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Forest plantations investments in southern Europe: a comparative trend analysis on returns, markets and policies

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List of Abbreviations and Acronyms

CAP	Common Agricultural Policy
EAFRD	European Agricultural Fund for Rural Development
EAV	Equivalent Annual Value
EC	European Commission
EU	European Union
EUR	Euro (€)
FAO	Food and Agriculture Organization (of the United Nations)
ha	Hectare
i	Discount rate
IRR	Internal Rate of Return
LEV	Land Expectation Value
LVT	Land Value Tax
m^3	Cubic meter
MAI	Mean Annual Increment
NPV	Net Present Value
PBP	Payback Period
RDP	Rural Development Plan
REITs	Real Estate Investment Trust
SNPF	Semi-Natural Planted Forests
SRI	Sustainable and Responsible Investments
TIMOs	Timberland Investment Management Organizations
TVM	Time Value of Money
UNFF	United Nations Forum on Forests
USD	United States Dollars ($)
VAT	Value Added Tax

Acknowledgements

There are many people who deserve a special thanks for the support they gave me during this Doctoral course. First of all, I'm particularly grateful to my supervisor Prof. Davide Pettenella for his guidance and constant encouragement throughout these three years. A very special thanks goes then to Inazio Martinez de Arano and Dr. Elena Gorriz from the Mediterranean Facility of the European Forest Institute, and to Prof. Margarida Tomé and Dr. Susana Barreiro from the Forest Research Center of the University of Lisbon; their positive cooperation has been essential to build the network of experts and organizations that contributed to this research. I would like to sincerely thanks also Lucio Brotto, Mauro Masiero and Nicola Andrighetto from ETIFOR for the enriching collaboration opportunities.

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Alex Pra

Padova, 10th December 2018

Summary

At global level there is a growing interest towards forest plantations as investment opportunities for profit generation, for building strategic assets, but also to address sustainable development challenges with the production of essential goods and services. These are the reasons why plantation investments are attracting new investors and expanding outside the traditional regions and markets.

In southern Europe, forest plantations represent a consolidated segment of investment for landowners. In future years, the increasing demand for timber and fibres driven by bioeconomy and bioenergy policies, might boost the interest towards forest plantations investments in this region, with an increasingly important role played by financial investors as well as by strategic partnerships between landowners, industrial companies and external investors.

In the light of this evolution, there is an urgent need for more information and valuation studies on forest plantations to support better investment and policy-making decisions. Recent research by Sedjo (1983; 2001) and Cubbage *et al.* (2007; 2010; 2014) estimated investment returns for the main species and contexts at global level. In this study, we used a similar approach to estimate and analyse, on a comparative perspective, investment returns for productive forest plantation species in the southern European context, focusing in some regions of Italy, Spain and Portugal. Our main interest involved forest plantations of private nature with the primary purpose of wood and fibers production. We carried out a financial analysis before-tax, using capital budgeting indicators to estimate returns at aggregate level, based on representative stand management regimes. Indicators were calculated according to a baseline scenario as well as in alternative scenarios, analyzing how the main policy and market factors are influencing returns. We also carried out a trend analysis – which represents the most original methodological contribution of this research – estimating how returns have changed in recent years as a result of the evolution of the key economic variables.

Overall, our results indicate that in southern Europe there are some opportunities for reasonably interesting returns for sectorial investors, i.e. landowners and forest-based industry, and in some cases also for financial investors. Nevertheless, the dynamicity of the regional timber market and the small-scale fragmented forest holdings are structural factors that new investors would have to take into consideration. More in specific, hybrid poplar plantations in northern Italy and Castile and León (Spain) are estimated to provide on average the potentially highest returns, but the large range of variability and the high land and opportunity costs are unlikely to make

them an attractive investment for non-landowners. Eucalyptus plantations in Portugal are estimated to be the only investment where non-landowners could expect to get relatively interesting and stable returns, although a recent law reform in the country could limit new investments. Maritime pine and radiata pine plantations in Portugal and Spain present lower returns, suffering the situation of depressed stumpage prices after the 2008 economic crisis, which strongly affected the sawmilling sector. We also extended our analysis to mixed and multipurpose plantations, i.e. polycyclic plantations, in the context of the Po valley (northern Italy); these showed potentially competitive profitability performances and advantages, in spite of the experimental character and technology transfer limitations.

From a more general perspective, our research provided valuable results to improve the knowledge on the potential investment returns from forest plantation in the region, offering means to compare the status and trends of investments, markets and policies. For example, it has emerged from our research that the current subsidy policies are not effective in providing a clear, balanced and stable framework for investments in forest plantations, and that a more strategic coordination at regional level is urgently needed in order to support the competitive position of the sector in front of the challenges posed by the bioeconomy strategy. Moreover, the methodological design and approach of this research could provide the basis for establishing a permanent observatory on forestry investments in southern Europe, allowing a better market monitoring, business analysis and policy-making in the future.

Riassunto

Investimenti in piantagioni forestali nell'Europa meridionale: un'analisi comparativa dell'andamento della redditività, dei mercati e delle politiche

A livello globale, vi è una crescita d'interesse verso le piantagioni forestali come opportunità d'investimento per generare profitto, per costruire *assets* strategici, ma anche per affrontare le sfide di sviluppo sostenibile attraverso la produzione di beni e servizi essenziali. Queste sono le principali ragioni per le quali gli investimenti in piantagioni stanno attraendo nuovi investitori e si stanno espandendo al di fuori delle regioni e dei mercati tradizionali.

Nell'Europa meridionale, le piantagioni forestali rappresentano un segmento d'investimento consolidato, soprattutto per i proprietari terrieri. Nei prossimi anni, la crescente domanda di legname spinta dalle attuali politiche per la bio-economia potrebbe stimolare ulteriormente l'interesse verso gli investimenti in piantagioni in questa regione, con un ruolo sempre più importante svolto da investitori finanziari e da *partnership* strategiche tra proprietari terrieri, imprese industriali ed investitori esterni.

Alla luce di quest'evoluzione, vi è un'urgente necessità di maggiori informazioni e studi di valutazione degli investimenti in piantagioni per sostenere migliori decisioni d'investimento e di politiche. I recenti lavori di Sedjo (1983; 2001) e Cubbage *et al*. (2007; 2010; 2014) hanno stimato i rendimenti degli investimenti per le principali specie e contesti a livello mondiale. In questo studio, abbiamo utilizzato un approccio simile per stimare e analizzare, in una prospettiva comparativa, i rendimenti degli investimenti in piantagioni produttive nel contesto dell'Europa meridionale, concentrandoci in alcune regioni di Italia, Spagna e Portogallo. Il nostro interesse principale si è indirizzato sulle piantagioni forestali di natura privata e aventi come obbiettivo primario la produzione di legname. Abbiamo effettuato un'analisi di tipo finanziario al lordo delle imposte, utilizzando indicatori di convenienza per stimare i rendimenti a livello aggregato sulla base di modelli gestionali rappresentativi. Tali indicatori sono stati calcolati prima sulla base di uno scenario base, e poi di scenari alternativi, analizzando l'effetto delle principali variabili esterne derivanti dal mercato e dalle politiche settoriali. Inoltre, abbiamo effettuato un'analisi degli andamenti, la quale rappresenta il contributo metodologico più originale di questo lavoro, dove abbiamo analizzato come sono cambiati, nel corso degli

ultimi anni, i margini d’investimento a fronte dell’evoluzione delle principali variabili economiche.

In generale, i risultati della ricerca indicano che, nell'Europa meridionale esistono alcune opportunità di rendimenti finanziari interessanti per gli investitori settoriali (cioè i proprietari terrieri e le industrie forestali) e in alcuni casi potenzialmente d’interesse anche per gli investitori finanziari. Ciononostante, è emerso che il contesto regionale è caratterizzato da fattori strutturali, legati alla dinamica del mercato del legname e dalla struttura fondiaria forestale, che devono essere presi in esame accuratamente dai nuovi investitori. Nello specifico, le piantagioni di pioppo nell'Italia settentrionale e Castiglia e León (Spagna) sono state stimate essere potenzialmente le più redditizie, ma è improbabile che gli ampi margini di variabilità e gli elevati costi di uso dei terreni li rendano un investimento interessante per non proprietari terrieri. Le piantagioni di eucalipto in Portogallo sono state stimate essere l'unico investimento in cui anche i non-proprietari possono aspettarsi livelli di redditività relativamente interessanti e stabili, anche se una recente riforma legislativa nel Paese potrebbe limitare nuovi investimenti. Le piantagioni di pino marittimo e pino radiata in Portogallo e Spagna presentano rendimenti sensibilmente inferiori, risentendo della situazione di prezzi bassi causata della crisi economica del 2008 che ha colpito pesantemente il settore delle segherie. Abbiamo anche esteso la nostra analisi a piantagioni miste e multifunzionali, ovvero le piantagioni policicliche nel contesto della pianura padana (Italia settentrionale); queste hanno dimostrato di poter offrire rendimenti finanziari e vantaggi potenzialmente competitivi, anche se è da tenere presente il loro carattere sperimentale e i limiti legati al trasferimento tecnologico.

Da un punto di vista più generale, la nostra ricerca ha fornito risultati preziosi per migliorare la conoscenza dei potenziali rendimenti degli investimenti delle piantagioni forestali nell’Europa meridionale, fornendo strumenti per analizzare e confrontare lo stato e l’andamento degli investimenti, dei mercati e delle politiche. Ad esempio, è emerso che le attuali politiche di sussidio non si rivelano efficaci nel fornire un quadro chiaro, equilibrato e stabile per stimolare gli investimenti in piantagioni forestali, e che è urgente un maggiore coordinamento strategico a livello europeo per sostenere la posizione competitiva del settore di fronte alle sfide che la strategia per la bio-economia pone. Inoltre, l’approccio e la metodologia di questa ricerca potrebbero fornire le basi per la creazione di un osservatorio permanente sugli investimenti forestali in Europa, consentendo in prospettiva un migliore monitoraggio del mercato, analisi settoriali e sviluppo di politiche.

Chapter 1

Introduction

The present Chapter presents the research background (1.1), problem statement (1.2), research questions and objectives (1.3), and the thesis contents and structure (1.4).

1.1 Research background

The importance of planted forests in the forest economy is increasing worldwide as well as the interest and opportunities for investments in their establishment and management. Based on FAO (2012a) definition, planted forests are those forests "predominantly composed of trees established through planting and/or deliberate seeding (…)", comprising both plantations established for producing commercial and industrial roundwood, and those established for protection purposes (i.e. landscape restoration, water regulation, climate amelioration, etc.). Planted forests include the planted component of semi-natural forests as well, which represent large areas in the northern hemisphere. The area covered by planted forests amounts to 278 million hectares, corresponding to the 6.9% of the world's forest cover, and have been growing at +4.9 million hectares per year between 1990 and 2015 (FAO, 2015; Payn *et al.*, 2015).

Based on the FAO (2005) data, Del Lungo *et al.* (2006) estimated that 76% of planted forests are established for productive purposes, playing an important role in matching the growing demand for wood and fibres in the northern hemisphere as well as in the sub-tropics and tropics (Jonsson and Whiteman, 2008). Jürgensen *et al.* (2014) and Carle and Holmgren (2008) estimated that planted forests are already contributing to half of the global industrial timber supply, and this contribution is expected to increase between 75 and 100% by 2050. Therefore, nowadays, timber production remains the main reason for investing in planted forests.

Nevertheless, there is also a growing awareness for the potential of planted forests to deliver other ecosystem services (e.g. Evans and Turnbull, 2004; UNEP, 2009; Bauhus *et al*., 2010; Dal Secco and Pirard, 2015), in particular if planted forests are compared to other forms of land uses (Pawson *et al.* 2013). For example, the European Union (EU) Rural Development Policy – the principal policy instrument that the EU has to drive investment decisions in the forestry sector – has been progressively focusing the public support towards multifunctional forest plantations investment (OECD, 2011; Alliance Environment, 2017). Even in the case of industrial timber-oriented investments, this awareness is reflected in the emergence of so-called responsible investors, adopting responsible management standards and guidelines to address the concerns about negative impacts of plantations on local communities, biodiversity, and soil and water resources (Brotto *et al.* 2016; Clark and Kozar, 2011; Masiero *et al.*, 2015).

In southern Europe, productive forest plantations – established with both native and exotic tree species – represent a consolidated segment of investment, in particular in the continental piedmonts (i.e. Po valley, Ebro river valley, Castilian plateau) and in the Atlantic rim (north of the Iberian Peninsula, Basque Country and Aquitaine). These plantations are almost exclusively privately owned, mainly by non-industrial individuals and families with small or medium ownership size. Plantation fast-growing species such as eucalyptus, maritime pine and radiata pine provide over 75% of Portuguese and Spanish wood production, in France only maritime pine contributes to 42% of the softwood production, in Italy hybrid poplars provide more than 50% of the industrial roundwood domestic supply (Martinez de Arano and Lasgourgues, 2014; Assopannelli, 2012). On the other hand, semi-natural forests in southern Europe are characterized by low productivity and declining utilization rates, with an increasingly recognized important multifunctional role (e.g. erosion control, water regulation, recreation, wild forest products production, etc.) (Forest Europe, 2015). In the near future, the demand for timber and biomass is expected to increase in southern European countries, boosted in particular by the EU bioeconomy and bioenergy policies, raising inevitably the pressure and attention on forest plantations in the region (EC, 2012; UNECE/FAO, 2011; Martinez de Arano, 2018).

The establishment of planted forests requires a considerable amount of financial resources; therefore, the investment aspect is crucial to determine their development and management. From a private perspective, the most important factor driving investments in planted forests is played by the financial returns they generate. At global level, recent forestry literature indicated interesting investment returns opportunities from planted forests (e.g. Sedjo, 1983; 2001; Cubbage *et al.*, 2014). In addition, financial research, mainly North American-based, highlighted the potential offered by forestry investments for portfolio diversification, indicating the biological growth component, the low volatility and the inflation hedging as the principal merits of these investments versus traditional stock and bond assets (Redmond and Cubbage, 1988; Zinkhan *et al.*, 1992; Cascio and Clutter, 2008; Mei and Clutter, 2010). These elements suggest that forestry investments, in particular connected to forest plantations, are likely to grow more in the future, also expanding in new regions and new market segments (i.e. those related to ecosystem services markets). Furthermore, in addition to the traditional categories of sectorial investors (i.e. local land owners, industries, small and medium industrial growers), an increasingly important role will be played by financial investors, as well as new partnerships between private and public actors (Indufor, 2012).

1.2 Problem statement

The expansion and growing importance of planted forests for industrial timber supply in many regions of the world, including southern Europe, together with the increased interest and typologies of private investors, result in a greater need for information and valuation studies on planted forests investments to support individuals, companies and institutions to make better investment and policy decisions.

While the general aspects of economics and management of planted forests have been investigated by numerous authors in literature (e.g. Kiepi, 1997; Buongiorno and Zhu, 2014; Evans and Turnbull, 2004, Bull *et al.*, 2006, etc.) and the methods to valuate forestry investment are rather consolidated (FAO, 1999; Zinkhan and Cubbage 2003; Stenger and Harou, 2015; Klemperer, 2003; Wegner, 2012), the specific topic of investment returns from planted forests is mainly tackled by private consulting studies, which are rarely made publicly available and, when they are, they often do not provide details on input data and methodology. In recent years, efforts to provide information of investment returns for important planted forest species at global level with a comparative perspective have been taken by Sedjo (2001) and by Cubbage *et al.* (2007; 2010; 2014). These studies estimated timber investment returns at aggregate level for a set of countries – principally in North America, Latin America and Oceania – identifying as well as the institutional, managerial and policy factors that affect investments.

In southern Europe there is a relative scarcity of literature on investments in forest plantations, despite their essential role in the regional timber production balance. There are some studies published in national/regional technical forestry magazines (e.g. Diaz Balteiro and Romero, 1994, Del Peso, 1995; Borelli and Facciotto, 1997, Aunos *et al.*, 2002, Rodriguez *et al.*, 2002; Vidal and Bequey, 2008), however, the diversity of objectives and approaches that characterize these studies does not allow an equal and overall comparison at regional level. So far, in southern Europe, no research has been tackling the topic of investment returns from forests plantations on a comparative perspective, providing means to compare current status and trends and the role of policy and market factors.

1.3 Research questions and objectives

The research is driven by the following **research questions**:

> Which are the potential investments returns for the main forest plantation species in southern Europe? Could these potential investment returns be attractive for sectorial investors and financial investors?

> Which are the main policy and market factors that influence financial profitability of forest plantations in the southern European context? To what extent?

> How has forest plantations financial profitability changed over recent years? How the identified policy and market factors have influenced this dynamic?

> What is the status of investments in productive forest plantations in the region? What is the role of forest plantations investments in the development of a bio-based economy in southern Europe?

These research questions have determined one overall objective and three specific objectives.

The **general objective** of the research is to estimate and compare potential investment returns for some of the main productive forest plantations in southern Europe – focusing in particular on Italy, Spain and Portugal – analysing their recent dynamic and the influence of the main policy and market factors.

The three **specific objectives** are:

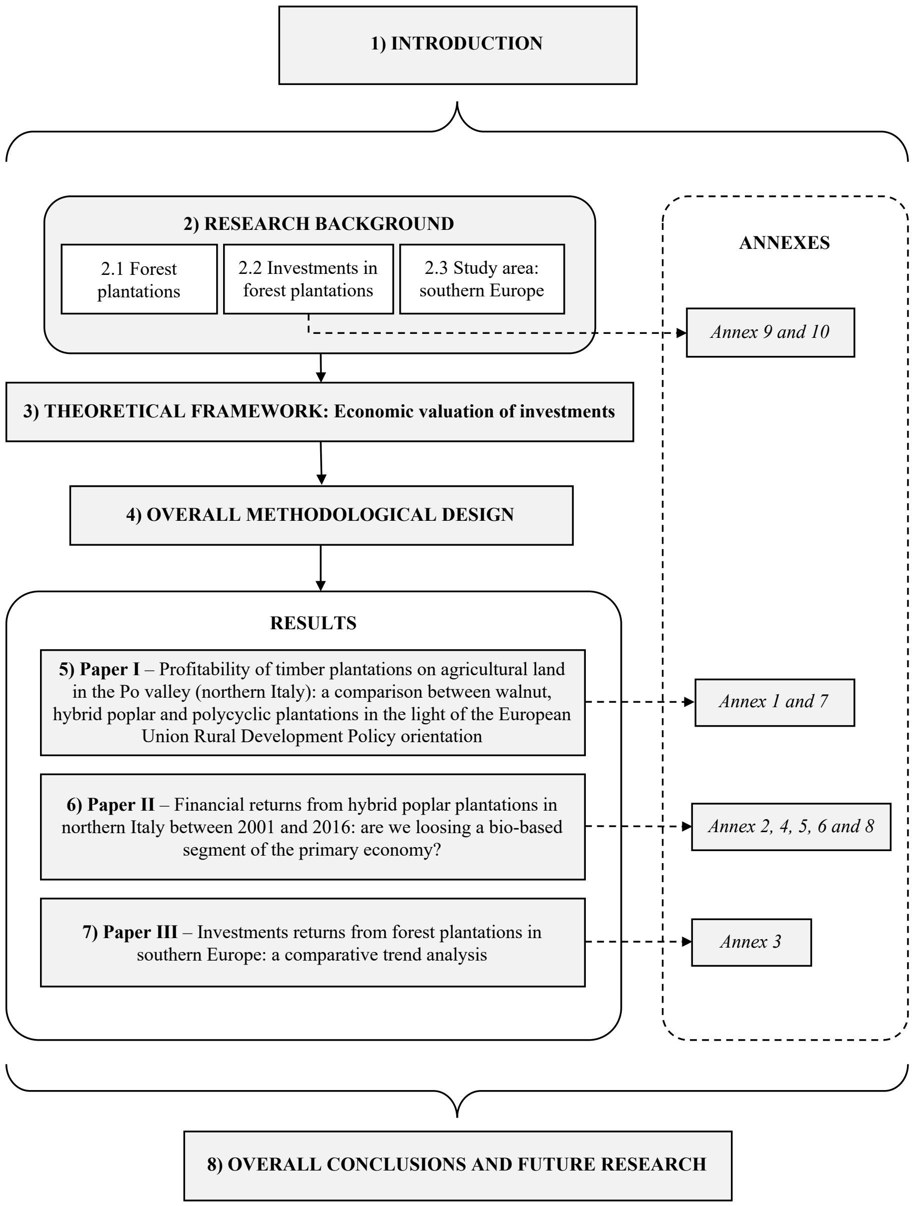
1) to estimate investments returns for some of the main plantation species and types in southern Europe at aggregate level and with a comparative approach;
2) to assess the effect of the main policy and market factors influencing investment returns, such as subsidy policies, land-use costs, opportunity-cost of alternative land uses, and timber prices variations;
3) to analyse investment returns dynamic in recent years (since the early 2000s), estimating how returns have changed as a result of the evolution of investment costs, timber prices as well as the dynamic of the main policy and market factors.

The results of the research contribute to a better knowledge on the potential timber investment returns from forest plantations in Italy, Spain and Portugal, providing means to compare the status and trends of these investments. In addition, the results will contribute as a 'benchmarking' exercise to support better investments decisions in the region.

1.4 Thesis contents and structure

Figure 1.1 provides an overview of the thesis contents and structure.

Figure 1.1: Thesis structure



Source: Own elaboration

Chapter 1 presents the research background and justification, the research questions and objectives and the thesis contents and structure. Chapter 2 introduces the background of the thesis, presenting definitions, concepts and state of the art related to: (i) forest plantations, (ii) investments in forest plantations, and (iii) the study area. Chapter 3 presents the theoretical framework of the thesis, summarizing the major theories of economic valuation of investments that constitute the reference points for the research. Chapter 4 describes the overall methodological design of the reseach. The core part of the thesis (Chapters 5, 6 and 7) consists of three papers, presented in chronological order, through which this research was developed. Paper I and II are manuscripts already accepted by international peer-reviewed journals, while Paper III is in preparation and will be submitted within 2018.

PAPER I (Chapter 5) – Pra, A., Brotto, L., Mori, P., Buresti Lattes, E., Andrighetto, N., Masiero, M., Pettenella, D. – *Profitability of timber plantations on agricultural land in the Po valley (northern Italy): a comparison between walnut, hybrid poplar and polycyclic plantations in the light of the European Union Rural Development Policy orientation*. (accepted by the European Journal of Forest Research on 06 November 2018)

PAPER II (Chapter 6) – Pra, A., Pettenella, D. – *Investment returns from hybrid poplar plantations in northern Italy between 2001 and 2016: are we losing a bio-based segment of the primary economy?* (accepted by the Italian Review of Agricultural Economics on 04 December 2018)

PAPER III (Chapter 7) – Pra, A., Brotto, L., Masiero, M., Barreiro, S., Orrandre, G., Onaindia, A., Tomé, M., Pettenella, D. – *Investments returns from forest plantations in southern Europe: a comparative trend analysis* (in preparation)

Table 1.1 reports the role of each author in the three papers reported in the thesis.

Table 1.1: Role and responsibility of authors

Responsibility/task	PAPER I	PAPER II	PAPER III
Overall responsibility	A.P.	A.P.	A.P.
Conception and design	A.P., L.B.	A.P.	A.P., M.M., L.B.,
Methodology design	A.P., L.B.	A.P., D.P.	A.P., D.P., S.B.
Data collection	A.P., L.B., P.M., E.B.	A.P.	A.P., S.B., G.O., A.O.
Data analysis	A.P., L.B.	A.P.	A.P., S.B.
Results interpretation	A.P., L.B.	A.P., D.P.	A.P., D.P., S.B.
Manuscript writing	A.P.	A.P.	A.P.
Revision	D.P.	D.P.	D.P., M.M., S.B., M.T.
Other	M.M. helped in structuring the policy framework, N.A. helped in developing the calculation spreadsheet	-	-

Note: *A.P. (Alex Pra); D.P. (Davide Pettenella); L.B. (Lucio Brotto); M.M. (Mauro Masiero); N.A. (Nicola Andrighetto); P.M. (Paolo Mori); E.B. (Enrico Buresti Lattes); S.B. (Susana Barreiro); M.T. (Margarida Tomé); G.O. (Gabriel Orrandre); A.O. (Aitor Onaindia);*

Chapter 8 presents the overall conclusions drawn from the research, including: (i) main results, (ii) methodological contributions, (iii) policy implications and (iv) future research needs. Bibliography is reported as a whole after the conclusive chapter. Finally, annexes integrate the thesis contents with additional elements and information (Table 1.2). Annexes 1, 2 and 3 present the supplementary material of the respective three papers included in the thesis. Annexes from 4 to 10 represent other publications (papers in Italian language, reports and book chapters) developed during the Ph.D. period which contribute and integrate the thesis contents. Some of these (Annexes 4 and 5) are reported integrally in the annexes with the kind permission of the publishers, while for the others (Annex 6, 7, 8, 9 and 10) we provide the link for web preview or download. In specific, Annexes 4 and 5 are two articles tackling more in depth the topic of the public support to hybrid poplar plantations in the northern Italian regions. Annexes 6 and 7 are two papers which presented preliminary results of the Paper I and II included in this thesis. Annex 8 is a technical report providing a comprehensive state-of-the-art of the poplar timber market and the results of an original survey that we carried out in Italy on the future perspective on the use of poplar timber in the plywood industry. Finally, Annexes 9 and 10 provides some more insights on the topic of sustainable and responsible forestry investments.

Table 1.2: Annexes of the thesis

Annex	Title
Annex 1	Supplementary material of Paper I
Annex 2	Supplementary material of Paper II
Annex 3	Supplementary material of Paper III
Annex 4	**PAPER:** Pra, A., Pettenella, D. (2016). *Pioppicoltura e PSR: un'opportunità da sfruttare meglio.* Informatore Agrario, 2016 (11), p. 33-35.
Annex 5	**PAPER:** Pra, A., Romano, R., Pettenella, D. (2016). *Dove va la pioppicoltura padana*? Sherwood - Foreste ed Alberi Oggi, 220.
Annex 6	**PAPER:** Pra, A., Pettenella, D. (2017). *Stima dell'andamento della redditività delle piantagioni di pioppo alla luce delle politiche di settore*. Forest@ 14: 218-230.
Annex 7	**PAPER** Pra, A., Brotto, L., Mori, P., Buresti Lattes, E., Polato, R., Pettenella, D. (2016). *Reddittività finanziaria delle piantagioni da legno: confronto tra pioppo, noce e piantagioni policicliche*. Sherwood – Foreste ed Alberi Oggi, 222.
Annex 8	**REPORT:** Levarato, G., Pra, A., Pettenella, D. (2018). *Quale futuro per la pioppicoltura? Indagine sul quadro attuale e le prospettive d'impiego industriale del legname di pioppo*. ETIFOR Srl – Spin-off dell'Università di Padova. Padova, Italia. ISBN 978-88-943378-0-8.
Annex 9	**BOOK CHAPTER:** Pra, A., Brotto, L. (2018) *Finanza a impatto e cambiamento climatico: Investimenti forestali*. Pp. 54-57. In: Venturi, P. and Perra, G. (eds.) La finanza di impatto per i cambiamenti climatici. AICCON – Italian Association for the Promotion of the Culture of Co-operation and of Nonprofit.
Annex 10	**BOOK CHAPTER:** Petrovska, R., Pra, A., Brotto, L. (2018) *Investimentos florestais sustentáveis e normas ambientais e sociais relacionadas*. Pp. 59-62. In: Oportunidades de Negócios Sustentáveis nas Florestas Tropicais Brasileiras. GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH.

Chapter 2

Background

This chapter presents the background of the thesis. Based on a literature review, it provides definitions, concepts and state-of-the-art related to forest plantations (2.1), including their definition and classification, resources and policy context; investments in forest plantations (2.2); and context information about the study area, i.e. southern Europe (2.3).

2.1 Forest plantations

2.1.1 Definition and classification of forest plantations

The issue of defining and classifying forest types is complex but also of paramount importance for gathering accurate and comparable statistical information as well as to improve scientific communication and public awareness.

If we just consider forest plantations, there is somehow a continuum from short-rotation industrial plantations to 'close-to-nature' plantations for conservation purposes, making a clear and reasonable classification extremely challenging, in particular on a global scale. In addition, the complexity increases as we consider that many plantations, as well as semi-natural forests, might have a mix of silvicultural treatments and histories (e.g. partly planted and parly naturally-regenerated). The terms 'planted forest', 'plantation' and 'forest plantation' have been often used interchanbeably as synonymous in forestry literature, also in recent times. In addition, there are other terms that can be often found in literature, e.g. 'industrial plantations', 'environmental plantations', 'tree farms', 'tree crops' and so on. Since the 1990s, there have been several attempts to provide a widely-accepted definition and classification of forest plantations, according to their purpose, species composition or scale, all based on artificial regeneration as common basic criterion (e.g. Adlard, 1993; Lund, 2000; CIFOR, 2002; Carle and Holmgren, 2003). At institutional level, before the Food and Agriculture Organization of the United Nations (FAO) took the lead on harmonizing forest-related definitions, the question of planted forests definitions was firstly raised at the United Nations Forum on Forests (UNFF) intersessional meetings on the Role of Planted Forests in Sustainable Forest Management in Chile (Anon., 1999) and New Zealand (Anon., 2003). For what concerns the FAO, until 2005, forest statistical data were collected based on two main categories: 'natural forests' and ‘plantations’. With the the Global Forest Resources Assessment (FRA) of 2005 (FAO, 2005), FAO introduced two new categories, ‘modified semi-natural forests’ and ‘semi-natural forests’, which resulted in four main categories based on the degree of human intervention and the regeneration methods. A new classification, formally introducing the term ‘planted forest’ as a macro-category (Table 2.1), has been adopted by FAO in 2012 (FAO, 2012a) and applied for the first time in the FRA of 2015 (FAO, 2015).

Table 2.1: Scope of planted forests

Natural forest			**Planted forest**			**Non-forest**
		Semi-natural forests		**Forest plantations**		
Primary	**Modified natural forests**	**Assisted natural regeneration**	**Planted component**	**Productive**	**Protective**	Trees outside forest (TOF)
			“Forest of native species, established through planting, seeding or coppice”	"Forests of primarly introduced and native species, established through planting or seeding mainly for productive purposes ”	“Forests of native or introduced species, established through planting or seeding mainly for provision of environmental services”	

Source: modified from FAO (2012a)

Planted forests are therefore defined as those forests “predominantly composed of trees established through planting and/or deliberate seeding, where planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity (…)”. Planted forest comprises both forest plantations established for productive (i.e. roundwood, fibre, fuelwood, non-wood forest products) and protective purposes (i.e. landscape restoration, hydrogeological preservation, climate amelioration, biodiversity conservation, etc.). In addition, planted forests include also the planted component of semi-natural forests, categorized as Semi Natural Planted Forests (SNPF), which represent large areas in the northen hemisphere (e.g Canada, Scandinavian countries, Russia). Trees on cities, farms, along roads and gardens are categorized as Trees Outside Forests, not included in the definition of planted forests. In this research, our main interests involved the sub-category forest plantations, in particular productive forest plantations, defined as “forests of primarily introduced and native species, established through planting or seeding mainly for productive purposes”, in our case wood production (FAO, 2012a).

2.1.1 Planted forests resources at global level

The most comprehensive sources of statistics on forests at global level is provided by the FAO's FRA. However, it has to be noted that the change of definitions and categories has determined some problems in comparing forest resource statistics from different sources and years. According to Payn *et al.* (2015) – who analysed in depth the data related to planted forests and forest plantations of the FRA from 1990 to 2015 – the area of planted forests has increased from 165.5 million ha in 1990 to 277.9 million ha in 2015, corresponding to an increase from 4.06% to 6.95% of the total forest cover. This increase took place despite the world total forest area has decreased from 4.28 billion ha to 3.99 billion ha between 1990 and 2015, resulting in a decrease of the global forest cover from 31.85% to 30.85%, although with significant differences among regions (i.e. it has worryingly decreased in the tropics and sub-tropics, while it has increased in the northern hemisphere). The area of planted forests has been steadily increasing since 1990, by 4.42 million ha per year on average, however, the rate of increase appears to have slowed in the 1990-2015 period (Payn *et al.*, 2015). Planted forests are located mainly in temperate zones (56%), in particular east Asia and Europe, while 29% are located in tropical and subtropical and only 15% in boreal regions. Temperate zones registered also the largest increase in planted forest area between 1990 and 2015, from 93.4 million ha to 154.4 million ha, where an important role has been played by China's large-scale afforestation programs. As a matter of fact, there are 20 top countries that accounts for 85% of the planted forest area, of which the main ones are China (79 million ha), United States (26.4 million ha), Russia (19.8 million ha), Canada (15.8 million ha), Sweden (13.7 million ha), India (12.0 million ha) and Japan (10.3 million ha) (Payn *et al.*, 2015). On the basis of FAO (2010) data, the proportions of the two sub-categories forest plantations and SNPFs is almost similar at global level. At regional level, South America and Oceania have almost no SNFPs, North and Central America have two-thirds of planted forests corresponding to forest plantations, Asia has a rather balanced proportion, while Europe has more than 65% of planted forests corresponding to SNPFs (Table 2.3). A term of comparison can be found in Indufor (2012), which provides statistical estimates based on the Fast-Growing High Yielding (FGHY) plantations category (i.e. which includes only intensively managed productive plantations, excluding SNPF, protection plantations and those established for bioenergy or non-wood products production). These are estimated to cover 54.3 million ha at global level, where the largest area is in the Americas and in Asia, respectively 25.6 million ha and 17.7 million ha (Indufor, 2012).

For what concerns the ownership, Del Lungo *et al.* (2006), indicate that the area of planted forests in public ownership has decreased from 70% in the 1990 to 50% in 2005, industrial ownership has been stable at about 18%, and smallholder ownership has raised from 12% in 1990 to 32% in 2005, although there are significant differences between regions and countries.

A summary of data on planted forests resources and industrial roundwood production is presented in Table 2.2.

Table 2.2: Planted forest resources and roundwood production data

Region	Total forests area 2015 (Million ha)	Total forests area 2015 (Million ha)	Annualised percentage change in planted forest are 1990-2015	Proportion of planted forest with introduced species	Planted forest industrial roundwood 2012 (1000 m^3)	Planted forests percentage of total roundwood
World	3,999.1	277.9	+2.0%	19%	770,200	46.3%
South America	842.0	15.0	+2.5%	88%	193,00	89.8%
Oceania	173.5	4.3	+1.9%	75%	47,500	84.0%
East and Southern Africa	274.8	4.6	+1.2%	65%	20,700	64.7%
Caribbean	7.1	0.7	+2.4%	42%	300	24.7%
East Asia	257.0	91.8	+2.2%	25%	78,700	46.9%
Central America	86.2	0.4	+0.6%	21%	1,600	18.0%
West and Central Africa	313.0	3.2	+3.2%	18%	5,100	14.1%
Southern and SE Asia	292.8	29.9	+3.4%	12%	82,700	52.0%
North Africa	36.2	8.4	+0.9%	10%	400	15.7%
Europe	1,105.4	70.4	+1.3%	8%	166,200	33.4%
West and Central Asia	43.5	6.7	+2.1%	3%	3,900	19.1%
North America	657.1	42.1	+2.5%	1%	170,100	36.0%

Source: based on Payn et al. (2015) and Jurgensen et al. (2014)

2.1.3 Contribution of planted forests to the global industrial timber supply

Planted forests vary widely in terms of species, location, management, but also for the main purposes, which may vary from exclusively productive to also protective. Del Lungo *et al.* (2006), based on FRA 2005 data (FAO, 2005), estimated that the 76.0% of planted forests were established for productive purposes. This percentage increases up to 78.5% if we consider only forest plantations, which were reported to cover 141 million ha (Table 2.3). Planted forests certainly play an essential role in matching the global demand for wood, fibres and other forest products, in particular industrial roundwood (i.e. sawnwood, plywood and veneer, reconstituted panels, and modular components such as laminated products, framing, floorings, etc.), wood fibres for pulp and paper, and biomass for energy (i.e. fuelwood, chips and pellets). In addition, there is a significant segment of forest plantations established for the production of non-wood forest products (e.g. rubber, cork, pine nuts).

Table 2.3: Planted forests and plantations by productive and protective function (000 ha)

Regions	Planted forests (2005)		sub-cat: Forest plantation (2005)	
	Productive function	**Protective function**	**Productive function**	**Protective function**
Africa	11,838	3,000	10,876	2,462
Asia	86,172	45,812	44,414	20,474
Europe	63,014	16,106	21,651	6,027
North/Central America	27,859	1,190	17,653	1,190
Oceania	3,833	32	3,833	32
South America	12,158	57	12,132	57
World	204,874	66,197	110,560	30,259
	271,071		140,819	

Source: Carle and Holmgren. (2008), based on FAO (2005) data

The range of species used for productive plantations is rather narrow. Globally, the most common species used for plantations are *Pinus* spp., followed by *Eucalyptus* spp., *Acacia* spp. (Carle and Holmgren, 2008). In temperate and Mediterranean regions mainly *Eucalyptus globolus*, hybrid poplars, *Pinus radiata*, *P. pinaster* and *P. taeda*, in the tropics and sub-tropics *Eucalyptus grandis*, *E. camaldulensis*, *E. globolus*, *Pinus caribaea*, *P. elliottii*, and *P. patula*, while in cooler areas (i.e. boreal regions) *Pinus sylvestris*, *Abies* spp., and *Picea* spp. Plantations are dominated by exotic or introduced species (>75%) in south America, Oceania and Eastern and Southern Africa, while in Europe and North America this percentage is below 10% (1% in North America). The global average is about 18% (Table 2.3). These species, in plantation contexts, usually reach much higher growth rates and yields than natural forests. Table 2.4 provides examples of Mean Annual Increment (MAI) and rotation for some of the main plantation species at global level, based on a review.

Table 2.4: Examples of MAI (m3/ha/yr) for some of the main plantation species at global level

Species and types	MAI (m^3/ha/yr)	Rotation (years)	Country or region	Source
Eucalyptus grandis and other tropical and sub-tropical eucalyptus hybrids	15-40	5-15	Brazil, South Africa, Uruguay, India, Congo, Zimbabwe	Cossalter and Pye-Smith, 2003
	15-40 (70 for Brazil)	7-20	South Africa, Brazil, Chile	Sedjo, 1999
	15-40	-	Brazil	Sedjo and Botkin, 1997
	30-70	-	Brazil	Tomberlin and Buongiorno, 2001
	30-40	12-15	Brazil, Colombia	Cubbage *et al.,* 2010
	32	20	South Africa	Cubbage *et al.,* 2010
	10-20	5-10	China, India, Thailand, Vietnam, Madagascar	Cossalter and Pye-Smith, 2003
Temperate eucalyptus (***E. globulus***)	15-30	10-15	Chile. Portugal, Spain. Argentina. Uruguay, south Africa, Australia	Cossalter and Pye-Smith, 2003
	11-12	-	Spain and Portugal	Sedjo and Botkin, 1997
	10-15	8-12	Spain and Portugal	Sedjo, 1999
	22-35	9-16	Uruguay and Argentina	Cubbage *et al.,* 2010

Tropical Acacias (*A. mangium, A. auriculiformis, A. crassicarpa*)	15-30	7-10	Indonesia, China, Malaysia, Vietnam	Cossalter and Pye-Smith, 2003
	15-25	-	Indonesia	Sedjo and Botkin, 1997
Pinus (*P. taeda, P. eliotti, P.radiata*)	8-35 (including *P. pinaster*)	10-35	Argentina, Chile, New Zealand, Australia, USA, Europe	Cossalter and Pye- Smith, 2003
	10-45	15-35	Brazil, East Africa, South Africa	Sedjo, 1999
	15-30	-	Argentina, Chile, New Zealand	Sedjo and Botkin, 1997
	10-25	-	USA, Chile, New Zealand, South Africa, Brazil	Tomberlin and Buongiorno, 2001
	20-30	15-20	Argentina, Brazil, Chile, Uruguay	Cubbage *et al.,* 2010
	12.5-15 (only *P. taeda*)	23-30	USA	Cubbage *et al.,* 2010
	20-35	20-22	Argentina, Brazil, Chile, Uruguay	Cubbage *et al.,* 2007
	7-12 (only *P. taeda*)	30-40	USA	Cubbage *et al.,* 2007
Caribbean pines (*P. caribea*)	15-35	10-18	Venezuela	Cossalter and Pye- Smith, 2003
	25	12	Venezuela	Cubbage *et al.,* 2010
Poplars	11-30	7-15	China, India, USA, Canada, Europe, Turkey	Cossalter and Pye-Smith, 2003
	9-37	-	Canada	Van Oosten, 2000
Sitka spruce (*Picea sitchensis*)	14	40	UK	Sedjo, 1999

Source: own elaboration based on cited sources

Concerning the contribution of planted forests to the global industrial timber supply, several assessments have been conducted in recent years by different authors. Jurgensen *et al.* (2014) carried out an assessment in 84 countries based on a mix of sources, estimating that planted forests were already providing 46.3% of the industrial roundwood globally (770 million m^3 per year). By region, the authors indicated that the industrial roundwood production from planted forests was 193 million m^3 in South America, followed by Asia (151 million m^3) and North and Central America (104 million m^3), while the production in Oceania, Europe and Africa was considerably less, ranging from 26 million m^3 to 47 million m^3. If considering only plantations (excluding SNPF), the production is estimated at 562 million m^3, equivalent to one third (33%) of the total production of industrial roundwood. Carle and Holmgren (2008) – based on a survey on the status of planted forests in 61 countries (representing over 95% of the total planted forests area) – estimated the potential industrial wood production from planted forests at 1.2 billion m^3, corresponding to the two-thirds of the overall global wood production. In this case, the authors indicate that the proportion of wood for industrial use is about 85% of all wood from planted forests. In addition, they estimate the total wood production to reach between 1.39 billion m^3 and 1.89 billion m^3 by 2030, depending on how technology and genetic improve over the years. Indufor (2012) estimates the production of industrial roundwood from Fast Growing High Yielding (FGHY) plantations at 520 million m^3 in 2012.

All these studies suggest that planted forest area will continue to expand in the future driven by the increasing demand for wood and fibre. Carle and Holmgren (2008) estimate the total wood production from planted forests to reach between 1.39 billion m3 and 1.89 billion m3 by 2030, depending on how technology and genetic improve over the years. Indufor (2012) predicts that the production level from FGHY plantations may increase by 2050 to about 1.082 million m^3 under a business as usual scenario or to 1.988 million m^3 in a maximum yield scenario.

2.1.4 Policy context and sustainability challenges

The potential role of planted forests in sustainable forest management has been recognized by the United Nations Conference on Environment and Development (UNCED), Earth Summit in Rio 1992 – which results are reflected in the Agenda 21 (UN, 1993) – and other UN legally binding conventions such as the Framework Convention on Climate Change and the Convention on Biological Diversity. Plantations have been recognized to play a significant role also in reaching the Millennium Development Goals, i.e. 'eradicate extreme poverty and hunger' (goal 1), 'ensure environmental sustainability' (goal 7), and 'develop global partnership for development' (goal 8) (Evans, 2009). These policy instruments recognize the key role that forest plantations have, if managed responsibly, in the provision of wood, fibres and other forest products, as well as other important social and environmental services. This aspect has been the aim of a growing number of responsible management standards and guidelines that have been recently developed addressing specifically forest plantations concerns, finding a balance between economic, environmental and social dimensions of the related investments (e.g. Clark and Kozar, 2011; Masiero *et al.*, 2015).

Nevertheless, the productivity and expansion and the on-going management of forest plantations are facing several major challenges deriving from climate change impacts and population growth. Impacts of climate change will affect species productivity and adaptation (Zhu *et al.*, 2012; Pearson, 2006) and will determine more frequent and severe weather events and pest problems (Dale *et al.*, 2001). On the other hand, population growth will certainly determine an increasing demand for wood and fibres, but also a substantially increasing competition for land use, in particular with agriculture (e.g. the United Nations projects that a 60% increase in food production will be needed by 2050). It is worthwhile to note that Payn *et al.* (2015) indicate that the decrease in expansion rate of planted forest area in the period 2010-2015 (+ 1.2% annually) is of concern because it is below the rate of 2.4% needed to meet the projected future demand of wood and fibre according to WWF and IIASA (2012), which would offset deforestation impacts on wood supply.

An additional key challenge that affects forest plantations is connected to societal expectations and perceptions. In recent years there have been serious concerns among citizens, policy-makers and NGOs about the negative impacts of forest plantations in some contexts, both of environmental and socio-economic nature, in particular related to native forest area conversion, use of non-native species, land tenure conflicts, and impacts on wildlife. Concerns mainly arose in the southern hemisphere, where the dominant model is the one of industrial plantations, intensively managed, with exotic species and with a low degree of local communities' involvement. Nevertheless, there are examples of conflicts around the topic of forest plantations also in Europe, e.g. in Portugal and Spain, connected to the issue of forest fires (Alvarez-Diaz *et al.*, 2015; Fernandes, 2008). These concerns are fuelling a strong debate also among scientists. In this sense, several authors blamed forest plantations for being "(…) poor substitutes of natural ones" and to cause negative impacts on local communities, biodiversity, soil erosion and water resources (e.g. Morrison and Bass, 1992; Carrere and Lohman 1996; Parretta, 1995; Montagnini *et al.*, 2005). On the one hand, obviously excluding those cases of bad and non-responsible management, several authors emphasizes the potential merits of forest plantations, such as the positive role of in decreasing pressure on the harvest of natural forests (Sedjo, 2001; Dal Secco and Pirard, 2015; Buongiorno and Zhu, 2014), the provision of important ecosystem services if compared to other land uses (Bull *et al.*, 2006; Pawson *et al.*, 2013; Evans and Thurnbull, 2004), and the positive contribution to climate change mitigation (Carle *et al.*, 2002). Indeed, in spite timber production remains the main reason for the expansion of forest plantations, there are more and more examples of forest plantations established for the purpose of climate change mitigation, e.g. under the Clean Development Mechanism (CDM) of the Kyoto Protocol and with Reducing Emissions from Deforestation and forest Degradation (REDD) schemes as well as under emerging markets for biodiversity protection and water conservation (e.g. Scheyvens and Lopez-Casero 2009; Bennet and Ruef, 2016; Hamrick and Gallant, 2017). For a comprehensive analysis of arguments for and against forest plantations, see Cossalter and Pye-Smith (2003).

2.2 Investments in forest plantations

Investments are a key driver in the establishment and management of forest plantations. Forestry investments represent an allocation of financial capital in a real asset, and consist in the acquisition and/or in the management of bare land to afforest or of a forest stand, with the goal to obtain a financial return, which is essentially generated by three components:

- the biological growth of trees producing wood, fibres or other marketable forest products;
- the increase over the medium-long term in the prices of timber and wood products;
- the long-term forested land capital appreciation.

Forestry investments have a long history in many countries, traditionally held by forest products companies to secure their timber supply as well as by local landowners as a source of income or for maintaining their capital. Forestry investments as assets for financial investors have a more recent history; assets in the context of financial investments, these are more commonly defined as timberland investments. The first remarkable examples of financial forestry investments have been promoted by pension funds in the United States and in the United Kingdom already in the 1970s and 1980s, which started to invest in forestry as a mean to diversify their investments to minimize the risk of large losses (FAO, 2012b). In addition to the combination of timber income and long-term land capital appreciation, the potential of forestry investments for financial portfolio diversification showed to play an important role in attracting new professional investors in the sector. In the last thirty years, research highlighted these potentials (Redmond and Cubbage, 1988; Cascio and Clutter, 2008; Mei and Clutter, 2010):

- the low volatility, since timber investments returns are inversely or negatively correlated with traditional stock market performances;
- inflation hedging capacity, as forestry investments provide protection from inflation;
- competitive risk-adjusted returns, providing interesting returns in relation to their volatility, in particular in emerging countries;
- biological growth component, which is independent to all factors typically affecting traditional investment assets.

Therefore, during the 1980s and 1990s, a growth and diversification of investments in forestry was observed, moving from sectorial investors (e.g. wood-working industry and local landowners) to financial investors, in particular institutional investors (Rinehart, 2010; Toppinen and Zhang, 2010). This trend led also to the emergence of Timberland Investment

Management Organizations (TIMOs) and Timberland Real Estate Investment Trusts (T-REITs) for managing these types of investment assets (Box 2.1). The spectrum of investors connected to forest plantations is summarized in Table 2.5.

Table 2.5: Spectrum of investors connected to forest plantations

Private				**Public**
Sectorial investors		**Financial investors**		
Individuals and families (**landowners or not land owners)**	Industry (forestry, energy, others)	Retail investors (e.g. individuals, small and medium sized companies)	Institutional investors (e.g. pension funds, banks, insurance companies, other investment funds)	Central or local Governments (also though State Forest Management Organizations)

The assets value under TIMOs and T-REITs management started to increase significantly already in the 1990s, from about 1 billion USD to 10-12 billion USD in North America (Zinkhan *et al.*, 1992). In the last 20 years TIMOs and T-REITs have been expanding gradually into new regions and markets, in particular in Oceania (e.g. New Zealand, Australia), South America (e.g. Chile, Brazil, Uruguay and Argentina) and Asia (e.g. Vietnam, Malaysia), driven by high biological growth rates, low costs of timber production, convenient land prices and acceptable risk levels. In addition, the geopolitical uncertainties and the declining general expected returns have stimulated institutional investors to increase the share of real assets (such as forestry investments) in their portfolios. Globally, the capital placed in forestry has increased in the last twenty years, reaching over 100 USD billion at present (FAO, 2012b, NewForests, 2017). An overview of forestry investment development is synthetically presented in Table 2.6.

Table 2.6: Synthetic historical development of forestry investments

	1980s	**1990s**	**2000s**	**2010s**
Products	Timber	Timber and certified timber	Timber, certified timber and carbon	Certified timber, bioenergy and ecosystem services
Drivers	First studies of forestry investments (as inflation hedge and balance in portfolio returns)	Benefits of diversification. Growing demand for wood, new markets and favorable conditions in emerging markets.		Benefits of diversification. Growing demand for forest products and ecosystem services in emerging markets. Possibility of Sustainable and Responsible Investments.
Ownership	Forest industry and local landowners. Emerging of institutional investors (mainly pension funds)	Expansion and consolidation of financial investors. Emerging of TIMOs and REITs		Growing role of private equity, sectorial and financial investors, partnerships
Regions	North America	North America, Oceania	North America, Oceania, South America	North America, Oceania, South America, Asia, Europe, Southern and Eastern Africa
Capital invested	1 billion USD	12 billion USD	30 billion USD	>100 billion USD

Source: modified from Indufor (2012)

Indufor (2012) suggests that forestry investments, in particular connected to forest plantations, will grow more in the future, with an increasingly important role played by partnerships between strategic and financial investors as well as between private and public actors, including local landowners, industries and small and medium sized tree growers.

In the case of forest plantations, the interest in investing goes along with the globally increasing demand for wood and fibres global (Jonsson and Whiteman, 2008), driven by the evolution in consumption habits that are shifting towards products with low environmental impact (e.g. the evolution in the building industry) and by bioeconomy policies that foster the transition towards production and energy systems based on biomaterials, such as wood and fibres. Nevertheless, in recent years, there are new raising trends related to ecosystem services (carbon credits, eco-tourism, non-wood forest products, etc.) and biomass for energy that are enhancing the attractiveness and potential of forestry investments in new regions. The forest sector is nowadays also a fertile ground for Sustainable and Responsible Investments (SRI). In recent years, SRI – i.e. those investments integrating of Environmental, Social and Governance (ESG) issues in the investment strategies – emerged as a growing trend at global level (UNECE/FAO, 2014). As an example, EUROSIF (2014) estimates that SRI in Europe have been growing by 35% annually since 2011. In the case of forestry investments, the adoption of strategies to improve ESG issues management (e.g. silvicultural and technological improvements, local communities' involvement, market diversification, etc.) showed to be able to add substantial value to the assets. At the core of SRI strategies there is the ability to measure ESG impacts and monitor progress, and in this regard, the forestry sector is at a very advanced level. Specifically, today there are more than 50 standards, quality protocols and rating systems applicable to forestry investments to ensure their environmental sustainability and to mitigate technological, legal, reputational and social risks (Brotto *et al.*, 2016).

Box 2.1 provides definitions of the main finance-related terms and concepts used in this thesis.

Box 2.1 – Finance-related terminology definitions (source: www.investopedia.com)

Investment: "An investment is an asset or item acquired with the goal of generating income or appreciation, (…) a wide variety of investment vehicles exist including stocks, bonds, commodities, mutual funds, exchange-traded funds (ETFs), foreign exchange, and real estate".

Investor: "Any person who commits capital with the expectation of financial returns".

Institutional investor: "is an organization that invests on behalf of its members. (…) There are six types: endowment funds, commercial banks, mutual funds, hedge funds, pension and insurance funds".

Retail investor: “a non-professional investor who buys and sells who deals in securities only occasionally, especially dealing in small quantities. Includes individual investors, odd-lotters and small investors”.

Financial portfolio: “a grouping of financial assets such as stocks, bonds, commodities, currencies and cash equivalents, as well as their fund counterparts, including mutual, exchange-traded and closed funds. A portfolio can also consist of non-publicly tradable securities, like real estate, art, and private investments. Portfolios are held directly by investors and/or managed by financial professionals.”.

Timber Investment Management Organization (TIMO): “a management group that aids institutional investors in managing their timberland investment portfolios. A TIMO acts as a broker for institutional clients. The primary responsibilities of TIMOs are to find, analyze and acquire investment properties that would best suit their clients. Once an investment property is chosen, the TIMO is given the responsibility of actively managing the timberland to achieve adequate returns for the investors”.

Real Estate Investment Trusts (REITs): “a company that owns, operates or finances income-producing real estate. For a company to qualify as a REIT, it must meet certain regulatory guidelines. REITs often trades on major exchanges like other securities and provide investors with a liquid stake in real estate”.

2.3 Study area: southern Europe

The study area of this thesis is southern Europe. Geographically, the area identified as southern Europe corresponds the Iberian Peninsula, southern France (i.e. Aquitaine, Occitanie, Provence-Alpes-Côte d'Azur), the Italian peninsula and the Mediterranean countries of southeast Europe, i.e. Slovenia, Croatia, Montenegro, Albania, Greece, Turkey and Cyprus. Table 2.7 summarizes some socio-economic indicators for the main southern Europe countries.

Table 2.7: Socio-economic profile of the main southern European countries

Country	Area (km^2)	Population	Population density (people/km^2)	GDP per capita (USD/people)	Human Development Index	Gini Index	EU member	Currency
Spain	505,990	46,700	92	40,290	0.884	34.5	Yes	EUR
France*	551,695	65,058	116	43,760	0.901	30.1	Yes	EUR
Turkey	783,356	80,810	105	11,114	0.761	40.0	No	Turkish Lira (TRY)
Italy	301,340	60,484	201	39,499	0.880	30.1	Yes	EUR
Greece	131,957	10,768	82	29,060	0.886	33.4	Yes	EUR
Portugal	92,212	10,291	111	31,965	0.847	33.5	Yes	EUR
Croatia	56,594	4,154	75	25,807	0.831	27.7	Yes	Kuna (HRK)
Slovenia	20,273	2,067	102	36,566	0.896	24.4	Yes	EUR

** only metropolitan France is considered*
Source: own elaboration based on official countries' statistics. Human Development Index (HDI) are based on UNDP (2018); GDP are based on IMF (2018); Gini Index are based on World Bank (2018)

For what concerns the forest types, southern Europe is characterized by two principal forest regions. On the one hand, the Atlantic rim (i.e. northern part of the Iberian Peninsula and Aquitaine), continental piedmonts (i.e. Po river valley, Castilian plateau) and some mountain ranges (i.e. Alps, Pyrenees, northern Apennines) are characterized by humid and temperate forests. On the other hand, most of central and southern Iberian Peninsula, southern France, southern and central Italy, Greece and the Adriatic coast of the Balkan region and Southern Europe are dominated by Mediterranean forests.

According to the State of Europe's Forests (Forest Europe, 2015), plantations cover 4.4 million hectares in south-west Europe (i.e. France, Spain, Italy and Portugal) corresponding to the 14% of the total forest area. Given the suitable edaphic and climatic conditions, forest plantations play an important role in particular in the Atlantic rim and in the continental piedmonts, with a significant share of exotic species. In the Atlantic rim, forest plantations are dominated by maritime pine (*Pinus pinaster*) and eucalyptus (*E. globolus* and *E. nitens*), but also radiata pine (*Pinus radiata*) and Scotch pine (*Pinus sylvestris*) play an important role in some areas.

Martinez de Arano *et al.* (2018) estimates that in the region these species produce around 30 million m^3 of roundwood, which corresponds to over 75% of Portuguese and Spanish wood production and 42% of the total French softwood production. In southern European continental piedmonts, a relatively important role in terms of forest plantations is played by hybrid poplar, in particular along the main rivers (i.e. Po in Italy, Duero and Ebro in Spain, Garonne in southern France). In these areas, hybrid poplar plantations cover around 250 thousand hectares in total and play an essential role in the regional timber balance, in particular for the plywood and other wood-based panel industries. For example, in Italy, hybrid poplars provide alone more than 50% of the industrial roundwood domestic supply (Assopannelli, 2012). Forest plantations in the region are mainly privately owned, with small size and fragmented ownership. Private ownership by individuals and families is the dominant model in southern Europe, even though there are examples of industrial owners, also with land lease arrangements. However, contrary to central and northern Europe, forest owners' organizations are relatively recent and there are very few examples of forest cooperatives. Table 2.8 summarizes the main data on forests, planted forests and productive plantations for the main southern European countries.

Table 2.8: Forest, planted forest and productive plantation in the main southern European countries

Country	Total forest area (000 ha)	Planted forest area (000 ha)	Percentage of planted forests on total forest area	Productive plantations area* (000 ha)	Main exotic species used	Main native species used
Spain	18,373	2,908	15.80%	1,486	*Pinus radiata* *Eucalyptus* spp. *Populus* hybrids	*Pinus pinaster* *Pinus sylvestris*
France	16,989	1,968	11.60%	1,064	*Populus* hybrids *Psedotsuga mentziesii* *Picea sitchensis* *Quercus rubra*	*Picea abies* *Pinus nigra* *Pinus pinaster* *Pinus sylvestris* *Larix decidua* *Acer* spp. *Quercus petrea*
Turkey	11,715	3,386	28.90%	1,977	n.a.	n.a.
Italy	9,297	639	6.90%	147	*Populus* hybrids *Pinus radiata* *Eucalyptus* spp. *Quercus* spp.	*Juglans regia* *Prunus avium* *Quercus petrea* *Quercus robur*
Greece	4,054	140	0.40%	-	-	-
Portugal	3,155	891	28.25%	1,068	*Eucalyptus* spp.	*Pinus pinaster*
Croatia	1,922	75	3.90%	61	*Pinus nigra* *Populus* hybrids	*Pinus halepensis* *Pinus sylvestris* *Populus nigra* *Picea abies*
Slovenia	1,248	34	2.7%	-	-	-
Europe	1,015,500	70,400	6.90%			
World	3,999,100	277,900	6.95%			

** Author's estimation based on FAO (2005) data;*
Source: own elaboration based on data from Del Lungo et al. (2006), FAO (2015) and Payn et al. (2015)

On the other hand, Mediterranean forests as well as the remaining semi-natural forests in the mountain regions are characterized by a low-productivity and low management intensity (i.e. with wood removals are generally less than half of the annual biological growth). Nevertheless, these forests have an increasingly recognized important multifunctional role (e.g. erosion control, water regulation, recreation, wild forest products production, etc.). Mediterranean forests are also considered among the most delicate ecosystems at global level and can count on a well-developed environmental protection framework.

Southern European forests plantations are increasingly exposed, due to climate change impacts, to biotic and abiotic phenomena. In particular, the major risks derive from forest fires and windstorms, but also pest and diseases represent a common concern for the future of forest plantations in the region (Gardiner *et al.,* 2010; Lindner *et al.,* 2010). Forest fires have been observed to significantly increase in frequency and severity and this is a rather new phenomena, strictly connected to rural abandonment and expansion of forest areas, which results in large cover of young forests and high fuel loads due to lack of management. In recent years, about 400 thousand hectares of forests have burnt annually in southern Europe. Windstorms are also an issue of growing concern, in particular in some other areas of the Atlantic rim, i.e. the extraordinary heavy windstorm Klaus in Aquitaine in 2009, which felled over 40 million m^3 of roundwood and destabilized the wood demand as well as the short and mid-term supply perspectives from the affected forests.

For what concerns the forest-based industry, its structure is diversified and dynamic in southern Europe. The regional sawmilling industry consists mainly of small and medium-sized enterprises with low innovation capacity, which have to face a high fragmented and heterogeneous wood supply and high harvest and logging costs. Nevertheless, there are some notable examples of woodworking industries with high industrial and technological production capacities, i.e. Italy is the third world furniture exporter, but the wood supply relies almost completely on imports. On the other hand, the pulp and paper and the wood-based panels sectors are based on large enterprises with higher capacity to compete on global markets. Both these sectors have been growing in recent years, in particular the pulp and paper industries in Portugal, France and Spain, and the wood-based panels industries in Italy and Spain. Driven by an important domestic pulp and paper industry, the forest-based industry represents the 2.1%, of Portuguese Gross Domestic Product (GDP), while in all other southern European countries is around or below 1% The bioenergy sector plays an increasingly important role as well, in particular the pellets industry (Martinez de Arano *et al.*, 2018).

Chapter 3

Theoretical framework: economic valuation of investments

This Chapter presents the theoretical framework of the thesis. Starting from the general economic theories underlying the research, we firstly describe the economic valuation approach used in the research, i.e. financial analysis approach (3.1), and secondly, we present the concepts, calculation methods and state-of-the-art literature of financial analysis applied to forest plantations investments (3.2).

The economic methods and approaches used in this thesis are the typical ones of the economic valuation of investments, in specific of the financial analysis. These methods are directly developed within the neoclassical economic theory, which nowadays still represent the most widely taught form of economics. Therefore, being derived from the neoclassical theory, they are based on three main assumptions, i.e. individual's rational behaviour, profit or utility maximization objective, and independent and informed valuation capacity. Nevertheless, in the discussion sections, we included also some elements of other economic branches, such as institutional economics (when discussing aspects related to contracts, transaction costs and public subsidies) and environmental economics (when discussing elements related to the environmental impacts in comparing investments opportunities, e.g. when comparing monospecific and mixed plantations investments).

3.1 The financial analysis approach

The economic valuation is defined as the process of evaluating an investment, a business or a project in order to determine its economic performance and suitability. As mentioned, in this thesis we refer specifically to the financial analysis approach. The choice is motivated by the fact that in this research we focus on investments which are of a private nature and where financial profitability is assumed as the most important driver for investing. The financial analysis considers costs and revenues in terms of market prices and it is carried out from the private perspective of an individual, a company or, more in general, an organization, carrying out the investment. In the economic literature the financial analysis is most common approach to evaluate the profitability of an investment.

Nevertheless – even though we don't consider it in this thesis – it is worthwhile to mention that the financial analysis methods can be extended in order to include the environmental and social dimensions of an investments, from the perspective of the society as a whole. In this case, we enter in the field of those evaluation techniques defined as Cost-Benefit Analysis (CBA) where e basic distinction is made between financial analysis based on market process and what is called economic analysis where elements such as externalities or welfare benefits are taken into consideration, using market prices where available but also non-market prices for those goods and services not traded in the market or with market prices not properly representing their true value (the willingness to pay). While financial analysis is rooted in the neoclassical theory and its applications to business management, CBA was developed in the '60s and '70s of last century thanks also to the contribution of environmental and development economics in order to better evaluate public-funded investments. The first main references for the application of CBA are represented by the guidelines developed by the Organization for Economic Cooperation and Development (OECD, 1968) and United Nations Industrial Development Organization (UNIDO, 1972). More recently, also the European Commission developed CBA guidelines specifically for Europe (EC, 2008a).

The main differences in terms of assumptions and application between the two approaches are summarized in Table 3.1.

Table 3.1: Financial versus economic analysis: assumptions and applications

Characteristic	Financial analysis	Economic analysis
Economic value assumptions	Individuals have measurable utility and seek to maximize profit; equilibrium market prices measure individual preferences	Individuals and society seek to maximize utility; aggregate social economic values measure society's preferences
Decision criteria	Efficiency; profits; financial present values and rates of return	Efficiency; net social benefits; economic present values and rates or return
Cost and prices	Measured by commercial market values	Measured by commercial market values, shadow prices, willingness to pay, and total economic value
Price measurements	Market costs and prices	Market costs and prices, or the total value of consumer's and producer's surplus for market and non-market goods
Data used	Market prices, price reporting series, historical data, wholesale or retail prices	Market prices, revealed preference analyses, stated preference surveys, benefit transfer
Applications	Financial analysis; individuals, companies, organizations, bank loans, taxes, subsidies	Economic analysis; society, community or country point of view, individual entities, lending agencies

Source: modified from Cubbage et al. (2015)

3.2 Financial analysis applied to forest plantations investments valuation

The application of the financial analysis approach in forest economics can count on a rather consolidated body of literature. Traditionally, the most common uses of financial analysis methods have been the calculation of the optimal rotation period of a forest stand, the estimation of the forest land value, and the cost-effectiveness analysis of silvicultural treatments (e.g. thinning, pruning, phytosanitary treatments) or afforestation/reforestation alternatives. These methods are explained in some of the most well-known books and manuals on forest economics, such as Price (1989), Gregersen and Contreras (1979), Pearse (1990), Klemperer (2003) and Solberg (2010).

In this research, we focus on estimating the financial returns of forest plantations investments. In recent years, various manuals and guidelines specifically addressing this topic have been published, demonstrating also its increasing relevance. Some of the most frequently quoted publications – which have been also used as main theoretical references this research – are Zinkhan and Cubbage (2003) and Cubbage *et al.* (2015). The work done by Diaz-Balteiro *et al.* (2014) represents a useful reference as well because it describes the financial analysis methods with a specific perspective on industrial plantations. Harrison and Herbohn (2016) provide an additional interesting guideline, aiming to support researchers and practitioners to overcome the most common defects and mistakes when valuating forestry projects.

3.2.1 The financial analysis process

One of the most common ways to estimate financial returns of forest plantations investments is to use analytical methods, such as the capital budgeting indicators (or profitability indicators). These indicators allow to assess and compare investments projects on a common basis. According to Gregersen and Contreras (1979), Cubbage *et al.* (2015) and other authors the main steps in a financial analysis of forest plantations investments process include:

i) defining the project objectives;
ii) collecting data;
iii) estimating the costs and prices inputs;
iv) developing the cash flow tables;
v) elaborating capital budgeting indicators;

vi) evaluating the rick and uncertainty of the investment (sensitivity analysis) and the non-monetary and non-quantitative elements influencing the project implementation.

Most of these elements (i, ii, iii and vi) are presented in Chapter 4, which describes the methodological aspects related to data collection, processing and interpretation. This Chapter provides instead the conceptual basis, calculation methods, and literature applications of the specific capital budgeting indicators used in the research.

3.2.2 Cash flow tables, discount rate and inflation

The development of the cash flow table is prior to the calculation of capital budgeting indicators. The cash flow tables report and describe the costs and revenues produced by each investment project activity along the investment timeline, as showed e.g. in Table 3.2.

Table 3.2: Example of cash flow table

	Year	**0**	**1**	**2**	**3**	**4**	**…**	***n***
Costs	**Site preparation**	500.00						
	Planting	1,500.00						
	Silvicultural management		100.00	100.00	100.00	100.00		100.00
	Administration costs		5.00	5.00	5.00	5.00		5.00
	…							
	Net costs	2,000.00	105.00	105.00	105.00	105.00		105.00
Revenues	**Timber sale**							5,000.00
	Subsidy		1,000.00					
	…							
	Net revenues	0	1,000.00	0	0	0		5,000.00
Net revenues – Net costs		-2,000.00	+895.00	-105.00	-105.00	-105.00		+4,895.00

One of the essential elements to be considered when analysing investments is the Time Value of Money (TVM), which is taken into consideration in most of the capital budgeting indicators formulas. The TVM is the assumption that money today is worth more than the same amount of money in the future, based on neoclassical economics theory of rationality. Therefore, capital must include an opportunity-cost. This opportunity cost is represented by the discount rate (i), and it is essential in determining if an investment is viable or not. In economic valuation, the choice of the appropriate discount rate is always controversial. Nevertheless, from a conceptual point of view, its choice should be easier within a financial analysis approach based on a private perspective. In this case, the discount rate it represents the investor's opportunity cost for the investment capital.

Discount rates cited in the literature for private-based forest plantations investments vary from 2% to up 12%, where values <6-7% are typically used in northern hemisphere, and > 8% in emerging countries (Price, 1993). Indications in the choice of the discount rates are provided also by public agencies, e.g. HM Treasury (2003) indicates a 3.5% discount rate for forestry investment in Europe, while the European Commission indicates a 5% the for investments in the forestry and agriculture sectors in the EU (Snowdon and Harou, 2013).

In addition, in the selection of the discount rate, also the inflation must be considered. Discount rates may be expressed in nominal terms (i.e. including inflation) or real terms (i.e. excluding inflation).

Table 3.3 presents examples of discount rates used in financial analysis of forestry literature.

Table 3.3: Examples of discount rates used in financial analysis of forestry investments

Country/Region	Species	Discount rate used	Reference
Global	Various selected spp.	2%	Row *et al.*, 1981
France	Poplar, walnut and admixtures	2%	Vidal and Bequey, 2008
Spain	Various selected spp.	3-10%	Del Peso *et al.,* 1995
Spain	*Populus* spp.	3%, 4.25%, 7%	Aunos *et al.*, 2002
Global	Various selected spp.	3.5%	Boardman *et al.,* 2005
Spain	*Eucalyptus* spp.	4%	Diaz-Balteiro *et al.*, 2009
Global	Various selected spp.	4%	Duku Kaakyre and Nanang, 2002
Global	Various selected spp.	4-8%	Cubbage *et al.*, 2014
Spain and Portugal	*Eucalyptus* spp.	4%, 6.5%, 7.5%, 12%	Kling, 2012
United States	*Populus* spp.	4.6%	Tankersley, 2006
United States	*Pinus* spp.	5%	Perdue *et al.*, 2017
Spain	*Eucalyptus* spp.	5%	Gimenez *et al.*, 2013
Portugal	*Eucalyptus* spp.	5%	CELPA, 2016
Spain	*Eucalyptus* spp.	5%	Arosa Gomez, 2000
United States	*Pinus* spp.	5.7%	Mills and Stiff, ?
Serbia	*Populus* spp.	6%	Keča *et al.*, 2017
Australia	Various selected spp.	7%	Spencer *et al.*, 1999
Vietnam	Various selected spp.	7-12%	Narayan Marasani *et al.*, 2017
America	Various selected spp.	8%	Cubbage *et al.*, 2007
Spain	*Populus* spp.	9%	Diaz Balteiro, 2008
Spain	*Eucalyptus*	10%	Cano and Britos, 2014
Serbia	*Populus* spp.	12%	Keča *et al.*, 2011

Source: own elaboration based on cited sources

3.2.3 Capital budgeting indicators used in the research

The capital budgeting indicators used in this research are:

- Net Present Value (NPV)
- Equivalent Annual Value (EAV)
- Internal Rate of Return (IRR)
- Land Expectation Value (LEV)
- Discounted Payback Period (PBP)

The main characteristics of the selected capital budgeting indicators are presented synthetically in Table 3.3.

The NPV represents the difference between the present value of revenues (cash inflow) and costs (cash outflow) over a period of time. NPV is an indicator of the absolute profitability, thus its value represents the total discounted profit associated with the investment. According to the NPV rule, for single investment decision one would accept an investment that has a positive NPV, which indicates that the projected revenues exceed the anticipated costs, making the investment financially viable. When comparing investments, the investor would choose the investments that has the greater NPV.

One of the limits of the NPV is that does not allow a comparison between investments with different rotations length on an equal basis. To overcome this limit, it is possible to distribute the NPV equally on an annuity-basis along the rotation period, assuming that the rotations can be repeated *ad infinitum*. This method is termed EAV (Cubbage *et al.*, 2007). It has to be noted that in forestry literature this method is also found as Equivalent Annual Annuity, Net Present Annuity, or simply Annuity. The EAV is useful to compare investments that have different rotations, e.g. to compare forestry investments with different rotation lengths, or to compare forestry investments with other land uses that generate annual incomes such as agricultural crops (Davis *et al.*, 2001).

IRR represents the discount rate (i) at which the NPV of the investment equals zero. Therefore, it is a useful indicator also because it does not imply any assumption on the discount rate (Brealey *et al.,* 2011). Due to the nature of the formula, the IRR must be calculated either using a software programmed to calculate it or through trial-and-error. As a decision rule, the higher an investment's IRR is, the more profitable it is in financial terms. Being an indicator of relative profitability, it can be used to rank multiple investments on a relatively equal basis, although it presents some limitations that have to be considered when interpreted (Diaz-Balteiro *et al.*, 2014).

LEV represents the present value of all future costs and revenues assuming that the rotation cycle will be replicated an infinite number of times, with the same species, type of management and subject to the same constraints. The LEV – also termed Soil Expectation Value or Bare Land Value – is based on the 'Faustmann formula' (Faustmann, 1849). The LEV is more a comparative indicator. Indeed, it was developed to solve the problems of comparing investments with unequal rotation lengths, and it is useful indicator for estimating the theoretical land value and compare land-use options. As for the NPV, also in this case, an investor should choose the investment with a positive LEV. Of course, the LEV will be greater than the NPV for a single rotation (as long as it is positive).

The discounted PBP indicates the length of time (years) required to recover the costs of the investment. Longer the PBP is, higher is the investment risk component associated to potential unforeseen events. Therefore, an investor would prefer the investments with shorter PBP (Klemperer, 1996), but as such PBP should not be considered as a proper profitability indicator but an indicator of risk exposure: an investment could have a much lower PBP than another having a NPV and a IRR also much lower.

Table 3.4: Selected capital budgeting indicators basic characteristics

Indicator	Formula	Profitability	Decision rule
NPV	$NPV = \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n}$	**Absolute**	NPV > 0 (and) NPV project a > NPV project b
	Where: n =year; R=revenues; C=costs; i= discount rate; N=investment horizon		
EAV	$EAV = LEV * i$	**Comparative**	EAV > 0 (and) EAV project a > EAV project b
	Where: LEV =Land Expectation Value; i= discount rate;		
IRR	$IRR = i: \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n}$	**Relative**	IRR > i (and) IRR project a > IRR project b
	Where: n =year; R=revenues; C=costs; i= discount rate; N=investment horizon		
LEV	$LEV = \frac{NPV * (1+i)^N}{((1+i)^N - 1)}$	**Comparative**	LEV > 0 (and) LEV project a > LEV project b
	Where: NPV =Net Present Value; i= discount rate; N=investment horizon		
PBP (discounted)	$PBP = n: \sum_{0}^{N} \frac{R_n}{(1+i)^n} = \sum_{0}^{N} \frac{C_n}{(1+i)^n}$ $0 \leq n \leq N$	**Comparative (indicator of risk exposure)**	PBP project a < PBP project b
	Where: n =year; R=revenues; C=costs; i= discount rate; N=investment horizon		

Source: own elaboration based on Klemperer (2003), Wegner (2012), Cubbage et al. (2015)

The suitability of one indicator in comparison to another one depends on the characteristics of the investments and on the investor's goals. Nevertheless, as a general rule, none of these indicators should be used as universal (Klemperer, 2003). The NPV is generally considered the most intuitive method to evaluate the profitability and some authors consider the NPV as a preferable criterion to be used when analysing short term investments (Brealey et al., 2008;

Wegner, 2012). Cubbage et al. (2015) suggested that at a known discount rate, NPV and LEV are the best indicators from a theoretical point of view for ranking alternative investments. However, it has to be taken into consideration that seldom is there a given discount rate. The IRR is *de facto* the most commonly used indicator in literature for investment comparisons. IRR is widely used when discount rates are uncertain and when comparing investments different than forestry (Sedjo, 2001; Cubbage et al., 2007). Hogaboam and Shook (2004) found that 52% of forest industry companies used IRR as preferred capital budgeting indicator, while only 18% used NPV.

3.2.4 Examples from forestry literature

In recent years there have been studies (Sedjo, 2001; Cubbage *et al.;* 2007; 2010; 2014) applying financial analysis to estimate investment returns from the main forest plantations species and contexts at global level. The main species considered are *Pinus* spp. (*P. taeda, P. carribea, P. patula, P. eliotti* and *P. radiata*) and *Eucalyptus* spp. (E. *grandis, E. globolus and E. dunnii*), while the investigated contexts are North America, New Zealand, South Africa and Latin American countries. The results of these studies, that serve as a reference for this research, are synthesized in Table 3.5.

Table 3.5: Examples of financial analysis of forest plantation profitability at global level

Species		Country/Region	IRR	NPV	Reference
***Pinus* spp.**	*P. taeda*	USA	12%-14.1%		Sedjo, 2001
		Brazil (south)	15.6%-17.5%		Sedjo, 2001
		USA	9.5%	333 USD/ha (*i*=8%)	Cubbage *et al.*, 2007
		Argentina (Misiones)	12.9%	1,148 USD/ha (*i*=8%)	Cubbage *et al.*, 2007
		Argentina (Corrientes)	10.5%	370 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Uruguay	15.1%	1,634 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Brazil	16%	1,870 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Brazil	20.8%	3,590 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
		USA (South Carolina)	8.5%	151 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
		USA (North Carolina)	6.9%	-269 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
	P. carribea	Venezuela	15%	1,509 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
	P. patula	South Africa	19.3%–17.7%		Sedjo (2001)
		South Africa	11.1%	1,677 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
	P. eliotti	Brazil	16.3%	2,309 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
	P. radiata	Chile	23.4% -17.0%		Sedjo (2001)
		New Zealand	11.9%–13.1%		Sedjo (2001)
		Chile	16.9%	2,729 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Chile	10.9%	2,270 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
		New Zealand	7.6%	204 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
***Eucalyptus* spp.**	*E. grandis*	Brazil (central)	20.2%-15.5%		Sedjo (2001)
		Argentina	13.8%	2,729 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Brazil	22.7%	3,716 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Uruguay	21.9%	2,890 USD/ha (*i*=8%)	Cubbage *et al,* 2007

		South Africa	12.4%	2,256 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
		Argentina	18.2%	2,176 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
		Brasil	25.5%	5,690 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
	E. dunnii	Brazil	22.9%	1,196 USD/ha (*i*=8%)	Cubbage *et al,* 2007
	E. globulus	Uruguay	12.8%	319 USD/ha (*i*=8%)	Cubbage *et al,* 2007
		Uruguay	22.9%	1,178 USD/ha (*i*=8%)	Cubbage *et al.,* 2010
***Picea* spp.**	*Picea abies*	Europe	4.6%-5.6%		Sedjo, 2001

Source: own elaboration based on cited source

Chapter 4

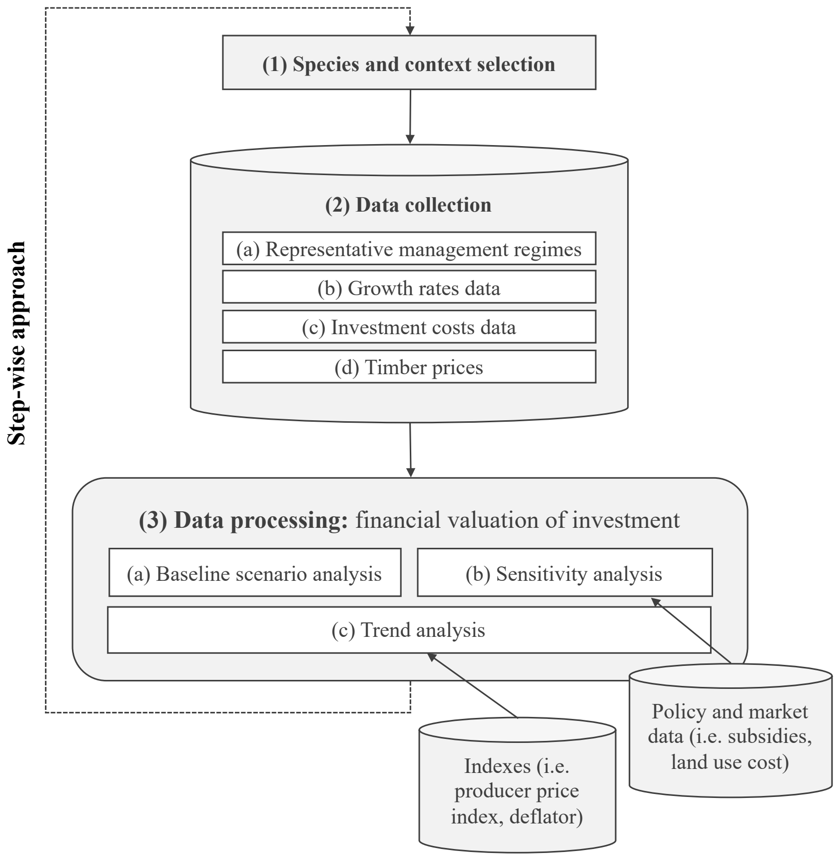
Overall methodological design

This Chapter presents the overall methodological design that connects the three papers presented in the thesis. In addition, it summarizes their focuses, assumptions and data sources. The Chapter is organized in the following sections: 1) general overview; 2) species and contexts selection; 3) data collection; and 4) data processing.

4.1 General overview

As presented in the introduction (Chapter 1), the research has been developed through the production of three main papers. Each of these three papers deals with the research objectives with different focuses, assumptions and data sources. Nevertheless, these papers are characterized by a common overall methodological design, as presented in Figure 4.1.

Figure 4.1: Research overall methodological design



Source: own elaboration

Table 4.1 provides an overview of the specific objectives tackled by each paper. In addition, it reports also the targets, which are important to understand the assumptions used in each paper.

Table 4.1: Specific objectives tackled in each paper and target

Paper	Specific objectives tackled	Target
PAPER I	• *SO-1: to estimate investments returns for some of the main plantation species and types in southern Europe at aggregate level and with a comparative approach* • *SO-2: to assess the effect of the main policy and market factors influencing investment returns, such as subsidy policies, land-use costs, opportunity-cost of alternative land uses, and timber prices variations*	Mainly local landowners
PAPER II	• *SO-1* • *SO-2* • *SO-3: to analyse investment returns dynamic in recent years (since the early 2000s), estimating how returns have changed as a result of the evolution of investment costs, timber prices as well as the dynamic of the main policy and market factors*	Mainly local landowners and industrial poplar growers
PAPER III	• *SO-1* • *SO-2* • *SO-3*	Sectorial and financial investors

4.2 Species and context selection

Table 4.2 and Figure 4.2 presents the specific species and contexts analysed in each paper. Our main interests involved the category of forest plantations, in particular productive forest plantations for wood and fibers production. In addition, our focus was on forest plantations which are of a private nature, i.e. those which are property of industrial producers, non-industrial private forest owners, and financial investors. Forest plantations which are owned by public organizations (e.g. State forest enterprises, research institutes, etc.) or those established with a primary protection aim are not analyzed in this research.

The species and contexts of analysis were included progressively through an iterative step-wise approach (instead of *a-priori* selected cases study). We included in our research some of the most important forest plantations species and contexts in terms of contribution to the regional timber supply and amount of investments, such as:

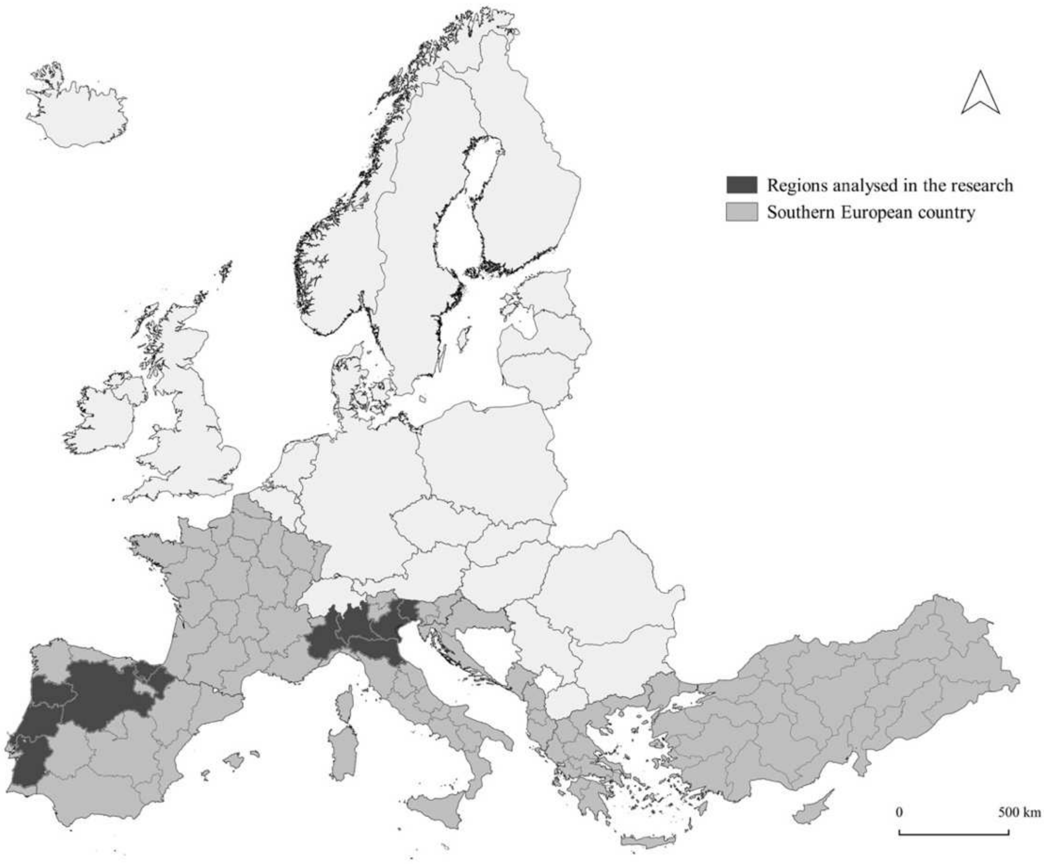
- hybrid poplar (*Populus x canadensis* clone 'I-214') in northern Italy (Emilia-Romagna, Friuli Venezia-Giulia, Lombardy, Piedmont, Veneto) and in Castile and León and Navarre (Spain);
- Eucalyptus (*Eucalyptus globulus* Labill.*)* in Portugal*;*
- Maritime pine (*Pinus pinaster* Aiton) in Portugal;
- Radiata pine (*Pinus radiata* D.Don) in the Basque Country (Spain).

For what concerns Paper I, we included, for policy-driven motivations, also high value hardwood plantations of walnut (*Juglans regia* L.) and polycyclic plantations, which are an innovative example of mixed and multi-rotation plantations.

Table 4.2: Species and contexts considered in each paper

Paper	Species	Context
PAPER I	• *Populus x canadensis* clone I-214 • *Juglans Regia* • Polycyclic plantations	Po river valley (northern Italy)
PAPER II	*Populus x canadensis* clone I-214	Northern Italy
PAPER III	• *Populus x canadensis* clone I-214 • *Eucalyptus globulus* • *Pinus pinaster* • *Pinus radiata*	• Northern Italy • Castile and León (Spain) • Navarre (Ebro river valley) (Spain) • Basque Country (Spain) • Portugal

Figure 4.2: Regions analyzed in the research



Source: own elaboration

4.3 Data collection

Data on management regimes, growth rates, investment costs and timber prices were collected in each of these contexts using different data sources. Table 4.3 summarizes data sources and data reference year in each paper.

Table 4.3: Data sources and reference year for each paper

Paper	Data sources	Data reference year
PAPER I	• Scientific and 'grey' literature • AALSEA and LIFE+ project InBioWood[1] experimental sites	2015
PAPER II	• Scientific and 'grey' literature • Industrial and non-industrial poplar growers (through interviews) • Farms archives, agricultural contractors' rates, public administration bulletins, Chambers of Commerce • FAOSTAT Agricultural Producer Price Index (country-specific) for time-series completion	• 2016 in the baseline and sensitivity analyses • In the trend analysis: 2001-2016 for investments costs and 2001-2018 for timber prices
PAPER III	• Scientific and 'grey' literature • Experts from forest owners' associations, industry, research institutes and public administration (though interviews) • Forestry and agricultural contractors' rates, public administration bulletins, Chambers of Commerce • FAOSTAT Agricultural Producer Price Index (country-specific) for time-series completion	• 2017 in the baseline and sensitivity analyses • In the trend analysis: depends on the species and context

In addition, for what concerns Paper II and III, the list of practitioners, experts and organizations contacted for collecting data is reported in Table 4.4. In these cases, face-to-face interviews and visits were carried out in Italy during 2016 and beginning of 2017, in Spain from March to May 2017 (with the support of the Mediterranean Facility of the European Forest Institute-EFIMED) and in Portugal during October-November 2017 (with the support of the Instituto Superior de Agronomia of the University of Lisbon). The interviews were followed in most of the cases by e-mail exchanges for results and interpretation revisions.

In all three papers, we empirically defined representative forest stand management regimes for each species and area, following an approach similar to the one used in Sedjo (1983) and Cubbage *et al.* (2007; 2014). We used these representative management regimes since the main study's objective was to estimate and compare potential returns at aggregate level under typical current conditions, and not to estimate optimal returns and neither carry out a site-specific or exhaustive analysis. For what concern the definition of management regimes, information

[1] For more details see: www.inbiowood.eu

mainly relied on literature (Paper I) or discussions with experts (Paper II and III). In some cases, we considered different management scenarios in order to cover a reasonable range of situations related to management options.

For each area we defined growth rates and yields which could represent the typical range of sites productivity in the analized contexts. In Paper I, growth rates and yields for hybrid poplar, walnut and polycyclic plantations are derived from the Association of Tree Farming for Economy and the Environment (AALSEA) and from the LIFE+ InBioWood experimental sites in Mantua (San Matteo delle Chiaviche, Ponte sull'Oglio, Viadana) and Verona (Gazzo Veronese, Villa Bartolomea) provinces. In Paper II and III, growth rates and yields were determined based on different approaches. For what concerns hybrid poplar, we determined the growth rates and yields based on literature and expert's knowledge both in Italy and Spain. In the case of Portugal, growth rates and yield for eucalyptus and maritime pine were determined using the StandsSIM Portuguese forest simulator (with GLOBULUS and PINASTER growth and yield models) developed by the Instituto Superior de Agronomia. For determining the growth rates for radiata pine in the Basque Country we used the yield tables developed by HAZI in collaboration with the forest owners' associations of the Basque Country (HAZI, 2017).

Plantations establishment and management costs were derived mainly from farm archives, forest owners' associations, agricultural and forestry contractors' rates, and public administration bulletins. The cost of the operations has been estimated assuming a minimum and maximum range in Paper I and II, while in Paper III we derived costs level assuming appropriate and ordinarily efficient implementation according to the typical industrial management standards.

In all three papers, for the analysis we considered timber stumpage prices, assuming standing trees to be purchased by external buyers. Stumpage prices were obtained from literature in Paper I, while in Paper II and III were mainly derived from forest owners' associations, with the exception of Italy, where stumpage prices are derived from Chambers of Commerce.

Table 4.4: List of contacted experts and organizations

Country/region	Expert name	Affiliation	Location	Date	Type of information*	Paper
Italy	Pierfranco Zanone	Industrial poplar producer (Aziende Agricole Torviscosa)	Torviscosa (UD), Italy	19/01/2016	GEN, FM, GR, PRI, SUB, LAND	II, III
Italy	Gianluigi Pippa	Professional poplar grower and representative of the regional poplar growers inside Confagricoltura-Veneto	Padova, Italy	07/03/2016	GEN, FM, GR, PRI, SUB, LAND	II
Italy	Raoul Romano	Research Unit on Bioeconomy and Forest Policy of the National Research Center on Agriculture Economics	Rome, Italy	09/03/2016	GEN, SUB	II
Italy	Fabio Boccalari	Professional poplar grower and president of the Italian Poplar Growers Association (API)	Mantova, Italy	17/02/2017	GEN, FM, GR, PRI, SUB	II, III
Italy	Francesco Mattioli	Professional poplar grower	Mantova, Italy	17/02/2017	GEN, FM, GR, PRI, SUB	II
Italy	Ivan Turco	Industrial poplar producer (Turco Ivan e Maria Rosa Pitton Snc)	Tolmassons (UD), Italy	10/02/2017	GEN, FM, GR, PRI, LAND	II, III
Italy	Nicoletta Azzi	Plywood industry and industrial poplar producer (Panguaneta SpA)	Sabbioneta (MN), Italy	15/11/2016	GEN, FM, PRI, LAND	II, III
Italy	Domenico Coaloa	Research Unit on Intensive Wood production of the National Research Center on Agriculture Economics	Casale Monferrato (AL), Italy	10/11/2015	GEN, FM, GR, PRI	II, III
Spain (Navarre)	Elena Baeza	Regional public administration of Navarre	Pamplona, Spain	23/03/2017	GEN, FM, GR, PRI, SUB, LAND	III
Spain (Navarre)	Gabriel Orrandre	Industrial poplar producer (Bosqalia)	Pamplona, Spain	23/03/2017	GEN, FM, GR, PRI, SUB, LAND	III
Spain (Navarre)	Antonio Astrain	Regional forest owner's association of Navarre (FORESNA)	Pamplona, Spain	24/03/2017	GEN, PRI, SUB	III
Spain (Navarre)	Emilio Garcia	Wood-panels industry and industrial poplar producer (Tableros Garfer)	Viana, Spain	24/03/2017	GEN, FM, PRI, LAND	III
Spain (Castile and León)	Jesus Rueda	National Poplar Commission	Valladolid, Spain	06/04/2017	GEN, FM, GR, PRI, SUB	III
Spain (Castile and León)	Angel Sanchez Martin	Regional public administration of Castile and León	Valladolid, Spain	06/04/2017	GEN, FM, SUB, LAND	III
Spain (Castile and León)	Nacho Arroyo	Public-owned industrial poplar producer (SOMACYL)	Valladolid, Spain	07/04/2017	GEN, FM, GR, PRI, SUB, LAND	III

Spain (Castile and León)	Olga Gonzalez	Regional forest Owners Association of Castile and León (FAFCYLE)	Valladolid, Spain	07/04/2017	GEN, PRI, SUB	III
Spain (Basque Country)	Amelia Uria Peña	Forest Owners Association of Alava province (ARABAKO)	Alava, Spain	25/05/2017	GEN, FM, PRI, SUB	III
Spain (Basque Country)	Ismael Mondragon	Provincial public administration of Gipuzkoa province	San Sebastian, Spain	26/05/2017	GEN, SUB	III
Spain (Basque Country)	Fernando Otazua	Forest Owners Association of Gipuzkoa province (GIPUZKOAKO)	San Sebastian, Spain	26/05/2017	GEN, FM, GR, PRI, SUB	III
Spain (Basque Country)	José Larrañaga	Sawmill industry (Serreria Larrañaga)	Azpetia, Spain	27/05/2017	GEN, PRI	III
Spain (Basque Country)	Aitor Omar Aspiazu	Provincial public administration of Bizkaia province	Bilbao, Spain	27/05/2017	GEN, SUB	III
Spain (Basque Country)	Fernando Azurmedi and Aitor Onaidia	Forest Owners Association of Bizkaia province (BIZKAIKO)	Bilbao, Spain	28/05/2017	GEN, FM, GR, PRI	III
Spain (Basque Country)	Irune Larreategi	Forest Owners Association of Bizkaia province (BIZKAIKO)	Bilbao, Spain	28/05/2017	SUB	III
Spain	Alvaro Aunós	University of Lleida	Lleida, Spain	22/03/2017	GEN, FM, PRI	III
Spain	Hugo Rodriguez	Forestry contractor (Servitec)	Ourense, Spain	10/05/2017	GEN, FM	III
Spain	Ana Orions	Spanish woodworking industries confederation (CONFMADERA)	Santiago de Compostela, Spain	11/05/2017	GEN, PRI	III
Spain	Juan Picos	Professor at University of Vigo	(Skype)	06/06/2017	GEN	III
Portugal	Francisco Goes	Portuguese pulp and paper industry association (CELPA)	Lisbon, Portugal	06/11/2017	GEN, FM, PRI, SUB	III
Portugal	Luis Fontes and André Simóes de Carvalho	Pulp and paper industry (Navigator)	Lisbon, Portugal	02/11/2017	GEN, FM, SUB, LAND	III
Portugal	Nuno Calado	Forest owner's association (UNAC)	Lisbon, Portugal	06/11/2017	GEN, FM, PRI, SUB, LAND	III
Portugal	Susana Carneiro	Research institute (CentroPinus)	(Skype)	17/11/2017	GEN, FM, SUB	III
Portugal	Joana Faria	FSC Portugal	(e-mail contact)	20/11/2017	GEN, PRI	III

* Acronyms refer to: GEN=general information; FM=forest management regimes; GR=growth rates and yields; PRI=timber stumpage prices; SUB=subsidies; LAND=land costs

4.4 Data processing

Data processing was rather similar in the three papers. We carried out a financial analysis, developing cash flow tables considering costs and prices in terms of market values and calculating typical capital budgeting indicators: NPV, EAV, IRR, LEV and PBP. The theoretical framework, presenting the conceptual basis and calculation methods behind these indicators is presented in Chapter 3.

Table 4.5 reports which of the indicators used in each paper. NPV and IRR have been used in all three papers; these are the most commonly used indicators in literature for investment projects comparisons. In Paper I and III, where we had to compare investments that have different rotation lengths, we used the EAV as primary indicator. The LEV (or Soil Expectation Value) was included in Paper II and III as an additional useful indicator for estimating the theoretical land value and compare land-use options. For what concerns the normalisation process, we always used one hectare as the reference unit. In papers I and III we included the discounted PBP as well, which is an indicator of risk exposure, i.e. length of time (years) required to recover the costs of the investment.

For what concerns the discount rate, we decided to use a real discount rate for all species and countries in each paper. Nevertheless, we also tested different ones to allow the readers to compare the results on different assumptions. A real discount rate, i.e. excluding inflation, is considered generally better for financial analysis, given that future inflation rates are unknown and difficult to predict (Cubbage *et al.*, 2015). Discount rates used in each paper are reported in Table 4.5.

The financial analysis has been organized in three steps (Table 4.5):

- baseline financial analysis;
- sensitivity analysis;
- trend analysis.

In the baseline financial analysis, no land use costs and subsidies were included. Therefore, we assumed that the investor already owns the land and need to make investment decisions. The baseline estimates provided a starting point to compare investment returns on an equal basis. However, the assumptions behind the baseline scenario are somehow based on a deterministic approach, with a simplification of real-world plantation investment cases always much more complex and diversified. Therefore, we also carried out sensitivity analyses to test the effect of alternative hypothesis (e.g. variations in investment costs or timber stumpage prices, public subsidies as available, opportunity costs of alternative production, land costs, etc.). Baseline and alternative scenario assumptions are summarized in Table 4.6.

We carried out as well a trend analysis in order to estimate how financial indicators have evolved over recent years as a result of the evolution of the investment costs and timber stumpage prices. Time series data have been converted from nominal values into real values using the general deflator indexes provided by countries' official institute of statistics. Capital budgeting indicators for the trend analysis were calculated for each year along the period covered by data combining two different calculation approaches: *ex-ante* and *ex-post*. The *ex-ante* approach provides us the expected returns, answering the question: what was the return's expectation at the time the investment was carried out? Thus, is calculated based only on values of the year when the investment was carried out. For example, in the case of a 10-years rotation plantation of hybrid poplar in Italy, the NPV of a plantation established in 2001 would be calculated as follows:

$$NPV\ ex\ ante_{2001} = \frac{R_{2001}}{(1+i)^{10}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2001}}{(1+i)^{2}} - \frac{C_{2001}}{(1+i)^{3}} - \cdots - \frac{C_{2001}}{(1+i)^{10}}$$

Where R_n and C_n are the sum of revenues and costs at year n.

On the other hand, the *ex-post* approach provides us the actual evolution of costs and prices throughout the years along the investment horizon, e.g. considering the same example of a 10 years rotation plantation of hybrid poplar in Italy, the NPV of 2001 would result from the following calculation:

$$NPV\ ex\ post_{2001} = \frac{R_{2011}}{(1+i)^{10}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2002}}{(1+i)^{2}} - \frac{C_{2003}}{(1+i)^{3}} - \cdots - \frac{C_{2011}}{(1+i)^{10}}$$

Therefore, the *ex-post* estimates provide information on the actual financial returns according to input variables evolution throughout the years. However, in this latter case, it has to be considered that we did not carry out any future projection estimation for the input variables which have been assumed as constant.

Finally, the analysis is carried out before income- and land-tax. This choice is motivated by the fact that the countries' tax regimes vary substantially depending on the legal status and the business model of the investors.

Table 4.5: Type of analysis, indicators and discount rates considered in each paper

Paper	Types of analysis	Indicators calculated	Discount rate
PAPER I	• Baseline financial analysis • Sensitivity analysis	• NPV (EUR/ha) • EAV (EUR/ha/yr) • IRR • PBP (discounted)	• 3.5% as baseline • 2%, 5% and 8% as alternatives
PAPER II	• Baseline financial analysis • Sensitivity analysis • Trend analysis (for the sensitivity scenarios as well)	• NPV (EUR/ha) • IRR • LEV (EUR/ha)	• 3.5% as baseline • 2%-12% as alternatives
PAPER III	• Baseline financial analysis • Sensitivity analysis • Trend analysis (only for the baseline scenario)	• NPV (EUR/ha) • EAV (EUR/ha/yr) • IRR • LEV (EUR/ha) • PBP (discounted)	• 5% as baseline • 2%-8% as alternatives

Table 4.6: Baseline assumptions and alternative scenario tested in each paper

Paper	Baseline assumptions	Alternative scenarios tested
PAPER I	• Minimum and maximum investment costs • Average and high site fertility (based on growth rates and rotation length) • Average stumpage price	• Opportunity cost of agricultural land use (real) • Subsidies (real) • Land lease (real) • Timber prices variations (hypothetical)
PAPER II	• Minimum and maximum investment costs • Average site conditions • Minimum and maximum stumpage price	• Subsidies (real) • Land lease (real) • Opportunity cost of alternative land use (real) • Risk insurance cost (real)
PAPER III	• Average investment costs • Low, medium and high site productivity (based on growth rates and rotation length) • Average stumpage price	• Increased investment costs (real) • Minimum and maximum stumpage prices (real) • Subsidies, if available (real) • Land lease and purchase

Chapter 5

Paper I – Profitability of timber plantations on agricultural land in the Po valley (northern Italy): a comparison between walnut, hybrid poplar and polycyclic plantations in the light of the European Union Rural Development Policy orientation

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Abstract

While forest plantations are increasing their key role of provisioning timber supply at global level, also their potential capacity to deliver other ecosystem services is gaining interest. In the European Union, the Rural Development Policy has been encouraging forest plantations on farmland, progressively focusing the public support to multifunctional forest investments.

In this study, we estimated and analysed potential financial returns from forest plantations on agricultural land, focusing specifically in the context of the Po valley (northern Italy). We compared potential investment returns from traditional monospecific walnut and hybrid poplar plantations with polycyclic plantations, an innovative model of mixed and multi-rotation plantation with much higher positive impact in terms of biodiversity. We defined different models according to site fertility and investment costs and carried out a financial analysis using capital budgeting indicators, i.e. IRR, NPV and EAV.

Our results show that polycyclic plantations can reach on average the highest investment returns, although there are significant variations depending on site fertility and investment cost levels. The diversification of species, rotations and final assortments of polycyclic plantations appears to be potentially successful elements to cope with market risks. Hybrid poplar plantations are the most consolidated segment of investment but show the largest variability in terms of returns. For walnut plantations, the longer payback period can influence negatively the investments attractiveness. Results were analysed and discussed also considering the opportunity costs associated to the alternative agricultural land use (annual crops), and the effect of subsidies, land use costs and timber stumpage prices variations. These proved to be determinant variables in influencing potential investments returns.

Keywords: Productive forest plantations, timber investments, mixed plantations, responsible management, poplar, Rural Development Policy, Italy.

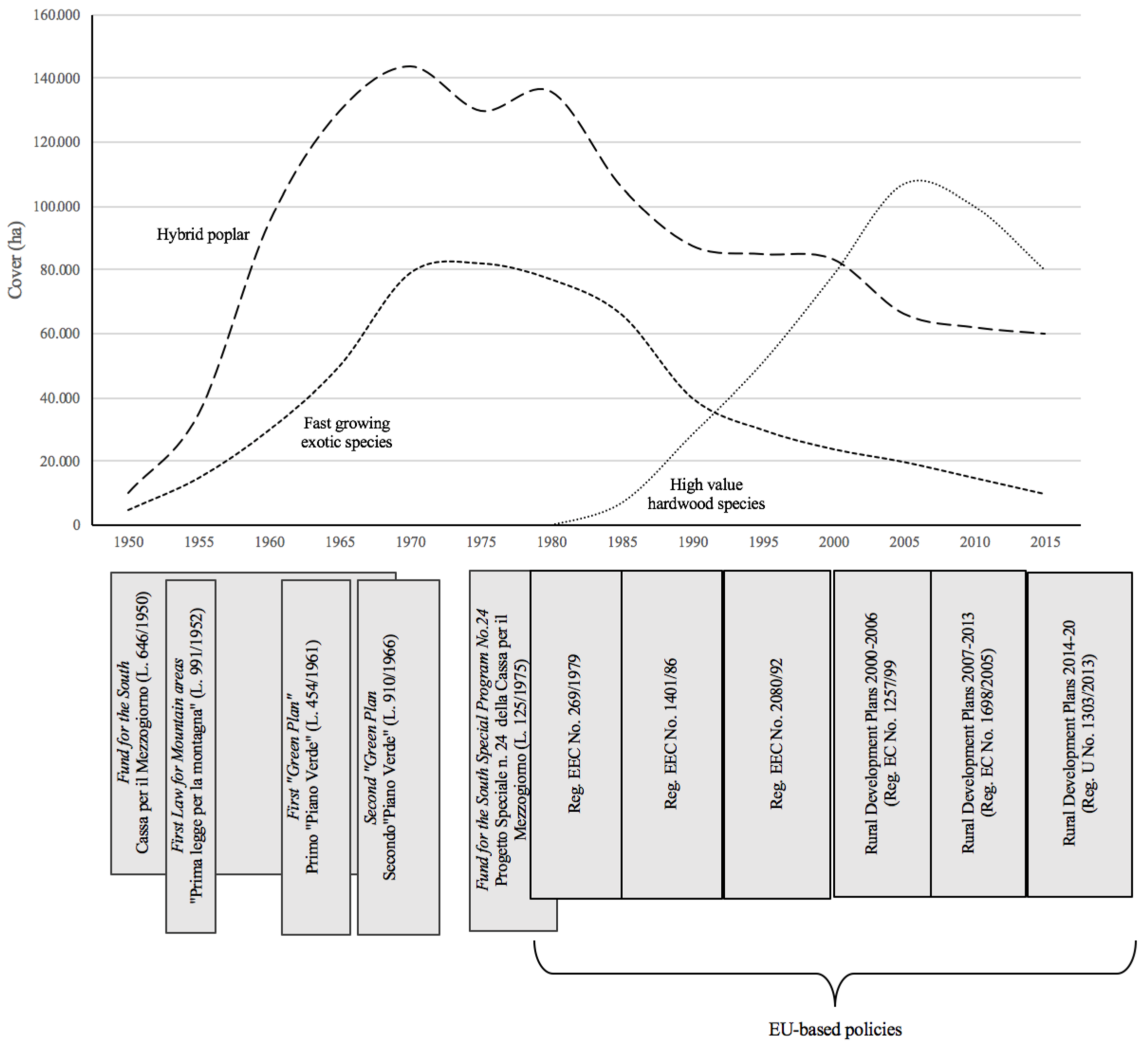
5.1 Introduction

Provisioning services, in particular timber production, remain therefore the main driver for the expansion of forest plantations worldwide (Carle and Holmgren, 2008; Jurgensen *et al.*, 2014). However, in the last 20 years, there has been also a growing awareness of the potential of forest plantations to deliver other ecosystem services (Boyle, 1999; Evans and Turnbull, 2004), in particular if plantations are compared to other forms of land uses as pastures or cropland (Pawson *et al.*, 2013). In the case of timber-oriented investments, this awareness is reflected in the emergence of so-called responsible investors, interested in combining their financial objectives with concerns about environmental and social impacts (Brotto *et al.*, 2016).

Considering that the majority of forest plantations are established, either directly or indirectly, with public subsidies (Cossalter and Pye-Smith, 2003; Bull *et al.*, 2006, Duesberg *et al.*, 2014), also public institutions have evidently a major role in influencing investments. In Europe, a growing role in supporting responsible investments in forest plantations is played by the European Union (EU) within its Rural Development Policy, the main policy instruments that the EU has to drive investments decisions in the agriculture and forestry sector within its Member States. This is reflected in the approach taken in the afforestation measures since the 1992 MacSharry reform (Regulation ECC No. 2080/1992) and the progressive shift from the primary idea of compensating land owners for taking agricultural land out of production (‘set aside’ approach) to the idea of incentivizing sustainable timber production from afforested areas, with an increasing attention to supporting new multifunctional forest plantations (Alliance Environment, 2017). As such, the concept of these afforestation measures could be assimilated both to a subsidy given to land owners to produce timber and to a kind of Payment for Ecosystem Services (PES) to increase the use of ecological and sustainability practices in new afforested areas, e.g. with the use of native and mix of species, as well as of voluntary forest certification schemes to guarantee responsible management practices (e.g. Harper, 1993; Baldock and Beaufoy, 1993; De Putter, 1995; Weber, 2005; OECD, 2011; Szedlak, 2017).

Among EU Member States, Italy represents a meaningful example of the impact of subsidies on the investments in forest plantations, with subsidy policies that have been dynamically adapted to the changing social demands. Figure 5.1 presents synthetically the evolution of the predominant segments of productive forest plantations types and the main subsidy policies in recent history of the country.

Figure 5.1: Evolution of the main segments of timber plantations in Italy in respect to policy developments, 1950-2015



Note: *estimates based on data from: INF (1985); Gasparini and Tabacchi (2011); ISTAT (1970); ISTAT (1980); ISTAT (2000); Lapietra et al. (1995); Istituto Sperimentale per la Selvicoltura (1982); Boggia (1987); Coletti (2001); Romano and Cilli (2009).*

Source: own elaboration.

Starting from the years just after the second World War, industrial plantations with exotic species (e.g. *Eucalyptus* globolus*, E. camaldulensis, Pinus radiata.*) were carried out in association to the need to support employment opportunities in rural and disadvantaged areas and to boost the industrial development, e.g. under the *Fund for the South* (L. 646/1950), the *First Law for Mountain Areas* (L. 951/1952) and the two "*Green Plans*" (L. 454/1961 and L. 910/1966) (Caruso, 1977; Pettenella, 1992). These types of plantations reached an extension of over 80 thousand hectares in the 70's of last century. However, in spite what happened in other countries of southern Europe, where these types of plantations became consolidated and important segment of investments (e.g. Spain and Portugal) (Forest Europe, 2015), in Italy the investments in new plantations with exotic species rapidly dropped as a consequence of two factors: the need for reducing public spending in the sector and a growing critical perception of the role of non-native species and monospecific plantations in rural landscapes.

An important shift occurred at the beginning of the 90's with a new phase of EU-based subsidy policies, firstly under the measures accompanying the Common Agricultural Policy (CAP) and later under the regional Rural Development Programs (RDPs) co-financed by the European Agricultural Fund for Rural Development (EAFRD). Under this new framework, in Italy a strong emphasis was given to the establishment of high value hardwood plantations, using native species with medium-long rotations such as walnut (*Juglans regia*), cherry (*Prunus avium*) and oaks (*Quercus robur*, *Quercus petraea*), following the example of other EU Member States such as for example France. Between 1994 and 2006, under the afforestation measures of the Reg. EEC No. 2080/1992 and the RDPs 2000-2006 (Reg. EEC No. 1257/1999), out of the 144,714 hectares of plantations planted in Italy, over 75% were high value hardwood plantations, mainly established on agricultural land by private small and medium landowners for the production of industrial wood (Colletti, 2001; Romano and Cilli, 2008). However, after having reached the age of 20 years required by the contractual obligations of the afforestation measures as a minimum rotation age, most of these plantations appear to have been converted back to the previous agricultural uses, with a consequent rapid decline in the area covered with these species (not precisely quantifiable due to the lack of recent inventory data).

The most consolidated segment of investments in plantations in Italy is represented by hybrid poplar plantations in the Po valley (northern Italy), traditionally grown on agricultural land and intensively managed in short rotation for the production of plywood and veneer logs. Historically, the dynamic of investments in poplar plantations has shown to be partially independent from the subsidy policies, mainly due to the key role that domestic poplar has for the plywood and wood-based panels industries (Castro and Zanuttini, 2008). However, after having reached the maximum expansion in the late 60's (over 140 thousand hectares), also the area covered by poplar plantations has been then steadily decreasing (Coaloa, 2008); according to the last National Forest Inventory data of 2005 (Gasparini and Tabacchi, 2011), poplar plantations shrunk to an area of approximately 66,000 hectares. Being the opportunity cost of these investments (i.e. the missed income from cereals and rice productions) the most critical factor behind the declining of investments in poplar plantations in the Po valley, the RDP's afforestation measures have been used to sustain poplar plantations. Despite the use of RDP's afforestation measures to set-up this type of plantations is considered incoherent with the EU Rural Development Policy objectives, it has been possible thanks to the relatively high degree of national and regional competence in the technical definition of the forestry measures in the RDPs. As an example, between 2007 and 2013, under the measures 221 ('afforestation of agricultural land') and 223 ('afforestation of non-agricultural land') of the Reg. EC No. 1968/2005, out of the 18,654 hectares planted in Italy, 25.2% were planted with fast-growing species (mainly hybrid poplars), against the EU average of 1.71% (Table 5.1) (Alliance Environment, 2017).

Table 5.1: Repartition by type of afforestation area supported under measures 221 and 223 of Reg. EEC No. 1968/2005

	EU-total	**Italy**
Total planted area	287,490 ha	18,654 ha
- of which conifers species	23.6%	1.29%
- of which broadleaved species	49.9%	60.48%
- of which fast-growing species	1.71%	25.22%
- of which mixed stands	24.7%	13.02%

Source: own elaboration based on data from Alliance Environment (2017)

Initially, the use of RDPs to support productive forest plantations with fast-growing species was generally allowed, given that poplar plantations were considered to represent an environmental improvement compared to the alternative annual intensive agricultural crops, as demonstrated by several studies (Chiarabaglio *et al.*, 2009; Chiarabaglio *et al.*, 2014). However, in more recent years, the intensive management and high pesticides and fertilizers inputs characterizing poplar plantation's management have led to growing reluctance by public institutions, including the European Commission (EC), to support this type of investment. This resulted in stricter environmental restrictions and new rules in the RDPs afforestation measures eligibility criteria requiring the use of new and 'environmentally friendly' poplar clones more resistant to pest and insect attacks but not widely accepted by poplar growers and plywood and veneer industries (Castro and Giorcelli, 2012). As a response to these issues, new examples of experimental mixed plantations have been tested in northern Italy since more than a decade: the so-called polycyclic plantations (Buresti Lattes *et al.*, 2008a, Facciotto *et al.*, 2014). These mixed plantations are defined as polycyclic because they include a mix of main and auxiliary species with different roles, objectives and rotations (Buresti Lattes *et al.*, 2007, Pelleri *et al.*, 2012); they are able to combine the production of different assortments, e.g. plywood and veneer logs from poplar clones with 10-14 years rotation, sawn logs from walnut or oaks with longer rotations (20-40 years), and biomass for energy from very fast growing species, such as willows and planes (Buresti Lattes and Mori, 2006; Ravagni and Buresti Lattes, 2007). The idea behind polycyclic plantation's concept is to integrate the positive environmental impacts associated to continuous tree cover and species admixture (Chiarabaglio *et al.*, 2014; Londi *et al.*, 2016) with firewood and timber production. In addition, polycyclic plantations can potentially be a permanent use of former agricultural land, with a much higher positive impact in terms of ecosystem services provision (Buresti Lattes and Mori, 2009). The area covered by experimental polycyclic plantations in Italy is estimated to be between 200 and 400 hectares in Veneto, Lombardy and Piedmont. Although research and experimentation on dynamics and functioning of admixtures of species in forest stands is a topic of increasing relevance in Europe (Bravo-Oviedo *et al.*, 2014; Del Río *et al.*, 2015), similar experiences of mixed plantations of poplar and high value hardwoods on agricultural land can be found only in France (Balandier and Dupraz, 2008; Vidal and Becquey, 2008; Rivest *et al.*, 2010).

In the paper we investigate the financial aspects of timber investments in the Po valley. Our focus is on productive forest plantations established on arable agricultural land mainly for the production of commercial timber (hereafter 'timber plantations'). These are sometimes found in literature as 'tree farms' (e.g. Facciotto *et al.*, 2014; Burest Lattes *et al.*, 2014). From a legal perspective, timber plantations are not considered a forestry activity and can be converted back to agricultural land use at any time according to Italian legislation (D.Leg. 34/2018 and previously D.Leg. 227/2001). We compare two traditional monospecific plantation types, i.e. walnut and hybrid poplar plantations, with polycyclic plantation. These have been empirically found to be the main types of timber plantations current options in the context of the Po valley. The Po valley is a relatively homogenous context, and it is a particularly interesting case study at European level due to the historically significant level of investments in timber plantations (in particular hybrid poplars) on arable and very fertile agricultural land.

Financial profitability of investment in forest plantations has been investigated by many authors (Sedjo, 1983; Sedjo, 2001; Zinkhan and Cubbage, 2003; Cubbage *et al.*, 2007; Cubbage *et al.*, 2014), also focusing specifically on poplar plantations (Anderson and Luckert, 2006; Tankersley, 2006; Keča *et al.*, 2011). However, in Italy timber plantations have rarely been analysed from a financial point of view. Only few studies have been published in Italian journals or technical magazines related to investments in hybrid poplar plantations (e.g. Borelli, 1994; Borelli, 1996; Borelli and Facciotto, 1997) and high value hardwood plantations (Berti and Mercurio, 1992; Ragazzoni, 1993; Cianciosi, 1997), while no investigation has been carried out yet to assess whether polycyclic plantations can offer competitive financial returns to land owners.

Our study objectives are: i) to estimate potential investment returns for walnut, hybrid poplar and polycyclic plantations in the Po valley; ii) to compare investment returns of timber plantations with alternative agricultural crops; and iii) to test the effect of subsidies, land use costs and timber stumpage prices variations on the financial performances of timber plantations.

5.2 Methodology

The methodology consisted in the following steps: 1) definition of timber plantations and alternative agricultural crops models considered in the study; 2) collection and analysis of data on investment costs, stumpage prices and productivity data; 3) financial analysis; and 4) sensitivity analysis. Each step is further described below.

5.2.1 Definition of timber plantations and alternative agricultural crops models considered in the study

The analysis compared three types of timber plantations (Table 5.2):

a) walnut plantations, the most widespread investment model among high value hardwood plantations;
b) traditional hybrid poplar plantations (clone *Populus* × *canadensis* 'I-214');
c) polycyclic plantations, where we distinguished three different sub-categories:
    - polycyclic plantations for plywood logs, with higher component of poplar clones for plywood and veneer production;
    - polycyclic plantations for energy, with higher component of species for firewood production;
    - polycyclic plantations for sawn logs, with higher component of high value

hardwoods for sawn logs production.

Planting schemes for polycyclic plantations are presented in Annex 1.1 of the supplementary material. Management regimes normally adopted for walnut and hybrid poplar plantations are described in Buresti Lattes *et al.* (2008b), Allegro *et al.* (2014), Chiarabaglio *et al.* (2014) and Mori (2015). Polycyclic plantations management regimes are derived from experimental sites of the Association of Tree Farming for Economy and the Environment (AALSEA) described in Buresti Lattes and Mori (2006; 2016). We defined management models and detailed them according to site fertility (average and high fertility) and investment costs (minimum or maximum). We defined the length of the rotation periods according to site fertility: high fertility corresponds to better growing conditions thus allowing shorter rotation periods (i.e. 10 years for poplar and 20 years for walnut and polycyclic plantations) than average fertility conditions (i.e. 12 years for poplar and 27 years for walnut and polycyclic plantations). We also identified three alternative agricultural crops: maize silage, maize grain and soy (Trestini and Bolzonella, 2015) and defined six models based on site fertility and production costs.

Table 5.2: Description of timber plantations types, species and rotations considered in the study

Types		Species	Number of trees at planting (trees/ha)	Rotation (years)		Number of rotations in one polycyclic plantations cycle
				In high site fertility	In average site fertility	
Walnut		*Juglans regia*	110	20	27	
Hybrid poplar		*Populus x canadensis I*-214 clone	278	10	12	
Polycyclic Plantations	for plywood logs	*Platanus x acerifolia*	278	6	7	3
		Populus x canadensis I-214 clone	111	10	12	2
		Juglans regia	28	20	27	1
		Auxiliary trees/shrubs	264	10	12	1
		TOTAL	681			
	for energy	*Platanus x acerifolia*	552	6	7	3
		Populus x canadensis I-214 clone	46	10	12	2
		Juglans regia	46	20	27	1
		Auxiliary trees/shrubs	161	10	12	1
		TOTAL	805			
	for sawn logs	*Platanus x acerifolia*	278	6	7	3
		Populus x canadensis I-214 clone	69	10	12	2
		Juglans regia	69	20	27	1
		Auxiliary trees/shrubs	243	10	12	1
		TOTAL	659			

Table 5.3 presents the twenty models of timber plantations and the six models of agricultural crops used in the study.

5.2.2 Collection and analysis of investment costs, stumpage prices and productivity data

We included as investment costs all the expenditures involved in the preparation, planting and maintenance of the selected types of plantations: site preparation (ploughing and harrowing), fertilization, seedlings purchase and transport, planting operations (marking, digging and planting), irrigation, disk harrowing, weeding, phytosanitary treatments, pruning, and finally removal of residues and stumps after harvesting. We did not include harvesting costs because trees are normally sold as standing trees. Unitary costs have been provided by AALSEA and are reported in Annex 1.2 of the supplementary material.

Table 5.3: Definition of the representative management models of timber plantations and agricultural crops defined according to site fertility and investment costs assumptions

Type*		Site fertility		Investment costs		Models	Source
		High	Average	Minimum	Maximum		
Maize silage		X		X		MHMIN	De Carli, 2015
Maize silage		X			X	MHMAX	Trestini and Bolzonella, 2015
Maize silage			X		X	MAMAX	Trestini and Bolzonella, 2015
Maize grain		X			X	GHMAX	Trestini and Bolzonella, 2015
Maize grain			X	X		GAMIN	Trestini and Bolzonella, 2015
Soy		X		X		SHMIN	Trestini and Bolzonella, 2015
Hybrid **poplar**		X		X		PHMIN	Ravagni and Buresti Lattes, 2007
Hybrid **poplar**		X			X	PHMAX	Ravagni and Buresti Lattes, 2007
Hybrid **poplar**			X	X		PAMIN	Ravagni and Buresti Lattes, 2007
Hybrid **poplar**			X		X	PAMAX	Ravagni and Buresti Lattes, 2007
Walnut		X		X		WHMIN	Ravagni and Buresti Lattes, 2007
Walnut		X			X	WHMAX	Ravagni and Buresti Lattes, 2007
Walnut			X	X		WAMIN	Ravagni and Buresti Lattes, 2007
Walnut			X		X	WAMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for plywood logs	X		X		PlyHMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for plywood logs	X			X	PlyHMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for plywood logs		X	X		PlyAMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for plywood logs		X		X	PlyAMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for energy	X		X		EneHMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for energy	X			X	EneHMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for energy		X	X		EneAMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for energy		X		X	EneAMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for sawn logs	X		X		SawnHMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for sawn logs	X			X	SawnHMAX	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for sawn logs		X	X		SawnAMIN	Ravagni and Buresti Lattes, 2007
Polycyclic plantations	for sawn logs		X		X	SawnAMAX	Ravagni and Buresti Lattes, 2007

** The combinations have been selected based on the availability of data

Species growth rates and yield in the context of the Po valley are based on a Mean Annual Increment (MAI) basis with data derived from AALSEA and from the LIFE+ InBioWood experimental sites in Mantua (San Matteo delle Chiaviche, Ponte sull'Oglio, Viadana) and Verona (Gazzo Veronese, Villa Bartolomea) provinces (Castro *et al.* 2013, Pelleri *et al.* 2013, Olivotto *et al.* 2016, Buresti Lattes *et al.* 2015, Mori and Buresti Lattes, 2017, other AALSEA studies not yet published). Investment costs and yields for the agricultural crops are derived from Trestini and Bolzonella (2015) and De Carli (2015).

Average timber stumpage prices based on main assortments (firewood, woodchip, pulpwood, plywood and sawn logs) have been identified for the Italian market through literature (Pasini and Pividori, 2014; Pasini and Pividori, 2015) and a market analysis (Table 5.4). Both cost values and timber stumpage prices include the Added Tax (VAT). Input data on productivity for different assortments are reported in Annex 1.3 of the supplementary material.

Table 5.4: Prices for different species, products and assortments used in the study

Product/Assortment	Unit	Value	Note	Reference year	Source
Maize silage	EUR/t	50	-	2015	Trestini & Bolzonella, 2015
Maize grain		163	-		
Soy		350	-		
Walnut sawn logs	EUR/m^3	300	-	June 2014	Pasini and Pividori, 2014; Pasini and Pividori, 2015
Poplar plywood logs	EUR/m^3	55	Given a price of 90 EUR/t of fresh biomass for processing trunk up to 20 cm DBH (Diameter Breast Height)	June 2014	
Poplar pulpwood	EUR/t	25	-	December 2014	
Chipwood	EUR/t	10	-	December 2014	
Plane tree firewood	EUR/t	35	Given a price of 55 EUR/t for harvesting, sizing and extraction and a final consumer price of 90 EUR/t of fresh biomass	December 2014	

5.2.3 Financial analysis

Cash flows tables were developed for all the 20 plantations models, which are presented synthetically in Annex 1.4 of the supplementary material. We considered cost and revenues in terms of market prices and assuming constancy through time. We carried out a financial analysis to compare alternative investments using three capital budgeting indicators to estimate financial returns and compare alternative investments: NPV, EAV and IRR (Klemperer, 2003; Wegner, 2012; Cubbage *et al*. 2015). These indicators have been calculated as follows:

$$NPV = \sum_{n=0}^{N} \frac{R_n - C_n}{(1+i)^n}$$

$$EAV = \frac{NPV * i}{1-(1+i)^{-N}}$$

$$IRR = i: \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n}$$

Where:
n = year number
R = revenues (cash inflow)
C = costs (cash outflow)
i = annual discount rate
N = rotation length.

Given that the NPV does not allow in our case the comparison between models with different rotations, we decided to use the EAV as our primary indicator. We also included the IRR as an additional indicator, despite it cannot be applied to annual agricultural investments. We calculated also the Payback Period (PBP) as an additional risk-exposure indicator that determines the length of time (years) required to recover the costs of the investment.

We decided to use a real discount rate of 3.5%, as indicated by HM Treasury 'Green Book' (2003). The analysis was carried out also testing alternative discount rates, which are: 2%, as the closest value to long-term bond interest rate of EU Member States provided by the European Central Bank (ECB, 2016); 5%, as identified by the European Commission for European investments in the forestry and agriculture sectors (Snowdon and Harou, 2013); and iii) 8%, as selected by Cubbage *et al.* (2014) for the comparison of investments returns at global level.

The analysis does not consider Land Value Tax and Income Tax. We firstly considered a baseline scenario, where land costs and subsidies have not been included.

5.2.4 Sensitivity analysis

Besides the discount rate, we completed other sensitivity analyses on many key variables, testing the effects of different hypothesis on subsidies, land use costs and timber prices variations.

Concerning subsidies, we considered the uniform CAP direct payment and the project-based grants of the afforestation measure 8.1 defined by the RDPs 2014-20 in the northern Italian regions (Emilia-Romagna, Friuli-Venezia Giulia, Lombardy, Piedmont and Veneto). CAP direct payment is applicable only to agricultural crops (EC, 2016). Timber plantations included in this study cannot benefit from the direct payment because, according to the Ministerial Decree 6513/2014, only very short rotation plantations with rotations below 8 years are eligible.

RDPs project-based grants break down into three components: reimbursement of a percentage of planting costs, compensation for income losses, and a premium for the stand maintenance. Eligibility criteria and contribution level differ among the five northern Italian regions (Table 5.5). Hence, we simulated regional scenarios as well as the average contribution level for the three components of subsidies across the five regions.

In the second sensitivity analysis, we included the land rent cost. This was calculated as the average land rent value of agricultural land suitable for timber plantations in the Po valley as reported by the Agricultural Annual Review of CREA (2016). We assumed that, given the active market for farmland renting in northern Italy, the average value of rents can be considered a good indicator of the real land use costs. This simulation was also performed in combination with the hypothesis of average subsidies contribution.

Finally, we simulated hypothetical variations of timber stumpage prices: ±20% variation in the stumpage price of plywood logs (poplar); ±30% in the stumpage price of sawn logs (walnut); and ±10% variation in the price of firewood. It was assumed that these ranges reflect the average variation rates in the Italian domestic market for standing trees in recent years.

Table 5.5: Subsidy contribution provided with the 2014-20 Rural Development Plans (Measure 8.1) of the northern Italian regions

Type	**Region**	**Site preparation and planting costs reimbursement (%)**	**Income loss compensation**		**Maintenance premium**	
			Amount (EUR/ha/yr)	**Duration (yr)**	**Amount (EUR/ha/yr)**	**Duration (yr)**
Short rotation plantation 8-12 year (Hybrid poplar)	Emilia-Romagna	40%*	-	-	-	-
	Friuli-Venezia Giulia	80%	-	-	-	-
	Lombardy	60%*	-	-	-	-
	Piedmont	60%*	-	-	-	-
	Veneto	80%	-	-	-	-
Average		65%	-	-	-	-
Medium-long rotations plantations >12 years (Polycyclic plantations and walnut)	Emilia-Romagna	100%	-	-	400	12
	Friuli-Venezia Giulia	100%	885	12	852 (1st yr) 668 (2nd and 7th yr) 239 (3rd to 6th yr)	7
	Lombardy	70%**	395	12	495	5
	Piedmont	80%	600	10	600	5
	Veneto	80%	250 (non-professional farmer) - 1,000 (professional farmer)	12	1,000 (1st to 5th yr) 500 (6th to 12th yr)	12
Average		85%	450	9	530	8

Note: These are grant based contributions subject to eligibility criteria. For a more detailed overview it is recommended to make reference to the official websites: Emilia-Romagna: http://agricoltura.regione.emilia-romagna.it/psr-2014-2020; Friuli-Venezia Giulia: https://www.sviluppoorurale.fvg.it/home/; Lombardy:

http://www.psr.regione.lombardia.it; Piedmont: http://www.regione.piemonte.it/agri/psr2014_20/; Veneto: http://www.avepa.it/psr-2014-2020.

* Percentages are higher (70% in Emilia-Romagna, 80-100% in Lombardy, 80% in Piedmont) if using poplar ‘environmentally friendly clones’ (Facciotto *et al.*, 2014) or holding FSC® or PEFC™ certification

**90% if holding FSC® or PEFC™ forest management certification.

All inputs used for the sensitivity analyses are reported in Table 5.6.

Table 5.6: Inputs used in the sensitivity analyses

Hypothesis			Types			
			Polycyclic plantations	**Walnut**	**Hybrid poplar**	**Agricultural crops**
Subsidies*	CAP Direct Payment		-	-	-	317 EUR/ha/yr
	RDP average contribution		See Table 5.5		See Table 5.5	-
	RDP Emilia Romagna		See Table 5.5		See Table 5.5	-
	RDP Friuli Venezia-Giulia		See Table 5.5		See Table 5.5	-
	RDP Lombardy		See Table 5.5		See Table 5.5	-
	RDP Piedmont		See Table 5.5		See Table 5.5	-
Land use cost	Annual land rent cost		462 EUR/ha/yr			
Timber stumpage prices variations	Poplar plywood logs	+20%	66 EUR/t			
		-20%	44 EUR/t			
	Walnut sawn logs	+30%	390 EUR/m^3			
		-30%	210 EUR/m^3			
	Firewood	+10%	38.50 EUR/m^3			
		-10%	31.50 EUR/m^3			

* We did not consider the Veneto RDP because at the time this paper was written no budget was y*et al*located to the Measure 8.1

3. Results

The results of the study are presented in the following order: 1) investment costs, yields and timber revenues, 2) potential investment returns, and 3) influence of subsidies, land use costs and timber stumpage prices variations on profitability indicators.

5.3.1 Investment costs, yields and timber revenues

Table 5.7 summarizes the main data on investment costs, yield and timber revenues (i.e. the values of standing tree sales at different rotation ages) of the cash flows.

Total investment costs include site preparation, planting and maintenance costs for the entire rotation period. The total investment costs of timber plantations range from 2,469 EUR ha^{-1} for walnut plantation models with minimum costs (WHMIN and WAMIN) to 9,898 EUR ha^{-1} for poplar model PAMAX. Polycyclic plantations have investment costs ranging between 3,618 EUR ha^{-1} (polycyclic plantations for plywood with minimum costs – PlyHMIN and PlyAMIN) and 6,707 EUR ha^{-1} (polycyclic plantations for sawn logs with maximum costs – SawnHMAX and SawnAMAX). The mean total investment costs of the simulated timber plantation models is of 5,274 EUR ha^{-1}. If we split investment costs into their three components it results that maintenance is the most important one, followed by planting and site preparation. Site preparation costs are rather homogenous and range from 463 to 679 EUR ha^{-1}. Planting costs have a higher variability, ranging from 443 EUR ha^{-1} for walnut plantations with minimum costs to 2,591 EUR ha^{-1} for the polycyclic plantations for energy with maximum costs (EneAMAX and SawnHMAX). The mean planting cost corresponds to 1,611 EUR ha^{-1} with a standard deviation of 730 EUR ha^{-1}. The high standard deviation for planting cost is explained by the great variability in number of planted trees among models: walnut plantations have the lowest density (110 tree ha^{-1}) while the polycyclic plantations for energy plantations reach the maximum (805 tree ha^{-1}). Maintenance costs show also a high variability, ranging from 1,563 EUR ha^{-1} for walnut plantations with minimum cost to 7,584 EUR ha^{-1} for poplar model PAMAX. The mean maintenance cost is 3,092 EUR ha^{-1} with a standard deviation of 1,707 EUR ha^{-1}. In this case, the high standard deviation is related to the variability on the intensity of management interventions: poplar plantations require more intensive irrigation and phytosanitary treatments compared to polycyclic plantations and walnut.

Table 5.7: Summary of input data on investment costs, productivity and timber revenues

Model code			Rot.	Investment Costs (EUR/ha)				Volume per ha		Timber revenues (EUR/ha)
				Site preparation	Planting	Maintenance	Total	MAI (m3/ha /yr)	Total yield (m3)	
Walnut		WHMIN	20	463	443	1,563	2,469	1.9	38	11,734
		WHMAX	20	679	734	2,518	3,931	1.9	38	11,734
		WAMIN	27	463	443	1,563	2,469	1.4	38	11,734
		WAMAX	27	679	734	2,518	3,931	1.4	38	11,734
Hybrid poplar		PHMIN	10	463	1,084	4,524	6,0710	26.9	269	12,931
		PHMAX	10	679	1,635	7,030	9,344	26.9	269	12,931
		PAMIN	12	463	1,084	4,890	6,437	22.4	269	12,931
		PAMAX	12	679	1,635	7,584	9,898	22.4	269	12,931
Polycyclic plantations	For plywoo d logs	PlyHMIN	20	463	1,530	2,424	3,618	23.0	460	22,179
		PlyHMAX	20	679	2,523	3,505	5,650	23.0	460	22,179
		PlyAMIN	27	463	1,530	2,424	3,618	17.0	460	24,998
		PlyAMAX	27	679	2,523	3,505	5,650	17.0	460	24,998
	For energy	EneHMIN	20	463	1,530	1,625	3,972	20.5	410	15,903
		EneHMAX	20	679	2,591	2,380	6,106	20.5	410	15,903
		EneAMIN	27	463	1,530	1,625	3,972	15.2	410	17,910
		EneAMAX	27	679	2,591	2,380	6,106	15.2	410	17,910
	For sawn logs	SawnHMIN	20	463	1,517	1,992	4,417	26.6	531	18,302
		SawnHMAX	20	679	2,527	2,900	6,707	26.6	531	18,302
		SawnAMIN	27	463	1,517	1,992	4,417	19.7	531	20,360
		SawnAMAX	27	679	2,527	2,900	6,707	19.7	531	20,360
Mean				571	1,611	3,092	5,274			20,084
Standard deviation				111	730	1,707	1,992			6,203

Productivity is expressed as MAI (m^3 ha^{-1} yr^{-1}) and as total yield (m^3 ha^{-1}). Chipwood obtained from branches, residues or auxiliary species in polycyclic plantations are excluded from the calculation. The MAI ranges from 1.4 m^3 ha^{-1} yr^{-1} for walnut plantations in average fertility sites (WAMIN and WAMAX) up to 26.9 m^3 ha^{-1} yr^{-1} in poplar (PHMIN and PHMAX) and polycyclic plantations for plywood logs in high fertility sites (PlyHMIN and PlyHMAX). The maximum total yield reaches a value of 269 m^3 ha^{-1} for poplar plantations in 10 years rotation and 531 m^3 ha^{-1} for the polycyclic plantations for sawn logs in a 20 years cycle. Concerning timber revenues, the range varies from a minimum of 11,734 EUR ha^{-1} for walnut plantations in a 27 years rotation up to a maximum of 12,931 EUR ha^{-1} for poplar plantations in a 10 years rotation.

5.3.2 Potential investment returns

Table 5.8 summarizes the investment returns for timber plantations estimated for the base case scenario using NPV, EAV, IRR and PBP. EAV is used as primary indicator in order to compare models with different rotations.

Table 5.8: Results of the financial analysis

Models			Rotation (years)	NPV (EUR/ha)	EAV (EUR/ha/yr)	IRR	PPB (yr)
Walnut		WHMIN	20	3,781	266	10.0%	20
		WHMAX	20	2,504	176	7.0%	20
		WAMIN	27	2,550	148	7.0%	27
		WAMAX	27	1,282	74	5.0%	27
		Mean walnut		2,529	166		
Hybrid poplar		PHMIN	10	3,774	454	12.0%	10
		PHMAX	10	884	106	5.0%	10
		PAMIN	12	2,923	303	9.0%	12
		PAMAX	12	-94	-10	n.a.	12
		Mean hybrid poplar		1,871	213		
Polycyclic plantations	For plywood logs	PlyHMIN	20	9,510	669	16.4%	10
		PlyHMAX	20	9,386	524	11.5%	10
		PlyAMIN	27	9,386	543	13.5%	12
		PlyAMAX	27	7,343	425	10.0%	12
		Mean for plywood		8,806	540		
	for energy	EneHMIN	20	6,351	440	13.7%	10
		EneHMAX	20	4,368	307	9.0%	10
		EneAMIN	27	6,094	353	11.0%	12
		EneAMAX	27	4,225	244	8.0%	12
		Mean for energy		5,259	336		
	for sawn logs	SawnHMIN	20	7,240	509	13.9%	10
		SawnHMAX	20	5,287	372	9.5%	10
		SawnAMIN	27	6,899	399	11.0%	12
		SawnAMAX	27	4,962	287	8.0%	12
		Mean for sawn logs		6,097	391		
	Mean polycycling plantations			6,721	423		
Overall mean					329		
Standard deviation					174		

The mean EAV for the simulated timber plantation models is 329 EUR ha^{-1} yr^{-1}. For walnut plantations the EAV ranges from 74 EUR ha^{-1} yr^{-1} (WAMAX) to 266 EUR ha^{-1} (WHMIN). The NPV for walnut plantations ranges between 1,282 EUR ha^{-1} (WAMAX, 27 years rotation) and 3,781 EUR ha^{-1} (WHMIN, 20 years rotation) and IRR values vary from 5.0% to 10.0%. Poplar plantations show a greater variability, with the EAV ranging from -10 EUR ha^{-1} yr^{-1} (PAMAX) to 454 EUR ha^{-1} yr^{-1} (PHMIN). In this case, NPV ranges between -94 EUR ha^{-1} (PAMAX, 12 years rotation) and 3,774 EUR ha^{-1} (PHMIN, 10 years rotation), with IRR values up to 12.0% for the best model. Among polycyclic plantations, EAV varies from 244 EUR ha^{-1} yr^{-1} (EneAMAX) to 669 EUR ha^{-1} yr^{-1} (PlyHMIN). The NPV varies between 7,343 EUR ha^{-1} (PlyAMAX, 27 years cycle) and 9,510 EUR ha^{-1} (PlyHMIN, 20 years cycle) for polycyclic plantations for plywood logs; between 4,225 EUR ha^{-1} (EneAMAX, 27 years cycle) and 6,351 EUR ha^{-1} (EneHMIN, 20 years cycle) for polycyclic plantations for energy; and between 4,962 EUR ha^{-1} (SawnAMAX, 27 years cycle) and 7,240 EUR ha^{-1} (SawnHMIN, 20 years cycle) for polycyclic plantations for sawn logs. IRR values of polycyclic plantations range from 8.0% to 16.4%.

Polycyclic plantation models have on average similar performances (mean EAV = 423 EUR ha^{-1} yr^{-1}) of agricultural crops (mean EAV = 457 EUR ha^{-1} yr^{-1}). Agricultural crops show the greatest variability depending on the site fertility and production costs. Poplar plantations show a mean EAV of 213 EUR ha^{-1} yr^{-1}. Walnut plantations show the lower mean EAV is showed by walnut plantations (166 EUR ha^{-1} yr^{-1}). The PBP represent the number of years that it takes to recover the investment costs. For walnut plantations in high fertility sites is 20 years and for those in average fertility sites is 27 years, while is 10 or 12 years, again depending on our assumption on site fertility, for poplar and polycyclic plantations.

Financial analysis results for agricultural crops are detailed separately in Table 5.9.

Table 5.9: Summary of investment costs, revenues and financial analysis of agricultural crops by capital budgeting indicators

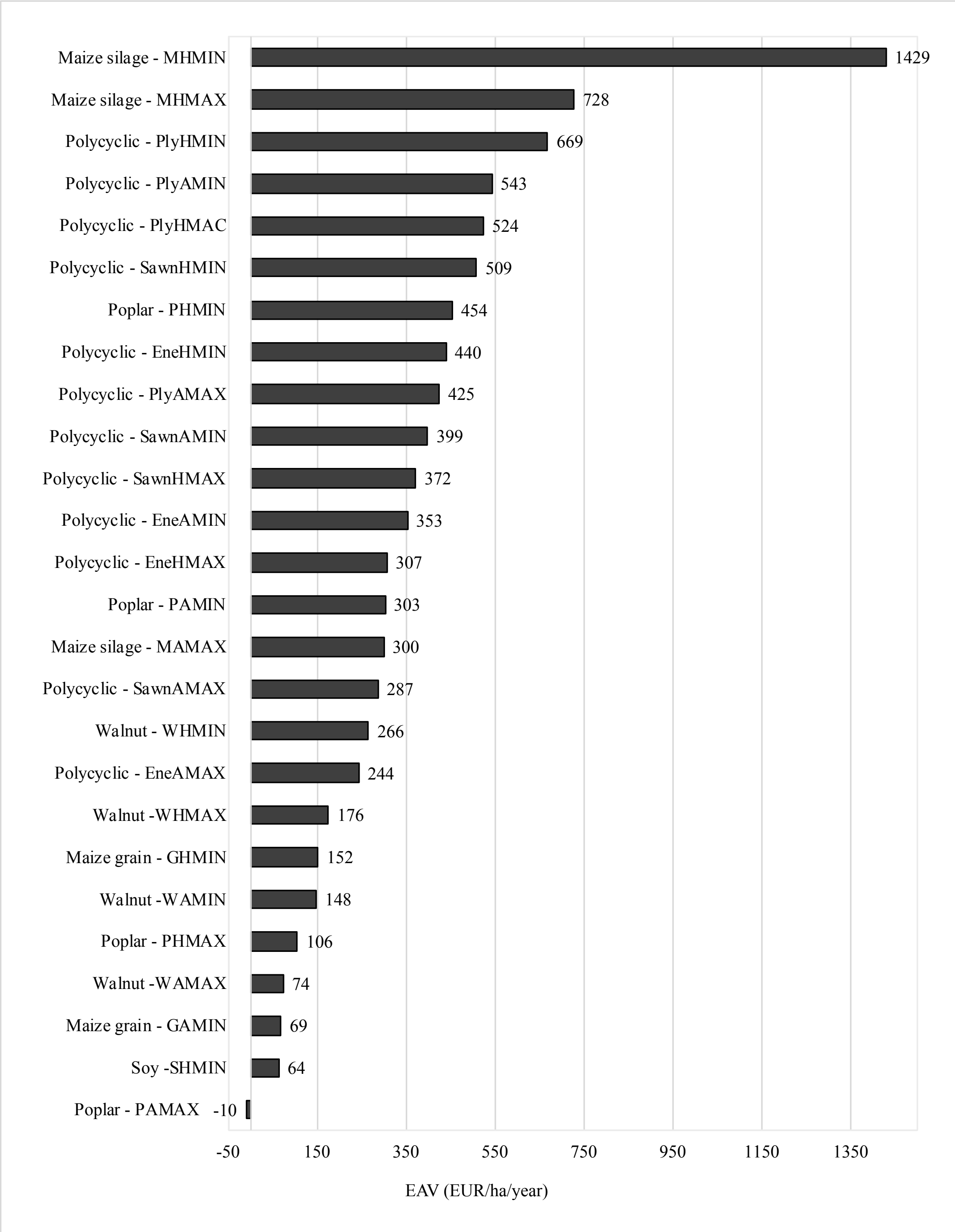
Type	Model code	Investment costs (EUR/ha)	Revenues (EUR/ha/)*	Capital budgeting indicators**, *i*= 3.5%	
				EAV (EUR/ha/yr)	NPV (EUR/ha)
Maize silage	MHMIN	1,109	2,445	1,429	20,316
	MHMAX	1,720	2,400	728	10,344
	MAMAX	1,720	2,000	303	4,259
Maize grain	GHMAX	2,140	2,282	152	2,160
	GAMIN	1,810	1,875	69	981
Soy	SHMIN	1,165	1,225	64	913

* Does not include uniform CAP Direct Payment

** Calculated simulating 27 years of agricultural crops with assumption of constancy.

Figure 5.2 ranks the financial performances of both timber plantations and alternative agricultural crops. The rank is expressed in terms of EAV per hectare to allow a comparison between investment horizons of different length. Maize silage models MHMIN and MHMAX have the best financial performances as they provide an EAV of, respectively, 1,429 and 728 EUR ha^{-1} yr^{-1}. Polycyclic plantations for plywood models result as the best ones among timber plantations. PlyHMIN model ranks 3rd with an EAV of 669 EUR ha^{-1} yr^{-1}, followed by PlyAMIN (543 EUR ha^{-1} yr^{-1}) and PlyHMAX (524 EUR ha^{-1} yr^{-1}). The best poplar plantation model ranks 7th with an EAV of 454 EUR ha^{-1} yr^{-1}, while the lower among the poplar plantation models ranks last and is the only model showing a negative NPV among the 20 models considered for timber plantations. Walnut plantations models are found between the 17th and 23rd positions. The remaining agricultural models rank far below in term of financial performances reaching only the 15th, 20nd and 24th and 25th position.

Figure 5.2: Profitability ranking of the 26 models of timber plantations and agricultural crops by EAV (EUR/ha/yr)

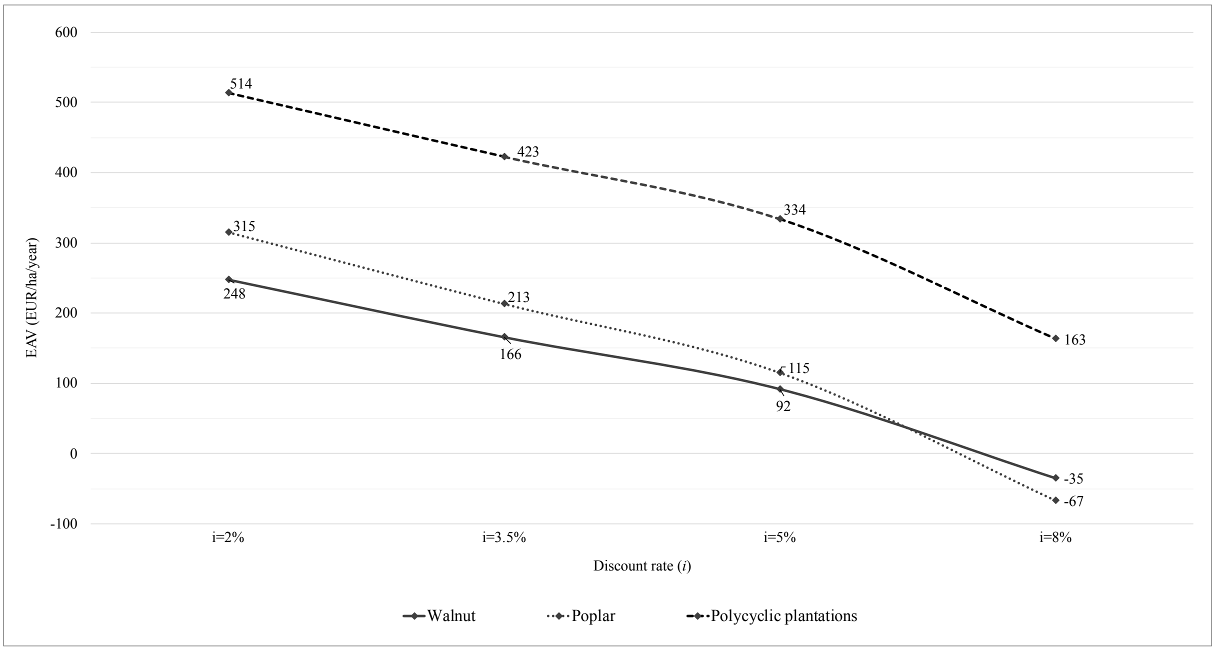


Source: own elaboration.

Figure 5.3 summarize the results according to alternative discount rates for the three types of timber plantations, presented using EAV as dependent variable. If we apply an 8% discount rate, EAV for timber plantation models results positive only in the case of polycyclic plantations (163 EUR ha^{-1} yr^{-1}), while walnut and poplar plantations present a negative one, respectively -

35 EUR ha^{-1} yr^{-1} and -68 EUR ha^{-1} yr^{-1}. In the case of a 2% discount rate, the EAV result 248 EUR ha^{-1} yr^{-1} for walnut plantations, 316 EUR ha^{-1} yr^{-1} for poplar and 514 EUR ha^{-1} yr^{-1} for polycyclic plantations. Finally, if we apply a 5% discount rate, walnut plantations present an EAV of 92 EUR ha^{-1} yr^{-1}, poplar plantations of 115 EUR ha^{-1} yr^{-1} and polycyclic plantations of 334 EUR ha^{-1} yr^{-1}.

Figure 5.3: Changes in the EAV (EUR/ha/yr) in relation to alternative discount rates



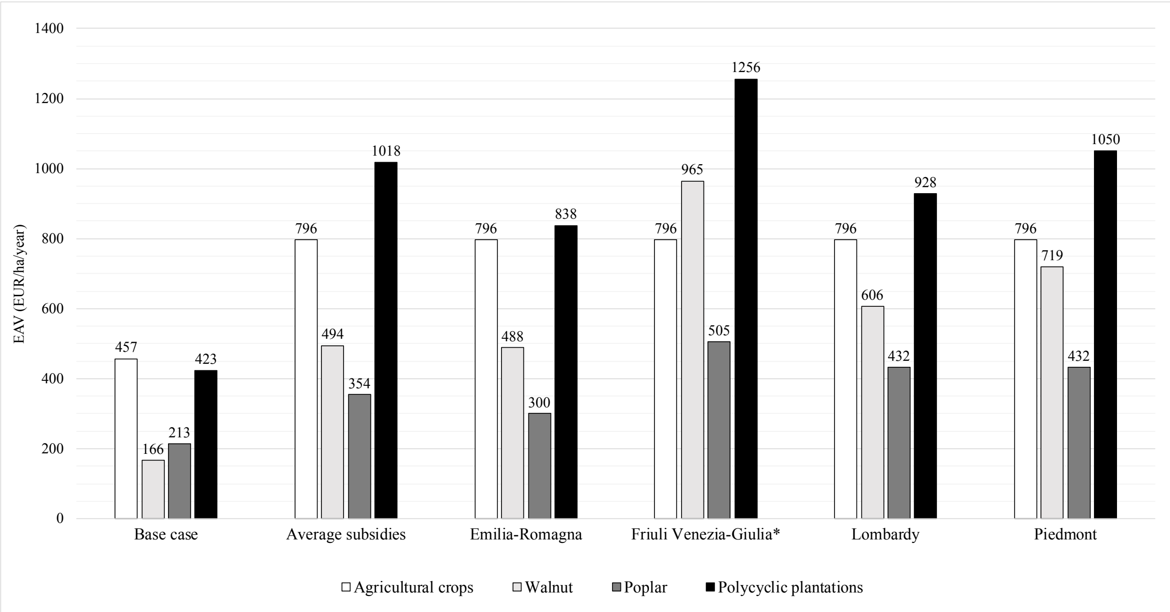
Source: own elaboration.

5.3.3 Influence of subsidies, land use cost and timber stumpage prices

The results of the sensitivity analysis of different assumptions of subsidies on the mean EAV of timber plantations and agricultural crops are presented in Figure 5.4.

The results show that these have a relevant effect on the financial performances of timber plantations and agricultural crops. The CAP direct payment of 317 EUR ha^{-1} yr^{-1} is applicable only to agricultural crops and it has the effect of increasing the average EAV of agricultural crops to 796 EUR ha^{-1} yr^{-1}. In the case of timber plantations, we simulated the average contribution level based on RDPs project-based grants and four regional-specific scenarios (Input data in Tables 6 and 7). In the hypothesis of average subsidy contribution, EAV of polycyclic plantations reaches a 1,081 EUR ha^{-1} yr^{-1}, while walnut a 494 EUR ha^{-1} yr^{-1} and poplar a 354 EUR ha^{-1} yr^{-1}. In the best hypothesis (Friuli Venezia Giulia), EAV of polycyclic plantations can increase to 1,256 EUR ha^{-1} yr^{-1}, walnut to 965 EUR ha^{-1} yr^{-1} and poplar to 505 EUR ha^{-1} yr^{-1}, while in the minimum hypothesis (Emilia Romagna) polycyclic plantations presents an average EAV of 838 EUR ha^{-1} yr^{-1}, walnut to 488 EUR ha^{-1} yr^{-1} and poplar to 300 EUR ha^{-1} yr^{-1}.

Figure 5.4: Results of sensitivity analysis on subsidies by EAV (EUR/ha/yr)

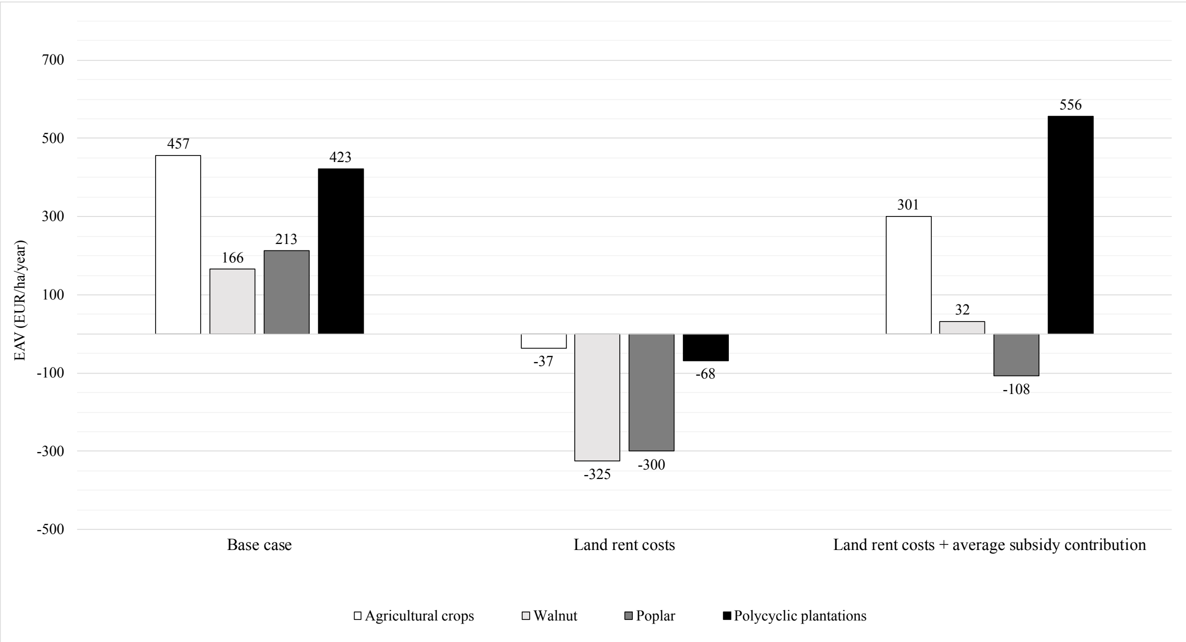


** In the case of Friuli Venezia-Giulia the model 'polycyclic plantation for plywood logs' has not been taken into consideration because of a limitation in the number of poplar clones accepted set in the measure (<10% of the total amount of plants per hectare)*

Source: own elaboration.

When we include an annual land rent cost in the simulation (Figure 5.5), calculated as the average land rent value of arable land suitable for plantations in the Po valley, none of the models present a positive EAV, if not supported by subsidies. EAV for agricultural crops is -37 EUR ha^{-1} yr^{-1}, for polycyclic plantations is -69 EUR ha^{-1} yr^{-1}, and for poplar and walnut respectively -300 EUR ha^{-1} yr^{-1} and -326 EUR ha^{-1} yr^{-1}. When adding an average subsidy contribution (including CAP direct payment for agricultural crops) EAV increases to 301 EUR ha^{-1} yr^{-1} for agricultural crops, to 556 EUR ha^{-1} yr^{-1} for polycyclic plantations, to 32 EUR ha^{-1} yr^{-1} for walnut, and it remains negative (-108 EUR ha^{-1} yr^{-1}) for poplar.

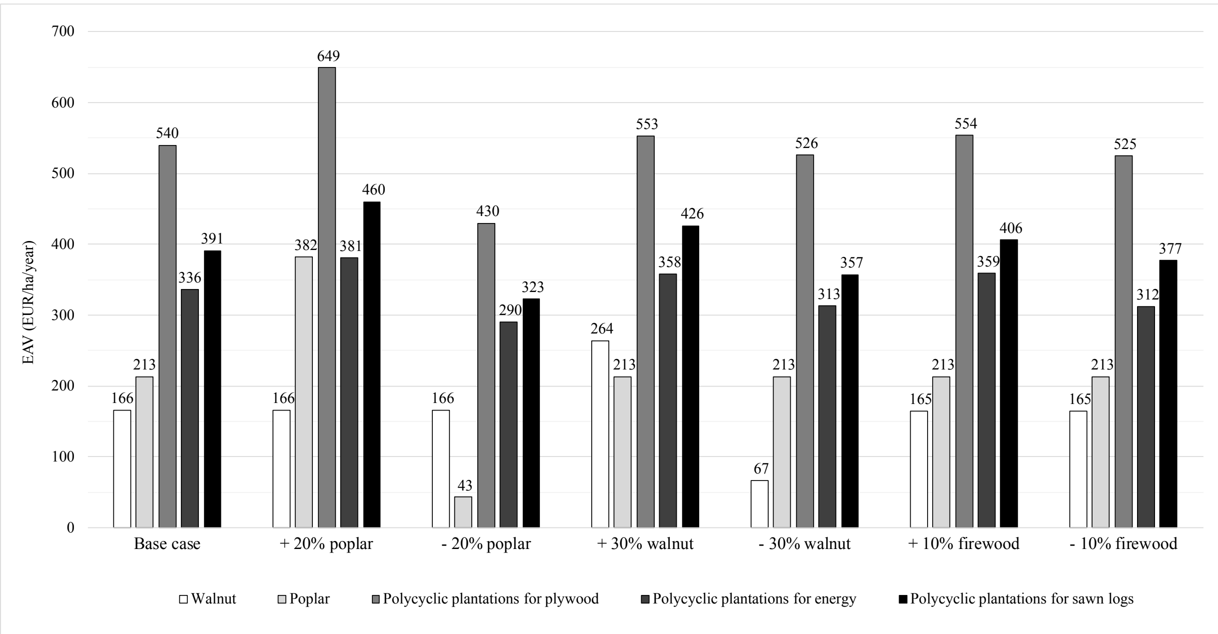
Figure 5.5: Results of the sensitivity analyses on land use cost by EAV (EUR/ha/yr)



Source: own elaboration

The results of the sensitivity analysis of the effects of timber stumpage price variations on investment profitability are presented in Figure 5.6.

Figure 5.6: Results of the sensitivity analyses on stumpage prices variations by EAV (EUR/ha/yr)



Source: own elaboration.

Poplar stumpage prices have varied on average by ±20% if we consider the prices registered by Chambers of Commerce in Italy (varying from 44 EUR/t to 66 EUR/t). A +20% in poplar stumpage price increases substantially the mean EAV of poplar plantations (382 EUR ha^{-1} yr^{-}

^{1}). However, polycyclic plantation models remain in line or more competitive given that all models have, although in different percentages, a poplar component. Polycyclic plantations for plywood show to be the most profitable plantation model under this assumption (650 EUR ha^{-1} yr^{-1}). A -20% in the stumpage price of poplar has the effects of reducing the EAV of poplar plantation models (44 EUR ha^{-1} yr^{-1}), while polycyclic plantations models maintain the best mean performances. A ±30% assumption in prices of walnut has been used to simulate the real variations that can happen in the market. With a +30% in walnut stumpage price, walnut monospecific plantations models reach an EAV of 264 EUR ha^{-1} yr^{-1}, slightly higher than poplar plantations but substantially lower than polycyclic plantations. Under a -30% in stumpage price assumption, EAV of walnut decreases to 67 EUR ha^{-1} yr^{-1}.

Firewood prices can be considered stable in the domestic market and the results show that a ±10% variation does not chance significantly the EAV of timber plantations models, including polycyclic plantations for energy models. The results of the sensitivity analyses are reported in the supplementary material (Annex 1.5 and Annex 1.6).

5.4 Discussion

Investment in timber plantations in the Po valley were analysed assuming representative stand management regimes and defining different models according to investment costs and site fertility. All inputs used in the study refer to the context of the Po valley and are derived from literature, market analysis and from the experimental sites of AALSEA and LIFE+ InBioWood project. These have been selected and analysed assuming appropriate management conditions; therefore, our estimates cannot represent all the situations and it has to be considered that different assumptions related to site characteristics and management regimes could led to significantly different results.

The average investment cost of establishing and managing a timber plantation, including site preparation, planting and maintenance costs, is 5,274 EUR ha^{-1}. The range of investment costs among plantation models is rather high and varies from 2,469 EUR ha^{-1} for walnut plantations to 9,898 EUR ha^{-1} for poplar plantations, depending on the number of trees to plant and the management intensity. Polycyclic plantations are based on the highest number of trees to plant, between 659 to 805 trees per hectare, while walnut plantations the lowest, 110 trees per hectare. Poplar plantations present the highest number of management interventions, in particular related to irrigation and phytosanitary treatments. On the other hand, polycyclic plantations need less management interventions, thanks to the species diversification and positive ecological interaction among them. According to recent study by Pelleri *et al.* (2013), the capacity of polycyclic plantations to be more resistant to external disturbances has been quantified in a potential reduction of 61% of the use fertilizers, irrigation and pesticides compared to monospecific hybrid poplar plantations. The hypothesis of a greater resistance of mixed plantations compared to monospecific ones has received an increasing evidence in literature, i.e. Jactel and Brokerhoff (2007), Stojanovic *et al.* (2015), Jactel *et al.* (2016).

The growth rates of timber plantation species in the Po valley range from 1.4 m^3 ha^{-1} yr^{-1} for walnut to 26.9 m^3 ha^{-1} yr^{-1} for poplar plantations. If compared with growth rates of fast-growing species at global level (e.g. Sedjo, 2001; Tomberling and Buongiorno, 2001), hybrid poplar in the Po valley is among the species with the highest MAI in the temperate zones.

We estimated investment returns of timber plantations using NPV, EAV, IRR and discounted PBP, using a 3.5% real discount rate. IRRs of walnut plantations varies from 5.0% to 10.0%; for poplar plantations can reach 12.0% in the best case but could be lower than 3.5% in the worst one, and for polycyclic plantations it ranges from 8.0% to 16.4%. However, when interpreting the results, it has to be considered that the results are presented “before tax”. For what concerns hybrid poplars and walnut plantations, our estimates appear to be in line with the values derived by other authors in the same context: Borelli and Facciotto (1997) estimated IRR of poplar plantation in the range 2%-8%, while Cianciosi (1996) estimated IRR of walnut plantation between 9.1% and 9.6%. In the case of polycyclic plantation, financial aspects have never been investigated in Italy. However, a term of comparison is provided by Vidal and Becquey (2008), who carried out a financial analysis of an experimental mixed plantation of hybrid poplar and walnut in agricultural land in France, where the IRRs estimated ranged between 6.9% and 7.6%, against a 5.5% of monospecific walnut and a 7.5% of monospecific poplar in the same context.

We also compared timber plantations with alternative agricultural crops by ranking all the models based on their EAV, used as primary indicator in order to equally compare plantations with different rotations and annual agricultural crops. Despite agricultural crops models have in general the greatest variability, maize silage models in high fertility sites dominates the rank, with EAV values of respectively 1,429 EUR ha^{-1} yr^{-1} and 728 EUR ha^{-1} yr^{-1} depending on the management costs. Maize grain and soy financial results ranked far below, especially for those cultivation models associated with average fertility conditions. Polycyclic plantations models result on average the best ones among timber plantations, with EAV ranging from 244 EUR ha^{-1} yr^{-1} to 669 EUR ha^{-1} yr^{-1}. The best results in the rank are provided by polycyclic plantations models with a high component of hybrid poplar for plywood logs. Poplar plantations models have the greatest variability among timber plantations, with EAV varying from -10 EUR ha^{-1} yr^{-1} to 454 EUR ha^{-1} yr^{-1}. Walnut plantations models result all in the lower half of the rank, with EAV ranging from 74 EUR ha^{-1} yr^{-1} to 266 EUR ha^{-1} yr^{-1}. Obviously, the choice of the discount rate affects substantially the EAV of a multi-year investment in timber plantations; we addressed this issue providing analyses based on alternative discount rates suggested in the sectorial literature.

Discussing the results of the sensitivity analyses to test the effect of subsidies, land use costs, and timber stumpage prices variations, our analyses indicate that these factors affect significantly timber plantations investments returns. In the average subsidy scenario, based on the current RDPs measure 8.1 project-based grants for northern Italian Region, the mean EAV values of polycyclic, poplar and walnut plantations increase respectively up to 1,018 EUR ha^{-1} yr^{-1}, 494 EUR ha^{-1} yr^{-1}, and 354 EUR ha^{-1} yr^{-1}. The results reflect the current approach of the RDPs derived from the Reg. EEC No. 1305/2013, that tends to incentivize more medium-long rotation with multifunctional role rather than short rotation plantations (with the objective of "support for sustainable and climate friendly land use"). The uniform CAP direct payment of 317 EUR ha^{-1} yr^{-1} has also strong effect on profitability levels of agricultural crops (Bolzonella *et al.*, 2014); this is not applicable to the timber plantations types considered in this study. It has been debated that in this type of contexts with high opportunity costs related to alternative agricultural land use, even if these forest plantations are profitable, land owners would not be attracted to invest in plantations that requires high capital advances and produce an income only at the end of the rotation (Alliance Environment, 2017). An additional indicator for exposure risk of the investment that we estimated in this study is the PBP; this has resulted to be shorter for poplar and polycyclic plantations, 10 or 12 years according to site fertility, while for walnut is 20 or 27 years. We can presume that subsidies can have a determining role in incentivizing land owners to establish plantations in this context. In addition, polycyclic plantations have also the advantage of producing a first income already at the seventh year (firewood from plane tree) and have cost of the investment recovered with the first poplar rotation completed (10 or 12 years).

The need to rent land appears to have great negative effects on the investments, if not supported by subsidies. The inclusion of a land rent cost without subsidies decreases mean NPV to negative values for all timber plantations as well as for agricultural crops models.

Timber stumpage prices are also a key factor to determine the profitability levels of timber plantations. We simulated several variations of poplar, walnut and firewood stumpage prices. This analysis is particularly relevant given that the Italian domestic timber market is far from being stable and the variations chosen for the analysis reflect the average real variations rates in recent years. Poplar timber market can be considered the most secure and fairly stable market. However, our results show that a 20% variation in poplar stumpage price affects significantly the EAV of an investment in this sector, that can increase up to 382 EUR ha^{-1} yr^{-1} (+20% in poplar stumpage price) or drop to 44 EUR ha^{-1} (-20%). Walnut timber market is historically the less stable, and consequently the profitability of the investment can radically change. Moreover, it has to be considered that walnut timber has the most floating price in the domestic market and the stumpage price used in the analysis is the most uncertain due to the lack of market information. Financial performances of poplar and walnut plantations showed to be very sensitive to timber stumpage prices variations, being these plantations monospecific. On the contrary, the diversification of species, rotations and final assortments of polycyclic plantations appears to be a successful key element to manage the risk of variations in timber prices.

Our analysis allows us to hypothesize the investments trends for these plantations in the upcoming future. Investments in poplar plantations are likely to be rather stable in the near future, driven mainly by a constant demand for timber to feed the plywood and veneer industries. In addition, current research on the development of new more environmentally friendly poplar clones, more resistant to pest and insect attacks and more adapted to specific soil characteristics (Vietto *et al.*, 2011; Facciotto *et al.* 2014) could lead to a reduction of management costs and consequently higher investment returns. On the contrary, investments in high value hardwoods plantations are likely to continue to fall despite the current framework of higher subsidies for medium-long terms plantations provided by the RDPs. The instability of the high value hardwood market for sawn logs, together with longer PBP is likely to determine this trend. Investments in polycyclic plantations are likely to growth in the near future, also boosted by the favourable subsidy policy framework. This trend will be probably driven by the encouraging results on poplar growth rates in polycyclic plantations (e.g. Castro *et al.*, 2013; Buresti Lattes *et al.*, 2015; Mori and Buresti Lattes, 2017) and the growing attention towards their better environmental impact compared to monospecific plantations (Buresti Lattes and Mori, 2009; Motta *et al.*, 2014; Chiarabaglio *et al.*, 2014; Londi *et al.*, 2016). On the other hand, polycyclic plantations present also limitations connected to the higher complexity for the land owners in terms management practices, and for forest enterprises for harvesting operations (Pelleri *et al.*, 2016), that will need to be addressed by practitioners. Moreover, it has to be considered that the polycyclic plantations models analysed in this study are somehow still of experimental character.

5.5 Conclusions

We estimated and discussed potential investment returns from timber plantations established on agricultural land, focusing specifically in the context of the Po valley, considering the opportunity costs associated to the alternative agricultural land use and the effects of factors such as subsidies, land use costs and timber stumpage prices. We compared two monospecific plantation types, i.e. walnut and hybrid poplar plantations, with polycyclic plantations. Walnut is the most widespread species among medium-long rotation high value hardwoods and had a significant expansion with the subsidies provided under the afforestation measures of the Reg. EEC No. 2080/1992 and Reg. EEC No. 1257/1999. Poplar plantations have been historically the most consolidated segment of investment in timber plantations in Italy; they are cultivated in intensive short rotations using hybrid clones, mainly clone 'I-214', for the production of plywood logs. Polycyclic plantations are an emerging example of mixed and multi-rotation plantations, with medium-long cycles or even potentially a permanent, with much higher positive impacts in terms of biodiversity and environmental services provision. Timber plantations were compared as well with the main alternative agricultural crops: maize silage, maize grain and soy.

When considering the base case scenario, where no land use costs nor subsidies have been included, our results show that polycyclic plantations could present on average the best financial performances and poplar plantations are on average more profitable than walnut plantations, although there are significant differences among the single models depending on site fertility and investment cost levels. If we consider also the sensitivity analyses performed in the study, the potential financial performances of polycyclic plantations demonstrate that mixed and multifunctional plantations can be competitive, and in some cases even more interesting, in financial terms than monospecific plantations. In addition, the capacity of polycyclic plantations to better deal with market risks compared to monospecific plantation, thanks to the diversification of species and final assortments, emerged as an important management solution. However, it has to be considered that polycyclic plantations require more technical knowledge and management competences by land owners and the problem of technology transfer should not be underestimated.

In the context of the Po valley, the opportunity costs for alternative land uses can be extremely high and market risk appears to be a crucial element in investment decisions. Longer payback periods might make annual agricultural crops more attractive for land owners. For non-land owners' investors, investments in timber plantations in the Po valley are rather risky and unlikely to be attractive.

Chapter 6

Paper II – Financial returns from hybrid poplar plantations in northern Italy between 2001 and 2016: are we losing a bio-based segment of the primary economy?

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Abstract

This work estimated financial returns at aggregate level from hybrid poplar plantations in northern Italy between 2001 and 2016. The results suggest that poplar can represent one of the most profitable investment among forest plantations in Europe, although the range of variability of potential returns is rather large. The decrease of expected returns over the last 15 years have negatively undermined the attractiveness for new investments, increasing the market risk component. We also assessed the effects of external variables such as public subsidies, land use cost, opportunity cost, and insurance cost. Land and opportunity costs appears to be crucial variables, as well as public subsidies, which have undergone substantial changes over the investigated period.

Keywords: Hybrid poplar, fast-growing species, timber production, investment analysis, Rural Development Policy, Italy.

6.1. Introduction

Poplar is one of the most fast-growing species at temperate latitudes, and its cultivation in productive forest plantations is widespread and of key importance in several geographical areas, i.e. North America, Europe, India, and China. The area covered by poplar plantations is estimated to be 8.6 million hectares at global level (FAO, 2012c). In Europe, poplar plantations reach almost one million hectares, with the highest shares in France, Turkey, Italy, Spain and Hungary (Nervo *et al.*, 2011).

In Italy, hybrid poplar plantations represent the most important segment of industrial timber production for the plywood, packaging, pulp and paper, and wood-based panels industries, providing more than 50% of the industrial hardwood domestic supply (Assopannelli, 2012; MIIPAF, 2012; Coaloa *et al.*, 1999; Coaloa, 2014). The large majority of these plantations, over 90%, are grown in the alluvial plains of northern Italy, in particular in the Po valley (ISTAT, 2016). The most suitable sites for poplar plantations are medium to high fertility arable agricultural land and river bends. Conventional poplar cultivation in northern Italy is characterized by intensively managed monospecific plantations, with short rotations cycles (9-12 years) and 278 to 330 trees per hectare. The cultivation techniques make hybrid poplar plantations more similar to agricultural crops rather than forestry in terms of labour and water inputs. Plantations are established from hybrid clones, where the predominant one has been since decades the *Populus x canadensis* 'I-214', attaining on average a Mean Annual Increment (MAI) between 20 and 27 m^3 per hectare per year. The largest part of hybrid poplar plantations is intended for the production of plywood and veneer logs, with an overall yearly domestic production of over one million cubic meters of industrial roundwood which is processed and used in Italy for the production of high-quality plywood and food packaging. Nevertheless, it is estimated that domestic supply is able to cover less than half of the industry domestic demand, which heavily relies on roundwood imports, largely from France and Hungary (FLA, 2018).

Despite the importance of this species for the industry, investments in poplar plantations have been undergoing a significant decline, started in the 1980s and more accentuated in the last two decades, reflected in the reduction of cultivated areas (Coaloa, 2008; Lapietra *et al.*, 1995). According to the data of the Agricultural Census of the Italian National Institute of Statistics (ISTAT), that considers only agricultural farms areas, poplar cultivated surface decreased from 83,368 hectares in year 2000 to 39,308 ha in year 2010 (-52.9%), while the number of farms cultivating poplar decreased by 59.3% (ISTAT, 2016). The last two National Forest Inventories, which comprise also hybrid poplar plantations outside agricultural farms, reported in year 1985 a cultivated area of 110,700 ha and in year 2005 of 66,270 ha (IFN, 1985; Gasparini and Tabacchi, 2011). This decline has been influenced by both economic variables directly related to the production, such as stumpage prices, management costs and land cost, suppliers' fragmentation and smallholder's weak contractual power, as well as external variables, i.e. the high opportunity costs related to alternative agricultural land-use (in particular for cereals production), environmental restrictions to cultivate in river bends (area which are in many cases identified as Site of Community Importance, Special Protection Area or Natura 2000 areas), non-effective subsidy policies (those related to the European Union's Common Agricultural Policy and its Rural Development Plans), and the growing risk component related to extreme weather events and pest attacks (Coaloa, 2009; Nervo, 2009; Castro and Zanuttini, 2008; Borelli, 1997).

In this context, investigation in the economic and financial aspects of hybrid poplar cultivation can contribute to a better understanding of this market segment evolution and its dynamics over time. In particular, the research questions that we aimed to answer with this study were: how profitability of hybrid poplar plantations has changed over the past 15 years as a result of the evolution of the key economic variables of investment costs and timber prices? And how external variables could have influenced this trend? Therefore, the objective of the study presented in this paper was to: i) estimate and analyse the evolution of financial returns at aggregate level from hybrid poplar plantations in northern Italy between 2001 and 2016; and ii) assess the impact of the major policy and market factors on the financial returns evolution, i.e. public subsidies, land use cost, opportunity costs of alternative agricultural land-use, and insurance policy cost.

Given the importance of this species at global level, various authors in the literature tackled the topic of cost-effectiveness of productive poplar plantations. i.e. Anderson and Luckert (2006) in Canada, Tankersley (2006) in southern United States, Keća *et al.* (2011) and Keća *et al.* (2012) in Serbia, Aunos *et al.* (2002) Diaz Balteiro and Romero (1994), Esteban López *et al.* (2005) and Del Peso *et al.* (1995) in Spain. In Italy, studies on financial aspects of hybrid poplar plantations are not recent. The most recent work on the profitability of poplar plantation is related to the ECOPIOPPO project, where the potential financial performances of conventional cultivation have been compared against those based on an experimental environmentally-friendly management standard (Coaloa and Vietto, 2005; Regione Piemonte, 2002). Other studies can be found in Borelli (1996), Borelli and Faciotto (1997) or in Prevosto (1969 and 1971). It has to be noted that in recent years, a considerable interest was given to financial performances of hybrid poplar in Short Rotation Coppice plantations aimed at the production of biomass for energy and for panel production (Coaloa and Facciotto, 2014; Di Candilo and Facciotto, 2012; Manzone *et al.*, 2009), unfortunately with limited impacts on the real investments in this sector.

6.2. Methodology

We defined a representative management regime for hybrid poplar plantations in northern Italy, following an approach similar to the one used in Sedjo (1983) and Cubbage *et al.* (2007). We decided to use a representative management regime since the study's objective was not to carry out an exhaustive analysis, but rather to estimate the financial returns evolution over the period 2001-2016 at aggregate level, assuming a management regime which could represent the most frequent situation for poplar growers in northern Italy, based on the 'typical farm' approach used in rural appraisal. In fact, poplar cultivation in northern Italy is based on a consolidated practice, i.e. same clone, same rotation period, same pruning regime, etc., with no much innovations in the last two decades.

The data and information on management regime and investment costs used in this study were provided by three industrial and four professional private poplar growers in Friuli Venezia-Giulia (Udine), Veneto (Rovigo) and Lombardy (Mantua) (interviewed face-to-face between January 2016 and February 2017), completed and adjusted with data from farms archives, regional bulletins and agricultural contractor's rates. When no historical data were available, due to the lack of book-keeping by poplar growers, we used the FAOSTAT (2018) Agricultural Producer Price Index for Italy to estimate missing data and complete the time series. The silvicultural regime is presented in Table 6.1.

Table 6.1: Representative silvicultural regime used in the analyses

Flow	Category	Operation	Year											
			0	1	2	3	4	5	6	7	8	9	10	11
Costs	Site preparation	Ploughing	1											Land recovery year
		Ripping	1											
		Harrowing	1											
	Planting	Seedlings purchase and transport	1											
		Mark. dig and planting	1											
		Localized irrigation	1											
	Silvicultural management	Disk harrowing		3	3	3	2	2	2	1	1			
		Phyt. treatment *Marssonina brunnea*		2	2	2	2	2						
		Phyt. treatment *Saperda carcharias*			1	1	1							
		Phyt. treatment *Cryptorhynchus lapathi*			1	1								
		Phyt. treatment *Phloeomyzus passerinii*							1	1	1	1		
		Weeding		1	1	1	1	1	1	1	1	1		
		Fertilization		1	1	1	1	1						
		Pruning		1	1	1	1	1						
		Irrigation		1	1	1	1	1	1	1	1	1		
	Cleaning	Stumps trituration and cleaning											1	
Revenues	Standing tree sale												1	

Note: *numbers refer to the number of operations carried out annually*

The analysis was carried out considering a plantation established from *Populus x canadensis* 'I-214' with a 6x6 planting spacing (278 trees per hectare, assuming a 5% of mortality at the end of the rotation) and 11 years rotation, including one year of land recovery. We assumed average site conditions and ordinarily efficient implementation according to the typical professional management standards.

Investment costs cover the period 2001-2016 and includes preparation, planting, silvicultural management costs and cleaning costs. Harvesting costs were not included because trees are sold as standing trees. We considered two ranges, one related to a situation of minimum investment costs (Cmin) and one to maximum investment costs (CMAX).

Regarding the poplar timber stumpage prices, we used the range of prices recorded by the Chambers of Commerce of Mantua (2018) and Chambers of Commerce of Alessandria (2018) which are available for the period 2001-2018 (Annex 2.1 of the supplementary material). In this case we also considered a range of minimum stumpage prices (Pmin) and maximum stumpage prices (PMAX). The large price variation between Pmin and PMAX is due to the number of variables that can influence prices, i.e. quality, location, and land owner's contractual power. Poplar stumpage prices are recorded by Chambers of Commerce in Euros per ton. Based on poplar grower's data, reviewed by experts, we assumed an average poplar timber production of 185 tons per hectare, using a conversion factor of 0.7 tons per tree.

Both cost and price values include the Value Added Tax (VAT) and have been converted from nominal values into real values using the inflation index provided by the Italian Institute of Statistics (ISTAT, 2017).

Based on the input data on investments costs and stumpage prices we considered four models:

- maximum investments costs and minimum stumpage prices (CMAX-Pmin);
- maximum investments costs and maximum stumpage prices (CMAX-PMAX);
- minimum investments costs and minimum stumpage prices (Cmin-Pmin);
- minimum investments costs and maximum stumpage prices (Cmin-PMAX).

To carry out the financial analysis, we firstly developed the cash flow tables considering cost and timber prices in terms of market prices. Secondly, we calculated three capital budgeting indicators to estimate financial returns: NPV, IRR, and LEV (Klemperer, 2003; Wegner, 2012; Cubbage *et al*. 2015). These have been calculated as follows:

$$NPV = \sum_{n=0}^{N} \frac{R_n - C_n}{(1+i)^n}$$

$$IRR = i: \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n}$$

$$LEV = \frac{NPV * (1+i)^N}{((1+i)^N - 1)}$$

Where:
n = year
R = revenues at year n
C = costs at year n
i = annual discount rate
N = rotation length.

The NPV represents the present value of future cash flows and is generally considered as a preferable indicator to be used when analysing short term forestry investments (Klemperer, 2003; Wegner, 2012). The IRR represents the discount rate (i) at which the NPV of the investment equals zero. Finally, we included the LEV (or Soil Expectation Value) as it is a useful indicator for estimating the theoretical land value. In practice, the LEV represents the present value of all future costs and revenues assuming that the rotation cycle will be replicated an infinite number of times into the future. Land use costs are not included initially in the calculation of LEV.

We calculated the capital budgeting indicators for each year along the period 2001-2016, combining two different calculation approaches: *ex-ante* and *ex-post*. The *ex-ante* approach provides us the expected returns, thus, is calculated based only on values of the year when the investment was carried out. In this case, the NPV of a plantation established in 2001 is calculated as follows:

$$NPV\ ex\ ante_{2001} = \frac{R_{2001}}{(1+i)^{11}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2001}}{(1+i)^{2}} - \frac{C_{2001}}{(1+i)^{3}} - \cdots - \frac{C_{2001}}{(1+i)^{11}}$$

Where R_n and C_n are the sum of revenues and costs at year n. On contrary, in the *ex-post* approach, we took into consideration the actual evolution of costs and prices along the investment horizon. In this case, the calculation is slightly different from the previous one:

$$NPV\ ex\ post_{2001} = \frac{R_{2011}}{(1+i)^{11}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2002}}{(1+i)^{2}} - \frac{C_{2003}}{(1+i)^{3}} - \cdots - \frac{C_{2011}}{(1+i)^{11}}$$

Therefore, the *ex-post* estimates provide information on the actual financial returns according to input variables evolution throughout the years. However, it has to be considered that we did not carry out any future projection, thus the values from 2016 for costs and 2018 for prices are assumed to be constant. This combined approach allowed us to estimate the variation between the *ex-ante* financial returns expectations and the *ex-post* returns.

Wwe decided to use a real discount rate of 3.5% (HM Treasury, 2003). However, different discount rates in the range 2%-12% (ECB, 2016; Keča *et al.*, 2011) were also tested to allow the readers to compare the results on other assumptions. The analysis is carried out before income- and land-tax. This choice is motivated by the fact that the Italian tax regime varies substantially depending on the legal status and the business model of the investors.

We firstly assumed a baseline scenario not including opportunity cost, land use costs, and subsidies. Secondly, we carried out sensitivity analyses in order to test the effects of different hypothesis:

(a) public subsidies, with the inclusion of a reimbursement of site preparation and planting costs, according to the afforestation measure grants by the regional Rural Development Plans (RDP);
(b) land use costs, with the inclusion of an annual land rent;
(c) opportunity costs of alternative crop production, with the inclusion in the cash flow of missed revenues from the alternative corn cultivation;
(d) the combination of (b) and (c);
(e) risk insurance costs, including the cost of an insurance policy that protect the land owner against losses due to extreme weather events.

The sensitivity analyses input data are presented in Table 6.2.

Table 6.2: Input data for sensitivity analyses

<table>
<tr><th>Year</th><th>Missed revenues from corn cultivation in northern Italy (EUR/ha/yr)*</th><th>Average annual land rent cost for selected types for land in the Po valley (EUR/ha/yr)</th><th>Reimbursement percentage of site preparation and planting costs according to Rural Development Plan measures (%)</th><th>Insurance cost (EUR/ha/yr)</th></tr>
<tr><td>2001</td><td>Data not available</td><td>378.60</td><td rowspan="5">60% according to Measure H of RDPs 2000-06 (Reg. ECC No. 1698/1999)</td><td></td></tr>
<tr><td>2002</td><td>Data not available</td><td>368.20</td><td></td></tr>
<tr><td>2003</td><td>Data not available</td><td>347.30</td><td></td></tr>
<tr><td>2004</td><td>Data not available</td><td>347.30</td><td></td></tr>
<tr><td>2005</td><td>Data not available</td><td>352.50</td><td></td></tr>
</table>

2006	Data not available	307.70		
2007	Data not available	317.10	70% according to Measure 221 of RDPs 2007-13 (Reg. ECC No. 1968/2005)	
2008	150.7	312.90		
2009	-65.40	310.80		
2010	304.90	326.50		
2011	394.40	333.80		
2012	433.40	328.00		
2013	242.30	315.00		
2014	234.40	383.00	60% according to Measure 8.1 of RDPs 2014-20 (Reg. ECC No. 1305/2013)	
2015	112.90	338.00		
2016	Data not available	350.00		1st to 3rd yr: 83 EUR 4th to 6th yr: 167 EUR 7th to 10th yr: 278 EUR

** Direct payments from the Common Agricultural Policy excluded*

For what concerns public subsidies (a) we referred to the average level of grant-based contribution of the RDP afforestation measures of the northern Italian regions (Emilia-Romagna, Friuli Venezia-Giulia, Lombardy, Piedmont and Veneto), co-funded by the European Agricultural Fund for Rural Development (EAFRD). The contribution consists in a reimbursement of a percentage of the plantation establishment costs (site preparation and planting costs). In the current programming period 2014-2020, derived from the Reg. ECC No. 1305/2013, the average reimbursements percentage of the establishment costs is 60% (Measure 8.1). In the programming period 2007-2013 (ECC No. 1698/2005), it was 70% (Measure 221), and in the programming period 2000-2006 (Reg. ECC No. 1698/1999), 100% of the establishment costs were covered (Measure H). We excluded premiums criteria related to the use of environmentally-friendly clones and voluntary forest certification schemes. The reimbursement was included in the cash flow as a revenue at year 1.

Regarding the annual land rent cost (b), we elaborated the data from the Agriculture Annual Review of CREA (former INEA), calculating the average values for the years from 2001 to 2016 of selected types of lands in the provinces of Alessandria, Mantua and Udine (CREA, 2016). The land rent cost was included in the cash flow as an annual cost from year 1 to 11.

For the third sensitivity analysis (c) we estimated the yearly missed net revenues from corn production using the data of the Farm Accountancy Data Network (FADN) (RICA, 2017). We elaborated the missed net revenues from corn production year by year from the farm accounts including an explicit cost for labour for five northern Italian Regions between 2008 and 2015. Outliers were removed using a standard mathematical procedure (i.e based on boxplots, excluding values that resulted beyond the quartiles by one-and-a-half interquartile range). Direct payments of the Common Agricultural Policy (CAP) were not included. The missed revenues were included in the cash flow as a cost from year 1 to 11.

Finally, the cost of an insurance policy (e) protecting the land owner against total and partial losses caused by fire, lightning, hail and windstorm was provided by an industrial poplar grower. The cost corresponds to the 2% of the timber stumpage value in the plantation (the timber stumpage value is defined at 15 EUR per tree in the first three years of rotation, 30 EUR per tree from year four to year six, and 50 EUR per tree from year seven to the end of the final harvest). We decided to assume the insurance cost as a proxy for including the risk-component in the analysis. Nevertheless, it has to be considered that, due to their high cost, insurance policies are used only by few industrial poplar growers in Italy.

6.3 Results

Results are presented in the following order: 1) evolution of investment costs and timber stumpage prices; 2) financial return estimates according to the baseline scenario; and 3) sensitivity analyses results.

6.3.1 Evolution of investment costs and timber stumpage prices

Table 6.3 summarizes investments costs, with reference to year 2016.

Table 6.3: Investment costs, 2016

Category	Operation	Cmin (EUR/ha)	CMAX (EUR/ha)	Percentage difference Cmin-CMAX	Incidence on total costs	
					Cmin	CMAX
Site preparation	Ploughing	151.50	222.20	37.8%		
	Ripping	60.60	70.70	15.4%		
	Harrowing	40.40	60.60	40.0%		
	Total	252.50	353.50	33.3%	3.8%	3.7%
Planting	Seedlings	842.30	1,066.60	23.5%		
	Mark. dig and planting	631.30	853.50	29.9%		
	Irrigation	80.80	101.00	22.2%		
	Total	1,554.40	2,021.10	26.1%	23.5%	21.0%
Silvicultural management	Disk harrowing	858.50	1,287.80	40.0%		
	Phyto. treat. *Marssonina brunnea*	848.40	1,131.20	28.6%		
	Phyto. treat. *Saperda carcharias*	181.80	212.10	15.4%		
	Phyto. treat. *Cryptorhynchus lapathi*	171.70	191.90	11.1%		
	Phyto. treat. P*hloeomyzus passerinii*	282.80	363.60	25.0%		
	Weeding	181.80	227.30	22.2%		
	Fertilization	404.00	656.00	47.5%		
	Pruning	656.50	1,111.0	51.4%		
	Irrigation	999.90	1,818.00	58.1%		
	Total	4,585.40	6,999.60	41.7%	69.3%	72.6%
Cleaning	Stumps removal and trituration	222.20	262.60	16.7%	3.4%	2.7%
TOTAL		6,614.50	9,636.40	37.2%		

The total investment costs vary between 6,614 EUR ha^{-1} (Cmin) and 9,636 EUR ha^{-1} (CMAX). We split investment costs in four categories: site preparation costs, planting costs, silvicultural management costs and cleaning costs. The total percentage difference between Cmin and CMAX is 37.2%, resulting to be particularly large for the silvicultural management costs (41.7%), followed by site preparation costs (33.3%), planting costs (26.1%) and cleaning costs (16.7%). For what concern the incidence of the single categories on the total investment costs, silvicultural management costs are the most significant, accounting for a 69.3% (Cmin) and 72.6% (CMAX), planting costs are also important being concentrated in the first year (23.5% Cmin and 21% CMAX), while site preparation costs accounts for a 3.8% (Cmin) and 3.7% (CMAX), and cleaning costs for a 3.4% (Cmin) and 2.7% (CMAX). On average, investment costs have increased in the period 2001 to 2016 by 25.5%, based on real values. If we look at the single categories, the largest increase results in the costs of planting and cleaning, respectively +38.0% and +37.0%, site preparation costs increased by 24.5%, and silvicultural management costs increased by 22.0%.

Table 6.4 presents the poplar stumpage prices (in EUR per ton^{-1}) evolution from 2001 to 2018, including the percentage difference between the minimum (Pmin) and maximum price (PMAX) and their annual percentage change over the period. The evolution of poplar stumpage prices is presented also graphically in Figure 6.1.

Table 6.4: Poplar stumpage prices, 2001-2018 (real values)

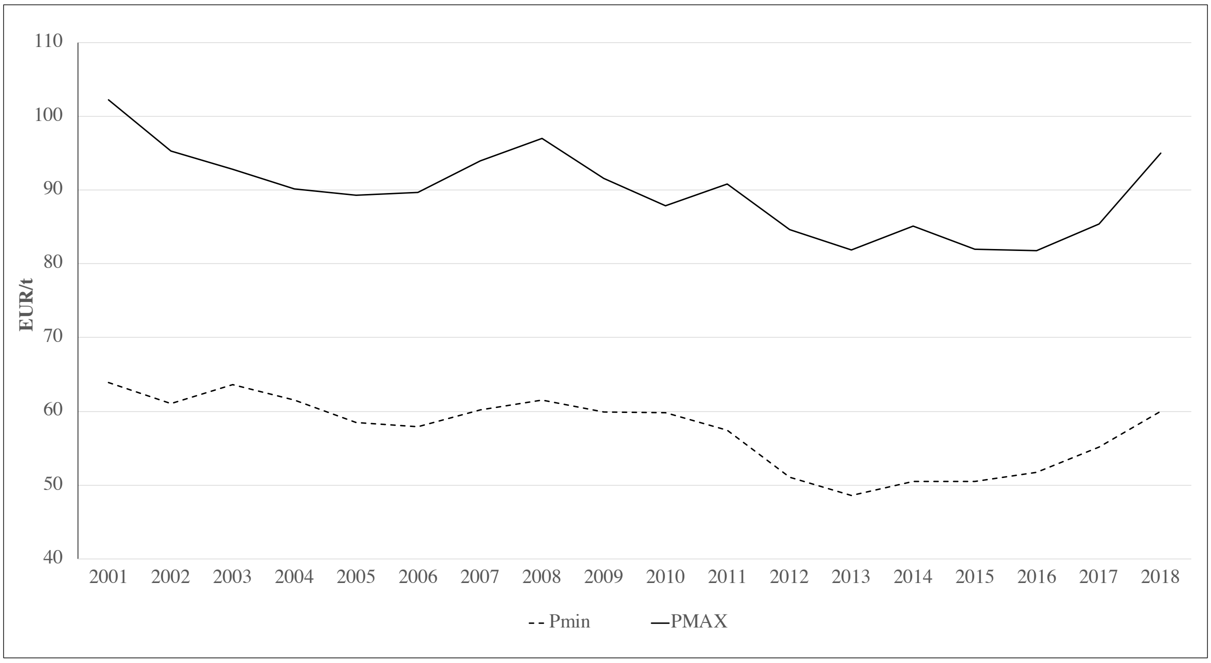
Year	Pmin (EUR/ton)	PMAX (EUR/ton)	Percentage difference Pmin-PMAX	Percentage variation 2001-2018 (2001=100)	
				Pmin	PMAX
2001	63.89	102.20	46.1%	100.0	100.00
2002	61.10	95.25	43.7%	95.6	93.2
2003	63.60	92.82	37.4%	99.5	90.8
2004	61.51	90.17	37.8%	96.2	88.2
2005	58.46	89.27	41.7%	91.5	87.3
2006	57.91	89.72	43.1%	90.6	87.8
2007	60.19	93.93	43.8%	94.2	91.9
2008	61.48	96.95	44.8%	96.2	94.9
2009	59.90	91.54	41.8%	93.7	89.6
2010	59.83	87.87	38.0%	93.6	86.0
2011	57.39	90.78	45.1%	89.8	88.8
2012	51.01	84.66	49.6%	79.8	82.8
2013	48.57	81.85	51.9%	76.0	80.1
2014	50.45	85.09	51.1%	79.0	83.3
2015	50.50	81.98	47.5%	79.1	80.2
2016	51.69	81.81	45.1%	80.9	80.0
2017	55.19	85.35	42.9%	86.4	83.5
2018	60.00	95.00	45.2%	93.9	93.0

Source: own elaboration based on data from the Chambers of Commerce of Mantua and Alessandria

In real values, prices have experienced a non-linear but overall decrease during the considered period. In the period 2001-2018 minimum prices decreased from 63.90 EUR per tree^{-1} to 60.00

EUR per ton^{-1} and maximum prices from 102.20 EUR per ton^{-1} to 95.00 EUR per ton^{-1}, which is a percentage decrease respectively of 6.5% and 7.6%. However, we can identify four major periodic phases in the evolution of stumpage prices: 2001 to 2005, 2005 to 2008, 2008 to 2015 and 2015 to 2018. Between 2001 and 2006 stumpage prices experienced a percentage decrease of 8.5% (Pmin) and 12.6% (PMAX). Between 2005 and 2008, they have increased in percentage terms by 5.1% (Pmin) and 8.6% (PMAX). The strongest reduction took place between 2008 and 2015, with Pmin and PMAX decreasing respectively of 17.7% and 15.6%. In the period 2015-2018 prices have increased considerably of 18% (Pmin) and 15.9% (PMAX). Regarding the percentage difference between Pmin and PMAX, which is the variance in percentage terms between the minimum and maximum price registered, the lowest variance is registered in 2003 (37.4%), while highest in years between 2012 (49.6%) and 2015 (47.5%), with the peak in year 2013 (51.9%).

Figure 6.1: Poplar stumpage prices (EUR/tree), 2001-2018 (real values)

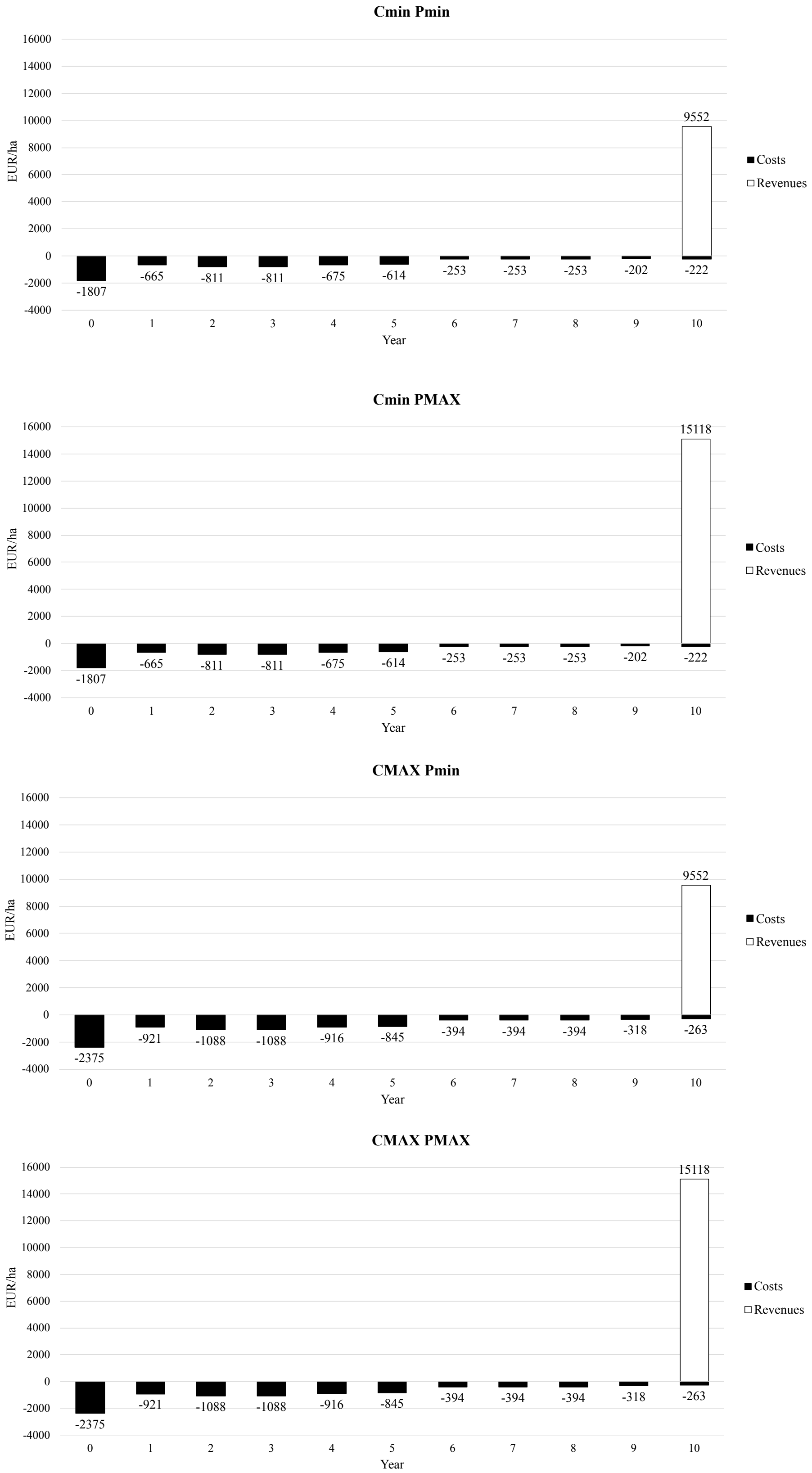


Source: own elaboration based on data from the Chambers of Commerce of Mantua and Alessandria

6.3.2 Financial return estimates according to the baseline scenario

Figure 6.2 presents the cash flow diagrams for the four models Cmin-Pmin, Cmin-PMAX, CMAX-Pmin, and CMAX-PMAX according to the baseline scenario, which does not consider land use costs and subsidies.

Figure 6.2: Cash flow diagrams, 2016



The capital budgeting indicators estimates are presented in Table 6.6, based on 2016 values. In the baseline scenario, NPV (at a 3.5% discount rate) vary from negative values in the CMAX-

Pmin model (-1,921 EUR ha^{-1}) to positive values in the other three models: 786 EUR ha^{-1} in Cmin-Pmin, 2,025 EUR ha^{-1} in CMAX-PMAX, and 4,732 EUR ha^{-1} in Cmin-PMAX. NPV standard deviation among the four models in the baseline scenario is 2,763 EUR ha^{-1}. IRR values range from negative results (CMAX-Pmin) up to 11.9% (Cmin-PMAX). LEV (calculated without considering land purchase costs and land sale returns) results -6,097 EUR ha^{-1} in the CMAX-Pmin model, 2,496 EUR ha^{-1} in Cmin-Pmin, 6,428 EUR ha^{-1} in CMAX-PMAX and 15,020 EUR ha^{-1} in Cmin-PMAX. LEV standard deviation among the four models is 5,237 EUR ha^{-1}.

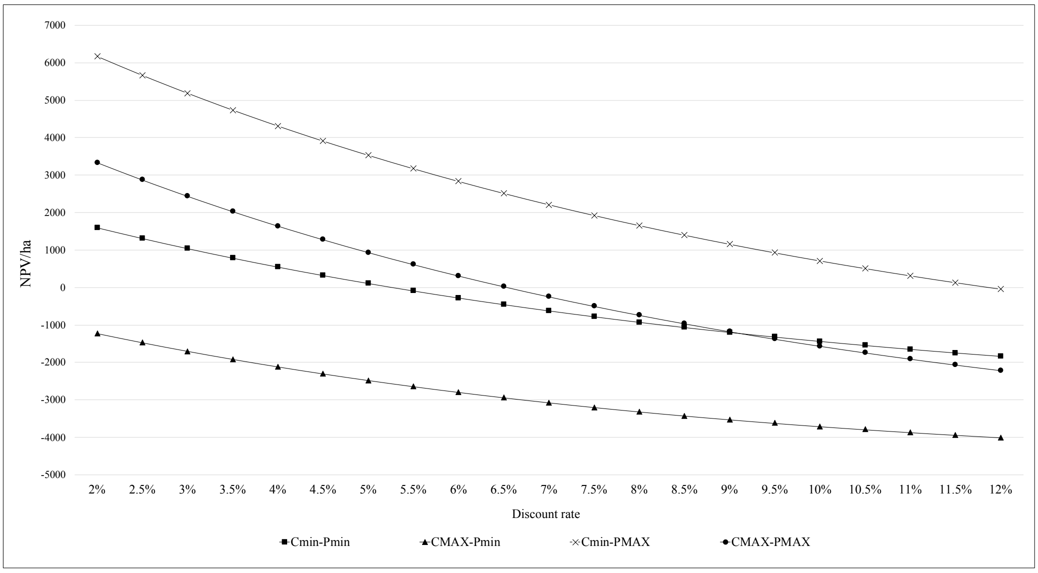
Table 6.5: NPV (EUR/ha), IRR and LEV (EUR/ha) according to the different scenarios, 2016

Scenario	Indicator	Cmin-Pmin	CMAX-Pmin	Cmin-PMAX	CMAX-PMAX	Standard dev.
Baseline	NPV	786	-1,921	4,732	2,025	2,763
	IRR	5.3%	n.a.	11.9%	6.5%	
	LEV	2,496	-6,097	15,020	6,428	5,237
(a) with subsidies	NPV	1,834	-544	5,780	3,402	1,695
	IRR	8.3%	n.a.	15.2%	9.3%	
	LEV	5,821	-1,727	18,345	10,797	8,442
(b) with land rent cost	NPV	-2,124	-4,832	1,821	-886	2,763
	IRR	n.a.	n.a.	6.5%	n.a.	
	LEV	-6,743	-15,336	5,782	-2,811	8,770
(c) with opportunity cost*	NPV	-152	-2,860	3,793	1,086	1,892
	IRR	n.a.	n.a.	10.0%	5.1%	
	LEV	-484	-9,077	12,040	3,447	5,475
(d) with land rent cost and with subsidy	NPV	-1,077	-3,455	2,869	491	2,660
	IRR	n.a.	n.a.	8.7%	4.3%	
	LEV	-3,418	-10,967	9,106	1,558	8,443
(e) insurance cost	NPV	-669	-3347	3,247	539	2,737
	IRR	n.a.	n.a.	9.2%	4.3%	
	LEV	-2,220	-10,813	10,305	1,712	8,677
Standard deviation NPV		1,400	1,793	1,470	1,469	
Standard deviation LEV		4,392	4,661	6,424	4,661	

Note: *results are based on 2016 data calculated with the ex-ante approach*
**Based on 2015 data*

Figure 6.3 presents the results according to different discount rates, using NPV as dependent variable.

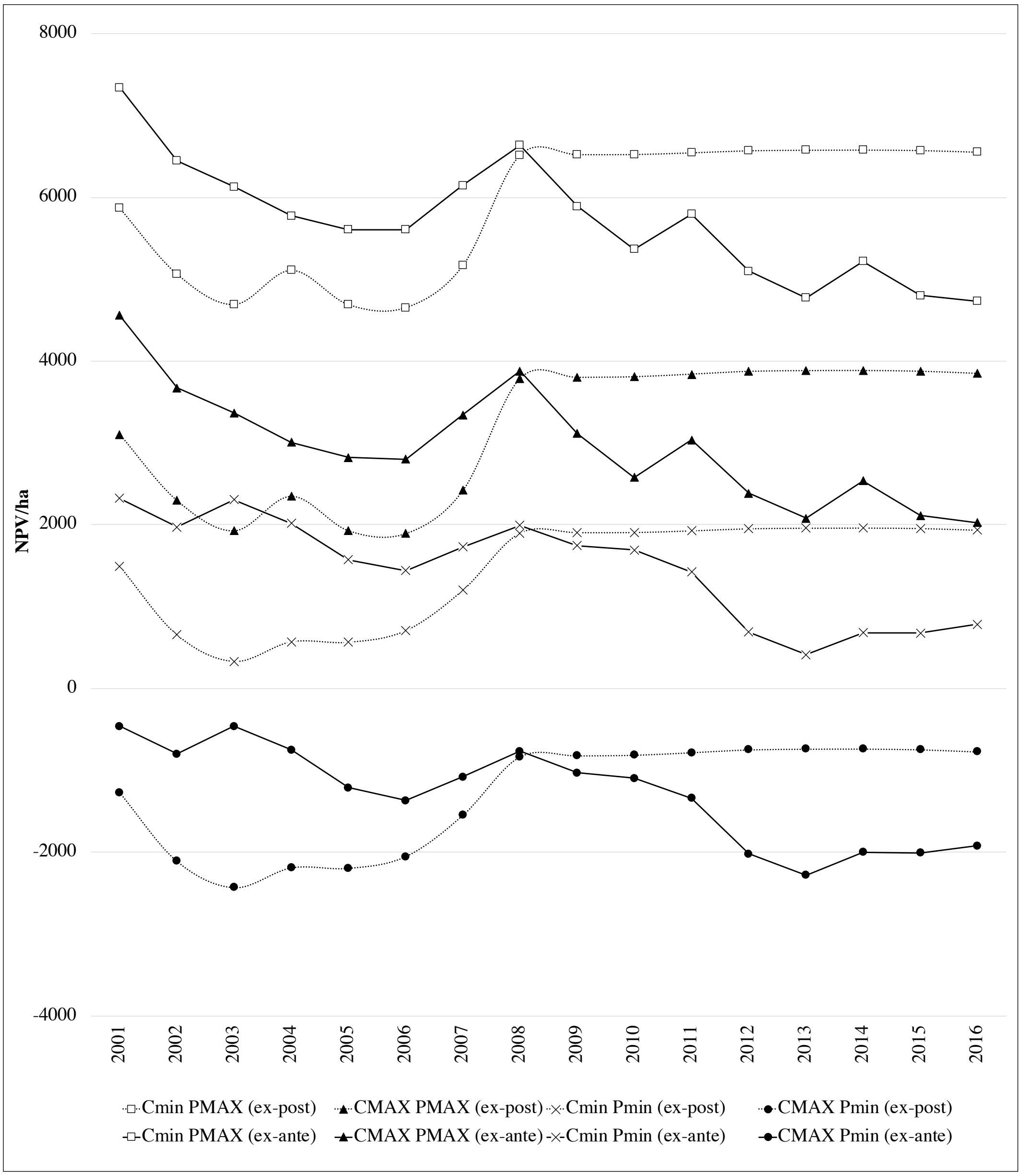
Figure 6.3: Changes in the NPV (EUR/ha) in relation to alternative discount rates, 2016



Source: own elaboration

The trend over the 2001-2016 period is presented in Figure 6.4, also in this case using NPV as dependent variable.

Figure 6.4: NPV in the baseline scenario, 2001-2016 (real values)



Source: own elaboration

If we consider the ex-ante results, representing the expected financial returns at the year the investment was carried out, these show a decline over the 15 years period and this trend is homogeneous for all the four models. In 2001, the NPV is ranging between -460 EUR ha^{-1} (CMAX-Pmin) and 7,344 EUR ha^{-1} (Cmin-PMAX), while in 2016 is respectively -1,921 EUR ha^{-1} and 4,732 EUR ha^{-1}. The NPV average decrease from 2001 to 2016 is -2,036 EUR ha^{-1}. IRR values decreased from 15.1% (2001) to 11.9% (2016) for the Cmin-PMAX model, from

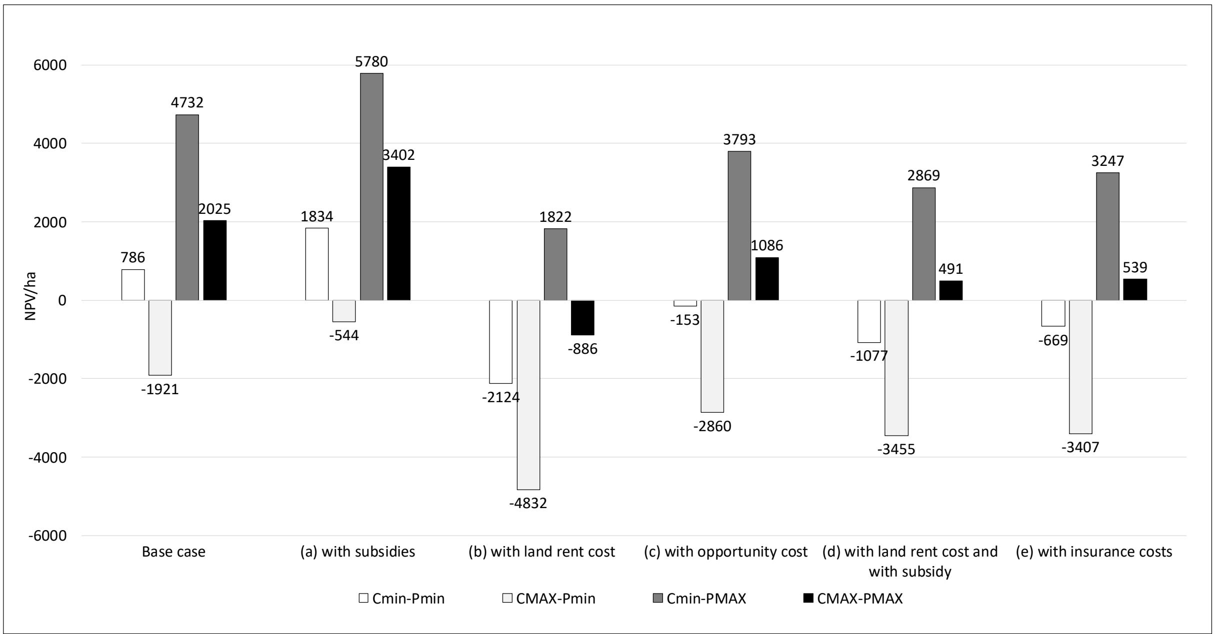
9.6% to 6.5% in CMAX-PMAX, and from 8.5% to 5.3% for in Cmin-Pmin. LEV decreased on average by 6,463 EUR ha^{-1} from 2001 to 2016. Concerning the ex-post estimates, NPV shows two periodic trends: a decline from 2001 to 2005 (2003 for Cmin-Pmin and CMAX-Pmin), and an increase from 2005 to 2008. From 2008 onwards, the lines flatten because we assumed constancy of values from 2018 onwards for prices.

The negative peak is in 2003 for the models associated with minimum prices and in 2005 in those associated to maximum prices. The NPV average decrease from 2001 to 2005 is 1,052 EUR ha^{-1}. From 2005 to 2008, NPV increase on average by 1,597 EUR ha^{-1}, due to the stumpage price substantial increase between 2016 and 2018. In overall terms, NPV raised from values that in 2001 were between -1,270 EUR ha^{-1} (CMAX-Pmin) and 5,869 EUR ha^{-1} (Cmin-PMAX), to values from -772 to 6,555 EUR ha^{-1} in 2016. IRR values raised from 6.7% in 2001 to 7.5% in 2016 for the Cmin-Pmin model, from 13.4% to 14.1% in Cmin-PMAX, from 7.9% to 8.8% in CMAX-PMAX. LEV decreased on average by 3,339 EUR ha^{-1} from 2001 to 2005 and increased by 5,068 EUR ha^{-1} from 2005 to 2008.

6.3.3 Sensitivity analyses results

The results of the sensitivity analysis testing different hypothesis on the NPV are presented in Figure 6.5, based on 2016 values (as Table 6.5).

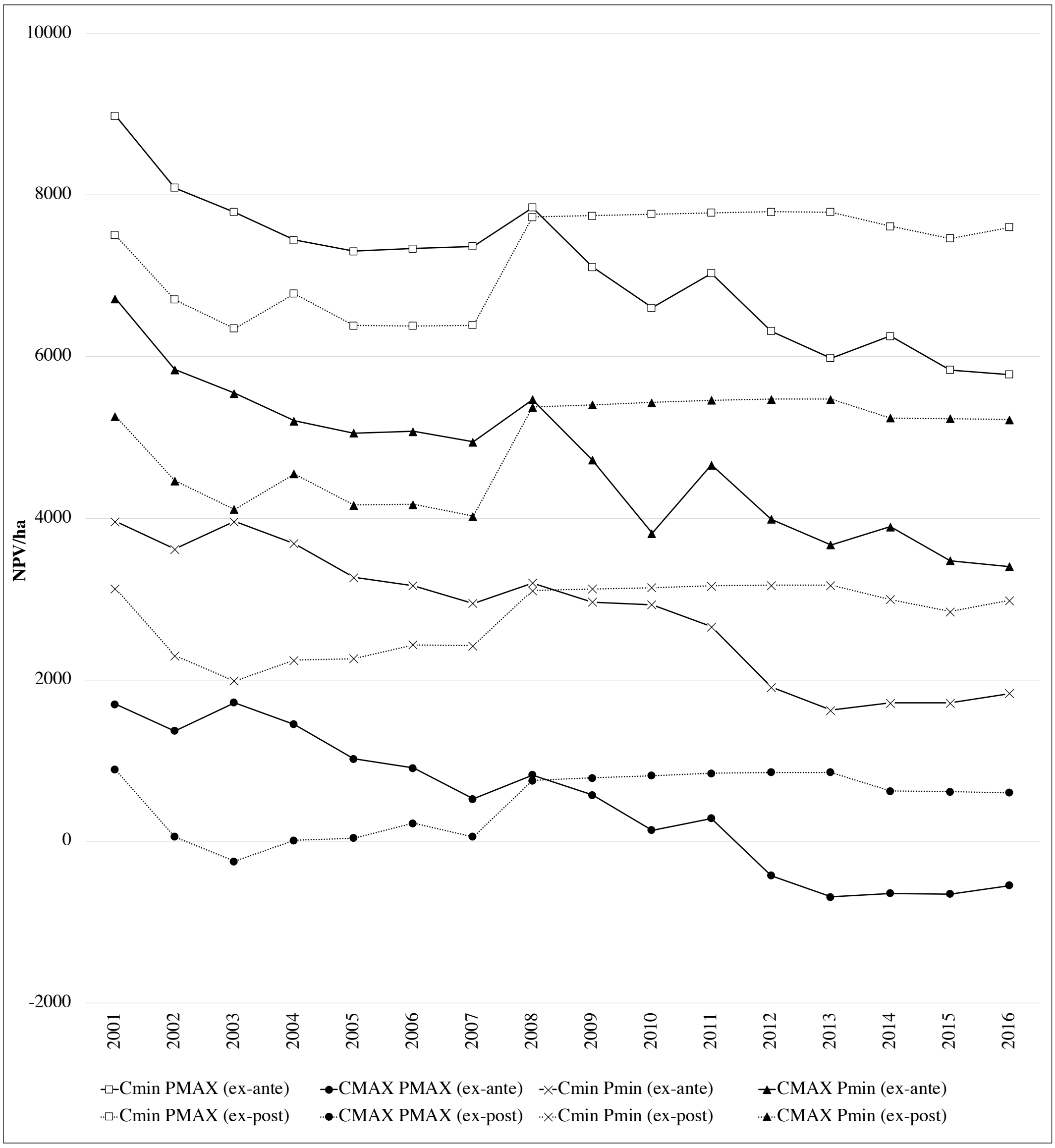
Figure 6.5: Sensitivity analysis results



Source: own elaboration

When public subsidies are included in the base-case scenario (a), the NPV raises to 1,821 EUR ha^{-1} in the Cmin-Pmin model, 5,780 EUR ha^{-1} in Cmin-PMAX, 3,402 EUR ha^{-1} in the CMAX-PMAX and -544 EUR ha^{-1} in the CMAX-Pmin model (remaining negative). The average NPV increases from the baseline scenario values is 1,212 EUR ha^{-1}. IRR values increase on average by 3.0%, reaching up to 15.2% in the best model (Cmin-PMAX). LEV reaches 5,821 EUR ha^{-1} in the Cmin-Pmin model, 18,345 EUR ha^{-1} in Cmin-PMAX, 3,402 EUR ha^{-1} in CMAX-PMAX, and -1,727 EUR ha^{-1} in CMAX-Pmin, with an average increase from the baseline scenario of 3,847 EUR ha^{-1}. Figure 6.6 shows the NPV trend when public subsidies are included in the analysis from 2001 to 2016. From the ex-ante curve the negative trend is accentuated due to the reduction, firstly in 2007 (from 100% to 70% reimbursement of establishment costs) and secondly in 2004 (from 70% to 60% reimbursement of establishment costs) of the average contribution level. In this case the NPV decreases on average in the period 2001-2016 of 2,722 EUR ha^{-1}.

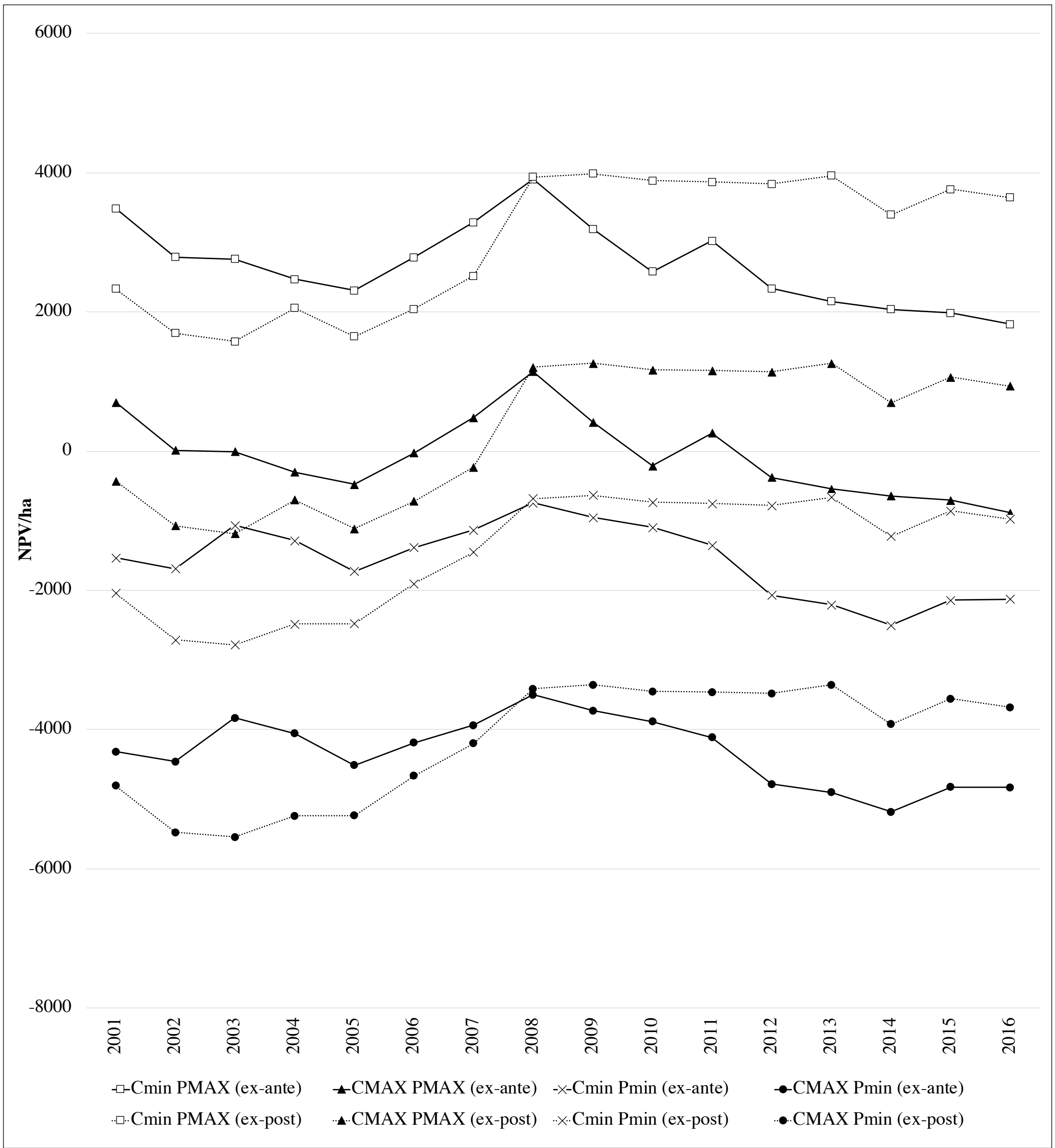
Figure 6.6: NPV in the scenario with public subsidies (a), 2001-2016 (real values)



Source: own elaboration

When we add to the baseline scenario an annual land rent cost (b), financial returns are positive only for the Cmin-PMAX model (NPV of 1,821 EUR ha^{-1}, IRR of 6.5% and LEV of 5,782 EUR ha^{-1}). All the other three models decrease to negative values, with an average decrease of 2,911 EUR ha^{-1} in terms of NPV, and 9,239 EUR ha^{-1} in terms of LEV. The NPV trend from 2001 to 2016 is presented in Figure 6.7. Land rent cost shows a declining trend from 2001 (379 EUR ha^{-1} per year) to 2006 (307 EUR ha^{-1} per year) followed by an overall increase up to 350 EUR ha^{-1} per year in 2016. When considering the ex-ante results, the four models decrease on average from 2001 to 2016 by 1,089 EUR ha^{-1}, with a decrease more accentuated between 2008 and 2016 (- 1,707 EUR ha^{-1}).

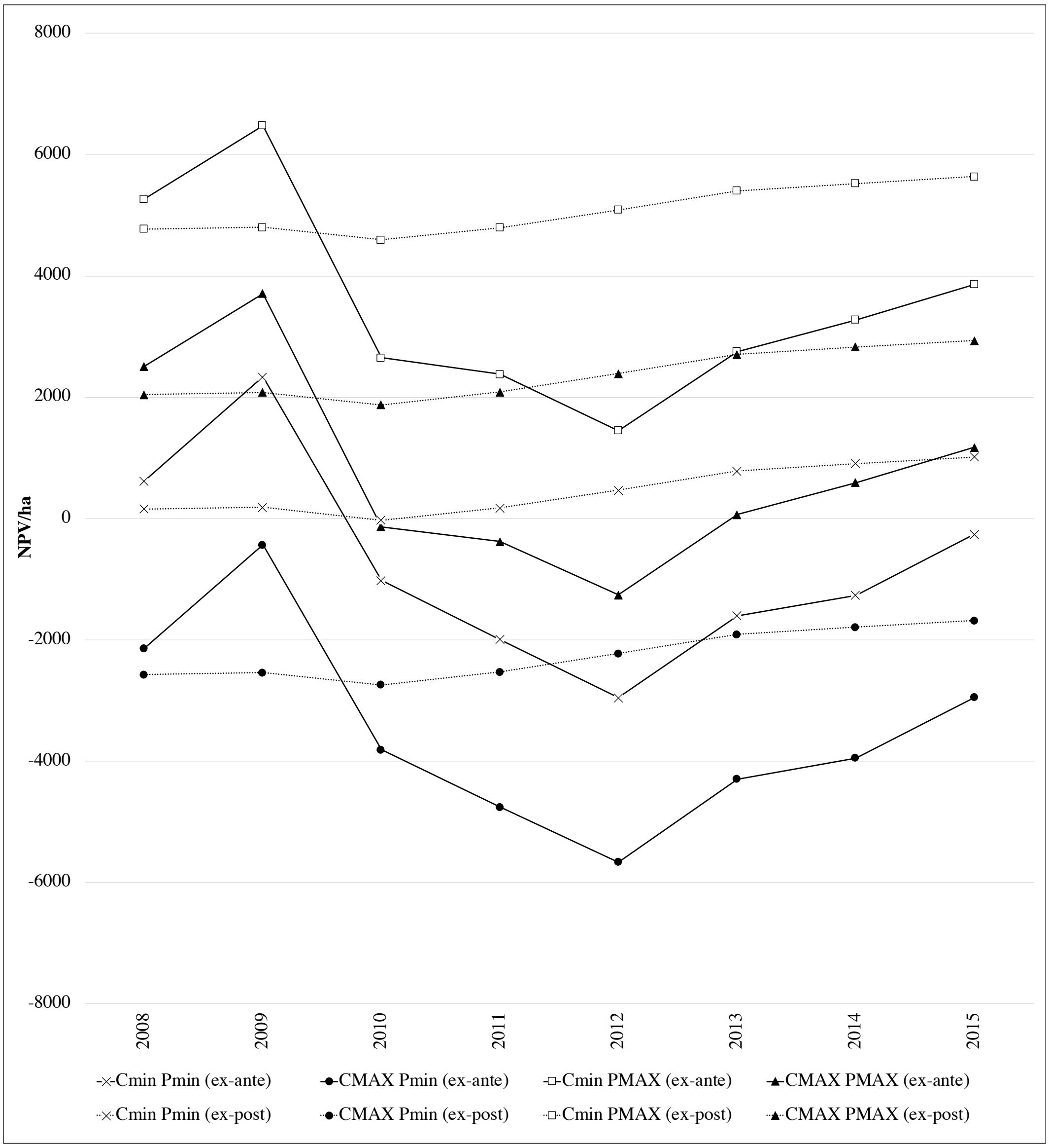
Figure 6.7: NPV with land rent cost (b), 2001-2016 (real values)



Source: own elaboration

When we include in the baseline scenario the opportunity cost (c) considering missed revenues from corn cultivation, NPV decreases on average by 932 EUR ha^{-1} and LEV by 5,392 EUR ha^{-1}. NPV goes negative for Cmin-Pmin and CMAX-Pmin models, respectively -152 EUR ha^{-1} and -2,860 EUR ha^{-1}. In the other two cases, Cmin-PMAX model's NPV is 3,793 EUR ha^{-1}, while in CMAX-PMAX is 1,086 EUR ha^{-1}. LEV is a particularly important indicator in assessing the opportunity cost of land use. In our sensitivity analysis it shows negative values for Cmin-Pmin (-484 EUR ha^{-1}) and CMAX-Pmin (-9,077 EUR ha^{-1}) models, while for Cmin-PMAX results 12,040 EUR ha^{-1} and for CMAX-PMAX 3,447 EUR ha^{-1}. It has to be considered that CAP direct payments to agricultural crops are not included in the analysis. In this case the time series is 2008-2015.

Figure 6.8: NPV with cost opportunity (c), 2008-2015 (real values)



Source: own elaboration

This trend is very well revealed in the ex-ante NPV estimates evolution, which present a positive peak in 2009 (NPV of -438 EUR ha^{-1} for CMAX-Pmin, 2,337 EUR ha^{-1} for Cmin-Pmin, 3,707 EUR ha^{-1} for CMAX-PMAX and 6,482 EUR ha^{-1} for Cmin-PMAX) and a negative peak in 2012 (NPV of -5,670 EUR ha^{-1} for CMAX-Pmin, -2,957 EUR ha^{-1} for Cmin-Pmin, -1,263 EUR ha^{-1} for CMAX-PMAX and 1,460 EUR ha^{-1} for Cmin-PMAX). When considering the ex-post estimates, the inclusion of opportunity cost results in a positive directional effect on the curves, which show an average increase of 877 EUR ha^{-1} from 2008 to 2015.

The fourth sensitivity analysis scenario (d) combines the inclusion of public subsidies (a) with annual land rent cost (b). In this case, NPV decrease on average by 1,699 EUR ha^{-1} and the LEV by 5,392 EUR ha^{-1} from the baseline scenario. NPV and LEV show negative values in the Cmin-Pmin and CMAX-Pmin models, while in the Cmin-PMAX model the NPV reaches 2,869 EUR ha^{-1} and LEV 9,106 EUR ha^{-1} and in CMAX-PMAX the NVP and LEV reach respectively 491 EUR ha^{-1} and 1,558 EUR ha^{-1}.

In the last sensitivity analysis scenario, we included an insurance cost (e). NPV results -669 EUR ha^{-1} in the Cmin-Pmin model, -3,347 EUR ha^{-1} in the CMAX-PMAX, 3,247 EUR ha^{-1} in Cmin-PMAX and 539 EUR ha^{-1} in CMAX-PMAX. On average, NPV decreased by 1,463 EUR ha^{-1}, and the LEV by 4,217 EUR ha^{-1} from base-case scenario values.

6.5 Discussion

This study was carried out based on a representative management regime and assuming average site quality and appropriate management conditions. Even though we aimed at representing the range of most frequent situations for poplar growers in northern Italy, our results cannot represent all specific cases. We assumed a representative management regime based on *Populus x canadensis* ‘I-214’, 278 trees per hectare and a 11 years rotation. Poplar plantations are characterized by a significant initial investment, with establishment costs, accounting on average for 26.0% of the total investment costs. Silvicultural management is relatively intensive, in particular in the first five years of the rotation cycle, with annual management operations requiring high labour and water inputs. Silvicultural management costs between year 1 and 10, comprising disk harrowing, phytosanitary treatments, fertilizations, pruning and irrigations, account on average for 71.0% of the total investment costs. Between 2001 and 2016, investment costs have increased by 25.5% in real terms, where planting operations cost (+38.0%) and final stumps removal and trituration cost (+37.0%) showed the highest increment.

Poplar timber stumpage prices vary substantially depending on quality, location and contractual power of the land owner. The percentage difference between minimum and maximum price range from 37.4% to 51.9%, depending on the year. Over the period 2001-2018, poplar stumpage prices evolution experienced an irregular trend. In specific, a strong decline has been observed between 2008 and 2015, with a percentage decrease by 17.7% in the minimum prices and 15.6% in the maximum prices. Then, from 2015 to 2018 poplar stumpage prices have experienced a substantial increase of 15.9% in the minimum prices and 18,0% in the maximum prices. These trends appear to be associated with a cycling nature of poplar timber prices already observed in the past (Garoglio, 1990). However, as highlighted already by Coaloa and Vietto (2005), in real terms poplar stumpage prices are on an overall downward trend. Coaloa and Vietto (2005) reported that average poplar stumpage prices in 2004 were already a 20.0% lower in real terms than those registered ten years before, which were already representing an historical minimum.

Financial returns were firstly estimated according to a baseline scenario, where no subsidies and land use cost were included. Based on 2016 data, NPV was estimated (at a 3.5% discount rate) in the range from -1,921 EUR ha^{-1} in the worst model, to 4,732 EUR ha^{-1} in the best model (associated with minimum investment costs and maximum stumpage prices). LEV range between -6,097 EUR ha^{-1} and 15,020 EUR ha^{-1}. IRR values goes from below 3.5% up to 11.9% in the best model. When interpreting the result, it has to be considered that the estimates represent a “before tax” situation, not including Land Value Tax and Income Tax. Our estimates show that poplar plantations offer interesting financial performances when connected to high stumpage prices, whereas, when these are low, investments are on the threshold of the financial viability or at a loss, in particular in the case of high establishment and silvicultural management costs. In recent years, research on the development of new more environmentally friendly poplar clones, more resistant to pest and insect attacks and more adapted to specific soil characteristics (e.g. Vietto *et al.*, 2011; Facciotto *et al.*, 2014) as well as the development of management standards for reducing energy and water inputs (e.g. Coaloa and Vietto, 2005) showed encouraging results. Further developments in these areas could lead to a reduction of silvicultural management costs and consequently lower market risk.

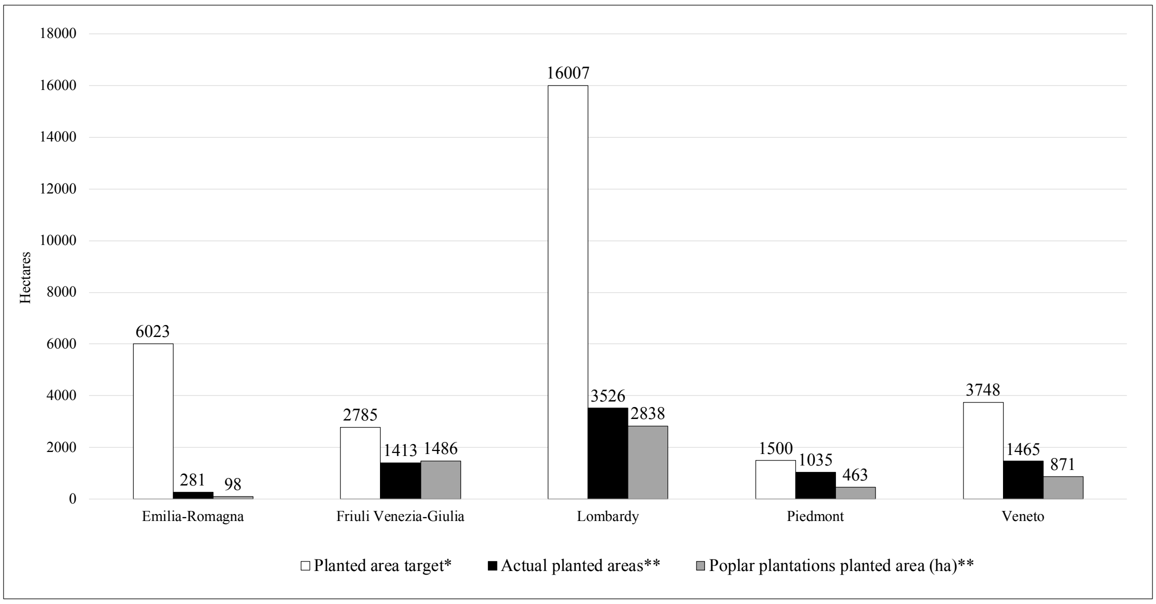
In the past, Borrelli and Facciotto (1996) and Borrelli (1997) estimated IRR of poplar plantation in northern Italy in the range 2%-8%, while another study related to the ECOPIOPPO project, suggested for the Piedmont context an average IRR value of 3.6% (using a stumpage price of 64 EUR ton^{-1}), which could increase to 8.1% with public subsidies (Regione Piemonte, 2002).

However, the authors highlighted that stumpage prices could have a large variability and, in the best situations, returns on investment could be considerably higher than those obtained in their simulations. In the best situations, hybrid poplar plantations in northern Italy showed to potentially provide higher financial returns than those estimated in literature for other contexts. In North America, average IRR values were estimated around 4.3% by Anderson and Luckert (2006) in Canada, while in southern United States between 6.4% and 9.1% by Tankersley (2006). In the context of Europe cultivation models are more similar to the one presented for northern Italy, in particular in Spain, although in all cases rotation cycles are longer (up to over 20 years). Keča *et al.* (2011) and Keča *et al.* (2012) estimated IRR of poplar plantations in Serbia between 4.3% and 6.9%. In France, Vidal and Becquey (2008), suggested IRR values for poplar plantation around 7.5%. In the case of Spain, Aunos *et al.* (2002) estimated IRR between 3.9% and 8% in the Ebro valley (Huesca and Lleida Provinces), while in the context of the Duero valley (Castilla y Leon Region) Estaban López *et al.* (2005) estimated NPV (at a 5% discount rate) to range between 5,108 EUR ha^{-1} and 10,929 EUR ha^{-1}. In less recent studies, Diaz Balteiro and Romero (1994) estimated IRR values of poplar plantations potentially up to 19%, and Del Peso *et al.* (1995) estimated NPV (at a 3% discount rate) to be between 2,255 EUR ha^{-1} and 9,783 EUR ha^{-1}.

For estimating the financial returns evolution between 2001 and 2016, we used two approaches: *ex-ante* approach, providing an estimation of the expected returns at the time the investments were carried out, and *ex-post* approach, providing an estimation of the actual returns considering the evolution of investment costs and stumpage prices throughout the years. From an *ex-ante* perspective, poplar plantations expected returns have experienced a significant and linear reduction in the period 2001-2016. In the baseline scenario, IRR values decrease on average by 3%, considering that in 2001 IRR values could reach 15.1%. NPV diminished on average by 2,036 EUR ha^{-1} between 2001 and 2016, from values that in 2001 were in the range -460 EUR ha^{-1} to 7,344 EUR ha^{-1}. LEV average decrease in the period was by 6,463 EUR ha^{-1}. In other words, from 2001 to 2016, financial returns expectations from investment in hybrid poplar plantations in northern Italy have been steadily declining, and this is likely to be the main reasons that have determined a continuous reduction of investment in this cultivation. However, it is interesting to compare these results with the ones based on the ex-post approach. In this case, the increase of stumpage prices between 2015 and 2018 makes the financial indicators of plantations established between 2005 and 2008 raise substantially. It has to be considered that we assumed stumpage prices values to be constant from 2018 onwards. So, when looking at the *ex-post* estimates, results from 2008 onwards have to be considered only partial. When the two analyses are compared, it emerges that until 2008 the expected returns at the time the investment was carried out were higher than the actual returns ten years after, while for those plantations planted in 2008 the actual returns were higher that what it was expected. However, actual returns for those plantations established from 2009 onwards will strongly depend on the future evolution of poplar stumpage prices. Besides the cycling nature of poplar stumpage prices, the high increment between 2015 and 2018 is likely to be associated to the expansion of the Italian plywood industry. Although data on plywood production and poplar removals are available only until 2011, this trend can be supported by international trade data. Eurostat (2018) reports that export of plywood from Italy has steadily increased from 2012 to 2016 (last year available), passing from 75,941 m^3 per year to 113,015 m3 per year. In addition, import of poplar roundwood showed an increase from 178,480 m^3 per year in 2015 to 213,802 m^3 per year in 2016, which might be an additional symptom of the shortage of domestic supply due to the decreasing investments in hybrid poplar plantations in northern Italy. In a recent market survey carried out by Levarato *et al.* (2018), it resulted that 70% of the Italian plywood industries have experienced increasing difficulties over the last ten years in the procurement of poplar roundwood from domestic sources. Therefore, it can be suggested that the evolution of poplar stumpage prices in the upcoming years will depend on the competitiveness of the Italian plywood industry. However, in spite the data on the export can suggest an optimistic evolution, there are several other factors influencing competitiveness which must be taken into account, Nevertheless, it is interesting to highlight that Levarato *et al.* (2018) reported that 9 of the Italian plywood industries out of 10 are planning either to expand the use of poplar timber in their production in future years or to keep it as constant. In addition, 8 out of 10 of these industries are (or would be, if available) prioritizing supply from domestic plantations.

Sensitivity analyses allowed us to assess the impact of some of the major policy and market factors. As public subsidies we considered the average grant-based contribution of the regional RDP’s afforestation measures, which result in the percentage reimbursement of the establishment costs. This percentage was 100% in the programming period 2000-2006 (Reg. EEC No. 1698/1999), 70% on average in the programming period 2007-2013 (Reg. EEC No. 1968/2005), and 60% on average in the programming period 2014-2020 (Reg. EEC No. 1305/2013). Based on 2016 values, public subsidies have the effect of raising NPV by 1,212 EUR ha^{-1} on average, with IRR reaching up to 15.2% in the best situation. Looking at the effect on the financial indicators, it is easy to understand that land owners consider public subsidies as a critical variable for investing, especially under uncertain market developments. However, it has to be considered the use of the RDP's afforestation measures to support hybrid poplar plantations has become more and more complex in the last two programming periods. The reason is the debate on the environmental impact of hybrid poplar plantations. On the one hand, some authors claim that poplar plantations still represent an environmental improvement compared to the alternative annual intensive agricultural crops (Chiarabaglio *et al.*, 2009; 2014). On the other hand, the idea of setting up intensively-managed and fast-growing timber plantations has been considered a contradiction to the EU objectives for rural development (that should inspire the national and regional RDP) that is increasingly oriented towards multifunctionality, the use of sustainability practices with low environmental impacts both in farming and in forestry. Besides the reduction of the average contribution level, this situation has produced an intricate framework in terms of eligibility criteria and requirements for applying to the RDP afforestation measures grants (Table 6.6), in particular related to the use voluntary forest certification schemes and the use of new and more environmentally friendly poplar ('MSA' clones) clones, which are not yet widely accepted by Italian poplar growers and plywood industries (Castro and Giorcelli, 2012). As a consequence, RDP grants have showed to be less attractive for land owners: between 2007 and 2013, under the afforestation measure 221 and 223 (which comprise also medium-long rotation species plantation and permanent woodland), only 7,720 ha were planted (5,756 ha with poplar) out of the over 30,000 planned at the launch of the measures (Figure 6.9), and only 1,333 beneficiaries were involved out of the target of 6,527 (Figure 6.10).

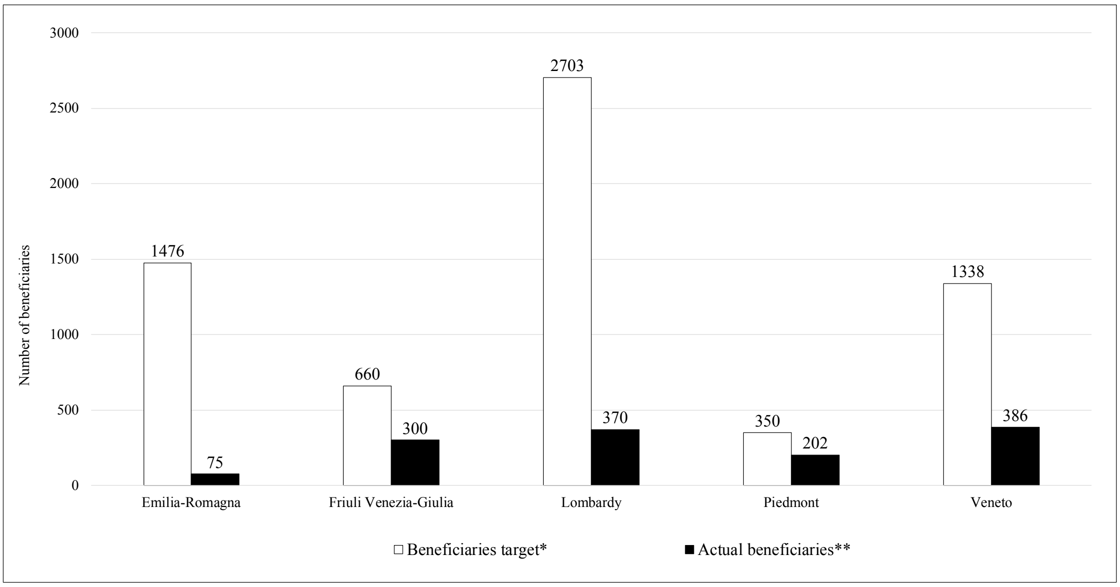
Figure 6.9: Comparison of target, achieved planted area, and area planted with hybrid poplars with the afforestation measures 221 and 223 of the RDP 2007-13 in the northern Italian regions



Note: *Data refer to the overall measure 221 and 223, which includes: a) plantations with fast growing species, b) medium-long rotation species plantations and c) permanent woodlands.*
** Official figures published by Regional administrations*
*** Annual Monitoring Reports of the European Rural Development Network (at 31/12/2014)*

Source: own elaboration based on data from Pra et al. (2016)

Figure 6.10: Comparison of targets and actual beneficiaries with the afforestation measures 221 and 223 of the RDP 2007-13 in the northern Italian regions



Note: *Data refer to the overall measure 221 and 223, which includes: a) plantations with fast growing species, b) medium-long rotation species plantations and c) permanent woodlands.*
** Official figures published by Regional administrations*
*** Annual Monitoring Reports of the European Rural Development Network (at 31/12/2014)*

Source: own elaboration based on data from Pra *et al.* (2016)

More in general, the differences in terms of requirements and contribution level among Regions and the irregularity of grants in last two programming periods, have become a potential further element of market destabilization, with concrete effects on the evolution of the market (e.g. land owners planning only when grants are available) and consequently of stumpage prices.

When an annual land rent cost is included in the analysis, considering the average value for poplar cultivation's suitable land in northern Italy, it emerges that rarely poplar plantations are financially viable. Only the best model shows a positive IRR value of 6.5%, NPV of 1,821 EUR ha^{-1}, and LEV of 5,782 EUR ha^{-1}, while indicators are negative for all the other models, with an NPV average decrease from the baseline scenario of 2,911 EUR ha^{-1} and LEV of 9,239 EUR ha^{-1}. The need to rent land appears to have great negative effect on the investment, even in case the investment is supported by subsidies.

Considering the opportunity costs of poplar investments referred to corn production, which represents the main competitive crop in the northern Italy, we found that only the best poplar cultivation models can be more competitive (if we exclude CAP direct payment). The lower risk component of an annual investment such as an agricultural crop against a multi-year investment with no income until the end of the rotation cycle as a poplar plantation, plays an important role in favour of the first one. However, when analysing the recent trend, it has been observed that the volatility of corn prices in recent years has reduced the risk gaps between the two cultivations.

Table 6.6: Synthesis and comparison of the eligibility criteria and requirements related to hybrid poplar plantations under the RDP 2007-13 and 2014-20 afforestation measures

Region	Eligibility criteria	RDP 2007-2013 (Measure 221 and 223)	RDP 2014-2020 (Measure 8.1)	Grants (year of publication)
Emilia Romagna	Clones diversification	-	>50% of 'MSA' clones	2008, 2010, 2011, 2012, 2016, 2017
	Certification	-	-	
	Minimum area	2 ha	1 ha	
	Grant contribution (establishment costs reimbursement percentage / cap)	70% / max 5,000 EUR	70% if using exclusively 'MSA' clones or if PEFC or FSC® certified, 40% in all other cases / max 4,000 EUR	
Friuli Venezia-Giulia	Clones diversification	-	If >200ha: at least three different clones (>10% each)	2008, 2010, 2011, 2016
	Certification	-	PEFC or FSC® certification required (alternatively: environmentally-friendly management codes recognized by the Region, i.e. 'ECOPIOPPO' code)	
	Minimum area	0.5 ha	0.5 ha	
	Grant contribution (establishment costs reimbursement percentage / cap)	45% if individuals, 65% if associated / max 5,000 EUR if PEFC or FSC® certified, 1,500 EUR in all other cases	80% / max 4,000 EUR	
Lombardy	Clones diversification	-	If >30ha: >50% 'MSA' clones, if <30ha: three different clones	2008-2013, 2016, 2018

			(two of them ‘MSA’ clones, representing >50% of the total)	
	Certification	-	Priority to PEFC or FSC® certified applicants	
	Minimum area	1 ha	1 ha	
	Grant contribution	80% if PEFC or FSC® certified and in Natura2000 area, 70% if only one of the two cases, 60% in all other cases / max 3,500 EUR	80% if using exclusively ‘MSA’ clones or if PEFC or FSC® certified, 60% in all other cases / min 1,667 EUR and max 3,440 EUR	
Piedmont	Clones diversification	-	<5ha: >22% ‘MSA’ clones, 5-15ha: > 33% ‘MSA’ clones, >15 ha: >50% use ‘MSA’ clones	2010, 2016, 2018
	Certification	-	Priority to PEFC or FSC® certified applicants (or alternatively applicants following environmentally-friendly management codes recognized by the Region, i.e. ‘ECOPIOPPO’ code)	
	Minimum area	1 ha	1 ha	
	Grant contribution	80% if PEFC or FSC® certified and in Natura2000 area, 70% in all other cases / max 3,500 EUR	70% if PEFC or FSC® certified, 50% in all other cases / max 4,000 EUR	
Veneto	Clones diversification	-	<10ha: >10% ‘MSA’ clones, >10ha: at least 3 clones (2 of them ‘MSA’ clones) of which each one >10% of the total	2008, 2009, 2010, 2011, 2017
	Certification	-	-	
	Minimum area	0.5 ha	0.5 ha	
	Grant contribution	80% / max 4,300 EUR	80%	

Source: translated from Pra et al. (2016)

Finally, we also tested the effect of an insurance policy covering total and partial losses caused by fire, lightning, hail and windstorm. Despite these types of investments are not common among poplar growers (but are growing, in particular among large scale land owners), we decided to assume this cost as a proxy of the investment risk component. The inclusion in the cash flow of an insurance cost has the effect of reducing on average NPV by 1,463 EUR ha^{-1}. Furthermore, it has to be noted that in the last years it has become more and more common to sell poplar stands before the end of the rotation period; an arrangement where the buyer (normally a middleman responsible of supplying the plywood industry) is able to manage a portfolio of poplar stands and the grower is payed for selling the immature trees and for keeping them growing till the buyer decide to harvest them.

6.6 Conclusions

In this study we estimated financial returns from hybrid poplar plantations in northern Italy between 2001 and 2016, analysing the evolution of investment costs and timber stumpage prices as well as assessing the effects of external policies and market variables, i.e. public subsidies, land use cost, opportunity cost of alternative agricultural land use, and insurance cost. Financial returns were estimated at aggregate level, based on a management regime representative of the most frequent situation for poplar growers in the area and defining minimum and maximum levels of investment costs and stumpage prices. We carried out a financial analysis before-tax using NPV, IRR and LEV as capital budgeting indicators, with a 3.5% real discount rate. The main input data and information on investment costs were obtained from poplar growers and farms archives, bulletins and agricultural contractor's rates, while data on stumpage prices were derived from Chambers of Commerce.

Our results show that the range of possible financial returns from hybrid poplar plantations in northern Italy is rather large. Financial returns vary depending on investment costs − determined by management intensity and cost of the operations − and stumpage prices. In general, our estimates show that when connected to high selling stumpage prices, poplar plantation can be profitable even in the case of high establishment and silvicultural management costs; on contrary, investments are at the limit of the financial viability or at a loss when connected to low stumpage prices. In the baseline scenario, where no subsidies nor land use cost are included, IRRs goes from below 3.5% to a maximum of 11.9%, with intermediate values in the range 5.3%-6.5%.

The evolution of financial returns in the last 15 years, between 2001 and 2016, have been influenced by the evolution of investments costs – which experienced a linear increase over the period – and stumpage prices, which have been subjected to a cyclical behaviour but with an overall downward trend in real terms. Expected returns have decreased significantly over the period, and this is likely to have increased the market risk component and negatively undermined the attractiveness for new investments in poplar plantations. However, based on an ex-post perspective, the increase of poplar stumpage prices between 15.9% and 18% from 2015 to 2018 have determined a substantial increase of the actual returns for those plantations established between 2005 and 2008, which have been higher than the expected returns. Nevertheless, the evolution of poplar stumpage prices in the upcoming years will ultimately depend on the competitiveness of domestic plywood industry, which on the one hand is expanding its export production, but on the other hand has to face a continuous reduction of poplar timber domestic supply.

Public subsidies, based on the regional RDPs derived from the EU Rural Development Policy regulations, have a considerable positive effect on the financial indicators, demonstrating to be a determinant variable for investment decisions. However, in the last two RDP's programming periods (2007-2013 and 2014-2020) diminished contribution level together with the irregularity of grants and the growing limitations in terms of management requirements are representing an additional factor of destabilization of the sector.

In the context of northern Italy, opportunity costs for alternative agricultural land use – considering that poplar plantations are established in medium to high fertility agricultural land and river bends – can be very high and unfavourable for poplar plantations. The recent increased volatility of cereals prices has probably having a positive effect on the investors' attitude towards poplar cultivation; however, the higher market risk associated to a 10 years investment might be still a major element of unattractiveness for land owners. In addition, also the need to rent land is rarely financially viable for poplar plantation, even if supported by subsidies. Finally, we have discussed the positive opportunities of risk reduction associated to insuring the plantations and to need selling system. All these results are a sign that poplar plantation investments in northern Italy, although they have faced serious financial problems in the last decades, can still represent the main segment for industrial wood production in Italy and one of the most profitable plantation investments in Europe.

Chapter 7

Paper III – Investments returns from forest plantations in southern Europe: a comparative trend analysis *(extended version)*

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Abstract

In southern Europe, forest plantations represent a rather consolidated segment of investment for landowners and forest-based industries. In future years, the expected increasing demand for timber, could drive the interest towards forest plantations investments also in this region, with an increasingly important role played by new financial investors and strategic partnerships.

In this study we analysed and compared investment returns for some of the most important productive forest plantation species in southern Europe, focusing in some regions of Italy, Spain and Portugal. We carried out a financial analysis using capital budgeting indicators, and in addition, we carried out a trend analysis to provide means for comparing the evolution of expected and actual returns in recent years.

The results indicate that in southern Europe there are some opportunities for reasonably interesting investment returns from forest plantations for sectorial investors (i.e. landowners and forest-based industry) and also potentially interesting opportunities for financial investors. However, it emerges from the analysis that the regional context is characterized by structural factors, related to i.e. timber market, subsidy policies, biotic and abiotic risks and forest holdings structure, which could limit the attractiveness of this region for new investors.

Key-words: Forest plantations; timber production; investment return; southern Europe; fast-growing species; hybrid poplar; eucalyptus; maritime pine; radiata pine.

7.1 Introduction

The importance of planted forests in the forest economy is increasing worldwide as well as the interest and opportunities for investments in their establishment and management. Based on FAO (2012a) definition, planted forests comprise both plantations established for producing commercial and industrial roundwood, and those established for protection purposes. Planted forests include the planted component of semi-natural forests as well, which represent large areas in the northern hemisphere. The area covered by planted forests amounts to 278 million hectares, corresponding to the 6.9% of the world's forest cover, and have been growing at +4.9 million hectares per year between 1990 and 2015 (FAO, 2015; Payn *et al.*, 2015). Based on the FAO (2005) data, Del Lungo *et al.* (2006) estimated that 76% of planted forests are established for productive purposes, playing an important role in supplying the growing demand for wood and fibres in the northern hemisphere as well as in the sub-tropics and tropics (Jonsson and Whiteman, 2008). Jürgensen *et al.* (2014) and Carle and Holmgren (2008) estimated that planted forests are already contributing to half of the global industrial timber supply, and this contribution is expected to increase between 75 and 100% by 2050. Therefore, in spite there is also an evident growing awareness for the potential of planted forests to deliver other ecosystem services (Boyle, 1999; Evans and Turnbull, 2004; UNEP, 2009, Bauhus *et al.*, 2010), timber production remains the main reason for investing in planted forests.

In southern Europe, productive plantations – established with both native and exotic tree species – represent a consolidated segment of investment, in particular in the continental piedmonts and in the Atlantic rim. Plantations play an essential role in the regional timber production balance. For example, fast-growing species such as eucalyptus, maritime pine and radiata pine provide over 75% of Portuguese and Spanish wood production, in France only maritime pine contributes to 42% of the softwood production, in Italy hybrid poplars provide more than 50% of the industrial roundwood domestic supply (Martinez de Arano and Lasgourgues, 2014; Assopannelli, 2012). On the other hand, semi-natural forests in southern Europe are characterized by low productivity and declining utilization rates, with an increasingly recognized important multifunctional role (e.g. erosion control, water regulation, recreation, wild forest products production, etc.) (Forest Europe, 2015). In the near future, the demand for timber and biomass is expected to increase in southern European countries, boosted in particular by the European Union (EU) bioeconomy and bioenergy policies, raising inevitably the pressure and attention on productive plantations in the region (EC, 2012; UNECE/FAO, 2011; Martinez de Arano, 2018). Table 7.1 summarizes the main data on forests, planted forests and productive plantations for the countries considered.

Table 7.1: Forest, planted forest and productive plantation area in southern Europe

Country	Total forest area (000 ha)	Planted forest area (000 ha)	Percentage of planted forests on total forest area	Productive plantations area* (000 ha)	Main exotic species used	Main native species used
Italy	9,297	639	6.90%	147	*Populus* hybrids *Pinus radiata* *Eucalyptus* spp. *Quercus* spp.	*Juglans regia* *Prunus avium*
Spain	18,373	2,908	15.80%	1,486	*Pinus radiata* *Eucalyptus* spp. *Populus* hybrids	*Pinus pinaster* *Pinus sylvestris*
Portugal	3,155	891	28.25%	1,068	*Eucalyptus* spp.	*Pinus pinaster*
Europe	1,015,500	70,400	6.90%			
World	3,999,100	277,900	6.95%			

** Author's estimation based on FAO (2005) data;*
Source: own elaboration based on Del Lungo et al. (2006), FAO (2015) and Payn et al. (2015);

The establishment of planted forests requires a considerable amount of financial resources; therefore, the investment aspect is crucial to determine their development and management. From a private perspective, the most important factor driving investments in planted forests is played by the financial returns they generate. In addition, recent research, mainly North American-based, highlighted the potential offered by forestry investments for financial portfolio diversification, indicating the biological growth component, the low volatility and the inflation hedging as the principal merits of these investments versus traditional stock and bond assets (Redmond and Cubbage, 1988; Zinkhan *et al.*, 1992; Cascio and Clutter, 2008; Mei and Clutter, 2010). In Europe, in addition to local land owners and industries, a more and more important role is played by strategic and financial investors as well as partnerships between private and public actors. Therefore, the expansion and growing importance of planted forests for industrial timber supply in many regions, together with the increased interest and number of private investors, result in a greater need for information and valuation studies to help individuals, companies and institutions to make better investment and policy decisions.

The topic of investment returns from planted forests is mainly tackled by consulting studies, which are rarely made publicly available and, when they are, they often do not provide details on inputs and methodology. In recent years, efforts to provide information of investment returns with a comparative perspective have been taken by Sedjo (2001) and by Cubbage *et al.* (2007; 2010; 2014), estimating timber investment returns at aggregate level for a set of countries, principally North and South America, South-East Asia and Oceania. In southern Europe there is a relative scarcity of literature on timber investment focusing on plantation species. Although there are some studies available in national/regional technical forestry magazines (Table 7.2) – e.g. Diaz Balteiro and Romero (1994), Borelli and Facciotto (1997), Aunos *et al.* (2002), Vidal and Bequey (2008) – there is a lack of studies that analyse timber investment returns in the region on a comparative perspective, using homogeneous and standard approaches and inputs.

Table 7.2: Selection of scientific literature studies on timber investments returns from plantations in southern Europe

Country/area	Species	MAI (m^3/ha/yr)	Rotation (years)	NPV* (EUR/ha)	IRR	Reference
Portugal and Spain	Temperate eucalyptus (including *E. globulus*)	15-30	10-15			Cossalter and Pye-Smith, 2003
Europe	*Pinus* spp. (including *P.radiata* and *P.pinaster*)	8-35	10-35			Cossalter and Pye-Smith, 2003
Europe	Poplars	11-30	7-15			Cossalter and Pye-Smith, 2003
Duero valley (Spain)	Hybrid poplar clone 'I-214'	10-25	14	1,954–8,338 (*i*=5%)**	-	Del Peso *et al.* (1995)
Spain	Hybrid poplar clones 'Campeador' and 'I-214'	24-40	10-13	2,312–9,406 (*i*=9%)**	11.3%-20.7%	Diaz Balteiro and Romero (1994)
Ebro valley (Spain)	Hybrid poplar clones 'I-MC' and 'I-214'	20-30	10-14	418–5,022 (*i*=4.25%)	4.5%-7.4%	Aunos *et al.* (2002)
France	Hybrid poplars	15	17	250–300 per year (*i*=2%)	7.5%	Vidal and Bequey (2008)
Spain and Portugal	*Eucalyptus globulus*	10-15	10-12	157–449 (*i*=6.5%)	7.0%-8.0%	King (2012)
Spain	*Pinus radiata*	14-21	30-38	-	5.8%-9%	Rodriguez *et al.* (2002)
Basque Country (Spain)	*Pinus radiata*	-	35	1,358 (*i*=3%)	<5%	Tolosana Esteban *et al.* (2013)
Italy	Hybrid poplar clone 'I-214'	-	10	-	2.0%-8.0%	Borrelli and Facciotto (1996)

** NPV is presented in nominal terms*
*** Converted from Spanish Pesetas to Euros (166.386 ESP = 1 EUR)*
Source: own elaboration based on cited sources

This paper intends to provide better information on the potential timber investment returns from the main plantation species in southern Europe – focusing in particular on Italy, Spain and Portugal – providing means to compare the status and trends of investment in plantations in the region. In addition, the results will contribute as a benchmark to support better investments decisions. In specific, we aim to: i) provide aggregate estimations of timber investment returns from plantation species with a comparative perspective; ii) assess the effect of the major policy and market factors influencing investment returns, such as subsidies, land use costs, and variations in investments costs and timber prices; and iii) analyse investment returns dynamic, estimating how they have changed as a result of the evolution of investments costs and timber stumpage prices in recent years.

7.2 Methodology

The methodology used in this study is described in the following steps: 1) species and region/area definition; 2) analysis of representative management regimes and growth data analysis; 3) baseline investment costs and timber stumpage prices collection; 4) financial analysis; 5) sensitivity analysis scenarios; and 6) trend analysis.

All input data used in this study were defined and collected with the cooperation of forest owners' associations, industries and research institutes in each area. Interviews and visits were carried out in Italy from February to November 2016, in Spain from March to May 2017 and in Portugal during October-November 2017. A list of people and institutions contacted in order to collect our data is presented in the Table 4.4 (Chapter 4).

7.2.1 Species and region/area definition

We selected some of the most important species and areas for productive plantation in southern Europe. In specific, we have included in our study hybrid poplar (*Populus x canadensis* clone 'I-214') in northern Italy, in Castile and León (Spain) and in Navarre (Spain), eucalyptus in Portugal (*Eucalyptus globulus* Labill.), maritime pine in Portugal (*Pinus pinaster* Aiton); and radiata pine (*Pinus radiata* D.Don) in the Basque Country (Spain).

In northern Italy, hybrid poplar plantations cover about 70 thousand hectares; although the cultivated areas have undergone a significant reduction since in the 1980s (Coaloa, 2008). The 1985 national forest inventory reported 110 thousand hectares of poplar plantations, compared to the 67 thousand hectares of the latest 2005 inventory (IFN, 1985; Gasparini and Tabacchi, 2011). In Spain, the majority of poplar plantations, about 50 thousand hectares, are located in Castile and León (Duero valley). In Navarre (Ebro valley) there are about 2 thousand hectares of plantations; we decided to include Navarre because it is somehow representative of the entire Ebro valley, which includes also the regions of Aragon and Catalonia, where poplar plantations are estimated to reach about 20 thousand hectares in total (Confemadera, 2010). Looking at the historical perspective, in Castile and León, the area covered by poplar plantations have slightly increased in the last decades, while in Navarre – and in general in all the Ebro valley – has been reducing in the last ten years. In all these areas the hybrid clone 'I-214' is the most widespread and historically consolidated, estimated to represent 90% of poplar plantations in Italy and about 70% in Spain. In 2010, Portugal had 755 thousand hectares of eucalyptus plantations and 624 thousand hectares of maritime pine plantations, representing respectively 23.9% and 19.8% of the country's forest cover. Eucalyptus plantations area has experienced a substantial increment in the last decades, led by a rampant domestic pulp and paper industry. In fact, eucalyptus plantations' cover increased by 42% compared to the 1990 National Forest Inventory, which reported 530 thousand hectares (the numbers are correct, but the source is not: DGRF, 1991). On contrary, the area covered by maritime pine has experienced a declining trend – from 1,047 thousand hectares registered in the 1990 national forest inventory (DGRF, 1991). Finally, the Basque Country in Spain has a total of 125 thousand hectares of radiata pine. This species has a dominant role in the region, where it represents the 32% of the total forest cover. It has experienced a slight decline in the last decades – from the 150 thousand hectares reported in the 1996 national forest inventory (MAPAMA, 2013).

7.2.2 Analysis of representative management regimes and growth data analysis

We defined representative forest stand management regimes for each species and region, following an approach similar to the one used in Sedjo (1983) and Cubbage *et al.* (2007; 2014). We used these representative management regimes since the main study's objective was to estimate and compare potential returns at aggregate level under typical current conditions, and not to estimate optimal returns and neither carry out a site-specific or exhaustive analysis. Table 7.3 summarizes the management regimes and growth rates assumed for the selected species and areas, while more specific information can be found in Annex 3.1 of the supplementary material. All study's assumptions have been checked and revised with experts in each area.

For what concern the definition of management regimes, information mainly relied on discussions with experts from private forest owners' associations, industries and research institutes. In all cases, we assumed appropriate and ordinary efficient forest management.

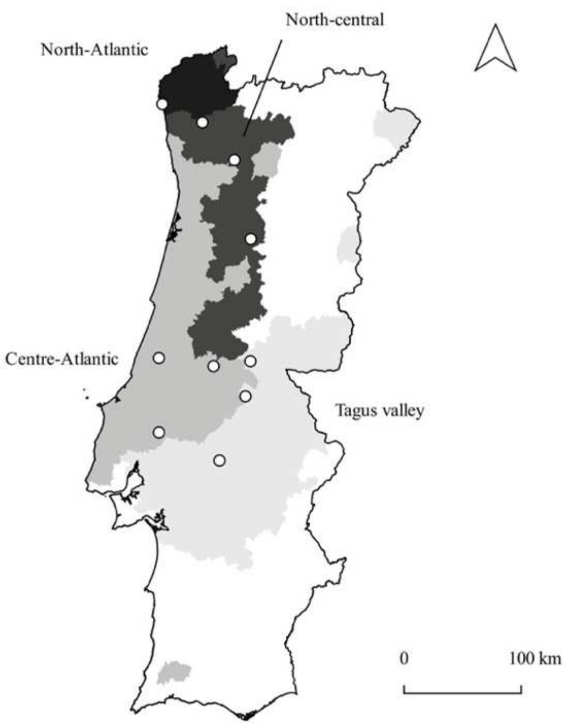
Hybrid poplar plantations have the most standardized management regimes, based on a consolidated practice both in Italy and Spain. Rotations are typically 10 years in northern Italy, where poplar is cultivated in medium to high fertility agricultural lands and river bends in the alluvial plains of northern Italy (0-100 meters elevation). In Navarre, plantations mainly established on agricultural lands in the Ebro valley river bends (200-400 meters elevation) with rotations of 12-13 years, while in Castile and León – where poplar is cultivated in agricultural lands and river bends of the Castilian plateau, at elevations ranging between 700 and 1,000 meters – rotations are longer and vary between 13 and 17 years. Planting density is typically 278 trees per hectare (6x6 spacing) in northern Italy and in Castile and León, while higher densities are practiced in Navarre, between 330 (5.4x5.4 spacing) and 400 (5x5 spacing) trees per hectare.

In the cases of eucalyptus and pines plantations, it has to be noted that management regimes could vary much more compared to poplar plantations, in particular among non-industrial private forest owners. For eucalyptus in Portugal we considered the typical management regime practiced by the industry, with a planting density of 1,100 trees per hectare and a 12-years planted rotation followed by a 12-years coppice rotation. For maritime pine in Portugal and radiata pine in the Basque Country we considered the management regimes currently recommended by the local forest owners associations. In Portugal, we considered a 35 years rotation regime, based on a planting density of 1,670 trees per hectare and with two commercial thinning at year 15 and 25. In the Basque Country, the currently recommended regime is based on a 35-years cycle (in the case of low productivity sites we extended the rotation to 40 years) with one pre-commercial thinning at year 8, and two commercial thinning at year 18 and 23. Planting density is typically 1,100 trees per hectare, even though in the past higher densities were more common. Indeed, in the case of pines, it has to be noted that technical rotations have changed over time to adapt to the market demand, i.e. currently, longer rotations over 40-45 years are not recommended due to the decreasing demand for large diameters Roundwood and high fire risk.

The growth rates and yields have been determined based on different approaches. For each region we defined a minimum, average and maximum growth rate, which could represent the typical range of low, average and high productivity sites in those contexts (Table 7.3). For what concerns the poplar clone 'I-214', we determined the growth rates and yields based on expert's knowledge; in fact, poplar represents the easier case being grown on agricultural land with a rather standardized management regime and a single final cut. In northern Italy, Mean Annual Increments (MAI) ranged between 20 and 27 m^3 per hectare per year, which results in a total yield between 190 and 257 m^3 per hectare (considering a 5% mortality). In Castile and León MAI typically range between 10 and 20 m^3 ha^{-1} yr^{-1}, while in Navarre it ranges between 17 and 25 m^3 ha^{-1} yr^{-1}, with yields respectively between 162 and 247 m^3 ha^{-1} and 210 and 285 m^3 ha^{-1} (also in these cases we considered a 5% mortality).

In the case of Portugal, we determined growth rates and yield for eucalyptus and maritime pine using the StandsSIM Portuguese forest simulator[2] – based on the GLOBULUS and PINASTER growth and yield models – developed by the Instituto Superior de Agronomia (ISA) of the University of Lisbon. References for this tool can be found in Barreiro *et al.* (2016). In order to get more accurate estimations, NFI5 plots (AFN, 2010) having eucalyptus as the dominant species were analysed. This allowed identifying the distribution of Eucalyptus (Figure 7.1) by ecological region (Ribeiro and Tomé, 2000): north-Atlantic, north-central, centre-Atlantic and Tagus valley. The climate data (days with rain) and elevation, both required as input, were obtained by selecting the municipalities representing the minimum, the mean and the maximum days with rain for each region and their corresponding elevations. The site index distribution in each region (Tomé *et al*., 2001a; 2001b) was used to build yield tables using the GLOBULUS 3.0 stand-level empirical model (Tomé et al., 2006). Model inputs are presented in Annex 2 of the supplementary material. In summary, MAI resulted between 11 and 29 m^3 ha^{-1} yr^{-1} in the north-Atlantic region, between 8 and 25 m^3 ha^{-1} yr^{-1} in the north-central region, between 7 and 18 m^3 ha^{-1} yr^{-1} in the centre-Atlantic one, and between 5 and 22 m^3 ha^{-1} yr^{-1} in the Tagus valley.

Figure 7.1: Portugal's ecological regions defined for eucalyptus simulations



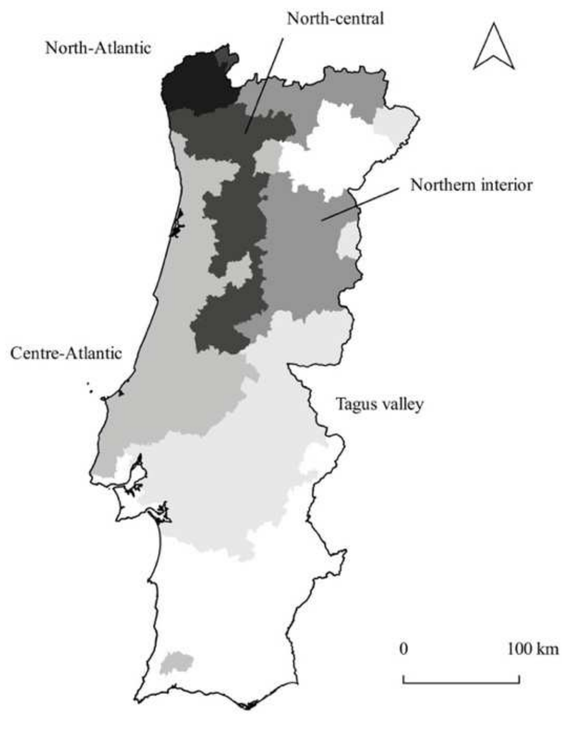
[2] Available at: http://www.isa.ulisboa.pt/cef/forchange/fctools/en/SimflorPlatform

Note: *dots represent the municipalities selected for the climate data; these are: Viana do Castelo (north-Atlantic); Amarante, Viseu and Braga (north-central); Cataxo, Ferreira do Zezere and Batalha (centre-Atlantic); and Mora, Provença-a-Nova and Gavião (Tagus Valley).*

Source: own elaboration

In the case of maritime pine, five ecological regions have been selected (Figure 7.2), i.e. north-Atlantic, north-central, centre-Atlantic, Tagus valley and northern interior. Growth and yield were calculated using the PINASTER model, which – differently from the previous – is a tree-level empirical model, using only the site index as input. The site index values for each region were obtained from the national forest inventory data, by selecting those plots with maritime pine as dominant species, plotting the cumulative distribution for site index category and graphically calculating the site index value corresponding to the quartiles 0.2, 0.4, 0.6, 0.8 and 1 (see Annexes 3.4). MAI resulted between 7 and 15 m^3 ha^{-1} yr^{-1} in the north-Atlantic region, between 4 and 14 m^3 ha^{-1} yr^{-1} in the north-central region, between 2 and 11 m^3 ha^{-1} yr^{-1} in the centre-Atlantic region, between 4 and 11 m^3 ha^{-1} yr^{-1} in the Tagus valley, and between 3 and 10 m^3 ha^{-1} yr^{-1} in the northern interior region.

Figure 7.2: Portugal's ecological regions defined for maritime pine simulations



Source: own elaboration

For determining the growth rates for radiata pine in the Basque Country we used the yield table – supported by an Excel spreadsheet model – developed by HAZI in collaboration with the forest owners' associations of the Basque Country (HAZI, 2017). In this case, MAI ranges between 14 and 22 m^3 ha^{-1} yr^{-1}, with a total yield along the rotation period respectively between 574 and 771 m^3 ha^{-1}.

7.2.3 Baseline investment costs and timber stumpage prices collection

Table 7.4 summarizes the plantations investment costs and timber stumpage prices assumed for the baseline scenario simulations. Plantations investments costs – including establishment and management costs – have been derived from forest owners' associations, agricultural and forestry contractor's rates or reference values provided by the public administration. Unitary values and their sources are reported in detail in the supplementary material. The cost of the operations has been estimated assuming the typical industrial management standard. Hybrid poplar plantations in northern Italy show the highest investment costs, 6,615 EUR ha^{-1} yr^{-1}, which results from the very intense management throughout the rotation period, i.e. management costs accounts for 73% (4,808 EUR ha^{-1}). The higher investment costs in Italy are determined by annual disk harrowing and weed control, fertilization and numerous phytosanitary treatments (in particular against *Marssonina brunnea*, *Saperda carcharias*, *Cryptorhynchus lapathi*, and *Phloeomyzus passerinii*), which occour in the majority of the cases and have a considerable impact on the costs balance. Similarly to northern Italy, also the poplar plantations in Navarre also show a relatively high investment costs, which in total are 6,037 EUR ha^{-1}, however, in Castile and León these are lower compared to the previous two cases, amounting to 4,732 EUR ha^{-1}. The higher management costs in Navarre compared to Castile and León are mainly determined by the need of annual irrigation; contrary of Castile and León – where the phreatic level is high – the Ebro valley in Navarre is characterized by clayey soils. In Spain phytosanitary problems in hybrid poplar plantations are rather rare, probably due to higher elevations and drier climate. In sporadic cases, treatments against *Sesia apiformis* and *Phloeomyzus passerini* are needed in Navarre, and against *Phloeomyzus passerini* and *Melasoma populi* in Castile and León, however, they don't appear to represent a common operation. In Portugal, the estimated cost to establish and manage a two-rotations eucalyptus plantation is around 3,890 EUR ha^{-1} and 3,496 EUR ha^{-1}. for a maritime pine plantation. Radiata pine in the Basque Country requires more management operations – such as more intense weed controls and fertilizations – compared to maritime pine in Portugal. The establishment costs have been estimated at 2,100 EUR ha^{-1} and management costs at 3,665 EUR ha^{-1}, for a total of 5,765 EUR ha^{-1}.

For the analysis we considered stumpage prices, assuming the timber to be purchased by external buyers, which in most of the cases is a middleman operating between the landowner and the industry. Stumpage prices were obtained mainly from forest owners' associations, with the exception of Italy, where stumpage prices were derived from Chambers of Commerce's bulletins. We had relatively good information on poplar and eucalyptus stumpage prices because of the more well-developed industry and transaction systems, while for maritime and radiata prices show to be subject to higher variability. Stumpage prices are based on 2017 values. Poplar timber is largely used for plywood veneers employed in the plywood or other wood-based panels industry. The average stumpage price for poplar in Italy is 54 EUR/m^3 according to the Chambers of Commerce. In Castile and León, the average stumpage prices were derived from the poplar timber auctions organized by the forest owner's association FAFCYLE, where in 2017 the average price was 58 EUR/m^3. In Navarre the average stumpage price has been obtained from the forest owner association FORESNA – which publishes a timber prices bulletin in its four-months magazine 'Navarra Forestal' – and this was 41 EUR/m^3 in 2017. In Portugal, stumpage prices are more difficult to obtain. Therefore, we had to assume an average value based on personal information provided by local forest owners' associations. Eucalyptus wood goes entirely to the pulp industry and the average stumpage price assumed is 31 EUR/m^3. Maritime pine plantations transactions are currently based on two main assortments, sawnwood and fuelwood. Sawnwood is bought at a stumpage price of 37 EUR/m^3 and fuelwood on average at 21 EUR/m^3. For what concerns radiata pine, data were obtained from the Basque forest owners associations, as reported in the timber prices bulletins published in the magazine 'Euskadi forestal'. In this case, stumpage price was on average 35 EUR/m^3 in 2017. In addition, we had to define the prices for commercial thinning's timber; based on discussions with experts, we defined 7.5 EUR/m^3 for the first commercial thinning and 18 EUR/m^3 for the second commercial thinning. Both investment costs and stumpage price values include the Value Added Tax.

Table 7.3: Management regimes and growth for the selected species in southern Europe

Species	Region/Area		Trees per hectare	Rotation (years)	Thinning and harvest (years)	MAI (m^3/ha/yr)	Total yield per rotation (m^3/ha)
***Popolus x canadensis* clone I-214**	**Italy**	Northern Italy	278 (6x6)	10	10	20	190*
						25	238*
						27	257*
	Spain	Castile and León (Duero Valley)	278 (6x6)	17	17	10	162*
				15	15	14	200*
				13	13	20	247*
	Spain	Navarre (Ebro Valley)	330 (5.4x5.4)	13	13	17	210*
			400 (5x5)	12	12	21	239*
						25	285*
Eucalyptus globulus	**Portugal**	North-Atlantic	1100 (3x3)	24	12, 24	11	272
						21	501
						29	692
		North-central				8	193
						17	397
						25	606
		Centre-Atlantic				7	165
						16	374
						28	668
		Tagus valley				5	119
						12	280
						22	520
Pinus pinaster	**Portugal**	North-Atlantic	1670 (2,5x2,5)	35	15, 25, 35	7	253
						11	375
						15	528
		North-central				4	152
						9	299
						14	504
		Centre-Atlantic				2	60
						6	216
						11	397
		Tagus valley				4	152
						8	267
						11	397
		Northern interior				3	105
						6	209
						10	336
Pinus radiata	**Spain**	Basque Country	1100 (3x3)	40	8, 18, 23, 40	14	574
				35	8, 18, 23, **35**	18	648
						22	771

** considering a 5% mortality*

Table 7.4: Investment costs and stumpage prices for the selected species in southern Europe, 2017

Species	Region/Area		Investment costs (EUR/ha)			Products	Product prices (EUR/m³)	Growth (m³/ha/yr)	Harvest sale (year)	Harvest price at year (EUR /ha)
			Establishment	Management	Total					
***Popolus x canadensis* clone I-214**	**Italy**	Northern Italy	1,807	4,808	6,615	Plywood veneer	54	20	10	10,260
								25		12,852
								27		13,878
	Spain	Castile and León (Duero Valley)	1,991	2,741	4,732	Plywood veneer	58	10	17	9,396
								14	15	11,600
								20	13	13,862
	Spain	Navarre (Ebro Valley)	1,736	4,301	6,037	Plywood veneer	41	17	13	8,610
								21	12	9,799
								25		11,685
Eucalyptus globulus	**Portugal**	North-Atlantic	2,252	1,610	3,890	Pulpwood	31	11	12 / 24	3,044 / 5,394
								21		6,158 / 9,400
								29		8,934 / 12,502
		North-central						8	12 / 24	2,105 / 3,878
								17		4,707 / 7,659
								25		7,397 / 11,374
		Centre-Atlantic						7	12 / 24	1,866 / 3,233
								16		4,446 / 7,160
								28		8,262 / 12,431
		Tagus valley						5	12 / 24	1,265 / 2,418
								12		3,346 / 5,310
								22		6,330 / 9,793
Pinus pinaster	**Portugal**	North-Atlantic	1,534	1,962	3,496	Fuel Sawn	37 for sawn, 21 for fuel	7	15 / 25 / 35	391 / 1,161 / 10,275
								11		400 / 1,001 / 8,148
								15		355 / 853 / 5,631
		North-central						4	15 / 25 / 35	355 / 1,027 / 7,074
								9		0 / 949 / 5,418
								14		0 / 582 / 6,556
		Centre-Atlantic						2	15 / 25 / 35	0 / 0 / 3,884
								6		0 / 0 / 3,031
								11		0 / 0 / 3,884
		Tagus valley						4	15 / 25 / 35	0 / 0 / 3,884
								8		586 / 1,466 / 14,306
								11		573 / 1,432 / 13,538
		Northern interior						3	15 / 25 / 35	355 / 1,125 / 10,726
								6		355 /1,125 / 10,726
								10		0 / 996 / 9,112
Pinus radiata	**Spain**	Basque Country	2,100	3,665	5,765	Fuel Sawn	35 for sawn, 7,5 for 1st com thin, 18 for 2nd com thin	14	8 / 18 / 23 / 35	0 / 279 / 622 / 14,442
								18		0 / 401 / 840 / 16,375
								22		0 / 512 / 1,267 / 20,177

7.2.4 Financial analysis

To carry out the financial analysis, we developed the cash flow tables considering costs and prices in terms of market values and estimated financial returns using typical capital budgeting indicators: NPV, EAV, IRR and LEV. Discounted PBP was also included as an additional indicator of risk exposure. The references we used for such approaches are found in Klemperer (2003), Wegner (2012) and Cubbage *et al*. (2015). These profitability indicators have been calculated as follows:

$$NPV = \sum_{n=0}^{N} \frac{R_n - C_n}{(1+i)^n}$$

$$EAV = LEV * i$$

$$IRR = i: \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} = \sum_{n=0}^{N} \frac{R_n}{(1+i)^n}$$

$$LEV = \frac{NPV * (1+i)^N}{((1+i)^N - 1)}$$

Where:
n = year
R = revenues (cash inflow)
C = costs (cash outflow)
i = annual discount rate
N = rotation length

We decided to use EAV and IRR as our primary indicators in the study, however, NPV, LEV and PBP estimations are provided in the tables as well.

For what concerns the discount rate, its choice it is always controversial. Discount rates cited in the literature for private-based timber investments vary from 2% to up 12%, where values <6-7% are typically used the in northern hemisphere. Cubbage *et al.* (2007; 2014) uses 8% discount rate for the comparison of timber investments returns at a global level. In our case, we decided to use a 5% real discount rate for all species and countries allowing all investments to be compared on the same basis. We also tested different discount rates between 2%-8% to allow the readers to compare the results on different assumptions.

Simulations were firstly carried out assuming a baseline scenario, where no land use costs and subsidies are included. Therefore, in this scenario we assumed that the investor already owns the land and need to make investment decisions.

The analysis was carried out before income- and land-tax. This choice is motivated by the fact that the tax regimes vary depending on the legal status and the business model of the investors.

7.2.5 Sensitivity analysis scenarios

We also estimated financial returns according to several alternative scenarios, testing the effects of different hypotheses:

(a) higher investment costs;
(b) maximum and minimum stumpage prices;
(c) a premium price for timber certified according to voluntary sustainable forest management standards such as FSC® or PEFC™;
(d) the inclusion of public subsidies as available;
(e) the inclusion of land costs as a factor of production, considering firstly a land lease and secondly land purchase;
(f) other hypotheses.

Table 7.5 summarizes the assumptions used for the sensitivity analysis. All the input variables used for the sensitivity analysis were based on real cases values and not hypothetical. These hypotheses were simulated while keeping constant all the other variables (*ceteris paribus*), and when reasonable, we also simulated combinations of hypothesis.

For what concerns the case of higher investment costs (a), data are derived from the same sources as the baseline data. Investment costs showed to vary more in some areas than in others and this is due to the need for longer site preparation operations, more intense weed control or more expensive consumables prices (i.e. water for irrigation, fertilizers, seedlings). The greatest percentage increase is for poplar plantations, in particular in Italy (+46%) and Navarre (+47%). In Castilla Leon investment costs for poplar plantations could rise by 36% and in the Basque Country for radiata pine plantations by 18%. Investment costs for eucalyptus and maritime pine plantations in Portugal could be subject respectively to a 24% and 33% increase compared to the baseline costs.

In the second scenario, we applied stumpage prices variations (b) when these have shown to be subject to relevant changes. These are also based on real data, derived from the baseline values sources as well and are based on 2017 values. Poplar prices showed to have the largest range among the considered species, in particular in Spain. In determining these values, we excluded rare and exceptional cases. Surprisingly, Castile and León – according to the results of the forest owners' association timber auctions – had the highest maximum prices registered (77 EUR/m^3), while the minimum price was 37 EUR/m^3. In Navarre, the maximum price registered was 62 EUR/m^3 and the minimum – the lower value for poplar timber – 20 EUR/m^3. In Italy, according to Chambers of Commerce, the maximum price was 66 EUR/m^3 and the minimum 43 EUR/m^3. Eucalyptus and radiata pine timber stumpage prices did not result to be subject to relevant variations, while in the case of maritime pine, stumpage price could be lower than what we assumed as our baseline (33 EUR/m^3 for sawn timber and 18 EUR/m^3 for fuel wood). We also considered the case of a premium price for timber certified according to voluntary sustainable forest management standards such as FSC® or PEFC™ (c); although only in Portugal there seems to be a rather structured premium price system, which affect pulpwood and fuelwood. According to forest owners' associations, certified eucalyptus is worth 4 EUR/m^3 more than the non-certified, and fuelwood from maritime pine stands 2.5 EUR/m^3 more. We have not included in our simulations the potential additional costs for sustainable forest management.

For what concerns public subsidies (d) we referred to the grant-based contributions of the national (in the case of Portugal) or regional (in the cases of Italy and Spain) Rural Development Plans (RDP) in the current programming period 2014-2020. RDPs are derived from the Reg. ECC No. 1305/2013 and co-funded by the European Agricultural Fund for Rural Development (EAFRD). None of the study's areas have in place other subsidies schemes than this one. In the northern Italian regions (Emilia-Romagna, Friuli Venetia-Giulia, Lombardy, Piedmont and Veneto), the average grant of the RDP afforestation measure 8.1 consists in a reimbursement of 60% of the plantation establishment costs. In Navarre, according to the regional RDP, the administration uses the measure 8.5.1 for providing a reimbursement of 50% of the poplar plantation establishment costs and pruning costs. However, according to the contractual obligations associated to the measure, poplar plantations rotations must be > 13 years in order to be eligible (in the simulations, we extended the rotation in order to include this hypothesis). In Castile and León there are no RDP measures to support poplar plantations. Neither in the case of eucalyptus there are available subsidies in Portugal in the current programming period. On contrary, maritime pine plantations in Portugal can count on a reimbursement of 75% of the plantation establishment costs (measure 8.1.1) and 40% of the pruning and weed control costs (measure 8.1.6). In the Basque Country, measures 8.1.1 and 8.1.3 provide respectively a 30%

reimbursement of establishment costs and 50% of pruning, weed control and fertilization costs. In addition, there are other RDP measures related to plantations that we did not considered because not in our scope, i.e. supporting fire prevention intervention, post-fire regeneration, and ecological improvement.

Regarding the inclusion of land cost as a factor of production (e), we firstly considered an annual land lease cost, and secondly, the land purchase price. In the case of land lease, the annual cost could vary greatly, from 60 EUR ha^{-1} yr^{-1} in the Tagus Valley (Portugal) to 350 EUR ha^{-1} yr^{-1} in northern Italy. In the case of Italy, land rent cost data were derived by calculating the average values for selected types of lands in the provinces of Alessandria, Mantua and Udine reported in the Agriculture Annual Review of CREA (2016). In Spain and Portugal, the values were derived from interviews to forest owners' associations and industries. Land lease is a rather common practice for pulp and paper industries in Portugal (for eucalyptus), and for the plywood industry in Italy and Spain to secure their poplar timber supply by establishing their own plantations. In Portugal, average land lease was estimated to be 60 EUR ha^{-1} yr^{-1} in the Tagus valley and northern Interior, 80 EUR ha^{-1} yr^{-1} in the north-central and centre-Atlantic regions, and 90 EUR ha^{-1} yr^{-1} in the north-Atlantic region. In Spain, the land lease cost for running poplar plantation is on average 200 EUR ha^{-1} yr^{-1} in Castile and León and 250 EUR ha^{-1} yr^{-1} in Navarre, even though it could be certainly higher in some areas. In the Basque Country the land lease practice is uncommon, and we estimated the average cost to be 150 EUR ha^{-1} yr^{-1}. For what concern land purchase, we assumed the land to be purchased at market price at year 0 and sold again at the end of the rotation cycle, without assuming land appreciation. In this case, land price is significantly higher for running poplar plantations being established on agricultural land, i.e. in Italy the average price is 33,000 EUR ha^{-1}, in Navarre 16,600 EUR ha^{-1}, and in Castile and León 12,250 EUR ha^{-1}. Data for Italy were derived from CREA (2016), while for Spain, we referred to the Land Prices Survey published every year by the Ministry of Agriculture, Fisheries, Food and Environment (MAPAMA, 2017). Forest land cost in the Basque Country is also relatively high, estimated at 8,000 EUR/ha. In the case of Portugal – according to forest owners associations – land prices vary on average from 3,000 EUR ha^{-1} in the Tagus Valley and northern interior, to 4,000 EUR ha^{-1} in centre-Atlantic and north-central, and 4,500 EUR ha^{-1} in the north Atlantic region. In the case of poplar plantations in Navarre we also simulated a scenario including the payment of the local Watershed Authority Tax (f), which amounts on average to 150 EUR ha^{-1} yr^{-1}.

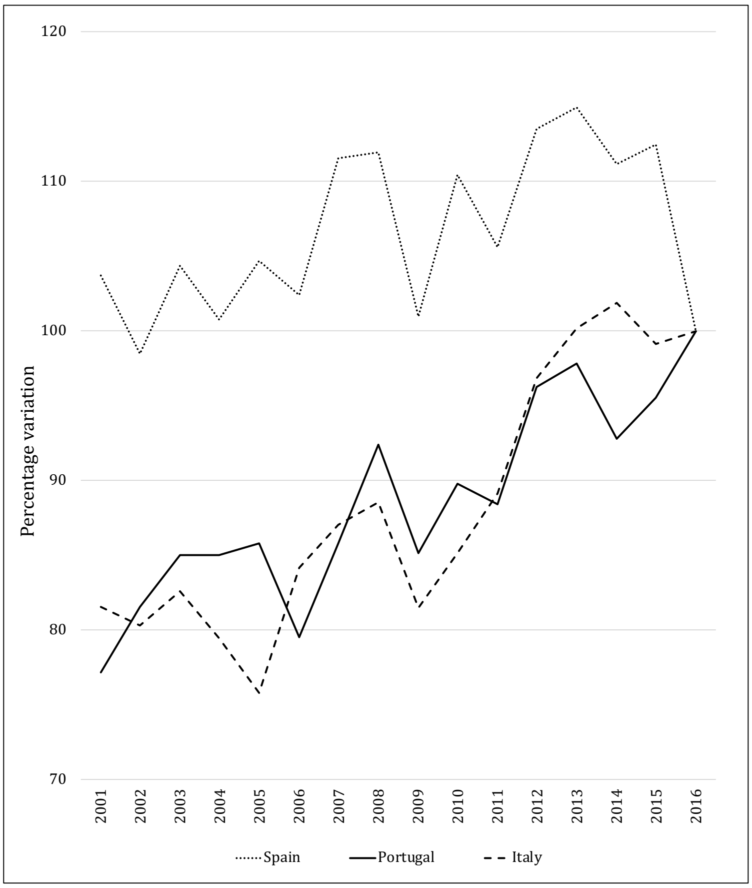
Table 7.5: Inputs for sensitivity analysis of timber investment returns for selected species in southern Europe, 2017

Species Country/region			High investment costs (EUR/ha)	Maximum stumpage price (EUR/m^3)	Minimum stumpage price (EUR/m^3)	FSC or PEFC premium price (EUR/Navarre)	Subsidies	Land lease (EUR/ha/yr)	Land purchase (EUR/ha)	Other
***Popolus x canadensis* clone I-214**	**Italy**	Northern Italy	9,636	66	43	-	Reimbursement of 60% of establishment costs (RDP2014-20 Measure 8.1.1)	350	33,000	-
	Spain	Castilla y Leon (Duero Valley)	6,437	77	37	-	No subsidies available	200	12,250	-
		Navarre (Ebro Valley)	8,882	62	20	-	Reimbursement of 50% of establishment costs and pruning costs (>13 years rotation) (RDP 2014-20 Measure 8.5.1)	250	16,600	Watershed Authority Tax: 150 EUR/ha/yr
Eucalyptus globulus	**Portugal**	North-Atlantic	4,830	-	-	+4	No subsidies available	90	4,500	-
		North-central						80	4,000	
		Centre-Atlantic						80	4,000	
		Tagus valley						60	3,000	
Pinus pinaster	**Portugal**	North-Atlantic	4,655	-	33 for sawn, 18 for fuel	+2,5 for fuel	Reimbursement of 75% of establishment costs, and 40% of pruning and weed control costs (RDP 2014-20 Measure 8.1.1 and 8.1.6)	90	4,500	-
		North-central						80	4,000	
		Centre-Atlantic						80	4,000	
		Tagus valley						60	3,000	
		Northern interior						60	3,000	
Pinus radiata	**Spain**	Basque Country	6,785	-	-	-	Reimbursement of 30% of establishment costs, and 50% of pruning, weed control and fertilization costs (RDP 2014-20 Measure 8.1 and 8.3)	150	8,000	-

7.2.6 Trend analysis

We carried out as well a trend analysis in order to estimate how financial returns in the baseline scenario have evolved over recent years as a result of the evolution of the investment costs and timber stumpage prices variables. Input data on investment costs and timber stumpage prices are derived from the same sources as baseline values. In the case of investment costs, when no historical data were available – due to the lack of published information or book-keeping by forest owners and industries – we used the FAOSTAT (2018) Agricultural Producer Price Index to estimate missing data and complete the time series between 2001 and 2017 (Figure 7.3).

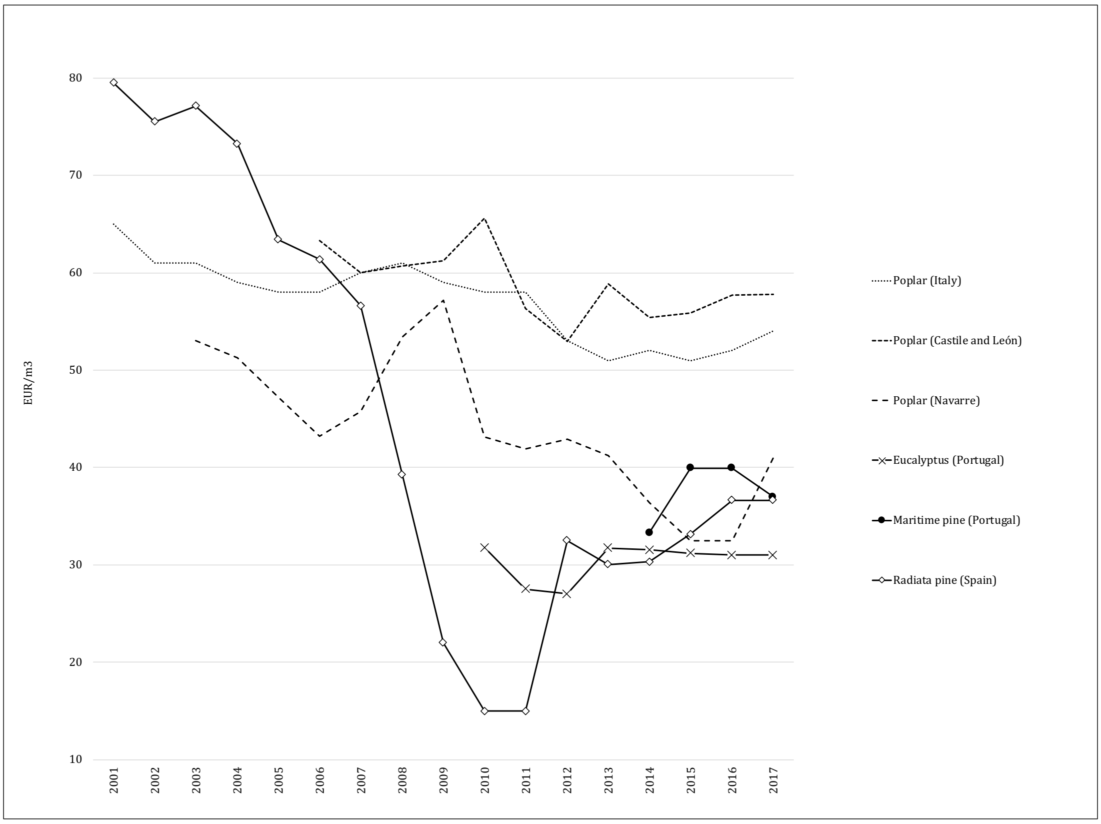
Figure 7.3: Agriculture Producer Price Index for Spain, Italy and Portugal, 2001-2017 (2017=100)



Source: own elaboration based on FAOSTAT (2017)

Timber stumpage prices changes are presented in Figure 7.4. We could collect prices data from 2001 for poplar in Italy and in the Basque Country for radiata pine, from 2003 for poplar in Navarre, and from 2006 for poplar in Castile and León. For what concerns Portugal, the scarcity of published information on timber prices did not allow us to determine prices before 2010 for eucalyptus and before 2014 for maritime pine. Both cost and price values have been converted from nominal values into real values using the general deflator indexes provided by countries' official institute of statistics (ISTAT, 2017; INE, 2017a; INE, 2017b).

Figure 7.4: Timber stumpage prices (EUR/m3) evolution for selected species, 2001-2017 (real values)



Source: own elaboration

Capital budgeting indicators were calculated for each year along the period covered by data (the length of the financial returns time-series depends on the stumpage prices). Two different calculation approaches were used: *ex-ante* and *ex-post*. Following the example, of a 10-years rotation plantation established in 2001, the *ex-ante* approach enabled us to estimate the expected return using the values of the year when the investment was carried out (NPV calculated using 2001 costs):

$$NPV\ ex\ ante_{2001} = \frac{R_{2001}}{(1+i)^{10}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2001}}{(1+i)^{2}} - \frac{C_{2001}}{(1+i)^{3}} - \cdots - \frac{C_{2001}}{(1+i)^{10}}$$

Where R_n and C_n are the sum of revenues and costs at year n. On the other hand, the *ex-post* approach considered the actual evolution of costs and prices throughout the investment horizon:

$$NPV\ ex\ post_{2001} = \frac{R_{2011}}{(1+i)^{10}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2002}}{(1+i)^{2}} - \frac{C_{2003}}{(1+i)^{3}} - \cdots - \frac{C_{2011}}{(1+i)^{10}}$$

However, in this latter case, no future costs estimation for the input variables was carried out, thus the values from 2017 onwards are assumed constant.

7.3 Results

The results of the study are presented in the following sections: 1) baseline results; 2) sensitivity analysis results; and 3) trend analysis results.

7.3.1 Baseline results

The results of the financial analysis according to the baseline scenario are presented in Table 7.6. Excluding land use costs and subsidies, plantations of hyrbid poplar in northern Italy and Castile and León and eucalyptus plantations in Portugal result the investments with the highest returns. On the other hand, investments in maritime pine and radiata pine results to be under the financial viability threshold according to this scenario.

As one moves from the minimum productivity sites to the maximum, EAV for hybrid poplar plantations in northern Italy vary from 64 to 332 EUR ha^{-1} yr^{-1} with average productivity sites presenting 256 EUR ha^{-1} yr^{-1}. In the case of Castille and Leon, EAV associated to the average productivity sites is lower (138 EUR ha^{-1} yr^{-1}), but in high productivity sites is slighly higher than in Italy (350 EUR ha^{-1} yr^{-1}). In Navarre, EAV is much lower with 47 EUR ha^{-1} yr^{-1} in average productivity sites and only reaching a maximum of 159 EUR ha^{-1} yr^{-1} (-43 EUR ha^{-1} yr^{-1} in low productivity sites). IRR behaves similarly to EAV, with northern Italy presenting the highest values (9.5%) for the average productivities followed by Castile and León (7.5%) and Navarre (6.1%) but with Castile and Leonholding the highest value for the high productivity sites. In low productivity sites, IRR value result 6.3% in northern Italy, 5.1% in Castille and Leon, while is below 5% in Navarre. The LEV for hybrid poplar plantations ranges from 1,290 EUR ha^{-1} to 6,638 EUR ha^{-1} in northern Italy, from 103 EUR ha^{-1} to 7,008 EUR ha^{-1} in Castile and León, and from -864 EUR ha^{-1} to 3,176 EUR ha^{-1} in Navarre. The PBP, in the case of poplar plantations, simply corresponds to the rotation age (when positive).

The highest financial returns among the species taken into consiederation are provided by eucalyptus plantations in Portugal, with EAV that can reach 402 EUR ha^{-1} yr^{-1} and IRR up to 12.5% depending on the region. These values refer to high productivity sites in the north Atlantic ecological region. However, there are significant differences among regions and productivity. On average, the best region for running eucalyptus plantations is the north Atlantic, followed by the north-central and central-Atlantic regions. The EAV in the average productivity sites is 221 EUR ha^{-1} yr^{-1} in north-Atlantic, 123 EUR ha^{-1} yr^{-1} in north-central, 101 EUR ha^{-1} yr^{-1} in central-Atlantic, and 15 EUR ha^{-1} yr^{-1} in the Tagus valley. When considering high productivity sites, the centre-Atlantic region shows potentally higher EAV (374 EUR ha-

^{1} yr^{-1}) compared to north-central (315 EUR ha^{-1} yr^{-1}). In the case of low productivity sites, EAV shows negative results for the north-central, central-Atlantic and Tagus valley regions, respectevely -67 EUR ha^{-1} yr^{-1}, -91 EUR ha^{-1} yr^{-1} and -134 EUR ha^{-1} yr^{-1}. In average productivity sites, IRRs are 9.8% in north-Atlantic, 7.9% in north-central, 7.5% in central-Atlantic, and 5.4% in the Tagus valley. In sites of high productivity, IRRs reaches up to 12.5% in north-Atlantic, 11.2% in north-central, 12.0% in central-Atlantic, and 10.0% in the Tagus valley. The average LEV for eucalyptus plantations in Portugal results 4,415 EUR ha^{-1} north-Atlantic, 2,461 EUR ha^{-1} in north-central, 2,025 EUR ha^{-1} in central-Atlantic, and 306 EUR ha^{-1} in the Tagus valley. PBP, when available, corresponds to year 24, age of the second rotation harvest.

For what concern maritime pine plantations in Portugal, financial indicators are mostly negative in the baseline scenario. Average productivy sites EAV is -20 EUR ha^{-1} yr^{-1} in north-Atlantic, -47 EUR ha^{-1} yr^{-1} in north-central, -79 EUR ha^{-1} yr^{-1} in central-Atlantic, -59 EUR ha^{-1} yr^{-1} in the Tagus valley and -90 EUR ha^{-1} yr^{-1} in the northern interior. EAV show positive results only in high productivity sites in the north-Atlantic and north-central regions, respectively 36 EUR ha^{-1} yr^{-1} (5.7% IRR and 714 EUR ha^{-1} LEV) and 26 EUR ha^{-1} yr^{-1} (5.5% IRR and 524 EUR ha^{-1} LEV). The average LEV results -408 EUR ha^{-1} in north-Atlantic, -933 EUR ha^{-1} in north-central, -1,572 EUR ha^{-1} in central-Atlantic, -1,189 EUR ha^{-1} in the Tagus valley, and -1,797 EUR ha^{-1} in the northern interior. When positive, PBP is 35 yrs, age of the plantations final cut. Similarly, also for radiata pine plantations in the Basque Country (Spain) financial returns indicators in the baseline scenario are negative. In this case, EAV is -56 EUR ha^{-1} yr^{-1} in average productivity sites, -2 EUR ha^{-1} yr^{-1} in high productivity sites and -81 EUR ha^{-1} yr^{-1} in low productivity ones. LEV are respectively -1,113 EUR ha^{-1}, -45 EUR ha^{-1}, and -1,613 EUR ha^{-1}.

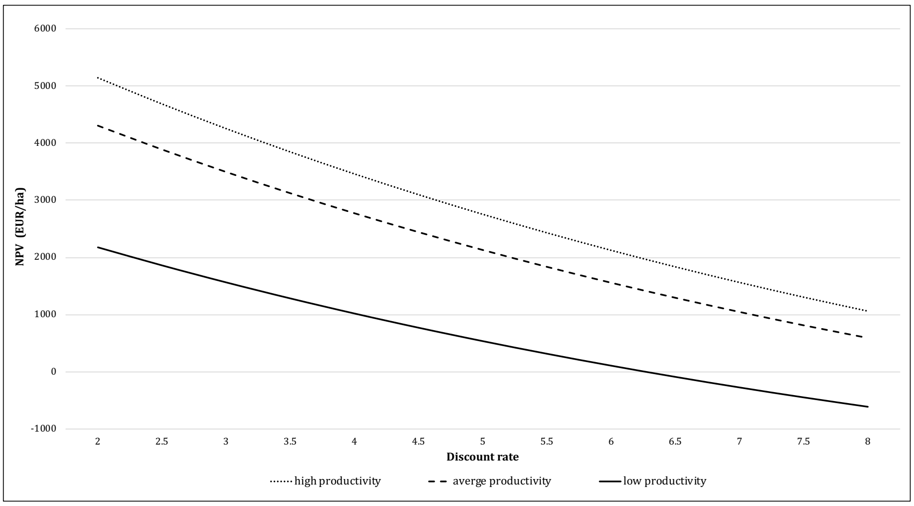
Table 7.6: Financial returns for selected species in southern Europe according to the baseline, 2017

Species	Country/region		Growth (m^3/ha/yr)	NPV (EUR/ha)	EAV (EUR/ha/yr)	IRR	LEV (EUR/ha)	PBP (years)
***Popolus x canadensis* clone I-214**	**Italy**	Northern Italy	20	536	64	6.3%	1,290	10
			25	2,127	256	9.5%	5,121	10
			27	2,757	332	10.6%	6,638	10
	Spain	Castile and León (Duero Valley)	10	60	5	5.1%	103	17
			14	1499	138	7.7%	2,766	15
			20	3469	350	11.1/	7,008	13
		Navarre (Ebro Valley)	17	-421	-43	n.a.	-864	13
			21	441	47	6.0%	940	12
			25	1492	159	8.1%	3,176	12
Eucalyptus globulus	**Portugal**	North-Atlantic	11	69	5	5.1%	101	24
			21	3,046	221	9.8%	4,415	24
			29	5,533	402	12.5%	8,049	24
		North-central	8	-924	-67	n.a.	-1,339	n.a.
			17	1,698	123	7.9%	2,461	24
			25	4,347	315	11.2%	6,301	24
		Centre-Atlantic	7	-1,256	-91	n.a.	-1,821	n.a.
			16	1,397	101	7.5%	2,025	24
			28	5,157	374	12.0%	7,474	24
		Tagus valley	5	-1,844	-134	n.a.	-2,673	n.a.
			12	211	15	5.4%	306	24
			22	3,263	236	10.0%	4,730	24
Pinus pinaster	**Portugal**	North-Atlantic	7	-1,373	-84	n.a.	-1,676	n.a.
			11	-334	-20	n.a.	-408	n.a.
			15	585	36	5.7%	714	35
		North-central	4	-2,033	-124	n.a.	-2,483	n.a.
			9	-763	-47	n.a.	-933	n.a.
			14	429	26	5.5%	524	35
		Centre-Atlantic	2	-2,188	-134	n.a.	-2,675	n.a.
			6	-1,287	-79	n.a.	-1,572	n.a.
			11	-282	-17	n.a.	-344	n.a.
		Tagus valley	4	-2,033	-124	n.a.	-2.483	n.a.
			8	-973	-59	n.a.	-1,189	n.a.
			11	-282	-17	n.a.	-344	n.a.
		Northern interior	3	-2,033	-124	n.a.	-2,483	n.a.
			6	-1,471	-90	n.a.	-1,797	n.a.
			10	-786	-17	n.a.	-960	n.a.
Pinus radiata	**Spain**	Basque Country	14	-1.384	-81	n.a.	-1,613	n.a.
			18	-911	-56	n.a.	-1.113	n.a.
			22	-37	-2	n.a.	-45	n.a.

Even though we preferred to use the EAV as primary indicator, NPV was also calculated to provide the absolute estimate of the plantation's cash flow present value.

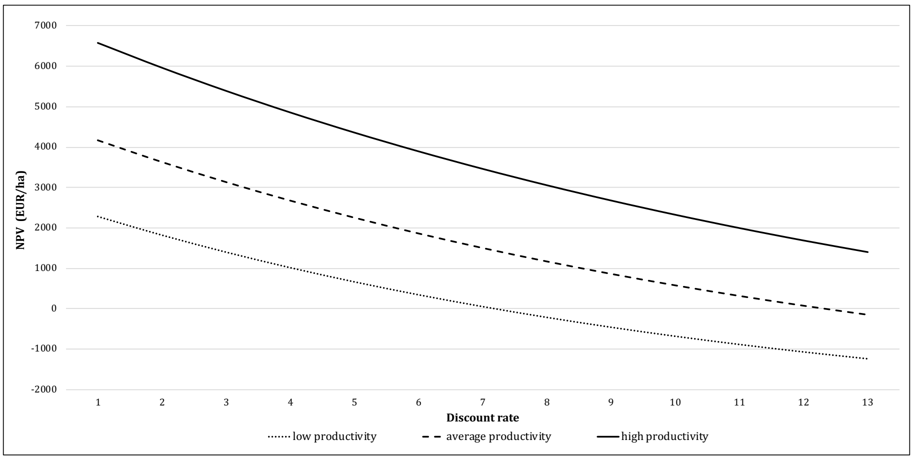
In addition, NPV allowed us to better test the effect of different discount rates. Figures from 7.5 to 7.10 present the results according to different discount rates, in the range 2%-8%, using NPV as dependent variable.

Figure 7.5: Changes in the NPV (EUR/ha) in relation to alternative discount rates for hybrid poplar in northern Italy, 2017



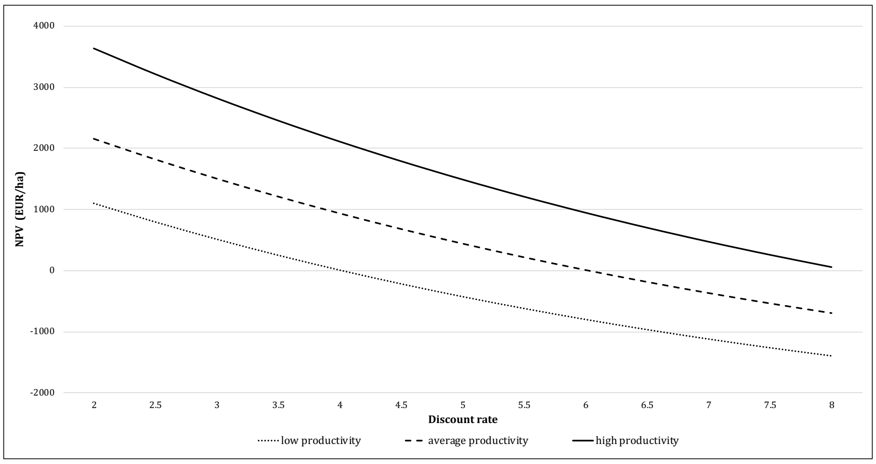
Source: own elaboration

Figure 7.6: Changes in the NPV (EUR/ha) in relation to alternative discount rates for hybrid poplar in Castile and León, 2017



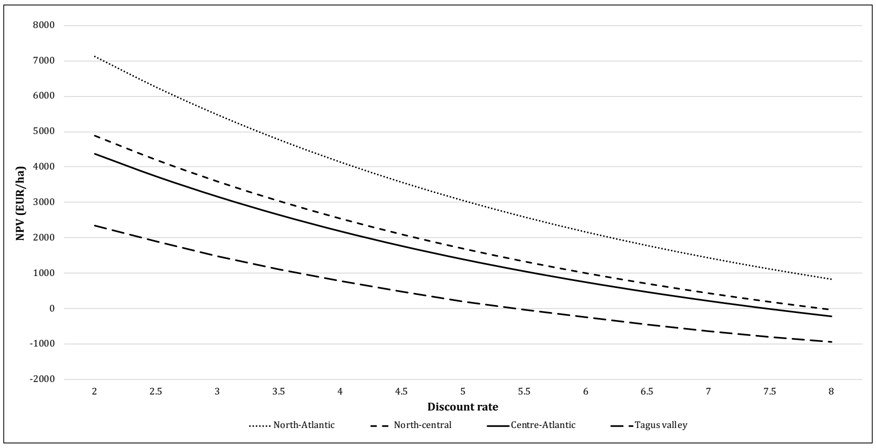
Source: own elaboration

Figure 7.7: Changes in the NPV (EUR/ha) in relation to alternative discount rates for hybrid poplar in Navarre, 2017



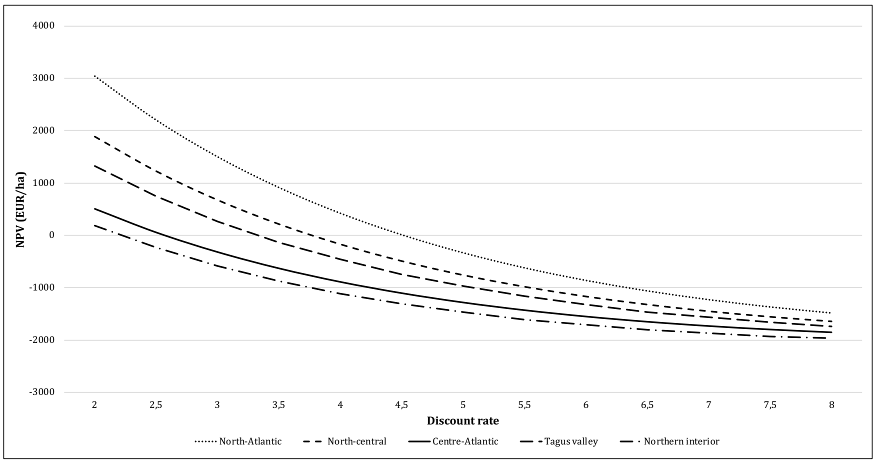
Source: own elaboration

Figure 7.8: Changes in the NPV (EUR/ha) in relation to alternative discount rates for eucalyptus in Portugal (average productivity sites), 2017



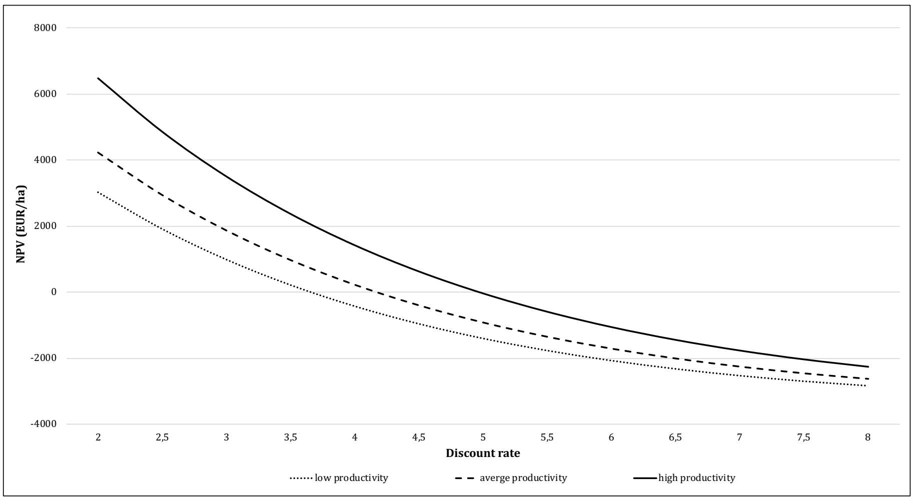
Source: own elaboration

Figure 7.9: Changes in the NPV (EUR/ha) in relation to alternative discount rates for maritime pine in Portugal (average productivity sites), 2017



Source: own elaboration

Figure 7.10: Changes in the NPV (EUR/ha) in relation to alternative discount rates for Pinus radiata in the Basque Country, 2017



Source: own elaboration

7.3.1 Sensitivity analysis results

The sensitivity analyses allowed us to test the effect of alternative hypothesis and, therefore, provide a more complete spectrum of the potential investments returns associated to the selected species and contexts.

The results of the sensitivity analysis are summarized by EAVs in Table 7.7 and by IRR in Table 7.8.

In addition, Figures 7.11 to 7.16 present the results individually by species and area, including as well the results obtained combinining alternative hypothesis. In these figures, results are expressed using EAV as dependent variable. The complete results, showing all indicators, can be found in the supplementary material. The hypothesis tested in the alternative scenarios showed to be able to alter substantially the investment returns of plantations, altough the extent of these changes is greater in some cases than in others, depending on the species and context type. In general, hybrid poplar plantations are the ones that showed the largest potential variability based on the hypothesis tested, while eucalyptus plantations in Portugal – again on a general perspective – present relatevely stable investment in financial terms.

Table 7.7: Financial returns according to the sensitivity analysis scenarios, EAV (EUR/ha/yr), i=5%, 2017

Species	Country/region		Growth (m^3/ha/yr)	Baseline	High investment costs	Maximum stumpage price	Minimum stumpage price	FSC or PEFC premium price	Subsidies	Land lease	Land purchase	Other	Standard deviation
***Popolus x canadensis* clone I-214**	**Italy**	Northern Italy	20	64	-248	233	-90		188	-235	-1,470		
			25	256	-57	467	63	-	380	-44	-1,278	-	457
			27	332	19	560	123		455	32	-1,202		
	Spain	Castile and León (Duero Valley)	10	5	-122	119	-123			-188	-586		
			14	138	1	305	-50	-	-	-53	-448	-	257
			20	350	199	599	70			161	-231		
		Navarre (Ebro Valley)	17	-43	-377	193	-279		93	-267	-831	-178	
			21	47	-306	345	-251	-	158	-189	-736	-95	330
			25	159	-194	514	-196		264	-77	-624	17	
Eucalyptus globulus	**Portugal**	North-Atlantic	11	5	-51			37		-85	-220		
			21	221	165	-	-	280	-	131	-4	-	107
			29	402	347			485		312	177		
		North-central	8	-67	-123			-45		-147	-267		
			17	123	67	-	-	170	-	43	-77	-	97
			25	315	359			387		235	115		
		Centre-Atlantic	7	-91	-147			-72		-171	-291		
			16	101	45	-	-	145	-	21	-99	-	94
			28	374	318			453		294	174		
		Tagus valley	5	-134	-189			-120		-194	-284		
			12	15	-40	-	-	48	-	-45	-135	-	71
			22	236	181			298		176	86		
Pinus pinaster	**Portugal**	North-Atlantic	7	-84	-151		-95	-80	11	-174	-309		
			11	-20	-88	-	-39	-16	74	-116	-245	-	100
			15	36	-32		10	42	130	-54	-189		
		North-central	4	-124	-192		-130	-22	-30	-204	-324		
			9	-47	-114	-	-62	-42	48	-127	-247	-	90
			14	26	-41		2	32	14	-54	-174		
		Centre-Atlantic	2	-134	-201		-139	-131	-39	-214	-334		
			6	-79	-146	-	-91	-74	16	-159	-279	-	92
			11	-17	-85		-36	-13	77	-97	-217		
		Tagus valley	4	-124	-192		-130	-22	-30	-184	-274		
			8	-59	-127	-	-74	-55	35	-119	-209	-	81
			11	-17	-85		-36	-13	77	-77	-167		
		Northern interior	3	-124	-192		-130	-122	-30	-184	-274		
			6	-90	-158	-	-100	-87	5	-150	-240	-	76
			10	-48	-116		-63	-44	47	-108	-198		
Pinus radiata	**Spain**	Basque Country	14	-81	-125	-76	-91		23	-231	-538		
			18	-56	-102	-51	-68	-	53	-206	-456	-	170
			22	-2	-49	5	-19		107	-151	-402		

Table 7.8: Financial returns according to the sensitivity analysis scenarios, IRR, 2017

Species	Country/region		Growth (m^3/ha/yr)	Baseline	High investment costs	Max stumpage price	Min stumpage price	FSC or PEFC premium price	Subsidies	Land lease	Land purchase	Other
			20	6.3%	n.a.	9.1%	n.a.		9.3%	n.a.	n.a.	
	Italy	Northern Italy	25	9.5%	n.a.	12.4%	6.2%	-	12.6%	n.a.	n.a.	-
			27	10.6%	5.3%	13.5%	7.3%		13.8%	5.5%	n.a.	
***Popolus x canadensis* clone I-214**			10	5.1%	n.a.	7.2%	n.a.			n.a.	n.a.	
		Castile and León	14	7.7%	5.0%	10.0%	n.a.	-	-	n.a.	n.a.	-
	Spain		20	11.1	8.0%	13.9%	6.6%			7.6%	n.a	
			17	n.a.	n.a.	8.5%	n.a.		7.7%	n.a.	n.a.	n.a.
		Navarre (Ebro Valley)	21	6.0%	n.a.	11.0%	n.a.	-	9.1%	n.a.	n.a.	n.a.
			25	8.1%	n.a.	13.1%	n.a.		11.1%	n.a.	n.a.	5.3%
			11	5.1%	n.a.			6.0%		n.a.	n.a.	
		North-Atlantic	21	9.8%	8.2%	-	-	10.7%	-	7.7%	n.a.	-
			29	12.5%	10.9%			13.5%		10.6%	6.7%	
			8	n.a.	n.a.			n.a.		n.a.	n.a.	
		North-central	17	7.9%	6.5%	-	-	8.8%	-	6.0%	n.a.	-
			25	11.2%	9.6%			12.1%		9.5%	6.2%	
Eucalyptus globulus	**Portugal**		7	n.a.	n.a.			n.a.		n.a.	n.a.	
		Centre-Atlantic	16	7.5%	6.0%	-	-	8.4%	-	5.5%	n.a.	-
			28	12.0%	10.4%			13%		10.4%	6.8%	
			5	n.a.	n.a.			n.a.		n.a.	n.a.	
		Tagus valley	12	5.4%	n.a.	-	-	6.3%	-	n.a.	n.a.	-
			22	10.0%	8.5%			10.9%		8.7%	6.1%	
			7	n.a.	n.a.		n.a.	n.a.	5.5%	n.a.	n.a.	
		North-Atlantic	11	n.a.	n.a.	-	n.a.	n.a.	7.8%	n.a.	n.a.	-
			15	5.7%	n.a.		5.2%	5.8%	9.1%	n.a.	n.a.	
			4	n.a.	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	
		North-central	9	n.a.	n.a.	-	n.a.	n.a.	7.0%	n.a.	n.a.	-
			14	5.5%	n.a.		5.0%	5.7%	8.9%	n.a.	n.a.	
			2	n.a.	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	
Pinus pinaster	**Portugal**	Centre-Atlantic	6	n.a.	n.a.	-	n.a.	n.a.	5.8%	n.a.	n.a.	-
			11	n.a.	n.a.		n.a.	n.a.	7.8%	n.a.	n.a.	
			4	n.a.	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	
		Tagus valley	8	n.a.	n.a.	-	n.a.	n.a.	6.6%	n.a.	n.a.	-
			11	n.a.	n.a.		n.a.	n.a.	7.8%	n.a.	n.a.	
			3	n.a.	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	
		Northern interior	6	n.a.	n.a.	-	n.a.	n.a.	5.2%	n.a.	n.a.	-
			10	n.a.	n.a.		n.a.	n.a.	6.8%	n.a.	n.a.	
			14	n.a.	n.a.	n.a.	n.a.		5.5%	n.a.	n.a.	
Pinus radiata	**Spain**	Basque Country	18	n.a.	n.a.	n.a.	n.a.	-	6.0%	n.a.	n.a.	-
			22	n.a.	n.a.	5.1%	n.a.		6.8%	n.a.	n.a.	

Increased investment costs have the effect of reducing the EAV of hybrid poplar plantations in Italy to 19 EUR ha^{-1} yr^{-1} (high productivity sites), -57 EUR ha^{-1} yr^{-1} (average productivity sites) and -248 EUR ha^{-1} yr^{-1} (low productivity sites); in Castile and León to respectevely 199 EUR ha^{-1} yr^{-1}, 1 EUR ha^{-1} yr^{-1} and -122 EUR ha^{-1} yr^{-1}; and in Navarre to -377 EUR ha^{-1} yr^{-1}, -306 EUR ha^{-1} yr^{-1} and -194 EUR ha^{-1} yr^{-1}. When available, IRRs reach a maximum of 5.3% in northern Italy and 8.0% in Castile and León. In the case of eucalyptus plantations in Portugal, the increased investment costs resulted in non-viable investments for the low productivity sites in all regions with EAV presenting negative values ranging from -51 to -189 EUR ha^{-1} yr^{-1} as we move south to the Tagus valley as well as for the average sites in this region (-40 EUR ha^{-1} yr^{-1}). As for marime pine in Portugal and radiata pine in the Basque Country, the high investment costs aggravate the non-viability of investments having EAV values varying between -88 and -158 EUR ha^{-1} yr^{-1} and -49 and -125 EUR ha^{-1} yr^{-1} for radiata pine.

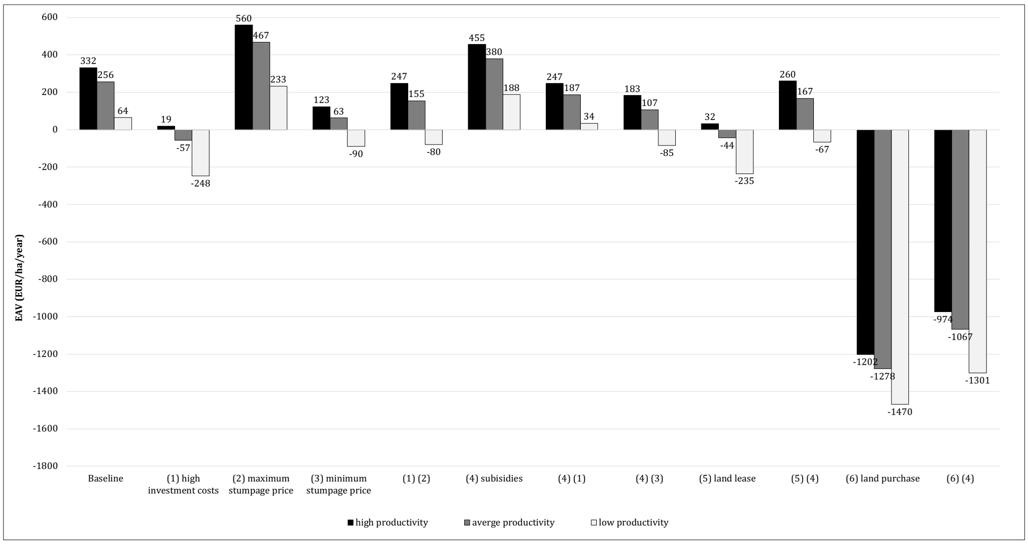
We tested the effect on the financial returns of stumpage prices variations, when these showed to vary substantially. When we assume the trees to be sold at the maximum stumpage price determined, the EAV for poplar plantatios in northern Italy increases to 233 EUR ha^{-1} yr^{-1}, 467 EUR ha^{-1} yr^{-1} and 560 EUR ha^{-1} yr^{-1}, respectively in minimum, average and high productivity sites. In Castile and León the indicator reaches 119 EUR ha^{-1} yr^{-1}, 305 EUR ha^{-1} yr^{-1} and 599 EUR ha^{-1} yr^{-1}, while in Navarre 193 EUR ha^{-1} yr^{-1}, 345 EUR ha^{-1} yr^{-1} and 514 EUR ha^{-1} yr^{-1}. IRRs ranges from 9.1% to 13.5% in northern Italy, from 7.2% to 13.0% in Castile and León, and from 8.5% to 13.1% in Navarre. In the case of radiata pine in the Basque Country, with maximum stumpage prices, EAV result 5 EUR ha^{-1} yr^{-1} in high productivity sites with an IRR of 5.1%, while it results negative in average (-51 EUR ha^{-1} yr^{-1} ones) and minimum (-76 EUR ha^{-1} yr^{-1}) ones.

On the other hand, when we assume the trees to be sold at the minimum stumpage prices determined, EAVs for hybrid poplar plantations in northern Italy show negative values in low productivity sites (-90 EUR ha^{-1} yr^{-1}), and in average and maximum ones, EAV decreases to respectevely 63 EUR ha^{-1} yr^{-1} and 123 EUR ha^{-1} yr^{-1} (IRRs of 6.2% and 7.3%). In Castile and León, with minimum stumpage prices, EAV is still positive only for high productivity sites (70 EUR ha^{-1} yr^{-1}), with IRR of 6.6%, and is negative for the others, -50 EUR ha^{-1} yr^{-1} and -123 EUR ha^{-1} yr^{-1}. In Navarre, with minimum stumpage prices, EAVs shows negative values in all cases, between -196 EUR ha^{-1} yr^{-1} and -279 EUR ha^{-1} yr^{-1}. We run this scenario also for maritime pine in Portugal, where stumpage prices could be lower than those we assumed as our baseline and observed that despite causing a slight decrease in EAV the viability threshold was never crossed (the situations for which EAV was positive remained positive). On the other hand, considering a premium price for certified maritime pine fuelwood (FSC® or PEFC™ scenario) resulted in a no-substancial impact (probably because it was not considered for sawnwood). Conversely, cosnidering premium prices for certified eucalyptus wood seems to have a higher impact in EAV that raised up to 280 EUR ha^{-1} yr^{-1} in north-Atlantic for average productivity sites.

We also tested the effect of public subsidies, based on the RDP grants available in each country or region. The average subsidy grant provided by northern Italian regions have a substantial impact on financial indicators, with EAV raising up to 188 EUR ha^{-1} yr^{-1}, 380 EUR ha^{-1} yr^{-1} and 455 EUR ha^{-1} yr^{-1} according to the site productivity, IRRs reach values between 9.3% and 13.8%. Subsidies showed to potentially have a determining impact also in those scenario where subsidies are combined with high investment costs or minimum stumapge prices hypotheses. In Navarre, subsidies increase the EAV to 93 EUR ha^{-1} yr^{-1}, 158 EUR ha^{-1} yr^{-1} and 264 EUR ha^{-1} yr^{-1}, with IRRs ranging from 7.7% to 11.1%. However, in the scenario combining subsidies and minimum stumapage prices, EAV is still negative, showing values between -73 EUR ha^{-1} yr^{-1} and -143 EUR ha^{-1} yr^{-1}. With the subsidy grants determined by the Portuguese RDP, investment in maritime pine plantations crossed the financial viability threshold except for most of the low productivity sites. Subsidized maritime pine plantations are only viable in the north-Atlantic region (EAV 11 EUR ha^{-1} yr^{-1}). In the scenario where subsidies and high investment costs are combined, EAV in average productivity sites result positive in north-Atlantic (41 EUR ha^{-1} yr^{-1}), north-central (15 EUR ha^{-1} yr^{-1}) and Tagus valley (2 EUR ha^{-1} yr^{-1}), while negative in the centre-Atlantic and northern interior region. Similarly, when subsidies are combined with minimum stumpage price, EAV in the average productivity sites result 56 EUR ha^{-1} yr^{-1} in the north-Atlantic region, 32 EUR ha^{-1} yr^{-1} in north-central, 4 EUR ha^{-1} yr^{-1} in centre-Atlantic, 21 EUR ha^{-1} yr^{-1} in the Tagus valley, and is negative in the northern interior region (-6 EUR ha^{-1} yr^{-1}). In the case of radiata pine plantations in the Basque Country, currently available subsidy grants have a determinant effect on the financial indicators as well. EAV of the subsidized investment result 23 EUR ha^{-1} yr^{-1} in low productivity sites, 53 EUR ha^{-1} yr^{-1} in the average ones and 107 EUR ha^{-1} yr^{-1} in the maximum ones, with IRRs ranging from 5.5% to 6.8%. Moreover, when supported by subsidies, plantations are financially viable also with high investment costs in average and high productivity sites, with EAV respectevely of 26 EUR ha^{-1} yr^{-1} and 79 EUR ha^{-1} yr^{-1}, while show negative EAV in low productivity sites (-3 EUR ha^{-1} yr^{-1}).

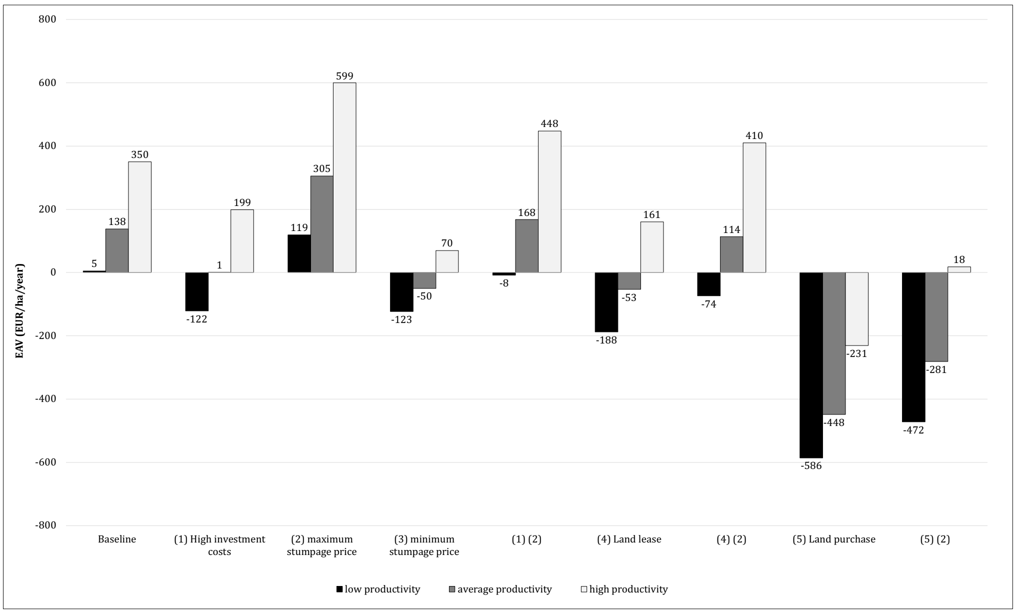
Land use costs show to have a relevant effect on the financial profitability indicators. In general, hybrid poplar plantations have to face significantly higher land costs then the other species, being grown on agricultural land. Forest land in the Basque Country is also relatevely expensive, while forest land in Portugal has a lower land cost, altough with differences among regions. Firstly, we simulated a scenario with the land-lease hypothesis, assuming an annual lease cost in the cash flow during the rotation cycle. In the case of hybrid poplar plantations in northern Italy, with land lease cost, financial indicators show still positive values only in high productivity sites (EAV of 32 EUR ha^{-1} yr^{-1} and IRR of 5.5%), while is negative in the average (-44 EUR ha^{-1} yr^{-1}) and minimum (-235 EUR ha^{-1} yr^{-1}) ones. When we combine the land lease hypothesis with the subsidies, the EAV shows positive results in maximum (260 EUR ha^{-1} yr^{-1}) and average productivity sites (167 EUR ha^{-1} yr^{-1}), while is still negative in minimum production sites. Similarly, for what concerns Castile and León, in the land-lease scenario, financial indicators are also positive only in high productivity sites (EAV of 161 EUR ha^{-1} yr^{-1} and IRR of 7.6%), and negative in the other two ones, with EAV of -53 EUR ha^{-1} yr^{-1} in the average and -188 EUR ha^{-1} yr^{-1} in the minimum. In the case of Navarre, poplar plantations result to be not financially viable when the investor have to sustain a land lease cost, with EAV varying from -77 EUR ha^{-1} yr^{-1} to -267 EUR ha^{-1} yr^{-1} depending on the site productivity. When the land lease hyphothesis is assocated with subsidies, investments result financially viable in average and high productivity sites, with EAV respectevely of 278 EUR ha^{-1} yr^{-1} and 109 EUR ha^{-1} yr^{-1}. For investment in radiata pine plantations, land lease costs result to be not financially viable (EAV between -152 EUR ha^{-1} yr^{-1} and -231 EUR ha^{-1} yr^{-1}), neither when the investment is supported by subsidies (EAV between -43 EUR ha^{-1} yr^{-1} and -127 EUR ha^{-1} yr^{-1}). In Portugal, eucalyptus plantations are on average the most convenient investment when land-lease or land-purchase are considered. Nevertheless, land lease is not affordable in low productivity sites with EAV dropping to values between -85 and -194 EUR ha^{-1} yr^{-1} in the first case and decreasing even further for land-purchase (between -220 and -291 EUR ha^{-1} yr^{-1}). For maritime pine plantations, the situation becomes even more dramatic for the land-lease and land-purchase scenarios with investment being non-viable for all situations even in high productivity sites. On average, leasing leads to EAV decreases close to 80 and 75 EUR ha^{-1} yr^{-1} (for eucalyptus and maritime pine, respectively), whereas purchasing over doubles the negative impact. Even when land-leasing is combined with subsidies, positive EAV can only be found for high productivity sites, yet presenting somewhat modest values of 40, 41, and 17 EUR ha^{-1} yr^{-1}, in north-Atlantic, north-central and Tagus valley (what about centre-Atlantic?), respectibely. Likewise, for a scenario considering purchasing the land for site establishment and selling it after the rotation cycle, eucalyptus plantation investments are only feasible in high productivity sites (IRRs ranging from 6.1% to 6.8%). In addition, also in Castile and León the option of land purchase result feasible, but only in high productivity sites and with trees sold with maximum stumpage prices (EAV of 18 EUR ha^{-1} yr^{-1} and IRR value of 5.1%). In Navarre, some of the poplar plantations established on river bends are subject to a tax set by the local Watershed Authority. The tax result not to be affordable for plantations in average and low productivity sites, with EAV showing respectevely - 95 EUR ha^{-1} yr^{-1} and -178 EUR ha^{-1} yr^{-1}, while in high productivity sites it decreases the financial indicators to 17 EUR ha^{-1} yr^{-1} in terms of EAV and 5.3% IRR. When this scenario is combined with the hypothesis of maximum stumpage price, EAV results 59 EUR ha^{-1} yr^{-1} in low productivity sites, 203 EUR ha^{-1} yr^{-1} in average ones and 372 EUR ha^{-1} yr^{-1} in maximum ones.

Figure 7.11: Financial returns according to the sensitivity analysis scenarios for hybrid poplar in northern Italy, expressed in EAV (EUR/ha/yr), i=5%, 2017



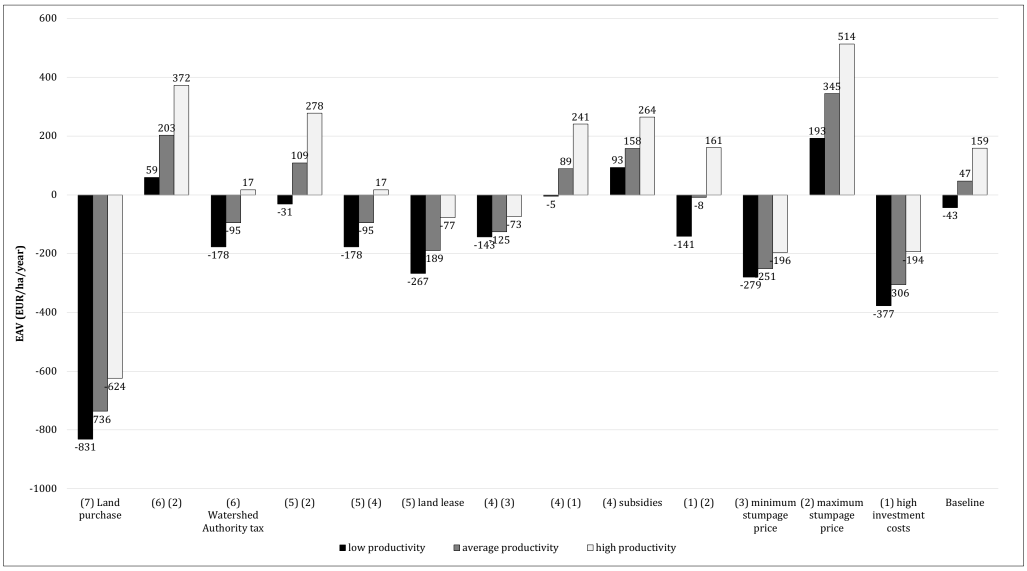
Source: own elaboration

Figure 7.12: Financial returns according to the sensitivity analysis scenarios for hybrid poplar in the Castile and León, expressed in EAV (EUR/ha/yr), i=5%, 2017



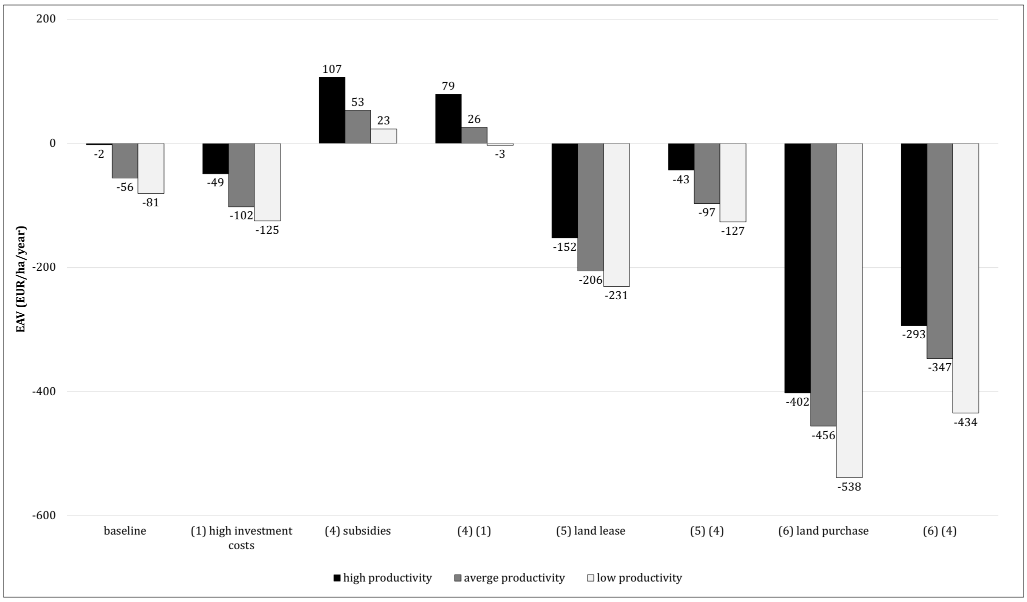
Source: own elaboration

Figure 7.13: Financial returns according to the sensitivity analysis scenarios for hybrid poplar in the Navarre, expressed in EAV (EUR/ha/yr), i=5%, 2017



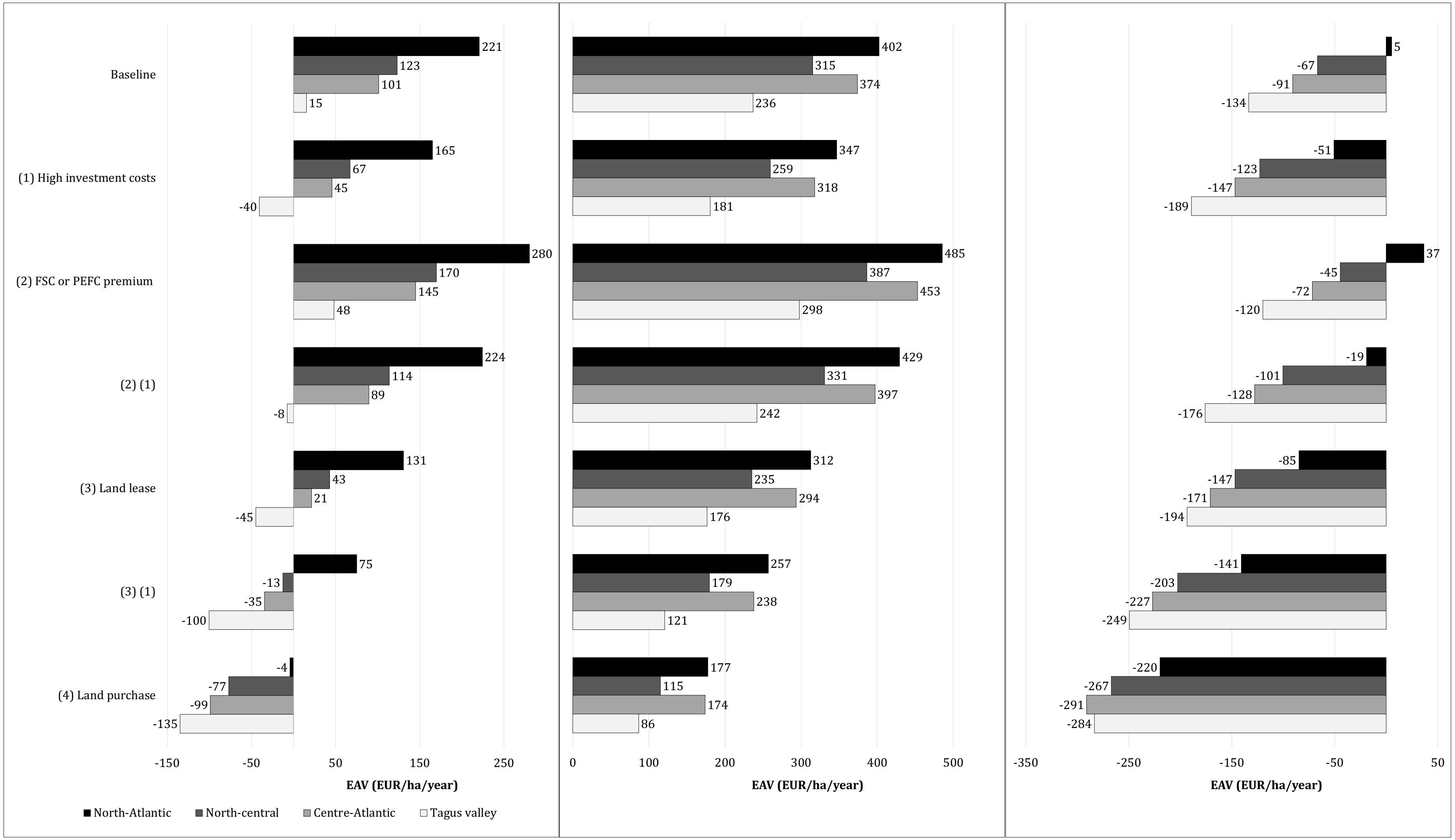
Source: own elaboration

Figure 7.14: Financial returns according to the sensitivity analysis scenarios for radiata pine in the Basque Country, expressed in EAV (EUR/ha/yr), i=5%, 2017



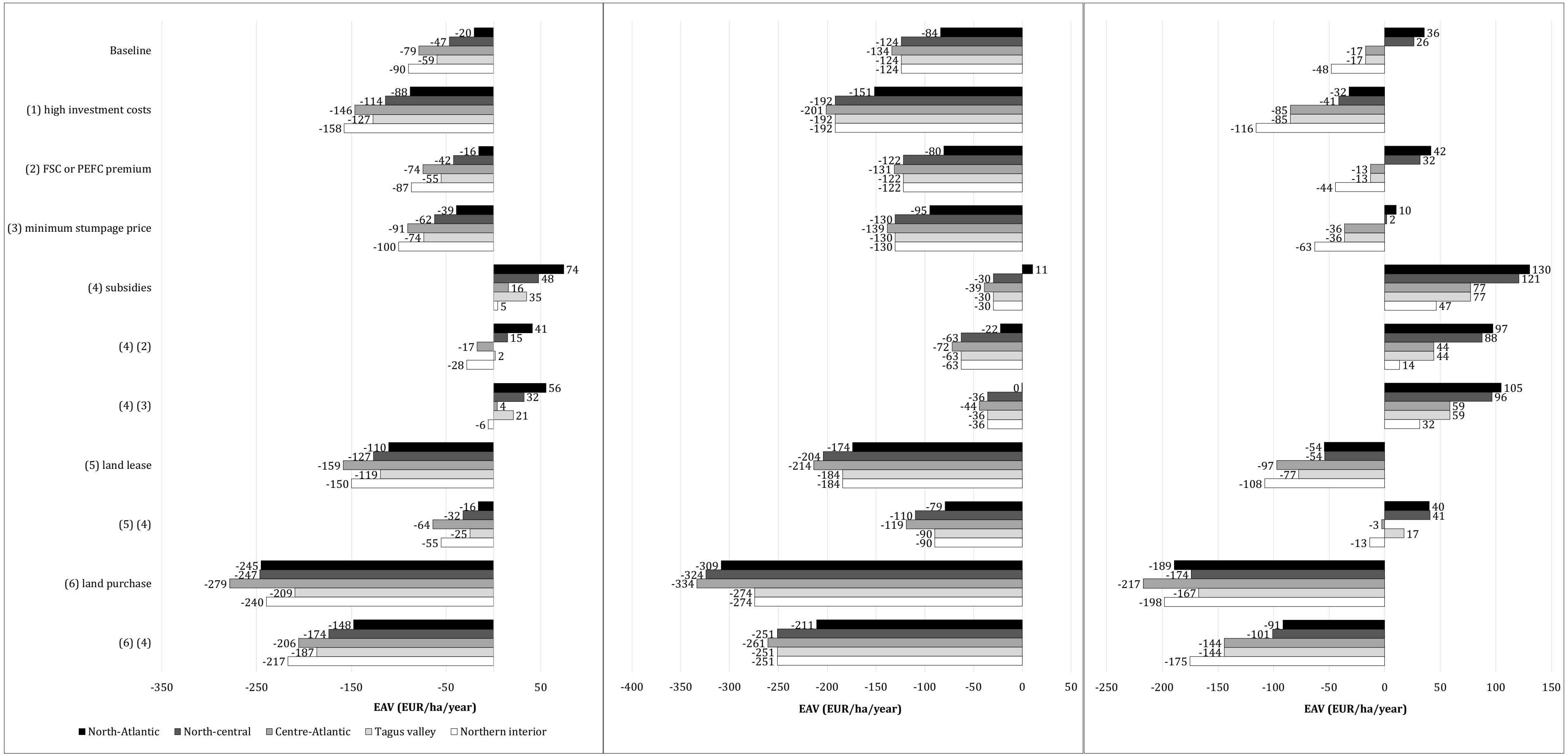
Source: own elaboration

Figure 7.15: Financial returns according to the sensitivity analysis scenarios for eucalyptus in Portugal (average, high, low productivity sites), expressed in EAV (EUR/ha/yr), i=5%, 2017



Source: own elaboration

Figure 7.16: Financial returns according to the sensitivity analysis scenarios for maritime pine in Portugal (average, high, low productivity sites), expressed in EAV (EUR/ha/yr), i=5%, 2017



Source: own elaboration

7.3.1 Trend analysis results

The results of the trend analysis are presented individually by species and area in Figures from 7.17 to 7.22, using EAV as a dependent variable. The complete results with all indicators are reported in the supplementary material. The trends are based on the baseline scenarios and were determined by estimating both the *ex-ante* returns, representing the expected financial returns at the year the investment was carried out and *ex-post* returns for the years where we had input data.

In the case of hybrid poplar plantations in northern Italy (Figure 7.17), if we consider the expected results these show a decline over the 15-years period. In 2001, the EAV was ranging from 213 EUR ha^{-1} yr^{-1} in low productivity sites to 534 EUR ha^{-1} yr^{-1} in high productivity sites. In 2017, EAV decreased to values between 64 EUR ha^{-1} yr^{-1} in low productivity sites and 332 EUR ha^{-1} yr^{-1} in high productivity sites. IRRs decreased from values between 8.8% and 13.2% in 2001 to values between 6.2% and 10.6% in 2017. For what concerns the *ex-post* curve, the indicator shows two periodic trends: a decline from 2001 until 2005, and a recover from 2005 to 2007, thanks to the stumpage prices' increase in recent years (note that, in *ex-post* terms, 2005 refer to plantations that were harvested in 2015 using stumpage prices from 2015). From 2007 onwards, the *ex-post* lines flatten because, as already mentioned, we assumed constancy of values from 2017 onwards.

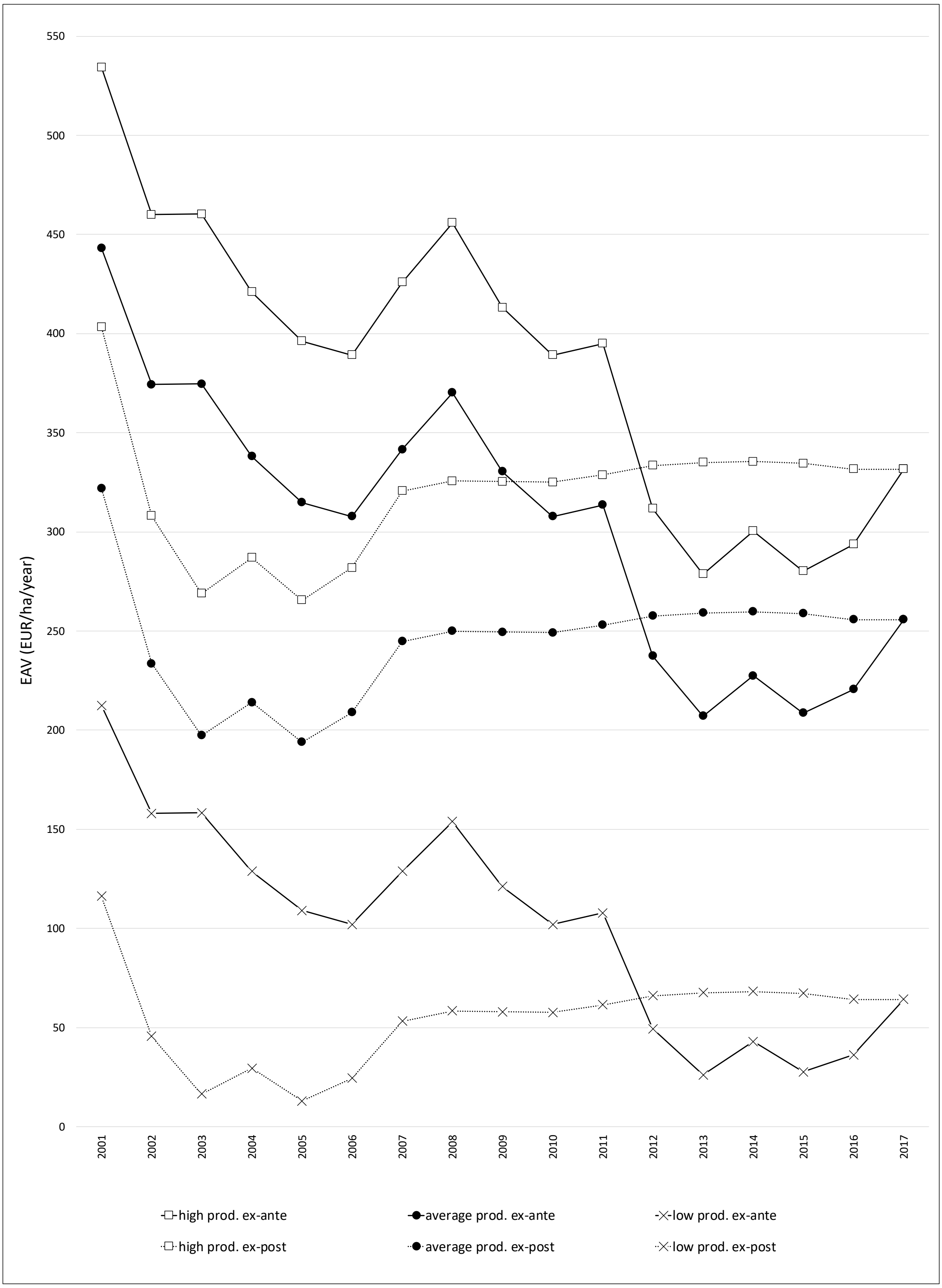
In the case of hybrid poplar plantations in Castile and León (Figure 7.18), *ex-ante* estimates show a largely variable trend, caused by the year-to-year variability of stumpage prices, with a positive peak in years 2008-2009 and a negative peak in 2012. However, on a general perspective, *ex-post* estimates suggest a positive trend, even though it has to be considered that this is resulting from the relatevely high stumpage prices registered in recent years. In 2006, *ex-post* calculated EAV ranged from -37 EUR ha^{-1} yr^{-1} in low productivity sites to 277 EUR ha^{-1} yr^{-1} in high ones and IRRs reaching up to 9.4%. In 2017, EAVs were ranging between 5 EUR ha^{-1} yr^{-1} and 350 EUR ha^{-1} yr^{-1}, with IRR increasing up to 11.1%.

Similarly, also in Navarre the year-to-year stumpage price variability results in a relatevely fluctuating curve from an *ex-ante* perspective (Figure 7.19). An expeptional rise of stumapge prices in 2008 and 2009 results in a positive peak in those years, with *ex-ante* EAVs ranging between 93 and 384 EUR ha^{-1} yr^{-1} and IRRs between 6.7% and 11.1%. A negative peak result is 2015, with *ex-ante* EAV ranging from -61 to -211 EUR ha^{-1} yr^{-1}. If looking at the *ex-post* curves, the low stumpage prices of 2015 are reflected in the financial returns of those plantations established in 2003 (EAVs between -112 and -259 EUR ha^{-1} yr^{-1}), which represent the negative peak, followed by a recover throughout the time series.

Potential financial returns from eucalyptus in Portugal show a rather stable trend in the 2010-2017 period (Figure 7.20). From an *ex-ante* perspective, the negative peak was in 2012, with EAV of 172 EUR ha^{-1} yr^{-1} in north-Atlantic, 85 EUR ha^{-1} yr^{-1} in north-central, 66 EUR ha^{-1} yr^{-1} in centre-Atlantic and -11 EUR ha^{-1} yr^{-1} in Tagus valley. Similarly, also the potential returns from marimie pine show a rather stable trend (Figure 7.21), altough we only simulated the 2014-2017 period. High stumpage prices in 2015 result in a positive peak, on an *ex-ante* basis, in that year, followed by a reduction of stumpage prices, in particular in 2017 due to the large forest fires events in the country.

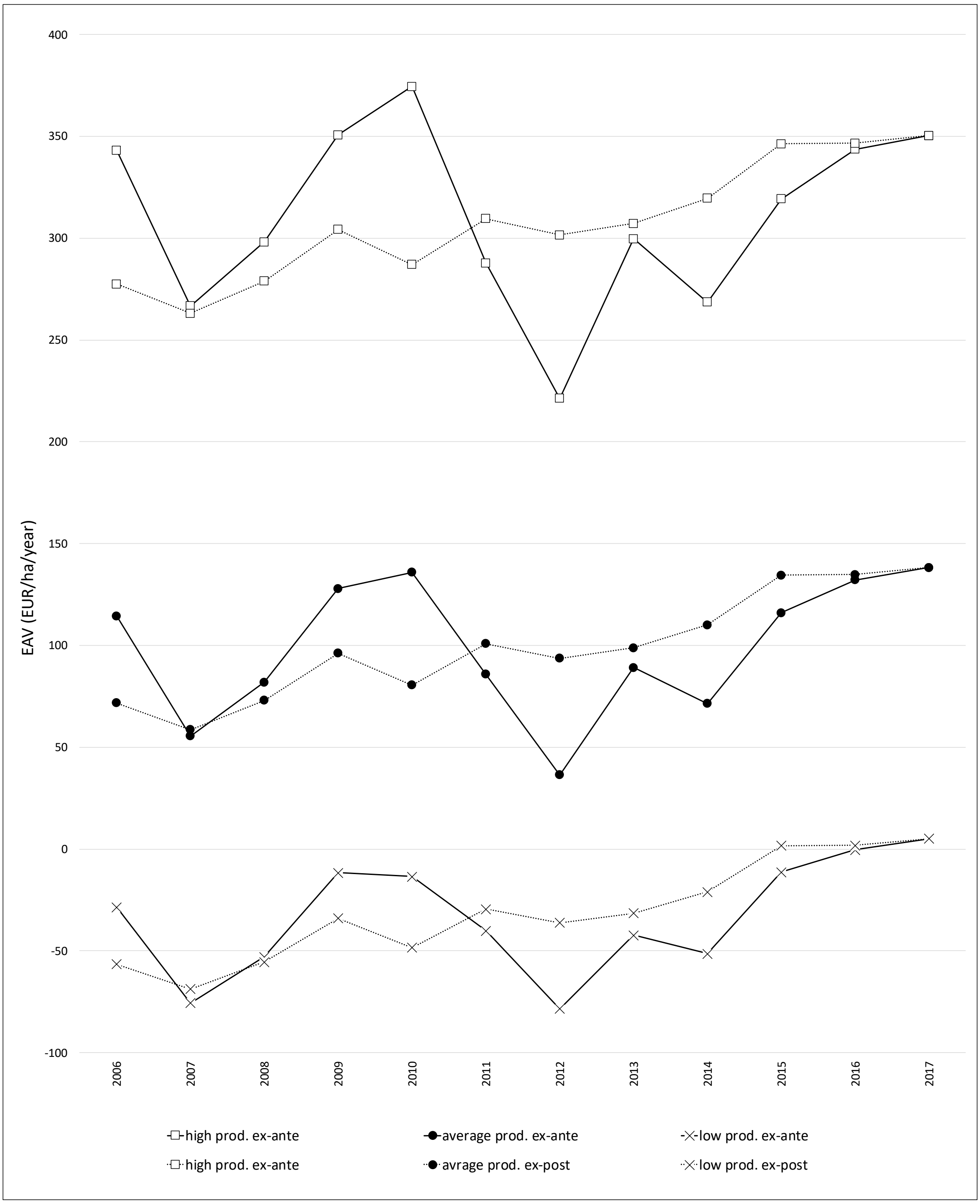
For radiata pine plantations in the Basque Country (Figure 7.22), the *ex-ante* trend shows to be significantly affected by the collapse of stumpage prices after the contruction crisis in 2008-2009, with a negative peak in 2010. From an *ex-ante* perspective, financial retuns in 2011 were rangining between -7 EUR ha^{-1} yr^{-1} and 160 EUR ha^{-1} yr^{-1} in terms of EAV, with IRRs that could reach 6.4% in high productivity sites. In 2010 EAV was estimated to range from -174 EUR ha^{-1} yr^{-1} to -204 EUR ha^{-1} yr^{-1}. Stumpage prices started to recover slowly after 2012, altough reaching values that are still distant from pre-crisis ones. The *ex-post* estimates show a slightly positive trend, altough it has to be considered that they are all calculated with 2017 stumpage price values. In 2001, *ex-post* calculated EAVs showed values from -79 EUR ha^{-1} yr^{-1} to -154 EUR ha^{-1} yr^{-1}, while in 2017 these vary between -2 EUR ha^{-1} yr^{-1} and -81 EUR ha^{-1} yr^{-1}.

Figure 7.17: Expected and current return trends according to the baseline for hybrid poplar in northern Italy, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



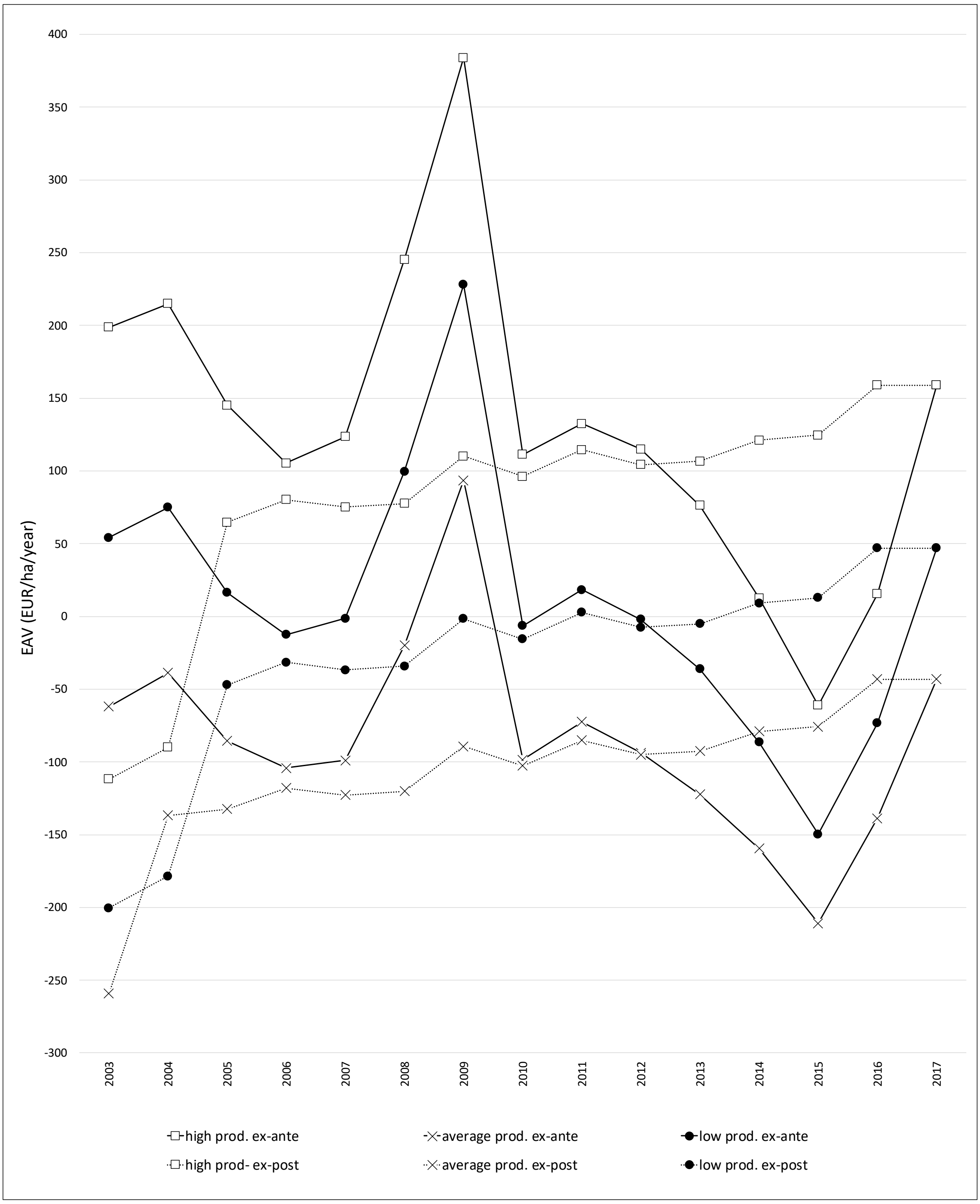
Source: own elaboration

Figure 7.18: Expected and current return trends according to the baseline for hybrid poplar in Castilla y Leon, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



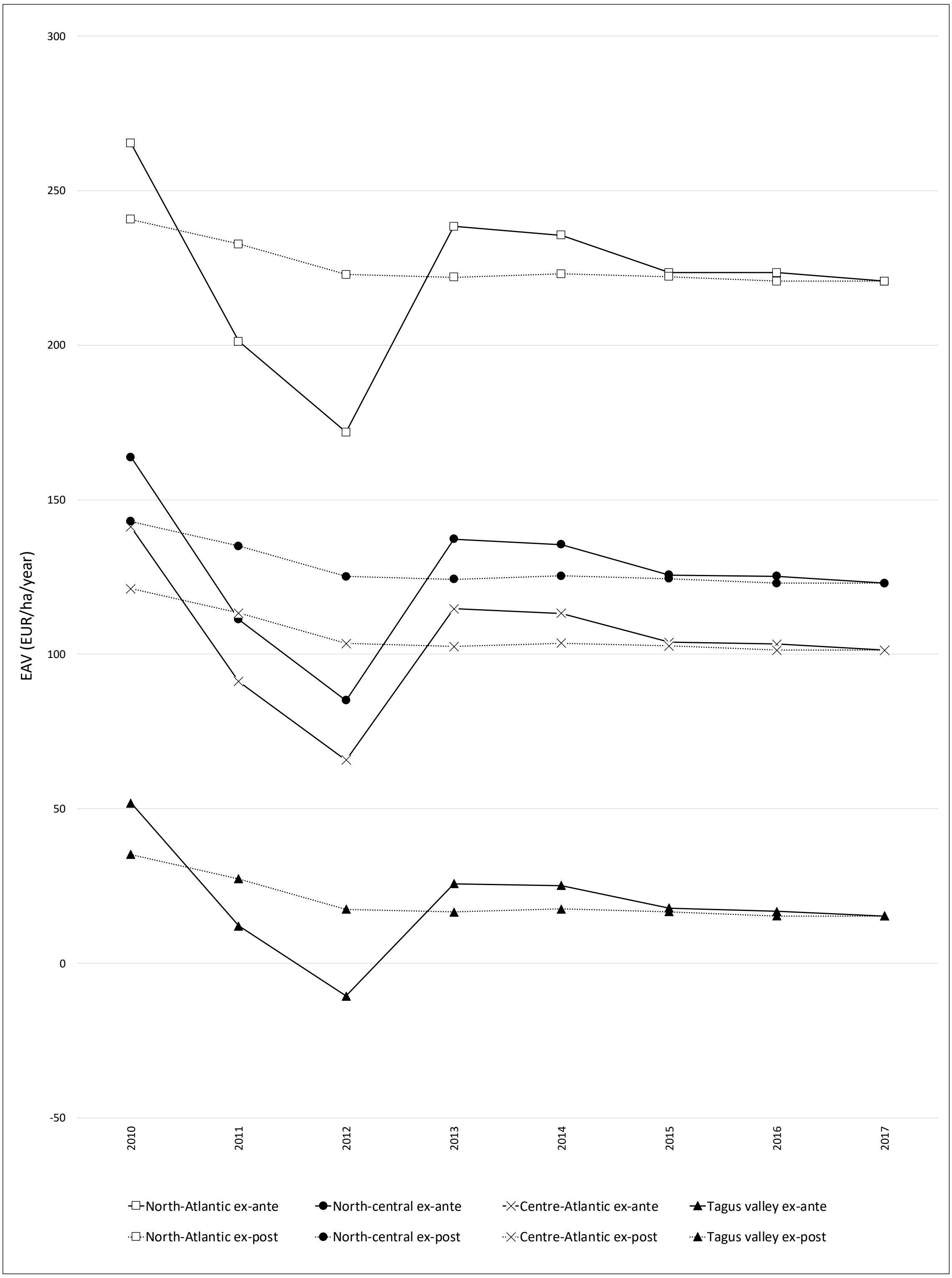
Source: own elaboration

Figure 7.19: Expected and current return trends according to the baseline for hybrid poplar in Navarre, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



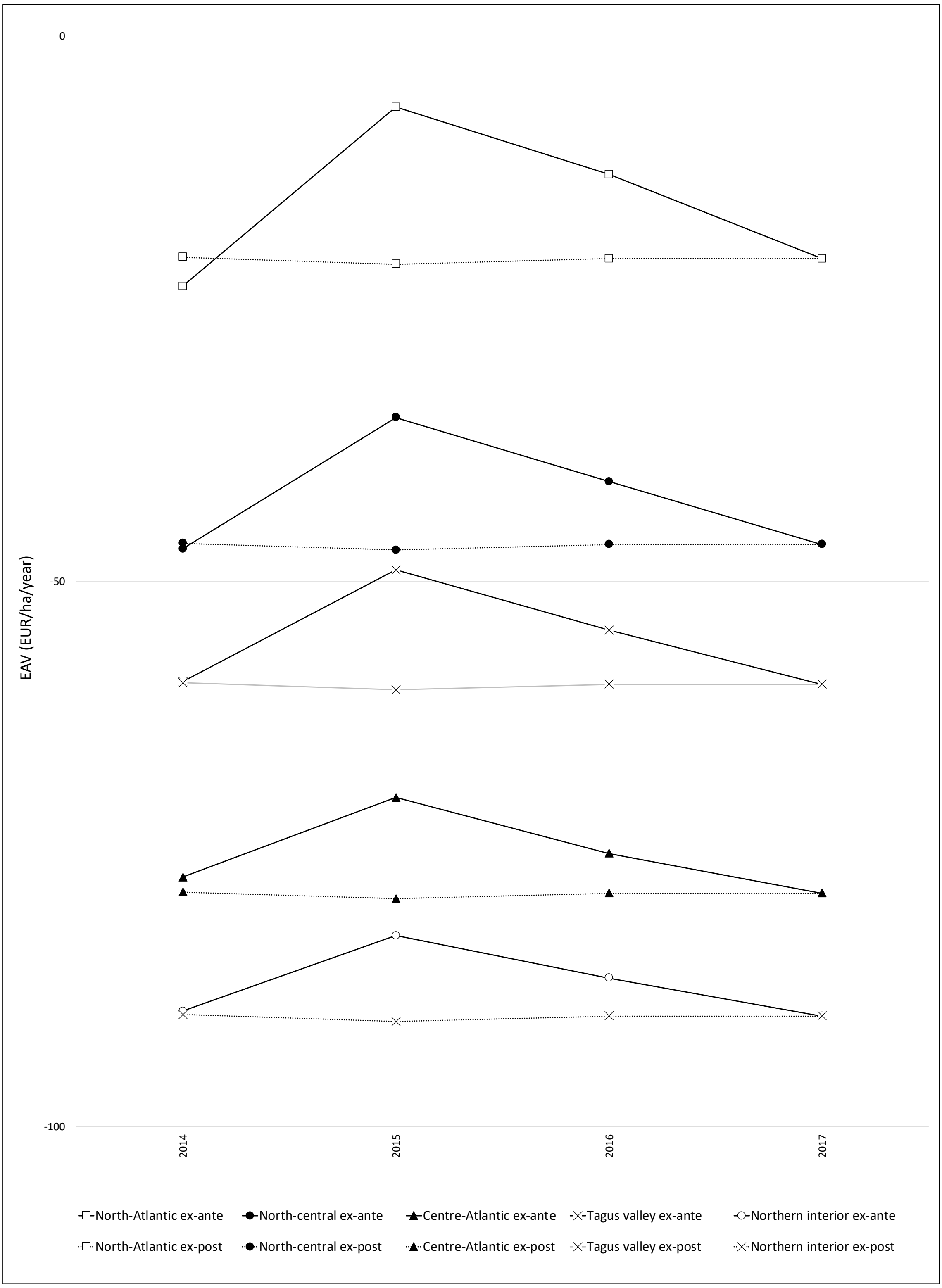
Source: own elaboration

Figure 7.20: Expected and current return trends according to the baseline eucalyptus in Portugal, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



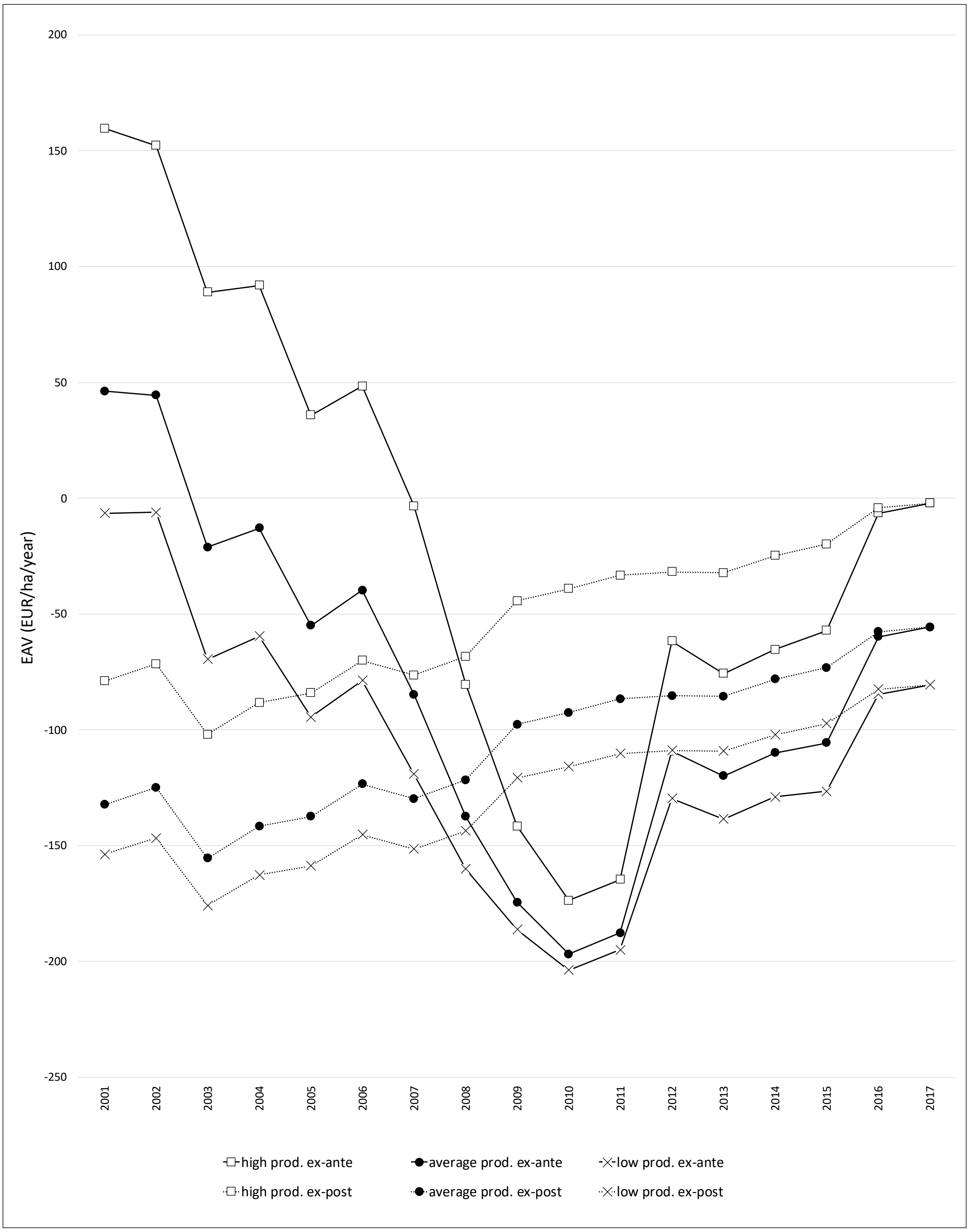
Source: own elaboration

Figure 7.21: Expected and current return trends according to the baseline for maritime pine in Portugal, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



Source: own elaboration

Figure 7.22: Expected and current return trends according to the baseline for radiata pine in the Basque Country, expressed in EAV (EUR/ha/yr), i=5%, 2001-2017 (real values)



Source: own elaboration

7.4 Discussion

For the estimation of potential investment returns we assumed appropriate and ordinarily efficient management conditions, and defined growth rates and yields that could represent the typical productivity range for plantations in the region. It is important to note that, evidently, our results cannot be considered exaustive of all potenatial specific cases and therefore, different assumptions in relation to management practices and intensity can lead to different results than those presented in our simulations. When interpreting the results, it has also to be consiedered that the analysis is carreid out before income- and land-tax. Thus, investors would need to carry out their additional analyses for taxes according to their legal status and business model.

Our results indicate that hybrid poplar plantations could provide on average the greatest financial returns on investmens among the species in southern Europe. Poplar is certainly one of the most fast-growing species at temperate latitudes. The typical MAI for the clone *Populus x canadensis* 'I-214' – which is the predominant clone used for productive plantations in Italy and Spain – is between 10 and 27 m^3 ha^{-1} yr^{-1} in southern Europe. In these three regions, hybrid poplar plantations are somehow based on the same production model, grown on agricultural land and river bends with a relatevely intensive management and short rotation cycles for top-quality plywood veneer production. Rotations range typically from 10 years in northern Italy to 13-17 years in Castile and León. According to the baseline scenario, potential IRRs range between 6.3% and 10.6% in northern Italy, between 5.1% and 11.1% in Castile and León, and could reach 8.1% in Navarre. Considering the EAV as indicator, estimates range between 64 and 332 EUR ha^{-1} yr^{-1} in northern Italy, 5 and 332 EUR ha^{-1} yr^{-1} in Castile and León, and -43 and 139 EUR ha^{-1} yr^{-1} in Navarre. However, if we consider all the potential alternative scenarios simulated, hybrid poplar plantations show also the widest range of variability among the species considered in the study, with the EAV standard deviations of 257 EUR ha^{-1} yr^{-1} in Castile and León, 330 EUR ha^{-1} yr^{-1} for Navarre, and even 457 EUR ha^{-1} yr^{-1} for northern Italy. The principal reasons are certainly the rather large variability of poplar stumpage prices and the high land use cost. For what concerns average stumpage prices, in 2017 these were higher in Italy and Castile and León, compared to Navarre, altough Spain holds the wider range between minimum and maximum values observed by forest owners' associations. Maximum stumpage prices were surprisingly much higher in Castile and León when compared to Italy and Navarre. When trees are sold at those stumpage prices, investment returns increase considerably, reaching IRRs that can vary between 7.2% to 13.9% in Castile and León, 9.1% to 13.5% in northern Italy, and

8.5% to 13.1% in Navarre. On the other hand, when trees are sold at minimum prices, only northern Italian and Castillean plantations in best productivity sites could still reach IRRs above the financial viability threshold. Nevertheless, we can presume minimum stumpage prices to correspond to poor quality trees, e.g. without or with imperfect pruining, damaged by wind or affected by pest or diseases. Therefore, if we consider professionally managed plantations, it is plausible to assume a stumpage price above the average. Overall, if we look at the trend over the last 10-15 years, poplar stumpage prices have decreased in real terms both in Italy and Spain, even tough with periodical fluctuations. In particular, an evident decline has been observed starting from 2008-09 in both countries, with a negative peak in 2011-12. However, while in Castile and León prices started to recover already in 2012-13, in Italy and Navarre they remained at their minimum levels until 2015. Since 2015, prices have been experiencing a substantial increase in all the three regions investigated, driven by the current expansion of the plywood industry in both countries. Indeed, contrary to other woodworking industries, the plywood industry in Italy and Spain are structured around global leading and exporting industrial groups which have had a better capacity to recover after the economic crisis started in 2008 and are now expanding thanks to more favorable market conditions. However, the industrial structure in Italy is rather different than in Spain; while in Italy the market is shared among several medium-sized plywood and wood-based panel industries, in Spain the market is dominated by one leading industrial group, which alone processes the 70-80% of the domestic poplar supply (about 400 thousand m^3/yr). It can be expected that the evolution of poplar stumpage prices in the upcoming years will ultimately depend on the competitiveness of these plywood industries. Nevertheless, also food-packaging industries from fruit and vegetables producing regions are playing a moderate but relatevely important role, in particular in Spain.

Land use cost also plays an important role cause hybrid poplar plantation are mainly grown on agricultural land in river bends – often directly competing with agricultural productions – land use cost is certainly higher compared to other plantation species grown on marginal or agricultural land or forest land. Land cost appears extremely high in northern Italy, with an average purchase cost of 33,000 EUR ha^{-1}, compared to Spain, where land purchase cost is on average 16,600 EUR ha^{-1} in Navarre and 12,250 EUR ha^{-1} in Castile and León. This means, for new investors, that purchasing land for setting hybrid poplar plantations is likely an unresonable option. On the other hand, land lease appears to be a potentially viable in some cases and, as a matter of fact, there are examples of industrial poplar growers managing poplar plantations on leased land both in Italy and Spain. In addition, there are also a few examples of land lease contracts based on a revenue-sharing agreement between the poplar grower and the land owner instead of the common contracts based on an annual cost. IRRs reached 5.5% in high productivity sites in northern Italy, and can increase up to 8.6% if supported by subsidies. In Castile and León, investments with land lease can reach a 7.6% IRR, up to 10.7% if trees are then sold at the maximum stumpage price (altough this a variable that can not be determined *a-priori* by the investor). However, in Navarre, based on the assumptions considered, land lease is only viable option only if the investment is supported by subsidies, with IRRs lower than 5.3% for this scenario. An aditional fact to consider by potencial investors is the taxation by the Watershed Authority in Navarre of plantations established on river bends. At the time this study was carried out, this still represented a controversial and debated issue which might be withdrawn in the future.

Investment costs are also subject to a certain degree of variability depending on the need for more intense site preparation or management operations. The “high investment costs” scenario showed that only plantations established on high productivity sites presented IRRs above the financial viability threshold. Hybrid poplar silvicultural management is relatively intensive, in particular in the first years of the rotation cycle, requiring high labour and water inputs. Both in Italy and Spain there is clearly a trend towards hiring professional contractors for managing of the plantation’s management operations, which reflects also a standardization of management regimes. This trend could be interpreted as a positive indicator of the sector’s consolidation and stability. Interestingly, in Italy it is becoming somehow common to sell poplar stands before the end of the rotation period, through an arrangement where the poplar grower is payed for selling the immature trees and for keeping them growing till the buyer (i.e. typically a middleman managing a portfolio of poplar stands and responsible of supplying the plywood industry) decides to harvest them.

Subsidies can certainly play a determinant role in increasing plantations’ profitability. At present, subsidies for hybrid poplar plantations funded by regional RDPs grants are only available in northern Italy and Navarre. These provide on average a reimbursement of 60% of the plantation establishment costs in northern Italy, and of 50% of the plantation establishment and pruning costs in Navarre leading to IRRs increases that can vary between 9.3% and 13.8% and 7.7% and 11.1%, respectively. Nonetheless, regional administrations reported that the use of RDP’s measures to support hybrid poplar plantations has become more complex in the last programming period and it is uncertain these measures will still be available in the future, at least with current conditions (e.g. in Castile and León the measure has not been opened, while northern Italian regions produced a intricate framework of eligibility criteria and requirements concerning clonal selection and responsible management certifications). Overall, the returns we estimated for hybrid poplar appear to be in line, or slightly higher, with those reported by the main references in these countries. In Italy, Borrelli and Facciotto (1996) and Borrelli (1997) estimated IRRs of poplar plantation in the range of 2%-8%, while another study suggested for the Piedmont context an average IRR value of 3.6%, which could increase to 8.1% with subsidies (Regione Piemonte, 2002). In Spain, Aunos *et al.* (2002) estimated IRRs between 3.9% and 8% for the Ebro valley (Huesca and Lleida Provinces), while for Castilla y Leon, Estaban López *et al.* (2005) estimated NPV (5% discount rate) to range between 5,108 EUR ha^{-1} and 10,929 EUR ha^{-1}. However, our estimations for Castile and León appear relatevely conservative if compared with the previous works by Diaz Balteiro and Romero (1994) and Del Peso *et al.* (1995), that respectevely estimated IRRs up to 19% and NPV (3% discount rate) between 2,255 EUR ha^{-1} and 9,783 EUR ha^{-1}.

Opportunities for relatevely high investment returns were also found for eucalyptus plantations in Portugal. *Eucalyptus globulus* is the most widespread plantation species in southern Europe and in Portugal, where it represents the dominant tree species (ICNF, 2013). Growth rates in Portugal are considerably high, in particular in the northern part of the country. MAI ranges between 11 and 29 m^3 ha^{-1} yr^{-1} in the high productivity sites and between 8 and 25 m^3 ha^{-1} yr^{-1} in average productivity sites. Our analysis indicates that eucalyptus plantations represent a relatevely stable investment from a financial point of view and can also provide high financial returns, but this can be achieved for the medium and high prouctivity sites. Indeed, establishing eucalyptus plantations in low productivity sites, with MAI between 5 and 10 m^3 ha^{-1} yr^{-1}, seems not worthwhile. According to the baseline scenario, potential IRRs range from 5.4% to 9.8% in medium productivity sites, and from 10.0% to 12.5% in high productivity sites, depending on the region. In EAV terms, returns range between 15 and 221 EUR ha^{-1} yr^{-1} in average productivity sites and between 236 and 402 EUR ha^{-1} yr^{-1} in the high productivity sites. Eucalyptus plantations have a rather simple management, which can count on consolidated industrial forest owners expeirence. The cost of establishing and managing a plantation can increase when more intense operations are needed. However, even under the "higher investment costs" scenario, IRRs could still reach reasonably high returns. Even tough stumpage prices are somehow difficult to obtain, average prices appear to have been rather stable in recent years. The pulp and paper industry in Portugal, also thanks to the large eucalyptus raw material supply from domestic sources, has been constantly increasing in the last decade and the sector appears solidly established, in spite the economic crisis and the strong international competition. The pulp and paper sector in Portugal is dominated by two global players. Interestingly, contrary to the tendency of French and other central and northern European industries, the major production of Portuguese industries production is graphic paper (CELPA, 2017). In the future there could be further developments with the pulp mills entering the bioenergy and biorefineries markets, even though there have not been signifinicant developments up to now. Given importance of sustainability labels in paper products, the stumpage price for FSC® or PEFC™ certified timber can usually gain additional 4 EUR/m^3 (e.g. APFC, 2015), which has the effect of increasing financial returns by a 1% in IRR values, even though potential additional costs for sustainable forest management have not been considered. Eucalyptus plantations represent the only case, among those analysed, where financial returns appear to be reasonably attractive also for non-owners' investors. In fact, land cost is cheaper in Portugal compared to Spain and Italy. Land lease is a common option for pulp and paper companies to establish their own plantations, typically based on 25 years' concessions. Most of these plantations are located in the Tagus valley, where land prices are cheaper. Under the "land lease" scenario, IRRs are still above the financial viability threshold in average productivity sites and can reach values from 8.7% to 10.6% in high productivity sites. On the other hand, under a "land-purchase" scenario to get positive financial returns, investors much choose only the best productivity sites, where IRRs could still reach about 6.1% to 6.7%. However, new investors would have to consider the limitations set by the recent law reform, amending the legal regime applicable to afforestation and reforestation actions in Portugal (Law No. 77/2017[3]). This law, entering into force in 2018, can have significant impacts on investments in eucalyptus plantations, e.g. by limiting the expansion of eucalyptus plantations into new areas (basically allowing only replanting) and requiring the investor to carry out compensative investments in woodlands with native species. This law is the result of a strong public debate on eucalyptus plantations in Portugal, related to the ecological impacts on biodiversity and water resources and, in particular, to the forest fire policy issue. Indeed, forest fires are a critical issue in Portugal, that investors would have to address through careful risk management planning. Forest fires increased in the last decades in terms of frequency and severity, i.e. large-scale fires hit Portugal in 2003, 2005, 2016 and especially in 2017, with 500 thousand hectares of forest burnt (including managed eucalyptus and maritime pine plantations).

[3] Available at: http://www.fao.org/faolex/results/details/en/c/LEX-FAOC168868

Maritime pine plantations do have a much lower financial returns compared to eucalyptus. Rotations are around 35 years and growth rates are substatially lower compared to eucalyptus, ranging from 3 to 7 m^3 ha^{-1} yr^{-1} in low productivity sites, from 6 to 11 m^3 ha^{-1} yr^{-1} in medium productivity sites and from 10 to 15 m^3 ha^{-1} yr^{-1} in the high productivity sites. According to the baseline scenario, average IRRs are ranging from 2% to 4.5%, resulting in nagative EAV s for all regions and productivities. Maritime pine plantations appear to provide reasonably attractive financial returns only when supported by subsidy grants, which – according to the Portuguese RDP – can reimburse 75% of the plantation establishment costs and 40% of pruning and weed control costs. Thus, under the "subsidies costs" scenario, IRRs can reach 7.5% in medium productivity sites and from 8.7 to 10.6% in the high productivity sites. However, it has to be consiedered that, for what concerns the establishment and management costs, we assumed only the essential management operations to be carried out. If we hypothesize a higher cost scenario, as in the case of more intense weed control operations due to high fire risk, financial indicators decrease considerably. As a matter of fact, in the case of maritime pine plantations, there is a trend towards natural regeneration rather than planting; this would allow avoiding establishment costs and reach higher financial returns. On the other hand, maritime pine stumpage prices are less certains because they depend on a small and regionalized timber market. Sawn wood and fuel wood are currenly the two main assortments with a certain market demand, with sawmills oriented towards small to medium sawn timber and the pellet market which plays a considerable role. In fact, sawnwood represent 41% (1.65 million m^3/yr) and pellets for the 18% (0.72 million m^3/yr) of the total maritime pine timber consumption (Centro Pinus, 2017). Adding to this, strong fluctuations have been observed in stumpage prices that soemtimes reach very low values, e.g. prices decreased considerable in autumn 2017 due to the large fire events and the consequent massive timber supply from burnt forests. Also, the sector has significantly suffered from the spread in the 2000s of the pine wilt nematode (*Bursaphelenchus xylophilus*). In 2009, the EU declared Portugal as infested with this pathogen and imposed serious restrictions on the export of pine wood products from the country (Rodrigues, 2008). This not only damaged the Portuguese sawnmill industry considerably, as it also has increased the risk perception toward these plantations, resulting in high rates of abandonment or conversion. According to the national inventory data, between 1995 and 2010, the area covered with maritime pine decreased by 27%, and one-third of this area has been converted with eucalyptus. Currently the sector is slowly recovering but its future is still uncertain. For non-owners' investors, the "land purchase" scenario for maritime pine plantations definetly appears to be not viable. On the other hand, the "lease plus subsidies" scenario could be viable in some regions (north-Atlantic, north-central and Tagus valley) in the high productivity leading to IRRs around 5% to 6.1%. An encouraging example in this sense is provided by Floresta Atlantica[4], the first Timberland Investment Management Organization (TIMO) in southern Europe. This public-private fund manages about 5,000 hectares of forest land (out of which 2.000 have maritime pine) in Portugal, half of this area with land lease agreements between the fund and landowners. An increasing recovery of the resin industry has been observed in recent year, thus in the near future, resin production can become an interesting revenue-generating activity to improve maritime pine plantation's investment returns.

The situation concerning radiata pine in the Basque Country is somehow similar to maritime pine in Portugal, even though the current situation is the result of the deep crisis that hit the Spanish construction sector in 2008-09. In the Basque Country, radiata pine is the dominant species, covering 125,000 hectares (32% of the Basque forest cover). Radiata pine cultivation in the Basque Country dates back to the 1950s and it is now managed based on a consolidated knowledge and practice. While in the early decades after its introduction radiata pine was mainly cultivated for pulpwood production, with rotations cycles of 20 to 25 years, since the 1980s the market is dominated by sawlogs production, resulting in longer rotations of 28 to 40 years depending on the site (Michel, 2006). The typical management regime is based on a rather intensive management and includes a pre-commercial thinning in the early years followed by two commercial thinnings. Growth rates are considerably high in the Basque Country, with MAI ranging from 14 to 22 m^3 ha^{-1} yr^{-1}. Despite the high growth rates, investment returns are relatively low compared to other species analysed in this study. IRRs in the baseline scenario are close to values between 3.5% and 5%, lead to negative EAV, ranging from -2 to -81 EUR ha^{-1} yr^{-1}, depending on site productivity. Similarly to what was observed for maritime pine in Portugal, radiata pine plantations could offer relatively interesting returns under the "subsidies" scenario, that allows IRRs to rise to values varying between 5.5% to 6.8%. Subsidy grants depend on the three Basque provincial of Álava, Biscay and Gipuzkoa, which on average result in a 30% reimbursement of establishment costs and 50% of pruning, weed control and fertilization costs. The analysis has shown that the "land-lease" and "land purchase" scenarios are not viable in any case, not even if combined with subsidies. Land cost is relatively high in the Basque Country and there are no examples of industrial forest owners that buy the land prior to plantation. In fact, the market is dominated by small private forest owners, mainly

[4] For more information, see: http://www.floresta-atlantica.pt

individuals and families with average ownership size between 2 and 9 hectares. On a global comparative perspective, investments return for radiata pine appear to be considerably higher in other parts of the world, e.g. Cubbage *et al.* (2010) reported IRRs of 7.6% in New Zealand and 15.6% in Chile, according to a baseline scenario. Nevertheless, the returns obtained appear to be in line with Tolosana Esteban *et al.* (2013), who estimated for radiata pine in the Basque Country a NPV (at a 3% discount rate) of 1,358 EUR ha^{-1}, that could reach 7,553 EUR ha^{-1} under a "subsidies" scenario. On the other hand, our profitability estimates are relatively lower than those found by other researchers – e.g. Rodríguez *et al.* (2002) estimated IRRs for radiata pine plantations in Spain of about 9% in good sites and 5.8% in poor ones – although it has to be considered that the current market conditions are definitely not comparable with those pre-2008. Today's situation is the result of the strong sawlogs' market collapse between 2008 and 2011 caused by the economic downturn that deeply affected the construction sector, in particular in the Mediterranean coast. Moreover, in 2009, the Klaus storm in the south-west of France, which fell 40 million m^3 of wood, disrupted even more the already weak market. As an explanatory example, radiata pine average stumpage price felt from 57 EUR/m^3 in 2007 to 22 EUR/m^3 in 2009 and even down to 15 EUR/m^3 in 2010. Today's average stumpage price is about 35 EUR/m^3, which indicates a slow market recovery. The generalized mistrust is reflected also in the reduction of the area covered by radiata pine, from 150 thousand hectares in the 1996 reported in National Forest Inventory (INF, 1996) to 125 thousand hectares reported in the 2011 inventory (INF, 2011). In general, it has to be considered that, differently from the plywood and pulp and paper industries, the wood industry in southern Europe is based on small and medium size sawmills with limited innovations and export capacity. As a matter of fact, the structural process that saw many of these small sawmills disappear started already in the early 2000s.

7.5 Conclusions

In this study we estimated and compared potential investment returns at aggregate level for productive forest plantation species in southern Europe based on representative management regimes for each context. In particular, we analysed hybrid poplar in northern Italy, in Castile and León (Spain) and in Navarre (Spain), eucalyptus and maritime pine in Portugal, and radiata pine in the Basque Country (Spain). Input data were collected and defined using several approaches, with the cooperation of forest owners' associations, industries and research institutes in each area, which also contributed, through their revisions and support, to improve the robustness of the study. We carried out a financial analysis before-tax using, using typical capital budgeting indicators and a common real discount rate of 5% for all species and contexts. Indicators were calculated according to a baseline scenario, where land-costs and subsidies were excluded, and then according to several alternative scenarios, testing the effect of higher investment costs, variations in stumpage prices, subsidies and land-use costs. We also carried out a trend analysis in order to provide means for comparing the evolution of expected and current returns in recent years.

Overall, our results indicate that in southern Europe there are some opportunities for reasonably interesting investments returns from forest plantations, in particular for current landowners, but there are structural factors that could limit the attractiveness of this region for new financial investors. IRRs are on average above 5% for eucalyptus plantations in Portugal and hybrid poplar plantations in Spain and Italy, reaching even values above 10% in the best cases. In general, investment returns from these two species in the southern European context appear to be competitive with the average returns from forest plantations estimated for the northern hemisphere (e.g. Sedjo, 2001; Cubbage *et al.*, 2007; 2014). However, the characteristics of these two investments are rather different. Hybrid poplar plantations present very high land and opportunity costs and stumpage prices characterized by a cyclical behaviour and a large range of variability. Therefore, they represent reasonably interesting investments mainly for current landowners. With land cost included, IRRs from hybrid poplar plantations would be above 5% only in the best sites or if supported by subsidies. Only in the cases of eucalyptus plantations an investor could expect to get attractive returns by leasing or buying land, being the land cost cheaper in Portugal. In addition, eucalyptus plantations showed to be the most stable investments among those analysed. Maritime pine in Portugal and radiata pine in the Basque Country have much lower rates of returns. In these cases, current landowners would accept IRRs below 5%, while for non-landowners, investments are rarely financially viable.

In general, the analysis indicated that growth rates and stumpage prices are the main factor affecting investment returns, more than the establishment and management costs. However, the southern European context is characterized by relatively high biotic and abiotic risk, in particular related to forest fire and pests. Therefore, investors could have to face much higher overhead costs than those we used in our simulation. This represents a further element making those plantations with shorter payback periods, i.e. hybrid poplar and eucalyptus, more attractive. On the other hand, environmental restrictions for these two species exists in all the analysed countries, which could limit the opportunities for new investments. The current subsidy policy framework, conditioned by the EU Rural Development Policy, showed to be quickly evolving and the financial support will be uncertain in future years for intensively managed plantations and non-native species (i.e. hybrid poplar, radiata pine and eucalyptus). The domestic industries and markets play a key role in determining the attractiveness of forest plantation investments. Besides the southern European timber market is far from being considered solid and developed as in other regions (i.e. North America or Central-Northern Europe), poplar and eucalyptus have relatively good prospects for market expansion and growth in the short-medium period. Pines suffer the weaknesses of the regional sawmilling industry stricture and the depressed saw timber prices after the 2008 economic crisis. Moreover, the small-sized and fragmented forest holding structure in southern Europe – which determined high transaction cost for investors – represent one of the most critical barriers for new financial investor to invest in this region.

Chapter 8

Overall conclusions and future research

This final Chapter presents the overall conclusion drawn from the research, including main results (8.1), market developments considerations (8.2), policy recommendations (8.3), and the future research directions (8.4).

8.1 Main results

This research is the first one to analyse forest plantation investments on a comparative perspective in the context of southern Europe, following a similar approach of the one used by Sedjo (1983; 2001) and Cubbage *et al.* (2007; 2010; 2014) in other regions and at global level. The overall results of our research indicate that, in the southern European context, there are some opportunities for interesting returns from forest plantations investments for sectorial investors (i.e. landowners and forest-based industry), and also potentially reasonably interesting opportunities for financial investors. However, there are significant differences among species and contexts as well as structural limitations in the region that needs to be considered.

Paper III (Chapter 7) provides investment returns estimations at aggregate level and on a comparative perspective in southern Europe. Our main interests involved forest plantations of private nature with the primary purpose of wood and fibers production, in particular: hybrid poplar in northern Italy, in Castile and León (Spain) and in Navarre (Spain), eucalyptus and maritime pine in Portugal, and radiata pine in the Basque Country (Spain). The results indicate that hybrid poplar plantations could provide the highest returns among these species. For current landowners, without an explicit land cost to sustain, IRRs are ranging from 6.3% to 10.6% in northern Italy and from 5.1 to 11.1% in Castile and León. In Navarre (Ebro valley), IRRs could reach 8.1%, but investors would have to accept also values below 5%. Subsidies of the RDPs have the effect of increasing the IRRs up to 13.8% in northern Italy and 11.1% in Navarra. However, the high land costs (i.e. being hybrid poplar plantations established on agricultural land), make land purchase options not financially viable, and land lease interesting only in few cases. Therefore, hybrid poplar plantations are unlikely to be an attractive investment for non-landowners, even though there are examples of industrial poplar growers with land lease arrangements both in Italy and Spain. It has to be considered that also the market risk component is rather high, due to the large range of variability and cyclical behaviour of poplar stumpage prices.

Focusing on the northern Italian context, in Paper II (Chapter 6) we analysed more in depth the issue of the continuous reduction of poplar plantations cultivated area in recent decades in northern Italy by looking at the evolution of financial returns from these investments in the last 15 years. The results showed that expected returns have decreased significantly over the period, and this is likely to have undermined the attractiveness for new investments in poplar plantations by landowners. Opportunity-cost also plays a determinant role, even though the volatility of cereal prices could have a positive effect on the investors attitude towards poplar cultivation, the competition with agricultural production seems to be unfavourable, also due to the current EU CAP direct payments regime (EC, 2016).

Opportunities for interesting returns exist also for eucalyptus plantations in Portugal (Paper III – Chapter 7). In this case, IRRs, without land cost, range from 5.4% to 12.5% on medium and high productivity sites, depending on the region (i.e. higher in the northern and coastal areas and lower in the central part and Tagus valley). Eucalyptus plantations are the only investment where a non-landowner investor could expect to get relatively interesting returns (IRRs > 5%) also by leasing or even buying land in some cases. In addition, eucalyptus plantations resulted to be the most stable investments on a trend perspective. Subsidies are not available for eucalyptus; on the contrary, investors would need to consider the limitations to investments in eucalyptus plantations set by a recent law reform (Law No. 77/2017). Pine plantations, i.e. maritime pine and radiata pine, have much lower rates of returns and higher market risks associated to longer payback periods. These investments appear to be potentially interesting only if supported by subsidies. We estimated potential IRRs for maritime pine in Portugal ranging from 2% to 4.5%, reaching between 8.7% and 10.6% in most productive sites and with subsidies. The situation for radiata pine in the Basque country is similar. Despite the considerably high growth rates, IRRs have been estimated to range from 3.5% to 5%, which could increase up to 6.8% with subsidies. Profitability levels have suffered from the depressed sawn wood prices after the 2008 economic crisis. Land cost is relatively high in this Spanish region, therefore, for non-landowners, this doesn't appear to be a financially viable opportunity.

Following the increasing interest towards close-to-nature alternatives in plantation forestry (e.g. Vidal and Becquey, 2008; Rivest *et al*., 2010; or more in general Bravo-Oviedo *et al*., 2014), in Paper I (Chapter 5) we compared potential investment returns from two monospecific plantation types, i.e. walnut (*Juglans regia*) and hybrid poplar plantations, with polycyclic plantations, an emerging example of mixed and multi-rotation plantations, with much higher positive impacts in terms of biodiversity. Our analysis suggests that this type of plantations can be competitive, and in some cases even more interesting in financial terms than monospecific ones. The diversification of species and final assortments allows to better cope with market risk, and moreover, they can benefit from the current subsidy schemes which tend to incentivize plantations with medium-long rotation with multifunctional role rather than short rotation ones. On the other hand, being these plantations still of experimental character, the problem of technology transfer should not be underestimated.

8.2 Market developments considerations

This research contributes to highlight also some structural aspects of the regional timber market that investors would have to take into consideration. The level of development of the timber market plays a key role in determining the attractiveness of forest plantation investments and, in this sense, the southern European timber market appears to be rather dynamic. On the one hand, the pulp and paper and the plywood industry sectors are based on large industrial companies which have relatively good prospects for market expansion and growth in the short-medium period. On the other hand, the sawmilling sector suffers from a weak structure, being based on small and medium-sized enterprises with low industrial and technological production capacities.

In the specific case of poplar, stumpage prices have shown to be subject to an overall cyclical behaviour but are currently experiencing a substantial increment both in Italy and Spain, likely to be connected with the expansion of the plywood industry (i.e. the main end-market for poplar timber). Annex 8 presents a market survey carried out in Italy, where we found that most of the Italian plywood industries are planning to increase the supply of poplar timber in future years and would prioritize supply from domestic sources. In addition, it has emerged from the analyses that in Italy and Spain there are elements indicating a process of market consolidation and stability, e.g. the standardization of management regimes, number of professional contractors operating in the sector, and, even more interestingly, in Italy there are numerous poplar stands' sale agreements between poplar growers and middlemen (i.e. responsible of supplying the industry) taking place before the end of the rotation period. However, this latter element reflects also a situation of shortage of raw material, which in the short-medium term represents a critical element for the competitiveness of the plywood industry in Italy.

Pulpwood prices have been stable in recent years in Portugal, due to consolidation of the pulp and paper market. At national level, the sector is dominated by two large industrial groups that have been constantly increasing their production levels in the last decade, in spite of the economic crisis and strong international competition. Nevertheless, the large dependency on export demand can be considered a risk element in the medium-long term. Sawnwood prices emerged to be less certain because they depend on a weak and regionalized market and, in general, are suffering the weak competitive position of the regional sawmilling industry and the effects of the 2008 economic crisis.

The exposure to biotic and abiotic risk has also affected the regional timber market. In southern Europe, the main risks are represented by forest fires and windstorms (Lindner *et al.,* 2010). In recent years, these provoked serious consequences to timber market, i.e. the large forest fires in Portugal in 2017 and the 'Klaus' windstorm in south-western France in 2009 caused a destabilization of the wood demand (and consequently prices). Pest outbreaks are an issue of concern as well, e.g. the spread of the pine wilt nematode in the 2000s in Portugal provoked a restriction on the export of pine wood products from the country, strongly damaging the domestic industry.

Overall, the region is characterized by a small-sized and fragmented forest holding structure – which determines high transaction costs for investors and represents the most critical barrier to the possibilities of carrying out economies of scale. Forest owners' organizations are rather recent in the region (i.e. in Spain and Portugal these are relatively more developed, while in Italy there aren't notable examples) and there are very few examples of forest cooperatives (even though there are interesting emerging cases, e.g. Noreña, 2015). From the investment perspective, the southern European context is mainly characterized by small scale investments by private individuals and industry, with some cases of lease arrangements and partnership between public and private actors. The only notable example of financial investor in the forestry sector is represented by Floresta Atlântica, a public-private TIMO launched in 2007 and operating in Portugal.

8.3 Policy recommendations

This research contributed also to shed light on the role of the policies which are directly or indirectly related to forest plantation investments in southern Europe. We mainly took into consideration the grants-based subsidies of the RDPs (i.e. derived from the Reg. ECC No. 1305/2013 concerning the programming period 2014-20), which are the only subsidy schemes in place in the countries analized in the research. Our results indicate that subsidies could be determinant variables for investment decisions, in particular in contexts of high opportunity-cost or high market risk. However, it emerges that the current RDPs does not provide a clear and stable framework for investing in forest plantations. In general, the use of RDPs afforestation measures to set up intensively-managed plantation, especially when non-native species are being used, appears contradictory with the objectives of the EU Rural Development Policy, which has progressively become more oriented towards conservation, multifuncionality and green practices both in farming and forestry (Paper I – Chapter 5). However, the interpretation of these objectives seems to be uneven and there is a substantial lack a coordination among Member States or even within them (i.e. Italy and Spain where RDPs are at regional or provincial level). Therefore, the current framework is characterized by heterogeneos eligibility criteria (in terms of e.g. species or clones, sustainability requirements, etc.) and irregular grants, producing a potential further element of market destabilization, with concrete effects on the evolution of the market.

A more strategic and coordinated framework at EU level is required in order to keep and improve the competitive position of the sector in front of the processes of globalisation of timber markets (e.g. Hansen *et al.*, 2014; Hetemäki and Hurmekoski, 2016). However, in this context, the vision of increased subsidiarity or even "re-nationalisation" that dominates the current policy dabate on the future of the EU CAP[5], does not seem to go towards this direction. From a more general perspective, this reflects also a lack of coordination among land-based

[5] For more information, see: https://ec.europa.eu/commission/publications/natural-resources-and-environment

policies at EU level, in particualr between the Rural Development Policy and the bioeconomy and bioenergy strategies, which at regional level are expected to drive an increase of timber and biomass demand (EC, 2012). In this situation, southern European economies are running the risk of relying on imported raw material, failing in meeting the objectives of sustainable rural development. It has also to be considered that the competitive advance of plantations to meet the increaseed demand for wood raw materials without undermining the existing semi-natural forests' capacity to provide their full range of forest ecosystem services (e.g. Binkley, 1997; Sedjo and Botkin, 1997; Sedjo, 1999; Sayer *et al.*, 2001) is not present in the policy debate on wood mobilsation (EC, 2008b).

8.4 Future research directions

Possible future developments of this research should move in three directions. Firstly, in order to complete the regional framework, the research could be extended to include other important segments of forest plantations investments in southern Europe, i.e. maritime pine and poplar in Aquitaine (France), maritime pine and eucalyptus in northern Spain, but also those forest plantations with the primary purpose of producing of non-wood forest products (i.e. cork and pine nuts) could be of relevant interest. In addition, in the future, also forest plantations with multifunctional purposes (e.g. polycyclic plantations) and those for the offer of regulating and cultural services might gain more financial interest with the development of European markets for ecosystem services (Bennet *et al.*, 2017; Hamrick and Brotto, 2017). In this context, exploratory research could be done to create a specific system of environmental accounts to be able to implement Payment for Ecosystem Services (PES) mechanisms (Wunder, 2005) to remunerate the positive externalities and incentivize these types of plantation.

Secondly, there are some aspects of this research that could be improved or integrated. Above all, the inclusion of a risk analysis component in the financial simulations could be a very relevant integration. In Paper II we tentatively addressed this issue by using a proxy, i.e. including the cost of an insurance policy in the cash flow tables. This approach could potentially be adopted also in the other papers, but a more in-depth survey and evaluation of insurance policies would be needed. More complex methods, e.g. probabilistic approaches or MonteCarlo simulation method, could also be adopted to quantify risk and uncertainty, however, the current data basis to test these approaches might be still somehow poor. Another relevant aspect touched by this work that could open new research questions concerns the investment decision criteria adopted by the different categories of investors (private individuals and families, industry, financial investors). We addressed this issue by using a wide range of capital budgeting indicators and different discount rates, however, it is clear that seldom financial profitability is the only criteria considered by investors. New research could be developed to investigate this issue in the context of forestry investments.

Finally, we think that the methodological approach of our research, in particular the conceptualization of a trend analysis, could provide a reference model for designing an information system/observatory on forestry investment in Europe, monitoring the financial returns expectation evolution, allowing better market monitoring, business analysis and policy-making in the sector. Similarly to what is done for agricultural investments with the Farm Accountancy Data Network (FADN)[6] at EU level. Moreover, in the forestry sector, a stable and complete informative framework related to financial profitability of forest plantations could provide also the needed basis for developing a survey on the value of non-marketed ecosystem services (i.e. economic analysis approach), extremely useful to define the system of public subsidies and incentives.

[6] For more information, see: http://ec.europa.eu/agriculture/rica/

Bibliography

Adlard, P.G. (1993) Historical background. Study No. 1 Shell/WWF Tree Plantation Review. Shell International Petroleum Group, London and World Wide Fund for Nature, Godalming.

Allegro, G., Bergante, S., Castro, G., Chiarabaglio, P.M., Coaloa, D., Facciotto, G., Vietto, L. (2014) Qualità e sostenibilità ambientale della pioppicoltura in filiere legno-energia. Quaderni Della Ricerca N. 160 - June 2014. Regione Lombardia, Milan.

Alliance Environment (2017) Evaluation study of the forestry measures under Rural Development: Final Report. Alliance Environment EEIG. European Commission, Directorate-General for Agriculture and Rural Development, Brussels.

Alvarez-Diaz, M., Gonz.lez-G.mez, M., and Otero-Giraldez, M.S. (2015) Detecting the socioeconomic driving forces of the fire catastrophe in NW Spain. Eur. J. For. Res. 134: 1087–1094. doi:10.1007/s10342-015-0911-1.

Anderson, J.A., Luckert, M.K. (2006) Can hybrid poplar save industrial forestry in Canada's boreal forest? A financial analysis and policy considerations. Western Forest Economist Meeting, Oregon. http://dx.doi.org/10.5558/tfc83092-1.

Anon. (1999) The Role of Planted Forests in Sustainable Forest Management. Intersessional Experts Meeting, UN Inter-governmental Forum on Forests, Santiago, Chile.

Anon. (2003) The Role of Planted Forests in Sustainable Forest Management. UNFF Intersessional Experts Meeting, Wellington, New Zealand.

APFC (2017) Boletim Informativo Fevrero 2017. Associação dos Produtores Florestais do Concelho de Coruche e Limítrofes. Available at: www.apfc.pt/

Arosa Gomez, C.A. (2000) Estudio de los rendimientos y de los turnos óptimos en Galicia del eucalypto, del pino y del roble. Cuaderno de Estudios Empresariales, 2000, l0: 31-59. I5SN: 1131-6985.

Asen, A., Savenije, H., Schmidt, F. (2012) Good Business: Making Private Investments Work for Tropical Forests. Wageningen.

Assopannelli (2012) La pioppicoltura in Italia. Associazione Federlegno – Assopannelli. Milan.

Aunos, G., Rodriguez, F., Garasa, M. (2002) Análisis de sensibilidad sobre la rentabilidad financiera de choperas de Huesca y Lérida. Montes 69: 25-32.

Balandier, P., Dupraz, C. (1999) Growth of widely spaced trees. A case study from young agroforestry plantations in France. Agroforestry Systems, 43: 151-167.

Baldock, D., Beaufoy, G. (1993) Nature Conservation and new Directions in the EC Common Agricultural Policy. IEEP, London.

Barreiro, S., Rua, J., Tomé, M. (2016). StandsSIM-MD: a Management Driven forest SIMulator. Forest Systems, Volume 25, Issue 2.

Bauhus, J.,Van der Meer, P., Kanninen, M., (2010) Ecosystem goods and services from plantation forests. Earthscan Forest Library, Earthscan, London. ISBN 9781849711685

Bennet, G., Leonardi, A., Ruef, F. (2017) State of European Markets 2017 Watershed Investments. Forest Trends' Ecosystem Marketplace, Washington DC.

Bennett, G., and Ruef, F. (2016) Alliances for Green Infrastructure: State of Watershed Investments 2016. Ecosystem Marketplace, Washington DC.

Berti, S., Mercurio, R. (1992) Sulla produttività e sula scelta del ciclo colturale delle piantagioni di noce da legno. Note di ricerca, 2 (1). Istituto Sperimentale per la Selvicoltura, Arezzo.

Binkley, C. (1997) Preserving nature through intensive plantation forestry: the case for forestland allocation with illustrations from British Columbia. For Chron 73(5):553–559.

Boardman, A.E., Greenberg, D.H. (2005) Cost-benefit analysis: concepts and practice, 3rd edn. Pearson–Prentice Hall, New York.

Boggia, L. (1987) Conclusioni sull'eucalitticoltura nazionale. Cellulosa e Carta, 38/5.

Bolzonella, C., Chiodini, G., Coletta, A. (2014) Impatto della nuova PAC sui cereali italiani. L'informatore Agrario 45.

Borelli, M. (1994). Redditività della coltivazione del pioppo all'interno dell'azienda agraria. Cellulosa e Carta, 5/6.

Borelli, M. (1996). Il sistema pioppo nazionale alle soglie del 2000: alcune considerazioni di natura politico-economica. Sherwood – Foreste e Alberi Oggi, 26.

Borelli, M., Facciotto, G. (1997) Redditività della coltivazione del pioppo al di fuori dell'azienda agraria. Sherwood - Foreste ed Alberi Oggi, 18: 37-4.

Bowyer, J., Howe, J., Guillery, P., Fernholz, K. (2005) Fast-growth tree plantations for wood production - environmental threat or a means of saving natural forests? Dovetail Partners Inc.

Boyle, J.R. (1999) Planted forests: views and viewpoints. New For. 17, 5–9.

Bravo-Oviedo, A., Pretzsch, H., Ammer, C., Andenmatten, E., Barbati, A., Barreiro, S., Brang, P., Bravo, F., Coll, Ll., Corona, P., Ouden, J., Ducey, M., Forrester, D., Giergiczny, M., Jacobsen, J., Lesinski, J., Löf, M., Manson, B., Matovic, B., Metslaid. M., Morneau, F., Motiejunaite, J., O'Reilly, C., Pach, M., Ponette, Q., Rio M, Short I, Skovsgaard, J., Soliño, M., Spathelf, P., Sterba, H., Stojanovic, D., Strelcova, K., Svoboda, M., Verheyen, K., Lüpke, N., and Zlatanov, T. (2014) European Mixed Forests: definition and research perspectives. Forest Systems 23.

Brealey, R., Myers, S., Allen, F. (2008) Principles of Corporate Finance. New York.

Brotto, L., Pettenella, D., Cerutti, P., Pirard, R. (2016) Planted forests in emerging economies: Best practices for sustainable and responsible investments. Occasional Paper 151. CIFOR, Bogor, Indonesia.

Bull, G.Q., Bazett, M., Schwab, O., Nilsson, S., White, A., Maginnis, S. (2006) Industrial forest plantation subsidies: Impacts and implications. For. Policy Econ. 9, 13–31. doi:10.1016/j.forpol.2005.01.004

Bullard, S.H. Straka, T. J. (2011) Basic Concepts in Forest Valuation and Investment Analysis: Edition 3.0. Faculty Publications. Paper 460. http://scholarworks.sfasu.edu/forestry/460

Buongiorno, J., Zhu, S. (2014) Assessing the impact of planted forests on the global forest economy. New Zeal. J. For. Sci. 44, S2. doi:10.1186/1179-5395-44-S1-S2

Buresti Lattes, E., Castro, G., Mori, P., Zanuttini, R. (2015) Sfogliatura del pioppo: confronto tra piante di 'I-214' di dimensioni tradizionali e di grandi dimensioni. Sherwood - Foreste ed Alberi Oggi n. 212, 9-12.

Buresti Lattes, E., Cavalli, R., Ravagni, S., Zuccoli Bergomi, L. (2007) Impianti policiclici di arboricoltura da legno: due esempi di progettazione e utilizzazione. Sherwood - Foreste ed Alberi Oggi n. 139, 37-39.

Buresti Lattes, E., Mori, P. (2006) Legname di pregio e biomassa nella stessa piantagione. Sherwood - Foreste ed Alberi Oggi, n. 127 5-10.

Buresti Lattes, E., Mori, P. (2009) Impianti policiclici permanenti: L'Arboricoltura da Legno si avvicina al bosco. Sherwood - Foreste ed Alberi Oggi, n.150.

Buresti Lattes, E., Mori, P., Pelleri, F., Ravagni, S. (2008b) Des Peuliers et des noyers en mélange, avec des plants accompagnateurs. Foret Entreprise n.178, 26-30.

Buresti Lattes, E., Mori, P., Pelleri, F., Ravagni, S., Bidini, M., Marchino, L. (2008a) New cultivation trends in Italian tree farming plantations. International Conference "Growing valuable broadleaved tree species", Freiburg 6-9 October 2008.

Buresti Lattes, E., Mori, P., Ravagni, S. (2014) The polycyclic plantations: narrowing the gap between tree farming and forest. In Genetic Consideration In ecosystem restoration using native species,188-194. FAO, Rome.

Buresti, E., Ravagni, S. (in press) Piantagioni di pioppo e noce comune: accrescimenti e sviluppo dopo i primi anni. Sherwood - Foreste ed Alberi Oggi.

Cano, G., Britos, J. (2014) Rentabilidad de la inversión en plantación de eucalyptus con fines maderables. Instituto Forestal Nacional, Dirección de Fomento Forestal, Dirección General de Plantaciones Forestales. ?.

Carle, J., Holmgren, P. (2008) Wood from planted forests: a global outlook 2005–2030. Forest Prod. J. 58, 6–18.

Carle, J., Vuorinen, P., Del Lungo, A. (2002) Status and trends in global forest plantation development. Forest Products J 52(7/8):12–23.

Carrere, R., Lohmann, L. (1996) Pulping the South: industrial tree plantations and the world paper economy. Zed Books Ltd, London.

Caruso, C. (1977) Evoluzione della legislazione forestale nazionale in materia di rimboschimenti. L'Italia Forestale e Montana, 32 (4).

Cascio, A.J., Clutter, M.H. (2008) Risk and required return assessments of equity timberland investments in the United States. Forest Products Journal 2008, 58(10):61-70.

Castro, G., Giorcelli, A. (2012) Nuovi cloni di pioppo: ignorati dalla pioppicoltura e dal mercato. Sherwood - Foreste ed Alberi Oggi, 186.

Castro, G., Mori, P., Zanuttini, R. (2013) Produttività di sfogliato e diametro dei fusti. Indagini preliminari sui cloni di pioppo "I214" e "Neva". Sherwood - Foreste ed Alberi Oggi n. 192, pp. 5-9, Compagnia delle Foreste, Arezzo, Italy.

Castro, G., Zanuttini, R. (2008) Poplar cultivation in Italy: history, state of the art, perspectives. IPC 23rd Sess. 'Poplars, Willows and People's Wellbeing'. Beijing, China, 27-30 October 2008.

CELPA (2016) Melhor Eucalyptus. Análise Financeira para o Eucalipto. URL: http://www.celpa.pt/melhoreucalipto/simeucalipto.html

CELPA (2017) Boletim Estatístico 2016 da Associação da Indústria Papeleira. CELPA Editores. Lisbon, Portugal.

Centro Pinus (2017) A FILEIRA DO PINHO EM 2016: Indicadores da Fileira do Pinho. Centro Pinus, Viana Do Castelo. Available at: www.centropinus.org.

Chamber of Commerce of Alessandria (2018). URL: http://www.al.camcom.gov.it/PriceLists/Pub/Item?id_level_2=8 . [Accessed March 2018].

Chamber of Commerce of Mantua (2018). URL: http://www.borsamerci.mn.it/listino/listino.jsp?cat=19&l=100&nocache=1486139503754&list=825&sid=null&filter_changeConn=bm. [Accessed March 2018].

Chiarabaglio, P.M., Allegro, G., Facciotto, G., Incitti, T., Rossi, A.E., Isaia, M., Chiarle, A. (2009) Impatto ambientale della pioppicoltura. Sherwood - Foreste ed Alberi Oggi n. 152, 19-23.

Chiarabaglio, P.M., Allegro, G., Giorcelli, A. (2014). Environmental sustainability of poplar stands. In: 'Actas de las Jornadas de Salicaceas 2014' Cuarto Congreso Internacional de Salicáceas en Argentina “Sauces y Álamos para el desarrollo regional” Ciudad de La Plata, Buenos Aires, Argentina, 18-21 March 2014.

Chiarabaglio, P.M., Coaloa, D. (2002) Stima del pioppeto: criteri oggettivi per la valutazione del pioppeto maturo. Regione Piemonte, Turin.

Cianciosi, L., (1997) Risultati economici di un impianto di arboricolutra da legno. Sherwood – Foreste ed Alberi Oggi.

Cielo, P., Settembri, P., Zanuttini, R. (2002) I cantieri di utilizzazione del pioppo: sistemi di lavoro, tempi e produttività. Ed. Compagnia delle Foreste, Arezzo, Italy.

CIFOR (2002) Typology of planted forests. InfoBrief, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/Typology/John-typology.pdf

Clark, M.R., Kozar, J.S. (2011) Comparing sustainable forest management certifications standards: a meta-analysis. Ecol. Soc. 16 (1), 3. URL: http://www. ecologyandsociety.org/vol16/iss1/art3.

Coaloa, D. (2008) Estensione della pioppicoltura dal secondo dopoguerra ad oggi. In: Libro bianco della pioppicoltura. Agrisole 26/2008: 19-22.

Coaloa, D. (2009). La pioppicoltura in Italia e nel mondo, stato attuale e prospettive future. Dendronatura, 30.

Coaloa, D. (2014) Stato attuale e prospettive della filiera pioppo-legno. Presentation at the workshop 'Misure di sostegno alla pioppicoltura nei prossimi PSR 2014-2020', Casale Monferrato, 27 June 2014.

Coaloa, D., and Facciotto, G. (2014). Biomass feedstock from multipurpose plantations: current situation and potential developments in Italy. 22nd European Biomass Conference and Exhibition, 23-26 June 2014. Hamburg, Germany.

Coaloa, D., and Vietto, L. (2005). Pioppicoltura ecologicamente disciplinata: costi del pioppeto secondo il disciplinare di produzione. Sherwood - Foreste ed Alberi Oggi, 113.

Coaloa, D., Chiarabaglio, P.M., and Borelli, M. (1999). La pioppicoltura nel sistema legno nazionale. Il Pioppo – I supplementi di Agricoltura, 4.

Coaloa, D., Facciotto, G., Chiarabaglio, P.M., Giorcelli, A., Nervo, G. (2016) Cloni di pioppo a Maggiore Sostenibilità Ambientale (MSA): vantaggi della loro coltivazione. Sherwood – Foreste ed Alberi Oggi, 216.

Coletti, L. (2001) Risultati dell'applicazione del regolamento CEE 2080/92 in Italia. Sherwood - Foreste ed Alberi Oggi(?).

Confemadera (2010) El cultivo y utilizacion del chopo en España. Observatorio Industrial del Sector Madera y Mueble. Madrid.

Cossalter, C., Pye-smith, C. (2003) Fast-Wood Forestry Myths and Realities. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

CREA (2016). Banca dati dei valori fondiari. URL: http://antares.crea.gov.it:8080/mercato-fondiario/banca-dati. [Accessed March 2017].

Cubbage, F., Davis, R., Frey, G., Behr, D.C. (2013) Financial and economic evaluation guidelines for community forestry projects in Latin America. PROFOR & the World Bank, Latin America and the Caribbean Region.

Cubbage, F., Davis, R., Frey, G., Behr, D.C., Sills, E. (2015) Financial and Economic Evaluation Guidelines for International Forestry Projects. In: Pancel L., Köhl M. (eds) Tropical Forestry Handbook. Springer, Berlin, Heidelberg.

Cubbage, F., Donagh, P.M., Balmelli, G., Olmos, V.M., Bussoni, A., Rubilar, R., Torre, R., Lord, R., Huang, J., Hoeflich, V.A., Murara, M., Kanieski, B., Hall, P., Yao, R., Adams, P., Kotze, H., Monges, E., Pérez, C.H., Wikle, J., Abt, R., Gonzalez R., Carrero, O., Falshaw, R. (2014) Global timber investments and trends, 2005-2011. Conference paper. New Zealand Journal of Forestry Science, 44, Suppl. 1.

Cubbage, F., Koesbandana, S., Mac Donagh, P., Rubilar, R., Balmelli, G., Olmos, V.M., De La Torre, R., Murara, M., Hoeflich, V.A., Kotze, H. (2010) Global timber investments, wood costs, regulation, and risk. Biomass and Bioenergy 34, 1667–1678. doi:10.1016/j.biombioe.

Cubbage, F., Mac Donagh, P., Sawinski Júnior, J., Rubilar, R., Donoso, P., Ferreira, A., Hoeflich, V., Olmos, V.M., Ferreira, G., Balmelli, G., Siry, J., Báez, M.N., Alvarez, J., (2007). Timber investment returns for selected plantations and native forests in South America and the Southern United States. New For. 33, 237–255. doi:10.1007/s11056-006-9025-4.

Dal Secco, L., Pirard, R. (2015) Do tree plantations support forest conservation? Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Dale, V.H., Joyce, L.A., McNulty, S., Neilson, R.P., Ayres., M.P., Flannigan, M.D., Hanson, P.J., Irland, L.C., Lugo, A.E., Peterson, C.J., Simberloff, D., Swanson, F.J., Stocks, B.J., Wotton, B.M. (2001) Climate hange and forest disturbances. BioScience 51:723–734

Davis, L., Johnson, K., Bettinger, P., Howard, T. (2001) Forest management. McGraw-Hill Book Co, New York.

De Carli, A. (2015) Studio di meccanismi economico finanziari a supporto delle azioni di ricarica delle falde. Analisi economico-finanziaria delle soluzioni tecniche per il riequilibrio delle falde nell'ambito del progetto AQUOR. Padova.

De Putter, J. (1995) The greening of European agricultural policy: the agri-environmental regulation of the MacSharry reform. Ministry of Agriculture, The Hague.

Del Lungo, A., Ball, J., Carle, J. (2006) Global planted forests thematic study: results and analysis. Rome. doi:10.1017/CBO97811074153244.

Del Peso, C., Reque, J.A., Bravo, F., Martínez P. (1995) El chopo como alternativa viable al cultivo del regadío en el valle del Duero. Estudio de rentabilidades. Montes 42, 20-24.

del Río M, Pretzsch H, Alberdi I, Bielak K, Bravo F, Brunner A, Condés S, Ducey MJ, Fonseca T, von Lüpke N, Pach M, Peric S, Perot T, Souidi Z, Spathelf P, Sterba H, Tijardovic M, Tomé M, Vallet P, Bravo-Oviedo A. (2015) Characterization of the structure, dynamics, and productivity of mixed-species stands: review and perspectives. European Journal of Forest Research 135:23-49.

Direcção Geral dos Recursos Florestais (1991). Perfil Florestal, Direcção Geral das Florestas. Divisão de Estudos, Lisbon.

Di Candilo, M. and Facciotto, G. (2012). Colture da biomassa ad uso energetico. Potenzialità e prospettive. 9-17. In: Progetti di ricerca SUSCACE e FAESI. Recenti acquisizioni scientifiche per le colture energetiche. Sherwood – Foreste ed Alberi Oggi, 183, Supplemento 2.

Díaz Balterio, L., Romero, C. (1994) Rentabilidad económica y turnos óptimos de choperas en España. Invest Agrar: Sist Recur For 3, 43-56.

Diaz-Balteiro, L., Bertomeu, M., Bertomeu, M. (2009) Optimal harvest scheduling in Eucalyptus plantations: A case study in Galicia (Spain), Forest Policy and Economics, Volume 11, Issue 8, 2009, Pages 548-554, ISSN 1389-9341, https://doi.org/10.1016/j.forpol.2009.07.005.

Diaz-Balteiro, L., Romero, C., Rodriguez, L.C.E., Ribeiro Nobre, S., Borges, J.G. (2014) Economics and Management of Industrial Forest Plantations. In: J.G. Borges et al. (eds.), The Management of Industrial Forest Plantations: Theoretical Foundations and Applications, Managing Forest Ecosystems 33, DOI 10.1007/978-94-017-8899-1_1, Springer Science+Business Media. Dordrecht.

Duesberg, S., Upton, V., O'Connor, D., Dhubháin, Á.N. (2014) Factors influencing Irish farmers' afforestation intention. Forest Policy Econ. 39, 13–20.

Duku-Kaakyire, A., Nanang, D.M. (2004) Application of real options theory to forestry investment analysis, Forest Policy and Economics, Volume 6, Issue 6, 2004, Pages 539-552, ISSN 1389-9341, https://doi.org/10.1016/S1389-9341(03)00003-0.

EBC (2016) European central Bank. Long-term interest rate statistics for EU Member States. URL: https://www.ecb.europa.eu/stats/money/long/html/index.en.html. [Accessed May 2016].

EC (2008a) Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020. European Commission, Directorate-General for Regional and Urban policy. Brussels, Belgium

EC (2008b) Mobilisation and efficient use of wood and wood residues for energy generation, Standing Forestry Committee ad hoc Working Group II. http://ec.europa.eu/agriculture/fore/publi/sfc_wgii_final_report_072008_en.pdf.

EC (2012) Innovating for Sustainable Growth: A Bioeconomy for Europe. European Commission. Brussels. COM (2012) 60 final

EC (2016) Direct Payments: eligibility for direct payments of the Common Agricultural Policy. European Commission, Brussels. https://ec.europa.eu/agriculture/sites/agriculture/files/direct-support/direct-payments/docs/direct-payments-eligibility-conditions_en.pdf.

Esteban López, V., Casquet Morate, L., Díaz Balteiro, L. (2005) El turno financiero óptimo al introducir la fiscalidad en el análisis. Aplicación a las choperas de Castilla y León. Invest Agrar: Sist Recur For (2005) 14(1), 122-136.

EUROSIF (2014) European SRI-Study 2014. European Sustainable Investment Forum.

Eurostat (2018) EUROSTAT database. URL: http://ec.europa.eu/eurostat/data/database. [Accessed February 2018].

Evans, J. (2009) Planted forests: uses, impacts and sustainability. FAO and CAB International, Wallingford, UK

Evans, J. (ed) (2009) Planted forests: uses, impacts and sustainability. Published jointly by FAO and CAB International. Wallingford, UK. ISBN 978-1-84593-564-1

Evans, J., Turnbull, J.W. (2004) Plantation forestry in the tropics. Role of Silviculture, and Use of Planted Forests for Industrial, Social, Environmental and Agroforestry Purposes 3rd edn. Oxford University Press, Oxford, UK.

Facciotto, G., Minotta, G., Paris, P., Pelleri, F. (2014) Tree farming, agroforestry and the new green revolution. a necessary alliance. Proceedings of the second international congress of silviculture Florence, November 26th - 29th 2014. http://dx.doi.org/10.4129/2cis-gf-tre.

FAO (1999) Forest plantation profitability model. URL: http://www.fao.org/forestry/finance/11867/en/

FAO (2005) Global Forest Resources Assessment 2005. Food and Agricolture Organization of the United Nations, Rome, Italy.

FAO (2010) Forest Resources Assessment 2010. Food and Agricolture Organization of the United Nations, Rome, Italy.

FAO (2012a) Forest Resources Assessment 2015: Terms and Definitions. Food and Agriculture Organization of the United Nations. Rome, Italy.

FAO (2012b) Timberland in institutional investment portfolios: Can significant investment reach emerging markets? Forest Policy and Institutional Working Paper. Available at: www.fao.org/forestry/finance/en/.

FAO (2012c) Improving lives with poplars and willows. Synthesis of Country Progress Reports. 24th Session of the International Poplar Commission, Dehradun, India, 30 Oct-2 Nov 2012. Working Paper IPC/12. Forest Assessment, Management and Conservation Division, FAO, Rome. http://www.fao.org/forestry/ipc2012/en.

FAO (2015) Global Forest Resources Assessment 2015. Food and Agricolture Organization of the United Nations, Rome, Italy.

FAOSTAT (2018) FAOSTAT Agricultural Producer Price Index. URL: http://ref.data.fao.org. [Accessed March 2018].

Faustmann, M. (1849) Calculation of the value which forestland and immature stands possess for forestry. Reprinted in J For Econ 1(1):7–44 (1995).

Fernandes, P.A.M. (2008) Forest fires in Galicia (Spain): the outcome of unbalanced fire management. J. Forest Econ. 14: 155–157. doi:10.1016/j.jfe.2007.11.002

FLA (2018) Not published data. Associazione Federlegno, Milan.

FOREST EUROPE (2015) State of Europe's Forests 2015. Madrid.

Gardiner, B., Blennow, K., Carnus, J.M. (2010) Destructive storms in European forests: past and forthcoming impacts. Final report to EC DG environment http://ec.europa.eu/environment/forests/fprotection.htm

Garoglio, P. (1990). Sui movimenti dei prezzi nel mercato del pioppo. Rivista di Economia Agraria, 45 (2).

Gasparini, P., Tabacchi, G. (2011). L'inventario Nazionale delle Foreste e deu serbatoi forestali di Carbonio INFC 2005. Secondo inventario forestale nazionale italiano. Metodi e risultati. Edagricole-Il Sole 24 Ore. Bolonia.

Giménez, J.C., Bertomeu, M., Diaz-Balteiro, L., Romero, C. (2013) Optimal harvest scheduling in Eucalyptus plantations under a sustainability perspective. Forest Ecology and Management 291 (2013) 367–376. http://dx.doi.org/10.1016/j.foreco.2012.11.045.

Gittinger, J. (1982) Economic analysis of agricultural projects, 2nd edn. The Economic Development Institute of the World Bank, the Johns Hopkins University Press, Baltimore, 505 p.

Gregerson, H.M., Contreras, A.H. (1989). Economic Analysis of Forestry Projects. Forestry Paper No. 17, Food and Agriculture Organization of United States, Rome.

Hamrick, K., Brotto, L. (2017) State of European Markets 2017 Voluntary Carbon. Forest Trends' Ecosystem Marketplace, Washington DC.

Hamrick, K., Gallant, M. (2017) Fertile Ground. State of Forest Carbon Finance 2017. Ecosystem Marketplace, Washington DC.

Hansen, E., Panwar, R., Vlosky, R. (2014). The Global Forest Sector. CRC Press, Boca Raton.

Harper S. (1993) The greening of rural policy. Belhaven, London.

Harrison, S., Herbohn, J. (2016) Financial Evaluation of Forestry Investments: Common Pitfalls and Guidelines for Better Analyses. Small-scale Forestry (2016) 15:463–479. DOI 10.1007/s11842-016-9334-1.

HAZI (2017) Ecuaciones de cubicación. HAZI, Arkaute Araba, Spain. URL: http://www.hazi.eus/es/proyectoshazi/5468-ecuaciones-de-cubicacion.html [Accessed June 2017].

Hetemäki, L., Hurmekoski, E. (2016). Forest Products Markets under Change: Review and Research Implications. Current Forestry Reports 2(3): 177-188.

HM Treasury (2003) THE GREEN BOOK: Appraisal and Evaluation in Central Government, London.

Hogaboam, L., Shook, S.R. (2004) Capital budgeting practices in the USA forest products industry: a reappraisal. Forest Products Journal 2004, 54(12):149-158.

ICNF (2013) IFN6 – Áreas dos usos do solo e das espécies florestais de Portugal continental. Resultados preliminares. Instituto da Conservação da Natureza e das Florestas. Lisboa.

IFN (1985) Inventario Forestale Nazionale 1985: sintesi metodologica e risultati. Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura, Rome.

IMF (2018). World Economic Outlook Database, April 2018. International Monetary Fund, URL: https://www.imf.org/. [Accessed August 2018].

INDUFOR (2012) Forest Stewardship Council (FSC) - Strategic Review on the Future of Forest Plantations. Helsinki.

INE (2017a) Actualización de rentas con el IPC. Instituto Nacional de Estadistica - Spanish Statistical Office, Madrid. URL: http://www.ine.es/calcula/calcula.do [Accessed on 10/11/2017].

INE (2017b) Atualização de Valores com Base no IPC. Instituto Nacional de Estatística - Statistics Portugal, Lisbon. URL: https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ipc [Accessed on 10/11/2017].

ISTAT (1970) Agricultural Census 1970. Italian National Institute of Statistics, Rome.

ISTAT (1980) Agricultural Census 1980. Italian National Institute of Statistics, Rome.

ISTAT (2000) Agricultural Census 2000. Italian National Institute of Statistics, Rome,

ISTAT (2010) Agricultural Census 2010. Italian National Institute of Statistics, Rome,

ISTAT (2016) Censimento Generale dell'Agricoltura. URL: http://censimentoagricoltura.istat.it [Accessed January 2017].

ISTAT (2017) Indice dei prezzi al consumo per le rivalutazioni monetarie. URL: http://rivaluta.istat.it/Rivaluta/ [Accessed November 2017].

Istituto Sperimentale per la Selvicoltura (1982) Annali dell'Istituto Sperimentale per la Selvicoltura. Volumi XII e XIII, 1981- 1982. Istituto Sperimentale per la Selvicoltura, Arezzo.

Jactel, H., Boberg, J., Brokerhoff, E.G., Catagneyrol, B., Koricheva, J., Meurisse, N. (2016) Effects of tree species diversity on resistance to biotic disturbances in planted forests. International Scientific Seminar "Sustainable intensification of planted forests: how far can we go?"Biarriz, France, 13/06/2016.

Jactel, H., Brockerhoff, E.G. (2007), Tree diversity reduces herbivory by forest insects. Ecology Letters, 10: 835-848. doi:10.1111/j.1461-0248.2007.01073.x.

Jonsson, R., Whiteman, A. (2008) Global forest product projections. Food and Agricultural Organization (FAO) of the United Nations, Rome

Jürgensen, C., Kollert, W., Lebedys, A. (2014) Assessment of Industrial Roun.dwood Production from Planted Forests. Planted Forests and Trees. Working Paper Series No. 48, (48).

Keča L., Keča, N., Pajić, S. (2011) Investment appraisal of poplar plantations in Serbia. Baltic Forestry 17(2):268-279.

Keča L., Keča, N., Pajić, S. (2012) Net Present Value and Internal Rate of Return as indicators for assessment of cost-efficiency of poplar plantations: a Serbian case study. International Forestry Review Vol.14(2).

Keča, L. (2017) Determination of the Optimal Financial Rotation Period in Poplar Plantations. Baltic Forestry 23(1):673–682.

Keipi, K. (1997) Financing forest plantations in Latin America: government incentives. Unasylva, 188: 50–56.

Klemperer, D. (2003) Forest Resource Economics and Finance. Blacksburg, VA, US.

Kling, C. (2012) Analysis of eucalyptus plantations on the Iberian Peninsula. Department of Forest Products, SLU, Uppsala.

Lapietra, G., Coaloa, D., Chiarabaglio, P.M. (1995) Necessario pianificare gli impianti di pioppo. Rapporto annuale sulla pioppicoltura 1994. L'Informatore agrario 51: 45-47.

Lausti, A. (2004) The inflation-hedging characteristics of forest ownership, private housing and stocks in Finland. Liiketaloudellinen Aikakauskirja 4/04(4):427–51.

Levarato, G., Pra, A., Pettenella, D. (2018) Quale futuro per la pioppicoltura? Indagine sul quadro attuale e le prospettive d'impiego industriale del legname di pioppo. ETIFOR Srl – Spin-off dell'Università di Padova. Padua.

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M.J., Marchetti, M. (2010) Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. Forest Ecol Manag 259:698–709

Londi, G., Campedelli, T., Cutini, S., Mattioli, F., Tellini Florenzano, G. (2016) Tree farming and biodiversity: bird communities as indicators of polycyclic tree farms positive role. Sherwood - Foreste ed Alberi Oggi, 219: 15-17 (available at: www.inbiowood.eu).

Lund, G.H. (2000) Definitions of Forest, Deforestation, Afforestation and Reforestation. Forest Information Services, Manassas, VA.

Lutz, J. (2009) Inflation and timberland returns. In Siry, J., Izlar, B., Bettinger, P., Harris, T., Tye, T., Baldwin, S., Merry, K., eds. Proceedings of the 2008 Southern Forest Economics Workers Annual Meeting; 9–11 Mar 2008; Savannah, GA and Athens, GA: Center for Forest Business, Warnell School of Forestry. 84–9.

Madsen, L.M. (2003) New woodlands in Denmark: the role of private landowners. Urban Forest. Urban Green. 1, 185–195.

Manzone, M., Airoldi G., and Balsari P. (2009). Energetic and economic evaluation of a poplar cultivation for the biomass production in Italy. Biomass and Bioenergy 33, 1258–1264. doi:10.1016/j.biombioe.2009.05.024.

MAPAMA (2013) Cuarto Inventario Forestal Nacional. Comunidad Autonoma del Pais Vasco/Euskadi. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid. ISBN: 978-84-491-1293-5

MAPAMA (2016) Encuesta de Precios de la Tierra 2016. Principales resultados. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

Martinez de Arano, I., Lasgourgues, Y. (2014) European regional outlook, south-western regional outlook. In: Hatemaki, L. (2014) Future of the European Forest-Based Sector: Structural Changes Towards Bioeconomy. European Forest Institute, Joensuu.

Martinez de Arano, I., Muys, B., Topi, C., Petenella, D., Feliciano, D.M.S., Rigolot, E., Lefevre, F., Prokofieva, I., Labidi, J., Carnus, J.M., Secco, L., Fragiocomo, M., Follesa, M., Masiero, M., Llano-Ponte, R. (2018) A forest-based circular bioeconomy for southern Europe: visions, opportunities and challenges: Reflections on the bioeconomy. European Forest Institute, Joensuu.

Masiero, M., Secco, L., Pettenella, D., Brotto, L. (2015) Standards and guidelines for forest plantation management: A global comparative study. Forest Policy and Economics 53:29–44.

Mei, B., Clutter, M. (2010) Evaluating financial performance of timberland investments in the United States. Forest Science 2010, 56(5):421-428.

Michel, M. (2006) El pino radiata en la historia forestal vasca. Analisis de un proceso de forestalismo intensivo. Munibe, suplemento 23, Donostia: Aranzadi Zientzi Elkartea.

MIIPAF (2012) Piano della filiera legno 2012-2014, Documento di Sintesi. Ministero delle Politiche Agricole, Alimentari e Forestali, Rome, Italy.

Mills, S.D., Stiff, C.T. (?) Financial performance of loblolly and longleaf pine plantations.

Montagnini, F., Cusack, D., Petit, B., Kannin, M. (2005) Environmental services of native tree plantations and agroforestry systems in Central America. J. Sustain. For. 21 (1), 51–67.

Mori, P. (2015) Piantagioni Policiciche: arboricoltura e selvicoltura più vicine. Atti del Congresso Internazionale di Selvicoltura (Firenze 2015), pp. 670-675.

Mori, P., Buresti Lattes, E. (2017) I-214 and Permanent Polycyclic Tree farms: relationships among diameter, productive area per plant and rotation cycle length. Sherwood - Foreste ed Alberi Oggi 229 (available at: www.inbiowood.eu).

Morrison, E., Bass, S. (1992) What about the people? In: Sargent, C., Bass, S., eds. Plantations Politics: Forest Plantations in Development. London: Earthscan Routledge. Chapter 5, 92–120.

Motta, R., Beretti, R., Boetto, G., Vacchaino, G., Miglietta, P., Cirulli, G. (2014) The Smart Tree initiative and permanent polycyclic plantations in the city of Turin. Isa European Conference of Arboriculture 2014 “Planning the green city: relationships between trees and infrastructures. Turin, 26-28 May 2014.

Narayan Marasenia, T., Lien Sonb, H., Cockfielda, G., Vu Duyb, H., Dai Nghiac, T. (2017) Comparing the financial returns from acacia plantations with different plantation densities and rotation ages in Vietnam. Forest Policy and Economics 83 (2017) 80–87.

Nervo, G. (2009) La filiera del pioppo: indirizzi e prospettive. Il contributo del CRA-PLF di Casale Monferrato per una pioppicoltura sostenibile. Presentation, Turin, 2 October 2009.

Nervo, G., Coaloa D., Vietto L., Giorcelli A., Allegro G. (2011) Current situation and prospects for European poplar culture: the role of research. Actas del Tercer Congreso Internacional de las Salicáceas en Argentina ‘Los álamos y los sauces junto al paisaje y el desarrollo productivo de la Patagonia’. Neuquen, Argentina 16-19 March 2011. pp. 9.

NewForests (2017) Timberland Investment Outlook. September 2017. NewForests Pty Limited. Available at: www.newforests.com.au.

Nicklin, S., Cornwell, B. (2012) Forests for People. In: Witthaus, M., Ballard, S., Ingleton, T., eds. United Nations Forum on Forests (UNFF) and Tudor Rose.

Noreña, R.R. (2015) The initiatives of forest cooperation in Galicia: the case of PROMAGAL. Presentation at SIMWOOD Workshop on Wood Mobilisation: The role of Forest Co-operatives. Wednesday, 6th May 2015.

OECD (1968) Manual for Industrial Project Analysis, Vol I and II. Paris.

OECD (2011) Evaluation of Agricultural Policy Reforms in the European Union. OECD Publishing. Paris.

Olivotto, L. (2016) Relazioni tra circonferenza del fusto e chioma: studio sul clone ‘I-214’ in piantagioni policicliche. Sherwood - Foreste ed Alberi Oggi 226: 39-42.

Paquette, A., Messier, C. (2009) The role of plantations in managing the world’s forests in the Anthropocene. Front. Ecol. Environ. 8 (1), 27–34.

Parrotta, J.A. (1995) Influence of overstory composition on understory colonisation by native species in plantations on degraded tropical site. J. Veg. Sci. 6, 627–636.

Pasini, A., Pividori, M. (2014) Request of valuable timber from tree farms: market survey in Verona province. in Tecniko & Pratico n. 108, supplemento di Sherwood - Foreste ed Alberi oggi, pp. 29-31 (available at: www.inbiowood.eu).

Pasini, A., Pividori, M. (2015) Wood biomasses for energy purposes from tree farming: a market survey in Verona province made within the LIFE+ InBioWood project. in Tecniko & Pratico n. 111, supplemento di Sherwood - Foreste ed Alberi oggi, pp. 28-29 (available at: www.inbiowood.eu).

Pawson, S.M., Brin, A., Brockerhoff, E.G., Lamb, D., Payn, T.W., Paquette, A., Parrotta, J.A. (2013) Plantation forests, climate change and biodiversity. Biodiversity Conservation 22 (5), 1203–1227.

Payn, T., Carnus, J.-M., Freer-Smith, P., Kimberley, M., Kollert, W., Liu, S., Orazio, C., Rodriguez, L., Silva, L.N., Wingfield, M.J. (2015) Changes in planted forests and future global implications. For. Ecol. Manage. 352, 57–67. doi:10.1016/j.foreco.2015.06.021

Pearse, P.H. (1990) Introduction to Forestry Economics. University of British Columbia press. Vancouver, Canada.

Pearson, R.G. (2006) Climate change and the migration capacity of species. Trends Ecol Evol 21(3):111–113

Pelleri, F. (2016) Innovazione e opportunità delle piantagioni da legno policicliche. Presentation at the workshop "Piantagioni da legno policicliche: aspetti tecnici e opportunità". Bologna, 25/06/2016.

Pelleri, F., Ravagni, S., Bianchetto, E., Bidini, C. (2013) Comparing growth rate in a mixed plantation (walnut, poplar and other nurse trees) with different planting designs: result from an experimental plantation in northern Italy. Annals of Silvicultural Research, 37 (1): 13-21.

Pelleri, F., Ravagni, S., Bidini, C., Bianchetti, E. (2012) Impianti policiclici e multifunzionali: Primo esempio in Toscana. Sherwood. 187.

Perdue, J.H., Stanturfb, J.A., Youngc, T.M., Huangc, X., Doughertyd, D., Pigottd, M., Guoe, Z. (2017) Profitability potential for Pinus taeda L. (loblolly pine) short-rotation bioenergy plantings in the southern USA. Forest Policy and Economics 83 (2017) 146–155. http://dx.doi.org/10.1016/j.forpol.2017.08.006

Pettenella, D. (1992) La politica dei rimboschimenti in Italia, (?).

Peupliers de France (2016) Populiculture - Fiches stations peuplier. Web site. [online] URL: http://www.peuplier- sdefrance.org/n/fiches-stations-peuplier/n:1151

Pra, A., Brotto, L., Mori, P., Buresti Lattes, E., Polato, R., Pettenella, D. (2016). Redditività finanziaria delle piantagioni da legno: confronto tra pioppo, noce e piantagioni policicliche. Sherwood – Foreste ed Alberi Oggi, 222.

Prevosto, M. (1969). Sugli accrescimenti e sui redditi ottenibili dai diversi tipi di pioppo più comunemente coltivati nella pianura lombardo-piemontese. Cellulosa e Carta, 20.

Prevosto, M. (1971). Accrescimenti e redditi dei tipi di pioppo più comunemente coltivati nella pianura lombardo-piemontese. Il Coltivatore e Giornale Vinicolo Italiano, 117.

Prevosto, M. (1980) Il pioppo nella realtà economica. Annali dell'accademia di agricoltura di Torino, Turin.

Price, C. (1989) The Theory and Application of Forest Economics. Oxford: Basil Blackwell Ltd.

Price, C. (1993) Time, Discounting and Value. Blackwell, Oxford

Ragazzoni, A. (1993) L'analisi di un investimento aziendale a noceto da legno nell'ottica della riforma PAC. L'Informatore Agrario, 47/1993.

Ravagni, S., Buresti Lattes, E. (2007) Gli impianti policiclici per la produzione di legname di pregio. in atti 6° Congresso Nazionale SISEF, Arezzo, Italy 25 – 27 September 2007.

Redmond, C.H., Cubbage, F.W. (1988) Risk and returns from timber investments. Land Economics 1988, 64:325 337.

Regione Piemonte (2002). Progetto “Ecocertificazione della pioppicoltura” (ECOPIOPPO), Relazione della Task 5 - Sub-task 5. (edited by: Brun, F., and Costamagna, S.). Regione Piemonte, Assessorato Politiche per la Montagna, Foreste e Beni Ambientali, Turin.

Ribeiro, F., Tomé, M. (2000) Classificação climática de Portugal Continental, baseada em informação do Atlas do Ambiente. Revista de Ciências Agrárias, vol. XXIII, nº 2: 23-38.

RICA (2016) Rete di Informazione Contabile Agricola: Banca dati. URL: http://www.rica.inea.it/public/it/index.php. [Accessed May 2017]

Rinehart, J. (2010) U.S. timberland post-recession. Is it the same asset? San Francisco: R&A Investment Forestry.

Rivest, D., Oliver, A., Gordon, A.M. (2010) Hardwood intercropping system: combining wood and agricultural production while delivering environmental services.

Rodrigues, J.M. (2008) National Eradication Programme for the Pinewood Nematode. In: Mota M.M., Vieira P. (eds) Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems. Springer, Dordrecht.

Rodríguez, R., Espinosa, M., Real, P. Inzunza, J. (2002) Analysis of productivity of radiata pine plantations under different silvicultural regimes using the 3-PG process-based model. Australian Forestry, 65(3): 165–172.

Romano, R., Cilli, S. (2009) Impatto delle Misure forestali nello sviluppo rurale 2007-2013. In: Atti del Terzo Congresso Nazionale di Selvicoltura. Accademia Italiana di Scienze Forestali, p. 1141-1148. 16-19 ottobre 2008, Taormina.

Row, C., Sessions, J., Kaiser, F. (1981) Discount rate for long-term Forest Service investments. Journal of Forestry 79(6):367–376.

Sayer, J., Chokkalingam, U., Poulsen, K. (2001) The restoration of forest biodiversity and ecological values. In: International seminar on restoration research on degraded forest ecosystems. Seoul.

Scheyvens, H., Lopez-Casero, F. (2009) REDD Negotiations: Progress, Challenges and Ways Forward. Hayama, Japan: Institute for Global Environmental Strategies. 1–8. IGES Briefing Notes on the Post-2012 Climate Regime. Issue No. 5.

Scholtens, B., & Spierdijk, L. (2008) The Diversification Properties of US Timberland: A Mean-Variance Approach. Groningen.

Sedjo, R. (1983) The comparative economics of plantation forestry: a global assessment. Baltimore: Resources for the Future/ Johns Hopkins Press.

Sedjo, R., Botkin, D. (1997) Using forest plantations to spare natural forests. Environment, 39(10):14-20.

Sedjo, R.A. (1999) The potential of high-yield plantation forestry for meeting timber needs. New Forest 17:339–359

Sedjo,R. (2001) The role of forest plantations in the world's future timber supply. Forest Chronicles 77(2):221–225.

Snowdon, P., Harou, P. (2013) Guide to Economic Appraisal of Forestry Investments and Programmes in Europe. European Forest Institute, Joensuu.

Sohngen, B., Mendelsohn, R., Sedjo, R. (1999) Forest Management, Conservation and Global Timber Markets, 81, 1–13.

Solberg, B. (2010) Economics of Forest Resources. European Review of Agricultural Economics, Volume 37, Issue 3, 1 September 2010, Pages 423–426, https://doi.org/10.1093/erae/jbq028

Spencer, R.D., Bull, T., Bugg, A., Burns, K., Baalman, P. (1999) Hardwood Sawlog Plantations for Selected Areas of South East Queensland. Bureau of Rural Sciences and Australian Bureau of Agricultural and Resource Economics, Canberra.

Spinelli, R., Magagnotti, N., Sperandio, G., Cielo, P., Verani, S., Yanuttini, R. (2011) Cost and Productivity of harvesting high-value hybrid poplar plantations in Italy. Forest Product Journal 62(1):64-70.

Stenger, A., Harou, P. (2015) Special issue on forest investments profitability, Journal of Environmental Economics and Policy, 4:2, 125-128, DOI: 10.1080/21606544.2014.990520.

Stojanovic, D., Levanic, T., Matovic, B., Bravo-Oviedo, A. (2015) Climate change impact on a mixed lowland oak stand in Serbia. Annals of Silvicultural Research 39:94–9.

Szedlak, T. (2017) Aforestation and land use change in the EU in a changing climate. Presentation at the Workshop 'Current status of afforestation in the EU', Brussels, 30/03/2017.

Tankersley, L. (2006) Hardwood plantations as an investment. University of Kentucky's, Cooperative Extension publication, FOR-101, 8 pp.

Testa, R., Di Trapani, A.M., Foderà, M., Sgroi, F., Tudisca, S. (2014) Economic evaluation of introduction of poplar as biomass crop in Italy. Renew. Sustain. Energy Rev. 38, 775–780. doi:10.1016/j.rser.2014.07.054.

Tolosana Esteban, E., Albizu Urionabarrenetxea, P.M., Vignote, Peña, S. (2013) Situación del mercado de madera de calidad de pino radiata. Influencia en el estado de sus masas. Análisis de alternativas de gestión.

Tomberlin, D., Buongiorno, J. (2001) Timber plantations, timber supply, and forest conservation. In: Palo, M., Uusivuori, J., Mery, G. (eds), World forests, markets, and polices world forests volume III. Kluwer Academic Publishers, Dordrecht.

Tomé, M., Borges, J.G., Falcão, A. (2001[a]). The use of Management-Oriented Growth and Yield Models to Assess and Model Forest Wood Sustainability. A case study for Eucalyptus Plantations in Portugal. In: Carnus, J.M., Denwar, R., Loustau, D., Tomé, M., Orazio, C. (Eds.), Models for Sustainable Management of Temperate Plantation Forests, European Forest Institute, Joensuu, pp. 81-94.

Tomé, M., Ribeiro, F., Soares, P. (2001b). O modelo Globulus 2.1. Departamento de Engª. Florestal. Instituto Superior de Agronomia. Universidade Técnica de Lisboa. Lisbon.

Toppinen, A., Zhang, Y. (2010) Changes in Global Markets for Forest Products and Timberlands. In Forest and Society - Responding to Global Drivers of Change (pp. 135–156). IUFRO World Series Vol. 25.

Trestini, S., Bolzonella, C. (2015) Opportunità di reddito con i cicli precoci. Conto Economico. L'informatore Agrario, 2015.

UN (1993) Agenda 21: Earth Summit – The United Nations Programme of Action from Rio. Agenda 21 full text (Chapter 11 on Deforestation), Rio Declaration and Forest Principles, UN Department of Economic and Social Affairs, Division for Sustainable Development, New York.

UNDP (2018). Human Development Indices and Indicators. 2018 Statistical Update. United National Development Programme, New York. [Accessed August 2018]

UNECE/FAO (2011) The European Forest Sector Outlook Study II: 2010-2030.

UNECE/FAO (2014) Forest Products Annual Market Review 2014. United Nation Economic Commission of Europe, Geneve.

UNEP (2009) Vital Forest Graphics. Published in Cooperation with FAO and UNFF. United Nations Environmental Programme, Nairobi.

UNIDO 1972. Guidelines for Project Evaluation. United Nations, New York.

Van Oosten, C. (2000) Activities related to poplar and willow cultivation and utilization in Canada 1996-1999. Report to the 21st session of the International Poplar Commission, Portland, Oregon, USA, 24-28 September 2000. Nanaimo, British Columbia, Canada, SilviConsult Woody Crops Technology Inc.

Vidal, C., Becquey, J. (2008) Le mélange peuplier-noyer est-il é economiquement intéresant? Institut pour le Développement Forestier - Forêt Entreprise, 178: 31-36.

Vietto, L., Nervo, G., Facciotto, G., Chiarabaglio, P.M., Coaloa, D. (2011) Activities for sustainable poplar plantations management in Italy. Actas del Tercer Congreso Internacional de las Salicáceas en Argentina 'Los álamos y los sauces junto al paisaje y el desarrollo productivo de la Patagonia' Neuquen, Argentina 16-19 March 2011.

Weber, N. (2005) Afforestation in Europe: lessons learned challenges remaining. In: Stanturf, J.A., Madsen, P. (Eds.), Restoration of Boreal and Temperate Forests. CRC Press, Boca Raton, pp. 121–135.

Wegner, J.E. (2012) Forestry economics: a managerial approach. Routledge, New York.

World Bank (2018) Gini Index. URL: https://data.worldbank.org/indicator/si.pov.gini. [Accessed August 2018]

Wunder, S. (2005). Payments for environmental services: some nuts and bolts. Center for International Forestry Research, Bogor.

WWF/IIASA (2012) Living Forests Report. Gland, Switzerland.

Zhu, K., Woodall, C.W., Clark, J.S. (2012) Failure to migrate: lack of tree range expansion in response to climate change. Glob Chang Biol 18(3):1042–1105. doi: 10.1111/j.1365-2486.2011.02571.x

Zinkhan, F.C., Cubbage, F.W. (2003) Financial analysis of timber investments. In: Sills EO, Abt KL (eds) Forests in a market economy. Kluwer Academic Publishers, Netherlands, pp 77–95.

Zinkhan, F.C., Sizemore, W.R., Mason, G.H., Ebner, T.J. (1992) Timberland investments: a portfolio perspective 1992 pp.208. ISBN: 0881922188. Portland.

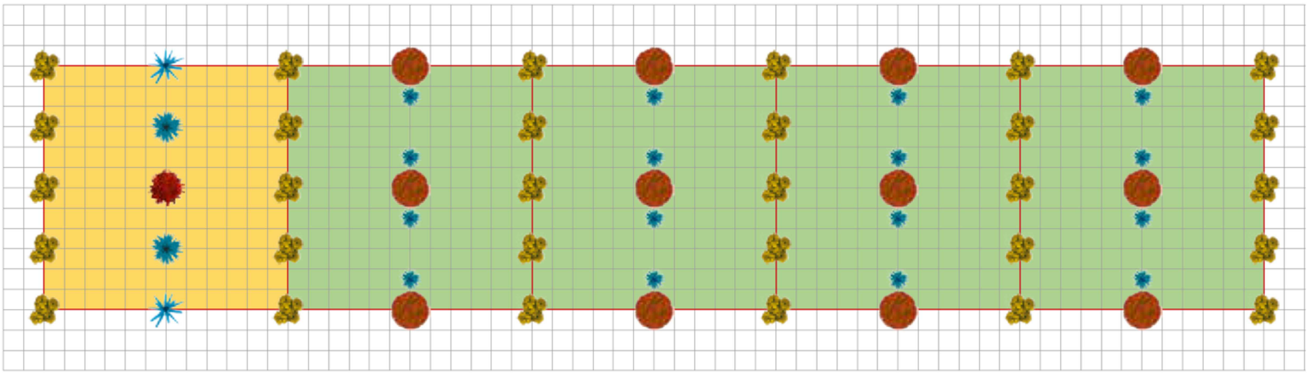
Annex 1

Supplementary material of Paper I

Annex 1.1 – Graphical representation of the polycyclic plantations planting schemes

Note: *Background with different colour mark the plantations blocks with main tree species with different rotations. Any square represents 1m^2.*

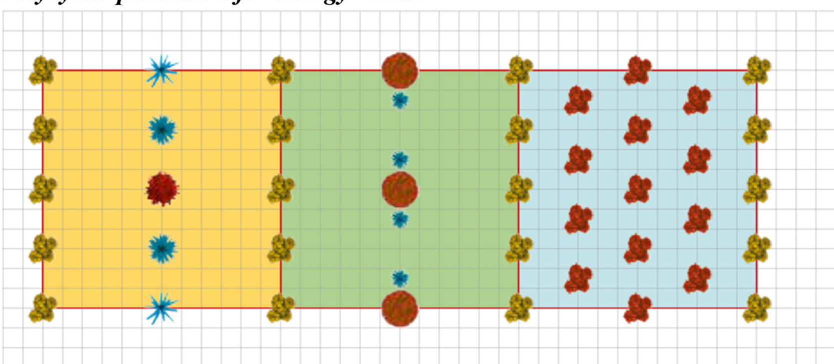
Polycyclic plantation for plywood model



Where:

- *Juglans regia* [28 trees/ha*]
- *Populus x canadensis* I-214 clone [111 trees/ha]
- *Platanus x acerifolia* [278 trees/ha]
- Auxiliary tree [14 trees/ha]
- Auxiliary shrub [250 plants/ha]

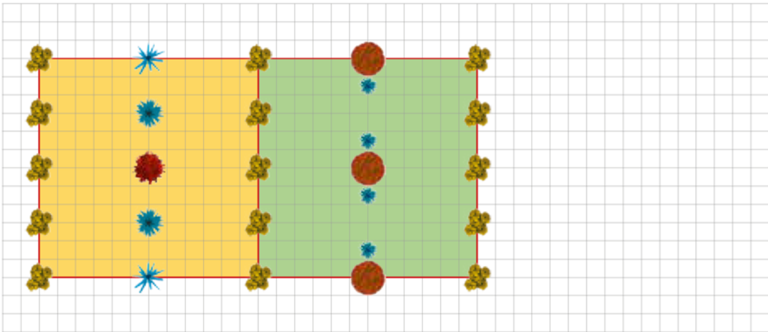
Polycyclic plantation for energy model



Where:

- *Juglans regia* [46 trees/ha*]
- *Populus x canadensis* I-214 clone [46 trees/ha]
- *Platanus x acerifolia* (with a dual role) [276 trees/ha]
- *Platanus x acerifolia* [276 trees/ha]
- Auxiliary tree [23 trees/ha]
- Auxiliary shrub [138 trees/ha]

Polycyclic plantation for sawn logs model



Where:

Juglans regia [69 trees/ha*]

Populus x canadensis I-214 clone [69 trees/ha]

Platanus x acerifolia [278 trees/ha]

Auxiliary tree [35 trees/ha]

Auxiliary shrub [208 trees/ha]

** 'double-planting' technique, meaning to plant two seedling at 40cm distance the one to the other with a selection at the 2nd-3rd year.*

Source: own elaboration

Annex 1.2 – Unitary cost of timber plantations management operations

Operation	EUR/tree		EUR/hectare	
	min	max	min	max
Soil fertilization (600kg/ha of NPK 8/24/24)			142.00	147.00
Ploughing			180.00	250.00
Harrowing			33.00	66.00
Soil hydraulic preparation			50.00	100.00
Planting scheme marking			58.00	116.00
Planting hole digging for main trees	0.21	0.42		
Planting hole digging for auxiliary trees and shrubs	0.15	0.30		
Seedlings of *Juglans regia*	1.20	2.20		
Seedlings of *Populus x canadensis* I-214 clone	2.50	3.62		
Seedlings of *Platanus x acerifolia*	1.00	1.80		
Seedlings trasport and planting	0.52	0.77		
Seedlings of auxiliary trees and shrubs	0.90	1.50		
Bamboo poles (purchase and installation)	0.35	0.65		
Shelters (purchase and installation)	2.00	3.00		
Hole covering with sand (purchase and installation)	0.52	0.77		
Localized irrigation (tractor with water tank)	0.15	0.30		
Phytosanitary treatment against *Cryptorrhynchus lapathi*	0.21	0.29		
Phytosanitary treatment trunk and canopy	0.21	0.29		
Localized fertilization (150kg/ha of ammonium nitrate)	0.12	0.15		
Weed control	0.12	0.15		
Pruning of walnut at year 2° and 3°	0.30	0.45		
Pruning of walnut at year 4°	0.40	0.55		
Pruning of walnut at year 5° and 6°	0.50	0.70		
Selection of one of the double-planted trees (walnut)	0.40	0.60		
Pruning of poplar at year 2°	0.45	0.60		
Pruning of poplar at year 3° and 4°	0.60	0.80		
Pruning of poplar at year 5°	0.80	1.00		
Cleaning from residues			33.00	49.00
Stumps removal			214.00	272.00
Final ploughing			46.00	52.00

Note: *Data provided by AALSEA and refer to 2016. VAT included.*

Annex 1.3 – Summary of input data on productivity for different products and assortments from plantations and agricultural crops

Type	Variable	Product	Unit	Value	Note	Source
Agricultural crops	high productivity	maize silage	t/ha	60.0	-	Trestini & Bolzonella 2015
	low productivity		t/ha	50.0	-	
	high productivity	maize grain	t/ha	14.0	-	
	low productivity		t/ha	11.5	-	
	average productivity	soy	t/ha	3.5	-	
Poplar	poplar DBH (Diameter Breast Height)		cm	32	DBH at 1.3 m high	Buresti Lattes *et al.*, 2015
	poplar volume	plywood veneer	m^3	0.72	average value derived from a test on 10 trees of diameter 32.1 (±0.5 cm). Three were felled, sized and peeled	Cielo *et al.*, 2002; Chiarabaglio and Coaloa 2002
	poplar weight	paper	t	0.173	as 20% of the poplar volume	
	poplar weight	chipwood	t	0.259	as 30% of the total poplar volume	
Polycyclic plantations	poplar DBH		cm	45	DBH at 1.3 m high	Buresti Lattes *et al.*, 2015
	poplar length		cm	728	-	Castro *et al.*, 2013
	poplar volume	plywood and veneer logs	m^3	1.16	average value derived from a test on 6 trees of diameter 45 (±0,5 cm). Three were felled, sized and peeled.	Buresti Lattes *et al.*, 2015
	poplar weight	paper	t	0.259	as 16% of the poplar volume. The percentage is derived from measures over 900 poplar trees in plantation managed by AALSEA	AALSEA
	poplar weight	chipwood	t	0.551	as 34% of the poplar volume. The percentage is derived from measures over 900 poplar trees in plantation managed by AALSEA	AALSEA
	Plane DBH		cm	20	-	AALSEA
	Plane length		cm	400	-	
	Plane weight	firewood	t	0.075	value measured for the first cycle on trees located at 2 m distance. Each tree weight 70-80 kg. From the second cycle the weight is doubled at 150kg/tree	
	Plane density		Kg/m^3	560	average dried weight	www.wood-database.com
Poplar, polycyclic plantations **and walnut**	poplar density		Kg/m^3	700	on fresh weight	Buresti Lattes *et al.* (in press)
	walnut DBH		cm	40	DBH at 1.3 m high	
	walnut length		cm	300	-	
	walnut volume	sawn logs	m^3	0.38	-	
	walnut density		Kg/m^3	750	on fresh weight	
	walnut weight	chipwood	t	0.424	on a conservative base is estimated that all stem and branches above sawn logs lumber is used for chipwood. The volume is estimated at 1.5 times the sawn logs timber.	

Table 1.4 – Cash flows for the 20 timber plantations models

Model		Flow	Year 0	1	2	3	5	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Walnut	WAMIN	Outflow	-906	-129	-192	-162	-139	-169	-116	-66	-66	-33	-33	-33	-33	-33	-33	-33	0	0	0	0	-293							
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,734							
	WAMAX	Outflow	-1,413	-219	-322	-277	-229	-274	-186	-116	-116	-58	-58	-58	-58	-58	-58	-58	0	0	0	0	-373							
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,734							
	WAHMIN	Outflow	-906	-129	-192	-162	-139	-169	-116	-66	-66	-33	-33	-33	-33	-33	-33	-33	0	0	0	0	0	0	0	0	0	0	0	-293
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,734
	WAHMAX	Outflow	-1,413	-219	-322	-277	-229	-274	-186	-116	-116	-58	-58	-58	-58	-58	-58	-58	0	0	0	0	0	0	0	0	0	0	0	-373
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,734
Hybrid poplar	PAMIN	Outflow	-1,547	-441	-524	-621	-621	-677	-421	-388	-355	-183	-293																	
		Inflow	0	0	0	0	0	0	0	0	0	0	12,931																	
	PAMAX	Outflow	-2,314	-644	-769	-977	-977	-1,033	-713	-655	-613	-277	-373																	
		Inflow	0	0	0	0	0	0	0	0	0	0	12,931																	
	PHMIN	Outflow	-1,547	-441	-524	-621	-621	-677	-421	-388	-355	-183	-183	-183	-293															
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	12,931															
	PHMAX	Outflow	-2,314	-644	-769	-977	-977	-1,033	-713	-655	-613	-277	-277	-277	-373															
		Inflow	0	0	0	0	0	0	0	0	0	0	0	0	12,931															
Polycyclic plantations – For plywood logs	PlyAMIN	Outflow	-1,993	-319	-226	-174	-144	-132	-7	0	0	0	-704	-97	-147	-67	-67	-89	-7	0	0	0	-247							
		Inflow	0	0	0	0	0	0	651	0	0	0	8,451	0	1,302	0	0	0	0	0	1,302	0	10,473							
	PlyAMAX	Outflow	-3,202	-498	-347	-275	-220	-183	-10	0	0	0	-1,021	-132	-199	-89	-89	-111	-10	0	0	0	-321							
		Inflow	0	0	0	0	0	0	651	0	0	0	8,451	0	1,302	0	0	0	0	0	1,302	0	10,473							
	PlyHMIN	Outflow	-1,993	-319	-226	-174	-144	-132	-7	0	0	0	0	0	-704	-97	-147	-67	-67	-89	-7	0	0	0	0	0	0	0	0	-247
		Inflow	0	0	0	0	0	0	0	651	0	0	0	0	8,515	0	1,302	0	0	0	0	0	0	1,302	0	0	8,409	0	0	4,819
	PlyHMAX	Outflow	-3,202	-498	-347	-275	-220	-183	-10	0	0	0	0	0	-1,021	-132	-199	-89	-89	-111	-10	0	0	0	0	0	0	0	0	-321
		Inflow	0	0	0	0	0	0	0	651	0	0	0	0	8,515	0	1,302	0	0	0	0	0	0	1,302	0	0	8,409	0	0	4,819
Polycyclic plantations – For energy	EneAMIN	Outflow	-1,993	-212	-173	-141	-112	-86	-12	0	0	0	-437	-40	-61	-28	-28	-37	-12	0	0	0	-247							
		Inflow	0	0	0	0	0	0	1,085	0	0	0	3,533	0	2,170	0	0	0	0	0	2,170	0	6,944							
	EneAMAX	Outflow	-3,270	-340	-277	-232	-179	-127	-16	0	0	0	-613	-55	-83	-37	-37	-46	-16	0	0	0	-321							
		Inflow	0	0	0	0	0	0	1,085	0	0	0	3,533	0	2,170	0	0	0	0	0	2,170	0	6,944							
	EneHMIN	Outflow	-1,993	-212	-173	-141	-112	-86	-12	0	0	0	0	0	-437	-40	-61	-28	-28	-37	-12	0	0	0	0	0	0	0	0	-247
		Inflow	0	0	0	0	0	0	0	1,085	0	0	0	0	3,577	0	2,170	0	0	0	0	0	0	2,170	0	0	3,504	0	0	5,403
	EneHMAX	Outflow	-3,270	-340	-277	-232	-179	-127	-16	0	0	0	0	0	-613	-55	-83	-37	-37	-46	-16	0	0	0	0	0	0	0	0	-321
		Inflow	0	0	0	0	0	0	0	1,085	0	0	0	0	3,577	0	2,170	0	0	0	0	0	0	2,170	0	0	3,504	0	0	5,403
Polycyclic plantations – For sawn logs	SawnAMIN	Outflow	-1,980	-268	-209	-161	-135	-113	-17	0	0	0	-532	-60	-92	-42	-42	-56	-17	0	0	0	-247							
		Inflow	0	0	0	0	0	0	649	0	0	0	5,296	0	1298	0	0	0	0	0	12,98	0	97,59							
	SawnAMAX	Outflow	-3,206	-423	-329	-261	-210	-162	-24	0	0	0	-758	-83	-124	-56	-56	-69	-24	0	0	0	-321							
		Inflow	0	0	0	0	0	0	649	0	0	0	5,296	0	1298	0	0	0	0	0	1,298	0	9,759							
	SawnHMIN	Outflow	-1,980	-268	-209	-161	-135	-113	-17	0	0	0	0	0	-532	-60	-92	-42	-42	-56	-17	0	0	0	0	0	0	0	0	-247
		Inflow	0	0	0	0	0	0	0	649	0	0	0	0	5,361	0	1,298	0	0	0	0	0	0	1,298	0	0	5,253	0	0	6,500
	SawnHMAX	Outflow	-3,206	-423	-329	-261	-210	-162	-24	0	0	0	0	0	-758	-83	-124	-56	-56	-69	-24	0	0	0	0	0	0	0	0	-321
		Inflow	0	0	0	0	0	0	0	649	0	0	0	0	5,361	0	1,298	0	0	0	0	0	0	1,298	0	0	5,253	0	0	6,500

Annex 1.5 – Results of the sensitivity analyses by EAV (EUR/ha) with a 3.5% discount rate*: alternative discount rates, subsidies and land use cost

Hypotesis		Mean agricultural crops	Mean walnut	Mean poplar	Mean polycyclic plantations
	Base case	457	166	213	423
Alternative discount rates	i=8%	470	-35	-68	163
	i=2%	453	248	316	514
	i=5%	461	92	115	334
Subsidies	Average subsidy contribution	796	494	354	1,018
	Emilia Romagna	796	488	300	838
	Friuli Venezia-Giulia	796	965	505	1,256
	Lombardy	796	606	432	928
	Veneto	796	719	432	1,050
Land-use cost	Land rent costs	-37	-325	-300	-68
	Land rent costs + average subsidy contribution	301	32	-108	556

**unless specified otherwise*

Source: own elaboration.

Annex 1.6 – Results of the sensitivity analyses by EAV (EUR/ha) with a 3.5% discount rate: timber stumpage prices variations

Hypotesis	Mean walnut	Mean poplar	Mean polycyclic plantations		
			for plywood logs	for energy	for sawn logs
+ 20% poplar stumpage price	166	382	659	382	460
- 20% poplar stumpage price	166	44	431	290	324
+ 30% walnut stumpage price	265	213	554	359	426
- 30% walnut stumpage price	67	213	527	313	358
+ 10% firewood price	166	213	554	360	406
- 10% firewood price	166	213	526	312	378

Annex 2

Supplementary material of Paper II

Annex 2.1 – Poplar timber stumpage prices (EUR/ton), 2001-2018 (nominal values)

Year	Chamber of Commerce of Alessandria		Chamber of Commerce of Mantua		Mean minimum	Mean maximum
	Min	Max	Min	Max		
2001	50.00	83.60	49.10	74.90	49.50	79.20
2002	48.00	77.10	49.00	74.10	48.50	75.60
2003	49.00	73.70	54.50	77.30	51.80	75.50
2004	47.40	70.50	54.60	79.00	51.00	74.80
2005	48.70	69.70	50.00	81.00	49.30	75.30
2006	49.40	73.20	50.20	81.20	49.80	77.20
2007	54.40	80.30	51.00	84.20	52.70	82.30
2008	60.10	87.20	51.00	87.90	55.50	87.60
2009	59.60	86.60	49.40	80.00	54.50	83.30
2010	57.20	78.20	53.40	84.20	55.30	81.20
2011	59.00	84.80	50.00	87.60	54.50	86.20
2012	58.00	83.40	41.80	82.20	49.90	82.80
2013	55.00	82.50	41.10	79.40	48.00	81.00
2014	55.00	84.80	45.00	83.80	50.00	84.30
2015	55.00	82.50	45.00	79.80	50.00	81.20
2016	55.00	80.00	47.20	81.80	51.10	80.90
2017	55.12	80.87	55.25	89.83	55.2	85.4
2018	60.00	95.00	60.00	95.00	60.0	95.0

Annex 2.2 - Changes in the NPV (EUR/ha) in relation to alternative discount rates, 2016

Discount rate	Cmin-Pmin	CMAX-Pmin	Cmin-PMAX	CMAX-PMAX
2%	1,598	-1,235	6,165	3,331
2.5%	1,311	-1,479	5,659	2,869
3%	1,041	-1,707	5,183	2,435
3.5%	786	-1,921	4,732	2,025
4%	547	-2,121	4,307	1,639
4.5%	321	-2,308	3,905	1,276
5%	109	-2,483	3,526	934
5.5%	-91	-2,647	3,167	612
6%	-280	-2,800	2,828	308
6.5%	-457	-2,943	2,508	22
7%	-624	-3,077	2,205	-248
7.5%	-781	-3,202	1,919	-502
8%	-930	-3,319	1,649	-741
8.5%	-1,069	-3,428	1,393	-966
9%	-1,200	-3,529	1,151	-1,178
9.5%	-1,324	-3,624	922	-1,378
10%	-1,440	-3,712	706	-1,566
10.5%	-1,549	-3,794	502	-1,743
11%	-1,652	-3,870	308	-1,910
11.5%	-1,749	-3,941	125	-2,067
12%	-1,840	-4,007	-48	-2,215

Annex 2.3 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the base case scenario, calculated ex-ante, 2001-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	2,325	8.2%	7,380	-460	n.a.	-1,461	7,344	15.1%	23,311	4,559	9.6%	14,471
2002	1,974	7.6%	6,264	-801	n.a.	-2,541	6,448	14.0%	20,465	3,674	8.6%	11,660
2003	2,305	8.2%	7,318	-462	n.a.	-1,466	6,133	13.7%	19,466	3,365	8.2%	10,682
2004	2,019	7.7%	6,410	-749	n.a.	-2,377	5,775	13.2%	18,330	3,007	7.8%	9,544
2005	1,572	6.8%	4,988	-1,214	n.a.	-3,852	5,608	12.9%	17,800	2,823	7.5%	8,960
2006	1,439	6.5%	4,568	-1,367	n.a.	-4,339	5,606	12.9%	17,795	2,800	7.5%	8,889
2007	1,728	7.1%	5,485	-1,079	n.a.	-3,423	6,148	13.5%	19,513	3,341	8.1%	10,605
2008	1,993	7.6%	6,326	-767	n.a.	-2,433	6,640	14.2%	21,075	3,880	8.8%	12,316
2009	1,745	7.1%	5,538	-1,030	n.a.	-3,270	5,890	13.2%	18,695	3,115	7.9%	9,888
2010	1,693	7.0%	5,373	-1,096	n.a.	-3,480	5,366	12.5%	17,033	2,577	7.2%	8,180
2011	1,424	6.5%	4,520	-1,338	n.a.	-4,246	5,798	13.1%	18,404	3,036	7.8%	9,638
2012	691	5.1%	2,193	-2,022	n.a.	-6,418	5,098	12.3%	16,182	2,385	7.0%	7,571
2013	413	4.5%	1,310	-2,280	n.a.	-7,238	4,773	12.0%	15,148	2,079	6.6%	6,600
2014	682	5.1%	2,166	-2,001	n.a.	-6,350	5,221	12.6%	16,571	2,538	7.3%	8,055
2015	679	5.1%	2,154	-2,009	n.a.	-6,378	4,803	12.0%	15,244	2,115	6.7%	6,712
2016	786	5.3%	2,496	-1,921	n.a.	-6,097	4,732	11.9%	15,021	2,025	6.5%	6,428

Annex 2.4 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the base case scenario, calculated ex-post, 2001-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	1,495	6.7%	4,746	-1270	n.a.	-4,031	5,869	13.4%	18,630	3,104	7.9%	9,853
2002	656	5.0%	2,082	-2108	n.a.	-6,691	5,063	12.3%	16,071	2299	6.9%	7,298
2003	331	4.3%	1,052	-2430	n.a.	-7,714	4,691	11.8%	14,890	1,930	6.4%	6,124
2004	572	4.8%	1,816	-2188	n.a.	-6,944	5,110	12.3%	16,221	2,351	6.9%	7,461
2005	566	4.8%	1,795	-2194	n.a.	-6,965	4,689	11.8%	14,885	1,930	6.4%	6,125
2006	707	5.1%	2,244	-2051	n.a.	-6,510	4,653	11.7%	14,768	1,895	6.3%	6,014
2007	1,202	6.1%	3,815	-1546	n.a.	-4,907	5,168	12.3%	16,405	2,421	7.0%	7,683
2008	1,900	7.4%	6,032	-832	n.a.	-2,640	6,520	14.1%	20,696	3,788	8.7%	12,024
2009	1,905	7.4%	6,048	-820	n.a.	-2,603	6,525	14.1%	20,712	3,800	8.7%	12,061
2010	1,907	7.4%	6,052	-813	n.a.	-2,579	6,527	14.0%	20,716	3,807	8.7%	12,085
2011	1,928	7.5%	6,118	-781	n.a.	-2,479	6,548	14.1%	20,783	3,839	8.8%	12,185
2012	1,953	7.6%	6,199	-747	n.a.	-2,379	6,573	14.2%	20,863	3,873	8.9%	12,294
2013	1,960	7.6%	6,220	-738	n.a.	-2,343	6,580	14.2%	20,884	3,882	8.9%	12,321
2014	1,961	7.6%	6,226	-737	n.a.	-2,339	6,581	14.2%	20,890	3,883	8.9%	12,325
2015	1,956	7.6%	6,207	-745	n.a.	-2,366	6,576	14.2%	20,871	3,875	8.9%	12,298
2016	1,935	7.6%	6,142	-772	n.a.	-2,451	6,555	14.1%	20,806	3,848	8.8%	12,213

Annex 2.5 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with public subsidies (a), calculated ex-ante, 2007-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	3,963	13.7%	12,578	1,699	7.1%	5,392	8,982	21.1%	28,510	6,718	14.6%	21,324
2002	3,619	13.0%	11,486	1,368	6.5%	4,342	8,093	20.0%	25,687	5,842	13.6%	18,543
2003	3,962	13.7%	12,575	1,720	7.2%	5,461	7,789	19.6%	24,723	5,548	13.2%	17,609
2004	3,690	13.2%	11,712	1,452	6.7%	4,607	7,446	19.2%	23,633	5,207	12.8%	16,528
2005	3,269	12.3%	10,375	1,021	5.8%	3,241	7,305	18.9%	23,187	5,058	12.5%	16,053
2006	3,169	12.0%	10,059	910	5.5%	2,889	7,336	18.9%	23,286	5,077	12.5%	16,116
2007	2,948	10.6%	9,359	527	4.6%	1,674	7,368	17.4%	23,387	4,947	11.4%	15,702
2008	3,200	11.2%	10,158	822	5.2%	2,609	7,847	18.1%	24,908	5,469	12.2%	17,358
2009	2,965	10.7%	9,412	576	4.7%	1,827	7,111	17.2%	22,570	4,721	11.2%	14,984
2010	2,931	10.6%	9,303	141	3.8%	448	6,605	16.5%	20,963	3,815	9.6%	12,109
2011	2,659	10.1%	8,440	286	4.1%	907	7,033	17.1%	22,324	4,660	11.1%	14,791
2012	1,910	8.6%	6,063	-419	n.a.	-1,331	6,318	16.3%	20,052	3,988	10.3%	12,658
2013	1,625	8.0%	5,158	-687	n.a.	-2,180	5,985	15.9%	18,996	3,673	9.9%	11,658
2014	1,717	8.0%	5,449	-641	n.a.	-2,035	6,255	15.9%	19,854	3,897	10.0%	12,371
2015	1,714	8.0%	5,441	-648	n.a.	-2,058	5,838	15.3%	18,530	3,476	9.5%	11,032
2016	1,834	8.3%	5,821	-544	n.a.	-1,727	5,780	15.1%	18,345	3,402	9.3%	10,797

Annex 2.6 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with public subsidies (a), calculated ex-post, 2007-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	3,133	12.1%	9,944	889	5.5%	2,822	7,507	19.3%	23,828	5,263	12.8%	16,706
2002	2,301	10.2%	7,304	60	3.6%	191	6,709	18.2%	21,293	4,468	11.7%	14,180
2003	1,988	9.4%	6,309	-248	n.a.	-787	6,348	17.6%	20,148	4,112	11.2%	13,052
2004	2,243	10.1%	7,118	12	3.5%	40	6,781	18.3%	21,523	4,551	11.8%	14,445
2005	2,263	10.1%	7,182	41	3.6%	129	6,387	17.7%	20,272	4,164	11.3%	13,218
2006	2,437	10.5%	7,735	226	4.0%	717	6,383	17.7%	20,259	4,172	11.3%	13,242
2007	2,422	9.7%	7,689	60	3.6%	190	6,389	16.3%	20,279	4,026	10.3%	12,780
2008	3,108	11.1%	9,865	757	5.0%	2,402	7,728	18.0%	24,529	5,377	12.1%	17,066
2009	3,126	11.1%	9,923	785	5.1%	2,493	7,746	18.1%	24,587	5,405	12.1%	17,157
2010	3,145	11.2%	9,982	815	5.2%	2,588	7,765	18.1%	24,646	5,436	12.2%	17,253
2011	3,163	11.2%	10,038	842	5.2%	2,674	7,783	18.2%	24,703	5,463	12.3%	17,338
2012	3,172	11.3%	10,069	856	5.3%	2,718	7,792	18.3%	24,734	5,476	12.3%	17,382
2013	3,172	11.3%	10,068	855	5.3%	2,714	7,792	18.3%	24,732	5,475	12.3%	17,378
2014	2,996	10.7%	9,509	623	4.8%	1,977	7,616	17.6%	24,173	5,243	11.8%	16,641
2015	2,846	10.2%	9,033	616	4.7%	1,954	7,466	17.0%	23,697	5,236	11.7%	16,618
2016	2,982	10.6%	9,467	604	4.7%	1,918	7,603	17.5%	24,131	5,224	11.7%	16,582

Annex 2.7 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with land rent cost (b), calculated ex-ante, 2001-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	-1,533	n.a.	-4,866	-4,318	n.a.	-13,707	3,486	8.5%	11,065	701	4.4%	2,225
2002	-1,687	n.a.	-5,356	-4,461	n.a.	-14,161	2,787	7.6%	8,846	13	3.5%	40
2003	-1,065	n.a.	-3,380	-3,832	n.a.	-12,164	2,762	7.7%	8,768	-5	n.a.	-16
2004	-1,287	n.a.	-4,086	-4,056	n.a.	-12,872	2,468	7.3%	7,835	-300	n.a.	-952
2005	-1,729	n.a.	-5,487	-4,514	n.a.	-14,327	2,308	7.1%	7,325	-477	n.a.	-1,515
2006	-1,385	n.a.	-4,395	-4,191	n.a.	-13,302	2,783	7.8%	8,832	-23	n.a.	-74
2007	-1,131	n.a.	-3,591	-3,938	n.a.	-12,499	3,288	8.5%	10,437	482	4.1%	1,529
2008	-742	n.a.	-2,354	-3,501	n.a.	-11,113	3,905	9.3%	12,396	1,146	5.0%	3,637
2009	-952	n.a.	-3,021	-3,727	n.a.	-11,828	3,194	8.4%	10,136	419	4.1%	1,329
2010	-1,095	n.a.	-3,476	-3,884	n.a.	-12,329	2,578	7.5%	8,184	-211	n.a.	-669
2011	-1,352	n.a.	-4,290	-4,114	n.a.	-13,057	3,023	8.2%	9,594	261	3.9%	827
2012	-2,070	n.a.	-6,569	-4,783	n.a.	-15,181	2,337	7.3%	7,419	-375	n.a.	-1,192
2013	-2,210	n.a.	-7,014	-4,903	n.a.	-15,561	2,150	7.1%	6,825	-543	n.a.	-1,723
2014	-2,500	n.a.	-7,934	-5,183	n.a.	-16,450	2,039	6.8%	6,471	-644	n.a.	-2,045
2015	-2,141	n.a.	-6,795	-4,829	n.a.	-15,327	1,983	6.8%	6,295	-705	n.a.	-2,237
2016	-2,124	n.a.	-6,743	-4,832	n.a.	-15,336	1,822	6.5%	5,782	-886	n.a.	-2,811

Annex 2.8 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with land rent cost (b), calculated ex-post, 2001-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	-2,041	n.a.	-6,477	-4,806	n.a.	-15,254	2,333	7.1%	7,407	-432	n.a.	-1,370
2002	-2,713	n.a.	-8,610	-5,477	n.a.	-17,383	1,695	6.2%	5,379	-1,069	n.a.	-3,395
2003	-2,781	n.a.	-8,828	-5,543	n.a.	-17,594	1,578	6.1%	5,010	-1,183	n.a.	-3,755
2004	-2,481	n.a.	-7,874	-5,241	n.a.	-16,634	2,058	6.8%	6,531	-702	n.a.	-2,229
2005	-2,477	n.a.	-7,863	-5,237	n.a.	-16,623	1,647	6.2%	5,227	-1,113	n.a.	-3,533
2006	-1,905	n.a.	-6,047	-4,663	n.a.	-14,801	2,041	6.8%	6,477	-717	n.a.	-2,277
2007	-1,450	n.a.	-4,601	-4,198	n.a.	-13,323	2,517	7.5%	7,989	-231	n.a.	-733
2008	-681	n.a.	-2,162	-3,413	n.a.	-10,834	3,939	9.4%	12,502	1,207	5.1%	3,830
2009	-633	n.a.	-2,010	-3,359	n.a.	-10,662	3,987	9.5%	12,654	1,261	5.2%	4,003
2010	-735	n.a.	-2,332	-3,454	n.a.	-10,963	3,885	9.4%	12,333	1,166	5.0%	3,701
2011	-751	n.a.	-2,385	-3,460	n.a.	-10,982	3,869	9.3%	12,279	1,160	5.0%	3,682
2012	-780	n.a.	-2,474	-3,479	n.a.	-11,043	3,840	9.3%	12,190	1,141	5.0%	3,621
2013	-661	n.a.	-2,098	-3,359	n.a.	-10,661	3,959	9.5%	12,566	1,261	5.2%	4,003
2014	-1,225	n.a.	-3,887	-3,923	n.a.	-12,451	3,395	8.6%	10,777	697	4.4%	2,213
2015	-856	n.a.	-2,718	-3,557	n.a.	-11,292	3,764	9.2%	11,946	1,063	4.9%	3,373
2016	-976	n.a.	-3,097	-3,683	n.a.	-11,690	3,644	9.0%	11,567	937	4.7%	2,974

Annex 2.9 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with opportunity-cost (c), calculated ex-ante, 2008-2015 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2008	620	4.7%	1,967	-2,140	n.a.	-6,792	5,267	11.7%	16,716	2,507	6.8%	7,957
2009	2,337	8.4%	7,417	-438	n.a.	-1,390	6,482	14.4%	20,574	3,707	8.8%	11,767
2010	-1,024	n.a.	-3,249	-3,813	n.a.	-12,102	2,650	7.7%	8,412	-139	n.a.	-441
2011	-1,996	n.a.	-6,335	-4,758	n.a.	-15,102	2,378	7.1%	7,549	-384	n.a.	-1,218
2012	-2,957	n.a.	-9,385	-5,670	n.a.	-17,996	1,450	5.8%	4,604	-1,263	n.a.	-4,007
2013	-1,604	n.a.	-5,092	-4,297	n.a.	-13,640	2,756	8.1%	8,747	63	3.6%	199
2014	-1,265	n.a.	-4,016	-3,948	n.a.	-12,531	3,273	8.9%	10,390	590	4.3%	1,874
2015	-263	n.a.	-835	-2,951	n.a.	-9,367	3,861	10.2%	12,254	1,173	5.2%	3,723

Annex 2.10 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with opportunity-cost (c), calculated ex-post, 2008-2015 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2008	155	3.8%	492	-2,577	n.a.	-8,181	4,775	10.9%	15,156	2,043	6.2%	6,484
2009	184	3.9%	584	-2,542	n.a.	-8,067	4,804	10.9%	15,248	2,078	6.2%	6,597
2010	-26	n.a.	-84	-2,746	n.a.	-8,715	4,594	10.3%	14,581	1,874	5.9%	5,950
2011	174	3.8%	551	-2,535	n.a.	-8,046	4,794	10.6%	15,215	2,085	6.2%	6,618
2012	469	4.4%	1,488	-2,231	n.a.	-7,081	5,089	11.2%	16,152	2,389	6.6%	7,583
2013	782	5.1%	2,482	-1,916	n.a.	-6,081	5,402	11.9%	17,146	2,704	7.1%	8,583
2014	905	5.3%	2,872	-1,793	n.a.	-5,692	5,525	12.2%	17,537	2,827	7.3%	8,972
2015	1,016	5.6%	3,226	-1,685	n.a.	-5,347	5,636	12.4%	17,890	2,935	7.5%	9,317

Annex 2.11 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with public subsidies and land rent cost (d), calculated ex-ante, 2007-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	105	3.7%	332	-2,159	n.a.	-6,854	5,124	12.1%	16,263	2,860	7.7%	9,078
2002	-42	n.a.	-134	-2,293	n.a.	-7,278	4,432	11.3%	14,068	2,181	6.9%	6,923
2003	591	4.8%	1877	-1,650	n.a.	-5,237	4,419	11.5%	14,025	2,177	6.9%	6,911
2004	383	4.4%	1216	-1,855	n.a.	-5,888	4,139	11.1%	13,137	1,901	6.6%	6,032
2005	-31	n.a.	-100	-2,279	n.a.	-7,234	4,005	10.9%	12,712	1,757	6.3%	5,578
2006	345	4.3%	1,096	-1,914	n.a.	-6,074	4,513	12.0%	14,323	2,254	7.2%	7,153
2007	89	3.7%	283	-2,332	n.a.	-7,402	4,509	11.2%	14,311	2,088	6.6%	6,626
2008	466	4.5%	1,479	-1,913	n.a.	-6,071	5,113	12.2%	16,228	2,734	7.5%	8,679
2009	269	4.1%	854	-2,121	n.a.	-6,732	4,414	11.2%	14,011	2,024	6.6%	6,426
2010	143	3.8%	454	-2,256	n.a.	-7,162	3,817	10.3%	12,114	1,417	5.7%	4,499
2011	-117	n.a.	-370	-2,490	n.a.	-7,904	4,258	11.0%	13,514	1,884	6.4%	5,980
2012	-850	n.a.	-2,699	-3,180	n.a.	-10,093	3,557	10.0%	11,290	1,227	5.5%	3,896
2013	-997	n.a.	-3,165	-3,309	n.a.	-10,504	3,363	9.8%	10,673	1,050	5.2%	3,334
2014	-1,465	n.a.	-4,651	-3,823	n.a.	-12,135	3,073	9.0%	9,754	715	4.6%	2,271
2015	-1,105	n.a.	-3,508	-3,468	n.a.	-11,007	3,019	9.0%	9,581	656	4.6%	2,083
2016	-1,077	n.a.	-3,418	-3,455	n.a.	-10,967	2,869	8.7%	9,106	491	4.3%	1,558

Annex 2.12 – NPV (EUR/ha), IRR and LEV (EUR/ha) in the sensitivity scenario with public subsidies and land rent cost (d), calculated ex-post, 2007-2016 (real values)

Year	Cmin-Pmin			CMAX-Pmin			Cmin-PMAX			CMAX-PMAX		
	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV	NPV	IRR	LEV
2001	-403	n.a.	-1,279	-2,647	n.a.	-8,401	3,971	10.7%	12,605	1,727	6.2%	5,483
2002	-1,067	n.a.	-3,388	-3,308	n.a.	-10,501	3,340	9.8%	10,601	1,099	5.3%	3,488
2003	-1,125	n.a.	-3,570	-3,361	n.a.	-10,667	3,235	9.8%	10,268	999	5.2%	3,172
2004	-810	n.a.	-2,571	-3,040	n.a.	-9,650	3,728	10.6%	11,834	1,498	6.0%	4,755
2005	-780	n.a.	-2,476	-3,002	n.a.	-9,529	3,344	10.0%	10,614	1,122	5.4%	3,560
2006	-175	n.a.	-556	-2,386	n.a.	-7,574	3,771	11.0%	11,969	1,560	6.2%	4,951
2007	-229	n.a.	-728	-2,592	n.a.	-8,226	3,737	10.3%	11,863	1,375	5.7%	4,364
2008	526	4.7%	1,670	-1,825	n.a.	-5,793	5,146	12.3%	16,335	2,795	7.7%	8,872
2009	587	4.8%	1,864	-1,753	n.a.	-5,565	5,207	12.4%	16,528	2,867	7.8%	9,099
2010	504	4.6%	1,598	-1,826	n.a.	-5,795	5,124	12.3%	16,262	2,794	7.7%	8,869
2011	484	4.6%	1,535	-1,837	n.a.	-5,829	5,104	12.3%	16,199	2,784	7.7%	8,835
2012	440	4.5%	1,396	-1,876	n.a.	-5,956	5,060	12.2%	16,061	2,744	7.6%	8,709
2013	551	4.7%	1,750	-1,765	n.a.	-5,604	5,171	12.4%	16,414	2,855	7.8%	9,060
2014	-190	n.a.	-603	-2,563	n.a.	-8,136	4,430	10.9%	14,061	2,057	6.5%	6,528

2015	179	3.9%	569	-2,196	n.a.	-6,972	4,799	11.6%	15,233	2,424	7.1%	7,693
2016	72	3.7%	228	-2,306	n.a.	-7,321	4,692	11.4%	14,892	2,314	6.9%	7,343

Annex 3

Supplementary material of Paper III

Annex 3.1 – Silvicultural regimes used in the study

***Note**: numbers refer to the times the operation is carried out annually (valid for the following tables as well)*

Hybrid poplar in northern Italy

Operations	Year											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Ploughing, ripping and harrowing	1											*Land recovery*
Seedlings purchase	1											
Mark, dig and planting	1											
Disk harrowing		3	3	3	2	2	2	1	1			
Phito. treat. *Marssonina brunnea*		2	2	2	2	2						
Phito. treat. *Saperda carcharias L*			1	1	1							
Phito. treat. *Cryptorhynchus lapathi*			1	1								
Phito. treat. *Phloeomyzus passerinii*							1	1	1	1		
Weed control		1	1	1	1	1	1	1	1	1		
Fertilization		1	1	1	1	1						
Pruning		1	1	1	1	1						
Irrigation	1	1	1	1	1	1	1	1	1	1		
Stumps removal and trituration											1	
Standing trees sale											1	

Hybrid poplar in Navarre

Operations	Year													
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Ploughing and harrowing	1													*Land recovery*
Land levelling	1													
Marking	1													
Seedlings purchase	1													
Dig and plant	1													
Disk harrowing		2	2	2	2	1	1							
Weed control		1												
Pruning		1	1	1	1	1								
Irrigation		1	1	1	1	1	1	1	1	1	1	1		
Stumps removal and trituration													1	
Standing trees sale													1	

Hybrid poplar in Castile and León

Operations	Year								
	0	*1*	*2*	*3*	*4*	*5*	*6*	*13*	*14*
Ploughing and harrowing	1								*Land recovery*
Marking	1								
Seedlings purchase	1								
Dig and plant	1								
Disk harrowing		2	2	2	2	1	1		
Weed control		1							
Pruning			1	1	1	1	1		
Stumps removal and trituration								1	
Standing trees sale								1	

Eucalyptus in Portugal

Operation	Year									
	Planted rotation						Coppice rotation			
	0	*1*	*2*	*3*	*4*	*12*	*14*	*16*	*17*	*24*
Stumps trituration and cleaning	1									
Heaping and ridging	1									
Harrowing	1									
Ripping	1									
Seedlings purchase	1									
Mark, dig and plant	1									
Manual fertilization	1									
Beating-up (15%)		1								
Fertilization in lines		1					1			
Weed control			1							
Fertilization total				1				1		
Weed control					1				1	
Thinning (1.6 shoots per stump)							1			
Standing trees sale						1				1

Maritime pine in Portugal

Operations	Year							
	0	*1*	*3*	*6*	*10*	*15*	*25*	*35*
Harrowing	1							
Ripping	1							
Seedlings purchase	1							
Mark, dig and planting	1							
Manual fertilization	1							
Beating up (15%)		1						
Weed control		1	1	1	1			
Pruning					1	1		
Com. thinning (Wilson factor=0.25)						1	1	
Final cut								1

Radiata pine in the Basque Country

Operations	Year							
	0	*1*	*3*	*8*	*12*	*18*	*23*	*35*
Cleaning pre-existing vegetation	1							
Soil preparation	1							
Seedlings purchase	1							
Mark, dig and plant	1							
Beating-up (15%)		1						
Weed control		1	1	1	1			
Fertilization		1			1			
Pruning				1	1			
Pre-commercial thinning (15%)				1				
Com. thinnng (20%)						1	1	
Final cut								1

Annex 3.2 – GLOBOLUS model inputs

Region	Site index range	Productivity	Municipality	Days of rain	Elevation (m above sea level)
North-Atlantic	16, 19, 22, 25, 28	average productivity site	Viana do Castelo	113	150
North-central	14, 17, 20, 23, 24	low productivity site	Amarante	87	350
		average productivity site	Viseu	102	450
		high productivity site	Braga	113	330
Centre-Atlantic	13, 16, 19, 22, 25	low productivity site	Cataxo	63	50
		average productivity site	Ferreira do Zezere	90	264
		high productivity site	Batalha	113	250
Tagus valley	11, 14, 17, 20, 23	low productivity site	Mora	88	150

	average productivity site	Provença-a-Nova	73	429.5
	high productivity site	Gavião	63	234.5

Annex 3.3 – PINASTER model inputs

Region	**Site index range**
North-Atlantic	22, 24, 25, 27, 29
North-**central**	18, 20, 22, 25, 28
Centre-Atlantic	15, 17, 20, 24, 26
Tagus valley	19, 20, 22, 25, 26
Northern interior	16, 18, 20, 22, 24

Annex 3.4 – Yield data for eucalyptus in Portugal (GLOBOLUS model outcomes elaborated)

Region	**Site productivity**	**Pulpwood (m³/ha)**	
		Planted rotation (year 12)	**Coppice rotation (year 24)**
North-Atlantic	low productivity site	98	174
	average productivity site	213	328
	high productivity site	361	513
North-central	low productivity site	14	68
	average productivity site	151	247
	high productivity site	239	367
Centre-Atlantic	low productivity site	60	104
	average productivity site	143	231
	high productivity site	267	401
Tagus Valley	low productivity site	11	41
	average productivity site	105	175
	high productivity site	204	316

Annex 3.5 – Yield data for maritime pine in Portugal (PINASTER model outcomes elaborated)

Region	**Site productivity**	**Operation**	**Fuel (m³/ha)**	**Sawn wood (m³/ha)**
North-Atlantic	low productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	28	0
		final harvest	110	115
	average productivity site	first thinning (year 15)	19	0
		second thinning (year 25)	28	15
		final harvest	119	210
	high productivity site	first thinning (year 15)	28	0
		second thinning (year 25)	34	21
		final harvest	138	309
North-central	low productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	0	0
		final harvest	108	44
	average productivity site	first thinning (year 15)	19	0
		second thinning (year 25)	26	12
		final harvest	112	156
	high productivity site	first thinning (year 15)	27	0
		second thinning (year 25)	33	20
		final harvest	133	290
Centre-Atlantic	low productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	0	0
		final harvest	99	26
	average productivity site	first thinning (year 15)	17	0
		second thinning (year 25)	25	9
		final harvest	97	97
	high productivity site	first thinning (year 15)	17	0
		second thinning (year 25)	27	15
		final harvest	112	226

Tagus Valley	low productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	0	0
		final harvest	108	44
	average productivity site	first thinning (year 15)	17	0
		second thinning (year 25)	25	13
		final harvest	109	130
	high productivity site	first thinning (year 15)	17	0
		second thinning (year 25)	27	15
		final harvest	112	226
Northern interior	low productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	0	0
		final harvest	108	44
	average productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	25	12
		final harvest	104	87
	high productivity site	first thinning (year 15)	0	0
		second thinning (year 25)	27	12
		final harvest	118	179

Annex 3.6 – Investment costs data

Hybrid poplar in northern Italy

Category	**Operation**	**Unitary cost (EUR/ha)**		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
		Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment	Ploughing	152	222	1	152	222			
	Ripping	61	71	1	61	71			
	Harrowing	40	61	1	40	61			
	Seedlings	842	1,067	1	842	1,067			
	Mark, dig and planting	631	853	1	631	853			
	Irrigation	81	101	1	81	101			
Management	Disk harrowing	51	76	17	859	1,288			
	Phito. treat. *Marssonina b.*	85	113	10	848	1.131			
	Phito. treat. *Saperda c.L*	61	71	3	182	212			
	Phito. treat. *Cryptorhynchus l.*	86	96	2	172	192			
	Phito. treat. *Phloeomyzus p.*	71	91	4	283	364			
	Weed control	20	25	9	182	227			
	Fertilization	81	131	5	404	657			
	Pruning	131	222	5	657	1,111			
	Irrigation	111	202	9	1,000	1,818			
	Stumps trituration and cleaning	220	260	1	222	263			
Total establishment costs					1,807	2,375	27.3%	24.6%	
Total establishment costs					4,808	7,262	72.7%	75.4%	
Total					6,614	9,636	100%	100%	45.7%

Hybrid poplar in Castile and León

Category	**Operation**	**Unitary cost (EUR/ha)**		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
		Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment	Ploughing and harrowing	231	328	1	231	328			
	Mark	60	122	1	60	122			
	Seedlings	501	639	1	501	639			
	Dig and plant	1,200	1,600	1	1,200	1,600			

Management	Disk harrowing	80	120	10	800	1,200			
	Weeding	41	48	1	41	48			
	Pruning	220	300	5	1,100	1,200			
	Stumps removal and cleaning	800	1000	1	800	1,000			
Total establishment costs					1,991	2,689	42.1%	41.8%	
Total establishment costs					2,741	3,748	57.9%	58.2%	
Total					4,732	6,437	100%	100%	36.0%

Hybrid poplar in Navarre

		Unitary cost (EUR/ha)		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
Category	Operation	Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment	Ploughing and harrowing	231	328	1	231	328			
	Land levelling	200	600	1	200	600			
	Mark	60	122	1	60	122			
	Seedlings	445	584	1	445	584			
	Dig and plant	800	1,100	1	800	1,100			
Management	Disk harrowing	80	120	10	800	1,200			
	Weeding	41	48	1	41	48			
	Pruning	220	300	5	1,100	1,200			
	Irrigation	130	200	12	1,560	2,400			
	Stumps removal and cleaning	800	1000	1	800	1,000			
Total establishment costs					1,736	2,734	28.8%	30.7%	
Total establishment costs					4,301	6,148	71.2%	69.3%	
Total					6,037	8,882	100%	100%	47.1%

Eucalyptus in Portugal

Category	**Operation**	**Unitary cost (EUR/ha)**		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
		Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment	Stumps trituration and cleaning	646	776	1	646	776			
	Heaping and ridging	257	309	1	257	309			
	Harrowing	98	118	1	98	118			
	Ripping	463	555	1	463	555			
	Seedlings*	304	364	1	304	364			
	Mark, dig and planting	322	386	1	322	386			
	Manual fertilization*	162	194	1	162	194			
Management	Beating up (15%)	48	58	1	48	58			
	Fertilization in lines*	105	126	2	210	252			
	Weed control total	119	142	1	119	142			
	Fertilization total*	112	135	2	224	270			
	Weed control	266	313	2	522	626			
	Thinning	248	298	1	248	298			
	Mantainance costs	10	480	24	240	480			

Total establishment costs					2,252	2,702	58.7%	56%	
Total establishment costs					1,611	2,126	41.7%	44.0%	
Total					3,863	4,828	100%	100%	25.0%

Note: *CAOF ('Comissão de acompanhamento das Operações Florestais') operations reference: Stumps trituration and cleaning* ***(55)****; heaping and ridging* ***(4)****; harrowing* ***(43)****; ripping* ***(46)****; mark, dig and planting* ***(6)****; manual fertilization* ***(12)****; beating up* ***(8);*** *fertilization in lines* ***(36)****; weed control total* ***(42)****; fertilization total* ***(58)****; weed control* ***(39)****; thinning* ***(29);***

Maritime pine in Portugal

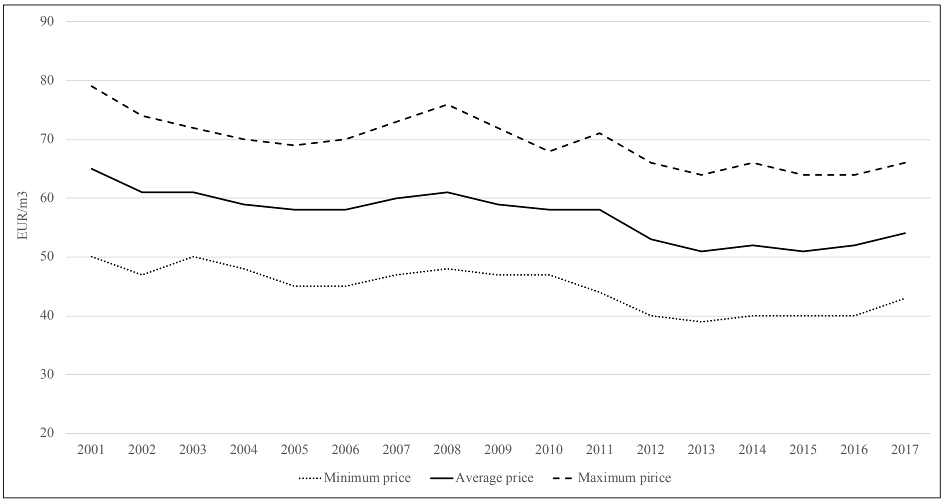
Category	**Operation**	**Unitary cost (EUR/ha)**		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
		Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment	Harrowing	98	147	1	98	147			
	Ripping	462	693	1	462	693			
	Seedlings*	269	269		269	269			
	Mark, dig and planting	484	581	1	484	581			
	Manual fertilization*	222	266	1	222	266			
Management	Beating up (15%)	73	87	1	73	87			
	Weed control	119	238	4	476	952			
	First pruning	644	773	1	644	773			
	Second pruning	594	713	1	594	713			
	General mainteinance costs	5	5	35	175	175			
Total establishment costs					1,535	1,956	44%	42%	
Total establishment costs					1,962	2,700	56%	58%	
Total					3,496	4,656	100%	100%	32.8%

Note: *CAOF ('Comissão de acompanhamento das Operações Florestais') operations reference: Harrowing* ***(43)****; ripping* ***(46)****; mark, dig and planting* ***(6)****; manual fertilization* ***(12)****; beating up* ***(8)****; weed control* ***(42)****; Pruning* ***(27)****.*

Radiata pine in the Basque Country

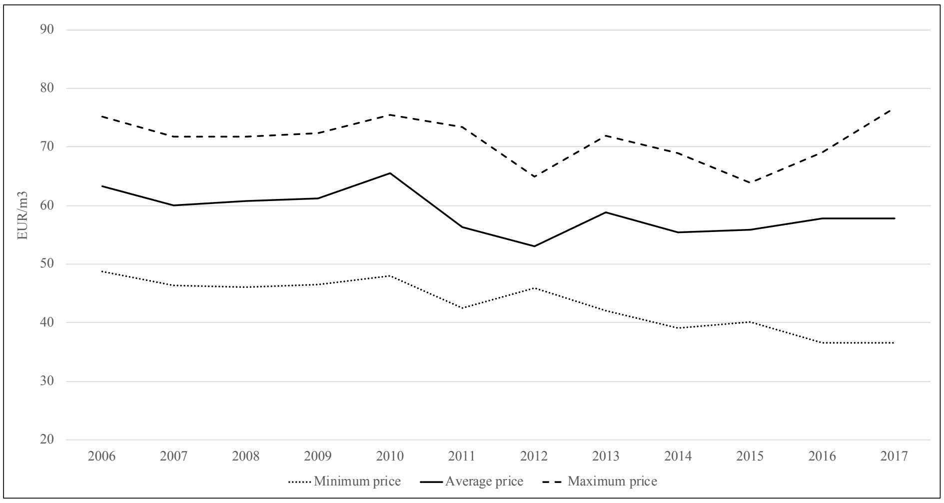
Category	**Operation**	**Unitary cost (EUR/ha)**		**Number of operations**	**Total cost (EUR/ha)**		**Incidence of total costs**		**Percentage difference baseline and higher costs**
		Baseline	Higher costs		Baseline	Higher costs	Baseline	Higher costs	
Establishment		2,100	2,500	1	2,100	2,500			
Management	beating up	205	205	1	205	205			
	weed control total	400	480	4	1600	1920			
	fertilization	160	160	2	320	320			
	pre-thinning	530	530	1	530	530			
	First pruning	505	655	1	505	655			
	Second pruning	505	655	1	505	655			
Total establishment costs					2,100	2,500	36.4%	36.8%	
Total establishment costs					3,665	4,285	63.4%	63.2%	
Total					5,765	6,785	100%	100%	17.3%

Annex 3.7 – Hybrid poplar stumpage prices in the northern Italy, 2001-2017 (real values)



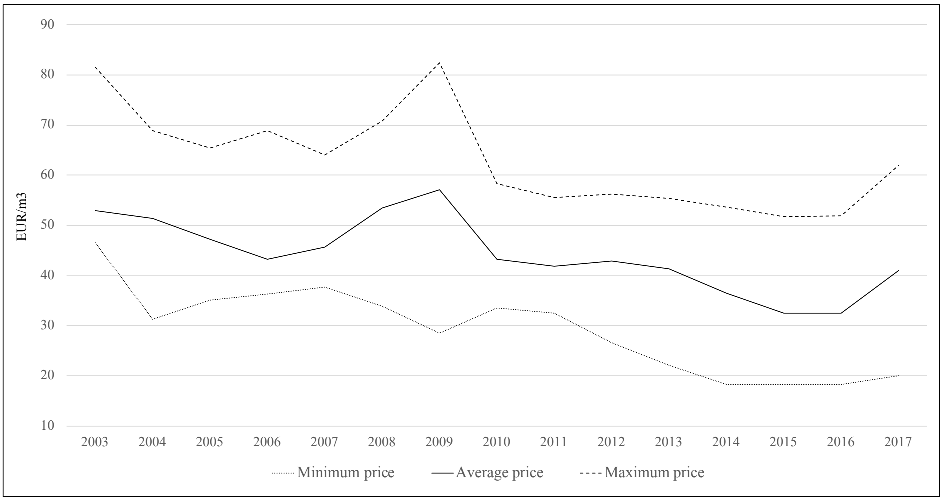
Source: own elaboration

Annex 3.8 – Hybrid poplar stumpage prices in Castile and León, 2006-2017 (real values)



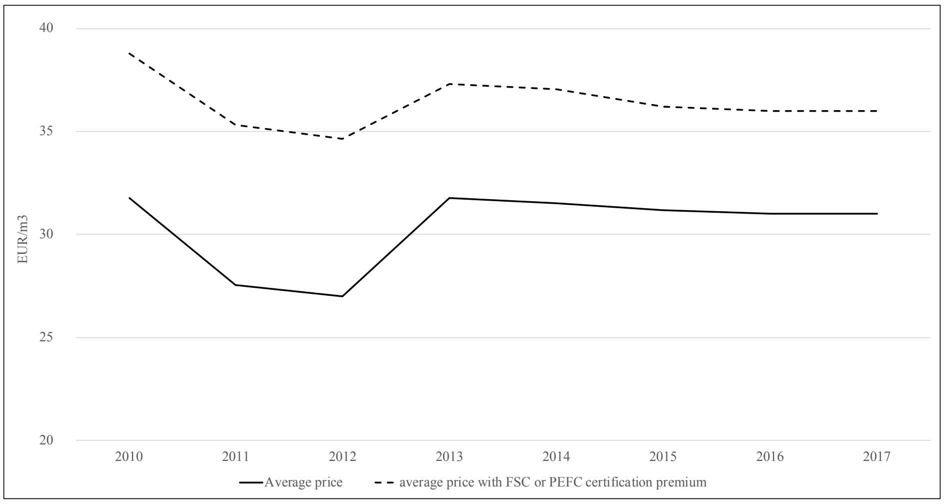
Source: own elaboration

Annex 3.9 – Hybrid poplar stumpage prices in Navarre, 2003-2017 (real values)



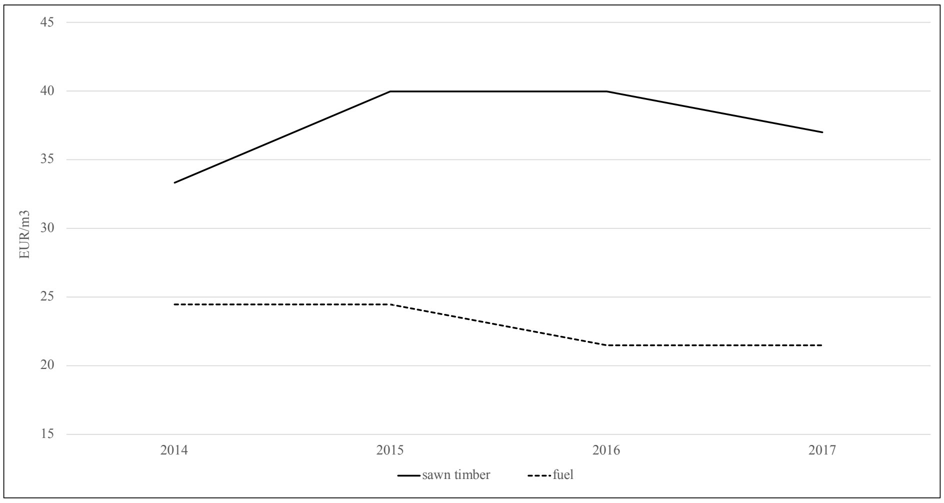
Source: own elaboration

Annex 3.10 – Eucalyptus stumpage prices in Portugal, 2010-2017 (real values)



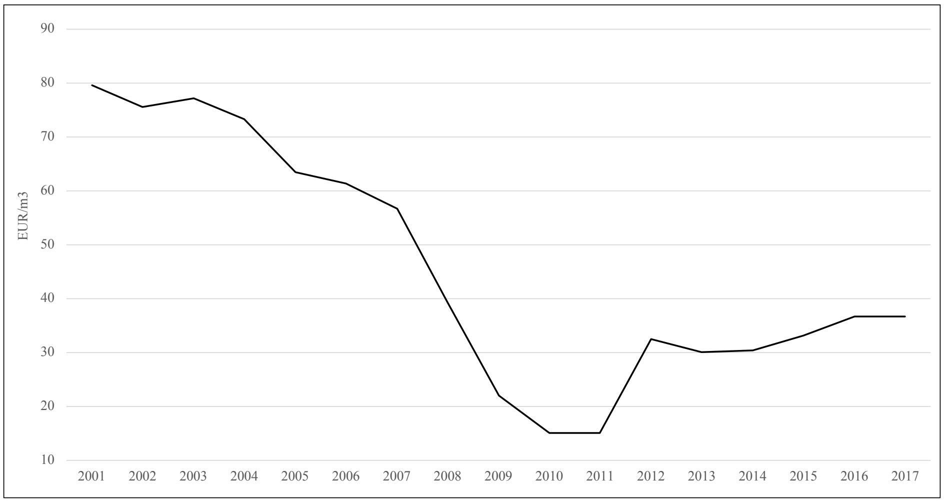
Source: own elaboration

Annex 3.11 – Maritime pine stumpage prices in Portugal, 2014-2017 (real values)



Source: own elaboration

Annex 3.12 – Radiata pine stumpage prices in the Basque Country, 2001-2017 (real values)



Source: own elaboration

Annex 3.13 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for hybrid poplar in northern Italy, 2017

discount rate	NPV			EAV		
	High productivity	Average productivity	Low productivity	High productivity	Average productivity	Low productivity
2	5,143	4,302	2,175	526	440	222
2.5	4,686	3,884	1,859	493	408	195
3	4,254	3,491	1,562	460	377	169
3.5	3,846	3,119	1,282	427	347	142
4	3,462	2,769	1,018	395	316	116
4.5	3,098	2,438	769	363	286	90
5	2,755	2,126	534	332	256	64
5.5	2,432	1,831	313	300	226	39
6	2,126	1,553	105	270	197	13
6.5	1,837	1,290	-91	239	168	-12
7	1,564	1,042	-276	209	139	-37
7.5	1,306	808	-450	179	110	-61
8	1,062	587	-614	149	82	-86

Annex 3.14 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for hybrid poplar in Castile and León, 2017

discount rate	NPV			EAV		
	Low productivity	Average productivity	High productivity	Low productivity	Average productivity	High productivity
2	2,289	4,167	6,589	153	307	544
2.5	1,828	3,628	5,974	127	278	511
3	1,407	3,131	5,400	102	249	478
3.5	1,023	2,673	4,866	78	221	446
4	672	2,250	4,367	53	193	413
4.5	352	1,859	3,902	29	165	382
5	60	1,499	3,469	5	138	350
5.5	-207	1,166	3,064	-18	111	319
6	-450	859	2,686	-42	85	289
6.5	-673	575	2,333	-64	59	259
7	-876	312	2,004	-87	33	229
7.5	-1,061	70	1,696	-109	8	200
8	-1,230	-154	1,409	-131	-17	171

Annex 3.15 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for hybrid poplar in Navarre, 2017

Discount rate	NPV (EUR/ha)			EAV (EUR/ha/yr)		
	High productivity	Average productivity	Low productivity	High productivity	Average productivity	Low productivity
2	1,097	2,155	3,642	91	190	321
2.5	792	1,818	3,220	68	166	293
3	510	1,503	2,826	45	141	266
3.5	248	1,210	2,458	23	117	239
4	6	936	2,114	1	94	212
4.5	-219	680	1,792	-21	70	185
5	-428	441	1,492	-43	47	159
5.5	-621	218	1,210	-65	24	133
6	-800	10	947	-86	1	107
6.5	-967	-184	702	-107	-21	82
7	-1,120	-366	472	-128	-44	56
7.5	-1,263	-535	257	-149	-66	32
8	-1,395	-693	56	-169	-88	7

Annex 3.16 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for eucalyptus in Portugal, 2017

discount rate	NPV				EAV			
	North-Atlantic	**North-central**	**Centre-Atlantic**	**Tagus valley**	**North-Atlantic**	**North-central**	**Centre-Atlantic**	**Tagus valley**
2	7,113	4,886	4,370	2,352	376	258	231	124
2.5	6,246	4,204	3,734	1,893	349	235	209	106
3	5,467	3,592	3,163	1,482	323	212	187	87
3.5	4,765	3,042	2,650	1,112	297	189	165	69
4	4,132	2,546	2,189	780	271	167	144	51
4.5	3,562	2,100	1,773	481	246	145	122	33
5	3,046	1,698	1,397	211	221	123	101	15
5.5	2,579	1,334	1,059	-32	196	101	80	-2
6	2,157	1,006	752	-251	172	80	60	-20
6.5	1,774	708	475	-450	148	59	40	-37
7	1,426	439	224	-629	124	38	20	-55
7.5	1,111	194	-3	-791	101	18	0	-72
8	823	-28	-210	-939	78	-3	-20	-89

Annex 3.17 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for maritime pine in Portugal, 2017

discount rate	NPV					EAV				
	North-Atl.	**North-central**	**Centre-Atlantic**	**Tagus valley**	**Northern interior**	**North-Atl.**	**North central**	**Centre-Atlantic**	**Tagus valley**	**Northern interior**
2	3,044	1,887	501	1,330	185	122	75	20	53	7
2,5	2,204	1,226	50	754	-237	95	53	2	33	-10
3	1,502	673	-324	273	-586	70	31	-15	13	-27
3,5	914	212	-636	-128	-874	46	11	-32	-6	-44
4	422	-174	-894	-462	-1,113	23	-9	-48	-25	-60
4,5	10	-495	-1,109	-741	-1,310	1	-28	-64	-42	-75
5	-334	-763	-1,287	-973	-1,471	-20	-47	-79	-59	-90
5,5	-622	-987	-1,434	-1,166	-1,604	-40	-64	-93	-76	-104
6	-862	-1,173	-1,555	-1,327	-1,712	-59	-81	-107	-91	-118
6,5	-1,063	-1,328	-1,655	-1,459	-1,799	-78	-97	-121	-107	-131
7	-1,230	-1,456	-1,737	-1,569	-1,870	-95	-112	-134	-121	-144
7,5	-1,369	-1,562	-1,803	-1,659	-1,927	-112	-127	-147	-135	-157
8	-1,485	-1,650	-1,857	-1,734	-1,971	-127	-142	-159	-149	-169

Annex 3.18 – Changes in the NPV (EUR/ha) and EAV (EUR/ha/yr) in relation to alternative discount rates for radiata pine in the Basque Country, 2017

	NPV			EAV		
discount rate	**Low productivity**	**Average productivity**	**High productivity**	**Low productivity**	**Average productivity**	**High productivity**
2	3,038	4,229	6,478	111	169	259
2,5	1,927	2,944	4,859	77	127	210
3	1,002	1,872	3,504	43	87	163
3,5	232	977	2,371	11	49	119
4	-409	230	1,422	-21	12	76
4,5	-941	-392	627	-51	-22	36
5	-1,384	-911	-37	-81	-56	-2
5,5	-1,750	-1,343	-592	-109	-87	-38
6	-2,053	-1,702	-1,056	-136	-117	-73
6,5	-2,303	-1,999	-1,444	-163	-146	-105
7	-2,509	-2,245	-1,767	-188	-173	-136
7,5	-2,677	-2,449	-2,035	-213	-200	-166
8	-2,814	-2,616	-2,258	-236	-224	-194

Annex 3.19 – Financial returns according to the sensitivity analysis scenarios for hybrid poplar in northern Italy, 2017

Hypothesis	Indicator	Productivity		
		High	Average	Low
baseline	NPV	2,757	2,127	536
	IRR	10.6%	9.5%	6.3%
	LEV	6,638	5,121	1,290
	EAV	332	256	64
(3) high investment costs	NPV	160	-470	-2,061
	IRR	5.3%	n.a.	n.a.
	LEV	386	-1,131	-4,962
	EAV	19	-57	-248
(2) maximum stumpage price	NPV	4,650	3,880	1,935
	IRR	13.5%	12.4%	9.1%
	LEV	11,196	9,343	4,660
	EAV	560	467	233
(3) minimum stumpage price	NPV	1,021	520	-747
	IRR	7.3%	6.2%	n.a.
	LEV	2,459	1,251	-1,800
	EAV	123	63	-90
(1) (2)	NPV	2,053	1,284	-661
	IRR	8.2%	7.1%	n.a.
	LEV	4,944	3,091	-1,592
	EAV	247	155	-80
(1) (3)	NPV	-1,575	-2,077	-3,344
	IRR	n.a.	n.a.	n.a.
	LEV	-3,793	-5,001	-8,052
	EAV	-190	-250	-403
(4) subsidies	NPV	3,783	3,153	1,562
	IRR	13.8%	12.6%	9.3%
	LEV	9,109	7,593	3,761
	EAV	455	380	188
(4) (3)	NPV	2,052	1,550	283
	IRR	10.4%	9.2%	5.9%
	LEV	4,940	3,732	681
	EAV	247	187	34
(4) (1)	NPV	1,517	887	-704
	IRR	8.0%	6.8%	n.a.
	LEV	3,653	2,136	-1,695
	EAV	183	107	-85
(5) land lease	NPV	268	-362	-1,953
	IRR	5.5%	n.a.	n.a.
	LEV	645	-872	-4,703
	EAV	32	-44	-235
(5) (4)	NPV	2,161	1,391	-554
	IRR	8.6%	7.4%	n.a.
	LEV	5,203	3,350	-1,333
	EAV	260	167	-67
(6) land purchase	NPV	-9,985	-10,615	-12,207
	IRR	n.a.	n.a.	n.a.
	LEV	-24,043	-25,559	-29,391
	EAV	-1,202	-1,278	-1,470
(6) (4)	NPV	-8,092	-8,862	-10,807
	IRR	n.a.	n.a.	n.a.
	LEV	-19,484	-21,338	-26,020
	EAV	-974	-1,067	-1,301

Annex 3.20 – Financial returns according to the sensitivity analysis scenarios for hybrid poplar in Castile and León, 2017

Hypothesis	Indicator	Productivity		
		Low	Average	High
Baseline	NPV	60	1499	3,469
	IRR	5.1%	7.7%	11.1%
	LEV	103	2,766	7,008
	EAV	5	138	350
(1) High investments costs	NPV	-1,422	8	1,968
	IRR	n.a.	5.0%	8.0%
	LEV	-2,433	14	3,976
	EAV	-122	1	199
(2) maximum stumpage price	NPV	1,390	3,309	5,933
	IRR	7.2%	10.0%	13.9%
	LEV	2,378	6,106	11,987
	EAV	119	305	599
(3) minimum stumpage price	NPV	-1,438	-540	692
	IRR	n.a.	n.a.	6.6%
	LEV	-2,460	-997	1,399
	EAV	-123	-50	70
(1) (2)	NPV	-92	1,817	4,432
	IRR	n.a.	7.4%	10.8%
	LEV	-158	3,354	8,954
	EAV	-8	168	448
(4) Land lease	NPV	-2,195	-577	1,590
	IRR	n.a.	n.a.	7.6%
	LEV	-3,755	-1,065	3,212
	EAV	-188	-53	161
(4) (2)	NPV	-865	1,233	4,054
	IRR	n.a.	6.8%	10.7%
	LEV	-1,480	2,275	8,191
	EAV	-74	114	410
(5) Land purchase	NPV	-6,845	-4,859	-2,285
	IRR	n.a.	n.a.	n.a.
	LEV	-11,711	-8,966	-4,617
	EAV	-586	-448	-231
(5) (2)	NPV	-5,515	-3,049	179
	IRR	n.a.	n.a.	5.1%
	LEV	-9,437	-5,627	362
	EAV	-472	-281	18

Annex 3.21 – Financial returns according to the sensitivity analysis scenarios for hybrid poplar in Navarre, 2017

Hypothesis	Indicator	Productivity		
		Low	Average	High
Baseline	NPV	-428	441	1,492
	IRR	n.a.	6.0%	8.1%
	LEV	-864	940	3,176
	EAV	-43	47	159
(1) High investments costs	NPV	-3,736	-2,873	-1,822
	IRR	n.a.	n.a.	n.a.
	LEV	-7,549	-6,116	-3,880
	EAV	-377	-306	-194
(2) maximum stumpage price	NPV	1,911	3,236	4,824
	IRR	8.5%	11.0%	13.1%
	LEV	3,861	6,890	10,271
	EAV	193	345	514
(3) minimum stumpage price	NPV	-2,767	-2,353	-1,841
	IRR	n.a.	n.a.	n.a.
	LEV	-5,590	-5,011	-3,920
	EAV	-279	-251	-196
(1) (2)	NPV	-1,398	-78	1,510
	IRR	n.a.	n.a.	7.0%
	LEV	-2,824	-166	3,216
	EAV	-141	-8	161
(4) subsidies	NPV	923	1,484	2,484
	IRR	7.7%	9.1%	11.1%
	LEV	1,864	3,160	5,290
	EAV	93	158	264
(4) (3)	NPV	-1,416	-1,177	-690
	IRR	n.a.	n.a.	n.a.
	LEV	-2,861	-2,507	-1,468
	EAV	-143	-125	-73
(4) (1)	NPV	-47	837	2,260
	IRR	n.a.	0	0
	LEV	-95	1,783	4,811
	EAV	-5	89	241
(5) land lease	NPV	-2,644	-1,774	-724
	IRR	n.a.	n.a.	n.a.
	LEV	-5,341	-3,778	-1,542
	EAV	-267	-189	-77
(5) (2)	NPV	-305	1,020	2,608
	IRR	n.a.	6.8%	9.1%
	LEV	-616	2,172	5,554
	EAV	-31	109	278
(5) (4)	NPV	-1,757	-888	162
	IRR	n.a.	n.a.	5.3%
	LEV	-3,551	-1,891	345
	EAV	-178	-95	17
(6) Watershed Authority Tax	NPV	-1,757	-888	162
	IRR	n.a.	n.a.	5.3%
	LEV	-3,551	-1,891	345
	EAV	-178	-95	17
(6) (2)	NPV	581	1,907	3,495
	IRR	6.0%	8.4%	10.6%
	LEV	1,175	4,059	7,441
	EAV	59	203	372
(7) land purchase	NPV	-8,224	-6,915	-5,865
	IRR	n.a.	n.a.	n.a.
	LEV	-16,617	-14,723	-12,487
	EAV	-831	-736	-624

Annex 3.22 – Financial returns according to the sensitivity analysis scenarios for eucalyptus in Portugal, 2017

Hypothesis	**Indicator**	**Average productivity sites**				**High productivity sites**				**Low productivity sites**			
		North-Atlantic	North-central	Centre-Atlantic	Tagus valley	North-Atlantic	North-central	Centre-Atlantic	Tagus valley	North-Atlantic	North-central	Centre-Atlantic	Tagus valley
Baseline	NPV	3,046	1,698	1,397	211	5,553	4,347	5,157	3,263	69	-924	-1,256	-1,844
	EAV	221	123	101	15	402	315	374	236	5	-67	-91	-134
	LEV	4,415	2,461	2,025	306	8,049	6,301	7,474	4,730	101	-1,339	-1,821	-2,673
	IRR	9.8%	7.9%	7.5%	5.4%	12.5%	11.2%	12.0%	10.0%	5.1%	n.a.	n.a.	n.a.
(1) High investment costs	NPV	2,276	928	627	-559	4,783	3,577	4,387	2,493	-701	-1,694	-2,026	-2,614
	EAV	165	67	45	-40	347	259	318	181	-51	-123	-147	-189
	LEV	3,299	1,345	909	-810	6,933	5,185	6,358	3,614	-1,015	-2,455	-2,937	-3,789
	IRR	8.2%	6.5%	6.0%	n.a.	10.9%	9.6%	10.4%	8.5%	n.a.	n.a.	n.a.	n.a.
(2) FSC or PEFC premium price	NPV	3,864	2,342	2,003	664	6,695	5,334	6,248	4,110	504	-617	-993	-1,657
	EAV	280	170	145	48	485	387	453	298	37	-45	-72	-120
	LEV	5,601	3,395	2,904	962	9,704	7,731	9,055	5,957	731	-895	-1,439	-2,401
	IRR	10.7%	8.8%	8.4%	6.3%	13.5%	12.1%	13.0%	10.9%	6.0%	n.a.	n.a.	n.a.
(2) (1)	NPV	3,094	1,572	1,233	-106	5,925	4,564	5,478	3,340	-266	-1,387	-1,763	-2,427
	EAV	224	114	89	-8	429	331	397	242	-19	-101	-128	-176
	LEV	4,485	2,279	1,788	-154	8,588	6,615	7,939	4,841	-386	-2,011	-2,555	-3,517
	IRR	9.1%	7.3%	6.9%	n.a.	11.9%	10.6%	11.4%	9.4%	n.a.	n.a.	n.a.	n.a.
(3) Land lease	NPV	1,804	594	294	-617	4,311	3,243	4,053	2,435	-1,172	-2,027	-2,360	-2,672
	EAV	131	43	21	-45	312	235	294	176	-85	-147	-171	-194
	LEV	2,615	861	425	-894	6,249	4,701	5,874	3,530	-1,699	-2,939	-3,421	-3,873
	IRR	7.7%	6.0%	5.5%	n.a.	10.6%	9.5%	10.4%	8.7%	n.a.	n.a.	n.a.	n.a.
(3) (1)	NPV	1,034	-176	-476	-1,387	3,541	2,473	3,283	1,665	-1,942	-2,798	-3,130	-3,442
	EAV	75	-13	-35	-100	257	179	238	121	-141	-203	-227	-249
	LEV	1,499	-255	-691	-2,010	5,133	3,585	4,758	2,414	-2,815	-4,055	-4,537	-4,989
	IRR	6.4%	n.a.	n.a.	n.a.	9.3%	8.1%	9.0%	7.3%	n.a.	n.a.	n.a.	n.a.
(4) Land purchase	NPV	-59	-1,062	-1,362	-1,859	2,449	1,588	2,397	1,193	-3,035	-3,683	-4,016	-3,914
	EAV	-4	-77	-99	-135	177	115	174	86	-220	-267	-291	-284
	LEV	-85	-1,539	-1,975	-2,694	3,549	2,301	3,474	1,730	-4,399	-5,339	-5,821	-5,673
	IRR	n.a.	n.a.	n.a.	n.a.	6.7%	6.2%	6.8%	6.1%	n.a.	n.a.	n.a.	n.a.

Annex 3.23 – Financial returns according to the sensitivity analysis scenarios for maritime pine in Portugal, 2017

Hypothesis	Indicator	Average productivity sites					High productivity sites					Low productivity sites				
		NA	NC	CA	TV	NI	NA	NC	CA	TV	NI	NA	NC	CA	TV	NI
Baseline	NPV	-334	-763	-1,287	-973	-1471	-1373	-2,033	-2,188	-2,033	-2,033	585	429	-282	-282	-786
	EAV	-20	-47	-79	-59	-90	-84	-124	-134	-124	-124	36	26	-17	-17	-48
	LEV	-408	-933	-1572	-1189	-1797	-1676	-2,483	-2,673	-2,483	-2,483	714	524	-344	-344	-960
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.7%	5.5%	n.a.	n.a.	n.a.
(1) High inv. costs	NPV	-1,442	-1871	-2395	-2081	-2579	-2480	-3,140	-3,296	-3,140	-3,140	-523	-679	-1389	-1389	-1894
	EAV	-88	-114	-146	-127	-158	-151	-192	-201	-192	-192	-32	-41	-85	-85	-116
	LEV	-1,761	-2286	-2925	-2542	-3150	-3030	-3,836	-4,026	-3,836	-3,836	-639	-829	-1697	-1697	-2313
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(2) FSC or PEFC prem.	NPV	-255	-687	-1220	-901	-1,418	-1,315	-1,993	-2,152	-1,993	-1,993	683	524	-207	-207	-726
	EAV	-16	-42	-74	-55	-87	-80	-122	-131	-122	-122	42	32	-13	-13	-44
	LEV	-311	-839	-1,490	-1,101	-1,732	-1,606	-2,434	-2,628	-2,434	-2,434	835	641	-253	-253	-887
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.8%	5.7%	n.a.	n.a.	n.a.
(3) min stumpage price	NPV	-639	-1,020	-1,483	-1,205	-1,639	-1,553	-2,132	-2,269	-2,132	-2,132	170	32	-589	-589	-1032
	EAV	-39	-62	-91	-74	-100	-95	-130	-139	-130	-130	10	2	-36	-36	-63
	LEV	-781	-1,246	-1,811	-1,472	-2,002	-1,897	-2,604	-2,771	-2,604	-2,604	207	39	-720	-720	-1260
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.2%	5.0%	n.a.	n.a.	n.a.
(4) subsidies	NPV	1,214	785	261	575	77	175	-485	-640	-485	-485	2,133	1,977	1,266	1,266	762
	EAV	74	48	16	35	5	11	-30	-39	-30	-30	130	121	77	77	47
	LEV	1,483	958	319	702	94	214	-592	-782	-592	-592	2,605	2,414	1,547	1,547	931
	IRR	7.8%	7.0%	5.8%	6.6%	5.2%	5.5%	n.a.	n.a.	n.a.	n.a.	9.1%	8.9%	7.8%	7.8%	6.8%
(4) (1)	NPV	673	244	-280	34	-464	-365	-1,025	-1,181	-1,025	-1,025	1,592	1,436	726	726	221
	EAV	41	15	-17	2	-28	-22	-63	-72	-63	-63	97	88	44	44	14
	LEV	822	298	-342	41	-567	-446	-1,252	-1,442	-1,252	-1,252	1,945	1,754	886	886	270
	IRR	6.3%	5.5%	n.a.	5.1%	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.6%	7.4%	6.4%	6.4%	5.4%
(4) (3)	NPV	909	528	66	343	-91	-5	-584	-721	-584	-584	1,718	1,580	959	959	516
	EAV	56	32	4	21	-6	0	-36	-44	-36	-36	105	96	59	59	32
	LEV	1,110	644	80	419	-111	-6	-713	-880	-713	-713	2,098	1,930	1,171	1,171	631
	IRR	7.2%	6.4%	5.2%	6.0%	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8.5%	8.3%	7.3%	7.3%	6.3%
(5) land lease	NPV	-1,808	-2,073	-2,597	-1,956	-2,454	-2,846	-3,343	-3,498	-3,015	-3,015	-889	-881	-1,591	-1,264	-1,769
	EAV	-110	-127	-159	-119	-150	-174	-204	-214	-184	-184	-54	-54	-97	-77	-108
	LEV	-2,208	-2,533	-3,172	-2,389	-2,997	-3,476	-4,083	-4,273	-3,683	-3,683	-1,086	-1,076	-1944	-1,544	-2,160
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(5) (4)	NPV	-260	-525	-1049	-408	-906	-1,298	-1,795	-1,950	-1,467	-1,467	659	667	-43	284	-221
	EAV	-16	-32	-64	-25	-55	-79	-110	-119	-90	-90	40	41	-3	17	-13
	LEV	-317	-642	-1281	-498	-1106	-1,586	-2,192	-2,382	-1,792	-1,792	805	814	-53	347	-269
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.0%	6.1%	n.a.	5.5%	n.a.
(6) land purchase	NPV	-4,018	-4,038	-4,562	-3,429	-3,927	-5,057	-5,307	-5,463	-4,489	-4,489	-3,099	-2,846	-3,556	-2,738	-3,242
	EAV	-245	-247	-279	-209	-240	-309	-324	-334	-274	-274	-189	-174	-217	-167	-198
	LEV	-4,908	-4,933	-5,572	-4,189	-4,797	-6,176	-6,483	-6,673	-5,483	-5,483	-3,786	-3,476	-4,344	-3,344	-3,960
	IRR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(6) (4)	NPV	744	367	-157	261	-236	-294	-902	-1,058	-798	-798	1,663	1,559	849	953	449
	EAV	45	22	-10	16	-14	-18	-55	-65	-49	-49	102	95	52	58	27
	LEV	909	448	-191	319	-289	-360	-1,102	-1,292	-975	-975	2,031	1,904	1,037	1,164	548
	IRR	5.9%	5.5%	n.a.	5.4%	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.7%	6.7%	6.0%	6.3%	5.6%

Annex 3.24 – Financial returns according to the sensitivity analysis scenarios for radiata pine in the Basque Country, 2017

Hypothesis	Indicator	Productivity		
		Low	**Average**	**High**
baseline	NPV	-1,384	-911	-37
	EAV	-81	-56	-2
	LEV	-1,613	-1,113	-45
	IRR	n.a.	n.a.	n.a.
(1) high investment costs	NPV	-2,143	-1,671	-797
	EAV	-125	-102	-49
	LEV	-2,498	-2,041	-973
	IRR	n.a.	n.a.	n.a.
(2) maximum stumpage price (38 EUR/m3)	NPV	-1,312	-828	76
	EAV	-76	-51	5
	LEV	-1,529	-1,011	92
	IRR	n.a.	n.a.	5.1%
(3) minimum stumpage price (33EUR/m3)	NPV	-1,556	-1,111	-306
	EAV	-91	-68	-19
	LEV	-1,813	-1,357	-374
	IRR	n.a.	n.a.	n.a.
(4) subsidies	NPV	401	874	1,748
	EAV	23	53	107
	LEV	468	1,067	2,135
	IRR	5.5%	6.0%	6.8%
(4) (1)	NPV	-50	423	1,297
	EAV	-3	26	79
	LEV	-58	516	1,584
	IRR	n.a.	5.5%	6.3%
(5) land lease	NPV	-3,957	-3,367	-2,493
	EAV	-231	-206	-152
	LEV	-4,613	-4,113	-3,045
	IRR	n.a.	n.a.	n.a.
(5) (4)	NPV	-2,172	-1,582	-708
	EAV	-127	-97	-43
	LEV	-2,532	-1,933	-865
	IRR	n.a.	n.a.	n.a.
(6) land purchase	NPV	-9,239	-7,461	-6,587
	EAV	-538	-456	-402
	LEV	-10,768	-9,113	-8,045
	IRR	n.a.	n.a.	n.a.
(6) (4)	NPV	-7,453	-5,676	-4,802
	EAV	-434	-347	-293
	LEV	-8,688	-6,933	-5,865
	IRR	n.a.	n.a.	n.a.

Annex 3.25 – Expected and current return trends according to the baseline for hybrid poplar in northern Italy, 2001-2017 (real values)

Year	Productivity	*Ex-ante*				*Ex-post*			
		NPV	**IRR**	**LEV**	**EAV**	**NPV**	**IRR**	**LEV**	**EAV**
2001	low	1,765	8.8%	4,250	213	965	7.2%	2,324	116
	average	3,681	12.1%	8,862	443	2,674	10.5%	6,439	322
	high	4,439	13.2%	10,688	534	3,351	11.6%	8,068	403
2002	low	1,312	7.9%	3,158	158	378	5.9%	911	46
	average	3,109	11.2%	7,486	374	1,940	9.2%	4,672	234
	high	3,821	12.3%	9,200	460	2,558	10.3%	6,160	308
2003	low	1,315	7.9%	3,165	158	136	5.3%	328	16
	average	3,112	11.2%	7,493	375	1,639	8.6%	3,947	197
	high	3,824	12.3%	9,207	460	2,234	9.7%	5,379	269
2004	low	1,070	7.4%	2,576	129	245	5.6%	589	29
	average	2,808	10.7%	6,762	338	1,777	8.8%	4,279	214
	high	3,496	11.8%	8,419	421	2,384	9.9%	5,739	287
2005	low	905	7.1%	2,180	109	108	5.3%	259	13
	average	2,615	10.3%	6,295	315	1,610	8.5%	3,877	194
	high	3,291	11.4%	7,924	396	2,205	9.6%	5,310	265
2006	low	847	6.9%	2,039	102	203	5.5%	490	24
	average	2,556	10.2%	6,155	308	1,736	8.7%	4,179	209
	high	3,233	11.3%	7,784	389	2,342	9.8%	5,639	282
2007	low	1,070	7.4%	2,575	129	442	6.0%	1,064	53
	average	2,838	10.6%	6,832	342	2,033	9.3%	4,896	245
	high	3,538	11.7%	8,518	426	2,663	10.4%	6,412	321
2008	low	1,278	7.8%	3,077	154	485	6.1%	1,167	58
	average	3,075	11.1%	7,405	370	2,076	9.4%	4,998	250
	high	3,787	12.2%	9,118	456	2,706	10.5%	6,515	326
2009	low	1,006	7.3%	2,421	121	481	6.1%	1,158	58
	average	2,744	10.5%	6,608	330	2,072	9.3%	4,989	249
	high	3,432	11.6%	8,265	413	2,702	10.5%	6,506	325
2010	low	847	6.9%	2,040	102	479	6.1%	1,153	58
	average	2,556	10.1%	6,155	308	2,070	9.3%	4,985	249
	high	3,233	11.2%	7,784	389	2,700	10.4%	6,501	325
2011	low	896	7.0%	2,156	108	510	6.2%	1,228	61
	average	2,605	10.3%	6,272	314	2,101	9.4%	5,059	253
	high	3,281	11.4%	7,901	395	2,731	10.5%	6,576	329
2012	low	410	6.0%	987	49	549	6.3%	1,321	66
	average	1,972	9.2%	4,748	237	2,140	9.5%	5,152	258
	high	2,590	10.3%	6,236	312	2,770	10.6%	6,,669	333
2013	low	217	5.5%	523	26	562	6.3%	1,352	68
	average	1,720	8.8%	4,142	207	2,153	9.6%	5,184	259
	high	2,315	9.9%	5,574	279	2,783	10.7%	6,700	335
2014	low	356	5.9%	858	43	566	6.3%	1,363	68
	average	1,889	9.1%	4,548	227	2,157	9.6%	5,194	260
	high	2,495	10.2%	6,008	300	2,787	10.7%	6,711	336
2015	low	230	5.6%	554	28	558	6.3%	1,344	67
	average	1,733	8.8%	4,172	209	2,149	9.6%	5,175	259
	high	2,328	9.9%	5,605	280	2,779	10.7%	6,692	335
2016	low	300	5.7%	723	36	534	6.3%	1,285	64
	average	1,833	8.9%	4,413	221	2,125	9.5%	5,116	256
	high	2,439	10.0%	5,873	294	2,755	10.6%	6,633	332
2017	low	534	6.3%	1,285	64	534	6.3%	1,285	64
	average	2,125	9.5%	5,116	256	2,125	9.5%	5,116	256
	high	2,755	10.6%	6,633	332	2,755	10.6%	6,633	332

Annex 3.26 – Expected and current return trends according to the baseline for hybrid poplar in Castile and León, 2006-2017 (real values)

Year	Productivity	*Ex-ante*				*Ex-post*			
		NPV	**IRR**	**LEV**	**EAV**	**NPV**	**IRR**	**LEV**	**EAV**
2006	low	3,397	10.2%	6,864	343	2,747	9.4%	5,550	277
	average	1,241	6.9%	2,290	114	777	6.3%	1,434	72
	high	-333	n.a.	-570	-29	-661	n.a.	-1,132	-57
2007	low	2,640	9.1%	5,333	267	2,604	9.1%	5,262	263
	average	602	5.9%	1,110	56	635	6.0%	1,171	59
	high	-885	n.a.	-1,514	-76	-804	n.a.	-1,375	-69
2008	low	2,950	9.6%	5,961	298	2,760	9.4%	5,577	279
	average	887	6.4%	1,637	82	790	6.3%	1,459	73
	high	-619	n.a.	-1,059	-53	-648	n.a.	-1,109	-55
2009	low	3,471	10.6%	7,013	351	3,012	10.0%	6,085	304
	average	1,386	7.3%	2,557	128	1,042	6.7%	1,922	96
	high	-137	n.a.	-234	-12	-397	n.a.	-679	-34
2010	low	3,707	10.6%	7,490	374	2,842	9.6%	5,742	287
	average	1,473	7.2%	2,718	136	872	6.4%	1,609	80
	high	-159	n.a.	-271	-14	-567	n.a.	-969	-48
2011	low	2,848	9.9%	5,754	288	3,063	10.1%	6,190	309
	average	931	6.6%	1,718	86	1,094	6.8%	2,018	101
	high	-468	n.a.	-801	-40	-345	n.a.	-590	-29
2012	low	2,191	8.8%	4,426	221	2,985	9.9%	6,032	302
	average	394	5.7%	726	36	1,016	6.7%	1,874	94
	high	-917	n.a.	-1,569	-78	-423	n.a.	-723	-36
2013	low	2,966	9.8%	5,993	300	3,041	10.0%	6,144	307
	average	965	6.6%	1,781	89	1,071	6.8%	1,977	99
	high	-495	n.a.	-847	-42	-367	n.a.	-628	-31
2014	low	2,658	9.5%	5,371	269	3,163	10.3%	6,390	319
	average	774	6.3%	1,428	71	1,193	7.0%	2,201	110
	high	-601	n.a.	-1,028	-51	-246	n.a.	-421	-21
2015	low	3,160	10.6%	6,386	319	3,427	11.0%	6,924	346
	average	1,257	7.2%	2,319	116	1,457	7.6%	2,689	134
	high	-133	n.a.	-228	-11	19	5.0%	32	2
2016	low	3,401	10.9%	6,872	344	3,430	11.0%	6,931	347
	average	1,433	7.5%	2,644	132	1,460	7.6%	2,695	135
	high	-5	n.a.	-9	0	22	5.0%	38	2
2017	low	3,469	11.1%	7,008	350	3,469	11.1%	7,008	350
	average	1,499	7.7%	2,766	138	1,499	7.7%	2,766	138
	high	60	5.1%	103	5	60	5.1%	103	5

Annex 3.27 – Expected and current return trends according to the baseline for hybrid poplar in Navarre, 2003-2017 (real values)

Year	Productivity	*Ex-ante*				*Ex post*			
		NPV	IRR	LEV	EAV	NPV	IRR	LEV	EAV
2003	low	-614	n.a.	-1,241	-62	-2,566	n.a.	-5,184	-259
	average	509	5.9%	1,085	54	-1,882	n.a.	-4,006	-200
	high	1,867	8.0%	3,976	199	-1,050	n.a.	-2,235	-112
2004	low	-384	n.a.	-775	-39	-1,353	n.a.	-2,734	-137
	average	704	6.3%	1,500	75	-1,677	n.a.	-3,571	-179
	high	2,018	8.4%	4,297	215	-844	n.a.	-1,798	-90
2005	low	-847	n.a.	-1,711	-86	-1,311	n.a.	-2,650	-132
	average	153	5.3%	325	16	-442	n.a.	-942	-47
	high	1,362	7.4%	2,901	145	608	6.2%	1,294	65
2006	low	-1,032	n.a.	-2,085	-104	-1,167	n.a.	-2,357	-118
	average	-118	n.a.	-252	-13	-297	n.a.	-633	-32
	high	989	6.9%	2,105	105	753	6.5%	1,603	80
2007	low	-979	n.a.	-1,979	-99	-1,214	n.a.	-2,454	-123
	average	-12	n.a.	-26	-1	-345	n.a.	-735	-37
	high	1,159	7.1%	2,467	123	705	6.4%	1,501	75
2008	low	-197	n.a.	-398	-20	-1,190	n.a.	-2,405	-120
	average	937	6.7%	1,994	100	-321	n.a.	-684	-34
	high	2,305	8.8%	4,907	245	729	6.4%	1,552	78
2009	low	925	6.7%	1,868	93	-885	n.a.	-1,787	-89
	average	2,143	9.0%	4,562	228	-15	n.a.	-33	-2
	high	3,606	11.1%	7,679	384	1,035	7.1%	2,203	110
2010	low	-974	n.a.	-1,968	-98	-1,016	n.a.	-2,053	-103
	average	-61	n.a.	-130	-7	-147	n.a.	-313	-16
	high	1,044	7.0%	2,223	111	903	6.8%	1,923	96
2011	low	-717	n.a.	-1,448	-72	-844	n.a.	-1,705	-85
	average	171	5.4%	364	18	25	5.1%	54	3
	high	1,245	7.5%	2,650	132	1,076	7.2%	2,290	114
2012	low	-926	n.a.	-1,872	-94	-940	n.a.	-1,899	-95
	average	-19	n.a.	-41	-2	-71	n.a.	-150	-8
	high	1,079	7.1%	2,298	115	980	6.9%	2,086	104
2013	low	-1,212	n.a.	-2449	-122	-917	n.a.	-1,853	-93
	average	-341	n.a.	-726	-36	-48	n.a.	-102	-5
	high	716	6.4%	1,524	76	1,002	7.0%	2,134	107
2014	low	-1,580	n.a.	-3,192	-160	-783	n.a.	-1,582	-79
	average	-813	n.a.	-1,731	-87	86	5.2%	183	9
	high	119	5.3%	253	13	1,136	7.3%	2,419	121
2015	low	-2,088	n.a.	-4,218	-211	-750	n.a.	-1,515	-76
	average	-1,407	n.a.	-2,995	-150	119	5.3%	254	13
	high	-575	n.a.	-1,224	-61	1,170	7.3%	2,490	125
2016	low	-1,373	n.a.	-2,774	-139	-428	n.a.	-864	-43
	average	-688	n.a.	-1,465	-73	441	6.0%	940	47
	high	145	5.3%	308	15	1,492	8.1%	3,176	159
2017	low	-428	n.a.	-864	-43	-428	n.a.	-864	-43
	average	441	6.0%	940	47	441	6.0%	940	47
	high	1,492	8.1%	3,176	159	1,492	8.1%	3,176	159

Figure 3.28 – Epected and current return trends according to the baseline for eucalyptus in Portugal (average productivity sites), 2010-2017 (real values)

Year	Region	*Ex-ante*				*Ex-post*			
		NPV	**EAV**	**LEV**	**IRR**	**NPV**	**EAV**	**LEV**	**IRR**
2010	North-Atlantic	3,661	265	5,306	11.0%	3,321	241	4,813	10.5%
	North-central	2,260	164	3,275	9.1%	1,973	143	2,859	8.6%
	Centre-Atlantic	1,948	141	2,823	8.6%	1,673	121	2,424	8.2%
	Tagus valley	715	52	1,037	6.5%	486	35	705	6.1%
2011	North-Atlantic	2,776	201	4,024	9.7%	3,212	233	4,655	10.2%
	North-central	1,535	111	2,225	7.9%	1,864	135	2,701	8.3%
	Centre-Atlantic	1,259	91	1,824	7.4%	1,563	113	2,266	7.9%
	Tagus valley	166	12	241	5.4%	377	27	546	5.8%
2012	North-Atlantic	2,371	172	3,437	8.9%	3,076	223	4,458	9.8%
	North-central	1,174	85	1,701	7.2%	1,727	125	2,504	8.0%
	Centre-Atlantic	907	66	1,315	6.7%	1,427	103	2,069	7.6%
	Tagus valley	-147	-11	-212	n.a.	241	17	349	5.5%
2013	North-Atlantic	3,290	238	4,769	10.1%	3,063	222	4,440	9.8%
	North-central	1,894	137	2,746	8.2%	1,715	124	2,486	8.0%
	Centre-Atlantic	1,583	115	2,295	7.8%	1,415	103	2,051	7.5%
	Tagus valley	355	26	515	5.7%	229	17	331	5.5%
2014	North-Atlantic	3,251	236	4,712	10.1%	3,077	223	4,460	9.8%
	North-central	1,870	135	2,710	8.2%	1,729	125	2,506	8.0%
	Centre-Atlantic	1,562	113	2,264	7.8%	1,429	104	2,071	7.6%
	Tagus valley	347	25	503	5.7%	243	18	352	5.5%
2015	North-Atlantic	3,084	223	4,470	9.8%	3,065	222	4,443	9.8%
	North-central	1,734	126	2,514	8.0%	1,717	124	2,489	8.0%
	Centre-Atlantic	1,434	104	2,078	7.6%	1,417	103	2,053	7.5%
	Tagus valley	246	18	357	5.5%	230	17	334	5.5%
2016	North-Atlantic	3,084	223	4,470	9.8%	3,046	221	4,415	9.8%
	North-central	1,728	125	2,504	8.0%	1,698	123	2,461	7.9%
	Centre-Atlantic	1,426	103	2,066	7.5%	1,397	101	2,025	7.5%
	Tagus valley	232	17	337	5.5%	211	15	306	5.4%
2017	North-Atlantic	3,046	221	4,415	9.8%	3,046	221	4,415	9.8%
	North-central	1,698	123	2,461	7.9%	1,698	123	2,461	7.9%
	Centre-Atlantic	1,397	101	2,025	7.5%	1,397	101	2,025	7.5%
	Tagus valley	211	15	306	5.4%	211	15	306	5.4%

Figure 3.29 – Expected and current return trends according to the baseline for maritime pine in Portugal (average productivity sites), 2014-2017 (real values)

Year	Region	*Ex-ante*				*Ex-post*			
		NPV	**EAV**	**LEV**	**IRR**	**NPV**	**EAV**	**LEV**	**IRR**
2014	North-Atlantic	-375	-23	-459	n.a.	-332	-20	-405	n.a.
	North-central	-770	-47	-940	n.a.	-761	-46	-930	n.a.
	Centre-Atlantic	-1,263	-77	-1,542	n.a.	-1,285	-78	-1,569	n.a.
	Tagus valley	-969	-59	-1184	n.a.	-971	-59	-1186	n.a.
	Northern interior	-1,464	-89	-1,788	n.a.	-1,469	-90	-1,794	n.a.
2015	North-Atlantic	-107	-7	-130	n.a.	-342	-21	-418	n.a.
	North-central	-572	-35	-699	n.a.	-772	-47	-943	n.a.
	Centre-Atlantic	-1,143	-70	-1,396	n.a.	-1,295	-79	-1,582	n.a.
	Tagus valley	-802	-49	-979	n.a.	-982	-60	-1,199	n.a.
	Northern interior	-1,351	-82	-1,650	n.a.	-1,480	-90	-1,807	n.a.
2016	North-Atlantic	-208	-13	-254	n.a.	-334	-20	-408	n.a.
	North-central	-669	-41	-817	n.a.	-763	-47	-933	n.a.
	Centre-Atlantic	-1,227	-75	-1,499	n.a.	-1,287	-79	-1,572	n.a.
	Tagus valley	-892	-54	-1,090	n.a.	-973	-59	-1,189	n.a.
	Northern interior	-1,414	-86	-1,727	n.a.	-1,471	-90	-1,797	n.a.
2017	North-Atlantic	-334	-20	-408	n.a.	-334	-20	-408	n.a.
	North-central	-763	-47	-933	n.a.	-763	-47	-933	n.a.
	Centre-Atlantic	-1,287	-79	-1,572	n.a.	-1,287	-79	-1,572	n.a.
	Tagus valley	-973	-59	-1,189	n.a.	-973	-59	-1,189	n.a.
	Northern interior	-1,471	-90	-1,797	n.a.	-1,471	-90	-1,797	n.a.

Figure 3.30 – Expected and current return trends according to the baseline for radiata pine in the Basque Country, 2001-2017 (real values)

Year	Productivity	*Ex-ante*				*Ex-post*			
		NPV	EAV	LEV	IRR	NPV	EAV	LEV	IRR
2001	low	-112	-7	-131	n.a.	-2,639	-154	-3,076	n.a.
	average	756	46	923	5,4%	-2,167	-132	-2,647	n.a.
	high	2,614	160	3,192	6,4%	-1,293	-79	-1,579	n.a.
2002	low	-104	-6	-121	n.a.	-2,519	-147	-2,936	n.a.
	average	727	44	889	5,4%	-2,046	-125	-2,499	n.a.
	high	2,493	152	3,045	6,4%	-1,172	-72	-1,431	n.a.
2003	low	-1,193	-70	-1,390	n.a.	-3,019	-176	-3,518	n.a.
	average	-347	-21	-424	n.a.	-2,546	-155	-3,110	n.a.
	high	1,456	89	1,779	5,7%	-1,672	-102	-2,042	n.a.
2004	low	-1,022	-60	-1,191	n.a.	-2,791	-163	-3,253	n.a.
	average	-211	-13	-258	n.a.	-2,319	-142	-2,832	n.a.
	high	1,503	92	1,836	5,8%	-1,445	-88	-1,764	n.a.
2005	low	-1,621	-94	-1,889	n.a.	-2,724	-159	-3,175	n.a.
	average	-901	-55	-1,101	n.a.	-2,252	-138	-2,750	n.a.
	high	586	36	716	5,3%	-1,377	-84	-1,682	n.a.
2006	low	-1,351	-79	-1,575	n.a.	-2,494	-145	-2,907	n.a.
	average	-651	-40	-795	n.a.	-2,022	-123	-2,469	n.a.
	high	791	48	967	5,5%	-1,147	-70	-1,401	n.a.
2007	low	-2,045	-119	-2,384	n.a.	-2,599	-151	-3,029	n.a.
	average	-1,389	-85	-1,696	n.a.	-2,126	-130	-2,597	n.a.
	high	-56	-3	-68	n.a.	-1,252	-76	-1,529	n.a.
2008	low	-2,748	-160	-3,203	n.a.	-2,465	-144	-2,873	n.a.
	average	-2,252	-138	-2,750	n.a.	-1,993	-122	-2,434	n.a.
	high	-1,318	-80	-1,609	n.a.	-1,118	-68	-1,366	n.a.
2009	low	-3,196	-186	-3,725	n.a.	-2,073	-121	-2,416	n.a.
	average	-2,859	-175	-3,492	n.a.	-1,600	-98	-1,955	n.a.
	high	-2,320	-142	-2,834	n.a.	-726	-44	-887	n.a.
2010	low	-3,496	-204	-4,075	n.a.	-1,988	-116	-2,317	n.a.
	average	-3,224	-197	-3,937	n.a.	-1,516	-93	-1,851	n.a.
	high	-2,845	-174	-3,475	n.a.	-641	-39	-783	n.a.
2011	low	-3,347	-195	-3,901	n.a.	-1,892	-110	-2,206	n.a.
	average	-3,074	-188	-3,755	n.a.	-1,420	-87	-1,734	n.a.
	high	-2,696	-165	-3,293	n.a.	-546	-33	-666	n.a.
2012	low	-2,224	-130	-2,592	n.a.	-1,869	-109	-2,178	n.a.
	average	-1,790	-109	-2,186	n.a.	-1,396	-85	-1,705	n.a.
	high	-1,010	-62	-1,234	n.a.	-522	-32	-637	n.a.
2013	low	-2,377	-139	-2,770	n.a.	-1,874	-109	-2,184	n.a.
	average	-1,965	-120	-2,400	n.a.	-1,402	-86	-1,712	n.a.
	high	-1,242	-76	-1,516	n.a.	-527	-32	-644	n.a.
2014	low	-2,214	-129	-2,581	n.a.	-1,753	-102	-2,043	n.a.
	average	-1,800	-110	-2,199	n.a.	-1,280	-78	-1,564	n.a.
	high	-1,071	-65	-1,308	n.a.	-406	-25	-496	n.a.
2015	low	-2,171	-127	-2,531	n.a.	-1,671	-97	-1,947	n.a.
	average	-1,731	-106	-2,114	n.a.	-1,198	-73	-1,464	n.a.
	high	-937	-57	-1,144	n.a.	-324	-20	-396	n.a.
2016	low	-1,453	-85	-1,693	n.a.	-1,416	-83	-1,651	n.a.
	average	-980	-60	-1,197	n.a.	-944	-58	-1,153	n.a.
	high	-106	-6	-129	n.a.	-70	-4	-85	n.a.
2017	low	-1,384	-81	-1,613	n.a.	-1,384	-81	-1,613	n.a.
	average	-911	-56	-1,113	n.a.	-911	-56	-1,113	n.a.
	high	-37	-2	-45	n.a.	-37	-2	-45	n.a.

Source: own elaboration

Annex 4

Pioppicoltura e PSR: un'opportunità da sfruttare meglio

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Di fronte alla crescente richiesta di sostegno e interesse pubblico verso la pioppicoltura, a gennaio 2014, le cinque regioni della pianura padana si sono fatte promotrici di una forte iniziativa di settore, sottoscrivendo, insieme alle principali associazioni del comparto agricolo italiano, l'Accordo interregionale per lo sviluppo della filiera del pioppo nelle regioni del nord Italia[7]. L'accordo, sottoscritto da Piemonte, Lombardia, Emilia-Romagna, Veneto e Friuli-Venezia Giulia, con l'obiettivo di stimolare uno sviluppo sinergico della filiera e aumentare le superfici coltivate, si è posto come punto di riferimento per le azioni politiche a venire, sollevando le speranze di pioppicoltori e operatori della filiera.

A distanza di due anni da questo importante accordo, quali sono stati gli interventi concreti delle regioni e il loro livello di coerenza? In quest'articolo cerchiamo di dare una prima risposta a questa domanda analizzando l'approccio alla pioppicoltura delle cinque regioni attraverso il loro principale strumento a disposizione per intervenire nel settore: i Piani di Sviluppo Rurale (PSR).

I nuovi PSR, approvati pochi mesi fa per quanto riguarda la programmazione 2014-2020, s'inseriscono in un quadro programmatorio dettato dalla Commissione Europea volto al perseguimento degli obiettivi strategici di gestione sostenibile delle risorse naturali e sviluppo territoriale equilibrato, previsti dal Reg. EU 1305/2013. Viene però lasciata flessibilità alle singole regioni nel delineare i propri criteri specifici su alcuni aspetti strategici. In quest'articolo si fa riferimento alla sottomisura 8.1 sul "sostegno alla forestazione/rimboschimento", in cui sono previsti contributi per l'impianto di piantagioni legnose a ciclo breve o a ciclo medio lungo, su terreni agricoli o non agricoli. Nello specifico, prendiamo in considerazione la tipologia d'intervento A, relativa alle piantagioni a ciclo breve nella quale sono ammessi contributi per l'impianto di specie a rapido accrescimento come il pioppo. Se per quanto

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[7] http://www.federlegnoarredo.it/ContentsFiles%5CDEFINITIVO_firme_accordo_pioppo_interregionale2014.pdf

riguarda spese ammissibili e beneficiari il quadro è essenzialmente univoco nei cinque PSR delle regioni padane, appare invece evidente, già da una prima analisi, che scelte fortemente diverse siano state fatte in merito ai criteri di ammissibilità al finanziamento, principi di selezione ed importi e aliquote finanziabili. Questi sono riportati in tre tabelle comparative allegate all'articolo. Nello specifico, la Tabella 1 riporta la comparazione dei criteri di ammissibilità adottati dalle cinque regioni, la Tabella 2 dei principi di selezione in ordine decrescente di importanza ed infine nella Tabella 3 gli importi e le aliquote finanziabili.

Contrariamente ad un'auspicabile coerenza d'approccio, in tutti e tre questi aspetti, emerge una sostanziale divergenza tra le cinque regioni. Un primo elemento discriminatorio da considerare, nei criteri di ammissibilità, riguarda il livello di diversificazione clonale richiesto dalle regioni per ottenere il contributo, con richieste molto diverse sull'uso di cloni a Maggiore Sostenibilità Ambientale (MSA) (vedi Tabella 1). A lato di quest'aspetto, vi è poi da considerare che non risultano più consentiti impianti di pioppo con l'impiego del solo clone "I-214", nonostante sia il clone di maggiore interesse da parte dell'industria del compensato. Ancora più disomogeneo appare il quadro dei principi di selezione adottati dalle regioni, dove certificazione forestale, disciplinari di produzione, localizzazione, tipo di beneficiario e ancora una volta diversificazione clonale hanno pesi significativamente diversi. Basti pensare, per esempio, a come la certificazione forestale secondo gli schemi PEFC e FSC, che di per sé determinano sistemi colturali molto diversi, sia un aspetto di primaria importanza in Lombardia, Piemonte e Friuli-Venezia Giulia (dove in quest'ultima la certificazione di gruppo gioca un ruolo importante), mentre non è nemmeno presa in considerazione in Emilia-Romagna e Veneto. In quest'ultimo in particolare, non viene fatto nessun riferimento specifico a requisiti di qualità ambientale, che invece entrano di peso nel PSR del Piemonte (diversità clonale e diversità specifica) e, anche se con diversi pesi, di Lombardia, Friuli-Venezia Giulia ed Emilia-Romagna (vedi Tabella 2). Anche per quanto concerne gli importi e le aliquote finanziabili, i cinque PSR appaiono disomogenei, andando, di fatto, a influire significativamente sulla bilancia dei costi-ricavi della pioppicoltura e quindi della sua convenienza nei cinque contesti territoriali. Volendo entrare nel merito, il costo ammissibile ad ettaro in Emilia-Romagna risulta essere quasi il doppio di quello di Piemonte, Lombardia e Friuli-Venezia Giulia, mentre non vi sono riferimenti specifici per il Veneto (vedi Tabella 3).

Vi è poi un altro importante aspetto relativo ai PSR che va preso in considerazione, ovvero l'interruzione dei bandi nell'ultimo anno in molte regioni, la quale ha lasciato a bocca asciutta i pioppicoltori in attesa di fare nuovi investimenti. Questo ha causato non poche conseguenze sulla produzione industriale delle filiere dipendenti dal pioppo, che di conseguenza fa sempre maggiore affidamento all'importazione di legname da altri paesi europei, Francia ed Ungheria *in primis*. Viene da chiedersi, di conseguenza, come sia pensabile favorire uno sviluppo solido e omogeneo della pioppicoltura e della sua filiera, se una delle sue componenti chiave, cioè il sostegno pubblico dei PSR, è così disomogeneo e variegato in un territorio a forte vocazione pioppicola come quello della pianura padana. Solo da questa prima analisi potremmo tranquillamente affermare che le regioni hanno mancato la principale opportunità nel dare seguito alle promesse fatte a gennaio 2014 al momento della stipula del sopracitato promettente accordo di settore, lasciando un grande punto interrogativo sul futuro della pioppicoltura.

Tabella 1 - Comparazione dei criteri di ammissibilità in riferimento alla Misura 8.1 - Tipologia A

Regione	Criteri di ammissibilità
Emilia-Romagna	• Diversificazione clonale con utilizzo prevalente di cloni a Maggiore Sostenibilità Ambientale (MSA)* • Impianti con investimenti maggiori a 200 esemplari/ha e non superiori a 2.000 esemplari/ha • Superficie minima pari o superiore a 1 ha in ambiti di pianura e a 0,5 ha in ambiti di collina e montagna
Friuli-Venezia Giulia	• Superficie minima 0,50 ettari • Per superfici superiori a 200 ettari deve essere assicurata una mescolanza di specie arboree che includa almeno il 10% di latifoglie per ogni zona o un minimo di tre specie o varietà arboree ivi compresi varietà clonali, di cui la meno abbondante costituisce almeno il 10% della superficie oggetto di intervento
Lombardia	• Densità ammissibile compresa tra 150 e 350 alberi/ha • Devono essere utilizzati solo i cloni di pioppo iscritti al "Registro Nazionale dei Materiali di Base" o in analoghi Registri di altri Stati dell'UE. • Per impianti fino a 30 ettari obbligatorio usare per almeno il 50% del totale uno o più cloni di pioppo scelti fra quelli indicati nella lista dei cloni MSA (impianto con almeno due cloni); • Per impianti oltre i 30 ettari obbligatoria la mescolanza a blocchi, usando almeno tre cloni, due dei quali scelti fra quelli indicati nella lista dei cloni MSA; questi ultimi devono rappresentare almeno il 50% del totale (impianto con almeno tre cloni). • Superficie minima 1 ettaro
Piemonte	• Per impianti di superficie compresa tra 1 e 4,99 ha: almeno 22% di cloni MSA sul totale delle pioppelle • Per impianti di superficie compresa tra 5 e 14,99 ha: almeno 33% di cloni MSA • Per impianti di superficie uguale o superiore ai 15 ha: almeno 50% di cloni MSA
Veneto	• Per impianti fino a 10 ettari, obbligatorio usare per almeno il 10% del totale uno o più cloni di pioppo scelti fra quelli indicati nella lista dei cloni MSA • Per impianti oltre i 10 ettari obbligatoria la mescolanza a blocchi, usando almeno tre cloni, due dei quali scelti fra quelli indicati nella lista dei cloni MSA; questi ultimi devono rappresentare ciascuno almeno il 10% del totale • Impianti ammessi unicamente nei comuni di pianura della classificazione ISTAT

** Si fa riferimento al Disciplinare di produzione integrata del pioppo approvato dalla Regione e agli elenchi di cui ai medesimi disciplinari e a quelli certificati da centri di ricerca riconosciuti*

Tabella 2 - Comparazione dei principi di selezione in riferimento alla Misura 8.1 - Tipologia A

Regione	Principi di selezione
Emilia-Romagna	• Richiedenti già attuatori d'interventi analoghi in precedenti periodi di programmazione • Superfici che si collegano funzionalmente a interventi in precedenza realizzati e funzionalmente ad aree ad alta valenza ecologica • Terreni agricoli demaniali golenali • Rilevanza all'area d'intervento

	• Richiedenti che hanno sottoscritto accordi per la redazione di Piani di Gestione Forestale in riferimento alla Misura 16 • Richiedente con impegni agro-ambientali relativi a precedenti programmazioni ancora in corso di esecuzione e richiedente con impegni sottoscritti per Misure 10 e 11 • Richiedente già beneficiario di altre operazioni della Misura 8 • Preferenza per richiedenti con minore rapporto superficie forestale/SAU
Friuli-Venezia Giulia	• Localizzazione dell'intervento, privilegiando gli interventi realizzati nelle aree agricole e nelle zone di tutela ambientale • Tipo di beneficiario privilegiando i richiedenti che hanno già ottenuto la certificazione per la gestione sostenibile dei pioppeti • Tipologia e caratteristiche dell'operazione favorendo: o gli impianti, anche di estensione inferiore a 200 ha, realizzati con l'utilizzo esclusivo di specie arboree autoctone; o i progetti che prevedono, indipendentemente dall'estensione dell'intervento, una mescolanza di specie arboree che includa almeno il 10 % di latifoglie per ogni zona o un minimo di tre specie arboree, ivi comprese varietà clonali, di cui la meno abbondante costituisce almeno il 10% della superficie di intervento; o tra gli impianti a ciclo lungo, quelli di tipo policiclico permanente • Presenza di strumenti di qualificazione delle metodologie produttive quali la certificazione forestale PEFC o FSC, o in alternativa disciplinari di produzione sul tipo di "Ecopioppo" o altri disciplinari riconosciuti e vigenti a livello nazionale e regionale
Lombardia	• Possesso di certificazione forestale • Localizzazione dell'intervento (in ordine decrescente: interventi realizzati in aree Natura 2000 e in altre aree protette coerenti con la pianificazione delle stesse aree, aree di pianura, aree di collina) • Tipologia di specie e varietà di piante utilizzate (in ordine decrescente: tipologia d'impianto, impiego di cloni a maggiore sostenibilità ambientale) • Caratteristiche del richiedente e dell'azienda (in ordine decrescente: giovane agricoltore, donna, azienda biologica)
Piemonte	• Qualità ambientale per la quale è previsto il requisito della diversità clonale (con cloni a Maggiore Sostenibilità Ambientale – MSA) • Diversità specifica (inserimento di altre specie in accompagnamento al pioppo) • Sostenibilità ambientale (adesione a sistemi di certificazione forestale sostenibile e ai disciplinari di produzione messi a punto nello studio "Ecopioppo"
Veneto	• Tipologia di beneficiario (IAP, giovane agricoltore, ecc.) • Localizzazione geografica (es. zone vulnerabili ai nitrati) • Tipologia di investimento e alla durata del ciclo colturale

Tabella 3 - Comparazione degli importi ed aliquote in riferimento alla Misura 8.1 - Tipologia A

Regione	**Importi e aliquote**
Emilia-Romagna	• Costo unitario massimo € 7.500/ha • Aliquota (%) del costo unitario riconoscibile per il pagamento è fissata al 100%
Friuli-Venezia Giulia	• Costo totale ammesso 4.000€/ettaro • L'aliquota di sostegno per gli imboschimenti con ciclo compreso tra 8 e 20 anni è pari all'80%.
Lombardia	• Costi per un minimo di 1.667,98 €/ha ed un massimo di 3.440,90 €/ha
Piemonte	• 70% dei costi ammissibili (su una spesa massima ammissibile di 4.000 euro/ha) per impianti monospecifici (solo cloni di pioppo) realizzati da imprenditori agricoli titolari di aziende che aderiscano a sistemi di certificazione di gestione forestale sostenibile; • 50% dei costi ammissibili (su una spesa massima ammissibile di 4.000 euro/ha) per impianti monospecifici realizzati da altri soggetti privati.
Veneto	• 80% della spesa ammessa

Annex 5

Dove va la pioppicoltura padana?

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Le Misure di sostegno pubblico, attraverso i Piani di sviluppo rurale, sono una variabile esterna importante nel determinare i livelli d'investimento in nuovi impianti a pioppo. L'articolo offre un quadro critico su come questi strumenti sono stati utilizzati nel precedente periodo di programmazione 2007-13 e sui nuovi indirizzi assunti nella programmazione 2014-2020.

Introduzione

La pioppicoltura padana può essere considerata a tutti gli effetti come la punta di diamante della produzione legnosa ad uso industriale in Italia. Un ruolo, quello del pioppo, che nel nostro Paese è di primaria importanza per le filiere dei compensati, degli imballaggi, della carta e dei pannelli a base di legno. Considerando le alternative di reddito nell'impiego dei terreni di norma utilizzati per queste piantagioni, si può facilmente sostenere che la pioppicoltura specializzata rappresenta l'investimento forestale a più alto tasso di rendimento in Europa.

Nonostante questo ruolo strategico, si è assistito, già dagli anni Ottanta, e in modo più significativo negli ultimi quindici anni, a un graduale declino del settore. Secondo i dati del Censimento dell'Agricoltura ISTAT, che considera solo i pioppeti all'interno delle aziende agricole, dal 2000 al 2010 (ultimo dato disponibile in senso temporale) le superfici della pioppicoltura specializzata sono diminuite da 83.368 a 39.308 ha (-53%), insieme al numero di aziende pioppicole che da circa 40mila è passato a 25mila (-60%) (ISTAT 2000; 2010).

Le variabili che incidono sugli investimenti pioppicoli sono interne al settore (prezzi del legname, cloni disponibili, canoni di concessione, ecc.), ma anche esterne: il rendimento delle coltivazioni agrarie alternative, il livello d'incentivazione alle piantagioni ed eventuali vincoli ambientali. Alla luce di queste considerazioni risulta chiaro il ruolo determinante che, direttamente e indirettamente, hanno i Piani di Sviluppo Rurale (PSR) nel settore pioppicolo attraverso l'insieme delle Misure a sostegno dei redditi agricoli e delle attività forestali.

Se diamo uno sguardo all'analisi recente in merito alla coltivazione del pioppo in Italia, osserviamo che questa si è interessata più agli aspetti legati alle coltivazioni a ciclo breve (Coaloa e Facciotto, 2014; Manzone *et al.*, 2009), alla difesa fitosanitaria (Giorcelli *et al.*, 2012), alle caratteristiche tecnologiche del legno (Buresti Lattes *et al.*, 2015; Castro *et al.*, 2014; Castro *et al.*, 2013) e all'impatto ambiatale (Coaloa *et al.*, 2016; Chiarabaglio *et al.*, 2014; Chiarabaglio *et al.*, 2011), mentre poca attenzione è stata posta sul monitoraggio del mercato e delle politiche di settore.

La Programmazione PSR 2007-13

I dati conclusivi dell'ultimo periodo di programmazione PSR 2007-2013, che in questi mesi iniziano ad essere pubblicati dalle amministrazioni regionali e dalla Rete Rurale Nazionale, ci permettono di fare una prima analisi su come questi strumenti sono stati impiegati.

Nei precedenti periodi il cofinanziamento comunitario per le misure di imboschimento ha rappresentato la principale fonte nazionale di sostegno per l'arboricoltura a ciclo medio lungo e la pioppicoltura. Con il Reg. CEE n. 2080 dal 1994 al 2000 sono stati, infatti, realizzati imboschimenti su terreni agricoli per 104.141 ha (su 141.000 ha di piantagioni programmate), di queste il 75% risulta costituito da impianti di latifoglie (Colletti 2001). Analogamente con il Reg. CE n. 1257/99, per il periodo di programmazione 2000-2006, con la Misura H si è previsto nuovamente l'imboschimento delle superfici agricole a finalità produttiva e finalità protettiva/multifunzionale e sono stati realizzati un totale di 40.573 ha (su circa 80.000 ha di piantagioni programmate); di queste oltre 80% risulta costituito da impianti di latifoglie (Romano e Cilli 2008).

Nella programmazione 2007-13 il sostegno alla pioppicoltura ha trovato la sua collocazione solamente all'interno della Misura 221 (la più significativa delle Misure forestali in termini di fondi allocati, considerando anche i fondi impegnati per i premi annui degli impianti realizzati nei precedenti periodi di programmazione), con la quale si prevedeva inizialmente di realizzare, secondo quanto indicato come obiettivo *target* dai PSR regionali, l'imboschimento di nuovi 72.612 ha di terreni agricoli. Con la Misura 223, si prevedeva invece l'imboschimento di terreni non-agricoli. I PSR predisposti dalle cinque Regioni padane (Emilia-Romagna, Friuli-Venezia Giulia, Lombardia, Piemonte e Veneto) presentavano nella definizione degli interventi un approccio omogeneo e obiettivi ambiziosi (Tabella 1). Gli obiettivi enunciati, in linea con gli indirizzi strategici dell'allora nuovo Programma Quadro per Il Settore Forestale, non sono stati poi però seguiti da un'attivazione coerente ed efficace dei bandi e dei finanziamenti messi a disposizione. Questo per motivazioni differenti che a loro volta variano da una Regione all'altra e possono essere ricondotti allo scarso interesse dei beneficiari, all'eccessivo appesantimento finanziario ed amministrativo dei trascinamenti dalle precedenti programmazioni, nonché dai limiti di programmazione e dai vincoli ambientali. Basti pensare che, da un punto di vista spaziale e temporale, se da un lato la Lombardia (l'esempio più positivo) ha garantito con un "bando aperto" la possibilità di contributo su scala annuale, dall'altro pochi bandi sono stati aperti dalle altre Regioni in considerazione, addirittura solamente uno (2010) nel caso del Piemonte, la principale regione pioppicola tra le cinque padane. In merito alle superfici finanziate nel periodo 2007-13 (riportate nella Tabella 2 con riferimento questa volta ai soli impianti di pioppicoltura), emerge anche ad una analisi superficiale un significativo ridimensionamento degli obiettivi prefissati a inizio programmazione. A livello nazionale dei 72.612 ha di terreni agricoli programmati per l'imboschimento risultano esserne stati realizzati poco meno di 25.000 ha. Per esempio, in Lombardia, con la sola Misura 221 era previsto l'imboschimento di 16.000 ha di cui ne sono stati effettivamente finanziati e collaudati circa 3.200 ha, poco più del 20%, dove i pioppeti contano per l'88% (2.082 ha a ciclo breve e 757 ha a ciclo medio-lungo). Per altre Regioni, come l'Emilia-Romagna e il Piemonte, dove sono stati finanziati impianti di pioppo per rispettivamente 99 e 463 ha, la scarsa efficacia dell'intervento è ancora più evidente.

Tabella 1: Confronto fra obiettivi previsti (target) e impianti realizzati complessivamente con le Misure 221 e 223 della programmazione 2007-13 (al 31 dicembre 2014).

Regioni	Misura 221				Misura 223			
	Superficie (ha)		Beneficiari (n°)		Superficie (ha)		Beneficiari (n°)	
	Obiettivo previsto*	Realizzato**	Obiettivo previsto*	Realizzato**	Obiettivo previsto*	Realizzato **	Obiettivo previsto*	Realizzato **
Emilia-Romagna	6.023	281	1476	75	-	-	-	-
Friuli-Venezia Giulia	2.710	489	630	126	75	924	30	174
Lombardia	16.000	3.223	2700	353	7	303	3	17
Piemonte	1.500	1.035	350	202	-	-	-	-
Veneto	3.328	1.159	*1270*	*314*	420	306	*68*	*72*

** Dati obiettivo target dalle Schede di Misura dei PSR regionali.*
*** Dati dalle Relazioni Annuali di Monitoraggio regionali (al 31/12/2014).*

Fonte: Nostra elaborazione su dati dei PSR regionali e da Relazioni Annuali di Monitoraggio.

Tabella 2: Impianti di pioppo oggetti di contributo nella programmazione 2007-13 (a rendicontazione conclusa 31 dicembre 2015, le differenze di somma tra le tabelle 1 e 2 sono dovute a periodi di rendicontazione differenti)

Regioni	Impianti di pioppo nella Misura 221 (ha)		Impianti di pioppo nella nella Misura 223 (ha)
	A ciclo breve	A ciclo medio-lungo	
Emilia-Romagna	98,34	n.a.	-
Friuli-Venezia Giulia	325,08*		1.161,25
Lombardia	2.081,67	757	-
Piemonte	463	n.a.	-
Veneto	871,38	n.a.	n.a.

** Nel caso del FVG le due tipologie della Misura 221 sono accorpate.*

Fonte: nostra elaborazione su dati delle Amministrazioni regionali.

Vi è da ricordare che anche la spesa per i trascinamenti degli impegni assunti nei precedenti periodi di programmazione, 1993-99 e 2000-2006, è stata significativa, arrivando a pesare per circa il 60-70% del totale speso, in quanto fino alla prima metà degli anni novanta si è previsto il riconoscimento, per 20 anni, di un sostegno al mancato reddito per ettaro di terreno agricolo imboschito[8].

La Nuova Programmazione PSR 2014-20

Pochi mesi fa sono stati approvati dalle Regioni i nuovi PSR per il periodo di programmazione 2014-2020, dove gli interventi a sostegno della pioppicoltura rientrano nella Misura 8.1 per il "sostegno all'imboschimento o rimboschimento di terreni agricoli e non-agricoli".

Per i nuovi PSR delle cinque Regioni padane che cosa cambia rispetto alla precedente programmazione? Innanzitutto, bisogna sottolineare che le scelte fatte per promuovere l'arboricoltura e in particolare la pioppicoltura erano state condivise dalle Regioni interessate in fase di programmazione, proprio al fine di poter proporre un'azione omogenea per l'intera area padana. A riguardo, con il Quadro Nazionale delle Misure Forestali nello Sviluppo Rurale

[8] Si noti, per inciso, la sproporzione del livello di incentivazione tra questi aiuti e quelli degli anni successivi, una sproporzione che ha determinato una rendita di posizione tra i beneficiari del passato. È difficile trovare delle spiegazioni legate alle difficoltà della pioppicoltura per queste evidenti sperequazioni, anzi sembra che si sia investito di meno proprio quando il settore andava più sostenuto.

2014-2020[9] realizzato dal Ministero delle Politiche Agricole, Alimentari e Forestali e approvato a Novembre del 2014 in Conferenza Stato-Regioni, si era sviluppato anche un accordo interregionale che prevedeva una base comune di intenti per la costruzione proprio della Misura 8.1. Rispetto al passato ogni Regione ha dovuto e voluto prendere in considerazione nuovi e più stringenti criteri di sostenibilità ambientale, quali: l'impiego di cloni a maggiore sostenibilità ambientale (msa), la certificazione della Gestione Forestale Sostenibile (GFS) e altri aspetti legati alla funzione dell'impianto e quindi alla localizzazione e/o alla tipologia di beneficiario. Un confronto di questi aspetti tra i cinque nuovi PSR delle Regioni padane è riportato nella Tabella 3. Nonostante i presupposti, emerge però per questo nuovo periodo di programmazione un'evidente disomogeneità e incertezza nell'impostazione degli interventi volti alla promozione della pioppicoltura. Ma come si è arrivati a una situazione così priva di elementi di coerenza? La risposta va cercata nella debole capacità di rappresentanza degli interessi legati alle filiere forestali da parte delle Regioni a Bruxelles e nella mancanza di un'azione di sostegno e coordinamento da parte del Ministero nella complessa fase di negoziazione dei PSR davanti alla Commissione Europea. Tale situazione è infatti degenerata in fase di contrattazione bilaterale per l'approvazione dei PSR dove non si è riusciti a portare una posizione comune nazionale, lasciando in questo modo le Regioni da sole a dover confrontarsi con una Commissione che fa fatica sempre di più a riconoscere la pioppicoltura come un intervento di imboschimento.

Il risultato è una forte disomogeneità tra le Regioni nella definizione finale della Sottomisura 8.1, proprio per quanto riguarda i criteri di ammissibilità e i principi di selezione, i criteri per l'impiego dei cloni MSA e per l'utilizzo della certificazione di GFS. Questa situazione acuisce ancora di più il difficile periodo per il settore e rappresenta, purtroppo, un aspetto molto critico per la promozione dell'"Intesa per lo sviluppo della filiera del pioppo", documento promosso dalle cinque Regioni padane, insieme alle principali associazioni del settore, e firmata nel Gennaio 2014 dai cinque assessori regionali in un incontro con ampio ritorno di stampa. Un accordo interregionale che aveva formalmente definito l'obiettivo di stimolare uno sviluppo coordinato e continuo della filiera.

Al di là dei proclami, si è constatato che, in un mercato già gravato di elementi di incertezza per l'andamento altalenante dei prezzi del legname e dei prodotti agricoli, l'amministrazione pubblica ha introdotto un ulteriore fattore di incertezza legato alla mancanza di una strategia

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[9] http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/14582

nazionale di sostengo al settore e a una conseguente discontinuità dei bandi. Una discontinuità che ha condizionato in negativo gli investimenti in nuovi impianti di pioppo negli ultimi anni. In riferimento al nuovo periodo di programmazione, ad oggi solo in tre Regioni (Lombardia, Piemonte e Friuli-Venezia Giulia) sono stati attivati i bandi per la Misura 8.1.

Tabella 3: Sintesi delle principali caratteristiche della Misura 8.1 in riferimento alla pioppicoltura.

Regioni	Cloni	Certificazione	Superficie	Contributo	Altri elementi
Emilia-Romagna	Utilizzo prevalente di cloni MSA (>50%).	-	1 ha in pianura; 0,5 ha in collina e montagna;	Massimale 4.000€ con aliquota 70-80% per pioppicoltura "ecocompatibile" e 40% per la tradizionale.	Precedenza ai richiedenti già attuatori d'interventi analoghi e all'area d'intervento;
Friuli-Venezia Giulia	Per superfici superiori ai 200 ha mescolanza di un minimo di 3 varietà clonali, di cui la meno abbondante costituisce almeno il 10% dell'impianto.	Obbligo presenza di strumenti quali la certificazione di GFS (PEFC o FSC) o in alternativa disciplinari di produzione riconosciuti quali "Ecopioppo".	0,5 ha	Massimale 4.000€ con aliquota all'80%.	Si da peso alla localizzazione dell'impianto
Lombardia	Per impianti fino a 30 ha almeno 50% di cloni MSA; Per impianti oltre i 30 ha mescolanza in blocchi (almeno 3 cloni, 2 dei quali msa e rappresentanti almeno il 50% dell'impianto).	Precedenza a chi è in possesso di certificazione di GFS.	1 ha:	Costi per un minimo di 1.667€ e massimo di 3440€/ha con aliquota al 60% (80% se in possesso di certificazione GFS o uso esclusivo cloni msa)	Si da peso alla localizzazione dell'impianto;
Piemonte	Per impianti fino a 5 ha almeno 22% cloni MSA; dai 5 ai 15 ha almeno il 33%; oltre i 15 ha il 50%.	Precedenza a chi aderisce a schemi di certificazione GFS e ai disciplinari di produzione di "Ecopioppo".	1 ha	Massimale 4.000€ con aliquota al 70% per agricoltori attivi con certificazione GFS, 50% tradizionali negli altri casi	Si da peso alla diversità specifica dell'impianto (inserimento di altre specie di accompagnamento al pioppo);
Veneto	Per impianti fino ai 10 ha almeno il 10% di cloni msa; oltre i 10 ha	-	-	-	Si da peso al tipo di beneficiario e localizzazione geografica.

	mescolanza in blocchi (almeno 3 cloni, 2 dei quali MSA appresentati ciascuno almeno il 10% del totale).	

Fonte: Nostra elaborazione sulla base dei testi finali dei PSR 2014-20

Un mercato poco monitorato

Vi è da considerare, a monte degli interventi di sostegno pubblico, che i livelli di conoscenza sul mercato del pioppo sono decisamente bassi e in progressiva fase di peggioramento, sia per quanto riguarda i dati sull'estensione delle superfici coltivate[10], sia per le variabili di carattere economico quali prelievi, prezzi e numero di operatori. Un *gap* informativo che s'inserisce purtroppo in un contesto dove la disponibilità di informazioni statistiche accurate e tempestive a livello nazionale si è andata riducendo, senza una corrispondente capacità delle Regioni di supplire a queste carenze. Il che è un problema da considerarsi grave, *in primis* perché una base informativa solida ed accurata è essenziale per attuare un programma specifico di sviluppo della filiera del pioppo. Il fatto che le piantagioni siano effettuate non solo in base all'andamento del mercato ma in termini significativi in base all'azione di sostegno pubblico, causa conseguenze negative anche sulla produzione industriale delle filiere dipendenti dal pioppo. Se da un lato queste continuano a fare affidamento sull'importazione di tondo da altri paesi europei per oltre i 2/3 della domanda interna, dall'altro, i trend di progressiva diminuzione dell'importazione di tondo di pioppo e di aumento dell'importazione di compensato (Eurostat, 2016) evidenziano le difficoltà che anche la stessa industria della prima trasformazione italiana sta vivendo in un momento, come quello attuale, dove per la prima volta dall'inizio della crisi economica vi sono le premesse per una ripresa della produzione interna di prodotti in legno. Se la diminuzione della capacità di produzione di compensati si dovesse consolidare, evidentemente la pioppicoltura italiana sarebbe la prima a risentirne. Già uno studio di qualche anno fa di Assopannelli dimostrava che le potenzialità per il rilancio della pioppicoltura c'erano, in quanto

[10] L'ultimo Inventario continuo della pioppicoltura padano-veneta (a cura dell'Istituto di Sperimentazione per la Pioppicoltura di Casale Monferrato, oggi CREA-PLF) è stato realizzato nel 1995-96; dal 2012 nell'annuario ISTAT non compaiono più i dati relativi alle utilizzazioni dei pioppeti.

la domanda nazionale di legname di pioppo ad uso industriale di circa 3,1 Mt (oggi in aumento) si tradurrebbe in una potenzialità di espansione delle superfici a 140.000 ha (AAVV 2008).

Considerazioni conclusive

Quali possono essere le azioni per cambiare direzione e cogliere le potenzialità di rilancio di questo settore? Nel 2017, come annunciato alcuni mesi fa dal commissario europeo per l'agricoltura Phil Hogan, si aprirà una finestra di revisione della Politica Agricola Comune (PAC), che permetterà di apportare significative modifiche ai singoli PSR. Questa si presenta dunque come l'occasione più importante per le Regioni della pianura padana di rimettersi in linea e dare seguito alle proprie promesse e impegni di sostegno alla pioppicoltura. Per fare questo però, un ruolo centrale deve essere giocato dal Ministero nel fare da collante tra le cinque Regioni in sede comunitaria, partendo dal proporre una rinnovata strategia comune. Un ottimo punto di partenza potrebbe essere l'accordo interregionale firmato due anni fa, magari rivisto puntando con maggiore enfasi su alcuni elementi. Per esempio, si potrebbe rivalutare l'utilizzo dei cloni a "maggior sostenibilità ambientale" (MSA), potenziare la certificazione della Gestione Forestale Sostenibile per l'arboricoltura ma sopratutto si dovrebbe valorizzare il concetto europeo di rimboschimento negli interventi nazionali di arboricoltura. In particolare, la diffusione e l'utilizzo di impianti policiclici, con diverse specie pregiate e anche cloni di pioppo, rappresenterebbe non solo un'innovazione colturale dagli ottimi risultati e una interessante forma di diversificazione produttiva ma soprattutto un elemento chiave per soddisfare anche le esigenze ambientali richieste dalla Commissione Europea. Inoltre, per la pioppicoltura specializzata, a fronte di una Commissione Europea, e nello specifico la DG Ambiente, sempre più riluttante a supportare finanziariamente gli impianti di pioppo, si potrebbe valutare anche altre forme di supporto, quali per esempio quelle relative agli strumenti assicurativi degli impianti e per la gestione del rischio nell'attività agricola, alla definizione di accordi contrattuali produttori-imprese industriali che facilitino l'offerta (Misura 19 sulla Cooperazione), al monitoraggio del mercato. Comunque, su questi e altri interventi un criterio generale dovrebbe prevalere: meglio pochi incentivi, ma erogati con sicurezza di accesso, continuità ed efficacia, piuttosto della politica dello "*stop and go*", o della "spinta al vagone" o del finanziamento a pioggia per ettaro agricolo. La politica delle dichiarazioni inattuate, dei piani ambiziosi e dei successivi incentivi erogati con discontinuità, frammentarietà e incertezza dovrebbero fare parte di quel passato che ha fatto più male che bene alla pioppicoltura italiana.

Bibliografia

AA.VV., 2008 - Declino della pioppicoltura in Italia e raccomandazioni per una strategia di rilancio. Assopannelli/Federlegno-Arredo, Milano.

Buresti Lattes E., Castro G., Mori, P., Zanuttini, R., 2015 – Sfogliatura del pioppo. Confronto fra piante di "I-214" di dimensioni tradizionali e grandi dimensioni. Sherwood - Foreste ed Alberi Oggi, 212.

Castro G., Fragnelli G., Zanuttini R., 2014 - La Pioppicoltura e il compensato di Pioppo dell'industria italiana. Lampi di Stampa.

Castro G., Mori P., Zanuttini R., 2013 – Produttività di sfogliato e diametro dei fusti: indagini preliminari sui cloni di pioppo I-214 e Neva. Sherwood - Foreste ed Alberi Oggi, 192.

Coaloa D., Facciotto G., Chiarabaglio P.M., Giorcelli A., Nervo G., 2016 – Cloni di pioppo a Maggiore Sostenibilità Ambientale (MSA): vantaggi della loro coltivazione. Sherwood – Foreste ed Alberi Oggi, 216.

Coaloa D., Facciotto G., 2014 – Biomass feedstock from multipurpose poplar plantations: current situation and potential development in Italy. In: Proceedings of the 22nd European Biomass Conference and Exhibition, Hamburg, 23-26 June 2014, pp. 112-115.

Chiarabaglio P.M., Allegro G., Rossi A.E., Savi L., 2014 – Studi sulla sostenibilità della pioppicoltura in Lombardia. Sherwood - Foreste ed Alberi Oggi, 206.

Chiarabaglio, P.M., Allegro, G., Giorcelli, A., Picco, F., Rossi, A.E., Isaia, M., Rizzioli, B., Nascimbeni, J., Coaloa, D., Solarolo, D., Demichelis, G., 2011 - Sostenibilità degli impianti di arboricoltura da legno in Piemonte 1–3.

Coletti L., 2001 - Risultati dell'applicazione del regolamento CEE 2080/92 in Italia. Sherwood - Foreste ed Alberi Oggi.

Giorcelli A., Gennaro M., Deandrea G., Chiarabaglio P.M., 2012 - Effetti diretti e indiretti di trattamenti chimici contro le ruggini del pioppo. Forest@ 9: 158-165. URL: http://www.sisef.it/forest@/contents/? id=efor0695-009

Eurostat, 2016 – Database. URL: http://ec.europa.eu/eurostat/data/database

ISTAT, 2000 - Censimento Generale dell'Agricoltura. Istituto Nazionale di Statistica, Roma.

ISTAT, 2010 - Censimento Generale dell'Agricoltura. Istituto Nazionale di Statistica, Roma.

Manzone M., Airoldi G., Balsari P., 2009 - Energetic and economic evaluation of a poplar cultivation for the biomass production in Italy. Biomass and Bioenergy 33, 1258–1264. doi:10.1016/j.biombioe.2009.05.024

Romano R., Cilli S., 2009 – Impatto delle Misure forestali nello sviluppo rurale 2007-2013. In: Atti del Terzo Congresso Nazionale di Selvicoltura, Taormina (ME), 16-19 ottobre 2008. Accademia Italiana di Scienze Forestali, p. 1141-1148.

Romano R., Marandola D., 2012 – Risorse forestali nello sviluppo rurale 2014-2020. Nuove opportunità e vecchie esigenze. Sherwood - Foreste ed Alberi Oggi, 182.

Annex 6

Stima dell'andamento della redditività delle piantagioni di pioppo alla luce delle politiche di settore

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Full text is available at the link: http://foresta.sisef.org/contents/?id=efor2394-014

Annex 7

Redditività finanziaria delle piantagioni da legno: confronto tra pioppo, noce e piantagioni policicliche

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Full text is available at the link:
https://www.inbiowood.eu/files/2017/Redditivita_finanziaria_della_piantagioni_da_legno_Sherwood%20222_Ottobre-Novembre%202016.pdf

Annex 8

Quale futuro per la pioppicoltura? Indagine sul quadro attuale e le prospettive d'impiego industriale del legname di pioppo

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Full text is available at the link:
https://www.etifor.com/it/pioppicoltura/

Annex 9

Impact investments and climate change: forestry investments

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Full text is available at the link:

http://www.aiccon.it/wp-content/uploads/2018/02/2018_Impact-Investing-for-Climate-Change.pdf

Annex 10

Investimentos florestais sustentáveis e normas ambientais e sociais relacionadas

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