Land Use Policy xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Measuring total social income of a stone pine afforestation in Huelva (Spain)

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ARTICLE INFO

Article history:
Received 26 January 2015
Received in revised form
29 September 2015
Accepted 9 October 2015

Keywords:
Ecosystem services
Public services
Private amenities
Conservationist forestry
Non-market valuation

ABSTRACT

We apply an experimental ecosystem accounting approach aimed at estimating the contribution of ecosystem services to total social income accrued from a Stone pine (*Pinus pinea* L.) forest as the result of afforestation in Huelva Province, Spain. The study encompasses private market products such as timber, pine cones, and forest conservation intermediate services; and non-market final services that include private amenities and public services such as landscape, free-access recreation and carbon sequestration services. We show how the total income of each single product is distributed amongst the factorial rewards to labor, and environmental and manufactured assets. Private products account for 46% of the average total income that the Stone pine forest would yield over its rotation, while public services comprise the remaining 54%. Our results also suggest that the production of public non-market services would offset the government compensation payments to support Stone pine afforestation and management. Finally, the results show that, on average, 7% of the estimated total income would be captured by the current System of National Accounts for forestry if applied to our case study (including only the net value added from timber and pine cone production and from plantation investment) and that 14% of this income would be dislocated into the government institutional accounts.

1. Introduction

Ecosystem services (ES) are increasingly being called upon to support and inform natural resources regulation and management (MA, 2005), and ecosystem accounting is gaining attention as an approach to integrate ES and their related assets into decision making (Hein et al., 2015). The interest in developing this approach, as an instrument to quantify and integrate complex ecosystems biophysical data in connection with economic activities, has prompted a rapidly expanding literature. This progress particularly focuses on the spatial assessment and modeling of physical flow accounts describing the supply of materials, and the regulating and cultural categories of ES (Wolff et al., 2015). In contrast, the conception of multiple market and non-market services and products that could be derived from ecosystems (Pearce, 1993), as well as the use of valuation techniques to price them, have been core to environmental economists for many decades (Pascual et al., 2010; Atkinson et al., 2012).

Notwithstanding the progress in these fields, only a few studies tackle the consistent integration of ecosystems economic accounts in line with the accounting principles of the System of National Accounts (SNA), which are based on exchange economic values rather than on welfare values (e.g., Caparrós et al., 2003; Campos and Caparrós, 2006; Edens and Hein, 2013; Hein et al., 2015; Remme et al., 2015; Sumarga et al., 2015). Concerns about how to display the value of single ecosystem services embedded in SNA outcomes prompted the development and revision of the System of Environmental–Economic Accounting, whose recently published Central Framework (SEEA-CF) serves as the international statistical standard for environmental accounting aligned with the production boundaries of the SNA (Bartelmus, 2013; United Nations, 2014a). The SEEA-CF underpins the estimation of environmental asset accounts for individual natural resources that provide materials or space to SNA economic activities (e.g., timber for forestry activity).

The present debate on challenges of the SNA extension addresses the interest in measuring the spatial contribution of private and public ecosystems services to the economic benefits beyond the SNA production boundaries (MA, 2005; UN, 2014b). The SEEA-CF partially provides this approach but is based on single marketable natural resources, which is far from the conception of ecosystems as functional units delivering multiple products. The

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http://dx.doi.org/10.1016/j.landusepol.2015.10.015
0264-8377/© 2015 Published by Elsevier Ltd.

recently released SEEA Experimental Ecosystem Accounts (EEA) discusses the recommendations for valuing ES on the basis of the SNA principles, and calls for testing experimental extensions of the SNA to include ecosystem services and benefits omitted by the SNA economic activities (UN, 2014b; Hein et al., 2015). However, the SEEA-EEA lacks the international statistical standard conferred on the SEEA-CF, and the scope of the experimental extensions to the SNA is still under discussion.

The SEEA-EEA discusses two alternative models for integrating ecosystems into the institutional sectors and economic activities of national accounts: (i) it considers ecosystems as an economic unit providing services to other units (i.e., farmers); and (ii) it identifies ecosystems as an environmental asset that contributes to the production function of farmers' economic activity. In both cases, the approach falls short of recognizing that government and landowners (farmers) hold a shared responsibility in the production process of ecosystem products (Edens and Hein, 2013). In many European countries, government expenditures targeting natural resources management and conservation have been significant in recent decades (ECC, 2009a,b) and economic accounts of ecosystems cannot overlook this relevant element.

The experimental Agroforestry Accounting System (AAS) represents an alternative approach to terrestrial ecosystems that overcomes the production boundary shortcomings of the SNA and SEEA-CF. This system integrates the environmental assets into the agroforestry farm production function to estimate the total social income (total income hereinafter) originated in multiple private and public activities within the agroforestry territory. This total income estimation considers, simultaneously, the flow of incomes arising from the production process (including natural growth) and changes in environmental and manufactured assets (comprising capital improvement, degradation and depletion) over the accounting period (see Caparrós et al., 2003; Campos and Caparrós, 2006 for details). The AAS shares with the standard SNA and the SEEA-CF the principle that only exchange values should be used, and this is applied to both marketable and non-marketable products.

In this study, we offer an innovative application of the AAS to a pure even-aged Stone pine (*Pinus pinea* L.) forest resulting from an afforestation investment in Huelva Province (Spain). We regard this forest ecosystem as a joint private and public asset that constitutes a single functional unit where landowners' and governmental resources and management have an effect on both naturally occurring and manufactured production processes. In this context, we measure total income accrued from a number of private and public forest products. This includes products for which market prices are available, such as timber, pine cones, and forest conservation intermediate services, and non-market final services such as private amenities, public landscape conservation, public recreation and carbon sequestration. These non-market services are integrated into the forest ecosystem accounts as imputed or as simulated exchange values.

We employ a set of accounting criteria to disaggregate total income into the factorial contributions of labor and manufactured and environmental assets to the pertaining forest product. In this framework, the environmental asset comprehends the forest ecosystem (UN 2014b: 156). Our study offers the environmental incomes delivered by the Stone pine forest ecosystem at different periods of its rotation. These AAS environmental incomes are referred hereinafter to as ecosystem services and are arranged into the Common International Classification of Ecosystem Services (CICES) as provisioning, regulating and cultural ES (Haines-Young and Potschin, 2013).

The valuation of ES associated with private and public forest products departs from market or simulated exchange values, using both the resource rent approach (UN, 2014b; Remme et al., 2015; Sumarga et al., 2015) and non-market valuation techniques (Caparrós et al., 2003; Oviedo et al., 2010). ES valuation also takes into account landowner and government direct and indirect manufactured costs involved in forest ecosystem production processes. There are few previous applications that integrate private and public non-market values (Campos and Caparrós, 2006) as we do in our study. While the application of extended economic valuation to non-market ES usually focuses on public values (Caparrós et al., 2003; Remme et al., 2015; Sumarga et al., 2015), our results show that landowner values are relevant to forest ecosystem total income.

Overall, our empirical application highlights that only a comprehensive approach to ecosystem production functions, which are independent from SNA accounting structure conventions (i.e., disconnecting government accounts from the ecosystem production function), allows a broad representation of ecosystem accounts and ES valuation. Our approach aims to contribute to the scientific debate on ecosystem accounting and its future implementation within a national accounting context.

2. Materials and methods

2.1. Case study

We selected the countryside and coastline areas in Southern Huelva Province (Andalusia, Spain) as our case study. Stone pine is the dominant native forest species in Huelva, occupying 28% of the area covered by trees in this province, and more than hundred thousand hectares. Holm and Cork oaks (*Quercus ilex* L. and *Quercus suber* L., respectively) are frequently found in the Stone pine distribution area, occupying together 18% of the area covered by trees in Huelva (MAAMA, 2013). Stone pines are part of a mosaic of land uses and vegetations that includes oak woodlands, other broadleaf and conifer forests, scrub, rough pastures and croplands (Montero et al., 2004). These diverse Mediterranean ecosystems are a reservoir for a large number of endemic plant and bird species (Myers et al., 2000). Around 80% of forests in Huelva are privately owned (MAAMA, 2013).

The abandonment of forest management in our case study area is likely to increase fire risk and to favor natural scrub revegetation, and this might affect the joint production of private and public forest products. This situation requires active landowner interventions to maintain the forest ecosystem in a productive condition. In this context, landowners are expected to demand public incentives to take part in afforestation and forestry management to avoid and reverse scrub encroachment. Afforestation with Stone pine has been supported in Huelva Province in the past two decades to boost sustainable forestry and to create permanent forest ecosystems (BOJA, 2008). In this study, we assume that pine afforestation displaces dense scrubs that are not leased out for grazing and hunting purposes. We use the growth and yield parameters estimated by Montero et al. (2004) for pure and even-aged Stone pine forests located in Huelva Province, considering five site qualities (see online Supplementary material for details). Q7

2.2. Total income and ecosystem services valuation

The total income (TI) accounts for the remunerations to the classic production factors: labor and capital, the latter embracing both manufactured assets (those produced by human activities) and environmental assets (those given by nature) (Campos, 2013; Edens and Hein, 2013). The AAS's TI estimation is consistent with the Hicksian income concept, which is defined as the maximum potential consumption in the accounting period without reducing the value of the opening capital stock at the closing period (Hicks, 1946: 177; McElroy, 1976: 229; EC, 2000: 87). Capital gain or loss

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Table 1
The AAS total income, ecosystem services and manufactured capital income identities.

Concept	Initials	Formula	Definitions (in alphabetical order)
Total income estimation			
Total output	TO	TO = IO + FO	CA_S: gross carbon sequestration,
Total cost	TC	TC = IC + LC + CFC	CA_R: carbon release
Net operating margin	NOM	NOM = TO − TC	Cd: capital destruction,
		NOM = ENOM + MNOM	CFC: consumption of fixed capital,
Net value added	NVA	NVA = TO − IC − CFC	Cr: capital revaluation
		NVA = NOM + LC	ENOM: environmental net operating margin
Capital income	CI	CI = TO − TC + CG	ECG: environmental capital gain
		CI = ES + MCI	FO: final output,
Capital gains	CG	CG = Cr − Cd − PCrc[(1)] + CFC	FS: final sales;
		CG = ECG	GFI: gross fixed investment;
Total income	TI	TI = NVA + CG	GNG: gross natural growth,
		TI = LC + ES + MCI	i: normal profitability rate,
			IC: intermediate consumption,
Ecosystem services (ES)	ES		IMC: immobilized manufactured capital,
Timber growth (TBg)	ES_{TBg}	$ES_{TBg} = ENOM_{TBg} + ECG_{TBg}$	IO: intermediate output,
		$ENOM_{TBg} = GNG_{TBg}$	LC: labor cost,
		$ECG_{TBg} = Cr_{TBg} - Cd_{TBg} - PCrc$	MNOM: manufactured net operating margin,
Pine cones (PC)	ES_{PC}	$ES_{PC} = ECG_{PC}$	MCG: manufactured capital gain,
		$ECG_{PC} = Cr_{PC} - Cd_{PC}$	PCrc: timber work in progress
Conservation forestry (CF)	ES_{CF}	$ES_{CF} = 0$	reclassification adjustment
Private amenities (PA)	ES_{PA}	$ES_{PA} = ENOM_{PA} = TI_{PA} - MCI_{PA}$	RMp: raw materials purchased,
Recreational services (RS)	ES_{RS}	$ES_{RS} = TI_{RS} - LC_{RS} - MCI_{RS}$	SSp: services purchased.
Landscape (LN)	ES_{LN}	$ES_{LN} = TI_{LN} - LC_{LN} - MCI_{LN}$	
Carbon sequestration (CAs)	ES_{CAs}	$ES_{CAs} = ENOM_{CAs} + ECG_{CAs}$	
		$ENOM_{CAs} = CA_S - CA_R$	
		$ECG_{CAs} = Cr_{CA} - Cd_{CA}$	
Manufactured capital income	MCI		
Timber pine cones carbon	MCI_{TB} MCI_{PC} MCI_{CA}	$MCI_{TB/PC/CA} = FS_{TB/PC/CA}$	
		$+ GFI_{TB/PC/CA} - RMp_{TB/PC/CA} - SSp_{TB/PC/CA} - CFC_{TB/PC/CA} - ES_{TBg/PC/CAs}$	
Other products (j)	MCI_{jMAX}	$MCI_{jMAX} = i \times IMC_j$	
	MCI_{jMIN}	$MCI_{jMIN} = TI_j - LC_j$.	

(CG) captures the changes borne to environmental and manufactured assets during the accounting period, and it is summed up to the net value added (NVA) accrued from the use of resources in production to derive the TI estimation: TI = NVA + CG. Capital income (CI) represents the aggregated remunerations to capital and it is estimated by adding the environmental net operating margin (ENOM), the manufactured net operating margin (MNOM), and the CG: CI = ENOM + MNOM + CG. The net operating margin is the balancing item between total outputs (TO) and costs (TC), which added to the compensations to labor (LC) would yield the net value added: NVA = NOM + LC (Table 1).

In this application, we assume constant prices, and that gross investment in manufactured assets equals their depreciation, hence no CG is assigned to manufactured assets. The manufactured capital income (MCI) represents the return on manufactured assets and is set equal to MNOM. The value of ES accounts for the ENOM and the environmental capital gain/loss (ECG). EGC depends on timber, pine cones, and carbon net capital revaluation and extraordinary destruction. Capital revaluation is mainly due to the discount effect from shortening the harvest period by one year at the closing period with respect to the opening one (Caparrós et al., 2003).

The value of ES is not directly observable, even for those services embedded in products that are provided in the market place. In cases where market prices are available, ES is appraised as a residual value considering that there is usually a quantifiable human input in terms of both labor and manufactured assets associated with the provision of market products. This ES quantification approach is known as the resource rent method (UN, 2014b; Remme et al., 2015; Sumarga et al., 2015). In this study, this approach is applied to approximate the unit environmental price for timber, pine cones, and carbon, and we use this price to value the growth and environmental asset associated with those products. The ES value associated with those products may depict a negative value over an accounting year. Carbon ES could be negative if releases of carbon dioxide (CO_2) surpass its sequestration in the period. Similarly, timber, pine cone, and carbon ES might be negative in case of relevant capital losses due to tree depletion in a certain period.

For non-market services, we use the simulated exchange value (SEV) to assess the price that would occur if a product outside of the market were internalized in a partial equilibrium context (Caparrós et al., 2003). SEV estimations take into account the demand for a non-market product, which is estimated using non-market valuation techniques, as well as the offer and market structure. SEV estimates do not necessarily reflect the value of ES, which depend on whether there are quantifiable human inputs associated with the provision of the relevant non-market service, and that in our case are represented by the costs afforded by the landowner and government to that end. Thus, once the non-market output values are estimated and production costs allocated, ES are quantified as residual values after LC and MCI are subtracted from the TI. In that case, we assume that ES can only emerge if TI > (LC + MCI), being the maximum value for MCI equal to the normal return (i) to the average manufactured investment (IMC) allocated during the account year to obtain a private or public product from the forest ($MCI_{MAX} = i \times IMC$) and LC ≥ 0. In this application we consider a normal real return to manufactured assets of 3%. In cases where the returns on capital are negative, ES would equate to zero and the negative income would be attributed to the manufactured investment ($MCI_{MIN} = TI - LC$) (Table 1).

2.3. SNA and AAS outputs and costs

Private products include natural growth and harvest[1] of timber and pine cones, government payments that the landowner receives

[1] Harvest is regarded as a manufactured activity, since it is not accounted for estimating the value of ES associated with timber and pine cones.

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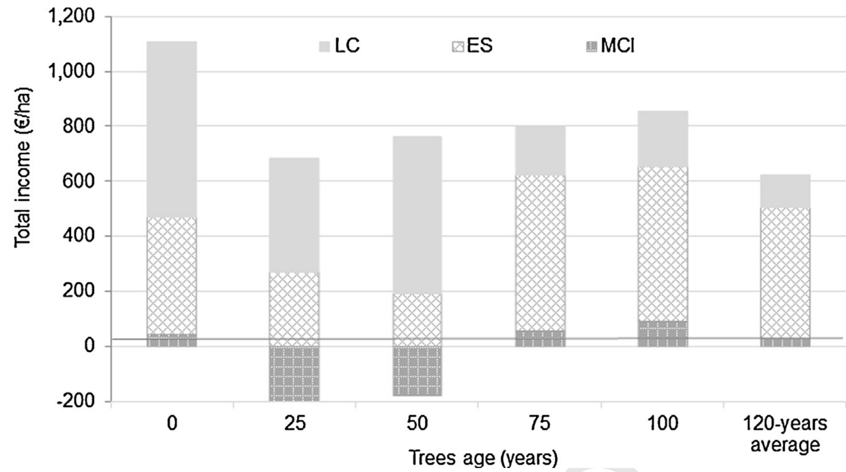

Q11 **Fig. 1.** Total annual income distribution by Stone pines age (€ ha^{-1}, year 2008)*.
*LC: labor income, ES: ecosystem services, MCI: manufactured capital income. Results for a discount rate of 3%.

for applying conservationist forestry treatments, and non-market private amenities. Public non-market products comprise the public recreation services enjoyed by open-access visitors to the forest, and the landscape conservation and carbon sequestration services enjoyed by society as a whole. Some forest products are left out of the analysis, either due to their marginal contribution to private incomes at the case study level (grazing and hunting incomes) or due to the lack of data (e.g., natural water yield, mushroom, and edible plant gathering and threatened biodiversity conservation). Outputs and costs correspond to those observed or estimated prices in the year 2008.

The SNA structures the national accounts by economic activities (forestry being one of them) and institutional sectors (e.g., households, government, and corporations) disconnected from the ecosystems that support those activities. As a consequence, some forest ecosystem products and costs that the SNA does not consider as part of the conventional forestry accounts may already be captured by this system, for instance, through the recording of governmental current expenses and investments in forest resources protection. The total forest income offered by that the SNA applied to forestry is the net value added (NVA_{SNA}), without including subsidies and taxes on production in this application. The NVA_{SNA} is estimated as a residual value between the SNA final output (FO_{SNA}), the intermediate consumption (IC_M) and the consumption of fixed manufactured capital (CFC): $NVA_{SNA} = FO_{SNA} - IC_M - CFC$. This residual value comprises the compensations to employees and the net operating surplus and mixed income (EC, 2000; ECC, 2009). FO_{SNA} records the sales, gross investment in self-produced manufactured assets (e.g., plantations), intra-consumption of raw materials, and personal consumption, donation and payment in kind of market products. On the costs side, the SNA takes into account as intermediate consumption the purchased raw materials and services and intra-consumption, and the consumption of fixed capital (e.g., buildings, plantations and machinery) in the period (EC, 2000).

TI estimation of the AAS broadens the NVA_{SNA} for forestry by including the net value added from non-SNA products ($NVA_{non\text{-}SNA}$) and the CG (Table 1). $NVA_{non\text{-}SNA}$ estimation comprises the operating benefits from: (i) new outputs of conventional economic activities (natural timber growth) and intermediate consumption (the standing timber that is harvested in the year); and (ii) new economic activities (private and public non-market products); as well as, the reallocation and integration of government investment and expenditures into the accounts of public non-market services delivered by forest ecosystems. Each single AAS activity can integrate private and public outputs and costs.

The SEEA-EEA guide suggests that the ES that contribute to the production of public benefits might be regarded as non-SNA benefits, regardless of whether the economic assets generating those services are privately or non-privately [publicly] owned and managed (UN 2014b: 42–43). The AAS approach explicitly broadens the SNA production boundaries to provisioning, regulating and cultural services that contribute to the production of non-market final services (e.g., private amenities, public recreation, landscape services, and reduction of CO_2 in the atmosphere).

2.3.1. Timber growth and harvest

We follow Caparrós et al. (2003)'s approach to estimate the natural timber growth (NGt). This output equals: $NGt = p'_p g_s$; where p'_p is a vector of the expected environmental prices and g_s is a vector of the timber growth (m^3 year^{-1}) for each one of the tree diameter Q9
classes standing at the end of the accounting year:

$$p'_p = (p^1_p, P^2_p, \ldots, P^d_p, \ldots P^m_p)$$

$$\text{Being } P^d_p = \sum_{j=d}^{m} \frac{\left(P^j_w - P^j_k\right) \times \pi_{jd}}{(1+r)^{t_j - t_d}} \text{ for each } d = (1, 2, \ldots, m) \quad (4)$$

where P^d_p is the vector of environmental prices, which is estimated as the forest gate price of timber (P^j_w) minus the expected manufactured cost (P^j_k) per cubic meter in a diameter class d. The manufactured cost comprises: (i) timber harvesting, (ii) the expected silvicultural treatments (those intended to enhance the timber yield) and (iii) a normal return to the IMC involved in the timber production process. P^d_p is affected by the conditional probability (π_{jd}) that a tree that is alive in a diameter class d is logged at each one of the j diameter classes that are to be reached ($\pi_{jd} = Pr\left(j/d\right), j \geq d$). This conditional probability depends on natural mortality, fire risk rates and the scheduled timber logging for Stone pine forests in Huelva Province. Finally, r is the discount rate and t_j and t_d the age (in years) of a tree belonging to the diameter class j and d, respectively. We use a real discount rate of 3% although results are evaluated considering their sensitivity to rates ranging from 2% to 5% (OCDE, 2009: 113).

The standing value of the timber that is harvested in the accounting year is recorded as an intermediate cost in the form of work-in-progress used (WPu). WPu is valued at the beginning of the accounting period as: $\delta(P_w - P_h)'q_h$, where p_h is a vector of the harvest cost for each diameter class; δ is the discount factor [$\delta = 1/(1+r)$]; and q_h is the quantity of the harvested timber.

2.3.2. Payments for forestry conservation services

The landowner benefits from direct government payments (compensations) for adopting conservationist forestry practices. It is accepted that these payments are intended primarily to increase the supply of environmental services (i.e., cultural landscape conservation and climate change mitigation) European Commission (ECC), 2009a,b(ECC, 2009). In this simulated case study, we consider an Andalusian government one-time payment to landowners for accomplishing an afforestation investment and other specific payments to carry out ordinary forestry activities, such as thinning or scrub clearing, which are also subject to government compensations for sustainable forest management (BOJA, 2008).

The outputs and costs of the conservationist forestry practices are accounted for in private forestry activity as a single use for which the landowner is responsible. Afforestation investment is recorded as a gross fixed capital formation item. The annual consumption of fixed capital associated with this investment is subsequently recorded as an intermediate output (conservation services) that forestry provides for the production of public non-market services. In the case of ordinary forestry operations, government payments to the landowner for carrying out those practices are recorded entirely as intermediate outputs. Both types of intermediate outputs are equally shared out as intermediate costs for the production of landscape, carbon and public recreational services.

The compensation payments may not equal the production costs of forestry operations, depending on whether the amount anticipated by the government for each practice (BOJA, 2008) is surpassed or not. We admit that enhancing the provision of public non-market services is the main government objective for encouraging conservationist forestry practices; although they also affect the production function of market products such as timber and pine cones. Thus, if a landowner voluntarily decides to apply a conservationist forestry practice with a total cost higher than the government compensation, the associated negative net operating margin will affect the private market income of the forestry activity in the accounting period. Landowner might be willing to undertake a conservationist forestry treatment that is not fully offset by government payments, if she/he considers that this practice would enhance the future pine cones or timber productivity. This situation might be punctual and we assume that the afforestation project and associated conservationist forestry practices will only take place if the present value of future private market benefits plus government compensations surpasses the present value of the afforestation investment and forestry operations costs. In the particular case of non-industrial forest owners the afforestation decision may be also influenced by non-market benefits from afforestation (e.g., private amenities), as landholders might be willing to accept lower compensations for increasing the share of forest in their properties (Ovando et al., 2010); even though our accounting proposal does not examine this option.

2.3.3. Private amenities

Private (non-industrial) forest landowners benefit from the consumption of amenities (e.g., recreation, life-style, and heritage values) as non-market outputs from the land. The discounted value of the future capital incomes derived from private amenities consumption is a component of land price. The SNA figures do not capture the income derived from the consumption of private amenities. Nonetheless, the private amenity output might incorporate the market value of intermediate services delivered by other activities that are already captured by SNA figures, and that are used to produce the amenity output. The imputed rental value of owner-occupied housing in the property is an example of those intermediate services, which might be embedded in the private amenity output. Accordingly, if there were any commercial intermediate consumption embedded in the amenity output, our amenity income figure would be overvalued.

As the price for the flow of private amenities is not directly observable, we need to draw upon non-market valuation techniques in order to obtain a monetary value for its final output. In this particular case, we employ the results of a contingent valuation (CV) survey applied to estimate the value of landowner private amenities of Los Alcornocales Natural Park (ANP) in Cádiz Province (Campos et al., 2009). We use the mean willingness to pay (WTP) estimated for the ANP to value landowner amenities in our study area (Stone pine forests in Huelva Province).

We acknowledge that this approach has limitations and that the ideal is always to have case-specific values. However, the private amenity values estimated from Campos et al. (2009) can be a good approximation of private amenity values in our study area. The woodlands from these two areas (the ANP and Stone pine forest in Huelva Province) are close to each other (no more than 150 km). Although the ANP woodlands are dominated by Cork oaks and in our study area the predominant tree species is the Stone pine, both species can be frequently found in mixed stands or neighbouring forests as part of a diverse land uses mosaic of forest, pastures and crops (Montero et al., 2004). Cork oaks and Stone pines have many similarities: they are native Mediterranean basin species, have a round shape, do not reach great heights and have a similar understory made up of scrub and swards. In terms of scenic and recreational features, these two forests do not present large differences and they probably do not show high divergences in landowner amenity preferences.

There is more uncertainty about the differences and similarities in the socioeconomic characteristics of landowners in these two areas. However, in Spain forest landowners belong to a relatively similar segment of the population, with a high-medium financial status, and are usually connected to the rural world. In general terms, these characteristics are probably similar. In addition, as these study areas are close to each other, it is likely that the average characteristics of the landowners are similar and have a small impact on the WTP for private amenities. Overall, we think that using the ANP values for private amenities is a better alternative than omitting landowner amenity values in our accounting case study.

The Campos et al. (2009) CV survey in the ANP (64 interviews with landowners) estimated, in 2002, the maximum amount of money that the woodland owners were willing to give up (to pay) annually before selling their property to invest in a more profitable (in monetary terms) non-agrarian asset. The mean of this WTP is €213 ha^{-1} and $year^{-1}$ and represents the output value of the landowner private amenities for the ANP in 2002. We assume this value to be similar to the amenity output value for the year 2008 in our case study. For this particular simulation we assume that the maximum WTP for the private amenities of each forest property could be potentially collected in a market. Thus, there would not be consumer surplus as the landowner would act as a monopolist. Under this assumption, the mean maximum WTP per hectare is an exchange value. The aggregated exchange value would result from multiplying the mean maximum WTP per hectare by all hectares of private properties of Stone pine forests in the analyzed region.

2.3.4. Public recreation and landscapes services

For the estimation of the monetary values of public recreation (an actual use value associated with visiting the forest) and landscape conservation services (an option value for having additional hectares of forest landscape in the future) of a Stone pine afforestation in Huelva, we use the results of a non-market valuation survey, which addressed these public services. This survey included a choice experiment for the valuation of public recreation in Stone pine forests in the southwest and west of Spain and a choice experiment for the valuation of a Stone pine afforestation program in the southwest of Spain. Both experiments cover the area where our case study is located (Huelva Province). The survey was conducted in 2008 through face-to-face interviews with 750 Spanish adults (≥18 years old) from 14 Spanish provinces located in the southwest and west of the country, including Huelva.[2] They were selected in consideration of the fact that they contain or are adjacent to most of the Stone pine forest areas in Spain (around 90% of the total area). Further details about this survey can be found in Oviedo and Caparrós (2014) and Oviedo et al. (2015).

The choice experiment used for valuing public recreation is described and analyzed in Oviedo et al. (2015). This experiment was included in 604 questionnaires,[3] but it was presented only to those respondents who answered a previous question by saying that they had visited a forest in Spain at least once in the last 12 months. This resulted in a total of 336 valid interviews for the valuation of public recreation. The goal was to obtain WTP estimates from actual forest recreationists as they are the ones making use of these recreational services and potentially giving an economic value to them. The experiment provides the WTP for a one-day visit to a forest characterized by the following attributes: the dominating tree species in the forest (Stone pine or Cork oak), the presence of infrastructures (yes or no), the presence of animals (yes or no) and the opportunity to pick mushrooms (yes or no). A payment for the access to the forest is also included, allowing for the estimation of WTP values.

We employ the mixed logit model presented in Oviedo et al. (2015), which uses a pooled choice and recoded ranking dataset to obtain the median WTP for a one-day visit to a forest where Stone pine is the dominating species and with no other attributes associated. This median WTP is €13 visit^{-1}. Assuming that the demand curve is linear with constant elasticity, this median WTP multiplied by half of the annual visits to the forest offers the maximum revenue that could be earned by a monopolist in the year in a hypothetical market. This corresponds to a benefit maximizing strategy if we assume that costs are constant. Under these assumptions, the value obtained is consistent with an exchange value given that the median WTP would be paid by 50% of the annual visits to the forest (Caparrós et al., 2003). Considering the half of total visits (13,359,885 × 50%) estimated by Oviedo and Caparrós (2014) and that those are distributed amongst the 450,000 ha of Stone pine forests in Spain, we obtain an output value of €193 ha^{-1} year^{-1} for the public recreation services. This public recreation output per hectare is assumed to apply equally to all hectares of Stone pine forest resulting from the afforestation in Huelva Province.

The experiment used for valuing the public landscape services associated with the afforestation is described and analyzed in Oviedo and Caparrós (2014). In this case, the valuation scenario was presented to all 750 survey respondents, as landscape services is a potential value to all society. This experiment provides the WTP of Spanish adults for an afforestation program with Stone pines in south-western Spain, which includes Huelva Province. The attributes characterizing the programs were the afforestation area, which covered up to 80,000 ha in intervals of 20,000 ha, and the land use removed because of the afforestation, which could be either scrubland or eucalyptus stands. The experiment also included a payment, as a one-time increase in taxes, for carrying out the afforestation program.

We use the estimated median WTP value per hectare for an afforestation investment covering 40,000 ha and removing scrubland, which stands for the present value of all future benefits derived from the afforestation, and can be converted to an annual WTP when using a proper discount rate. The median WTP represents the amount that would be accepted by half of the population. As the experiment used an increase in taxes as the payment-vehicle, the aggregated value of landscape services is obtained by multiplying the median WTP by the total target population (Spanish individuals ≥ 18 years old from the provinces where the survey was conducted), because the tax would be mandatory. We consider that this is the most appropriate procedure for estimating an exchange value for these services given the scenario used. The median WTP used is €31.65 person^{-1} and it is obtained from the mixed logit model presented in Oviedo and Caparrós (2014). Multiplying this median WTP by the Andalusian adult population (6,698,925 persons > 18 years old), we obtain an aggregated present value for landscape services of €5301 ha^{-1}.

2.3.5. Carbon net sequestration

Carbon gross sequestration is assessed using Montero et al. (2006)'s equations that relate tree diameter with the aboveground and root biomass and carbon stock of Stone pines. We assume that the landowner is paid when the carbon sequestration takes place and has to pay (the same amount of money) when carbon is released, as a result of tree harvesting, burning or death. In all of these cases, we assume that carbon release is instantaneous. Carbon sequestration/release is regarded as a public benefit/cost, and it is valued using the average CO_2 price for the European Union Allowances (EUA), issued under the EU ETS (Emission Trading System) in 2008, that is €22 tCO_2^{-1} (SENDECO2, 2015). The EUA may be seen as an upper bound price for forestry CO_2 when compared to other market allowances and project-based CO_2 transactions in 2008. Nonetheless the EUA renders the best price reference since the EU ETS embraced 73% of the emission units sold in 2008 in industrialized countries (Caapor and Ambrosi, 2009). The EU ETS, however, does not include forestry credits, and it is a highly volatile market, whose prices oscillated from €3.5 tCO_2^{-1}, to €16.5 tCO_2^{-1} between 2009 and 2014 (SENDECO2, 2015). In consideration of this volatility, we further estimate the carbon incomes for a lower bound carbon price of €3.5 tCO_2^{-1}.

2.3.6. Government expenditures

Public costs include direct government expenditures to provide landscape services related to preventing and reducing the occurrence of forest fires and providing public recreation services to open-access visitors. Those government expenditures are SNA values, which we reallocate into the AAS forest ecosystem accounts as output (gross investment), intermediate services, labor, and fixed capital consumption costs of public non-market services, whose provision is affected by government resources and management. Government investment and services are rated as their production costs European Commission (ECC), 2009a,b(ECC, 2009).

Because of the lack of specific data on the government expenditures in the Huelva Stone pine area, we use the data on the expenditures and manufactured capital used by the government to provide the landscape and public recreation services in the woodlands (including forest and scrublands) of the ANP in 2002 (Campos et al., 2005; Oviedo et al., 2010). Government expenditures depend mainly on the regional government, and it is presumed that those expenses would not depict relevant variation amongst Andalusian provinces. To update these costs to the year 2008, we consider that the government forest expenditures have increased in line with the

[2] These provinces are Cádiz, Málaga, Seville, Córdoba, Huelva, Badajoz, Cáceres, Valladolid, Madrid, Segovia, Toledo, Salamanca, Zamora and Ávila.

[3] The remaining 146 questionnaires included another valuation scenario which is not relevant to the goals of this paper.

funds that the Andalusian government has assigned to the Regional Forest Plan Implementation in 2002 and 2008 (see Supplementary material). We estimate that in 2008 government gross fixed investment in infrastructures used to provide landscape services attains €16 ha^{-1} and €4 ha^{-1} in the case of public recreation. Government total production cost accrues €108 ha^{-1} and year, 88% attributed to landscape and 12% to public recreation.

3. Results

We estimate the contribution of single private and public products to TI and the value of ES in five different accounting periods that include the afforestation year, and years 25, 50, 75 and 100 after the simulated plantation would have taken place (Figs. 1 and 2). The total income figures reflect, for each one of the analyzed periods, the investments, outputs and production costs related to forestry operations, government expenditures and public and private outputs that the Stone pine plantation would yield in specific years of its rotation. Government payments for forestry conservation practices, tree growth, net carbon sequestration and harvesting profiles are time varying variables. On the contrary, the output value of private amenities, landscape services, and public recreation, as well as, the direct government expenditures are independent of the age of trees and we assume they remain constant over the analyzed periods.

We also provide the average TI and ES values for the entire Stone pine rotation (Table 2). The average results differ substantially from the annual incomes estimated for the specific accounting periods, since on an average yearly basis, pine cone production, carbon sequestration or timber growth values encompass all the yield and growth oscillations observed along the afforestation cycle (see online Supplementary material). Over the 120-year rotation the effect of government payments on private and public accounts is moderate in comparison to those years in which important conservationist forestry operations are scheduled (years 25 and 50). Finally, it is worth mentioning that in the average year, both timber and carbon capital gains are marginal, which makes sense given its proximity to a steady state situation.

3.1. Total income and ecosystem services distribution

The estimated total social income averages an annual income of €621 ha^{-1} over the Stone pine rotation, while the fluctuations in TI values are relevant across the different ages of the Stone pine trees. The contributions of labor,[4] environmental and manufactured asset as production factors vary along with the different accounting periods (Fig. 1). Rewards to labor explain on average 19% of TI, 15%% of total private income, and 22% of total public income. The value of labor compensations changes considerably across the analyzed periods, which primarily depends on the expected forestry and harvesting operations, as it is assumed that the direct government expenditures for the provision of non-market public services would remain constant in the future.

The contribution of ES to total income averages 77% of total income over the Stone pine rotation, 79% of total private income and 76% of the public one. As expected, the ES value varies in accordance with the scheduled conservation forestry operations. ES values are smaller at the earlier stages of the rotation, when more intensive conservationist forestry interventions are expected (years 25 and 50). We also calculate that 89% of the estimated ES average value corresponds to cultural services (private amenities, landscape and public recreation), 3% to provisioning services (timber and pine cones) and 8% to regulating services (carbon). Finally, the manufactured capital income explains on average the remaining 4% of TI, while accounts for 6% of the total private income and 2% of the corresponding public figure (Fig. 1).

Total income yield by private products varies substantially across the five analyzed periods, with an average share of 46% over the entire rotation (Fig. 2a). The forestry activity explains a large share of total private incomes at the afforestation year and in those years where forestry conservation practices are scheduled (e.g., year 50). Nonetheless, private amenities would explain the largest part of total private income (74%) over the entire rotation. In this particular case, the average total private income from growing pinecones would be two times higher than the income from growing timber, and also, on an average basis, the government compensations would exceed the total costs afforded by the landowner for applying forestry conservation practices (Table 2). The small relevance of private forestry provisioning services respect to the regulating and cultural services included in this study (Fig. 2b) is explained, in part, by a low private profitability for growing timber and pine cones in the studied area. The market revenues for those forestry products barely cover labor and manufactured costs involved in their production, making the residual ES value a small quantity.

The TI delivered by non-market public products also displays relevant variations from negative incomes in year 50, in which a relevant intermediate cost from the application of forestry conservation practices is anticipated, to a maximum value by the year 75, when no conservationist forestry practices are expected (Fig. 2a). Carbon is another factor that adds variability to public TI and ES values. Both the environmental net operating margin and capital gain associated with carbon fluctuate along the afforestation rotation. A negative carbon CG indicates an anticipated environmental asset loss, due to a decrease in the carbon sequestration ability in the near future (e.g., as a result of a reduction in existing inventories), which affects the present value of the expected future carbon net sequestration at the closing period. On the other hand, we estimate that the lower-bound carbon price of €3.5 tCO_2^{-1} would reduce the average TI associated with carbon by −130% with respect to the EUA CO_2 average price observed in 2008. The effect of the minimum CO_2 price observed in EU ETS market between 2009 and 2014 (SENDECO2, 2015), on our TI estimations is, however, marginal with an average difference of −4% between the two carbon price scenarios over the entire forest rotation.

3.2. Sensitivity of total income to discount rates

Our results show that the estimated TI is relatively sensitive to the discount rate applied. This discount rate affects, on one side, the quantification of capital gains and on the other side, the landscape output. We find that timber and carbon capital gains are less sensitive to discount rates, since we deal with long-term outputs and costs. The landscape output value would range from €106 ha^{-1} year^{-1} for a discount rate of 2% to €265 ha^{-1} year^{-1} for a discount rate of 5%, which makes this output, the major factor explaining the sensitivity of the results to different discounting scenarios.

3.3. Payments for conservationist forestry and public non market services

The main benefits from Stone pine afforestation investment come from the production of public non-market services (Table 2). Our results also show that government payments to conservationist forestry practices are expected to enhance the production of public non-market forest services while increasing the private incomes from forestry activity. Nonetheless, the relevant analysis of gov-

[4] Our capital income estimates do not include any reward for a landowner's self-employed labor; rather they only remunerate for the landowner's investment.

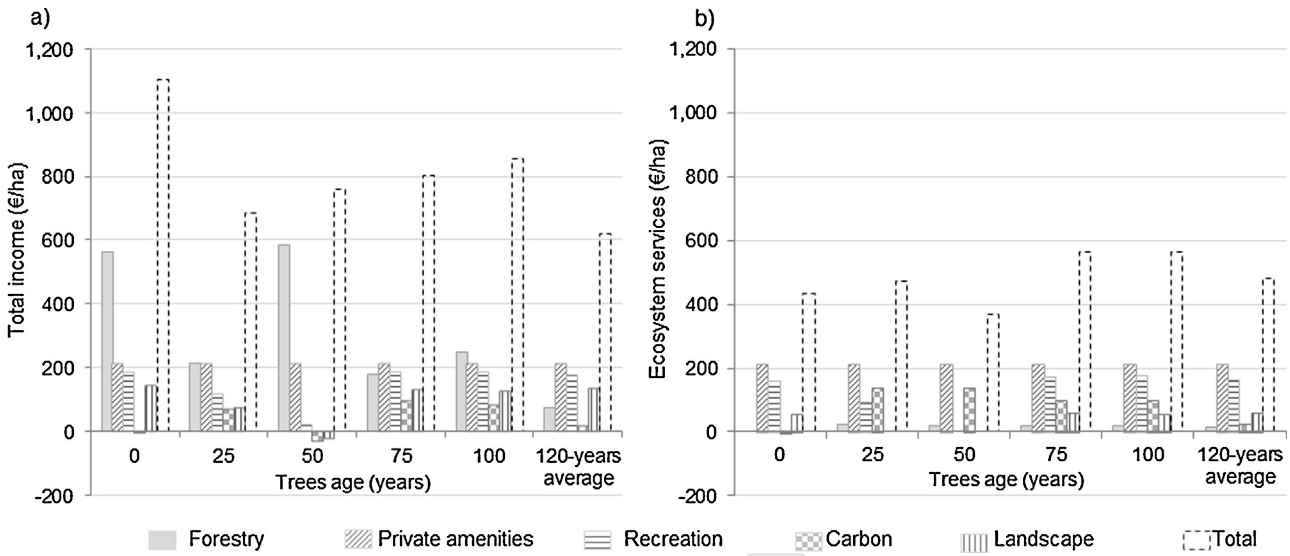

Fig. 2. Total annual income and ecosystem services by single product and Stone pines age (€ ha^{-1}, year 2008)*.
*In the case of total income, forestry includes timber, pine cones and conservation forestry; for ecosystem services it only includes timber and pine cones. Results for a discount rate of 3%.

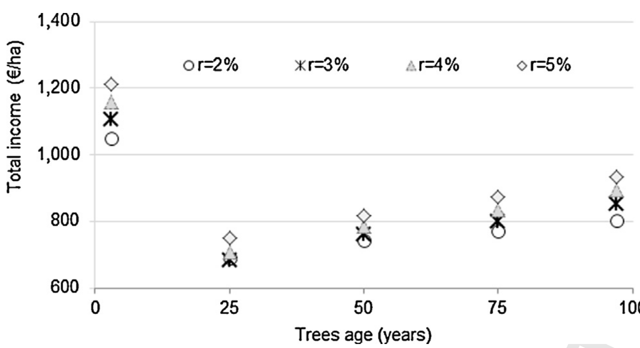

Fig. 3. Sensibility of AAS total annual income to discount rates by Stone pines age (€ ha^{-1}, year 2008).

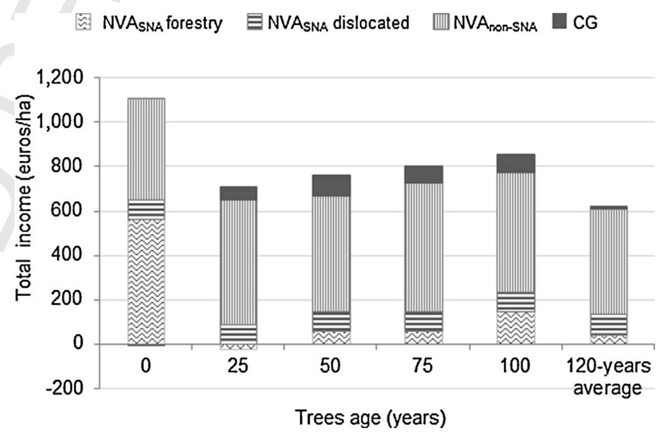

Fig. 4. SNA and AAS contribution to total annual income by Stone pines age (€ ha^{-1}, year 2008)*.
*NVA: net value added, CG: capital gain. Results for a discount rate of 3%.

ernment incentives for afforestation should consider the displaced land use: a dense treeless scrubland, in our case study.

We estimate that on average a treeless scrubland is able to generate an average annual TI of €320 ha^{-1}, in turn made up of a private income of €213 ha^{-1}, and a public income of €107 ha^{-1}, (Table 2),[5] which represents 48% of the TI that the Stone pine plantation is expected to yield on average over its rotation. The afforestation project would also increase the aggregated total private income by 35% and the public income by 211%. Even so, the income associated with carbon would be lower (−33%) in the afforestation scenario with respect to the initial use of the land. This result is explained by higher carbon releases due to a more intensive forestry management (i.e., tree thinning) in the afforestation scenario and by the absence of additional manufactured cost (forestry intermediate services) attributed to carbon in the event that afforestation does not take place (Fig. 3).

3.4. SNA net value added versus AAS total income estimations

The AAS extensions to the official economic accounts for forestry (NVA_{SNA}) are relevant in terms of their contribution to a comprehensive TI figure (Fig. 4). In the year in which pines are planted, the NVA_{SNA} accounts for 51% of the TI, because it records the net value added from the plantation investment. For the subsequent accounting years (25, 50, 75 and 100), the NVA_{SNA} of forestry activity is able to capture in the best of the cases (year 100) 18% of the TI that a Stone pine ecosystem provides, and barely 7% of TI over the entire Stone pine rotation.

Ninety-three percent of the TI estimated by the AAS for the average rotation would be omitted in the SNA applied to forestry. Some 14% would be dislocated into the accounts of the government, as an institutional SNA sector, in the form of labor compensations associated with gross investment and expenditures in activities such as preventing and fighting forest fires or the provision of public services to open access visitors of natural areas. A relevant part of the AAS extensions ($NVA_{non\text{-}SNA}$) to the forest net value added would be omitted (77%) in the System of National Accounts. Basically, the SNA will hide or omit the contribution of ecosystems services embedded into the total forest income that the AAS estimates. This includes the

[5] Public recreation and landscape output values were estimated specifically for Stone pine forests in Spain, thus TI values associated to those uses in treeless scrublands account for government investment and ordinary expenditures for fighting against forest fires and providing public recreation services. See online Supplementary material for details on scrubland total income estimation.

Please cite this article in press as: Ovando, P., et al., Measuring total social income of a stone pine afforestation in Huelva (Spain). Land Use Policy (2015), http://dx.doi.org/10.1016/j.landusepol.2015.10.015

Table 2
Total income distribution for the entire Stone pine rotation and the initial treeless scrubland (€ ha^{-1}, year 2008).

Class	Forestry (market)			Non-market services				Total social
	Private uses				Public uses			
	Timber	Pine cones	Conservation	Private amenities	Recreation	Carbon	Landscape	
Afforestation project (120- years average annual income) (A)								
1. Labor income(LC)	5	21	18	0	5	0	66	115
2. Capital income (CI)	13	17	1	213	174	17	70	506
2.1 Ecosystem services(ES)	14	0	0	213	165	27	62	481
2.2 Manufactured (MCI)	-1	16	1	0	9	−9	9	25
3. Total income (TI)	19	38	19	213	179	17	136	621
Treeless scrubland (annual income) (B)								
1. Labor income(LC)	0	0	0	0	5	0	66	71
2. Capital income (CI)	0	0	0	213	-4	40	0	249
2.1 Ecosystem services(ES)	0	0	0	213	0	40	13	266
2.2 Manufactured (MCI)	0	0	0	0	-4	0	-13	-17
3. Total income (TI)	0	0	0	213	1	40	66	320
Total gain ((A – B)/A) (%)	100	100	100	0	99	-130	52	48

entire value of net timber growth and carbon sequestration, and the ES associated with both private amenities and public non-market final services. Finally, the environmental capital gains associated with timber, pine cones and carbon account, on average, for 2% of TI over the Stone pine rotation, and will be also omitted by the SNA (Fig. 4).

4. Discussion

4.1. Contribution to the ecosystem accounting debate

In this study we have estimated that a large part of the TI, especially the value of the ES delivered by a Stone pine forest over its entire rotation, would be missing in the official economic accounts for forestry. This situation is connected to the production boundaries and the fragmentary conception of ecosystems by the SNA, but also to the difficulties and controversies regarding non-market valuation at relevant spatial scales (Atkinson et al., 2012) and their coherent integration into a System of National Accounts (Day, 2013; Edens and Hein, 2013). These difficulties may also include the estimation of environmental assets values and associated capital gains.

The omission of natural timber growth, work-in-progress used and changes in timber stocks are not justified by the restrictions imposed by the production boundaries of the SNA, being more related to the practical implementation of the forestry economic accounts. Other pilot proposals for extending SNA forest accounts, such as the Integrated Environmental and Economic Accounting for Forests (IEEAF), prompted the inclusion of natural timber growth and work-in-progress used into the production account (EC, 2002). Meanwhile, the SEEA-CF focuses on the estimations of the timber-related physical and monetary environmental asset account, incorporating the natural timber growth and removal during the accounting period. The SEEA-CF proposes to further adjust the timber NVA_{SNA} by subtracting the value of the timber harvested in excess of natural growth (when removals surpass normal year-on-year variations in quantities of natural growth) to estimate what in the SEEA terminology is known as the "depletion-adjusted net value added" (UN 2014a: 22). This SEEA-CF depletion concept does not match the AAS capital gain, which accounts for both improvement (gain) and depletion (loss) of timber inventories over the accounting year, and for capital adjustments for previously unforeseen events.

The production boundaries of the SNA (and the SEEA-CF) restrict non-market products to those that accrue to economic owners, which are defined as "an institutional unit entitled to claim the benefits associated with the use of an asset in the course of an economic activity by virtue of accepting the associated risks" (UN, 2014a: 47). These boundaries would include, in theory, the private amenities derived from the tenancy of woodlands and this could be partially accounted in land transactions, since private amenities are captured in the forestland market price (Campos et al., 2009). The ES value estimated for private amenities might be overrated, as we assume that those final services are provided as a joint production of ecosystem activities, and are not being affected by other manufactured costs such as those related to owner-occupied housing services within the forest property. Further research would be needed to analyze how housing, hunting, livestock and other services in a forestry property affect private amenities value.

The SNA production boundary challenges the integration of public products for which only the government is the virtual economic owner. It is also worth noting that public recreation services, additional to the onsite public recreation value we have estimated in this study, may be an attribute of other market products that are accounted offsite the forest, for instance, in the tourism industry market. This industry may partially incorporate recreation services from public visitors who make use of accommodation services in the visited natural area; but we do not know the proportion of those services that is already embedded in the SNA. Forest carbon sequestration has the characteristic of a public good and it is not currently captured by any single industry (Edens and Hein, 2013).

Another issue concerning the integration of public non-market services comes from the potential overlapping of values. In our particular application, there could be overlap between landscape and public recreation values for respondents who are forest recreationists and also pay for the afforestation. They may be discounting future recreation values in their WTP for the afforestation because the resulting forest will be available for recreation activities. The design of these two choice experiments tried to avoid this potential overlapping by using a different payment vehicle in each valuation exercise (a one-time tax payment for landscape values and both an entrance fee and an increase in trip expenditures for public recreation values). Thus, respondents could clearly differentiate the two payments and, therefore, the two forest non-market services about which they are being asked. We note, however, that our result that public non-market services comprise 54% of TI over the entire rotation of the afforestation may be an upper bound. Future research should consider this issue and incorporate ways to identify and solve the potential overlapping of public non-market services in valuation surveys.

The SNA partially integrates the value of non-market products into the SNA government accounts. This sectorial account considers the ordinary expenditures and investment in forest environmental protection services. As we consider that those investments and services are rated at their production cost, we were able to estimate the labor income that is already captured in the SNA government accounts (dislocated income). Ideally, those values should be attributed to the economic activities whose production processes are being affected, in such a way that the estimation of functional accounts for single forest ecosystem products becomes possible. Note that if the SEEA-EEA guidelines were applied to our study case and its non-SNA benefit concept were extended to landscape and public recreation final services (and those were valued using the same methods as in this study), their associated ES would be overvalued. This overrated amount would equal the ordinary government expenditures that affect the provision of non-market public final services.

4.2. Incentives to enhance the provision of public non-market products

Government payments for conservationist forestry practices are intended to encourage the provision of public non-market products, although their economic effects might be implicitly displayed in private forestry yields, as well as in the avoided damage or losses of private and public environmental assets. The AAS records as part of the private production accounts the intermediate and final outputs resulting from the application of conservationist forestry treatments. In that sense, we recognize that the landowner benefits from government payments to these forestry practices. On the other hand, we also acknowledge that society assumes a cost equal to the government payments weighed against the benefits of increasing the provision of non-market ES attached to the afforestation investment.

Current government payments to landowners and direct expenditures for the provision of ES are set in a context in which there is insufficient information on the social preferences regarding their consumption. Unless we elicit those preferences, we ignore to what extent those payments capture the social benefits of non-market products. In this study we offer the simulated or imputed exchange values for landscape, carbon sequestration and public recreation as the resulting benefits of the Stone pine conservation policies. This valuation approach is independent from current government or other institutional expenditures on their provision, which makes the AAS a valuable instrument for evaluating forest conservation policies and incentives. Nevertheless, we recognize that other afforestation effects on products omitted in this research could have a negative influence on ES results, as it could be the case of decreasing the superficial water runoff due to land-use change.

5. Conclusions

This research presents the experimental Agroforestry Accounting Systems as an alternative approach to estimate the total income and the value of the ecosystem services that forests deliver. This AAS application integrates the institutional sectors of the System of National Accounts and other extended activities into a single multifunctional unit to include forest market and non-market ecosystem services and products. Our research demonstrates that the SNA for forestry provides an incomplete picture if it is applied to measure the total income in a forest ecosystem. The SNA's partial and fragmentary conception of ecosystems, and its production boundaries, which are also shared by the Central Framework of the System of Environmental–Economic Accounting, narrows the policy-relevant information for designing forest conservation incentives and regulations. Current SEEA Experimental Ecosystem Accounting guidelines aligned with the SNA will potentially result in a partial representation of forest ecosystem accounts, as long as it continues to omit government output and costs for the provision of public non-market services. Our AAS approach is a novel experimental accounting proposal beyond the SNA production boundaries, but consistent with the SNA exchange value and total income principles.

This study contributes to the current debate on extending the ecosystem accounts by highlighting the need to address the interactions between private and public forest activities and management decisions, and their effects on the provision of both market and non-market ecosystem services. In this application, we estimate that non-market public products would explain more than the half of the total income delivered by an afforestation project, and that this new forest would increase the aggregated value of those products with respect to the initial treeless land use. We also find that the production of public non-market services would offset the government compensations to support both the afforestation project and sustainable forest management. Our results suggest that landowners would increase their private incomes if the afforestation takes place. These results are particular to the case study, but give some insights on the potential of ecosystem accounting as a useful tool for evaluating forest conservation policies and incentives.

Acknowledgments

This paper received the support of the Spanish National Research Council (CSIC) research projects Bases for the sustainable management of the stands of *P. pinea* L. in the Iberian Peninsula: ecological, silviculture models, genetic diversity and economic and social valuation of products (CPE03-001-C5), and DYNOPAGROF (SEJ2005-05085/ECCON). The authors are indebted to Alejandro Caparrós and Gregorio Montero for their early contribution to the environmental valuation and silvicultural models used in this work, respectively. We are very grateful to Giles Atkinson and two anonymous referees for their constructive comments for improving the earlier versions of this paper. This paper reflects only the authors' views and not the views of the supporting institutions.

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