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Investment 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 investments among forest plantations in Europe, although the range of potential returns is rather large, including negative returns. The decrease of expected returns over the last 15 years has 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 cost, opportunity cost, and insurance cost. Land use and opportunity costs appear to be crucial variables, as well as public subsidies, which have undergone substantial changes over the period.

Keywords: Hybrid poplar, fast-growing species, timber production, investment analysis, Italy.
JEL codes: Q23, Q56, L73.

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, 2012). 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%, is 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 energy 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 farm 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, 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 or Special Protection Area), 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, 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, an explicit land 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 ECO-PIOPPO project, where the potential financial performances of conventional cultivation have been compared against those based on an experimental environmentally-friendly management standard (Coaloa, Vietto, 2005; Regione Piemonte, 2002). Other studies can be found in Borelli (1997), Borelli and Facciotto (1996) 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, Facciotto, 2014; Di Candilo, Facciotto, 2012; Manzone *et al.*, 2009), unfortunately with limited impacts on the real investments in this sector.

A preliminary version of this work has been published in Italian language in a national-level technical forest journal (Pra, Pettenella, 2017).

2. METHODOLOGY

We defined a representative management regime for hybrid poplar plantations in northern Italy, follow-

Tab. 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			
		Phytosanitary treatment *Marssonina brunnea*		2	2	2	2	2						
		Phytosanitary treatment *Saperda carcharias L*			1	1	1							
		Phytosanitary treatment *Cryptorhynchus lapathi*			1	1								
		Phytosanitary 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.
Source: own elaboration.

ing an approach similar to the one used by Sedjo (1983) and Cubbage *et al.* (2007) for the estimation of timber investments returns for selected species at global level. We decided to use a representative management regime since the study's objective was not to carry out a site-specific or 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 is rather homogeneous in northern Italy and it 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 (e.g. Borelli, 1997; Borelli, Facciotto, 1996; Coaloa, Vietto, 2005).

The data and information on management regime and investment costs used in this study were provided by three industrial and four non-industrial 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 1. The analysis was carried out considering a plantation established from *Populus* × *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 include preparation, planting, silvicultural management costs and cleaning costs. Harvesting costs were not included because trees are typically sold as standing trees to external buyers. We considered two cost 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. 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 growers 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 situations: 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 elaborated the cash flow tables considering costs and timber prices in terms of market prices. Secondly, we calculated three capital budgeting indicators to estimate financial returns: Net Present Value (NPV), Internal Rate of Return (IRR), and Land Expectation Value (LEV). The references used for the calculation and interpretation of such approaches can be found in Zinkhan and Cubbage (2003), Klemperer (2003), Bullard *et al.* (2011) and Wagner (2012). The formulas for these indicators are the following:

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

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

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

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

We decided to use the NPV and IRR as they are the two most widely spread and accepted decision indicators in sectorial literature. 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.

We calculated these indicators for each year along the period 2001-2016, combining two different calculation approaches: *ex-ante* and *ex-post*. The *ex-ante* approach allows us to estimate the expected returns, answering the question: what was the return's expectation at the time the investment was carried out? Thus, indicators are calculated based only on values of the year when the investment was carried out. For example, in the case of a plantation established in 2001, the NPV would be calculated as follows:

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

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, for example:

$$NPV\ ex\ post_{2001} = \frac{R_{2011}}{(1+i)^{11}} - \frac{C_{2001}}{(1+i)^{1}} - \frac{C_{2002}}{(1+i)^{2}} - \frac{C_{2003}}{(1+i)^{3}} - \ldots - \frac{C_{2012}}{(1+i)^{11}}$$

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.

In financial analysis, the choice of the discount rate in financial analysis is ultimately a decision of the investor who looks at the market prices with a discount rate that represents its opportunity cost for using its capital. In our study, for the NPV and LEV we decided to use a real discount rate of 3.5% (HM Treasury, 2003). How-

Tab. 2. Input data for sensitivity analyses.

Year	Missed revenues from corn cultivation in northern Italy (EUR/ha/year)*	Average annual land rent cost for selected types for land in the Po valley (EUR/ha/year)	Reimbursement percentage of site preparation and planting costs according to Rural Development Plan measures (%)	Insurance cost (EUR/ha/year)
2001	….	378.60		
2002	….	368.20		
2003	….	347.30	*60%* according to Measure H of RDPs 2000-06 (Reg. ECC No. 1698/1999)	
2004	….	347.30		
2005	….	352.50		
2006	….	307.70		
2007	….	317.10		
2008	150.70	312.90		
2009	-65.40	310.80	*70%* according to Measure 221 of RDPs 2007-13 (Reg. ECC No. 1968/2005)	
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		
2015	112.90	338.00	*60%* according to Measure 8.1 of RDPs 2014-20 (Reg. ECC No. 1305/2013)	
2016	….	350.00		1st to 3rd year: 83 EUR/yr 4th to 6th year: 167 EUR/yr 7th to 10th year: 278 EUR/yr

* Direct payments from the Common Agricultural Policy excluded.
Source: own elaboration.

ever, 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 with their own references.

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, subsidies, and land cost (i.e. rent), assuming thus that the investors already own the land.

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) an explicit land 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 pests, fire, windstorm and hail.

The sensitivity analyses input data are presented in Table 2.

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 1305/2013, the average reimbursements percentage of the establishment costs is 60% (Measure 8.1). In the programming period 2007-2013 (ECC 1698/2005), it was 70% (Measure 221), and in the programming period 2000-2006 (reg. ECC 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 benefit 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 net missed revenues from corn production using the data of the Farm Accountancy Data Network (FADN) (RICA, 2017). We elaborated the net missed 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 based on boxplots (excluding those 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 from corn production showed a large variation among the years, presenting even a negative value in 2009 (-65.40 EUR). The net missed revenues were included in the cash flow as a cost from year 1 to 11.

Finally, the cost of an insurance policy () protecting the land owner against losses caused by pests, fire, windstorm and hail was provided by an industrial poplar grower. The cost corresponds to the 2% of the timber stumpage value in the plantation (where 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). Although insurance policies are not widely used among poplar growers in northern Italy, there is an increasing number of insurance companies offering these types of policies. We decided to assume the insurance cost as a proxy for including the risk-component in the analysis.

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.

3.1 Evolution of investment costs and timber stumpage prices

Table 3 summarizes investments costs, with reference to year 2016. 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 concerns 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 account 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 by 25.5% in the period 2001 to 2016, 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 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 stumpage prices (in EUR per ton^{-1}) is presented in Figure 1.

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 ton^{-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 by 17.7% and 15.6%. In the period 2015-2018, prices have increased considerably by 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%).

3.2 Financial return estimates according to the baseline scenario

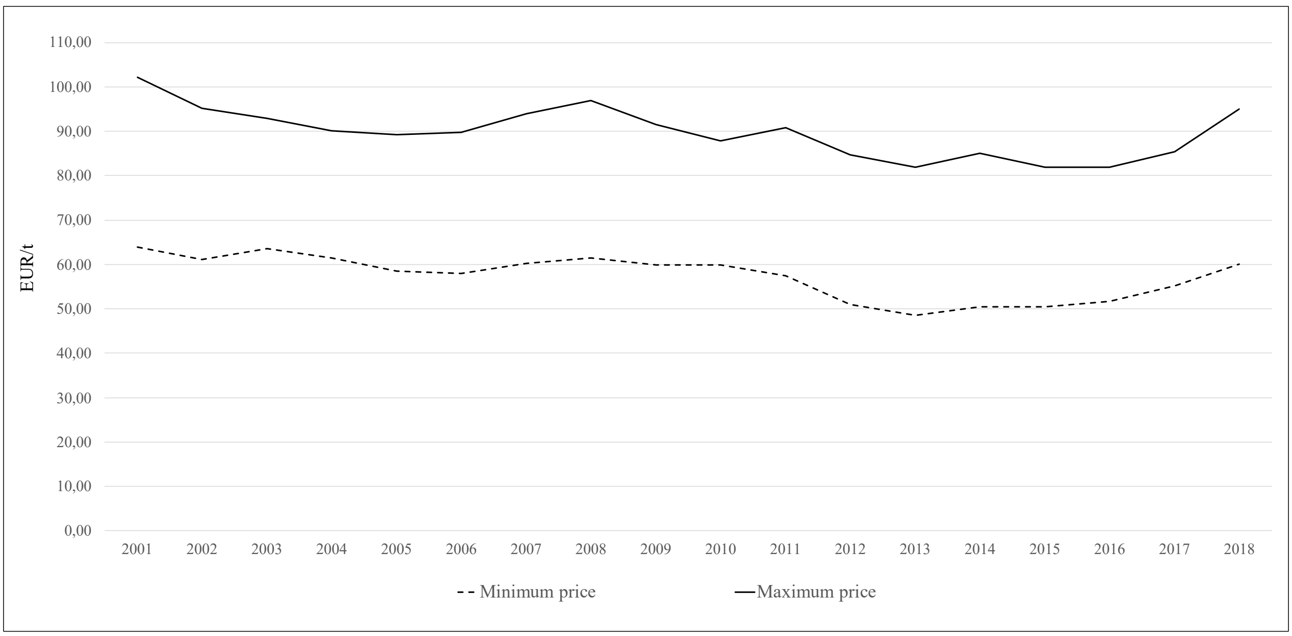
The capital budgeting indicators estimates are presented in Table 5, based on 2016 values. In the baseline

Tab. 3. Investment costs, 2016.

Category	Operation	Cmin (EUR/ha)	CMAX (EUR/ha)	Percentage difference Cmin-CMAX	Percentage 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%*		
	Phytosanitary treatment *Marssonina brunnea*	848.40	1,131.20	*28.6%*		
	Phytosanitary treatment *Saperda carcharias L*	181.80	212.10	*15.4%*		
	Phytosanitary treatment *Cryptorhynchus lapathi*	171.70	191.90	*11.1%*		
	Phytosanitary treatment 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%*			

Source: own elaboration.

Fig. 1. Poplar stumpage prices (EUR/ton), 2001-2018 (real values).



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

Tab. 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*	*100.0*
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.

scenario, NPV (at a 3.5% discount rate) varies from negative values in CMAX-Pmin (-1,921 EUR ha^{-1}) to positive values in the other three situations: 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 situations 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 results 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, while it indicates a negative value in CMAX-Pmin (-6,097 EUR ha^{-1}). (Barnes, 2002). LEV standard deviation among the four situations is 5,237 EUR ha^{-1}.

The trend over the 2001-2016 period is presented in Figure 3, also in this case using NPV as dependent variable. The full lines represent the *ex-ante* estimates, while the dotted lines the *ex-post* estimates. 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 situations. 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) in Cmin-PMAX, from 9.6% to 6.5% in CMAX-PMAX, and from 8.5% to 5.3% 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 in 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 when associated with minimum prices and in 2005 when associated to maximum prices. The NPV average decrease from 2001 to 2005 is 1,052 EUR ha^{-1}. From 2005 to 2008, NPV increases 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 between -772 and 6,555 EUR ha^{-1} in 2016. IRR values raised from 6.7% in 2001 to 7.5% in 2016 in Cmin-Pmin, 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.

3.3 Sensitivity analyses results

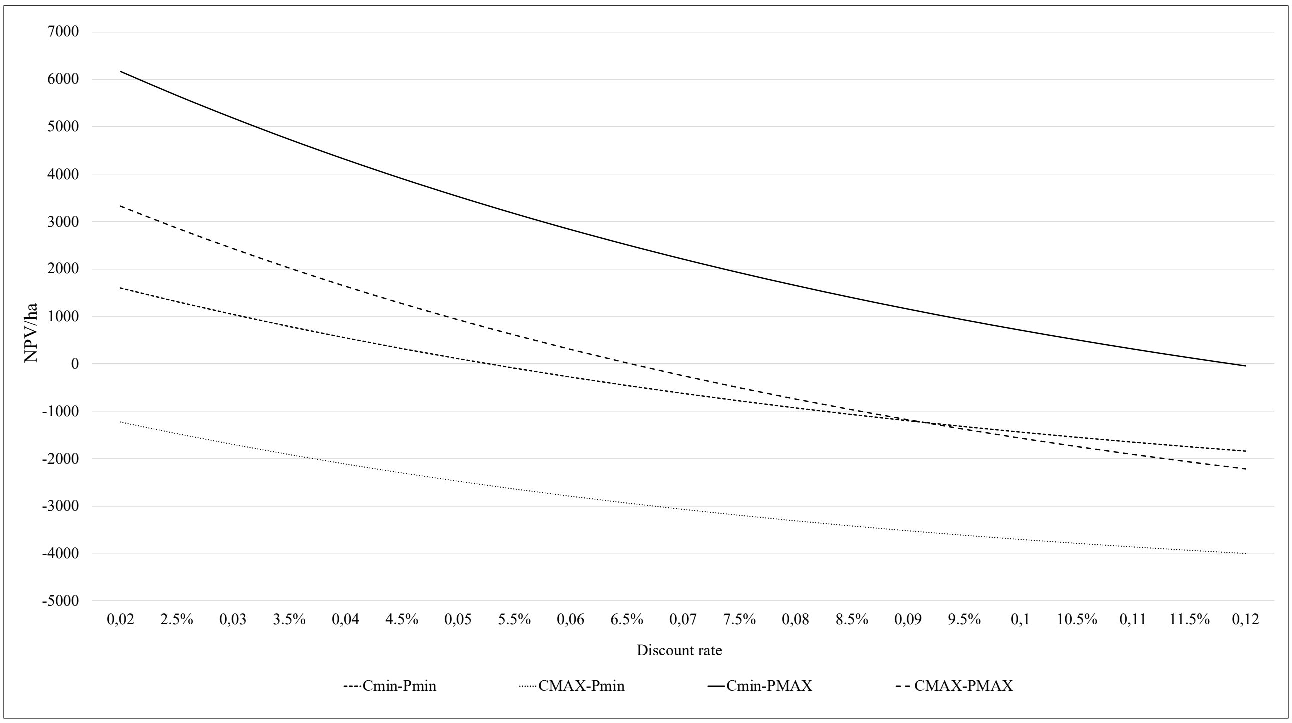
The results of the sensitivity analysis testing different hypothesis on the NPV are presented in Figure 4, based on 2016 values (as Tab. 5).

Tab. 5. NPV (EUR/ha), IRR and LEV (EUR/ha) (i= 3.5%) according to the different scenarios, 2016.

Scenario	Criteria	Cmin-Pmin	CMAX-Pmin	Cmin-PMAX	CMAX-PMAX	Standard deviation
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		

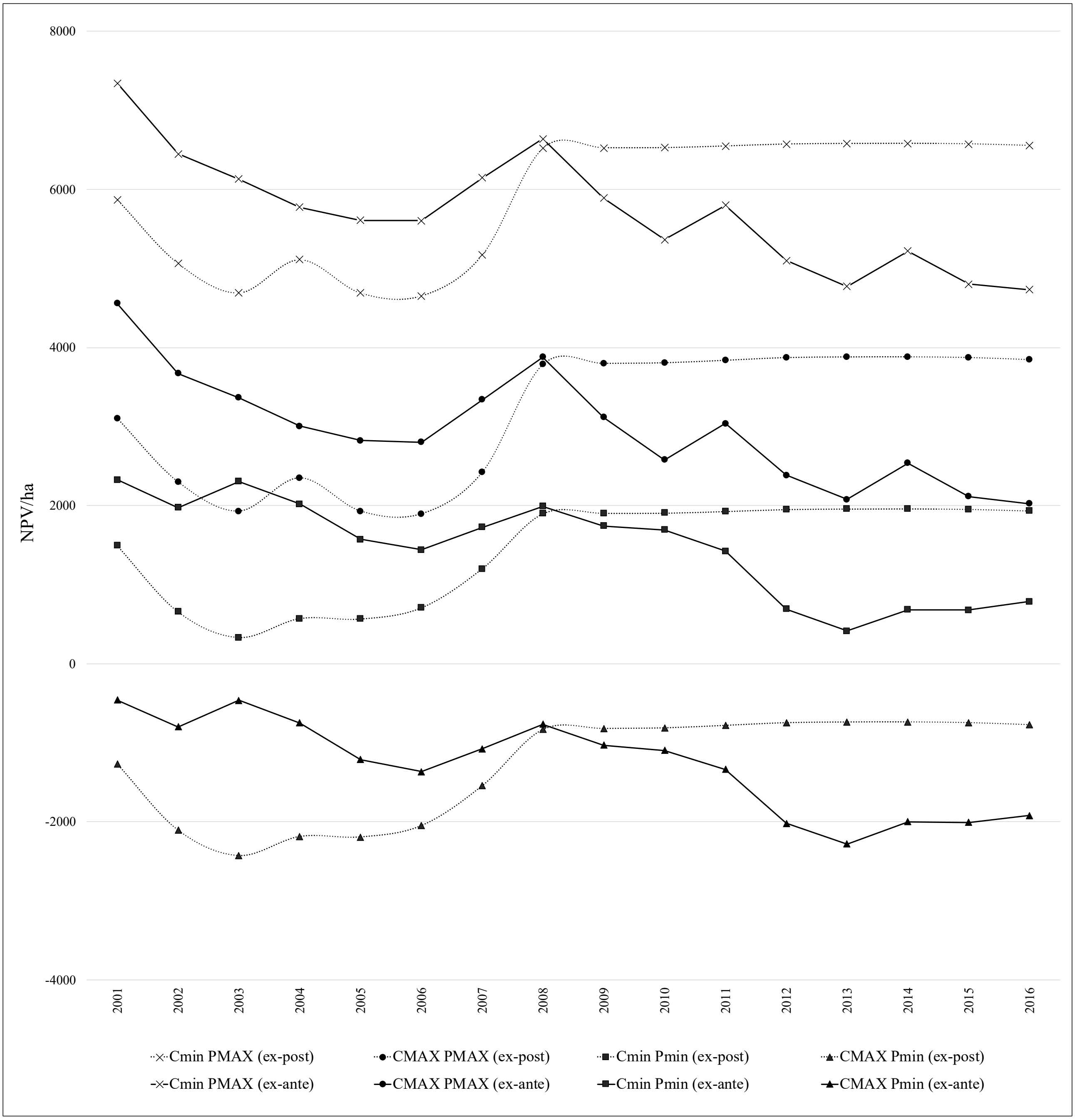
Note: results are based on 2016 data calculated with the *ex-ante* approach.
*Based on 2015 data.
Source: own elaboration.

Fig. 2. Changes in the NPV (EUR/ha) in relation to alternative discount rates, 2016.



Source: own elaboration.

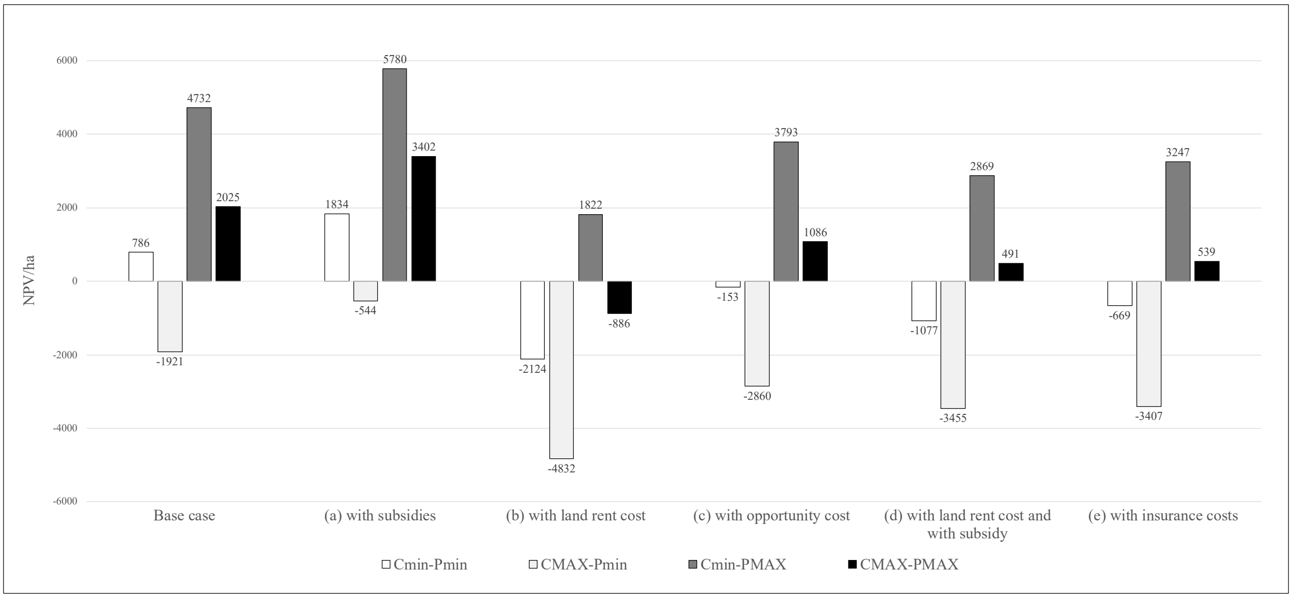
Fig. 3. NPV (EUR/ha, *i*= 3.5%) in the baseline scenario, 2001-2016 (real values).



Source: own elaboration.

When public subsidies are included in the baseline scenario (a), the NPV raises to 1,821 EUR ha^{-1} in Cmin-Pmin, 5,780 EUR ha^{-1} in Cmin-PMAX, 3,402 EUR ha^{-1} in CMAX-PMAX and -544 EUR ha^{-1} in CMAX-Pmin (remaining negative). The average NPV increases from the baseline scenario values do amount to 1,212 EUR ha^{-1}. IRR values increase on average by 3.0%, reaching up to 15.2% in the best situation (Cmin-PMAX). LEV reaches 5,821 EUR ha^{-1} in Cmin-Pmin, 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}.

Fig. 4. Sensitivity analysis results.



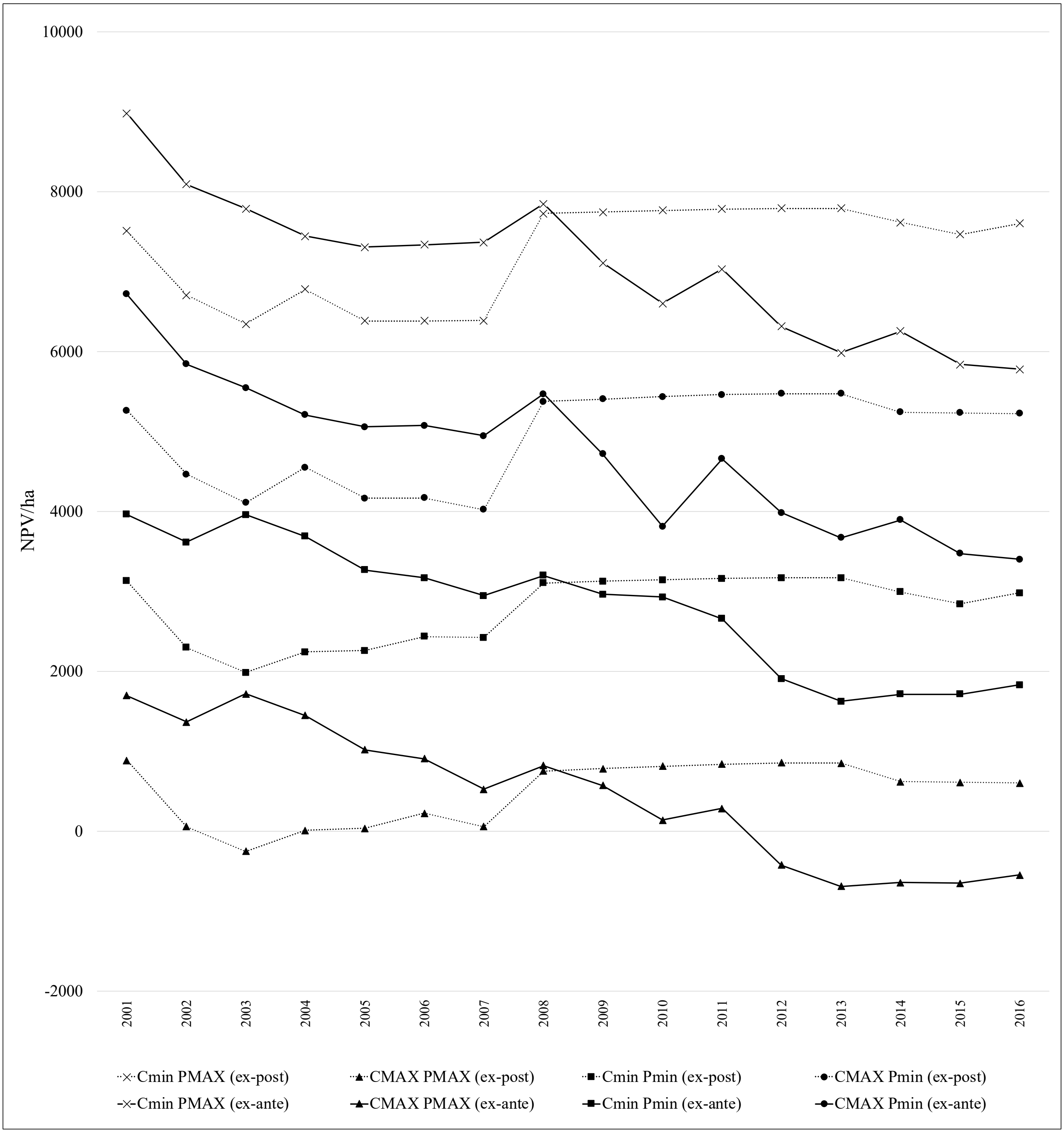
Source: own elaboration.

Figure 5 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 by 2,722 EUR ha^{-1} in the period 2001-2016 of.

When we add to the baseline scenario an annual land rent cost (b), financial returns are positive only for the Cmin-PMAX situation (NPV of 1,821 EUR ha^{-1}, IRR of 6.5% and LEV of 5,782 EUR ha^{-1}). All the other three situations 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. 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 situations decrease on average by 1,089 EUR ha^{-1} from 2001 to 2016, with a decrease more accentuated between 2008 and 2016 (-1,707 EUR ha^{-1}). In the *ex-post* results, the land rent cost trend lowers the NPV increase along the period, which is on average +1,217 EUR ha^{-1} (2001-2016).

When we include in the baseline scenario the opportunity cost (c) considering net 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 in Cmin-Pmin and CMAX-Pmin , respectively -152 EUR ha^{-1} and -2,860 EUR ha^{-1}. In the other two cases, the NPV in Cmin-PMAX 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}), while in Cmin-PMAX results 12,040 EUR ha^{-1} and in 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. Figure 7 shows the NPV trend when the opportunity cost is included in the analysis. In this case the time series is 2008-2015. The net missed revenues from corn cultivation trend reflect the situation of high volatility of corn prices in recent years, with a negative peak in the 2009. This trend is very well revealed in the *ex-ante* NPV estimates evolution, which presents a positive peak in 2009 (NPV of -438 EUR ha^{-1} in CMAX-Pmin, 2,337 EUR ha^{-1} in Cmin-Pmin, 3,707 EUR ha^{-1} in CMAX-PMAX and 6,482 EUR ha^{-1} in Cmin-PMAX) and a negative peak in 2012 (NPV of -5,670 EUR ha^{-1} in CMAX-Pmin, -2,957 EUR ha^{-1} in Cmin-Pmin, -1,263 EUR ha^{-1} in CMAX-PMAX and 1,460 EUR ha^{-1} in 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.

Fig. 5. NPV (EUR/ha, *i*= 3.5%) in the sensitivity scenario with public subsidies (a), 2001-2016 (real values).

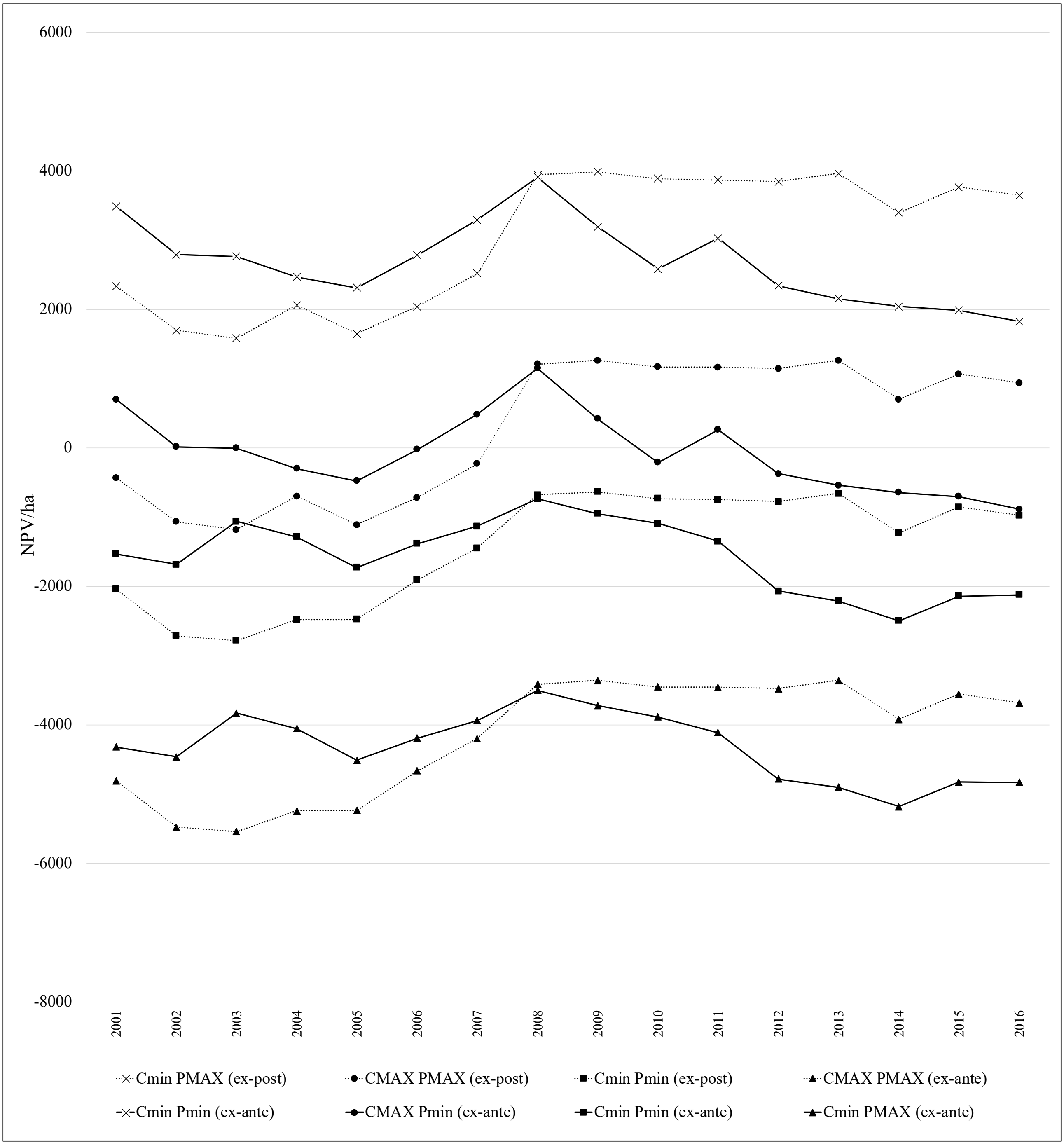


Source: own elaboration.

The fourth sensitivity analysis scenario (d) combines the inclusion of public subsidies (a) with annual land rent cost (b). In this case, NPV decreases 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 Cmin-Pmin and CMAX-Pmin , while in Cmin-PMAX 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 includ-

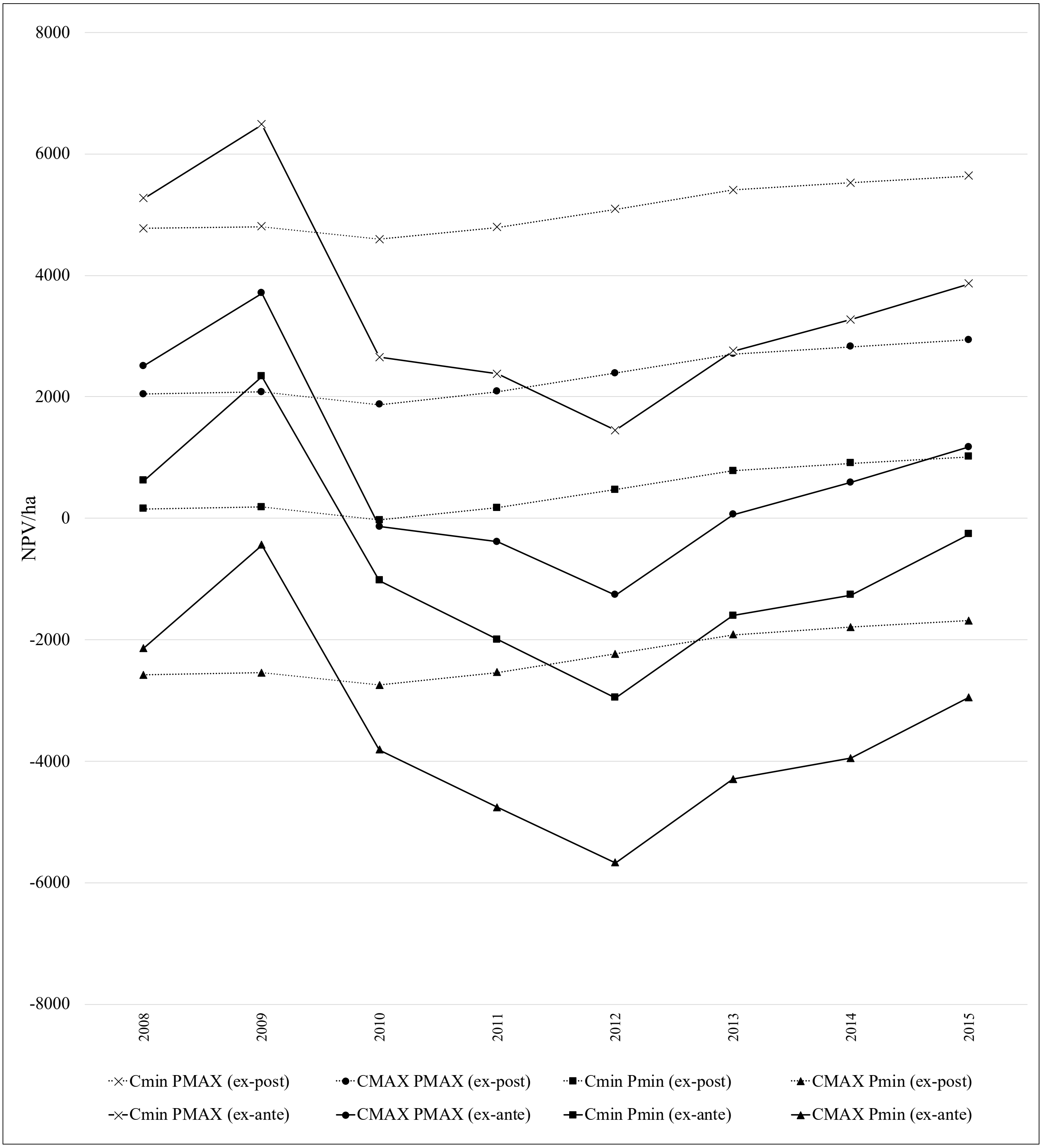
Fig. 6. NPV (EUR/ha, *i*= 3.5%) in the sensitivity scenario with land rent cost (b), 2001-2016 (real values).



Source: own elaboration.

ed an insurance cost (e). NPV results -669 EUR ha^{-1} in Cmin-Pmin, -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 baseline scenario values. IRRs decreased to 9.2% in Cmin-PMAX and to 4.3% in CMAX-PMAX.

Fig. 7. NPV (EUR/ha, *i*= 3.5%) in the sensitivity scenario with cost opportunity (c), 2008-2015 (real values).



Source: own elaboration.

4. 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, evidently, our results cannot represent all specific cases. Therefore, it has to be considered that different assumptions in relation to site characteristics, management intensity and stumpage prices can lead to slightly different results than those we estimated.

We assumed a representative management regime based on *Populus x canadensis* 'I-214', 278 trees per hectare and a 11 years rotation. The total investment costs to establish and manage a poplar plantation in one rotation cycle range between 6,614 EUR ha^{-1} and 9,636 EUR ha^{-1}. Poplar plantations are characterized by a significant initial investment, with establishment costs (including site preparation and planting operations), 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 energy 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 goes from 37.4% to 51.9%, depending on the year. Over the period 2001-2018, poplar stumpage prices evolution experienced an irregular trend. In particular, 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 explicit land 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 situation (associated with maximum investment costs and minimum stumpage prices), to 4,732 EUR ha^{-1} in the best situation (associated with minimum investment costs and maximum stumpage prices). LEV ranges between -6,097 EUR ha^{-1} and 15,020 EUR ha^{-1}. IRR values swing from negative values up to 11.9% in the best situation. When interpreting the results, 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, Vietto, 2005) showed encouraging results. Further developments in these areas of research 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)[1] 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 than 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 m^3 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 ultimately 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 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 on hybrid poplar plantations financial returns. As public subsidies we considered the average grant-based contribution of the regional RDP's afforestation measures, which result in the reimbursement of a percentage of plantation establishment costs. This percentage was 100% in the programming period 2000-2006 (reg. EEC 1698/1999), 70% on average in the programming period 2007-2013 (reg. EEC 1968/2005), and 60% on average in the programming period 2014-2020 (reg. EEC 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. These results highlight the determining role of this variable for investments' decisions. 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

[1] Our conversion from Pesetas to Euros, using a conversion of EUR 1 = ESP 166.386

developments. However, it has to be considered how 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, Chiarabaglio *et al.*, 2014). On the other hand, the idea of setting up intensively-managed and fast-growing timber plantations has been considered a contradiction to the European Union 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 (Tab. 6), in particular related to the use of voluntary forest certification schemes to guarantee responsible management practices 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 measures 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 (Fig. 8), and only 1,333 beneficiaries were involved out of the target of 6,527 (Fig. 9). More in general, the differences in terms of requirements and contribution level among Regions and the irregularity of grants in the last two programming periods (Tab. 6), 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 in the best situation it 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 situations, 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 in the best situations poplar cultivation 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.

Finally, we also tested the effect of an insurance scheme covering damages against pests, fire, windstorm and hail. Despite these types of investments are not common among poplar growers (but are growing, in particular among industrial and 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 the NPV by 1,463 EUR ha^{-1} and the LEV by 4,217 EUR ha-1 from baseline scenario values. 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.

5. CONCLUSIONS

In this study we estimated the evolution of financial returns from hybrid poplar plantations in northern Italy between 2001 and 2016, analysing how profitability indicators have changed over the past 15 years as a result of the evolution of the key economic variables of investment costs and timber prices. In addition, we assessed the effects of external variables such as public subsidies, an explicit land cost, opportunity cost of alternative agricultural land use, and insurance cost.

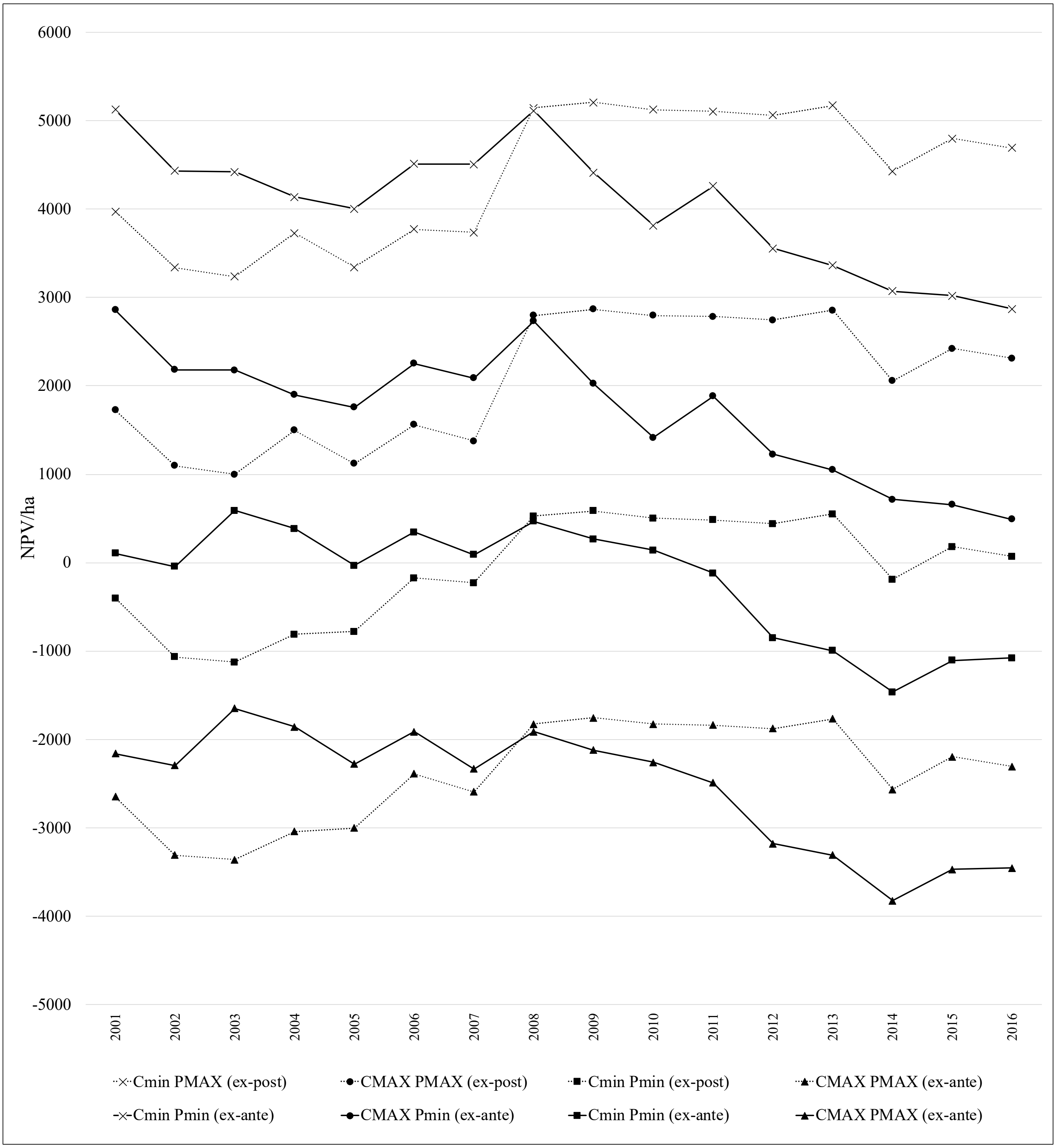
Financial returns were estimated at aggregate level, based on a management regime representative of the most frequent situation for poplar growers in the area and defining minimum and maximum levels of investment costs and stumpage prices. We carried out a financial analysis before-tax using Net Present Value (NPV),

Tab. 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 Programming period 2007-2013 (Measure 221 and 223)	RDP Programming period 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 (two of them 'MSA' clones, representing >*50%* of the total)	2008-2013, 2016, 2018
	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%	

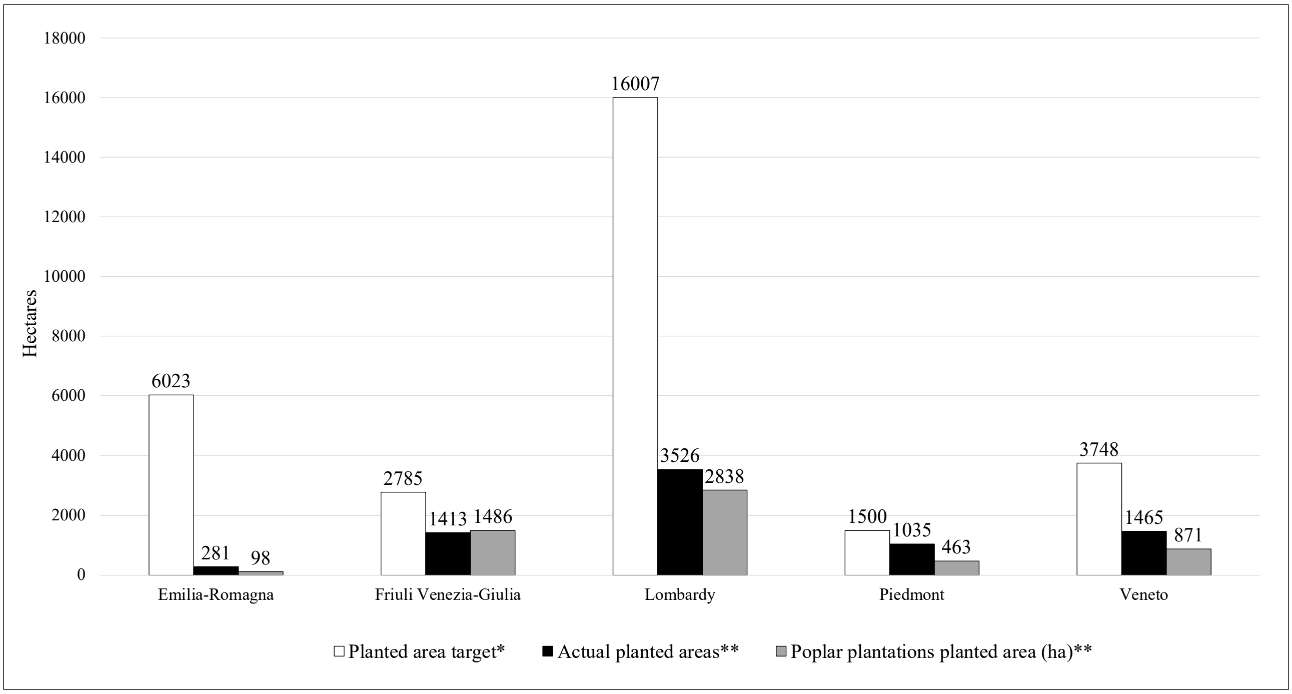
Source: own elaboration.

Fig. 8. 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).

Fig. 9. 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).

Internal Rate or Return (IRR) and Land Expectation Value (LEV) as capital budgeting indicators. 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 cost are included, IRR values go from negative up 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 has 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 11 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 timber production in Italy and one of the most profitable forest plantation investments in Europe.

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