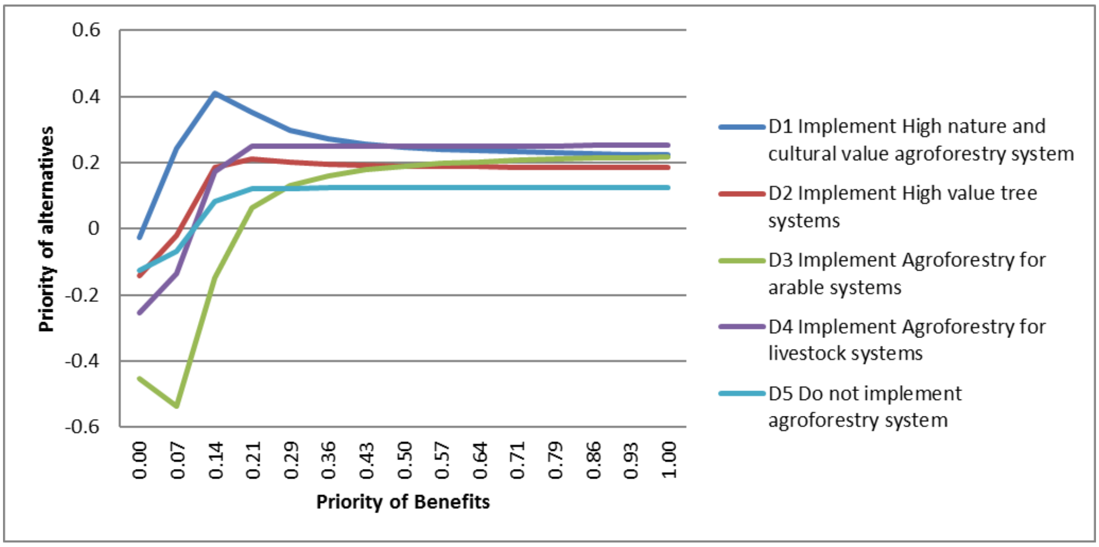


Figure 5.35. Sensitivity analysis of Benefits sub-network for the Pannonian region model.

When low priority was assigned to the costs criteria, all decision alternatives (D1-D5) had more or less similar priority. *high natural and cultural value agroforestry* (D1) gained the highest overall priority (Figure 5.36) when medium importance was allocated to the costs. With increasing importance of the costs, all agroforestry systems (D1-D4) lost overall priority although *high natural and cultural value agroforestry* (D1), *high value tree agroforestry* (D2) and *do not implement agroforestry* (D5) ranked highest.

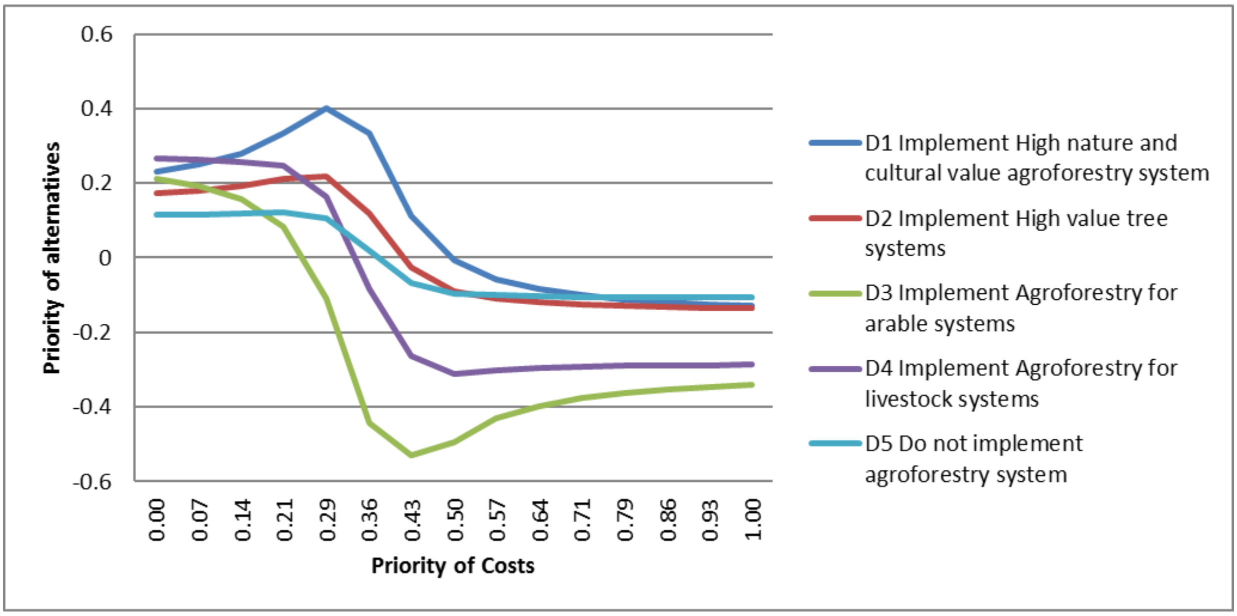


Figure 5.36. Sensitivity analysis of Costs sub-network for the Pannonian region model.

When low to medium importance was given to the opportunities, *high natural and cultural value agroforestry* (D1) had the highest overall priority and arable agroforestry the lowest (Figure 5.37). However, with increasing importance of the opportunities, the overall priority of all five management alternatives (D1-D5) converged to a similar level.

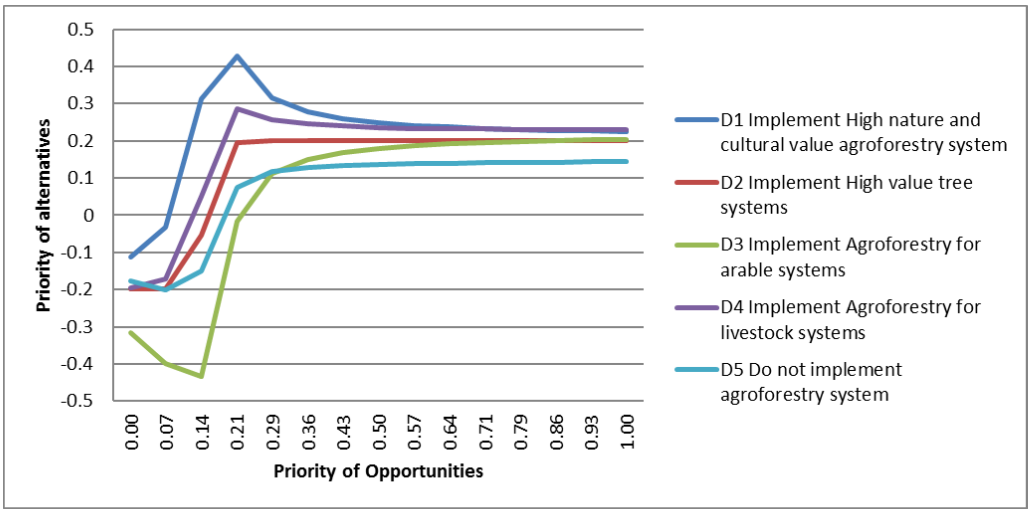


Figure 5.37. Sensitivity analysis of Opportunities sub-network for the Pannonian region model.

High natural and cultural value agroforestry (D1) had the highest overall priority when low to medium importance was given to the risks (Figure 5.38). The overall priority of all management alternatives (D1-D5) decreased to a similar low level with increasing importance of the risks.

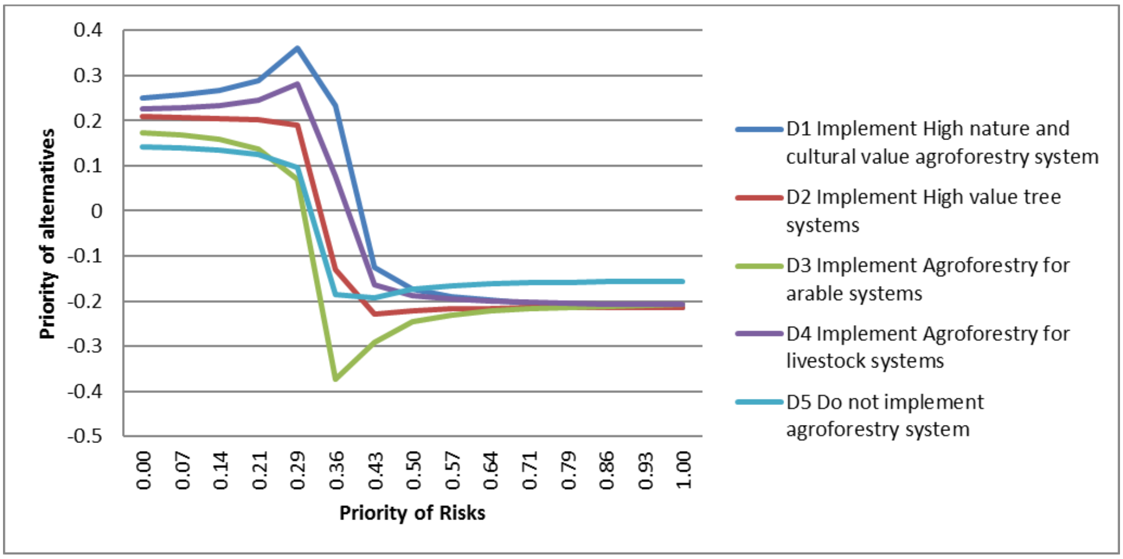


Figure 5.38. Sensitivity analysis of Risks sub-network for the Pannonian region model.

5.6 Discussion

5.6.1 Characterisation of different system in different regions

Most research on farmer responses to agroforestry has been undertaken in low external input conditions in the tropics to understand local practice, opportunities for improvement and why agroforestry interventions succeed or fail (Graves et al. 2004, Barrance et al. 2003; Fischler and Wortmann 1999; Franzel 1999; Dreschel and Rech 1998). Less research exists to determine farmer perception of agroforestry systems in labour-scarce highly-mechanised agricultural systems with high external inputs. This is particularly true for within field planting schemes, and most research has focussed on boundary systems, for example riparian strips (Ducros and Watson 2002), hedgerows (Morris et al. 2002), and windbreaks (Matthews et al. 1993), and in some cases, silvopasture systems (McAdam, et al. 1997). Such techniques appear to be more favourably viewed by farmers because they have an accepted function, perhaps providing shelter and protection for crops or animals from harsh weather conditions, demarcating field boundaries, controlling animal movements, and providing fodder and fuelwood, or controlling pollution, particularly into water bodies (Graves et al. 2005).

In Canada, Matthews et al. (1993) found that whilst farmers were familiar with and willing to use windbreaks, woodlots, and plantations on their farms, few were aware of, or willing to use within-field trees on cropped land, because of a perception that there would be little economic benefit and added management burdens. Lawrence and Hardesty (1992) in United States of America found that a range of key land management stakeholders, including extension services, academics, and private and state land managers, viewed the greatest potential for agroforestry to be in “government mandated” soil conservation programmes. The constraints were considered to be lack of information, technical assistance, establishment costs, and lack of historic use of such systems. Workman et al. (2003) in a study on landowners and extension professionals in the USA found that most farmers used field boundary agroforestry techniques such as riparian buffers and windbreaks. The main functional advantages were aesthetic benefit, shade, wildlife habitat, and soil conservation. However, competition between trees and crops, lack of information and markets for tree products, added management expense, lack of equipment, lack of familiarity, and lack of demonstrations were viewed as major constraints.

In Europe, Graves et al. (2009) found that farmer perceptions regarding silvoarable systems varied substantially between Atlantic and Mediterranean areas of Europe. Trees were more numerous on Southern European than on Northern European farms. Most farmers were willing to use silvoarable systems if they were profitable, but the form of agroforestry envisaged varied. The farmers also identified a number of risks, and were concerned that the long-term nature of agroforestry could leave them exposed to reductions in the value of timber and felt some form of insurance or subsidy would be required to promote adoption. Concern also existed regarding long-term eligibility of the land to EU subsidies and agri-environment support measures.

Graves et al. (2009) found that when farmers were asked to envisage silvoarable systems, in Northern Europe they tended to identify wide alleys and low tree densities, whilst in Southern Europe they envisaged cropping right up to the tree, narrow alleys and relatively high tree densities. Most farmers felt that silvoarable systems would not improve the profitability of their farm. But in the Mediterranean zone, farmers were more likely to feel that economic benefit could be derived than in Atlantic Europe. In the Atlantic zone, farmers were more likely to perceive ecological benefits than those in Southern Europe. In southern Europe yield declines of the intercrop were seen as a greater constraint than in the Atlantic zone, whereas Atlantic zone farmers considered complexity of work and mechanisation as likely constraints.

In our study, the highest overall priority was assigned to the implementation of *High natural and cultural value agroforestry* (D1) and *livestock agroforestry* (D4) in all of the five examined regions across Europe (Figure 5.39). In practice, *high natural and cultural value agroforestry systems* (D1) would be linked to grazed *livestock systems* (D4) in the form of wood pastures and parklands. The assigned priorities, reflect very well the actual current distribution of the different types of agroforestry systems across Europe, as these two systems are indeed the two most common.

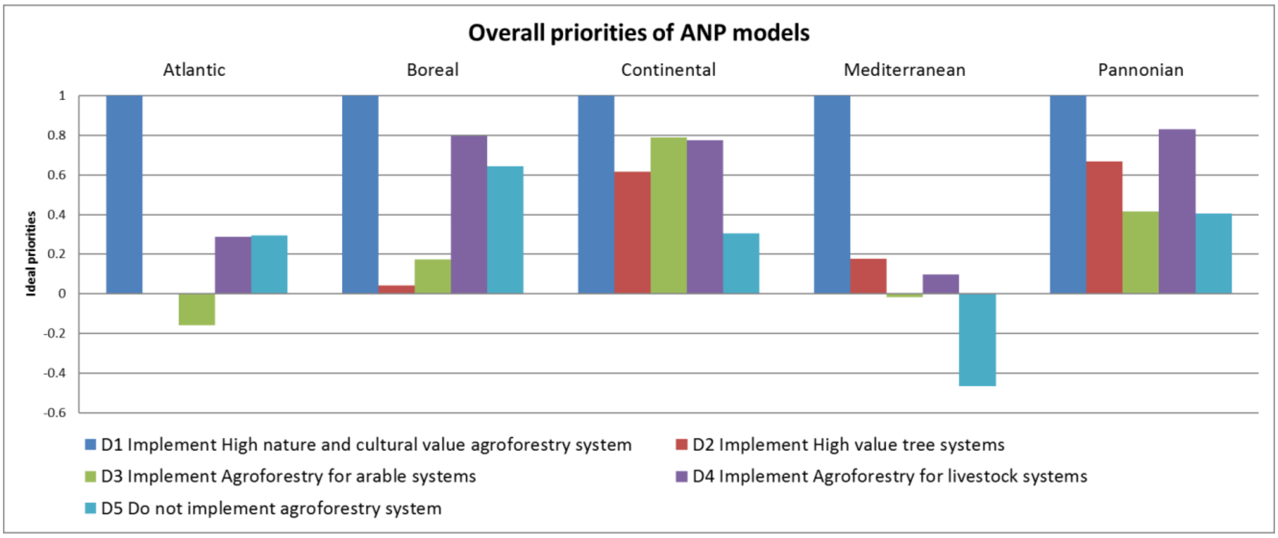


Figure 5.39. Overall priorities of ANP models

Plieninger et al. (2015) found that wood-pastures, which have a substantial overlap with high natural and cultural value agroforestry, are still relatively widespread in most of the European regions and cover about 20 million hectares. The definition of wood pastures by Plieninger et al. (2015) included open woodland that may not be currently grazed, whereas evidence of grazing was important in the assessment of agroforestry by den Herder et al. (2017). Within the AGFORWARD project, hedgerow systems were also considered as high nature and cultural value agroforestry. Den Herder et al. (2017), using the LUCAS dataset, identified that livestock agroforestry was present in most European regions and covers about 15 million hectares; much of this would also be considered as agroforestry of high nature and cultural value.

In the Continental and Pannonian regions *high value tree* (D2) and *arable agroforestry* (D3) had a high priority (Figure 5.39). Examples of such systems in these regions include intercropped and grazed fruit tree orchards such as *streuobst*. According to Herzog (1998) and den Herder et al. (2016), these practices are present in the Continental and Pannonian regions. The Mediterranean region, on the other hand, gave a negative overall priority to *do not implement agroforestry* (D5) and a very high priority to *high natural and cultural value agroforestry* (D1). This is very well reflected in the actual distribution of agroforestry as the countries belonging to the Mediterranean zone have generally the highest agroforestry cover in Europe, ranging from 10.9% of the UAA in Italy to about 40.9% of the UAA in Cyprus (den Herder et al. 2017).

Do not implement agroforestry (D5) had a high overall priority in the boreal region. This is actually not reflected by the current distribution of agroforestry practices: den Herder et al. (2017) found that countries in the Boreal zone (Sweden, Finland) had about 6-15 % of their agricultural land under agroforestry. Although this percentage is not very high, it is higher than the average for the Atlantic, Continental and Pannonian zone were agroforestry cover ranges from about 0.6% (Denmark) to about 11.7% (Slovenia) of the utilized agricultural area. It could be that local experts expect farmers in the boreal region to be hesitant to change to agroforestry practices due to adverse climatic conditions and low profit margins due to lower crop productivity and relatively high production costs. Hence farmers may find it a safer alternative to continue with their usual (non-agroforestry) farming practices because it is risky to change a practice that works under these difficult climatic conditions.

It should be noted that the result of this study are based on 'ideal' farm descriptions with alternative management scenarios. These farm descriptions were based on expert knowledge of the participants in the study, and may deviate from the actual situation. Some participants argued that a 'typical' farm management description of a given region cannot be made as 'typical' farms do not exist due their strong heterogeneity. Nevertheless, the farm descriptions were based on the best "compromise" of available expert knowledge and were mainly used as a means to help the survey participant to visualize what a so-called "typical" farm would look like.

The benefits, costs, opportunities and risks associated with agroforestry had different effects on farm management decisions. In all European regions, *high natural and cultural value agroforestry* (D1) and *livestock agroforestry* (D4) were associated with high benefits (Figure 5.40). *Arable agroforestry* (D3) was also thought by the experts to deliver high benefits in the Atlantic, Continental and Pannonian regions. The management alternative of *No implementation of agroforestry* (D5) received it highest ranking (similar to the agroforestry alternatives) in the Atlantic region.

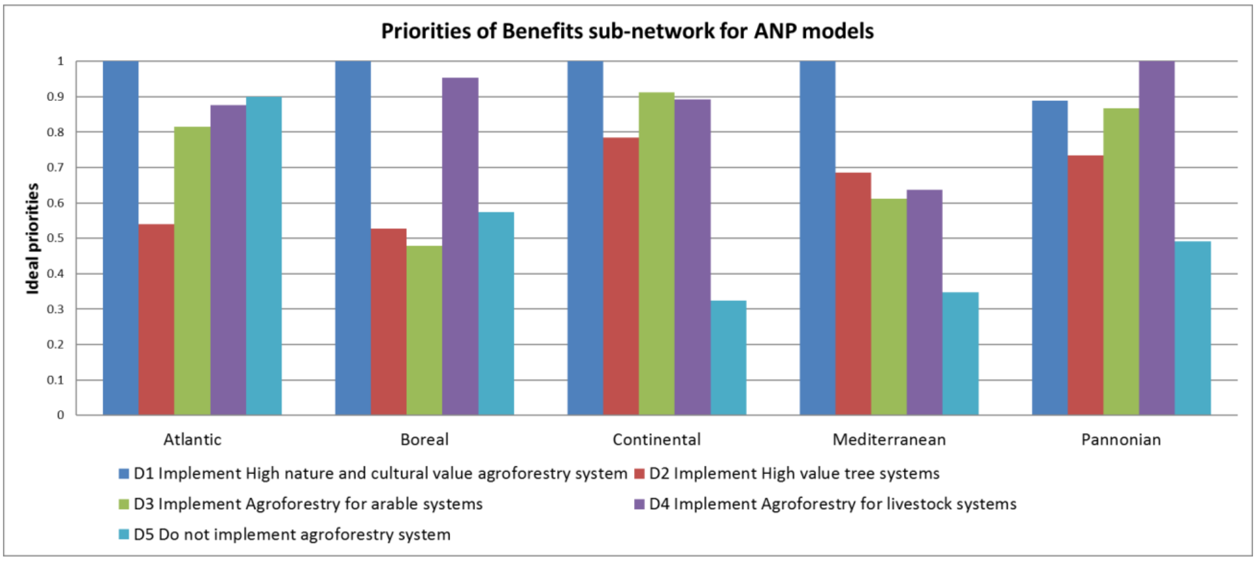


Figure 5.40. Ideal priorities of Benefits sub-networks across ANP models

In all regions, similar environmental, economic and social aspects were perceived as the most important benefits of agroforestry (Table 5.11). *Lower input of pesticides and fertilizers, improved water quality,* and *improved flood regulation* were perceived as the most important environmental benefits. These finding are consistent with previous research with farmers where benefits of agroforestry were largely viewed as environmental (Graves et al. 2005). *Lower business risk due to diversification* and *production of higher quality crops and timber* were seen as the most important economic benefits. This is consistent with the findings of Camilli et al. (2016), who observed that Italian farmers similarly thought that one of the most important benefits of silvopastoral systems was the production of high quality products which meet the consumer demands.

Table 5.11. Comparison of key criteria across ANP models (the conditions are that they have the highest or second highest priority in their cluster / sub-network)

	Regional model				
	Atlantic	**Boreal**	**Continental**	**Mediterranean**	**Pannonian**
Environmental Benefits (B.EV.)	1 Lower input of pesticides and/or fertilizers	1 Lower input of pesticides and/or fertilizers	1 Lower input of pesticides and/or fertilizers	1 Lower input of pesticides and/or fertilizers	1 Lower input of pesticides and/or fertilizers
	6 Improved water quality	6 Improved water quality			
			7 Improved flood regulation	7 Improved flood regulation	7 Improved flood regulation
Economic Benefits (B.EV.)	2 Lower labor cost				
	3 Lower business risk due to diversification	3 Lower business risk due to diversification	3 Lower business risk due to diversification	3 Lower business risk due to diversification	3 Lower business risk due to diversification
		5 Production of higher quality crops and timber	5 Production of higher quality crops and timber	5 Production of higher quality crops and timber	5 Production of higher quality crops and timber
Social Benefits (B.S.)	1 Family tradition	1 Family tradition	1 Family tradition	1 Family tradition	1 Family tradition
	3. Knowledge and information on agroforestry systems	3. Knowledge and information on agroforestry systems	3. Knowledge and information on agroforestry systems	3 Knowledge and information on agroforestry systems	3 Knowledge and information on agroforestry systems
Costs (C)	2 Increased labor requirements	2 Increased labor requirements	2 Increased labor requirements	2 Increased labor requirements	2 Increased labor requirements
	3 Competition between crops, trees and animals	3 Competition between crops, trees and animals	3 Competition between crops, trees and animals	3 Competition between crops, trees and animals	3 Competition between crops, trees and animals
Opportunities (O.)	3 Assistance from extension services		3 Assistance from extension services		
	4 Availability of subsidies	4 Availability of subsidies	4 Availability of subsidies	4 Availability of subsidies	4 Availability of subsidies
		8 Higher employment		8 Higher employment	8 Higher employment
Risks (R.)	2 Lack of subsidies	2 Lack of subsidies	2 Lack of subsidies	2 Lack of subsidies	2 Lack of subsidies
	4 Low market opportunities	4 Low market opportunities	4 Low market opportunities	4 Low market opportunities	4 Low market opportunities

Less obvious in the literature is the importance of social benefits, in this case the finding that such systems provided the opportunity for social gain in the form of increased knowledge and information on agroforestry systems or the continuation of family tradition. There are however some studies focussing on the social aspects of agroforestry. In our study, *Family tradition* and *knowledge and information on agroforestry systems* were perceived as the most important social benefits (Table 5.11). This is consistent with the findings of Saha et al. (2011), who in a study on home gardens in Kerala in India, found that ancestral practice had a high impact on farmers' decisions including tillage, plant residue and fertiliser application. Agroforestry is in many areas a traditional land management practice and the current generation of farmers have seen their ancestors practicing it. It is therefore likely that ancestral recommendations affect farmers' decisions today.

In their study, Saha et al. (2011) found that education positively influenced the decision to plant trees, perhaps because they had a stronger understanding of the environmental benefits of trees. This does not mean that lower educated farmers were unaware of the environmental benefits. It could be that educated farmers have better access to scientific and practical information and were in a better position to implement agroforestry practices. Several studies have found that neighbours, friends and peers have a relatively large influence on farm management decisions (Saha et al. 2011, Sereke et al. 2015). Unfortunately this important aspect was not considered in our study.

In relation to costs, the application of *livestock agroforestry* and *arable agroforestry* was seen as more beneficial than *high value tree agroforestry* (Figure 5.41). Increased labour requirements and competition between crops, trees and animals were viewed as the most significant costs (Table 5.11), an observation also reported by Sereke et al. (2014) and Camilli et al. (2016).

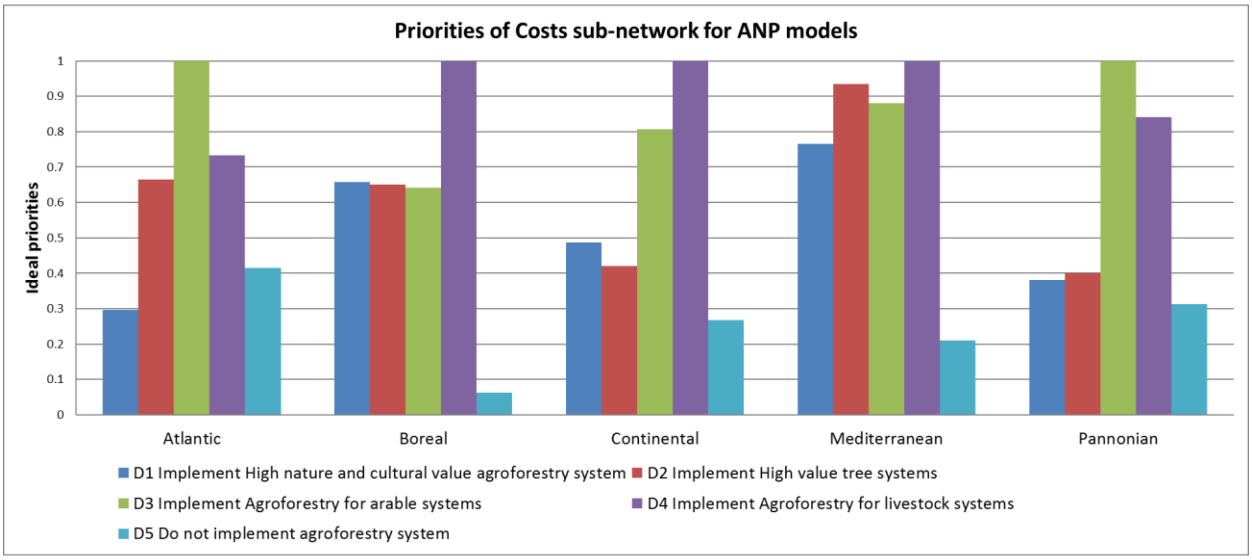


Figure 5.41. Ideal priorities of Costs sub-networks across ANP models

The results for opportunities (Figure 5.42) need to be considered alongside the risk (Figure 5.43). In the Atlantic zone, *Do not implement agroforestry* was predicted to result in both higher risks and opportunities than the alternatives. *Implement high nature and cultural value agroforestry* and *Implement agroforestry for livestock* was seen as offering relative high opportunities and low risks in the Boreal and Continental regions. In the Mediterranean, *Do not implement agroforestry* was seen as offering low opportunities. In the Pannonian region, each of the agroforestry systems offered a high level of opportunity and risk. The availability of subsidies and assistance from extension services would create the greatest opportunities for the system, but low market opportunities and lack of subsidies were seen as the greatest risks (Table 5.11). A similar response was reported by Camilli et al. (2016), where farmers expressed the need for assistance by extension services in field trials and complained that the bureaucratic complexity of the Common Agricultural Policy discourages them from applying grants for establishing new agroforestry systems.

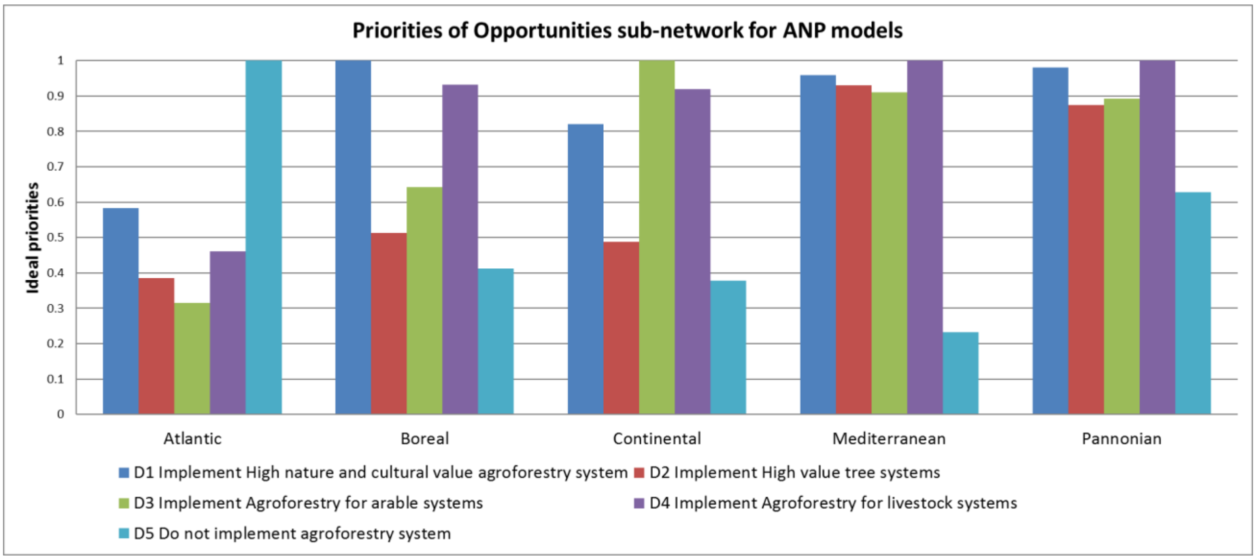


Figure 5.42. Ideal priorities of Opportunities sub-networks across ANP models.

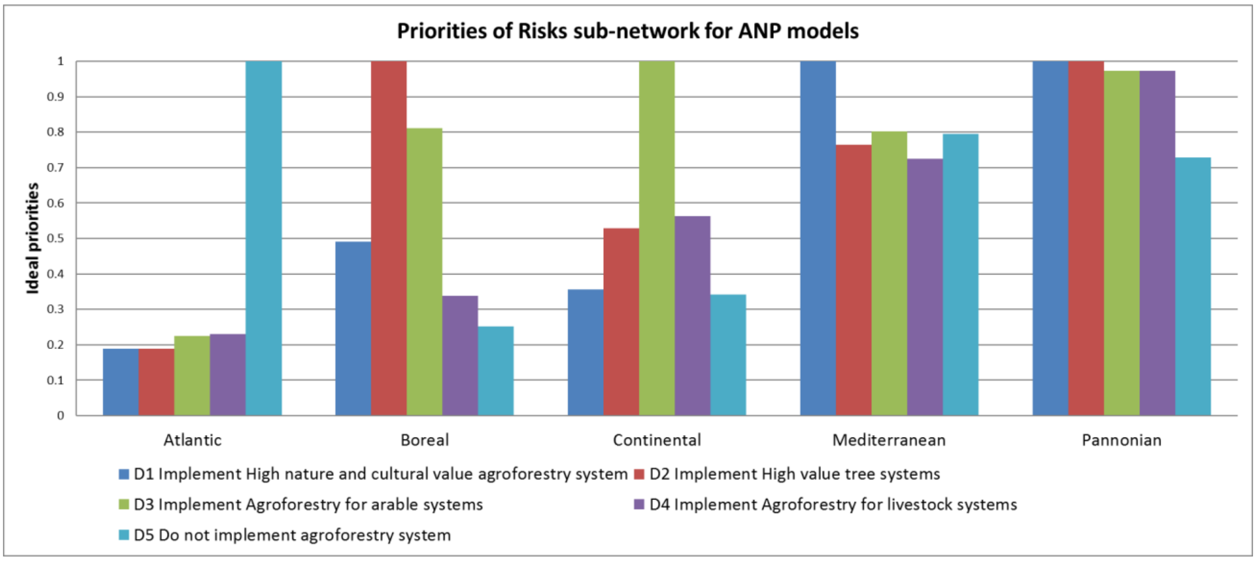


Figure 5.43. Priorities of Risks sub-networks across ANP models.

Pannel (1999) has suggested that long term technologies face several challenges when proposed as innovations. Firstly, the farmer must have the information that the alternative system exists, secondly the farmer must be satisfied that it can be trialled, thirdly perceive that it is worth trialling, and fourthly consider that it meets objectives, particularly profit. These conditions are not easily obtained in long-term systems. For example, trialling silvoarable systems successfully to test for profit is difficult, and the initial constraints and disadvantages, such as high initial investment costs and increased difficulty of machine operations are readily apparent, but the full benefits may only be observed over a long period.

In some situations, for example the case of wood pasture, agroforestry is managed relatively extensively with minimal use of external inputs such as pesticides and fertilizers. The outputs of such systems (e.g. meat) are perceived to be of high quality. The tree canopies protect the soil from direct rainfall impact and limit soil erosion, and can help moderate extremes of high temperature which can cause major reductions in crop and grass yields. Traditional forms of agroforestry typically involve ancient practices which are culturally important. On the other hand, modern agroforestry practices can require new labour and management skills to optimise the competition among the components. Camilli et al. (2016) also reported that that management was perceived as a major constraint in implementing agroforestry in Italy. The Common Agricultural Policy (CAP) has recognized that the establishment of agroforestry systems should be encouraged because of “their ecological and social value” (EU Reg. 1698/2005) and a financial mechanism was introduced in the 2007-2013 EU Rural Development Program (RDP) to support the first establishment of agroforestry systems on arable lands. In the new CAP, 2014-2020 period, agroforestry systems still receive support according to the Article 23 of the EU Reg. 1305/2013. Nevertheless, the farmers’ interest to get available grants is hampered by the complexity of the bureaucracy procedure to obtain them and the lack of knowledge concerning agroforestry (Pisanelli et al. 2014).

5.6.2 Discussion on the methodological constraints, and ways to proceed

By using the ANP methodology, we were able to identify key criteria affecting farmers’ decisions whether to adopt an agroforestry system or not. There are however some limitations in using the ANP model. From the application point of view, using the ANP model proved to be complicated. The high level of complicatedness also made it difficult to maintain the interest of the participants during the various iterations required to develop the model. Wolfslehner et al. (2005) also noted that one of the major drawbacks of ANP is that the complicatedness increases exponentially with the number of indicators and their interdependencies, due both to the numbers of pairwise comparisons and to the dimensions of questionnaires. In their study, Wolfslehner et al. (2005) recommended that the size of the indicator set is kept as low as possible, that strong emphasis is placed on clear delineations and definitions of the examined indicators, and only the direct interconnections between the systems elements are defined. Beside the large number of questions when using ANP, Wolfslehner et al. (2005) also noted linguistic problems. Similarly, in this study, the semantics used in many of the pairwise comparisons describing complex issues may have been hard to follow by some of the participants.

5.7 Conclusions

This study has attempted to determine how experts working in five different bio-geographic zones in Europe understand the benefit, cost, opportunity and risk criteria in relation to five land management alternatives (comprising four different types of agroforestry and a counterfactual “*Do not implement agroforestry*”). In general there was very strong agreement provided by the experts working in Boreal, Mediterranean, Continental and Pannonian biogeographical zones. In each of these regions the principal environmental benefit criteria were to reduce inputs and to improve water quality and/or runoff control. The key economic benefit criteria were seen as diversification to reduce business risk and to improve the quality of crop and tree products. The key social benefit criteria were to maintain traditions and to improve the knowledge of agroforestry. In the Atlantic region, the same criteria were also established but lower labour costs were seen as a key economic criterion. In each region, the same major costs criteria associated with agroforestry decisions were increased labour costs and increased competition between trees, crops, and animals. The major determinant of opportunities associated with agroforestry decisions were availability of subsidies and higher employment. Assistance from extension services was also highlighted in the Atlantic region. The major risks were and a lack of subsidies and low market opportunities.

Aside from these rather descriptive statements, the research design of the study does not allow drawing-up of inferential conclusions, such as causal relations between certain elements of the model. However, even listing the most important elements behind the uptake of agroforestry might affect future drawing-up of policies aimed at supporting these kind of farming practices. Interested readers can also make many conclusions themselves about the priority of given management alternatives under different conditions. An example of this situation would be primacy of no agroforestry alternative in the Mediterranean model when importance of costs is high. As the model was designed by experts with a quite broad perspective, they have put more weight on benefits than on costs. From a farmer's perspective, the large economic costs might be more important than large environmental benefits. Supporting policies and other factors such as security of agri-environmental subsidies and support from extension services are some ways of decreasing the practical 'costs' of agroforestry and thereby they can contribute to the increased uptake and implementation of agroforestry.

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