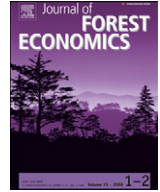




Contents lists available at ScienceDirect

Journal of Forest Economics

journal homepage: www.elsevier.de/jfe



Landowner net benefit from Stone pine (*Pinus pinea* L.) afforestation of dry-land cereal fields in Valladolid, Spain[☆]

Paola Ovando^{a,*}, Pablo Campos^{a,*}, Rafael Calama^b, Gregorio Montero^b

^a Institute for Public Goods and Policies (IPP), Spanish National Research Council (CSIC), C/Albasanz, 26–28. 28037 Madrid, Spain

^b Centre of Forestry Research (CIFOR), Spanish National Agriculture and Food Research Institute (INIA), Spain

ARTICLE INFO

Article history:

Received 27 May 2008

Accepted 21 July 2009

JEL classification:

Q23

Q54

Q58

Keywords:

Cost–benefit analysis

Silviculture models

Carbon sequestration

Government subsidies

ABSTRACT

This analysis measures the net benefit that a landowner could obtain from changing current dry-land cereal fields into Stone pine plantations in Portillo and Viana (Valladolid, Spain). We apply cost–benefit analysis techniques to estimate the present value of Stone pine afforestation net benefit by considering an infinite series of forestry rotations. We simulate three Stone pine silviculture models at each of the two sites. In addition, we estimate landowner extended net benefits from Stone pine afforestation when we consider a hypothetical payment for the carbon sequestration service. Results show that, when government subsidies are included, Stone pine afforestation only offers positive landowner net benefit in Portillo when both medium and high-stocking silviculture models are applied. Taking into account carbon prices up to €45 tC^{−1} (€12.3 tCO₂^{−1}), Stone pine afforestation gives landowner positive extended net benefits for the three silviculture models simulated at the Portillo and Viana sites.

© 2009 Elsevier GmbH. All rights reserved.

[☆] P. Ovando and P. Campos wrote the original text and revisions, and were responsible of collecting the economic information on revenues and cost and applying the cost benefit analysis techniques used. R. Calama and G. Montero developed the PINEA 2 model application for simulating the three different operative silviculture models for Stone pine stand in two representative sites of Valladolid province, and attended to the technical forestry revision required by two anonymous reviewers.

* Corresponding authors. Tel.: +34 91 602 2790/2535; fax: +34 91 602 2971.

E-mail addresses: paola.ovando@cchs.csic.es (P. Ovando), pablo.campos@cchs.csic.es (P. Campos).

Introduction

Spanish national and regional governments have subsidized large afforestation programmes following the implementation of the 1992 and 1999 European Union (EU) Common Agricultural Policy (CAP) reforms. EU grants for afforestation on crop and pasture lands was noteworthy in Spain, which was partly favoured by the higher Community part-financing as an Objective 1 region. Indeed, Spain accounts for 45% of the areas afforested under Regulation 2080/1992 within the EU-15 (IDF, 2001). Evergreen oak species were the preferred choice in Spain (covering 50% of the planted area), while pure and mixed plantations of Stone pine (*Pinus pinea* L.) make up 6% (23,500 ha) of the Spanish afforested area in the period 1993–1999 (MAPA, 2002). More than 50% of these Spanish Stone pine plantations were established in Castilla-León, where this species is widely used for afforestation in semiarid climate zones (Junta de Castilla y León, 2002). Thus, the number of Stone pines has notably increased in Valladolid over the past decade¹ (STMA, 2008).

The Stone pine is one of the most widely spread conifers in the Iberian Peninsula and it grows in almost all of the countries of the Mediterranean basin. In Spain, the Stone pine covers a surface area of over 400,000 ha, which represents around 50% of its world distribution range (Montero and Cañellas, 2000). Stone pines cover, as the dominant species, 48,000 ha in Valladolid province (Castilla-León, Spain), which represent 39% of its total forested area (STMA, 2008). In Valladolid, 43% of the area in which Stone pines grow is classified as *montes de utilidad pública* (MUPs) – woodlands regulated by a special Spanish forestry law – which are owned and managed by different public entities, with the remaining 57% being privately owned (DGCN, 1996). The private forests are frequently divided up into extremely small plots, which in Valladolid results in 96% of private forests belonging to estates of less than 10 ha (STMA, 2008).

Private and public benefits from Spanish Stone pine afforestation have scarcely been analysed (e.g. Campos, 1998; Mutke et al., 2000), in part due to the previous data shortcomings on this species' timber growth functions, and pine cone yields. However, the Stone pine does not seem to be an exception, since the published references of cost–benefit analyses dealing with the benefits of afforestation programmes in Western Mediterranean countries are quite scarce (e.g. Díaz-Balteiro and Romero, 1995; Mutke et al., 2000; Campos et al., 2003; Tassone et al., 2004; Ovando et al., 2009). Recent advances made regarding the modelling of Stone pine management in Valladolid province enable us to undertake a cost–benefit analysis of Stone pine afforestation. We simulate the application of three silviculture models considering complete Stone pine productive cycles (Calama et al., 2007). These models are differentiated by average stand density and main production aim (cone or timber) at two representative Stone pine sites in Valladolid province (Spain), namely *Portillo* and *Viana*. Both sites differ in their higher natural productivity, with pine cones predominating in Portillo and timber in Viana. The reduced size of a relevant share of private forests in Valladolid province, as mentioned above, hinders and increases the cost of the application of those forestry techniques typically employed for favouring timber and pine cone growth, as they are the three silvicultural models simulated in this study. Therefore, our results refer to the extended net benefits that industrial private or public landowners would attain from Stone pine afforestation and management.

Stone pines traditionally supplied joint products such as resin, bark (for tannins), pine cones, timber and firewood; and, to a lesser extent, hunting and grazing practiced by the local population and landowners (Campos, 1998; Mutke et al., 2000; Montero et al., 2004; Calama et al., 2008). Resin and bark are no longer harvested, while the demand for timber, firewood and grazing is in decline (Mutke et al., 2000; STMA, 2008). More recently, government policy has aimed to encourage the production of higher quality cones, which is being upheld to adapt to the supply needs of Spanish industry, now the world's largest processor with a share of close to 45% of total world pine nut production (Barranco and Ortuño, 2004). All these goods and services (except resin and bark) are

¹ In the 10-year period between the Second and Third Spanish National Forestry Inventories, stocks of *Pinus pinea* (the number of standing trees belonging to diametrical classes equal to or greater than 10 cm) increased by 37% (STMA, 2008).

current landowner market revenues from Stone pine afforestation, the relative contribution of which varies according to the yield orientation of the Stone pine silvicultures we simulate in this study.

On the other hand, the public environmental benefits of Stone pines were traditionally related to soil protection against surface erosion and the consolidation of coastal dunes, and more recently to the provision of shelter and food for local wildlife and recreation (Montero et al., 2004; STMA, 2008). Typically, those public non-timber benefits are not traded but they may be internalized by government compensations on the basis of increasing the supply of the former environmental public goods (Kurttila et al., 2006; Caparrós et al., 2007). In this study, we assume that current government incentives seek to compensate landowners for the incurred opportunity cost against the above-mentioned public environmental benefits supply. Furthermore, a new single public environmental output, namely the carbon sequestration service, has been recently established as a key afforestation benefit (van Kooten et al., 1995; Díaz-Balteiro and Romero, 2003; Tassone et al., 2004).

The first objective of this study is to estimate the landowner benefits of Stone pine afforestation compared with those of continuing with current dry-land (i.e. non-irrigated) cereal farming, which is the dominant agricultural land use in Valladolid province² and represents the direct land opportunity cost forgone due to afforestation. In this province the abandonment of cereal farming, especially in marginal agriculture areas, may represent a chance for Stone pine extension while benefiting from EU afforestation grants (Castillo and Moreno, 1996; Gordo, 2004). Our second objective is to measure the additional benefit that a landowner (private or public) might receive from Stone pine afforestation at the Portillo and Viana sites if a hypothetical payment from net carbon sequestration service is implemented.

We estimate the present value of afforestation benefits by considering an infinite series of forestry rotations (Niskanen, 1999; Campos et al., 2007). We consider the rotation length as given by silviculture modellers' recommendations to favour timber or pine cone production (Montero et al., 2008) as detailed in "The Stone pine silviculture models simulated in Portillo and Viana" section.

This paper is organised as follows. In "Methodology" section, we describe the two case studies in which the Stone pine afforestation models are simulated and depict the tree silviculture models. We then continue with the methods, data and valuation criteria used to carry out the extended cost–benefit analysis we apply. In "Results" section, we show the landowner economic results of the three simulated Stone pine afforestation models at the Portillo and Viana sites. Finally, in "Discussion and conclusions" section, we discuss and make our conclusions regarding industrial landowner afforestation benefits and Stone pine afforestation policy incentives.

Methodology

The Portillo and Viana Stone pine afforestation sites

The Portillo and Viana³ study sites are situated in the south of Valladolid province (see Fig. 1). Portillo lies in the Western Limestone Plains whose marly and clayey tertiary slopes separate it from the surrounding sandy areas. Portillo lies at an average altitude of 845 m above sea level and has 4757 ha covered by Stone pine forest. Viana lies in the open sandy areas of the *Meseta Norte* (Northern Plateau) upon quartz-sand soils formed by windblown and sedimentary fluvial deposits at an average altitude of 707 m above sea level, and has 7211 ha of Stone pine forest (Calama et al., 2008).

² Dry-land cereal farming is the dominant type of agricultural land use in Valladolid province (Western Spain), with 413,960 ha, which represents 52% of the utilised agricultural land (UAL) in this province (Junta de Castilla y León, 2004). Barley is the main dry-land cereal crop in Valladolid, accounting for 76% of the area used for dry-land herbaceous plant cropping (Junta de Castilla y León, 2008). In the municipal district of Viana (Valladolid), UAL is 12,718 ha, of which 66% is used to grow dry-land herbaceous crops, while in the municipal district of Portillo (Valladolid), UAL is 4205 ha, with 82% of this surface area being used for cultivating dry-land herbaceous crops (SIE, 2008).

³ Portillo and Viana are the names of the most representative municipalities of the forestland areas known as Limestone Plain West and *Meseta Norte*, respectively. Portillo contains the settlements of La Parrilla, Portillo and Camporredondo; whilst Viana comprises Viana de Cega, Valdestillas, Boecillo, La Pedraja del Portillo, Matapozuelo, Mojados and Alcazarén.

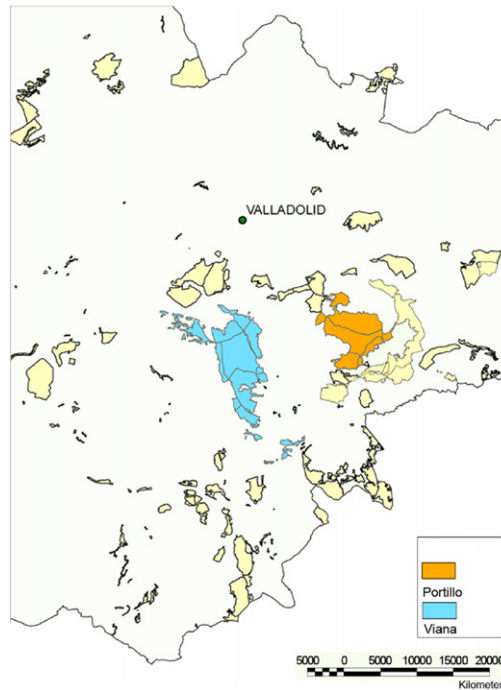


Fig. 1. The Portillo and Viana case study sites.

As well as lying in different locations and having different soil conditions, these two areas also differ as regards pine cone and timber yields. Portillo is more suited for pine cones than Viana, which is primarily due to a higher clay content in its soils and a higher average annual rainfall (485 mm) as compared to Viana (369 mm) (Calama et al., 2008). Portillo has more water available in the soil – which is one of the main factors governing the yield of pine cones (Calama et al., 2008). The Viana site, on the other hand, is better suited for growing timber than Portillo.

The Stone pine silviculture models simulated in Portillo and Viana

In this article, we apply the PINEA2 operative tool model (Calama et al., 2007), which is an integrated single tree-level model developed for the management of even-aged Stone pine stands (including plantations) within the Northern Plateau of Spain. The PINEA2 forest growth simulator can be used for both natural and artificial Stone pine stands, as they show an even-aged structure. PINEA2 cannot be applied to artificial stands with a very high initial density of plantation (>2000 stems/ha), which is quite an uncommon initial density within the study area. The PINEA2 model enables us to simulate the development of a Stone pine stand over time and predict its yields using Stone pine stand data such as age, dominant height, and breast height diameter. PINEA2 makes it possible to compare different Stone pine afforestation scenarios based on controlling total rotation length and stand density across the silvicultural cycle by way of scheduled thinning.

At each site we simulate three alternative silviculture models (SIL 1, SIL 2, and SIL 3) for an even-aged Stone pine stand with the objective of measuring the variations in joint pine cone and timber outputs and their corresponding landowner benefits (Table 1). These three silviculture models are widely used for Stone pine stands in Spain as a whole (Montero et al., 2008). SIL 1 has been proposed as the method for optimizing single tree cone yield, which is especially important for the manual collection of cones (largely used in Central Spain and the best cone production areas of the Northern Plateau). SIL 1 supports high thinning and maintains a lower stand density (Table 1). SIL 2 is less

Table 1

Selected physical indicators of Stone pine afforestation silvicultural models in Portillo and Viana sites (average annual data).

Class	SIL 1		SIL 2		SIL 3	
	Portillo	Viana	Portillo	Viana	Portillo	Viana
Cycle length (years)	120	120	100	100	80	80
Thinning intensity	High	High	Medium	Medium	Low	Low
Average stand density ^a (trees ha ⁻¹)	110	110	175	175	213	213
Sawtimber (m ³ ha ⁻¹ yr ⁻¹)	0.09	0.14	0.07	0.13	0.12	0.20
Pulpwood (m ³ ha ⁻¹ yr ⁻¹)	0.47	0.67	0.64	0.96	0.69	1.01
Firewood (t ha ⁻¹ yr ⁻¹)	0.36	0.43	0.47	0.56	0.52	0.63
Branches > 7 cm diam.	0.13	0.16	0.17	0.21	0.20	0.23
Branches from 2 to 7 cm diam.	0.23	0.27	0.29	0.35	0.32	0.39
Pine cones (kg ha ⁻¹ yr ⁻¹)	223.79	89.35	267.42	85.87	270.56	73.4
Pine cones (kg tree ⁻¹ yr ⁻¹)	2.03	0.81	1.53	0.49	1.27	0.34
Average net carbon sequestration ^b (tC ha ⁻¹ yr ⁻¹)	0.59	0.69	0.69	0.82	0.90	1.09

^a Trees of a diameter at breast height (diam.) equal to or higher than 10 cm.^b Refers to carbon sequestration in forest biomass net of carbon emissions due to fossil fuel consumption.

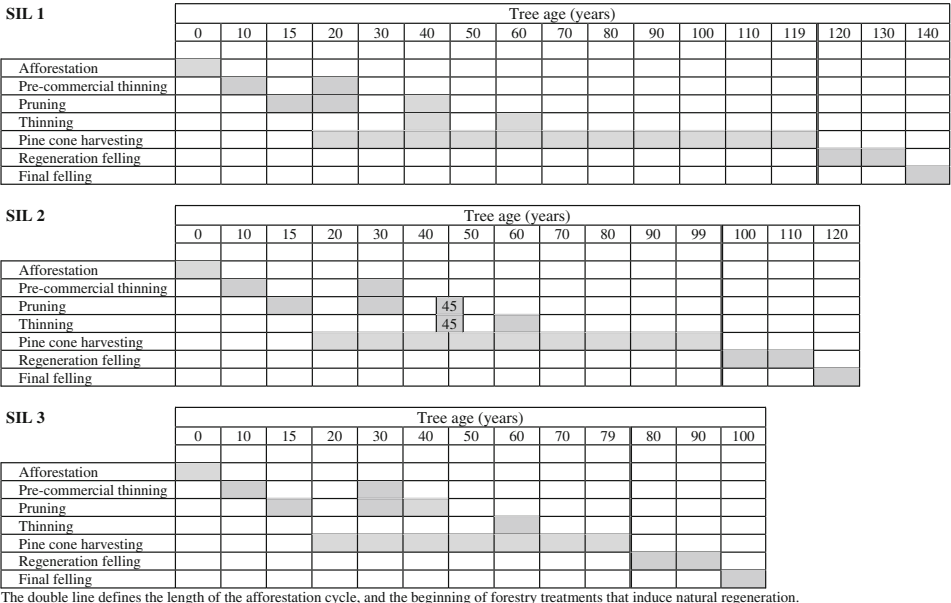
heavily thinned than SIL 1 and has a medium stand density (Table 1), and it represents the scenario typically used in the study area, where traditional management has focused in jointly optimizing both timber and individual cone yield. Finally, SIL 3 is the scenario traditionally used when focusing on timber yield (widely applied in southern Spain), thus it is only lightly thinned and maintains the highest stand density (Table 1). We analyse a silvicultural scenario of 120 years (productive cycle) for SIL 1, while for SIL 2 we simulate a silvicultural scenario of 100 years and one of 80 years for SIL 3. In Stone pines, cone yield at tree level maintains an almost exponentially increasing rate up to 120–140 years, while timber yield attains its maximum rate of growth at 70–80 years (Montero et al., 2008).

Each of the three aforementioned silviculture models shares a series of pine tree forestry treatments (thinning, pruning, and final felling), whose frequency, and the sequence in which they are applied, varies in each of the silviculture models (Fig. 2). Intensity of thinning is the single forestry operation that most differentiates the silviculture models we analyse. We consider a typical applied thinning, namely *thinning from below*, which consist of eliminating suppressed and dominated trees, since they usually show a very small crown with very little cone yield due to shadowing and competition for soil and water resources. A criterion for selecting the trees to eliminate is to favour the crown development of dominant, co-dominant, and intermediate trees, which are those bearing larger cone crops.

Table 1 shows the average annual physical expected yields for pine cones on a per hectare and tree basis as estimated by the PINEA2 model. PINEA2 also provides expected yields regarding the volume of commercial timber that can be harvested from a stand of Stone pines in accordance with its location and the silviculture process developed (Fig. 2). We break down the volume of timber felled into sawtimber and pulpwood. In addition to the felling of timber to supply industry, the felling of complete pine trees for thinning purposes and final felling result in a relevant harvest of firewood. We estimate the quantity of firewood harvested by using Montero et al. (2006) functions, which associate the diameter of a Stone pine with the weight of the biomass in branches, which in turn are classified into two groups: those of over 7 cm in diameter and those of between 2 and 7 cm in diameter. We assume that the wood of branches with a diameter of more than 7 cm is destined for the timber industry as pulpwood, while the wood derived from branches whose diameter is 7 cm or smaller will be used as firewood, thereby replacing fossil fuels.

Cost–benefit analysis of Stone pine afforestation

We estimate the Stone pine afforestation cost–benefit analysis results using 2007 government subsidies, local market revenues and costs, and a hypothetical carbon sequestration service payment.



The double line defines the length of the afforestation cycle, and the beginning of forestry treatments that induce natural regeneration.

Fig. 2. Forestry treatments schedule for an afforested Stone pine stand according to silviculture models SIL 1, SIL 2, and SIL 3.

Table 2
Government grants for Stone pine afforestation and forestry treatments (year 2007).

Class	Unit	Unitary value (€/unit)	Observations
Afforestation grants			
Planting cost	ha	2200	Maximum amount
Individual tree protectors	unit	1.68	Maximum amount
Maintenance cost premium	ha	180	Arable land (during 5 years)
Income loss cover premium	ha	121	Land owner not farmer (during 20 years)
Forestry management grants			
Cleaning	ha	344	70% of total expenditures until the maximum amount is reached
Pruning	ha	414	
Forestry residues pile up and removal	ha	521	

Source: Own elaboration from BOCyL (2007a, 2007b).

Stone pine afforestation revenues and costs

This study considers EU grants for financing the first planting of arable land with Stone pines and the subsequent 5-year maintenance cost premium and 20-year income losses cover premium,⁴ as well as additional grants for different forestry treatments offered by the Regional Government of Castilla-León for the process of managing the Stone pine stands throughout their entire production cycle (Table 2). Both, public and private landownership can benefit from afforestation grants in Castilla-Leon (BOCyL, 2007a). We assume that the Castilla-Leon Government considers that other

⁴ Afforestation grants, maintenance cost premiums and income loss cover premiums form part of the EU afforestation of agricultural land incentives.

Table 3

Stone pine and cropland output prices and rents (year 2007).

Class	Unit	Price (€/unit)	Prices range ^a (€/unit)
Timber at stumpage price ^b			
Logs lower than 30 cm diam.	m ³	12.5	
Logs of 30–40 cm diam.	m ³	17.5	
Logs higher than 40 cm diam.	m ³	21.1	
Timber at forest gate price ^b			
Logs lower than 20 cm diam.	m ³	21.8	
Firewood at stumpage price			
Branches > 7 cm diam.	t	8.1	
Firewood at forest gate price			
Branches of 2–7 cm diam.	t	5.0	
Branches > 7 cm diam.	t	18.0	
Cone at stumpage price	kg	0.3	0.15–0.55
Annual hunting rent	ha	4.7	
Annual grazing rent	ha	5.5	
Annual cropland rent	ha	109.2	
Carbon sequestration price	tC	20.0	10.0–70.0

^a Price range used for sensitivity analysis.^b Timber stumpage price depends on the diameter at breast height (diam.) of logs.

public benefits other than carbon sequestration are worth enough to justify the government subsidies allocated to Stone pine afforestation. Based upon this assumption, there is no double counting of public total compensation for Stone pine afforestation when we further add a hypothetical payment to the landowner for the carbon sequestration service.

The landowner sales of pine cones and timber are valued at stumpage prices,⁵ and firewood sales from silvicultural treatments are valued at forest gate prices (Table 3). The values we place on hunting and grazing rents correspond to the annual leasing prices stated by the different local information sources surveyed. We consider these two Stone pine forest rents to have the same value in all of the simulated silviculture scenarios. Grazing is not allowed during the first 20 years of the plantation life-cycles; since this use negatively affects the seedlings' growth and it is incompatible with any income loss cover premium payments (Appendices A and B).⁶

The data we use to value the market revenues and costs generated by Stone pine afforestation were gathered using a reduced number of postal surveys sent to the managers of enterprises responsible for forestry activities, harvesting the pine cones and felling timber in the Portillo and Viana areas. Following this postal survey we complete the data collection by telephone interviews and, in a few cases, face-to-face interviews held with the managers of the enterprises that answered the survey. We also interviewed foresters devoted to Stone pine plantation management in Valladolid province.

Costs incurred by the landowner include the initial planting and the subsequent management operations required until the standing sale of the pine cones (annually after year 20) and the timber (and associated firewood). We assume that the benefits derived from grazing and hunting rights and from the hypothetical payment for the carbon sequestration service are joint-products of those of the silviculture activity and, therefore, involve no additional cost to the landowner. The concept of total cost (TC) followed is the same as in the system of national accounts (Eurostat, 2000). Thus, we classify the silvicultural models TC as labour costs (LC) and intermediate consumption (IC). The latter

⁵ In Valladolid province landowners frequently sell standing pine cones and timber to enterprises that specialise in harvesting these products. Pines cone collection is not free, since the Stone pine woodland owners, both public and private, have complete property rights on standing pine cones.

⁶ In the case of facilitated natural regeneration cycle, grazing not being allowed until the stand is 15 years old or over (Appendix B).

Table 4Unitary cost of silviculture treatment in Portillo and Viana sites (2007 € unit⁻¹).

Class	Unit (u)	Labour cost	Intermediate consumption		Total
			Machinery ^a	Plants and individual tree protectors	
Afforestation	ha	620.0	273.9	1,886.7	2780.7
Pre-commercial thinning					
First	ha	336.3			336.3
Second	ha	289.1	35.5		324.6
Shrub clearing	ha	52.5	73.6		126.1
Residues pile up and removal	t	10.0	17.3		27.3
Pruning					
First	ha	228.7	31.6		260.3
Second ^b	ha	300.7	49.7		350.4
Third ^b	ha	413.7	54.2		468.0
First thinning ^c	ha	208.0	25.3		233.3

^a This concept of cost considers intermediate cost in raw materials (i.e. fuels) and services, and fixed capital consumption related to the use of machinery.

^b Average cost considering the six scenarios evaluated.

^c Average cost considering SIL 1 and SIL 2 scenarios in Portillo and Viana. First thinning costs are covered by the landowner. Firewood and pulpwood obtained are sold at forest gate.

refers to expenditures in leasing machinery⁷ and afforestation plants and individual tree protectors (Table 4, and Appendices A and B).

Carbon sequestration benefit

We estimate carbon sequestration as the physical quantity that includes the growth of the forest biomass, the carbon accumulated in residues and forestry products and its decay, the carbon dioxide emissions saved by replacing fossil fuels with firewood, and the carbon dioxide emissions caused by the use of fossil fuels during the management of the Stone pines. The aggregation of these carbon pools enables us to estimate the amount of net carbon sequestration each period (for more details, see Ovando et al., 2008). Our carbon estimates omit carbon sequestration on agriculture and forest soils due to the lack of specific data on soil carbon fluxes in Stone pine areas. Nonetheless, scientific literature on this issue suggests that converting a cultivated cropland to forestland typically increases soil carbon at rates of 0.3–0.6 t per hectare and year for a period of several decades (Freibauer et al., 2004). Thus, other thing being equals, it is likely that Stone pine afforestation would lead to higher net carbon sequestration and landowner present value benefits (C) than the ones we estimate in this study (Table 5).

To estimate net carbon sequestration we consider the Carbon Flow Method (van Kooten et al., 1995), which essentially implies that the landowner gets paid when carbon sequestration takes place and has to pay when carbon is released. The amount to be paid is set at equal to the carbon price associated with CO₂ emissions. The payment can come from the government (with a subsidy for sequestration and a tax on liberation) or from an efficient carbon trading system. This is a reasonable incentive mechanism to be set up by Annex-I governments within the Kyoto framework since, as shown above, what counts at international level is the total carbon budget of the country (Caparrós et al., 2007).

As net carbon sequestration is considered to be a public environmental benefit, we value this service by dealing with the marginal cost of the damage caused by the increase in the concentration

⁷ This machinery costs include raw materials, services, depreciation, and business margin.

Table 5Stone pine afforestation landowner carbon benefits at the Portillo and Viana sites (2007 € ha⁻¹)^a.

Class	Portillo			Viana		
	SIL 1	SIL 2	SIL 3	SIL 1	SIL 2	SIL 3
CO ₂ emissions saving	3.0	3.8	3.9	3.7	4.6	4.8
Carbon sequestration in forest biomass and products	311.0	344.1	382.1	345.3	434.8	477.6
Emission from fossil fuels consumption	-6.7	-6.1	-7.1	-6.0	-6.7	-5.8
Carbon benefits (C)	307.2	341.8	378.9	343.0	432.7	476.5

^a Discount rate 4%; carbon price € 20 tC⁻¹.

of carbon dioxide (CO₂) in the atmosphere (equivalent to the damage avoided). Recent literature includes numerous estimates of this marginal cost of the carbon, displaying a great variability. We simulate the net carbon sequestration present value revenues for carbon prices ranging from €10 to €70 tC⁻¹ (€3–19.1 tCO₂⁻¹), with a central value of €20 tC⁻¹ (€5.4 tCO₂⁻¹) (Table 5), which falls within the range of the estimates of marginal costs available (Tol, 2005) and, at its lower limits, of the prices that have been frequently observed in the emerging carbon trading markets (CCPO, 2006).

Landowner present values from Stone pine afforestation

We estimate the present value of landowner benefits from Stone pine afforestation considering that this plantation would lead to a permanent Stone pine forest. Two productive cycles are differentiated, the afforestation (first cycle) of a hectare of cropland (Appendix A) that, once its cycle (rotation) length (T_j)⁸ has been reached, will continue as a Stone pine forest with perpetually facilitated natural regeneration cycles with a frequency of T_j . The first afforestation cycle (f) is followed by a second production cycle (n) – known as facilitated natural regeneration (Appendix B) during which the application of the same silviculture model j will, in each area i , result in identical and successive cycles of facilitated natural regeneration of a Stone pine plantation, which, we assume, will be repeated indefinitely.

The present value for an infinite time horizon ($V_{ij,\infty}^f$) of a flow variable $y_{ij}(t)$ associated with afforestation using Stone pines corresponds to the sum of the benefits of the afforestation cycle ($V_{ij,f}$) and the successive cycles of facilitated natural regeneration ($V_{ij,n}$):

$$V_{ij,f} = \sum_{t=0}^{T_j} \delta^t y_{ij,f}(t),$$

$$V_{ij,n} = \sum_{t=0}^{T_j} \delta^t y_{ij,n}(t),$$

$$V_{ij,\infty}^f = V_{ij,f} + \delta^{T_j+1} (1 + \delta^{(T_j)} + \delta^{(T_j) \times 2} + \delta^{(T_j) \times 3} + \dots) V_{ij,n},$$

$$V_{ij,\infty}^f \cong V_{ij,f} + \delta^{T_j+1} \left[\frac{1}{1 - \delta^{T_j}} \right] V_{ij,n},$$

where δ is the discount function defined by $1/(1+r)$, with r being the annual rate of discount; $y_{ij,f}$ an annual landowner benefit associated with the Stone pine afforestation cycle; $y_{ij,n}$ an annual landowner benefit associated with the facilitated natural regeneration production cycle.

⁸ The rotation length of the T_j production cycle is defined by the age of the pine trees at which the simulated silviculture models prescribes the application of the regeneration felling process in the Stone Pine stand resulting from the initial afforestation or from successive natural regenerations, with subscript j being the length of the silvicultural cycle; that is: SIL 1 = 120, SIL 2 = 100, and SIL 3 = 80.

We calculate the landowner benefit at market prices (B_{MP})⁹ as the present value of revenues minus the cost of the Stone pine plantation and operating management. To estimate the landowner benefit at factor cost (B_{FC}) – which is the real benefit that the landowner expects to receive – we include the present value of the government operating subsidies (grants) net of taxes on products and cost (OST) as additional Stone pine afforestation benefits to the landowner.

We compare the Stone pine afforestation landowner benefit at factor cost (B_{FC}) with the present value of the landowner's cropland rent (LR)¹⁰ to estimate the Stone pine afforestation net benefit at factor cost ($NB_{FC} = B_{FC} - LR$). LR is estimated considering an annual constant land rent (z) from leasing the land out for growing dry-land cereals, and we apply the same discount rate (r) to this cropland use taking into account the estimated present values of Stone pine afforestation benefits ($LR = z/r$). We also estimate the extended net benefit at factor cost (ENB_{FC}) that the landowner would get in the event of a hypothetical government or market payment for the net carbon sequestration climate change mitigation service, considering carbon value (C): $ENB_{FC} = NB_{FC} + C$.

Sensitive analysis

Discounting is still a highly controversial issue and very much affects the analysis of forestry investment alternatives (Price, 1997). It has been frequently argued that when forestry investment externalities are thought to be relevant, public forestry investment projects should be discounted at a lower rate than private ones. Whilst, a number of economists argue in favour of using similar discount rates in the idealised situation of competitive markets, others claim that using higher discount rates for private projects must depend on the imperfections in markets (see Groux, 2003). This controversy is far from being resolved with universal consensus. In this paper, we estimate present values for discounting rates ranging from 1% to 10%, with a central value of 4%. The sensitive analysis of results to discount rates enables us to simulate how landowner preferences could influence the demand of Stone pine forest investment. In this way, we leave the results to the discount rate taken into account by the landowner open.

Results

Tables 1–5 show the main physical and economic results of the Stone pine afforestation simulated silvicultural models (scenarios) in the Portillo and Viana pine growing areas. These results are obtained when applying an assumed market discount rate of 4%, and a carbon price of €20 tC⁻¹ (€5.4 tCO₂⁻¹). Figs. 2–4 show the sensitivity of the results obtained to variations in the discount rate and the stumpage prices of pine cones and carbon sequestration. Table 6 depicts the different benefits that the landowner may receive from Stone pine afforestation considering site location, market values, government subsidies, carbon sequestration payment, and land opportunity cost (land rent) at 2007 prices.

Without considering government grants, that is, under pure market conditions, the afforestation of croplands using Stone pines generates a negative benefit (B_{MP}) in the six analysed scenarios. This occurs irrespective of location and the simulated silviculture model, and for a landowner that requires, at least, a real profitability rate from the Stone pine afforestation of 4%. At both the Viana and Portillo sites, the silviculture models with a high degree of thinning to favour the yield of pine cones per individual tree (SIL 1) generates the greatest losses among all the afforestation scenarios analysed (Table 6).

The operating subsidies net of taxes (OST) granted for planting and of managing Stone Pine stands reached a present value of nearly €5800 ha⁻¹ in our six simulated afforestation scenarios (Table 6). Thus, when current government grants are taken into account, Stone pine afforestation provides a positive benefit at factor cost (B_{FC}) at the Portillo and Viana sites (Table 6). The differences between the productivity of timber and pine cones of the two areas under study are more acute than those

⁹ The values at market prices referred to do not include government subsidies and taxes on products and cost.

¹⁰ The average annual rent, updated to 2007 prices, of dry-land fields in Castilla-León is €109.2 (MAPA, 2007, 2008).

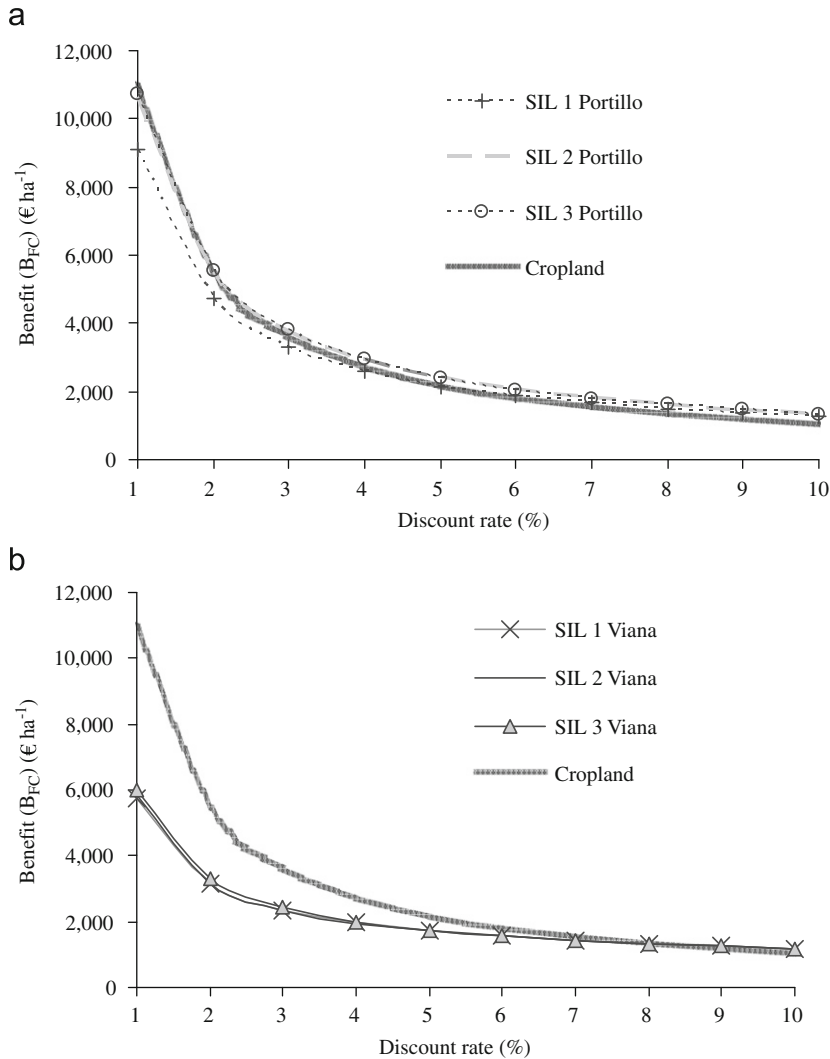


Fig. 3. Sensitivity of afforestation and cropland landowner benefits at factor cost to discount rate in Portillo and Viana sites (2007 € ha⁻¹).

shown by the simulated silviculture models compared within the same area. In Portillo, Stone pine afforestation generates a significantly higher B_{FC} than those produced in Viana. These differences are mainly due to pine cone productivity, which in Portillo generates landowner benefits at factor cost (B_{FC}) that on average are 43% higher than those of Viana (Table 6).

In Viana, which is an area that is naturally better suited to the production of timber, timber yield represents 1.4 times the figure estimated for Portillo (Table 1). However, the occurrence of the revenues of timber standing sales is delayed in time, since this product is obtained as a result of selective thinning or clearcutting, and this only take place at least 30 years after the plantation is first established.

The present value of cropland rent (LR) – at the infinite time horizon and using a discount rate of 4% – that a landowner receives for leasing out his land for dry-land cereal farming is €2731.4 ha⁻¹. Compared with this current agricultural landowner benefit, Stone pine afforestation in Portillo tends

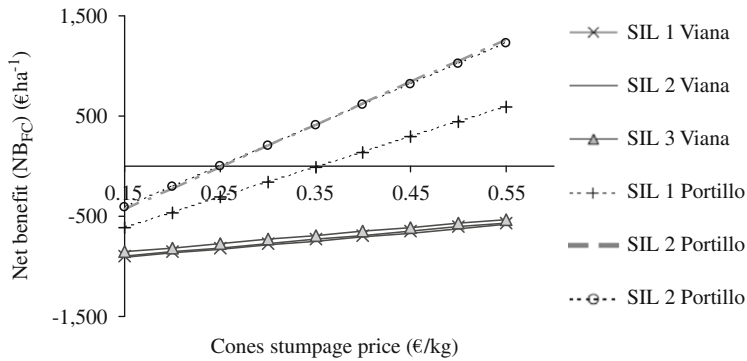


Fig. 4. Sensitivity of afforestation landowner net benefits at factor cost to pine cone stumpage price in Portillo and Viana sites (2007 € ha⁻¹).

Table 6

Stone pine afforestation landowner benefits at the Portillo and Viana sites (2007 € ha⁻¹)^a.

Class ^b	Portillo			Viana		
	SIL 1	SIL 2	SIL 3	SIL 1	SIL 2	SIL 3
1. Benefits at mp (B_{MP})	-3268.4	-2831.3	-2848.3	-3840.4	-3820.7	-3783.3
2. Net operating subsidies (OST)	5839.2	5763.7	5781.4	5798.5	5764.2	5782.5
3. Benefits at fc (B_{FC}) (1+2)	2570.7	2932.4	2933.1	1958.1	1943.4	1999.2
4. Cropland rent (LR)	2731.4	2731.4	2731.4	2731.4	2731.4	2731.4
5. Net benefit at fc (NB_{FC}) (3–4)	-160.7	201.0	201.7	-773.3	-788.0	-732.2
6. Carbon benefits (C)	307.2	341.8	378.9	343.0	432.7	476.5
7. Extended net benefits at fc (ENB_{FC}) (5+6)	146.5	542.8	580.6	-430.3	-355.3	-255.7

^a Discount rate 4%; carbon price € 20 tC⁻¹.

^b mp: market prices, fc: factor cost.

to be a profitable alternative for an industrial landowner (Table 6). This is so when we simultaneously apply: (i) high-stocking (SIL 3) or medium-stocking (SIL 2) silviculture models, (ii) we include the current grants available for afforestation and forest management, and (iii) we allow for a real discount rate of the forestry investment of at least 3% (Fig. 3a). The application of an intensive thinning scheme (SIL 1) aimed, in the main, at increasing individual tree pine cone production, could be competitive with respect to agriculture land with a rate of rental equal to or less than €102.8 ha⁻¹ yr⁻¹. However, any upward variation of 7.4% or over in land rental prices would render any afforestation scenario unprofitable in Portillo when, in the best case scenario, we apply a medium-stocking (SIL 2) silviculture model.

In Viana, on the other hand, the afforestation of a dry-land cereal field would generate losses – negative net benefits (NB_{FC}) – with respect to the agricultural use of the land (Table 6). At this site, the SIL 3 model, which presents the best economic results, can only be competitive with agricultural lands with a rate of rental equal to or less than € 80.0 ha⁻¹ yr⁻¹. Cropland rent and Stone pine afforestation benefits tend to be equal in Viana for discounting rates equal or higher than 7% (Fig. 3b). This result is influenced by the high level of grants to afforestation during the first 20 years of the plantation life cycle (see Appendix A). In Viana, landowners who demand profitability rates higher than 7% from forest investment may prefer changing the use of land to forest.

The growing demand of the pine nut industry has led to pine cone harvesting being expanded to areas whose Stone pine plantations offer a lower natural productivity of pine cones, as is the case with the Viana area. In this area, the quantity of pine cones harvested during the production cycle in any of the types of silviculture models we are comparing here is notably lower than the quantity

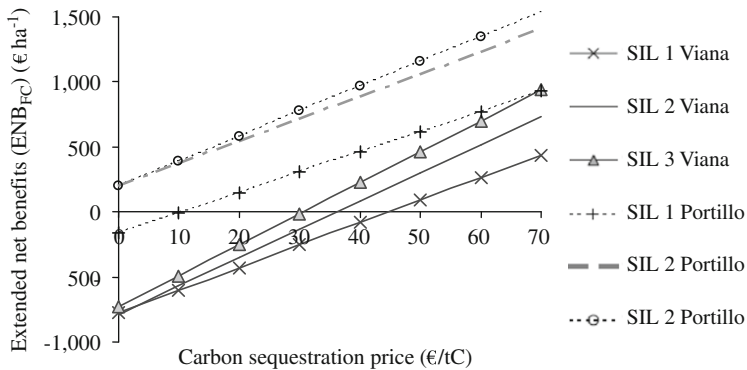


Fig. 5. Sensitivity of afforestation landowner extended net benefits to carbon price in Portillo and Viana sites (2007 € ha⁻¹).

harvested in Portillo (Table 1). At this site, the annual distribution of the production of pine cones within the cycle tends to increase when the pine trees are over 40 years old, which explains why the landowner net benefits (NB_{FC}) are practically insensitive to variations in the cone stumpage prices (Fig. 4). On the contrary, in Portillo, NB_{FC} can be significantly affected by variations in the cone stumpage price. In this area, a cone stumpage price of less than €0.25 kg⁻¹ (equivalent to a drop of 20% against the 2007 price) would significantly reduce the landowner's profitability from a Stone pine plantation (Fig. 4). In particular, in Portillo, increases in the cone stumpage price would most favour the application of the SIL 2 and SIL 3 silviculture models.

The inclusion in the analysis of a hypothetical payment to the forest owner for the net carbon sequestration service could alter land use preferences. In this simulated situation, and assuming that the price reaches €20 tC⁻¹, the sequestration of carbon via the growth of the Stone pine forest biomass and the emission savings due to the replacement of fossil fuels represent a positive carbon benefit (C) of up to €378.9 ha⁻¹ in Portillo and of €476.5 ha⁻¹ in Viana (Table 5). The results obtained from the extended cost–benefit analysis show that carbon sequestration can convert the Stone pine plantation, in which we simulate a silviculture model that keeps stand density relatively low (SIL 1), into a comparatively profitable option in Portillo when the per tonne of carbon is equal to or greater than €10 tC⁻¹ (Table 6 and Fig. 5). It goes without saying that the effect on economic results of the net carbon sequestration service is extremely sensitive to the prices paid for it. In the case of the simulated afforestation scenarios in Viana, carbon prices in excess of €45 tC⁻¹ would change the preferences of an agricultural landowner in favour of a Stone pine afforestation scenario if the SIL 1 model is applied, and between €30 and €35 tC⁻¹, respectively, when the SIL 3 and SIL 2 models are simulated (Fig. 5).

Discussion and conclusions

Summarizing the results, this study shows that, given the current market prices and government incentives in four of the six scenarios of the two areas studied, changing the use of a dry-land cereal field in favour of Stone pine afforestation is not profitable for an industrial landowner. We have observed that, even though the six Stone pine afforestation scenarios currently benefit from significant grants, the Stone pine would generate different net benefits according to the simulated silviculture models used and the natural suitability for pine cone and timber yields of each site. In Portillo, high-stocking (SIL 3) or medium-stocking (SIL 2) silviculture models present slightly landowner's positive net benefit at factor costs (NB_{FC}). Meanwhile, the SIL 1 model in Portillo and the three simulated afforestation scenarios, in Viana, would result in significant losses for the landowner when the use of the land is changed from cereal farming to a Stone pine plantation. The results obtained in this study concord with Mutke et al.'s (2000) work, who suggest that traditional Stone pine plantations can hardly compete with dry-land barley farming in Valladolid.

On the other hand, it is worth pointing out that the net benefit that the landowner could obtain from investing in Stone pine afforestation is extremely sensitive to variations in cone stumpage prices and, to a lesser extent, given the length of time before it can be felled, to variations in the prices of timber. A drop of 20% in pine cone stumpage prices would have a negative effect on the profitability of the Stone pine afforestation schemes both in Portillo and in Viana. Our results also show that increases in cropland rental prices equal to or greater than 7.4% might dissuade the landowner from investing in Stone pine afforestation schemes.

Cereal farming benefits from government subsidies may influence the cropland rent, although the current cereal farming rent might decline in the near future under the new CAP mechanisms (Oñate et al., 2007). This expected decrease in land rent may not occur if world cereal prices stabilize at above the current level. These expected opposite trends regarding government cereal subsidies and world cereal prices make the level of future cropland rent highly uncertain. At present, the level of Valladolid cropland rent of dry-land fields must be considered as an upper limit of the land opportunity cost for Stone pine afforestation. The lower limit for the landowner opportunity cost may result from the abandonment of marginal agricultural land to allow it to naturally become pastureland. In this study, we adopted a conservative perspective for the Stone pine afforestation and dry-land cereal crop comparison, and chose the upper limit for the cropland rent displaced by the hypothetical Stone pine afforestation.

In expectation of a future development of the greenhouse gas emission rights market, governments could well establish direct compensations to landowners for the net carbon sequestration within the Stone pine plantation and for the use of the firewood products derived from silviculture management procedures. Carbon sequestration might provide an incentive to landowners to invest in Stone pine afforestation schemes, especially with respect to those afforestation scenarios that would result in a loss of benefits if all that is booked is the revenues and costs derived from the market goods and services. However, the landowner's decision depends, to a great degree, on carbon prices. In the case of Viana, carbon would, at the very least, have to reach a price of €30 tC⁻¹ to make it profitable for an industrial landowner to invest in a Stone pine plantation that will result in a permanent forest dominated by this species.

The usefulness provided by the extended cost–benefit analysis of Stone pine afforestation when it comes to offering information to help policy-makers' decisions must be highlighted in terms of tolerable social cost, namely through the subsidies that government offers to encourage afforestation on agricultural lands. A number of studies analyse agricultural land afforestation with slow-growing native species (such as the Stone pine) in Mediterranean areas, show that market benefits alone do not provide enough incentives to change land use (Campos et al., 2003; Caparrós et al., 2007). Stone pine afforestation could provide a set of public benefits that are external to the landowner, which might be compensated (as they are through subsidies) by governments (society) on the basis of increasing the supply of environmental public goods.

In our extended cost–benefit analysis, we have not estimated the public benefits generated by the Stone pine afforestation schemes, except for the carbon sequestration service. This measurement is necessary to carry out a full economic output analysis of Stone pine afforestation. It shall be worth completing the landowner benefits we have analysed in this study as and when new information becomes available regarding recreational values, the conservation of the natural environment (option and existence values) and the collection of wild mushrooms associated with both the public and private usage of Stone pine plantations, and regarding the structure and amount of direct government expenditures on this type of forest in the province of Valladolid, among others that might be of interest in specific cases.

Acknowledgment

This paper was carried out within the framework of the research project Bases for the sustainable management of the stands of *Pinus pinea* L. in the Iberian Peninsula: ecological-silviculture models, genetic diversity and economic and social valuation of products (National RDI Plan: CPE03-001-C5).

We would like to thank Francisco Javier Gordo for his valuable comments. The authors are indebted to the editor and two anonymous reviewers, whose comments greatly improved the manuscript.

Appendix A. Landowner costs and revenues from a first Stone pine afforestation cycle according to SIL 2 model in Portillo (2007 euros per hectare)

See Table A1.

Table A1

Year	Class	Costs			Revenues		
	Afforestation cycle management	Labour cost	Intermediate consumption ^a	Total cost	Sales	Subsidies	Total revenues
0	Plantation	620.0	2160.7	2780.7		2780.7	2780.7
0–99	Hunting rent ^b				4.7		4.7
1	Seedling reposition	50.0	168.0	218.0			
1–5	Maintenance cost premium ^b					180.0	180.0
1–20	Income loss cover premium ^b					121.0	121.0
2	Weeding	52.5	73.6	126.1			
5	Weeding	52.5	73.6	126.1			
10	Pre-commercial thinning	336.3		336.3			
10	Residues removal	60.0	104.2	164.2		114.9	114.9
15	Shrub clearing	52.5	73.6	126.1			
15	Pruning	228.7	31.6	260.3		182.2	182.2
15	Residues removal	60.0	104.2	164.2		114.9	114.9
20–24	Pine cones ^d				161.4		161.4
21–99	Grazing rent ^b				5.5		5.5
25–29	Pine cones ^d				133.9		133.9
30	Pre-commercial thinning ^c	284.0	34.5	318.5	134.4		134.4
30	Pruning	328.0	54.2	382.2		267.6	267.6
30	Residues removal	120.0	208.3	328.3		229.8	229.8
30–34	Pine cones ^d				72.8		72.8
35–39	Pine cones ^d				103.1		103.1
40–44	Pine cones ^d				108.0		108.0
45	Thinning ^c	204.6	24.9	229.5	173.2		173.2
45	Pruning	437.7	54.2	492.0		344.4	344.4
45	Residues removal	120.0	208.3	328.3		229.8	229.8
45–49	Pine cones ^d				77.8		77.8
50–54	Pine cones ^d				89.8		89.8
55–59	Pine cones ^d				94.3		94.3
60	Thinning				136.3		136.3
60	Residues removal	97.5	169.3	266.8		186.7	186.7
60–64	Pine cones ^d				75.7		75.7
65–69	Pine cones ^d				84.6		84.6
70–74	Pine cones ^d				88.9		88.9
75–79	Pine cones ^d				93.3		93.3
80–84	Pine cones ^d				97.9		97.9
85–89	Pine cones ^d				102.7		102.7
90–94	Pine cones ^d				107.6		107.6
95–99	Pine cones ^d				112.7		112.7

^a IC: Intermediate consumptions costs.

^b Annual revenues along the referred period (year).

^c Timber and firewood obtained from second pre-commercial thinning and first thinning are sold at forest gate.

^d Five-year average annual revenues.

Table B1

Year ^a		Class	Costs			Revenues		Total revenues total
<i>f</i> cycle	<i>n</i> cycle	Natural regeneration cycle management	Labour cost	Intermediate consumption ^b	Total cost	Sales	Subsidies	
120	0	2 Regeneration felling				755.7		755.7
120	0	Residues removal	120.0	208.3	328.3		229.8	229.8
	0–99	Hunting rent ^c				4.7		4.7
130	10	20 Regeneration felling				652.0		652.0
130	10	Residues removal	120.0	208.3	328.3		229.8	229.8
135	15	Pre-commercial thinning	336.3		336.3		235.4	235.4
135	15	Pruning	228.7	31.6	260.3		182.2	182.2
135	15	Residues removal	60.0	104.2	164.2		114.9	114.9
135–139	15–19	Pine cones ^e				13.3		13.3
	15–99	Grazing rent ^c				5.5		5.5
140	20	Final felling				433.6		433.6
140	20	Residues removal	97.5	169.3	266.8		186.7	186.7
	20–24	Pine cones ^e				161.4		161.4
	25–29	Pine cones ^e				133.9		133.9
	30	Pre-commercial thinning ^d	284.0	34.5	318.5	130.5		130.5
	30	Pruning	328.0	54.2	382.2		267.6	267.6
	30	Residues removal	120.0	208.3	328.3		229.8	229.8
	30–34	Pine cones ^e				72.8		72.8
	35–39	Pine cones ^e				103.1		103.1
	40–44	Pine cones ^e				108.0		108.0
	45	Thinning ^d	204.6	24.9	229.5	173.2		173.2
	45	Pruning	437.7	54.2	492.0		344.4	344.4
	45	Residues removal	120.0	208.3	328.3		229.8	229.8
	45–49	Pine cones ^e				77.8		77.8
	50–54	Pine cones ^e				89.8		89.8
	55–59	Pine cones ^e				94.3		94.3
	60	Thinning				136.3		136.3
	60	Residues removal	97.5	169.3	266.8		186.7	186.7
	60–64	Pine cones ^e				75.7		75.7
	65–69	Pine cones ^e				84.6		84.6
	70–74	Pine cones ^e				88.9		88.9
	75–79	Pine cones ^e				93.3		93.3
	80–84	Pine cones ^e				97.9		97.9
	85–89	Pine cones ^e				102.7		102.7
	90–94	Pine cones ^e				107.6		107.6
	95–99	Pine cones ^e				112.7		112.7

^a Age of the trees from the afforestation cycle (*f* cycle) or from the facilitated natural regeneration cycle (*n* cycle).

^b IC: Intermediate consumptions costs.

^c Annual revenues along the referred period (year).

^d Timber and firewood obtained from second pre-commercial thinning and first thinning are sold at forest gate.

^e 5-year average annual revenues.

Appendix B. Landowner costs and revenues from Stone pine facilitated natural regeneration cycle according to SIL 2 model in Portillo (2007 euros per hectare)

See Table B1.

References

- Barranco, J., Ortuño S.F., 2004. Aproximación al sector del piñón en España. Revista Española de Estudios Agrosociales y Pesqueros 201, pp.165–189.

- Boletín Oficial de Castilla y León (BOCyl), 2007a. ORDEN MAM/1014/2007, de 5 de junio, por la que se convocan ayudas, cofinanciadas por el Fondo Europeo Agrícola de Desarrollo Rural (FEADER), para los costes de implantación de la primera forestación de tierras agrícolas, para el año 2007. BOCyl 110 de 7 de junio de 2007, pp. 12307–12334.
- Boletín Oficial de Castilla y León (BOCyl), 2007b. Orden MAM/10/2007 de 3 de enero, por la que se convocan subvenciones cofinanciadas por el Fondo Europeo de Desarrollo Rural (FEADER) para la gestión de montes en régimen privado. Suplemento 4, de 5 de enero de 2007.
- Calama, R., Sánchez-González, M., Montero, G., 2007. Management oriented growth models for multifunctional Mediterranean forests: the case of Stone pine (*Pinus pinea* L.). *EFI Proceedings* 56, 57–70.
- Calama, R., Gordo, F.J., Mutke, S., Montero, G., 2008. An empirical ecological-type model for predicting Stone pine (*Pinus pinea* L.) cone production in the Northern Plateau (Spain). *Forest Ecology and Management* 255 (3–4), 660–673.
- Campos, P., 1998. Rentas comerciales del pino piñonero y del eucalipto en el parque natural de Doñana. In: Campos, P., López, J. (Eds.), *Renta y naturaleza en Doñana. A la búsqueda de la conservación con uso*. Icaria Editorial, Barcelona, pp. 29–78.
- Campos, P., Martín, D., Montero, G., 2003. Economías de la regeneración natural y de la reforestación del alcornoque. In: Pulido, F., Campos, P., Montero, G. (Eds.), *La gestión forestal de la dehesa*. Junta de Extremadura/IPROCOR, Mérida, pp. 107–164.
- Campos, P., Daly-Hassen, H., Ovando, P., 2007. Cork oak forest management in Spain and Tunisia: two case studies of conflicts between sustainability and private income. *The International Forestry Review* 9 (2), 610–626.
- Caparrós, A., Cerdá, E., Ovando, P., Campos, P., 2007. Carbon sequestration with reforestations and biodiversity scenic values. *Nota Di lavoro* 28.2007, Fondazione Eni Enrico Mattei.
- Castillo, M., Moreno, C., 1996. Respuesta diferencial de los cultivadores cerealistas a la reforma de la PAC en algunas comarcas de Castilla y León. *Revistas Española de Economía Agraria* 178, 193–232.
- Climate Change Projects Office (CCPO), 2006. Carbon prices. Available online: <www.dti.gov.uk>.
- Díaz-Balteiro, L., Romero, C., 1995. Rentabilidad financiera de especies forestales arbóreas de crecimiento medio y lento en el vigente marco de ayudas públicas. *Revista Española de Economía Agraria* 171, 85–108.
- Díaz-Balteiro, L., Romero, C., 2003. Forest management optimisation models when carbon captured is considered: a goal programming approach. *Forest Ecology and Management* 174, 447–457.
- Dirección General para la Conservación de la Naturaleza (DGCN), 1996. Segundo Inventario Forestal Nacional 1986–1995 (IFN2). DGCN, Madrid.
- Eurostat, 2000. Manual on Economic Accounts for Agriculture and Forestry – EAA/EAF 97 (Rev.1.1). European Communities, Luxemburg.
- Freibauer, A., Rounsevell, M., Smith, P., Verhagen, A., 2004. Carbon sequestration in European agricultural soils. *Geoderma* 122, 1–23.
- Gordo, F.J., 2004. Selección de grandes productores de fruto de *Pinus pinea*. PhD. Thesis. Escuela Técnica Superior de Ingenieros de Montes, Universidad Politécnica de Madrid.
- Grout, P.A., 2003. Public and private sectors discount rates in public–private partnerships. *The Economic Journal* 113, 2–68.
- Institute for Forestry Development (IDF), 2001. Evaluation of the Community aid scheme for Forestry measures in agriculture of Regulation No. 2080/92. Final Report.
- Junta de Castilla y León, 2002. Plan Forestal de Castilla y León. Available online: <<http://www.jcyl.es>>.
- Junta de Castilla y León, 2004. Anuario de estadística de Castilla y León 2004. Available online: <<http://www.jcyl.es>>.
- Junta de Castilla y León, 2008. Estadísticas Agrarias 2007. Análisis provincial por especies. Available online: <<http://www.jcyl.es>>.
- Kurttila, M., Pykäläinen, J., Leskinen, P., 2006. Defining the forest landowner's utility – loss compensative subsidy level for a biodiversity object. *European Journal of Forest Resources* 125, 67–78.
- Ministerio de Agricultura, Pesca y Alimentación (MAPA), 2002. Forestación de Tierras Agrícolas. Cuadro resumen de las realizaciones por unidades de obra desde la puesta en marcha del programa hasta 15 de octubre de 1999. MAPA, Madrid, unpublished document.
- Ministerio de Agricultura, Pesca y Alimentación (MAPA), 2007. Anuario de Estadística Agroalimentaria 2006. Secretaría General Técnica. MAPA, Madrid.
- Ministerio de Agricultura, Pesca y Alimentación (MAPA), 2008. Resultados de la encuesta de Precios Percibidos por los Agricultores y Ganaderos. Available online: <http://www.mapa.es/estadistica/pags/preciospercibidos/indicadores/Publicacion_completa.pdf>.
- Montero, G., Cañellas, I., 2000. Selvicultura de *Pinus pinea* L. Estado actual de los conocimientos en España. In: Castilla-León Government (Ed.), *I Simposio del Pino Piñonero (Pinus pinea L.)*, Valladolid, February 22–24, vol. I, pp. 21–38.
- Montero, G., Candela, J.A., Rodríguez, A. (Coords.), 2004. El pino piñonero (*Pinus pinea* L.) en Andalucía. Consejería de Medio Ambiente, Junta de Andalucía, Seville.
- Montero, G., Ruiz-Peinado, R., Muñoz, M., 2006. Producción de biomasa y fijación de CO₂ por los bosques españoles. *Monografías INIA. Serie Forestal* 13, Madrid.
- Montero, G., Calama, R., Ruiz-Peinado, R., 2008. Selvicultura de *Pinus pinea* L. In: Serrada, R., Montero, G., Reque, J. (Eds.), *Compendio de Selvicultura Aplicada en España*, INIA-FUCOVASA, Madrid, pp. 431–470.
- Mutke, S., Díaz-Balteiro, L., Gordo, F.J., 2000. Análisis comparativo de la rentabilidad comercial privada de plantaciones de *Pinus pinea* L. en tierras agrarias de la provincia de Valladolid. *Investigación Agraria: Sistemas y Recursos Forestales* 9 (2), 269–303.
- Niskanen, A., 1999. The financial and economic profitability of field afforestation in Finland. *Silva Fennica* 33 (2), 45–157.
- Oñate, J.J., Atance, I., Bardají, C., Lluvia, D., 2007. Modelling the effects of alternative CAP policies for the Spanish high-nature value cereal-steppe farming systems. *Agricultural Systems* 94, 247–260.
- Ovando, P., Campos, P., Calama, R., Montero, G., 2008. Rentabilidad de la forestación de tierras agrícolas marginales con pino piñonero (*Pinus pinea* L.) en la provincia de Valladolid. IPP-CSIC/CIFOR-INIA Working Paper, 49pp. Available upon request from the authors.
- Ovando, P., Campos, P., Oviedo, J.L., Montero, G., 2009. Cost–benefit analysis of cork oak woodland afforestation and facilitated natural regeneration in Spain. In: Aronson, J., Pereira, J.S., Pausas, J.G. (Eds.), *Cork Oak Woodlands on the Edge*. Ecology, Adaptive Management, and Restoration. Island Press, pp. 177–188.

- Price, C., 1997. Twenty-five years of forestry cost–benefit analysis in Britain. *Forestry* 70 (3), 171–189.
- Sistema de Información Estadística de la Junta de Castilla y León (SIE), 2008. Indicadores de la Agricultura por Municipios. Datos del Censo Agrario de 1999. Available online: <<http://www.jcyl.es/sie/>>.
- Servicio Territorial de Medio Ambiente (STMA), 2008. Plan de Ordenación de los Recursos Forestales de la provincia de Valladolid. Junta de Castilla y León, Valladolid. Available online: <<http://www.jcyl.es/>>.
- Tassone, V.C., Wesseler, J., Nesci, F.S., 2004. Diverging incentives for afforestation from carbon sequestration: an economic analysis of the EU afforestation program in the south of Italy. *Forest Policy and Economics* 6, 567–578.
- Tol, R.S.J., 2005. The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy* 33, 2064–2074.
- van Kooten, G.C., Binkley, C.S., Delcourt, G., 1995. Effect of carbon taxes and subsidies on optimal forest rotation age and supply of carbon services. *American Journal of Agricultural Economics* 77, 365–374.