Environmental incomes: Refined standard and extended accounts applied to cork oak open woodlands in Andalusia, Spain

Pablo Campos[a,*], Alejandro Álvarez[a], José L. Oviedo[a,b], Bruno Mesa[a], Alejandro Caparrós[a], Paola Ovando[a,c]

[a] Spanish National Research Council (CSIC)-Institute of Public Goods and Policies (IPP), Spain
[b] Spanish National Research Council (CSIC)-Institute of Marine Sciences of Andalusia (ICMAN), Spain
[c] The James Hutton Institute, United Kingdom

ABSTRACT

In this research, our objectives are twofold: firstly to conceptualize and compare the ecosystem services and environmental incomes of individual activities at producer, basic and social prices using the extended accounts (Agroforestry Accounting System) and the refined standard accounts (a slightly refined standard System of National Accounts), and secondly, to apply both methodologies at a scale of 4,095 land-cover tiles predominantly occupied by cork oak open woodlands (COW), which cover 248,015 ha in Andalusia, Spain. This analysis considers spatial-explicit characteristics of COW across Andalusia. The 15 COW economic activities valued in 2010 include: timber, cork, firewood, nuts, grazing, conservation forestry, residential services, private amenity, fire services, water supply, mushroom, carbon, free access recreation, landscape conservation services and threatened wild biodiversity preservation services. In this research, the ecosystem service is defined as an economic indicator that provides information on the contribution of nature to product consumption by humans in the period, but with an uncertain meaning of ecological sustainability. We show that environmental income is the maximum economic value in the period of sustainable ecosystem service with both ecological and economic significance only if the future sustainable biophysical silvicultural management scenarios are accounted for. To measure environmental incomes, we model the future sustainable silviculture while considering all the management practices required to maintain cork oak woodlands in perpetuity. We use farm-level data to estimate voluntary opportunity costs incurred by land and livestock owners associated with hunting and livestock activities of the farmer as well as their subsequent scaling up to COW land-cover tiles in order to estimate environmental incomes at social prices for each individual activity. In this study, we measure the ecosystem services and incomes of the COW private amenity and public landscape activities at social prices, that is, their basic prices less own compensated and auto-consumed non-commercial intermediate consumption of services used by the private amenity and public landscape activities. The ecosystem services and environmental incomes of cork oak open woodlands measured by the extended accounts at basic prices in 2010 were 1.1 and 1.2 times higher, respectively, than those estimated at social prices. The ecosystem services and environmental incomes measured at basic prices by the refined standard accounts were 0.3 and 0.2 times, respectively, those estimated by the extended accounts at social prices.

1. Introduction

Gross value added (GVA)[1] is the indicator commonly used by nations and is estimated by the national statistical offices using the standard System of National Accounts (SNA) (European Commission et al., 2009). GVA measures the gross operating income of the economic activities in the territory of a nation over a period (a year). This GVA corresponds to the aggregate values of labor cost and gross operating margin (owner s profit) of economic activities. The SNA total product (TP), manufactured during the period within the borders of a nation is the aggregate values of the GVA plus the costs of manufactured intermediate consumption (inputs of raw materials and services) and depreciation (consumption) of manufactured (man-made) fixed capital investments. The TP is calculated by the SNA at market prices and

production cost, the latter referring to intermediate and final public goods and services without market prices offered free of charge by public administrations. The SNA prioritizes the measurement of the total product of commercial activities to satisfy the consumption demands of citizens, but omits the costs of the depletion, degradation and extraordinary destruction of natural habitats caused by economic activities, which are beyond the measurement of GVA. Likewise, the SNA does hide and not estimate the values of ecosystem services delivered by the consumption of final products with and without market prices, respectively.

Hence, the main limitations of the SNA as regards the measurement of the total income for the domestic territory of a nation are, on the one hand, that the GVA does not incorporate the value of the ecosystem service embedded in the simulated price of the consumption of final products without market prices and, on the other, the absence of valuation of the capital gains (CG) of manufactured capital (CGm) and environmental assets (EAg). Overcoming the aforementioned limitations requires the integration of the SNA into a system of extended accounts incorporating environmental assets work in progress used and services into the total product function. The measurement of total income (TI) requires a system of extended accounts that reconsiders the SNA concept of economic activity along with the substitution of the production cost price for the consumer revealed or stated simulated exchange price to value the final products consumed without market prices (Caparrós et al., 2017)

In this study, we are interested in measuring the contributions of ecosystem environmental assets to the total income of a nation. This purpose is broader than that of the SNA adjusted net value added proposed in the ongoing satellite System of Environmental Economic Accounting-Experimental Ecosystem Accounting (SEEA-EEA) (United Nations, 2017; United Nations et al., 2014a, 2014b; van de Ven et al., 2019). The extended accounts approach applied in this research is an Agroforestry Accounting System (AAS) for multiple land uses. The AAS could be applied to any farm or ecosystem type, at any scale. However, although "business accounts and national accounts have been harmonized and aligned in order for business accounts to feed into the statistical production process of the System of National Accounts […] at this moment there is no globally accepted uniform / standardized approach for business accounting of natural capital" [environmental asset] (Lammerant, 2019: p.3). The AAS extends the refined standard accounts (a slightly refined standard System of National Accounts) with the aim of estimating total income in a manner consistent with the transaction value principle of national accounts of society (McElroy, 1976; Stone, 1984).

The current challenge to the national statistical offices with regard to extending the boundary of SNA economic activity is to complement the SNA by developing a satellite SEEA-EEA (European Commission, 2011; United Nations, 2017; United Nations et al., 2014a, 2014b). The ongoing SEEA-EEA framework is expected to become a standard ecosystem accounts system in the near future, linking ecosystem services and the changes in environmental assets with the adjusted net value added (NVAad) of ecosystem degradation/enhancement (United Nations et al., 2014b: Table 6.1). However, there is no consensus as yet on the boundaries of the economic activities of a nation or on the concepts of total income and ecosystem services and, therefore, "the precise description of the relationships between economic assets, ecosystem services and the associated production, consumption, and balance sheet [capital account] data in the standard national accounts is subject to ongoing discussion" (Atkinson and Obst, 2017: p. 11).

In this research, our general objectives are twofold: firstly, to conceptualize and compare the geo-referenced ecosystem services and environmental incomes of individual activities at producer, basic and social prices using the AAS and the refined standard System of National Accounts (rSNA), and secondly, to apply the AAS and the rSNA production and capital accounts to 4,095 land-cover tile basic spatial units (BSU), predominantly occupied by cork oak (*Quercus suber* L.) open

woodlands (COW), which were the predominant land use in Andalusia-Spain in 2010. The single objectives of this article is to compare the estimates for gross/net value added, ecosystem services, change in environmental asset, adjusted change in environmental net worth according to work in process used, and environmental income. Producer, basic and social prices are compared in each methodology. Variations are compared between the ASS and rSNA methodologies for ES and GVA and the types of prices applied.

The integration of ecosystem services and incomes of the rSNA in the AAS is based on the recording of the production and capital accounts. This research discusses the similarities and differences between the rSNA and AAS methodologies in relation to the integration of ecosystem services and environmental incomes in a consistent manner with the concept of society total income (Alfsen and Greaker, 2006: p. 15; European Communities, 2000: p. 87).

The main contributions of this study to the ecosystem accounting debate are the following: firstly, that we define and calculate the ecosystem services and incomes of the individual activities of cork oak woodlands at social prices, avoiding the overvaluation problem inherently incurred in estimates of amenity and landscape ecosystem services and incomes at producer and basic prices. In the case of amenity and landscape activities this is done by defining the social price of these activities as the basic price less the manufactured investment voluntary unitary opportunity cost incurred by farmers in the period. Secondly, that we link the environmental income (EI) for the period under the rSNA and AAS with ecosystem services (ES) through the estimation of the adjusted change in environmental net worth (CNWead) according to work in progress used (WPeu). Thirdly, the AAS environmental income shows the expected future ecological-economic environmental asset enhancement/degradation due to the deviation in the results for a period compared with the expected scenarios at the opening of the period.

This research continues in Section 2 with a brief review of the literature on monetary ecosystem accounting frameworks applied at farm and regional/national scales. Section 3 describes the COW economic rationale and the economic activities reconsidered, Section 4 conceptualizes the notions of ecosystem services and environmental incomes as well as the integration of the rSNA ecosystem services and incomes of the Andalusian COW into the AAS. Section 5 describes and compares the results of the rSNA and the AAS frameworks. Section 6 discusses the main results of this research along with policy issues in the implementation of extended accounts beyond COW. Finally, Section 7 concludes with the main findings and policy challenges arising from this research.

2. Brief review of the literature on economic ecosystem accounting

Governmental and academic institutions are currently developing methodological guidelines and experimental applications for the future implementation of the SEEA-EEA in order to broaden the SNA. As key indicators, the SEEA-EEA proposes the ecosystem service (ES), the environmental asset revaluation (EAr), the degradation-adjusted net value added (NVAad) and net operating surplus (NOSad) (United Nations, 2014a, 2014b; United Nations, 2017).

Scarce literature exists in relation to the application of the SEEA-EEA and integration of results for multiple institutional sectors (including the government). The application of extended accounts in Campos et al. (2019a, 2019b) developed a modified version of the Model B of the SEEA-EEA (United Nations et al., 2014b: Table 6.1). Ogilvy et al. (2018)) incorporate the government among the institutional sectors in their integrated valuation of ecosystem services. Other authors have applied the SEEA-EEA to individual goods and services, but they do not integrate ecosystem services and environmental assets of the ecosystems in the production and capital accounts (EFTEC, 2015; Eigenraam and Obst, 2018; Keith et al, 2017; La Notte et al., 2019a,

2019b; Ogilvy et al. 2018; Remme et al, 2015; Sumarga et al, 2015). The *Knowledge Innovation Project on an integrated system of natural Capital and ecosystem services Accounting* (KIP INCA) aims to contribute to the future design of the European Union SEEA-EA (European Commission, 2016).

Ogilvy et al. (2018) estimate the grazing lease transaction value of silvopastoral ecosystems in Northern Australia[2], dealing with multiple grazing scenarios, both sustainable and unsustainable. These scenarios generate different values for livestock grazing environmental assets (Ogilvy et al., 2018: p. 264). The biophysical sustainability of grazing is an external result of the grazing lease through the preceding subjective choice of biological scenarios both sustainable and unsustainable[3]. The authors note that the SNA implicitly incorporates the degradation (consumption of environmental fixed asset) or enhancement (natural growth productivity improvement) in "other changes in volume" register. They also highlight the fact that the Australian Accounting Standard (IAS) integrates the environmental asset degradation or enhancement in its "revaluation loss" concept (Ogilvy et al., 2018). Campos et al. (2016) assume that environmental assets of the biophysical productivity of grazing remain indefinitely invariable.

In the context of the SEEA experimental design, La Notte et al. (2019a, 2019b) propose that the concept of sustainable potential ecosystem services is applicable "if a sustainability threshold can be established" for an infinite time horizon. This concept is similar to the environmental income[4] established in this research, as we assume that the environmental assets at the closing of the period correspond to a scenario of perpetual biophysical sustainable management of the COW. In this case, the ecosystem services can only coincide with the environmental income if the adjusted change in environmental net worth (CNWead) according to work in progress used (WPeu) is zero (Campos et al., 2019b).

In Campos et al. (2019b) the extended (AAS) and refined standard (rSNA) methodology were applied to five non-industrial privately-owned cork oak farm (COF_PR) case studies in Andalusia-Spain, with the main objective of measuring the ecosystem services and incomes at social prices for 18 individual activities, farmer, government and the COF_PR aggregate activities. The COF_PR total area is composed of multiple types of ecosystems, with vegetation and land uses types including cork oak, holm oak, conifer trees, other tree species, shrubland, grasslands and croplands (Campos et al., 2019b: Table 1, p. 9). The non-commercial intermediate products of services (ISSnc) and own ordinary non-commercial intermediate consumption of services (SSncoo) on the farms are the same services and values. The total incomes for the activities of the farms as a whole at producer, basic, and social prices show the same values. These results for the farms as basic spatial units (BSU) come from having registered the ISSnc in the supply side and the SSncoo in the use side of AAS production account. This is not the case for ecosystem services and incomes of the individual, farmer, and government activities valued at producer, basic, and social prices, which present different values (Campos et al., 2019b: Table 1, p. 14).

3. Economic rationales, activities and incomes reconsidered

This Section summarizes the economic rationale and the key concepts of the extended accounts (AAS) and refined standard accounts (rSNA) applied in this research. The purpose of this Section is to facilitate the understanding of the results and discussion in Sections 5 and 6 (see detailed developments in Campos et al., 2019a, 2019b and

---

[2] The lease price corresponds to the grazing resource rent only if there is no farmer silvopastoral manufactured cost.

[3] In this case the owner of the livestock is obliged to pay for the ecological restoration after the termination of the lease contract.

[4] The suggestion that free consumption of environmental goods and services are part of people's real income was proposed by Krutilla (1967: p. 779).

Table 1
Physical indicators for cork oak open woodland land-cover tiles in Andalusia (2010).

Class	Unit	Indicators		
		Useful land (ha)	Quantity	Quantity/ha
1. Timber				
Stock	m^3	12,036	6,927,442	575.6
Natural growth	m^3	12,036	29,298	2.4
Harvest	m^3	12,036	4,137	0.3
2. Cork				
Stock	t	248,015	192,657	77.7[*]
Natural growth	t	248,015	80,662	32.5[*]
Harvest	t	248,015	17,873	7.2[*]
3. Firewood				
Stock	m^3	89,189	2,178,039	24.4
Natural growth	m^3	89,189	39,589	0.4
Harvest	m^3	89,189	605	0.0
4. Grazing	FU	248,015	148,568,023	599.0
Livestock grazing	FU	248,015	60,229,866	242.8
Game grazing	FU	248,015	88,338,158	356.2
5. Residential	m^2	248,015	88,549	35.7[*]
6. Recreation	vi	248,015	1,077,028	4.3
7. Mushrooms	kg	248,015	917,909	3.7
8. Carbon				
Fixation	t CO_2	248,015	1,303,936	5.3
Woody product natural growth	t CO_2	248,015	701,384	2.8
Shrub natural growth	t CO_2	248,015	602,551	2.4
Emissions	t CO_2	248,015	210,203	0.8
Woody product extractions	t CO_2	248,015	37,266	0.2
Shrub cutting	t CO_2	248,015	172,936	0.7
Net fixation	t CO_2	248,015	1,093,733	4.4
Woody products	t CO_2	248,015	664,118	2.7
Shrubs	t CO_2	248,015	429,615	1.7
9. Threatened wild species	n°	248,015	128	0.1
10. Water supply	m^3	88,665	158,924,119	1,792.4

Abbreviations: m^3 is cubic meter; t is ton; FU is forage unit (metabolic energy of a kg of barley); m^2 is square meter; vi is free recreational visit; kg is kilogram; t CO_2 is tons of carbon dioxide; n° is number
(*)These indicators are expressed in their units per 100 ha.
Note: a 0.0 value denotes a value less than 0.05.

Supplementary texts S1–S4).

3.1. Economic rationale for cork oak open woodlands

The extended accounts (AAS) are designed to measure the environmental incomes in a manner consistent with the concept of society total income. In this research, the AAS should be considered as our refined version of the ongoing SEEA-EEA Model C, by incorporating a government institutional sector (Campos et al., 2019a, 2019b, 2019c; van de Ven et al., 2019). In our AAS framework, the values of ecosystem services embedded in the individual products consumed and the environmental gains accrued from environmental assets (ecosystems) in the period are based upon the economic rationales of owners (farmers), the government, and consumers. These economic actors are those making decisions on investment and consumption, subject to current and planned (long term) social institutional frameworks. We assume that both public farmers (acting as collective owners of land) and the government (acting as a collective economic institutional unit responsible for the free supply of public final products) have a desire to conserve the COW environmental assets on the basis of the assumed current social management and expected future scheduled sustainable management of the ecosystem. We assume that private industrial farmers do not exist in the cork oak open woodlands (COW) of Andalusia. Non-industrial private landowners invest with the dual motive of obtaining an ordinary net operating margin (NOMo) consisting of the desired mix of ordinary manufactured net operating margin (NOMmo)

and private amenity environmental net operating margin (NOMea). These assumed rationales of the non-industrial private landowners for their investments in the COW account for the fact that they do not contribute with donated non-commercial intermediate services (ISSncd$_{F,PR}$) to the productions of the final public goods and services consumed (PGSc). We assume that public owners favor the production of free PGSc through the donation of non-commercial intermediate production of services (ISSncd$_{F,PU}$), while the government does so through the ordinary total cost paid through taxes (TCo$_G$).

The literature on silvopastoral farm case studies and natural final public product consumption has consistently demonstrated that non-industrial farmers could voluntarily accept monetary opportunity cost in the economic management of hunting and livestock activities due to private amenity and public product consumption (Campos et al., 2017; Ovando et al, 2010; Oviedo et al., 2017; Masiero et al., 2019; Raunikar and Buongiorno, 2006) (Supplementary text S1).

3.2. Economic activities and products reconsidered

The definition of economic activity in the SNA requires a production function with the use of at least one remunerated manufactured factor of production. In this COW research, we broaden the concept of economic activity to include public products that use at least one environmental or manufactured production factor without the requirement that it should be remunerated. An example of the former is the carbon final product consumption (FPcca) that, in the case of the COW, does not contain remuneration of environmental production factors. In the case of the latter, an example would be mushrooms, as the time spent by recreational visitors collecting this product is not remunerated.

We define an economic activity as the allocation of the production factor services of a spatial unit, organized into the production and capital accounts attributed to a main product and other possible associated products that are inseparable at all stages of production process. The 15 COW economic activities valued and managed by the farmers and government are: timber, cork, firewood, nuts, grazing, conservation forestry, residential services, private amenity services, fire services, water supply, mushroom collection, carbon services, recreation services, landscape conservation services, and wild biodiversity preservation services.

We assume that any consumption and/or appropriation of products, inside or outside the COW land-cover tiles and whose resource rents are not internalized by market transactions, corresponds to a public economic activity managed by the government. This concept of public final product is weaker than that referring exclusively to pure public products guaranteed by the absence of rivalry in consumption and the technical impossibility of excluding free consumption (Koop and Smith, 1993). In the COW, landscape conservation services, threatened wild species preservation services and carbon services are examples of pure public product consumptions. Other public products are quasi-private–public, such as retained (dammed) water supplies, mushrooms collected by recreational visitors and recreational services enjoyed by free-access visitors.

The total product (TP) of an economic activity is composed of at least one product generated in the period in all its possible phases and uses of the intermediate product (IP) and final product (FP). The FP may contain the final product consumed (FPc) and the accumulated own-account gross capital formation (GCF). The GCF is separated into manufactured gross capital formation (GCFm) and natural growth (NG). The latter is expected to be harvested in the future as an environmental work in-progress-used (WPeu) or will contribute in the future, as a asset cost service in the form of consumption of environmental fixed asset (CFCe), to the productions expected to be harvested.

In COW, intermediate production (IP) is considered to be any product generated within the COW that is re-used in another COW activity, regardless of whether or not the affected activities are valued in this research. Although this does not present conceptual controversy, the

omission of its explicit valuation in the SNA is a practical reality. In the COW activities valued in this article, there is no compensated, auto-consumed or donated non-commercial intermediate production of services (ISSnc).

The residential services, conservation forestry and fire services activities total products do not depend on biological production factors and therefore, by definition, these economic activities cannot contribute with ecosystem services embedded in their total products. However, we emphasize that they *do* contribute to their generation indirectly through their uses as own ordinary intermediate consumption of services by the activities of amenity and landscape.

3.2.1. Conservation forestry activity

The direct management of COW by the government involves public expenditure on the maintenance and/or enhancement of woody vegetation for fire prevention purposes. We assume that the owner does not incur any costs in the period and is limited to authorizing government forestry intervention tasks. The farmer income may be affected in the future through the economic changes induced by the government forestry intervention tasks in other farmer economic activities which are not directly linked in this case study to the conservation forestry activity.

This conservation forestry activity is limited to recording the total product (TPcf), which is composed of the commercial intermediate production of services (ISSccf) and the own account manufactured gross fixed capital formation (GFCFmcf). The TPcf is valued according to costs of production, and for that reason, the manufactured net operating margin investment (NOMmi) is zero, and the existence of the environmental net operating margin is not implied. The inclusion of the conservation forestry activity in the farmer activities is justified by the assumption that it is the landowner who holds the legal ownership of the activity and that the government is the authorized executor of forestry tasks by farmers in order to carry out investments in the public interest. This is why the conservation forestry activity ISSccf must be considered an input of own ordinary commercial intermediate consumption of services (SScoola) of the landscape activity.

3.2.2. Private amenity

The final product auto-consumption of the private amenity (FPcaa) by the private non-industrial landowner requires the production factors of the own ordinary manufactured intermediate consumption of services auto-consumption (SSooa) and the environmental fixed asset service of the amenity, which we note as environmental net operating margin (NOMea). The SSooa are produced by the non-industrial owner residential services and the animal activities and estimated by the respective owner voluntary ordinary manufactured investment opportunity costs. These costs are reflected in the manufactured commercial intermediate products of services of the residential service activity (ISScrs) and non-commercial intermediate products of services of the hunting (ISSnchu) and livestock (ISSncli) activities.

Land prices are assumed to vary over the period solely due to auto-consumption of future amenities by non-industrial landowners. The reasoning for the omission of private amenity consumption in public cork oak open woodlands is that the value of the auto-consumption is restricted to physical persons and cannot be attributed to institutions. In other words, having assumed the stability of future costs it follows that all unanticipated future variation in the environmental fixed asset of the amenity would be due to the unanticipated variation in the willingness to pay for future auto-consumption of amenities by the owners. Thus, the non-industrial owners will maintain the investments in the residential activity and the animal activities produced by the ISScrs and ISSncli of the period into the future, and these will be used by the amenity activity as intermediate consumption of SScooa and SSncooli respectively. The manufactured investment rationale of the residential and the animal activities of the non-industrial owners will not be affected in the future as long as the variations in the final product auto-

consumption of the amenity (FPcaa) does not generate a lower than normal residual net environmental margin of the amenity activity.

3.2.3. Landscape activity

The scheduled management of the natural vegetation, hunting and livestock, take into account the future continuity and/or improvement of the final products consumed expected from the cultural landscape activity. We estimate the passive landscape final product consumption (FPcla) in the period in accordance with the marginal willingness to pay (simulated transaction price) of adult consumers residing in Spain. We define landscape activity as the final products of ordinary passive consumption services (FPcla) and the production of own account manufactured gross fixed capital formation (GFCFmla) in the period, the latter associated with future flows of FPcla. The total manufactured production costs (TCla) of the landscape activity include the ordinary costs (TCola) and the investment costs (TCila). The TCola include the own ordinary intermediate consumption of services (SSoola) that come from the conservation forestry (ISSccf), fire services (ISScfs), hunting (ISSnchu) and livestock (ISSncli) intermediate products. The existence of a negative value for the environmental net operating margin (NOMela) is not admissible and if the normal manufactured net operating margin (NOMmnla) is higher than the net operating margin residual value (NOMrla) of the FPcla minus the TCola, then we assume that the NOMrla corresponds entirely to the residual manufactured net operating margin (NOMmla). In this case, the NOMela would be zero. In short, the conservation of cultural landscapes depends on the conservation forestry, hunting, and livestock activities of the owners who supply the intermediate product of services (ISS) to the landscape activity for use as own ordinary intermediate consumption of services (SSoola).

3.2.4. Wild threatened biodiversity activity

The passive existence value of the different genetic varieties to a consumer should be assumed to be equal to the degree of threat of permanent disappearance of the threatened species. The current welfare that a passive consumer perceives to be guaranteed over the next 30 years, by which a wild threatened species does not disappear during that time frame, is the same for all species due to the existence of this service. The final product consumption of the wild threatened biodiversity preservation activity in the COW land-cover tiles, just as in the landscape conservation activity, is obtained by applying the simulated exchange value of the marginal willingness to pay stated by Spanish consumers. The biodiversity of the 128 species in the COW land-cover tiles is valued for the total of the forests in Andalusia and distributed among the areas in which they are present (Campos et al., 2019a: Supplementary text S10.2, pp. 39–40).

3.3. Andalusian cork oak woodlands commercial intermediate products and own ordinary non-commercial intermediate consumption of services

In our application of extended accounts, we also take into account the commercial intermediate production of services (ISSc) and their respective own commercial intermediate consumption of services (SSco) for the individual activities. Commercial intermediate raw materials (IRMc) and intermediate commercial services (ISSc) are produced by grazing activity (IRMcg), residential services (ISScrs), conservation forestry (ISSccf) and fire service (ISScfs) activities. In the activities considered in this COW research, there is no own ordinary intermediate consumption of raw materials (RMco). Due to the omission of the manufactured activities of hunting and livestock in this cork oak open woodlands (COW) study, the intermediate product (IP) and own intermediate consumption (ICo) do not have the same value.

The own ordinary intermediate consumption of services (SSoo) is classified into commercial (SSooo) and non-commercial (SSncoo), and these are used by the private amenity (SSooa), recreation services (SSoore), landscape services (SSoola) and biodiversity (SSoobi)

activities. The SSncoo is derived from the non-commercial intermediate products of hunting (ISSnchu) and livestock (ISSncli) activities omitted in this cork oak open woodlands case study.

It is necessary to measure the SSncoo at a basic spatial unit (BSU) farm scale. A farm is the independent economic unit in which the farmer and the government make investment decisions. Some individual activity investments by the farmer offer intermediate products of services that affect the own ordinary intermediate consumption of other activities in the same BSU. This does not occur in the case of a land-cover tile, the results for which come from the data associated with farm activities. In this research, we have applied extended accounts to five private and two public cork oak farms to estimate their production of non-commercial intermediate products of services (ISSnc) linked to the hunting and livestock activities, along with their registers in the form of SSnco used by amenity and landscape activities (see Supplementary texts S2-S3).

We have imputed the estimated average per-hectare values of ISSnc supplied for the seven cork oak farms and we register their SSncoo counterpart to the publicly and privately-owned aggregate areas of the Andalusian COW land-cover tiles (see Supplementary texts S1-S2). This imputation of the SSncoo is somewhat experimental and therefore the estimated aggregate monetary results for the COW land-cover tiles at social prices should be taken with caution.

3.4. Price types applied to cork oak open woodland

The prices of the stocks of cork, timber and firewood produced are valued according to their net present value (physical quantities times their environmental price) at the opening and closing of the period. The consumed products are valued, depending upon the state they are in before and after the final product consumption, at their environmental, stumpage and farm gate prices.

The environmental price of a consumed product corresponds to the unitary resource rent. The stumpage price of the product consumed represents the transaction price before the product is harvested, and the farm gate price is the harvested price of the stockpiled product.

The COW refined standard accounts (rSNA) estimate ecosystem services, ordinary environmental net operating surplus and gross value added at both producer and basic prices. Extended accounts address these indicator values at social prices. The value of the total product at social price ($TP_{sp,AAS}$) in the extended accounts embeds the individual values of its total production costs ($TC_{sp,AAS}$) and the net operating margin ($NOM_{sp,AAS}$). The AAS net operating margin at social price ($NOM_{sp,AAS}$) of the COW is measured as the net operating margin at basic price ($NOM_{bp,AAS}$) minus the own ordinary auto-consumed and donated non-commercial intermediate consumption of services (SSncooa/d) used by amenity and landscape activities. These latter services are valued at the ordinary manufactured investment voluntary opportunity cost incurred by the farmers in the hunting and livestock activities.

In this COW application, the basic price (price at factor cost) represents the producer price (market price) minus the government compensations (operating subsidies net-of-taxes on production). We note the government compensation as the non-commercial intermediate product of services compensation (ISSncc). We register the ISSncc counterpart as own ordinary non-commercial intermediate consumption of services (SSncooc) used by the landscape activity.

The valuations of products at different prices do not influence the aggregate estimates for the COW if all the activities as a whole have been considered. Thus, the valuation of the economic variables at social price is the reference which is consistent with the total income of COW activities as a whole. However, the different types of prices do have an influence on the estimates of ecosystem services and the gross value added of the farmer, government, COW activities valued, and on the amenity and landscape activities implicated by the use of SSncoo.

The extended accounts concepts and valuations of these activities

which are integrated with the refined standard accounts can be found in published scientific literature (Campos et al., 2016, 2017, 2019a, 2019b, 2019c; Caparrós et al., 2017; Martinez-Jauregui et al., 2016; Ovando et al., 2016; Oviedo et al., 2017). The extended accounts final product consumptions with regard to the landscape and biodiversity are valued by the ordinary total production cost (government ordinary cost plus the public farmer SSncod and the consumers' stated willingness to pay additional taxes). These landscape and biodiversity final product consumptions are maintained, without future price variation, when valuing their closing environmental assets.

The COW maps show the individual land-cover tile ecosystem service results valued at producer prices. However, the uncertainties associated with the aggregate ecosystem services and incomes are mitigated by the measurement of the individual activity ecosystem services of the COW at social prices in this research. The ecosystem results at producer prices show bias towards overvaluation of the private amenity and landscape ecosystem services. For illustrative purposes, the economic results for the COW at producer, basic and social prices are presented in tables and figures, allowing the comparison of individual activity ecosystem services at social prices without overvaluation bias. The valuations at social prices allow for a complete analysis of the results of the economic activities derived from economic rationales of farmer and government management in the Andalusian COW.

3.5. Cork oak woodland incomes reconsidered

The total income of an economic activity is defined as the maximum possible consumption of its total product while maintaining the same value of its total capital at the closing of the period (European Communities, 2000: p. 87).

The economic ecosystem services (ES) concept, consistent with its valuation at environmental price (resource rent price), we define as the nature contribution to the consumption of total of products (TPc) directly or indirectly by people in a period. However, there are definitions from other disciplines in the literature on ES that are inconsistent with our residual simulated exchange environmental economic definition. These definitions of ES, beyond the exchange value of the products price consumed in which they are embedded, are not compatible with the definition of ecosystem environmental incomes, and therefore we do not consider them in this research. The estimation of ecosystem services according to the residual method of accounting gives priority to the economic payments of labor and manufactured capital services[5].

Environmental income (EI) is the contribution of the ecosystem to the total income. The economic contribution of nature to the transaction value of products depends on set circumstances of specific places and times in which the final consumption by people, either directly or indirectly, takes place. The concept of environmental income (EI) is defined as the profit still to be appropriated by the owner of a environmental asset at the closing of the period once prior human labor (LC) and manufactured capital income (CIm) have been remunerated.

4. Extended versus refined standard accounts environmental incomes

Section 4 focuses on the environmental income (EI) accounting identities and their relationship with the ecosystem services (ES) and changes in environmental assets. It also focuses on the adjusted change in environmental net worth (CNWead) both in extended and refined standard accounts. In this study, we omit the methods used for valuing non-market products (see details of the application of these methods in Campos et al. (2017, 2019a). Furthermore, we do not describe the of the biological silviculture modeling methodology that supports these

AAS and rSNA frameworks in their application to the cork oak open woodlands of Andalusia. Readers interested in the valuation and silvicultural modeling methods applied can find details in Campos et al. (2019a), Ovando et al. (2019) and Montero et al. (2015).

4.1. Total income factorial allocation

The total product function f of an economic activity j may contain the production factor services of the environmental work in progress used (WPeuj), manufactured intermediate consumption (ICmj), labor cost (LCj), environmental fixed asset (EFAj) and manufactured fixed capital (FCmj) (Eq. (1)) for the period:

$$TPj \equiv f(WPeuj, ICmj, EFAj, FCmj) \quad (1)$$

The production and capital accounts register of an economic activity aims to estimate the total income (TIj) (Eq. (2)), separating it into its components of net value added (NVAj) (eq. (3)), estimated as the balancing item of the production account, and the capital gain (CGj) as an adjusted balancing item of the capital account revaluation (Eq. (2)). The total income components can be reorganized to show their factorial allocation of labor cost (LCj), manufactured capital income (CImj) and environmental income (EIj) (Eq. (4)):

$$TIj = NVAj + CGj \quad (2)$$

$$NVAj = LCj + NOMj \quad (3)$$

$$TIj = LCj + CImj + EIj \quad (4)$$

4.2. Environmental income

We assume when measuring total environmental income[6] of the COW that the omitted activities of hunting and livestock do not incorporate ecosystem services. This assumption ensures that the omitted hunting and livestock activities in this COW study do not influence the valuation of the environmental income of the activities valued. However, these omitted activities are partially taken into account due to their notable contributions through the use of own ordinary non-commercial intermediate consumption of services (SSncoo) of compensation (SSncooc), auto-consumption (SSncooa) and donation (SSncood) by the COW amenity and landscape activities. Thus, we are able to estimate the total environmental income of the COW in a manner consistent with the theory of factorial allocations of total income at social prices (see details in Campos et al., 2017, 2019b: Supplementary texts S3, pp. 15–19).

We estimate the environmental income (EIj$_{ep}$) by taking into account the fact that the production factor services of labor and manufactured capital are paid when the first observed or simulated product transactions occur. The production and capital accounts of a product j allow the estimation of the environmental income (EIj$_{ep}$) embedded in the total income (TIj). The environmental income (EIj$_{ep}$) of an activity j is estimated by the adjusted ecosystem environmental net operating margin (NOMej$_{ep}$) according to the environmental asset gain (EAgj$_{ep}$) (Eq. (5)). In other words, like an investment in a stock market corporate, an environmental asset (ecosystem production factors) j generates an expectation of EIj$_{ep}$ for its owner, consisting of the environmental dividend (NOMej$_{ep}$) and the change in the environmental asset price (EAgj$_{ep}$) at the closing of the period:

$$EIj_{ep} = NOMej_{ep} + EAgj_{ep} \quad (5)$$

where the subscript ep is environmental price.

In this research our interest is centered on the valuation of environmental income (EIj$_{ep}$) by the accounting identities attached to

---

[5] The environmental asset of private amenity is the only one not estimated by the residual method in this case study (Oviedo et al., 2017).

[6] Except for the tourist industry services located in the COW area and its surroundings.

ecosystem services (ESj_{ep}) and the adjusted change in environmental net worth ($CNWeadj_{ep}$). Our aim is to show the EIj_{ep}, as an equivalent indicator of the maximum possible sustainable ecosystem service contribution to total product consumption ($TPcj$) in the period. Reorganizing the ecosystem production account records and adding the $EAgj_{ep}$ derived from the capital account records, then adding and subtracting the $WPeuj$ to the right side of Eq. (5) leads to the accounting Eq. (6) for environmental income (EIj_{ep}), which is linked to ecosystem services (ESj_{ep}) and the adjusted change in environmental net worth ($CNWeadj_{ep}$) (Supplementary text S4):

$$EIj_{ep} = ESj_{ep} + CNWeadj_{ep} \qquad (6)$$

The ecosystem services would only represent the environmental income consistently within the concept of total income stationary state situations. In other words, the adjusted change in environmental net worth (CNWead) of the valued activity j would be zero in the period.

4.2.1. Ecosystem services

The economic rationales of workers and investors in manufactured capital require that the value of the product be primarily destined to pay for the services provided by the production factors used for intermediate consumption (ICj), human labor (LCj) and the normal manufactured net operating margin investment ($NOMmnj$). This prerequisite for the valuation of the ordinary environmental net operating margin ($NOMeoj$) characterizes it as always having a contribution of zero or positive value. On the other hand, the investor in ordinary manufactured capital assumes the risk that the value of the residual manufactured net operating margin ($NOMmrj$) may be lower than $NOMmnj$ and in this circumstance the value of the $NOMeoj$ would be zero, and then, the ordinary manufactured net operating margin equates to the $NOMmrj$.

The SEEA-EEA guidelines term the resource rent (RRj_{ep}) of a product consumption j as their ecosystem service (ESj) (United Nations, 2017). In the latter case, it holds that the ecosystem service of an individual product j (ESj_{ep}) is not a product[7] but the contribution of nature to the product consumption exchange value (Eq. (7)). Thus ESj_{ep} is estimated as the environmental work in progress used ($WPeuj_{ep}$) and/or its ordinary environmental net operating margin ($NOMej_{ep}$) embedded in a total product consumption j ($TPcj$) in the period. Thus, the ESj may comprise an environmental intermediate consumption cost ($WPeuj$) and/or an ordinary environmental operating income ($NOMeoj$) (Campos et al., 2019b: Eq. (11), p. 6):

$$ESj_{ep} = WPeuj_{ep} + NOMeoj_{ep} \qquad (7)$$

The economic components that contribute to the total product (TPj) (Eq. (8)) of an economic activity are total cost (TCj) (Eqs. (9)–(11) and the production account (including the generation of income account) balancing item term net operating margin ($NOMj$) (Eqs. (12)–(13)). These TPj could be separated into four manufactured and four environmental components (Fig. 1). These eight possible items of total product (TPj) of an economic activity contain the contributions of the intermediate consumption of environmental work in progress used ($WPeuj$), the manufactured intermediate consumption ($ICmj$), the services of human labor (LCj), the consumption of environmental fixed asset ($CFCej$), the consumption of manufactured capital ($CFCmj$), the manufactured net operating margin ($NOMmj$) and the environmental net operating margin ($NOMej$).

$$TPj = TCj + NOMj \qquad (8)$$

$$TCj = ICj + LCj + CFCj \qquad (9)$$

$$ICj = ICmj + WPeuj \qquad (10)$$

$$CFCj = CFCmj + CFCej \qquad (11)$$

$$NOMj = NOMmj + NOMej \qquad (12)$$

$$NOMej = NOMeoj + NOMeij \qquad (13)$$

The environmental net operating margin ($NOMej$) is defined as the contribution of the ecosystem operating income to the observed or simulated market value of the total products (TPj) generated in the period. The $NOMej$ is separated into the ordinary environmental net operating margin ($NOMeoj$) and the environmental net operating margin of investment ($NOMeij$). In this COW research, $NOMeij$ is estimated according to the value of the accumulated natural growth (NGj) at the closing of the period minus the consumption of environmental fixed assets ($CFCej$).

The valuation of ecosystem services according to individual product consumption poses the challenge of identification, measurement, and linking the intermediate services on the supply side and the average own ordinary intermediate consumption of services on the cost side of the production account.

The total products consumed in rSNA and AAS applied to the COW activities contain double counting of the commercial intermediate products of services ($ISSc$) used as $SScoo$ by the activities of private amenity services, recreation services, landscape services and wild threatened biodiversity services. The COW grazing commercial intermediate products of raw materials ($IRMcg$) are used by the omitted hunting and livestock activities in the COW. Thus, in this research, the own ordinary commercial intermediate consumption of raw materials of grazing ($RMcog$) used by hunting and livestock activities are not embedded in this COW case study final product consumption.

In order to measure in a consistent manner, the total contribution of COW ecosystem services to the final product consumption (FPc) of the COW, we adjust the latter according to the intermediate product of grazing ($IRMcg$) as adjusted final product consumption ($FPcad$) (Eq. (14)):

$$TPcad = TPc - IP + IRMcg \qquad (14)$$

4.2.2. Adjusted change in environmental net worth

We assume that the adjusted change in environmental net worth ($CNWeaj_{ep}$) is produced taking into account the individual economic activities and their respective individual environmental assets (which are estimated from the recorded data) in the production and capital accounts.

The change in environmental net worth (CNWe) estimate depends on both accounting records conventions on natural growth (NG) and on consumption of environmental fixed asset (CFCe) (Eq. (15)). It may be necessary to adjust the affected activities in order to avoid double counting of the environmental net operating margin of investment (NOMei) and environmental asset gain (EAg) (see Supplementary text S2).

Fig. 2 shows the environmental components of the production account that lead to the net operating margin of investment (NOMei) estimate and the environmental asset gain component (EAg) that comes from the capital account. The sum of these two components provides the change in environmental net worth (CNWe) (Eq. (15)). The CNWe adjustment for environmental work in progress used (WPeu) provides the adjusted change in environmental net worth (CNWead) (Eq. (16)). However, the CNWead generally coincides with the change in environmental assets (CEA) in the period (Eq. (17)). The adjusted change in environmental net worth (CNWead) (Eq. (16)), though commonly equivalent to CEA (Eq. (17)), this may not be the case for adjustments where the total products consumed do not incorporate the consumption of environmental fixed asset and natural growth does not correspond to its net opening value. In this circumstance, Eq. (6) gives the general

---

[7] Nevertheless, ecosystem service and its respective individual product could be of the same value. This is the case in the absence of manufactured investment and/or paid human labor in its production function (e.g., water supply and carbon sequestration in this research).
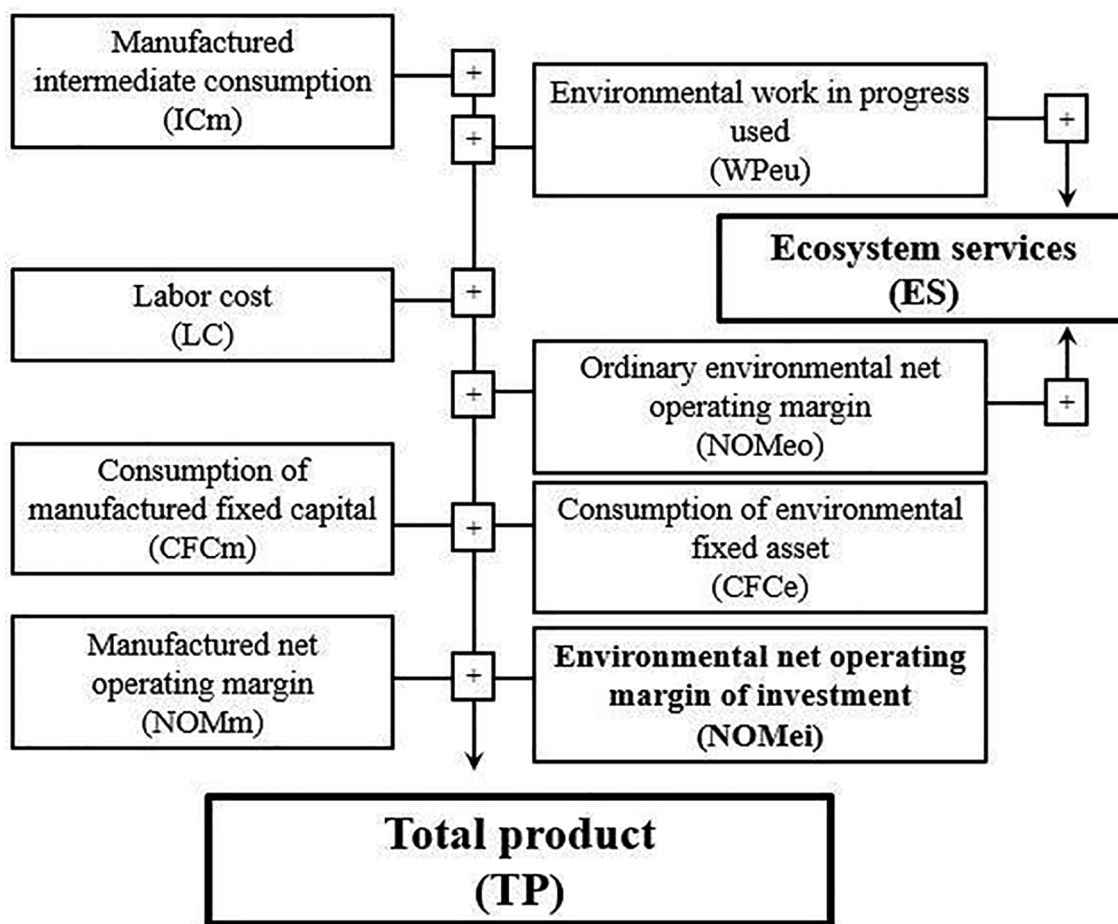
Fig. 1. Agroforestry Accounting System total product.

application that links environmental income of a product j with its ecosystem service and the adjusted change in environmental net worth (CNWead) according to WPeu (Campos et al., 2019b: Eq. (15), p. 8):

$$CNWe = NOMei + EAg \qquad (15)$$

$$CNWead = CNWe - WPeu \qquad (16)$$

$$CEA = EAc - EAo \qquad (17)$$

where EAc is closing environmental asset and EAo is opening environmental asset.

4.3. Integration of the refined standard accounts in the extended accounts

The rSNA and AAS methodologies have been applied in Campos et al. (2019a, 2020a, 2020b) at regional scale and in Campos et al. (2017, 2019b, 2019c) at farm scale to value total products, ecosystem services, incomes and environmental assets of individual activities, farmer, government, Andalusian region forest land-cover tiles and farm case studies. In Campos et al. (2019a) we applied the two accounting frameworks to Andalusian region forests, woodlands, shrublands and rough grasslands to value economic variables at production cost and producer prices. In Campos et al. (2020a) we apply the rSNA and AAS methodologies to the Andalusian region holm oak open woodlands and in Campos et al. (2020b) we extended Campos et al. (2020a) to the refined System of Environmental-Economic Accounting (SEEA). In Campos et al. (2017) the rSNA and AAS are applied to a publicly-owned holm oak *dehesa* (farm). Campos et al. (2019b) compare the rSNA and AAS at the scale of five privately-owned cork oak farms and in Campos et al. (2019c) they are applied to sixteen privately-owned holm oak *dehesa* case studies in Andalusia; the valuation being broadened to basic

and social prices in these farm scale case studies.

In this cork oak open woodlands case study, the refined standard accounts (rSNA) measures the COW products, ecosystem services and incomes as follows: (i) the intermediate products of the grazing and residential services, the famer final product consumption, mushrooms and water supply for irrigated crops were valued at imputed market prices, (ii) the accumulated final products of the natural growths were valued at discounted environmental prices, and (iii) intermediate products of forestry conservation services and fire services, final water supply for other economic sectors (including households), own account manufactured gross fixed capital formation, final product consumption of private amenities, recreation services, landscape services and threatened wild biodiversity are valued at production cost.

It should be noted that the rSNA values the same activities as the AAS in this study, except that the former does not incorporate the valuation of government activities without observed on-site transaction prices and without manufactured production costs (e.g., carbon activity in the application to COW). Labor cost (LC) does not vary with the rSNA and AAS methodologies applied to the Andalusian COW and consequently, the variation in net value added depends solely on the differences in their respective net operating margins. We value and compare the AAS and rSNA methodologies applied, focusing on the variables of gross and net value added (GVA and NVA), ecosystem services (ES), changes in environmental assets (CEA), adjusted changes in net environmental assets (CNWead) according to WPeu and environmental incomes (EI).

In this research, the refinement of the SNA (rSNA) consists of incorporating natural growths (NG) for farmer and government activities, including the ordinary total products of mushrooms and water at
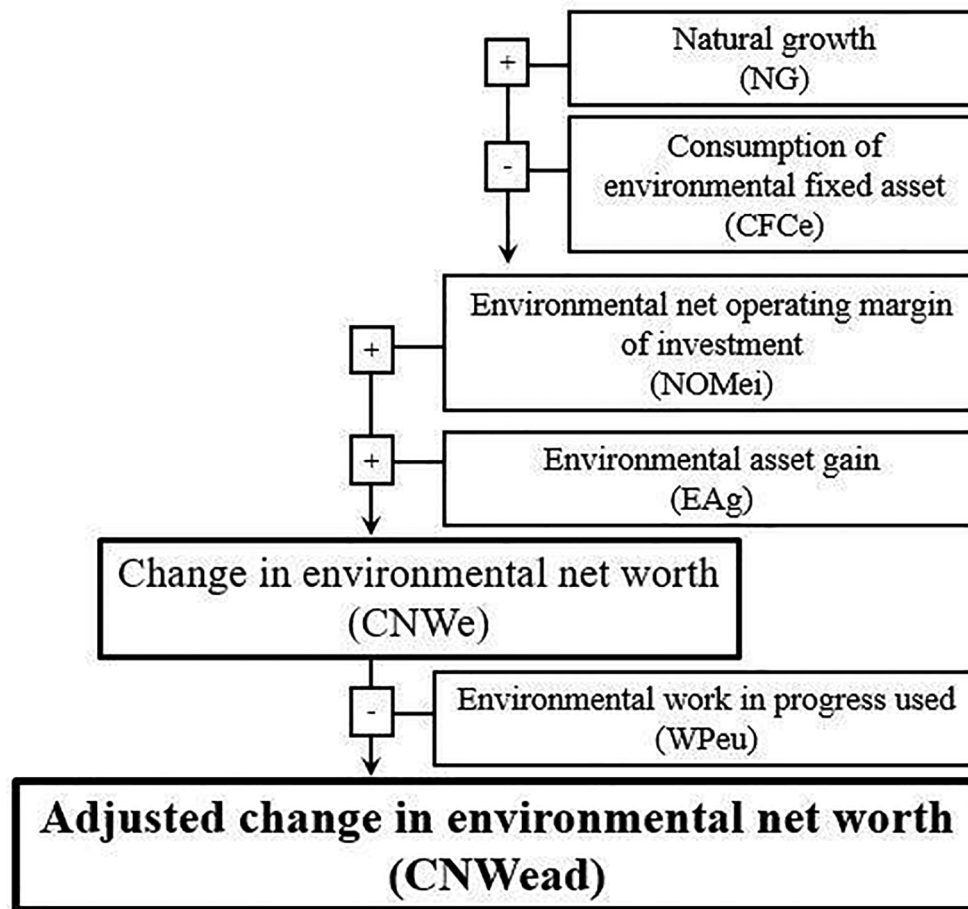
Fig. 2. Agroforestry Accounting System adjusted change in environmental net worth.

market prices. Within the rSNA production account balancing net operating surplus (NOS_{rSNA}) at producer and basic prices, we can find their possible components of environmental work in progress used (WPeu), the ordinary manufactured net operating margin ($NOMmo_{rSNA}$), the ordinary net environmental operating margin ($NOMe_{rSNA}$) and the ecosystem services (ES_{rSNA}). The rSNA capital account gives the changes in environmental assets (CEA_{rSNA}), adjusted changes in environmental net worth ($CNWead_{rSNA}$) according to the WPeu and environmental income (EI_{rSNA}), among other indicators.

In this research, our refinement of the SNA consists of separating the net operating surplus of the SNA at producer prices (market prices) into its components of environmental work in progress used ($WPeu_{rSNA}$) and the net operating margin at producer prices ($NOM_{pp,rSNA}$) (Eq. (18)). We classify $NOM_{pp,rSNA}$ as ordinary manufactured ($NOMmo_{pp,rSNA}$), ordinary environmental ($NOMeo_{rSNA}$) and environmental investment ($NOMei_{ep,rSNA}$) (Eq. (19)). As it is not a component of the total products consumed in the period, the $NOMei_{ep,rSNA}$ does not form part of the net ordinary operating surplus of the rSNA ($NOSo_{rSNA}$) (Eq. (20)). We estimate the net operating margin at basic prices ($NOM_{bp,rSNA}$) by subtracting the intermediate consumption of donated services ($SSncoc_{rSNA}$) from the $NOS_{pp,rSNA}$ (Eq. (21)):

$$NOS_{pp,rSNA} = WPeu_{rSNA} + NOM_{pp,rSNA} \qquad (18)$$

$$NOM_{pp,rSNA} = NOMmo_{pp,rSNA} + NOMeo_{ep,rSNA} + NOMei_{ep,rNA} \qquad (19)$$

$$NOSo_{rSNA} = WPeu_{rSNA} + NOMmo_{rSNA} + NOMeo_{rSNA} \qquad (20)$$

$$NOM_{bp,rSNA} = NOM_{pp,rSNA} - SSncoc_{rSNA} \qquad (21)$$

We are interested in linking the $NOM_{bp,rSNA}$ with the net operating margin at social prices of the extended accounts ($NOM_{sp,AAS}$). This

linkage is achieved in the COW application by: (i) subtracting the $SSncoa/d$ from the $NOM_{bp,rSNA}$, (ii) adding the difference from the price of the private amenity derived from farmer willingness-to-pay ($\Delta FPaa_{ep;AAS}$) to the values of the final products consumed valued by the refined standard accounts at cost price of the private amenity service, (iii) adding the difference from the revealed or stated marginal consumer willingness-to-pay ($\Delta PGS_{ep,AAS}$) to the cost price of the consumption of public goods and services without market prices (a part of the economic forest water, recreational service, landscape conservation service and existence service of the threatened wild biodiversity), (iv) adding the final product ($FPa_{ep,AAS}$) and subtracting the consumption of environmental fixed asset ($CFCea_{ep,AAS}$) of additional activities without manufactured production costs (Eq. (22) and Fig. 3):

$$NOM_{sp,AAS} = NOM_{bp,rSNA} - SSncooa_{AAS} - SSncood_{AAS} + \Delta FPaa_{ep,AAS}$$
$$+ \Delta PGS_{ep,AAS} + FPa_{ep,AAS} - CFCea_{ep,AAS} \qquad (22)$$

The integration of rSNA ecosystem services (ES) in the AAS can be done directly when its components have been previously estimated in the AAS production and capital accounts (Eq. (23) and Fig. 4):

$$ES_{sp,AAS} = ES_{bp,rSNA} - SSncooa_{AAS} - SSncood_{AAS} + \Delta FPaa_{ep,AAS}$$
$$+ \Delta PGS_{ep,AAS} + FPa_{ep,AAS} - r*IMCmo \qquad (23)$$

where $ES_{sp,AAS}$ are the ecosystem services at AAS social prices, $ES_{bp,rSNA}$ are the ecosystem services at basic rSNA prices; $SSncooa_{AAS}$ is the own ordinary intermediate consumption of auto-consumed services; $SSncood_{AAS}$ is the own ordinary intermediate consumption of donated services; $\Delta FPaa_{ep,AAS}$ is the increase in the value of the final auto-consumed private amenity final product valued by the consumer marginal willingness to pay (WTP) of the non-industrial owners in the AAS;
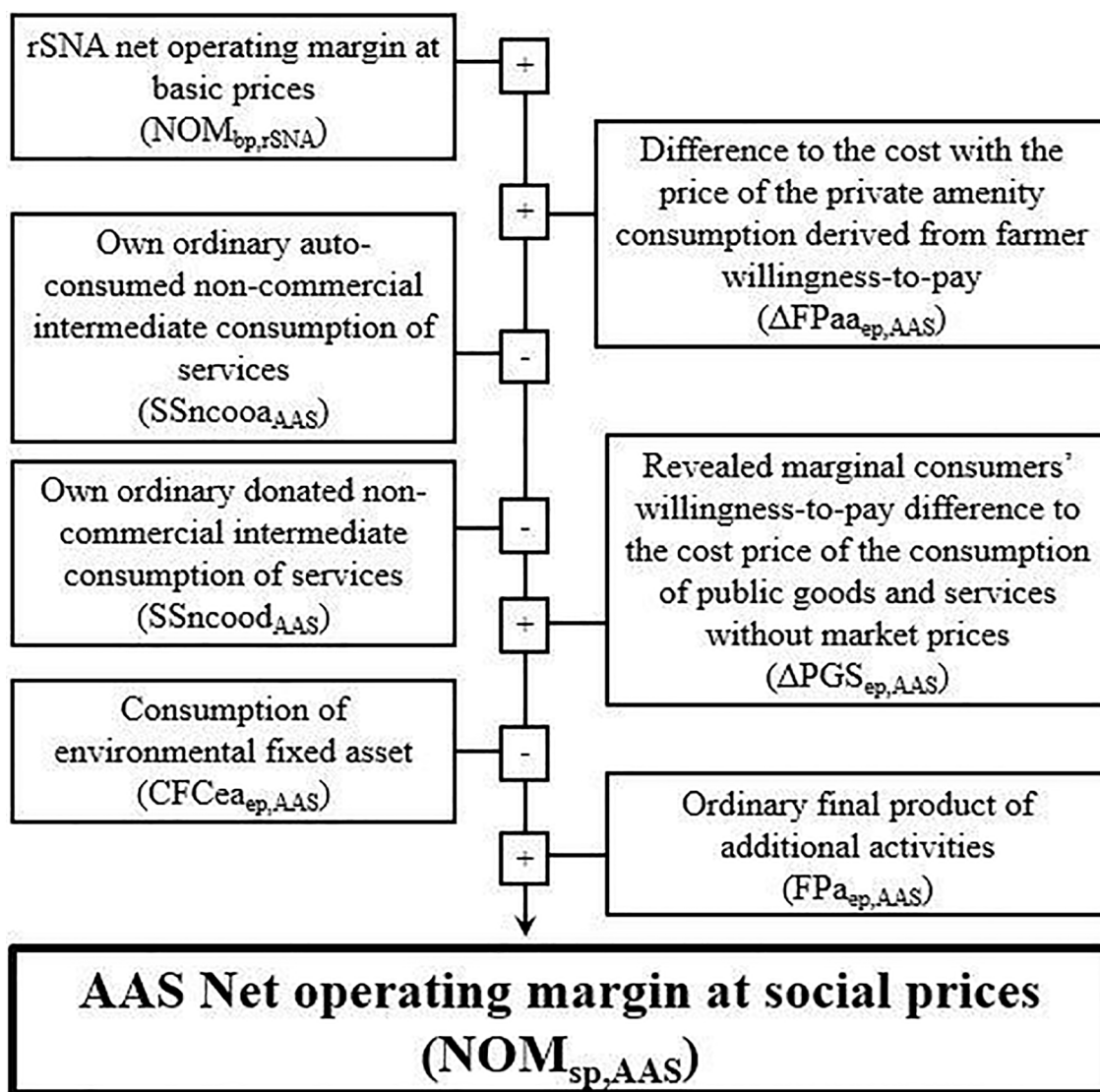
Fig. 3. Integration of the rSNA net operating margin at basic prices in the AAS net operating margin at social prices.

$\Delta PGS_{ep,AAS}$ is the increase in the value of public goods and services without market prices consumed by people free of charge valued by the consumer marginal WTP; $FPa_{ep,AAS}$ is the final product of activities additional to those of the rSNA government activities without observed on-site transaction prices; and without manufactured production costs; r is normal rate of capital return; and $r*IMCmo$ is the normal remuneration of ordinary manufactured immobilized capital from activities without market prices estimated solely by the AAS.

The integration of environmental income (EI) is direct, as in the case of the known ecosystem services and the records of the AAS production and capital accounts (Eq. (24) and Fig. 5):

$$
\begin{aligned}
EI_{sp,AAS} = \ & EI_{bp,rSNA} - SSncooa_{AAS} - SSncood_{AAS} + \Delta FPaa_{ep,AAS} \\
& + \Delta PGS_{ep,AAS} + FPa_{ep,AAS} - CFCea_{ep,AAS} \\
& + EAra_{ep,AAS} - EAwra_{ep,AAS} - r*IMCmo
\end{aligned}
\tag{24}
$$

where $EI_{sp,AAS}$ is the environmental income at social prices for the AAS system, $EI_{bp,rSNA}$ is the environmental income at basic rSNA prices; $CFCea_{ep,AAS}$ (consumption of environmental fixed assets of additional activities); $EAra_{ep,AAS}$ is additional environmental asset revaluation); and $EAwra_{ep,AAS}$ are the adjusted environmental asset withdrawal reclassifications of the activities additional to those of the rSNA government activities without observed on-site transaction prices and without

manufactured production costs.

5. Extended versus refined standard accounts frameworks applied to cork oak open woodlands in Andalusia

5.1. Data sources

The extended versus the refined standard accounts frameworks are applied to cork oak open woodlands in Andalusia-Spain with the ultimate aim of measuring total environmental incomes based on the imputation of estimated spatially-explicit values, depicted by vegetation type at farm scale. This micro data, as well as those obtained at the larger scale of government institutions and also produced by the authors, are requirements for the application of extended accounts at social prices in this research. This research was made possible thanks to data collected through the RECAMAN project[8] and other sources of literature. The area of the farm is the independent economic unit which integrates the interdependencies between the pertinent economic

---

[8] Five monographs of the RECAMAN project are available online: http://libros.csic.es/advanced_search_result.php?tipo_busqueda=sencilla&texto=recaman&x=0&y=0.
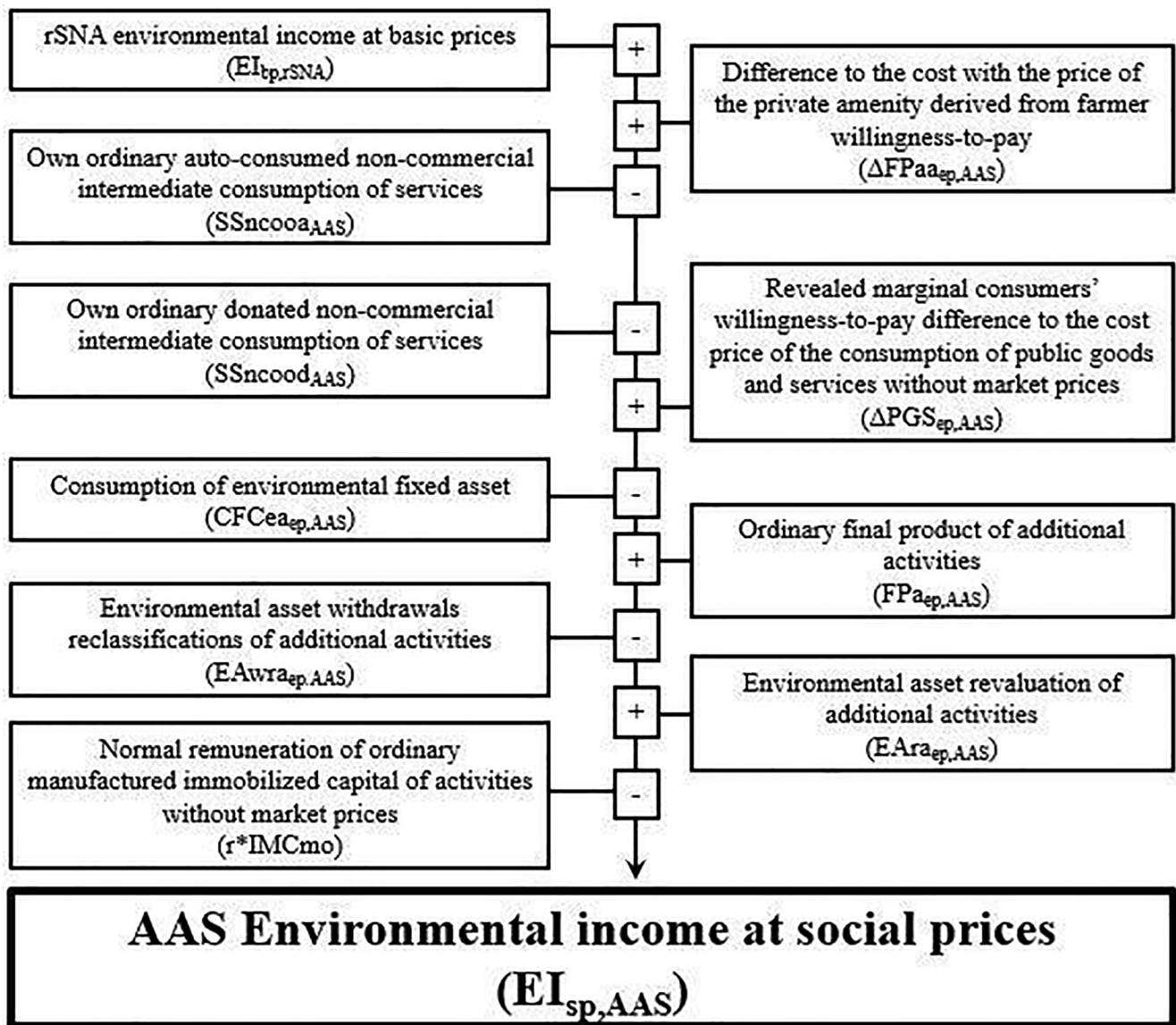
Fig. 4. Integration of the rSNA ecosystem services in the AAS ecosystem services at basic and social prices respectively.

activities of the farmer in a manner consistent with the concept of total income. In contrast, the consumption of the final products of the private amenity and public activities without market prices requires data from the relevant areas at scales beyond that of the case study farms. The land-cover tiles of the Forest Map of Spain (DGCN, 2008) provide the spatial reference for physical and economic data on vegetation and forest uses. Thus, the data is sourced and provided by the farms, the government and the consumers of products at larger scales (e.g., recreational visitors, general public).

5.2. Physical results for cork oak open woodlands

The application includes the area of the 4,095 land-cover tiles of the Forest Map of Spain (FMS) of Andalusia-Spain (DGCN, 2008) with an average size of 60.6 ha, consisting predominantly of cork oaks with capacity coverage fractions between 5% and 75% (Table S1), while the primary data on the trees comes from the third National Forest Inventory (IFN3) (Campos et al., 2019a). The COW total surface area is 248,015 ha, with 84% being privately-owned and 16% publicly-owned. The COW of Andalusia are associated with more than 10 other oaks (mainly *Quercus faginea* Lam. and *Quercus canariensis* Willd.), broadleaf

tree species (*Olea europaea* L. and *Ceratonia siliqua* L.) and other conifer trees (Campos et al., 2019c) (Table S2).

Our measurements of the physical results highlight the differences between growths and extractions of woody products, biological productivity and other key physical indicators that reveal other goods and services produced and used by the fifteen activities taken into account in this 2010 study of the Andalusian COW.

Grazing and cork are the main products, the first as an intermediate product grazed by the game species and livestock, and the second as a multi-period final product harvested for sale. The firewood from cork oak is not used because the trees are not subject to habitual pruning and although the consumption of firewood from the pruning of holm oak (*Quercus ilex* L.) is recorded; in this case study this consumption has a negligible final economic value. The carbon emissions of shrubs are of considerable importance in the consumption of the environmental fixed asset of the cork oak open woodlands, although this raw material has no use as an energy source in the COW of Andalusia (Table 1).

Given the nine year rotation periods for cork stripping (extraction), it is necessary to classify the environmental assets of the cork oak woodland as environmental work in progress (WPe) awaiting the next stripping of the cork oak. Furthermore, the environmental biological
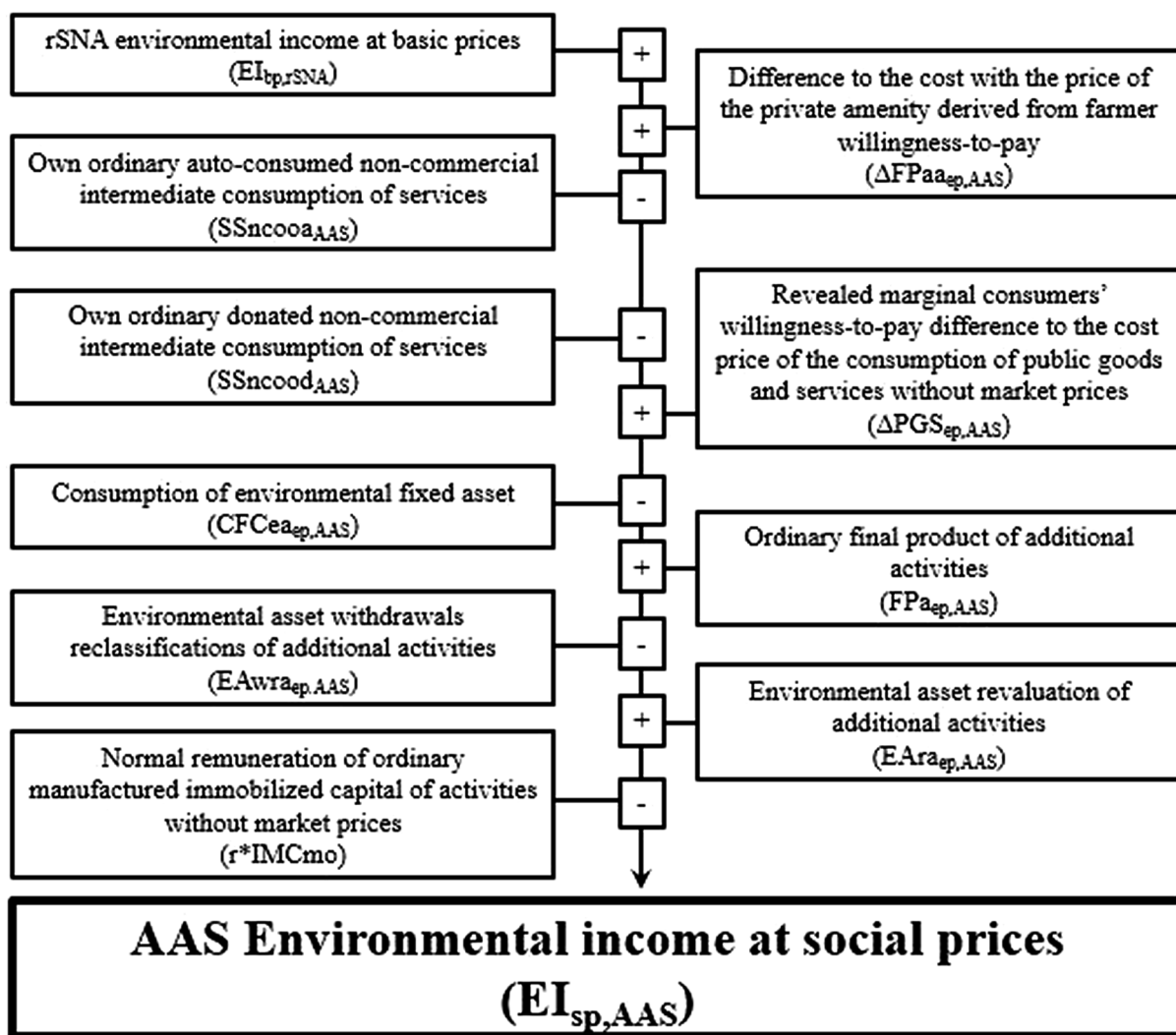
Fig. 5. Integration of the rSNA environmental income in the AAS environmental income at basic and social prices, respectively.

fixed assets (EFAb) of the cork oaks must be inventoried at the discounted resource rent value (discounted environmental price) of the future productions of cork and acorn, and the environmental fixed assets of the land (EFAl) must be classified according to the net present value of the cork and the acorns that are expected to be extracted in the infinite cycles of successive cork oak regenerations recorded at a later date for the cork oaks inventoried in the period.

Although it is unusual for the extraction of the woody product not to result in the death of the tree that produces it, there are COW land-cover tiles which contain associated plantations of eucalyptus with the same three environmental asset classifications as those of the cork oak ecosystem type, although in the case of the eucalyptus, it is the aerial trunk and superficial root that remain after the cutting. The cork product differs from the single-use timber product in that the environmental assets (timber) of the latter are classified in a single asset category of ongoing environmental work in progress. Cork-stripping is regulated by Spanish Forest Law in rotations of nine or more years in Andalusia, while cork harvesting is repeated around 15 times (rotations) over the entire life cycle of the whole cork oak, although cork stripping will usually become non-profitable after 170 years. The physical natural growths of cork, timber and firewood are, respectively, 4.5, 7.0 and 65.4 times of those of their extractions in the period (Table 1). Thus, from an ecological perspective, there are no over-extractions of woody products in the period. Timber growths and harvests associated with the three conifer species are negligible.

The browse from bushes and shrubs, specifically in times of persistent Mediterranean drought, is of critical importance for wild game species and livestock fodders. We have measured acorn yields from cork and holm oaks. Other wooded-land fruit yields consumed by wild fauna and managed animals (livestock and game) are not estimated due to lack of data. The consumption of acorns in COW is estimated in accordance with the acorn biological production functions of cork and holm oaks applied to the tree inventories for the COW land-cover tiles (Campos et al., 2019a). Our estimations of grass-browse consumption in the livestock activity are obtained by the residual value derived from total acorn production, calculated by the biological production function of individual trees scaled up to the existing standing trees, minus the total forage units consumed in the period. Our results for the grazing of grass-browse and acorns should be interpreted with caution and, in contrast to our assumption of future stability of grazing productivity, overgrazing could exist locally. This is because total fodder consumption includes a large proportion of supplementary livestock feed, which is necessary given the year-round presence of the herds on the farms and the fact that the natural environment of the COW ecosystem is characterized by the absence of natural growth of grass in the summer period and, depending on rainfall (which can be irregular), grazing may also be scarce in the autumn–winter seasons. The total consumption of grazing by the game species exceeds that of the livestock in the COW (Table 1).

The physical capital of the water reveals that 30.3% of the

precipitated water is regulated in watershed public reservoirs. 76.3% of the reservoir water has an ecological use (evaporation, ecological flow, flood management drains and others) (Campos et al., 2019c: Table 1, p. 10). The remaining 23.7% of the reservoir water has economic use for agricultural irrigators (85%) as well as industrial, service and household uses (15%).

Private non-industrial property farmers of cork oak open woodlands usually have residential homes, the services of which are imputed as own commercial intermediate consumption of services of private amenity activity (Table 1).

The carbon emissions from shrub clearance to favor the natural growth of grass are of considerable importance in the environmental cost of the cork oak open woodlands, although this raw material has no use as firewood in the COW of Andalusia (Table 1). Carbon fixation is 6.6 times higher than emission, with the positive contribution of shrubs being 1.6 times more than the positive net fixation by trees (Table 1).

The great variety of Andalusian COW landscape types favors recreational use by free access visitors. The cork oak open woodlands registered 4.3 vi/ha in 2010 (Table 1).

Andalusian cork oak woodlands are home to 128 threatened wild species that are managed by the government and subjected to long-term preservation programs (Table 1).

5.3. Economic results for cork oak open woodlands

In this research, the valuations of the own ordinary non-commercial intermediate consumption of services (SSncoo) are made by scaling up the estimates for five private farms and two public cork oak farms to the cork oak open woodland land-cover tiles (COW) of Andalusia (see Supplementary texts S3-S4). Given the small number of farms, the results at basic and social prices scaled-up to all the area of the COW land-cover tiles should be interpreted with caution. As we are aware of the uncertainty associated with the results of the valuations at basic and social prices, we prefer to maintain the results for the COW ecosystem service land-cover tiles of Andalusia at producer prices.

The description of the economic results takes into account the individual farmer and government activities, farmer and government activities and those of the cork oak open woodlands of Andalusia as a whole. The economic estimates of the extended accounts are made at producer, basic and social prices and those of the refined standard accounts at producer and basic prices.

5.3.1. Capital account

The values of the environmental assets of the farmer coincide in the refined standard (rSNA) and extended (AAS) accounts (Tables 2, S3-S5). The government environmental assets without market prices (recreation, landscape and wild threatened biodiversity activities) are null in the rSNA, since the products in these activities are valued at manufactured production cost. The COW aggregate environmental assets of farmers and government present similar values, while the aggregate value of the manufactured fixed capital of the farmer is significantly higher than that of government (Tables 2, S3-S5).

In 12 of the 15 activities valued for the cork oak woodlands of Andalusia, the production functions depend on their renewable environmental assets (EA). The residential services, conservation forestry and fire services activities do not require the renewable environmental assets services (Table 2). The manufactured fixed capitals (FCm) used by these three activities in the generation of their total products are integrated in the respective farmer and government activities (Table 2).

The environmental assets represent the largest contribution to the total capital of the COW (Table 2). The environmental assets of cork, private amenity and landscape contribute in similar amounts and when added together, their values account for 67% of the total environmental asset value (EAo) and 64% of the total opening capital (Co) (Table 2). Of the remaining nine environmental assets, the highest values correspond to grazing, public recreational activities, water supply, carbon

and mushrooms, which account for 31% of the total environmental asset value (EAo) (Table 2).

The minor contributions of the environmental assets of the timber and firewood activities correspond to the residual vegetation covers of conifers and holm oaks in the COW (Tables 1-2, S1-S5).

Wild biological species contribute to the various environmental assets of the COW although their values are unknown, except for the passive existence value component of the environmental asset. We have estimated this existence value through a choice experiment exercise in a survey of Spanish adults (Campos et al., 2019a). The environmental asset of the wild biodiversity preservation passive use, represented by its existence values, reflects the fact that Spanish consumers declare a willingness to pay (WTP) which is higher than the cost incurred by the government in the preservation programs for the 128 threatened species in the COW of Andalusia (Tables 1-2). The reduced existence value of the threatened species is estimated based on the assumption that the management in the period and the expectation of compliance with the scheduled management for the preservation of threatened species in the period 2010–2040 remain unchanged for the current 128 species (Campos et al., 2019a; Díaz et al., 2020).

The total environmental income for the period contains the value of the environmental asset gain (EAg). This EAg incorporates the future resource rent expectations of the environmental assets that, brought to their net present value, give rise to the value of the closing environmental assets (EAc) of the period. The EAc, with respect to the opening assets (EAo), are affected by the entries (EAe) and withdrawals (EAw) of the period. Both environmental asset account movements correspond to accumulations of entries from the natural growth of ongoing productions and other entries. Among the withdrawals are those of environmental work in progress used, extraordinary destructions and other instrumental accounting withdrawals. Even in the situation in which environmental prices do not vary, there is a revaluation of the environmental assets of environmental work in progress (WPe) given the decrease (of a period/year) in the amount of time until the expected extraction and the associated effect of the discount rate (Tables 2, S3-S4).

In the COW, the total capital revaluation (Cr) is negative due to the fall in prices of manufactured construction capital in the period (Tables 2, S3-S4). The environmental assets show a moderate positive aggregate revaluation, but with notable contrasts among individual activities. In the case of cork, the fact that there are at least nine rotations including work in progress produced and the remaining cork to be produced and harvested over the rest of the life cycle in the future - means that, due to the discount effect, there is a revaluation of 287.8 €/ha. In contrast, the fall in land prices associated with the private amenity use causes a substantial loss (negative revaluation) of −306.1 €/ha. The gain (positive revaluations) in the environmental assets of carbon and other minor assets, when added to those of the cork and amenities, give an aggregate revaluation of the environmental assets as a whole of 14.6 €/ha (Tables 2, S3-S4).

The estimates under the AAS and rSNA methodologies are the same for farmers environmental assets, water, mushrooms and manufactured fixed capital (Tables 2, S3-S5). The rSNAs does not estimate the environmental assets of the public products of carbon, recreation, landscape, or threatened wild biodiversity consumed.

5.3.2. Production account

The slight refinement of the standard System of National Accounts (rSNA) for the cork oak open woodlands consists of accounting for the commercial intermediate product of services (ISSc), the final product of natural growth (NG), the own intermediate consumption of services (SSo) both commercial (SScoo) and compensated non-commercial (SSncooc), and the environmental work in progress used (WPeu).

The ISSc added to the total product of the standard SNA amounts to 64 €/ha, one third of which corresponds to the farmer activities of residential services and forest conservation, and two thirds to the

Table 2
Agroforestry Accounting System capital account for cork oak open woodlands in Andalusia (2010: €/ha).

Class	1. Opening capital	2. Capital entries				3. Capital withdrawals						4. Reva-luation	5. Closing capital
		2.1 Bought	2.2 Own	2.3 Other	2.4 Total	3.1 Used	3.2 Sales	3.2 Destructions	3.3. Reclassification	3.4 Other	3.5 Total		
	(Co)	(Ceb)	(Ceoo)	(Ceot)	(Ce)	(Cwu)	(Cws)	(Cwd)	(Cwrc)	(Cwot)	(Cw)	(Cr)	(Cc)
1. Environmental asset	17,278.6		74.4	72.2	146.6	85.3			142.3	11.6	239.3	14.6	17,200.5
1.1 Farmer	8,604.9		74.4		74.4	85.3			72.3		157.6	−15.4	8,506.3
Timber	17.3		0.2		0.2	0.2			0.2		0.4	1.3	18.4
Cork	3,614.0		74.2		74.2	85.1			72.1		157.1	287.8	3,818.9
Firewood	30.8		0.1		0.1	0.0			0.0		0.1	1.3	32.0
Nuts	1.6											0.0	1.7
Grazing	1,010.3											0.2	1,010.6
Livestock grass and browse grazed	*701.8*												*701.8*
Livestock acorn grazed	*8.6*											*0.2*	*8.9*
Game grazed fodder	*299.9*												*299.9*
Amenity	3,930.8											−306.1	3,624.7
1.2 Government	8,673.7			72.2	72.2				70.1	11.6	81.7	30.0	8,694.1
Recreation	1,434.7												1,434.7
Mushrooms	903.9												903.9
Carbon	907.9			72.2	72.2				70.1	11.6	81.7	30.0	928.3
Landscape	3,993.7												3,993.7
Biodiversity	278.5												278.5
Water	1,155.0												1,155.0
2. Manufactured	676.0	0.6	12.3		12.9			0.0			0.0	−38.1	650.8
2.1 Farmer	563.8		3.9		3.9							−28.9	538.8
Plantations	45.8		3.9		3.9							0.2	49.9
Constructions	518.0											−29.1	488.9
2.2 Government	112.2	0.6	8.4		9.0			0.0			0.0	−9.2	112.0
Plantations			0.0		0.0							0.0	0.0
Constructions	94.4		6.7		6.7							−7.7	93.5
Equipments	3.4	0.6			0.6			0.0			0.0	0.0	4.0
Others	14.4		1.6		1.6							−1.5	14.5
Total (1 + 2)	17,954.6	0.6	86.7	72.2	159.5	85.3		0.0	142.3	11.6	239.3	−23.5	17,851.2

Note: a 0.0 value denotes a value less than 0.05 €/ha.

14

Table 3
Refined System of National Accounts production account at basic prices for cork oak open woodlands in Andalusia (2010: €/ha).

Class	Timber	Cork	Fire-wood	Nuts	Grazing	Conserv. forestry	Residential	Amenity	Farmer	Fire services	Recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Government	Cork oak open woodlands
	1	2	3	4	5	6	7	8	Σ1-8	9	10	11	12	13	14	15	Σ9-15	Σ1-15
1. Total product (TP$_{bp}$)	0.7	172.5	0.2	0.8	33.6	10.5	14.7	14.7	247.6	48.4	11.3	27.3		91.7	6.9	66.0	251.6	499.2
1.1 Intermediate product (IP$_{bp}$)					33.6	6.7	14.7		54.9	42.7							42.7	97.6
1.1.1 Raw materials (IRM)					33.6				33.6									33.6
1.1.1.1 Grass and browse (IRMgb)					22.1				22.1									22.1
1.1.1.2. Acorn (IRMa)					1.4				1.4									1.4
1.1.1.3 Game grazed fodder (IRMgg)					10.1				10.1									10.1
1.1.2 Commercial intermediate services (ISSc)						6.7	14.7		21.3	42.7							42.7	64.0
1.2 Final product (FP$_{pp}$)	0.7	172.5	0.2	0.8		3.9		14.7	192.7	5.7	11.3	27.3		91.7	6.9	66.0	208.9	401.6
1.2.1 Final product consumption (FPc$_{pp}$)	0.5	98.3	0.1	0.8				14.7	114.4		10.3	27.3		91.0	5.8	66.0	200.4	314.8
1.2.2 Gross capital formation (GCF$_{rSNA}$)	0.2	74.2	0.1			3.9			78.3	5.7	0.9	0.0		0.7	1.1		8.4	86.7
1.2.2.1 Manufactured (GCFm)						3.9			3.9	5.7	0.9	0.0		0.7	1.1		8.4	12.3
1.2.2.2 Natural growth (NG)	0.2	74.2	0.1						74.4									74.4
2. Refined intermediate consumption (IC$_{rSNA}$)	0.5	88.2	0.0	0.2	0.5	3.5	0.7	14.7	108.3	14.2	4.3	0.0		86.2	2.0		106.8	215.1
2.1 Manufactured intermediate consumption (ICm)	0.3	3.2	0.0	0.2	0.5	3.5	0.7	14.7	23.0	14.2	4.3	0.0		86.2	2.0		106.8	129.7
2.1.1 Bought (ICmb)	0.3	3.2	0.0	0.2	0.5	3.5	0.7		8.3	14.2	1.9	0.0		1.9	1.9		20.0	28.3
2.1.2 Own services (ICmoo$_{bp}$)								14.7	14.7		2.4			84.3	0.0		86.7	101.4
2.1.2.1 Commercial (SScoo)								14.7	14.7		2.4			49.3	0.0		51.8	66.4
2.1.2.2 Compensated non-commercial services (SShcooc)														35.0			35.0	35.0
2.2. Environmental work in progress used (WPeu)	0.2	85.1							85.3									85.3
3. Consumption of fixed capital (CFC)	0.0	0.0	0.0	0.0	1.2	0.4	5.2		6.8	3.2	1.9	0.0		0.8	0.6		6.5	13.4
4. Refined net value added (NVA$_{bp,rSNA}$)	0.1	84.3	0.1	0.6	32.0	6.6	8.8		132.5	31.0	5.0	27.3		4.6	4.3	66.0	138.3	270.7
4.1. Labor cost (LC)	0.6	18.4	0.0	1.3	2.6	6.6	2.9		32.4	30.9	5.0	0.1		4.6	4.3		45.0	77.4
4.2. Refined net operating margin (NOM$_{bp,rSNA}$)	−0.5	65.9	0.1	−0.7	29.4	0.0	5.9		100.1	0.1		27.2				66.0	93.3	193.4
4.2.1 Manufactured net operating margin (NOMm$_{bp,rSNA}$)	−0.7	−8.4	0.1	−0.7	0.7	0.0	5.9		−3.1	0.1		0.0					0.1	−2.9
4.2.2 Environmental net operating margin (NOMe$_{rSNA}$)	0.2	74.2	0.1		28.7	0.0			103.2			27.1		0.0	0.0	66.0	93.1	196.3

15

Table 3 (continued)

Class	Timber	Cork	Fire-wood	Nuts	Grazing	Conserv. forestry	Residential	Amenity	Farmer	Fire services	Recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Government	Cork oak open woodlands
	1	2	3	4	5	6	7	8	Σ1-8	9	10	11	12	13	14	15	Σ9-15	Σ1-15
4.2.2.1 Ordinary net operating margin (NOMeo$_{bp,rSNA}$)					28.7				28.7			27.1			0.0	66.0	93.1	121.9
4.2.2.2 Net operating margin of investment (NOMei$_{rSNA}$)	0.2	74.2	0.1						74.4									74.4

Note: a 0.0 value denotes a value less than 0.05 €/ha.

government activity of fire services (Table 3). The ISSc are used as intermediate consumption of services (SScoo) by the amenity (SScooa) and landscape (SScoola) activities. SScooa come from residential services, and SScoola come from forestry conservation and fire services (Table 3).

The intermediate consumption of WPeu consists almost entirely of cork, the standing price of which is its environmental price (this does not include the cost of forestry which is assumed to be zero) at the opening of the period (Table 3).

The rSNA allows the net operating surplus of the SNA (NOS$_{SNA}$) to be separated into WPeu and the net operating margin (NOM$_{rSNA}$), which has an estimated value of 193.4 €/ha. It allows for a further separation of the latter into manufactured (NOMm$_{rSNA}$) and environmental (NOMe$_{rSNA}$), with values of −2.9 €/ha and 196.3 €/ha respectively (Table 3). The slightly negative value of the total NOMm$_{rSNA}$ of the COW indicates that the total ordinary manufactured costs of cork extraction exceed the differential of its road side price once extracted with respect to its standing price (Table 3). Although the standing prices of cork work in progress used (WPeu) and at the road side (FPcco) have been imputed (these are not observed transactions), it is possible that the slightly negative value of the NOMm$_{rSNA}$ is due to biases in the assumed environmental and/or roadside prices. Nevertheless, it is clear that the value of the net operating margin (NOM$_{rSNA}$) of the cork is determined by the environmental net operating margin of investment (NOMei$_{rSNA}$) originating in the natural growth of the period, since the extraction of cork does not generate an environmental net operating margin (NOMeo$_{rSNA}$) (Table 3). On the other hand, the rSNA applied to the COW does estimate the NOMeo$_{rSNA}$ of the grazing, mushrooms, and water supply activities for an aggregate amount that exceeds the NOMei$_{rSNA}$ of cork growth in the period (Table 3).

The cork activity contributes to the ecosystem services and aggregate incomes of the 14 COW activities valued by the rSNA (carbon activity is ignored), making up 41% of the total ecosystem services (ES$_{ep,rSNA}$) of 207 €/ha, 31% of the total net value added (NVA$_{bp,rSNA}$) of 271 €/ha, 24% of the labor cost (LC$_{rSNA}$) of 77 €/ha, and 34% of the net operating margin (NOM$_{bp,rSNA}$) of 193 €/ha (Table 3).

With respect to the production account of the rSNA, that of the AAS applied in the COW presents the following modifications: (i) the valuation of consumed final products without market prices at production cost (producer price) is replaced by the simulated exchange value estimated by the consumer marginal willingness to pay for the activities of private amenity, recreational service, passive service of landscape conservation and passive service of preservation of threatened wild biodiversity; (ii) it adds the own non-commercial intermediate consumption of amenity services (SSncoa) and donations (SSncod). This originates from the intermediate production of ISSnca/d associated with the activities, omitted in this study, of hunting and livestock, which are assumed to graze in the COW managed by the farmers; and (iii) it incorporates the public carbon activity.

The total product estimated by the AAS methodology allows the total environmental income of the COW to be measured, since it has been assumed that the omitted animal activities do not contain environmental production factors that have not been previously incorporated in the COW activities, such as grazing (IRMcg). The official statistics of the Forestry Account (EAF) allow the incorporation of captures at environmental price (unitary resource rent), and in this study we replace the number of captures with the grazing consumed by the hunting species, with the same environmental value as the captures (European Communities, 2000).

The substitution of the production cost in the valuation of consumed final products without market prices is in line with the exchange principle of the SNA, a principle which is breached by the SNA due to a lack of data on the marginal consumer's willingness to pay (WTP) of non-industrial owners and public consumers. The substitution of the production cost for the WTP in the AAS is not due to a theoretical, but rather to a practical criterion of insufficiency of the SNA estimates of
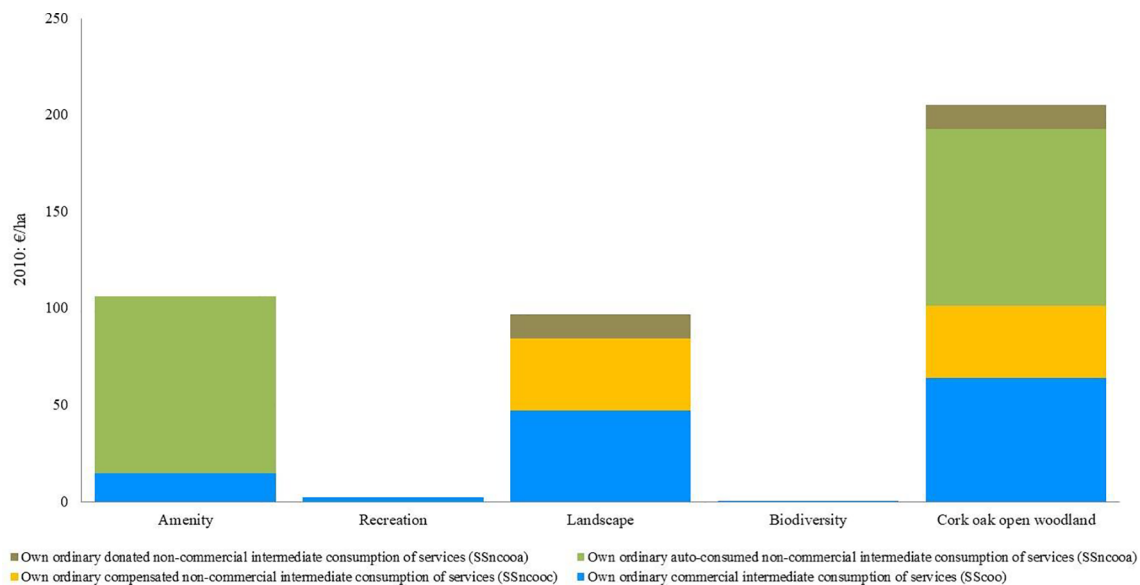
Fig. 6. AAS intermediate consumption of services at social prices in cork oak open woodlands (2010: €/ha).

the consumed final products without market prices.

The changes in the valuations introduced by the AAS and the incorporation of carbon resulted in the doubling of the COW total product with respect to the rSNA (Tables 3–4, S6).

The amenity and landscape activities are those that use the inputs of own non-commercial intermediate consumption of amenity services (SSncooa), donated (SSncod) and compensated (SSncooc), respectively, and that together account for 69% of the total own ordinary intermediate consumption of services (SSoo), amounting to 205 €/ha (Tables 4, S7; Fig. 6).

The government contributes indirectly to the final product (FP) of the cultural landscape activity through the forest fire-fighting service activity (SScoofs), and directly through the other remaining costs of the landscape activity. The total SSoola account for 94% and 43% of the TCola and the FPcla respectively. The NOMela makes up 99% and 54% of the NOMla and the FPcla, respectively.

The AAS estimates of the environmental margin (NOMe) and ecosystem services (ES) of the amenity and landscape activities decrease markedly with the change from basic to social price valuations, with values remaining the same for all other activities because the basic and social prices coincide. Since the value of the environmental margin at basic price ($NOMe_{bp,AAS}$) is their value at social price ($NOMe_{sp,AAS}$) added to the SSncooa and SSncood respectively, under the AAS, the estimates of the $NOMe_{bp,AAS}$ and of the ecosystem services (ES) of the amenity and landscape activities increase by 35% and 10%, respectively with respect to their valuations at social prices (Tables 4, S6).

The cork activity contributes to the ecosystem services and aggregate incomes of the 15 COW activities valued by the AAS, making up 12% of the total ecosystem services ($ES_{ep,AAS}$) of 704 €/ha, 11% of the total net value added ($NVA_{sp,AAS}$) of 758 €/ha, 24% of the labor cost (LC_{AAS}) of 77 €/ha, and 10% of the net operating margin ($NOM_{sp,rAAS}$) of 681 €/ha (Table 3).

Estimations of ecosystem services and incomes from cork activity under the AAS and rSNA methodologies applied to the COW reveal that it is the landowner amenity service and government public activities that generate the majority of contributions to ecosystem services and operating incomes.

5.3.3. Environmental incomes

The AAS environmental income ($EI_{ep,AAS}$), where positive, represents the maximum sustainable ecosystem service of the COW of Andalusia for the period without environmental asset loss and, where

negative, indicates the negative change in environmental worth in 2010. The AAS environmental income values for the famer and government activities and for the Andalusian COW activities as a whole, are shown in Fig. 7 with a per hectare average for the totality of the 248.015 ha of cork oak open woodlands of Andalusia.

The contributions to environmental income from timber and firewood products of coniferous and oak trees, respectively, as well as nuts (including pine nuts and chestnuts), are negligible for the Andalusian COW as a whole. The main contributor to the environmental income of farmers in 2010 was cork, with the second most important being the grazing consumed by game species and livestock. The environmental income of the amenity is negative because of the decline in land prices in the period. As a consequence, the farmer environmental income is lower than that of cork (Fig. 7). It should be remembered that the residential services, conservation forestry and fire services activities, by definition, do not contribute to the environmental income. The environmental income of the government is slightly higher than that of the farmers and the activities of landscape, water supply and recreation are those which account for the greatest contribution towards it. However, the lesser contributions of mushrooms, carbon and threatened biodiversity are also worthy of note (Fig. 6). The sum of the 12 COW activities contributing to environmental income amounted to 554 €/ha in 2010 (Fig. 7). The estimates of the components of environmental income from the production account (ecosystem service) and the capital account (adjusted change in environmental net worth) are described separately below.

Given that, on the one hand, it is the private amenity and landscape activities which contribute most to the COW ecosystem services and on the other, that the non-commercial intermediate production of services (ISSnc) provides the inputs to own non-commercial intermediate consumption of services (SSncoo), the reduced sample of cork oak woodlands that have been used to estimate the non-commercial intermediate products of services (ISSnc) of the hunting and livestock activities means that the valuation must be interpreted with caution and therefore we do not present values at basic and social prices at land-cover tile scale in this study.

We estimate the ecosystem services at producer prices ($ES_{pp,AAS}$) for the 12 activities that produce them at the scale of the basic spatial unit (BSU) of 4,095 COW tiles in Andalusia. The tiles are classified according to the values, ordered into five strata (Fig. 8). The highest values correspond to mountainous areas and the lowest values to lowland areas due to the lower fraction of capacity cover in the predominantly open
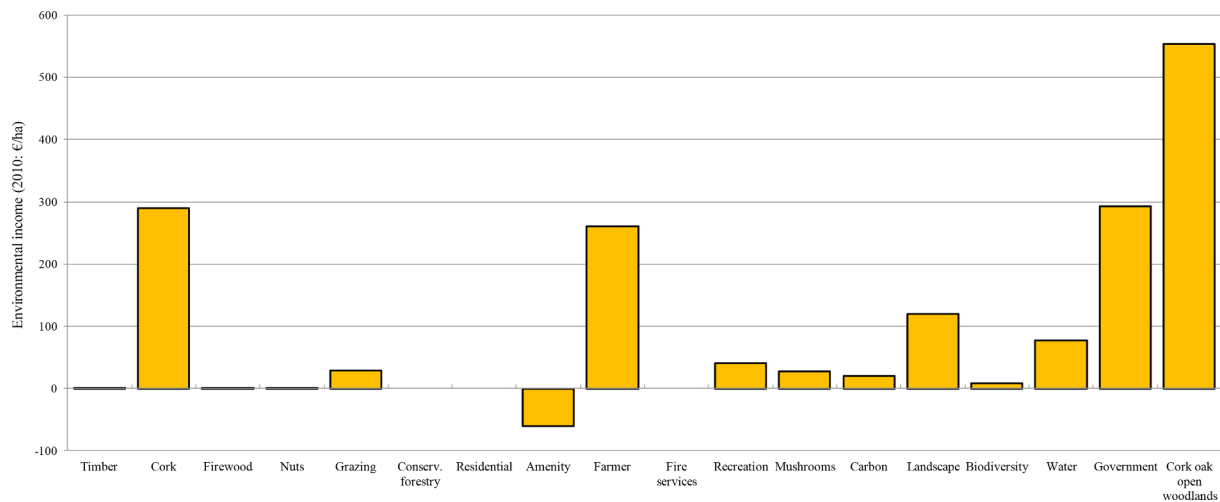
Fig. 7. AAS environmental incomes at social prices for cork oak open woodlands in Andalusia (2010: €/ha).

Ecosystem services (2010: €/ha)

- 0 - 250
- 251 - 500
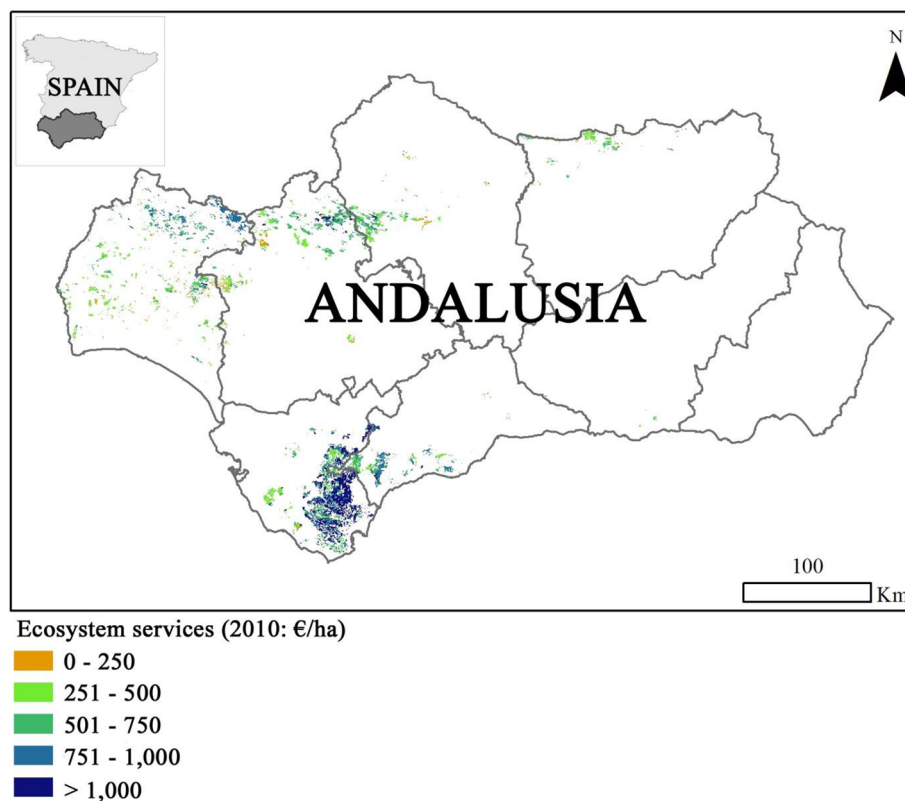- 501 - 750
- 751 - 1,000
- > 1,000

Fig. 8. Andalusian map of cork oak open woodland land-cover tiles for Agroforestry Accounting System total ecosystem services at producer prices (2010: €/ha).

cork oak woodland land-cover tiles.

We have proceeded to estimate the values of ecosystem services at social prices ($ES_{sp,AAS}$) for the 12 natural-based activities in the Andalusian COW area as a whole by scaling up the estimated results for five private estates and two public estates of open cork oak woodlands in Andalusia (see Supplementary texts S2-S3, Fig. 9). As this is a re- duced sample of estates, we have not been able to derive representative statistical values for the totality of the COW land-cover tiles in Anda- lusia. However, we believe that it is illustrative to transfer these data to provide values for the amenity and landscape activities as a whole. Despite the lack of representativeness, the aggregate values for the activities reveal greater consistency in the estimates of the ecosystem services of the amenity and landscape, and therefore, the ecosystem services of the farmers, the government and the COW as a whole. Our

values at social prices highlight the fact that individual estimates of ecosystem services, in the presence of government compensation and landowner voluntary opportunity costs, present non-negligible over- valuation biases, as found for the COW.

The ecosystem services make up 74.0% of the COW adjusted final product consumed at social price ($FPcad_{sp,AAS}$). This percentage is 74.1% for farmers and 73.9% for government (Fig. 8, Table S7). The value of 704 €/ha for the ecosystem services comprises 87.9% ordinary environmental net operating margin at environmental price (NO- $Meo_{ep,AAS}$) and the remaining 12.1% corresponds to extractions of woody products at environmental price ($WPeuw_{ep,AAS}$). In the COW we estimate their contributions, in similar proportions, to the ecosystem provisioning and regulating services (Table S7). However, the propor- tions of these three classes of services differ substantially among the
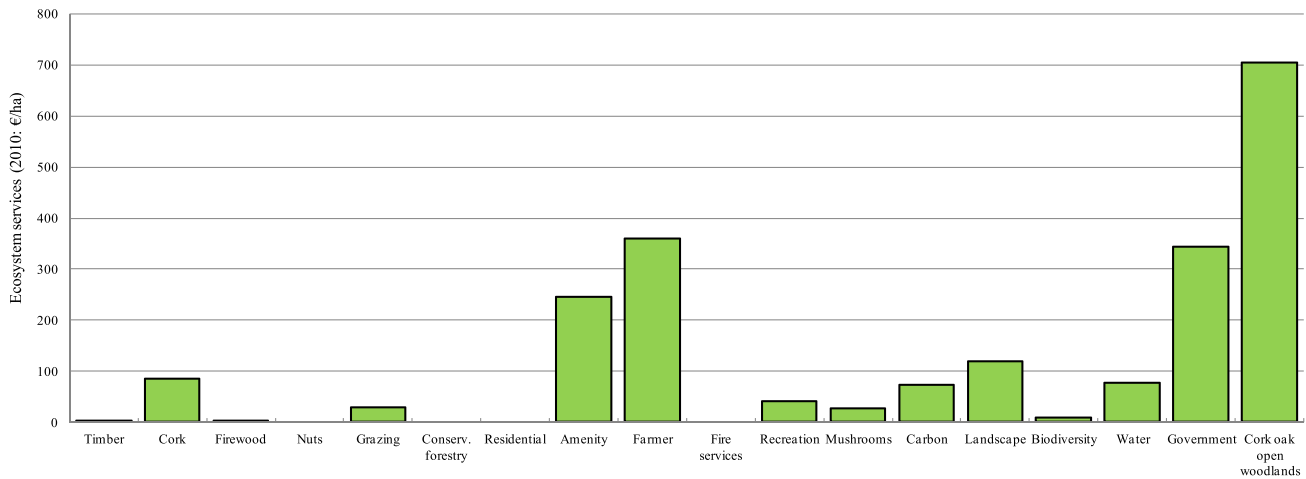
Fig. 9. Agroforestry Accounting System ecosystem services for Andalusian cork oak open woodlands in Andalusia (2010: €/ha).

farmer, government and aggregate ecosystem cultural services.

We estimate a negative result for the adjusted change in environmental net worth (CNWead$_{ep,AAS}$) for the studied COW activities as a whole, indicating an economic over-consumption of total COW ecosystem services (ES$_{sp,AAS}$) in the period, exceeding the value of the environmental income (Fig. 10). This would not be the case for the ecological sustainability of the COW, which is assured since natural physical growth in the period exceeds extractions of cork, wood and firewood, as long as there has been no extraordinary destruction of environmental stocks.

In 2010, the main environmental income of cork oak open woodlands came from the activities of cork, landscape, and water (Figs. 8–10). The environmental income of the private amenity varies significantly between years due to variations in the price of the land, with the last negative variation taking place in 2010; this being the cause of the CNWeada$_{ep,AAS}$ exceeding the notable positive value of its ecosystem service (Fig. 11). However, in the period 1994–2010, the real annual cumulative rate variation in the land price was 3.4% (Ovando et al., 2016), so the environmental asset gains of the amenity activity in the period 1994–2010 presented notable real positive values.

5.3.4. Result sensitivity to prices and accounting frameworks

The description of the sensitivity of the results to the framework

type (AAS and rSNA) will refer to the gross and net value added (NVA), labor cost (LC), gross and net operating margin (NOM), ecosystem services (ES), adjusted change in environmental net worth (CNWead) and environmental income (EI).

Despite the fact that the rSNA considers the same activities as the AAS (with the sole exception of carbon which is excluded in the former), the differences between the two accounting frameworks as regards the valuations of the final products without market prices consumed lead to significantly different results for ecosystem services, gross value added and environmental income of the COW of Andalusia. The rSNA do not estimate the ecosystem services or the CNWead of the final products without market prices consumed, with the exception of the revaluation of the environmental fixed assets of the amenity activity. The latter depends on the in-period changes in the implicit environmental price of the COW land market. The results for the gross value added (GVA) of the Andalusian COW do not vary with producer, basic and social prices as long as all economic activities are considered. This is not the case in this research, which has omitted the hunting and livestock activities of the Andalusian COW, which provide own non-commercial intermediate consumption of services (SSnco) of the private amenity and landscape conservation activities. In this research, the estimations of the GVA, GOM, ES and EI associated with the COW private amenity and landscape activities are sensitive to the type of
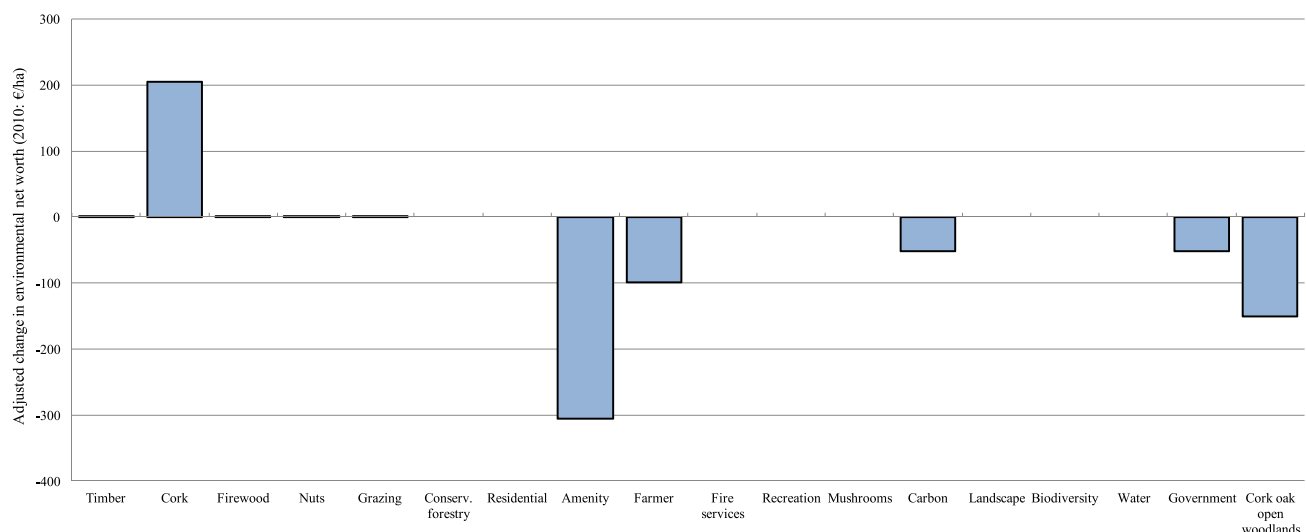

Fig. 10. Agroforestry Accounting System adjusted change in environmental net worth at social prices for cork oak open woodlands in Andalusia (2010: €/ha).
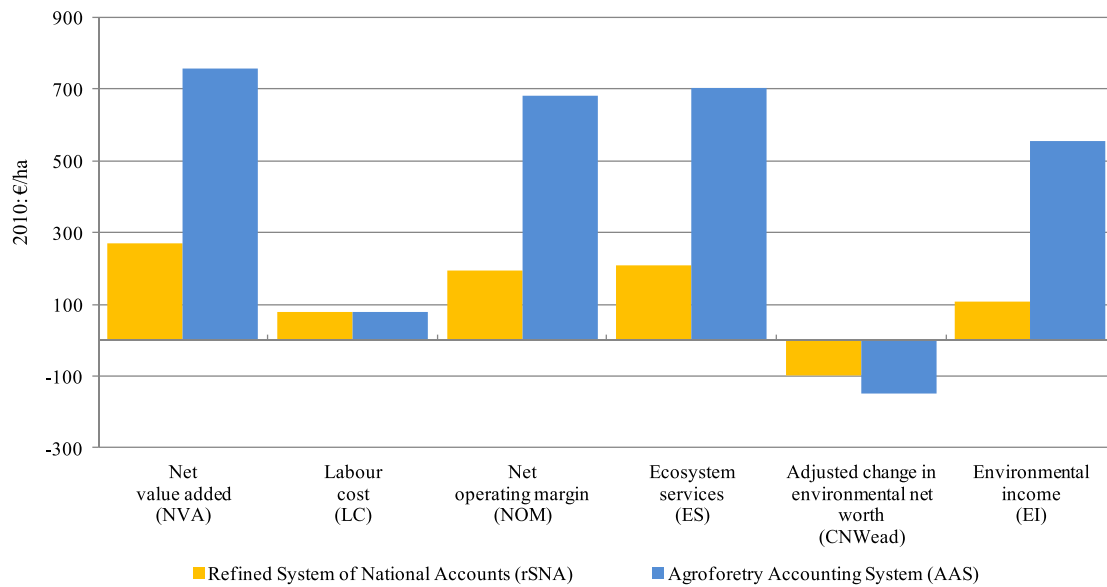
Fig. 11. AAS versus rSNA total ecosystem services and incomes at social and basic prices respectively for cork oak open woodlands in Andalusia (2010: €/ha).

price applied in this research and. Thus, the type of price applied will also lead to variations in the aggregate results for farmers, government and the COW activities considered as a whole.

The NVA of the COW measured by the AAS at social prices is 2.8 times that estimated by the rSNA at basic price. This difference is due to the changes in the types of price and the intermediate consumptions applied in the final products of services without market prices consumed (amenity, recreation, landscape conservation and wild biodiversity preservation services) as well as the omission of the carbon activity in the rSNA methodology (Tables 3-4 and Fig. 11).

We have not imputed self-employed labor in the 15 COW activities and both the AAS and rSNA methodologies estimate the same employee labor. In this circumstance the net operating margin (NOM) differs by the same amount as the NVA, since the NOM results from subtracting the labor cost (LC) from the NVA (Tables 3-4 and Fig. 11).

The substitution of the valuation at production cost for the simulated exchange value that would be paid by non-industrial owners and public consumers for the final products without market prices consumed along with the incorporation of the carbon activity and the noncommercial intermediate consumption of amenity and donation services (SSncooa/d) underlie the fact that the total ecosystem service of the COW measured by the AAS at social price is 3.4 times higher than the respective basic price measured by the rSNA (Tables 3–4 and Fig. 11).

The rSNA has a lower loss of adjusted change in environmental net worth (CNWead) than the AAS as it does not omit the loss of carbon activity (Figs. 10–11). The differences in environmental incomes (EI) are estimated from the AAS and rSNA methodologies estimated at social and basic prices respectively, while the sums of the differences in the ES and CNWead values are estimated directly. In the COW, the AAS estimates a total environmental income 5.1 times higher than that estimated by the rSNA (Fig. 11).

The commercial activities of the farmers present the same values for the respective ecosystem services whether measured by the AAS or rSNA methodology, the difference being that the rSNA does not estimate the ecosystem service of the amenity activity, because the rSNA values the final consumed product of amenity auto-consumption at production cost prices (Figs. 11–12). The rSNA omits ecosystem services from government activities without market prices as well as water consumed by other economic and household users (Figs. 11–12).

The amenity activity accounts for most of the farmer ecosystem services measured by the AAS, but the fact that that the rSNA has a value of zero shows that the rSNA does estimate the CNWead of the amenity and thus generates a loss of environmental income from water which is significantly higher than the loss estimated by the AAS (Figs. 11–13). The environmental income of individual government activities coincides with their respective ecosystem services, with the exception of carbon, which has a negative CNWead value (Figs. 11–13).

In the rSNA, the gross value added ($GVAr_{SNA}$) and ecosystem services (ES_{rSNA}) do not vary if producer or basic prices are applied, because the final products consumed from the amenity activities ($FPcaa_{rSNA}$) and landscape ($FPcla_{rSNA}$) are valued at production cost (Table 3). On the other hand, the AAS value the $FPcaa_{AAS}$ and $FPcla_{AAS}$, respectively, by the marginal willingness-to-pay of farmers and consumers. Thus, for the considered activities of COW, the AAS estimate of the gross value added at producer prices ($GVA_{pp,AAS}$) is an over-valuation, being 1.2 times the estimate at social price of the $GVA_{sp,AAS}$. The farmer and government activities present overvaluations of the $GVA_{pp,AAS}$ which are, respectively, 1.2 and 1.1 times greater than the valuations at the social price of the $GVA_{sp,AAS}$ (Tables 5–6). As the labor cost is the same in the two accounting frameworks, the AAS gross operating margin (GOM) at social price is 3.4 times the value estimated by rSNA at basic price (Table 5).

As the sum of all the considered COW activities, the estimations at producer price overvalue the ecosystem services ($ES_{pp,AAS}$), being 1.2 times the estimate at social price of the $ES_{sp,AAS}$. The $ES_{pp,AAS}$ of the farmers are 1.2 times the estimations of the $ES_{sp,AAS}$, and 1.1 times in the case of the government (Tables 5–6). The $ES_{pp,AAS}$ overvaluation of the amenity and landscape activities is 1.4 times the $ES_{sp,AAS}$.

When we compare the valuations of ecosystem services and gross value added under the rSNA and AAS applied to the cork oak open woodland activities, we find that there is a notable undervaluation in the case of the rSNA (Tables 5–6). The results at basic prices in the rSNA for the $GVA_{bp,rSNA}$ and $ES_{bp,rSNA}$ of the COW farmers and government are 0.3 times the $GVA_{sp,AAS}$ and $ES_{sp,\ AAS}$ estimated by the extended accounts (Tables 5–6, S8).

The rSNA incorporates the environmental incomes of the final products at market prices consumed (timber, cork, firewood, nuts, grazing, water, and mushroom) and the incomplete environmental income of the amenity according to revaluation of the implicit market price of its environmental fixed asset.

The notable range of the inter-period variation in the revaluation of

Table 4
AAS production account at social prices for cork oak open woodlands in Andalusia (2010: €/ha).

Class	Timber (1)	Cork (2)	Fire-wood (3)	Nuts (4)	Grazing (5)	Conserv. forestry (6)	Residential (7)	Amenity (8)	Farmer (Σ1-8)	Fire services (9)	Recreation (10)	Mush-rooms (11)	Carbon (12)	Land-scape (13)	Bio-diversity (14)	Water (15)	Government (Σ9-15)	Cork oak open woodlands (Σ1-15)
1. Total product (TP$_{sp}$)	0.7	172.5	0.2	0.8	33.6	10.5	14.7	351.5	584.5	48.4	52.9	27.3	72.2	224.0	15.2	77.7	517.8	1,102.3
1.1 Intermediate product (IP$_{sp}$)					33.6	6.7	14.7		54.9	42.7							42.7	97.6
1.1.1 Raw materials (IRM)									33.6									33.6
1.1.1.1 Grass and browse (IRMgb)					22.1				22.1									22.1
1.1.1.2. Acorn (IRMa)					1.4				1.4									1.4
1.1.1.3 Game grazed fodder (IRMgg)					10.1				10.1									10.1
1.1.2 Commercial intermediate services (ISSc)						6.7	14.7		21.3	42.7							42.7	64.0
1.2 Final product (FP$_{pp}$)	0.7	172.5	0.2	0.8		3.9		351.5	529.6	5.7	52.9	27.3	72.2	224.0	15.2	77.7	475.1	1,004.6
1.2.1 Final product consumption (FP$_{cpp}$)	0.5	98.3	0.1	0.8				351.5	451.3	5.7	52.0	27.3	72.2	223.4	14.1	77.7	466.7	917.9
1.2.2 Gross capital formation (GCF)	0.2	74.2	0.1	0.2		3.9			78.3	5.7	0.9	0.0		0.7	1.1		8.4	86.7
1.2.2.1 Manufactured (GCFm)						3.9			3.9	5.7	0.9			0.7	1.1		8.4	12.3
1.2.2.2 Natural growth (NG)	0.2	74.2	0.1	0.2					74.4	5.7	0.9	0.0		0.7	1.1		8.4	74.4
2. Intermediate consumption (IC$_{sp}$)	0.5	88.2	0.0	0.2	0.5	3.5	0.7	106.1	199.8	14.2	4.3	0.0		98.7	2.0		119.3	319.0
2.1 Manufactured intermediate consumption (ICm)	0.3	3.2	0.0	0.2	0.5	3.5	0.7	106.1	114.5	14.2	4.3	0.0		98.7	2.0		119.3	233.7
2.1.1 Bought (ICmb)	0.3	3.2	0.0	0.2	0.5	3.5	0.7		8.3	14.2	1.9	0.0		1.9	1.9		20.0	28.3
2.1.2 Own services (ICmoo$_{sp}$)								106.1	106.1		2.4			96.8	0.0		99.2	205.4
2.1.2.1 Commercial (SScoo)								14.7	14.7		2.4			46.9	0.0		49.4	64.0
2.1.2.2 Non-commercial (SSncoo)								91.5	91.5					49.9			49.9	141.3
2.1.2.2.1 Compensated (SSncooc)														37.4			37.4	37.4
2.1.2.2.2 Auto-consumed (SSncooa)								91.5	91.5									91.5
2.1.2.2.3 Donated (SSncood)														12.5			12.5	12.5
2.2. Environmental work in progress used (WPeu)	0.2	85.1	0.0						85.3									85.3
3. Consumption of fixed capital (CFC)	0.0	0.0	0.0	0.0	1.2	0.4	5.2		6.8	3.2	1.9	0.0	11.6	0.8	0.6		18.2	25.0
3.1 Manufactured (CFCm)	0.0	0.0	0.0	0.0	1.2	0.4	5.2		6.8	3.2	1.9	0.0		0.8	0.6		6.5	13.4
3.2 Environmental (CFCe)													11.6				11.6	11.6
4. Net value added (NVA$_{sp}$)	0.1	84.3	0.1	0.6	32.0	6.6	8.8	245.4	377.9	31.0	46.7	27.3	60.5	124.5	12.7	77.7	380.3	758.2
4.1. Compensation of employees (LC)	0.6	18.4	0.0	1.3	2.6	6.6	2.9		32.4	30.9	5.0	0.1		4.6	4.3		45.0	77.4
4.2. Net operating margin (NOM$_{sp}$)	−0.5	65.9	0.1	−0.7	29.4	0.0	5.9	245.4	345.5	0.1	41.7	27.2	60.5	119.9	8.4	77.7	335.4	680.8

(continued on next page)

Table 4 (continued)

Class	Timber	Cork	Fire-wood	Nuts	Grazing	Conserv. forestry	Residential	Amenity	Farmer	Fire services	Recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Government	Cork oak open woodlands
	1	2	3	4	5	6	7	8	Σ1-8	9	10	11	12	13	14	15	Σ9-15	Σ1-15
4.2.1 Manufactured net operating margin (NOMm$_{sp}$)	−0.7	−8.4	0.1	−0.7	0.7	0.0	5.9		−3.1	0.1	1.7	0.0		0.2	0.2	15	2.2	−0.8
4.2.2 Environmental net operating margin (NOMe)	0.2	74.2	0.1		28.7			245.4	348.5		40.0	27.1	60.5	119.7	8.1	77.7	333.1	681.7
4.2.2.1 Ordinary net operating margin (NOMeo)		74.2			28.7			245.4	274.1		40.0	27.1	72.2	119.7	8.1	77.7	344.8	618.9
4.2.2.2 Net operating margin of investment (NOMei)	0.2	74.2	0.1						74.4				−11.6				−11.6	62.8

Note: a 0.0 value denotes a value less than 0.05 €/ha.

the amenity environmental assets can influence the comparison of the results of the refined and extended standard accounts, due to the omission by the former of the ecosystem service in the final amenity product consumed.

The AAS and rSNA frameworks provide data to measure the environmental income of the farmers from the commercial activities (other under farmers in Tables 5–6), and the incorporation of the environmental income of amenity in both methodologies. The farmer environmental income under the rSNA is less than 0.1 times the amount estimated by the AAS (Table 5, S8). The government environmental income under the rSNA is 0.3 times that estimated by the AAS. For the COW activities as a whole valued in this research, the environmental incomes measured by the rSNA are 0.2 times those estimated by the AAS extended accounts (Table 5). If we exclude the environmental income from the consumed private amenity product, then the rSNA show an environmental income that is still only 0.7 times that estimated by the AAS.

5.4. Who is paying for producing the final public goods and services consumed in the cork oak open woodlands?

In the COW we estimate that public land and livestock owners pay 8% of the 162 €/ha ordinary total cost (TCo$_G$) incurred in the production of the public goods and services consumed (PGSc) through donations of own non-commercial intermediate consumption of services (SSncod$_{F,PU}$) used by landscape activity and originating in the non-commercial intermediate production of services donations (ISSncd$_{F,PU}$) of the omitted hunting and livestock activities. The government payments are 23% of TCo$_G$ from own non-commercial intermediate consumption of services compensation (SSncooc$_F$) originating in the ISSncc$_F$ of the omitted hunting and livestock activities, while the remaining 69% of TCo$_G$ comes from the TCo$_G$ of activities managed directly by the government.

5.5. Agroforestry accounting System applications to non-industrial privately-owned predominantly cork oak farm case studies and cork oak woodland land-cover tiles in Andalusia-Spain

In Campos et al. (2019b), the Agroforestry Accounting System (AAS) was applied to five non-industrial privately-owned cork oak farm (COF$_{PR}$) basic spatial economic units in Andalusia. The COF$_{PR}$ total incomes (TI$_{sp,PR}$) were measured at social prices for 18 individual economic activities, aggregate farmer and government activities as well as the COF$_{PR}$ economic activities as a whole. In aggregate terms the COF$_{PR}$ and the COW$_A$ coincide when the same 18 activities are considered, although in the case of COW$_A$, the hunting, livestock, and agriculture activities are omitted due to lack of data. In the case of the Andalusian cork oak open woodland (COW$_A$) land-cover tiles (basic spatial units), the AAS is applied to 15 individual activities. These two AAS applications present clear differences with regard to the types of ecosystems associated with the respective BSU of the farms, as well as the land-cover tiles in which the cork oak ecosystem is predominant. We can say that the BSUs of the COF$_{PR}$ present all the complexities associated with the real management by the owners and the government, whereas the BSU of the land-cover tiles contribute geo-referenced economic information related to the management of the COF of Andalusia for the 18 activities which affect the 15 COW$_A$ activities valued. In other words, the real source of economic information on the activities of the owners comes from the economic BSU of the farms, and this is transferred, with appropriate modifications, to the BSU of the land-cover tiles of predominantly cork oak open woodland in both the third National Forest Inventory (IFN3) and the Forest Map of Spain (FMS). The COW area of the COW$_A$ land-cover tiles is 45 times that of the COF$_{PR}$ (Table ST1, S2).

In the research related to the 4,095 IFN3 land-cover tiles in which the COW$_A$ predominate and which coincides with the COF$_{PR}$ research,
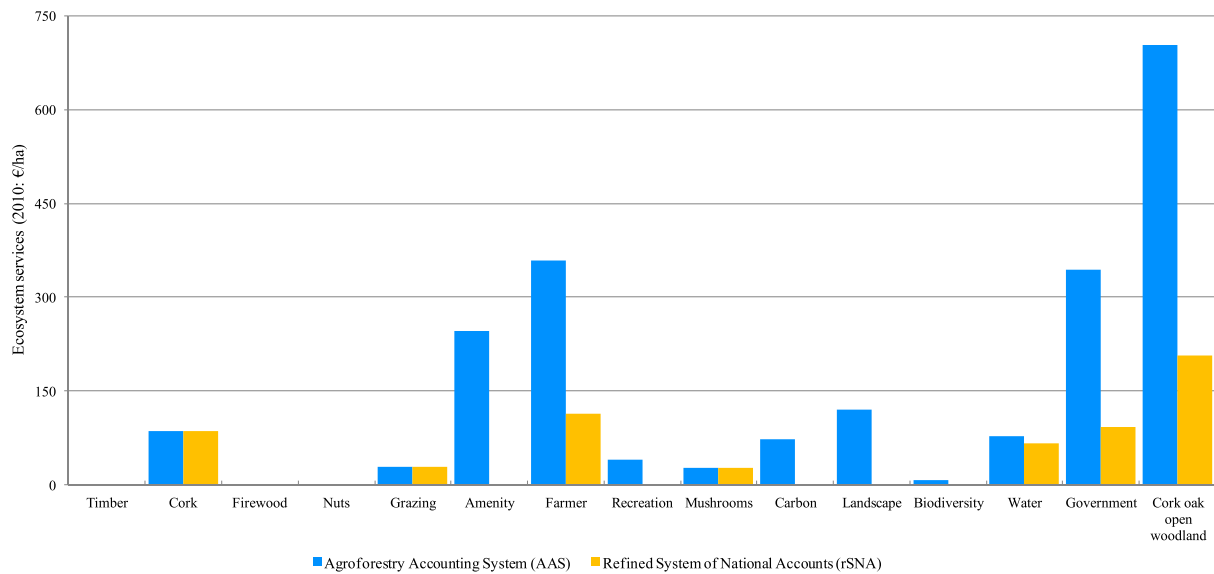
Fig 12. AAS versus rSNA ecosystem services at social and basic prices respectively for cork oak open woodlands in Andalusia (2010: €/ha).

the COW surface area is mostly common to both while the other economic characteristics differ. However, there a no major differences in the results as regards total ecosystem services, environmental income and environmental assets (Campos et al., 2019b).

The cork oak woodland (COW$_{PR}$) of the COF$_{PR}$ makes up 56.6% of the total surface area (Supplementary text S1, Table ST1). Other grazed open woodland areas of holm oaks, Algerian oaks and wild olive trees account for 25%, which, when added to the COW$_{PR}$, means that COF$_{PR}$ open oak woodlands (OW$_{PR}$) account for 81.6% of the total surface area. Scrubland (SL) and grassland (GL) make up 12.9% and 2.6% of the COF$_{PR}$ total surface area respectively. Coniferous forests, riparian forests and other mixed forest land (OFL) account for 2.3% of the COF$_{PR}$ total surface area. Non-agricultural area (NAL) accounts for 0.5% of the COF$_{PR}$ total area. The 4,095 privately and publicly-owned tiles of the Andalusian COW$_A$ occupy the total surface area. Although the area of pure COW$_A$ corresponds to 13.8%, the percentage is 55.3% where a second tree species coexists with the COW in the same land-cover tiles and 30.9% where a third or more species coexist (Table S2).

Based on the data for the five privately-owned COF$_{PR}$ and two publicly-owned COF$_{PU}$, own compensated, auto-consumed and donated non-commercial intermediate consumption services (SSncoo) were scaled up from the seven predominantly cork oak farms (COF) to the aggregate private and public COW$_A$ land-cover tiles (see Supplementary texts S3-S4). This scaling up of the ISSncoo from the seven COF farms to the 4,095 COW$_A$ tiles as SSncoo illustrates the possibility of valuing the indicators of ecosystem services and COW$_A$ incomes at social prices and consequently, allows homogeneous comparison of the 15 activities common to the two studies (Table 7).

Table 7 presents a comparison of a selection of economic results for COW$_A$ and COF$_{PR}$. The comparison of the 18 COF$_{PR}$ activities and the 15 COW$_A$ activities clarifies the fact that in the case of the former, the basic spatial unit (BSU) is a property. That is, a farm that integrates the aggregate average economic results of the COF$_{PR}$ under the responsibility of a physical private owner (the private activities) as well as public activities associated with the COF$_{PR}$, for which the government is responsible. In COW$_A$, the land-cover tile is the BSU. In this case, the
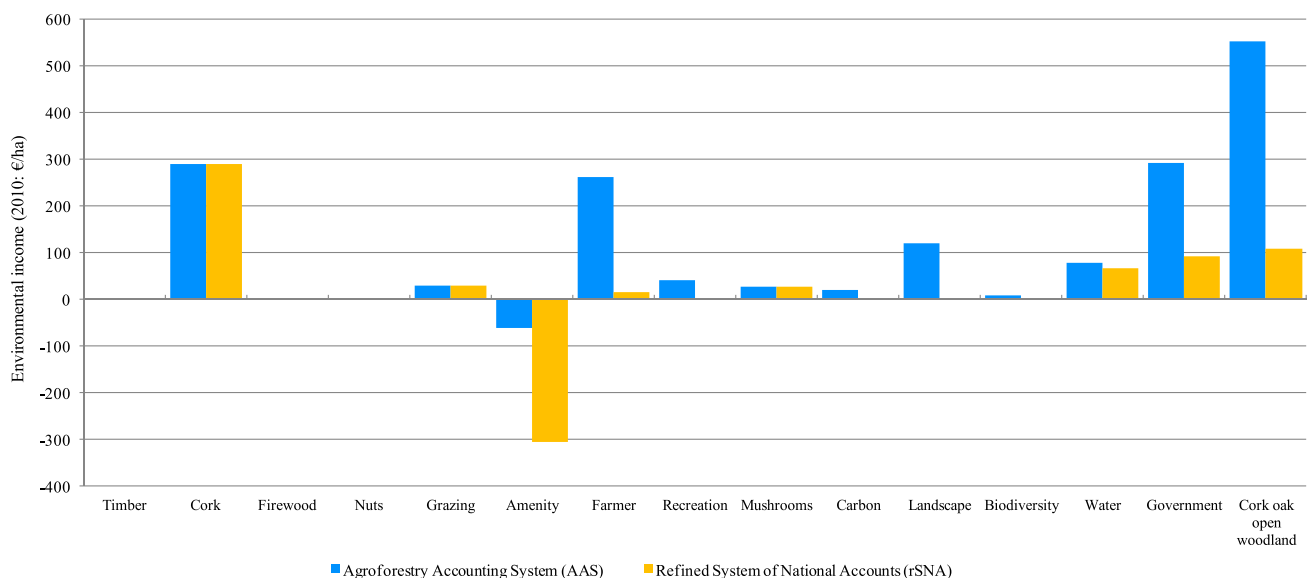

Fig. 13. AAS versus rSNA environmental income at social and basic prices respectively for cork oak open woodlands in Andalusia (2010: €/ha).

Table 5

AAS versus rSNA ecosystem services and incomes of cork oak open woodlands at producer, basic and social prices in Andalusia (2010: €/ha).

Class	Farmer			Government			Cork oak open woodlands
	Amenity	Other	Sub-total	Landscape	Others	Sub-total	
Agroforestry Accounting System							
AAS at social prices							
Ecosystem services (ES_{sp})	245.4	114.0	359.4	119.7	225.1	344.8	704.2
Gross value added (GVA_{sp})	245.4	139.3	384.7	125.3	273.2	398.5	783.2
Gross operating margin (GOM_{sp})	245.4	106.9	352.3	125.3	228.2	353.5	705.9
Environmental income (EI_{sp})	−60.7	321.6	260.9	119.7	173.3	293.0	553.9
AAS at basic prices							
Ecosystem services (ES_{bp})	331.3	114.0	445.4	132.2	225.1	357.3	802.6
Gross value added (GVA_{bp})	331.3	139.3	470.6	137.8	273.2	411.0	881.7
Environmental income (EI_{bp})	25.3	321.6	346.8	132.2	173.3	305.5	652.3
AAS at producer prices							
Ecosystem services (ES_{pp})	331.3	114.0	445.4	169.5	225.1	394.6	840.0
Gross value added at (GVA_{pp})	331.3	139.3	470.6	175.2	273.2	448.4	919.0
Environmental income (EI_{pp})	25.3	321.6	346.8	169.5	173.3	342.9	689.7
Refined System of National Accounts							
rSNA at basic prices							
Ecosystem services (ES_{bp})		114.0	114.0	0.0	93.1	93.1	207.2
Gross value added (GVA_{bp})		139.3	139.3	5.5	139.3	144.8	284.1
Gross operating margin (GOM_{bp})		106.9	106.9	0.8	99.0	99.8	206.8
Environmental income (EI_{bp})	−306.1	321.6	15.5	0.0	93.1	93.1	108.6
rSNA at producer prices							
Ecosystem services (ES_{pp})		114.0	114.0	0.0	93.1	93.1	207.2
Gross value added (GVA_{pp})		139.3	139.3	5.5	139.3	144.8	284.1
Environmental income (EI_{pp})	−306.1	321.6	15.5	0.0	93.1	93.1	108.6

Abbreviations: subscript sp is social prices, subscript bp is basic prices and subscript pp is producer prices.

activities may not correspond to the rationale of a single owner, although in the case of public activities they will correspond to the rationale of the government. We will focus on comparing the economic results for the 15 economic activities common to the COW_A and COF_{PR}, and comment on the aggregate economic results per hectare for the period 2010 considering the comparative COW_A/COF_{PR}* indexes.

The economic index results are markedly different, with the exception of the ecosystem services and environmental income, which are slightly closer, although the differences between individual activities (not addressed here) are generally larger. Table 7 shows that the greatest differences between the eight economic indicators compared correspond to the resource rents from extractions of woody products (WPeu), the labor cost (LC) and the environmental net operating margin (NOMe). These are followed by differences in net value added and environmental assets. The values for LC and WPeu are lower in COW_A than in COF_{PR}. The comparison of the results for LC and WPeu must be interpreted with caution when analyzing their significance as the extraction of cork is the main source of labor demand in the 15 compared activities common to the COW_A and COF. Greater differences arise due to the bias associated with the number of farms included in

the study, in this case seven, where cork extractions from the same cork tree take place in multi-year rotations of nine or more years. Thus, the physical extraction of cork in the COW_A corresponds to 22% of the estimated physical growth in the period, whereas in the case of the COF_{PR} it corresponds to 80%.

6. Discussion

6.1. The environmental income as a maximum possible sustainable ecosystem service

In this article we omit the development of the sustainable biological modeling that supports this complex research applied to Andalusian cork oak open woodlands (for details see Campos et al., 2019a; Campos et al., 2017). Our assertion that environmental income represents the maximum possible sustainable ecosystem services is consistent with the concept of ecological sustainability of the ecosystem based on scheduled future conservationist scenarios applied to Andalusian COW.

Environmental assets represent the net present value of the expected future ecosystem service consumption without taking into account a

Table 6

AAS versus rSNA ecosystem services and gross valued added indexes at producer, basic and social prices for cork oak open woodlands in Andalusia (2010).

Class	Farmer			Government			Cork oak open woodlands
	Amenity	Other	Sub-total	Landscape	Others	Sub-total	
Ecosystem services							
$ES_{pp,AAS}/ES_{sp,AAS}$	1.4	1.0	1.2	1.4	1.0	1.1	1.2
$ES_{bp,AAS}/ES_{sp,AAS}$	1.4	1.0	1.2	1.1	1.0	1.0	1.1
$ES_{bp,rSNA}/ES_{sp,AAS}$		1.0	0.3		0.4	0.3	0.3
$ES_{pp,rSNA}/ES_{pb,rSNA}$		1.0	1.0		1.0	1.0	1.0
Gross value added							
$GVA_{pp,AAS}/GVA_{sp,AAS}$	1.4	1.0	1.2	1.4	1.0	1.1	1.2
$GVA_{bp,AAS}/GVA_{sp,AAS}$	1.4	1.0	1.2	1.1	1.0	1.0	1.1
$GVA_{bp,rSNA}/GVA_{sp,AAS}$		1.0	0.4	0.0	0.5	0.4	0.4
$GVA_{pp,rSNA}/GVA_{bp,rSNA}$		1.0	1.0	1.0	1.0	1.0	1.0

Abbreviations: subscript sp is social prices, subscript bp is basic prices and subscript pp is producer prices.

Table 7
Agroforestry Accounting System applications to privately owned non-industrial cork oak farm case studies versus cork oak woodland land-cover tiles in Andalusia (2010).

Class	Campos et al. (2019b)	This research	Index at social prices	
			(COW_A/COF_{PR})	$(COW_A/COF_{PR})*$
Basic spatial unit	Privately owned cork oak farm (COF_{PR})	Andalusian cork oak woodland tiles (COW_A)		
Economic activities	Timber, cork, firewood, nuts, grazing, conservation forestry, hunting, residential, livestock, agriculture, amenity, fire services, recreation, mushrooms, carbon, landscape, biodiversity and water	Timber, cork, firewood, nuts, grazing (livestock and game grazing), conservation forestry, residential, amenity, fire services, recreation, mushrooms, carbon, landscape, biodiversity and water		
Total area (ha)	5,512	248,015		
Land covers and uses	COW, OW, OFL, SL, GL, NAL	COW		
Economic indicators	Farmer (F), government (G) and cork oak farm (COF)	Farmer (F), government (G) and cork oak woodland (COW)		
Net value added (€/ha)	$NVA_{sp,COF} = 749.5$	$NVA_{sp,\,COW} = 758.2$	1.01	1.14
Labor cost (€/ha)	$LC_{COF} = 184.4$	$LC_{COW} = 77.4$	0.42	0.58
Net operating margin (€/ha)	$NOM_{sp,COF} = 565.5$	$NOM_{spCOW} = 680.8$	1.20	1.28
Environmental work in progress used (€/ha)	$WPeu_{ep,COF} = 191.5$	$WPeu_{ep,\,COW} = 85.3$	0.45	0.45
Environmental net operating margin (€/ha)	$NOMe_{ep,COF} = 528.1$	$NOMe_{ep,\,COW} = 681.7$	1.29	1.29
Ecosystem services (€/ha)	$ES_{ep,COF} = 660.3$	$ES_{ep,\,COW} = 704.2$	1.07	1.07
Environmental income(€/ha)	$EI_{ep,COF} = 536.4$	$EI_{ep,\,COW} = 553.9$	1.03	1.03
Environmental asset(€/ha)	$EA_{ep,COF} = 15,110.5$	$EA_{ep,\,COW} = 17,278.6$	1.14	1.14

Abbreviations: sp is social prices, ep is environmental prices, pp is producer prices, HOW is holm oak woodlands, GL is grass land, NAL is non agrarian land, OW is open woodlands, OFL is other forest land and SL is shrubland.

*This indicator excludes hunting, livestock and crops activities in COFPR, but considers game grazing in COFPR.

25

visible link with the ecosystem services of the period. The visible link between the ecosystem services and the environmental assets of the ecosystems is provided by the adjusted change in environmental net worth (CNWead). Ecological sustainability is taken out of the economic valuation through the scheduled future silviculture aimed at ensuring no degradation of the biophysical endowments of natural resources (including wildlife biodiversity), or over-extractions during the complete cycles of plant and game species. In other words, ecological sustainability is a political purpose assumed in order to avoid irreversible losses of unique genetic variety, and which conditions the generation of the environmental income of the period. In this research, the future endowments of the biophysical environmental stocks are programmed to repeat the uses infinitely assuming all other present circumstances remain equal. The valuation of an environmental asset at the closing of the period is a subjective expectation in which we try to minimize the degree of uncertainty in our application to the Andalusian COW. In the COW, every ecosystem service repeats itself in complete cycles, regenerating in infinite complete cycles.

The environmental assets generate ecosystem services and environmental incomes that vary from on period to another. Given that the physical productivity taken into account is that of the complete cycle of the products harvested, in the case of a product with a production cycle longer than one period (year), it is not necessarily the case that physical extractions exceeding the physical natural growth in the period mean that the environmental income for the period is not sustainable. It is necessary to wait until the end of the complete cycle of natural growths for the periods until the final extraction of the product, and then by comparing it with the previous complete cycle, determine whether the physical productivity over the complete cycle varied either positively or negatively, and in turn draw conclusions with regard to its possible biophysical sustainability. It is not possible to determine the biological sustainability until we know whether, at the end of the cycle in which all the biological extractions take place, the amount of the physical biological asset is above the critical threshold for risk of disappearance of the unique genetic variety.

6.2. Measuring the government fair compensation to farmers for future supply of public goods and services

In this research, as well as that of Oviedo et al. (2017) and Campos et al. (2017, 2019b) cited in this article, voluntary opportunity cost assessments reflect the real behavior of farmers as regards management decisions for investment in their oak woodland farms. This valuation of the farmer voluntary opportunity cost as non-commercial intermediate product is necessary for acceptable measurement of future compensations for manufactured investments by the owner involving non-accepted negative ordinary manufactured net operating margins. The minimum acceptable compensation (ISSnccm) can be measured by the balance between the normal ordinary manufactured net operating margin (NOMmn) minus the residual ordinary manufactured net operating margin (NOMm). The opportunity cost accepted by the owner is represented by the minimum accepted ordinary manufactured net operating margin (NOMma), provided that the former exceeds the sum of the latter two (Eq. (25)):

$$ISSnccm = NOMmn - NOMm - NOMma \qquad (25)$$

The government can avoid over/under compensation biases to landowners by estimating beforehand their maximum willingness to pay for the auto-consumed/donated non-commercial intermediate services (ISSnca/d) of hunting, livestock and any other farm activities. Thus, we can determine the value of the non-commercial intermediate production (ISSnc) that guarantees obtaining the normal net operating margin (NOMmn) of the owner's individual activity. Due to this, we can obtain as a residual value, the minimum compensation accepted by the owners for an effective government compensation (purchasing) of non-commercial intermediate services (ISSncc) (Eq. (26)):

$$ISSncc = NOMmn - ISSncoa/d \qquad (26)$$

We have assumed that the estimated amounts of own ordinary non-commercial intermediate consumption of services (SSncooa/d) are voluntarily accepted opportunity cost (VOC) by the owners and, the farmer individual activity VOC being considered by the owners to be a private amenity/government compensation non-commercial intermediate product of services (ISSncoa/d). We do not know whether the owners would be willing to pay more for the same offer of final products consumed of amenities and public products. If we assume that owners do not wish to increase SSncooa/d payments, we would then find that owners required an increase in government compensations in order to maintain the current supply of final public goods and services consumed (PGSc) or enhance the supply (positive environmental net operating margin of investment: NOMei > 0). This assumption is based on the expectation by the owner of a possible future upward variation in the remaining production costs, or a decrease in the prices of the final products consumed, all other aspects of interest remaining unchanged.

If we assume that consumers are willing to pay a fair increase in government offsets to maintain and/or improve the current offer of PGSc in the future, what should fair compensation be, in addition to the current compensation that the government pays to the landowners?

We have shown that the accounting procedure to obtain the ISSncc is simple and direct when the manufactured normal net operating margin (NOMmn), the auto-consumed and donated production of non-commercial intermediate services ISSnca and ISSncd, respectively, (Eq. (26)) are all known. The problem raised in the previous question is that of determining the government's maximum tolerable fair price (fp) of compensations (ISSncc$_{fp}$) to landowners. Through appropriate procedures (opinion polls of owners, experts and consumers, application of methods of revealed investment preferences of owners and others), the government has to estimate the minimum ranges of the ISSnca/d$_{Mi}$ accepted by owners and the maximum payment of the ISSncc$_{fp}$ by the government and/or the active and passive consumers of the PGSc (Eq. (27)):

$$ISSncc_{fp} = NOMmn - ISSnca/d_{Mi} \qquad (27)$$

A complication associated with implementing a fair payment system (ISSncc$_{fp}$) to ensure the government's desired volume of PGSc production is that it will require accounting audit to estimate the residual values of the ISSnca/d. This requires an accounting audit protocol that determines the eligible investments for the estimations of the NOMmn and the ISSnca/d$_{Mi}$ to be agreed upon by the owners in advance of the execution of the investments in the period. In this situation, both the rSNA and AAS methodologies provide the accounting records that make it possible to determine the ISSnca/d and consequently, to determine the public fair payment (ISSncc$_{fp}$) to the owners.

6.3. Building ecosystem accounting for informing policy options

Among the possible motivations for governments to implement new environmental- economic statistics for ecosystems are the following: (i) governments are responsible for the design and implementation of the policies to avoid or mitigate the loss of the legacy of environmental assets received by current generations, which are to be transmitted to future generations on the basis of principles of inter-generational public legacy, (ii) the normalization of the measurement of biophysical sustainability requires a subjective scientific consensus of the critical biophysical thresholds of environmental assets, in which they are recognized as carriers of non-reproducible natural diversities which are industrially and culturally unique, (iii) standardized scientific data on the goods and services of ecosystems that contribute to human wellbeing should be visible in order to provide data that contributes to improving the design of environmental policies and the enhancement of human wellbeing, (iv) the future implementation of the extended environmental-economic accounts of ecosystems, which are perceived by

governments as key statistics for "ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (Mountford, 2011: p. 3), (v) the accounts of the physical stocks and environmental assets of the ecosystems at global, national, regional and local scales provide the tools to generate data allowing the design and practice of international conventions, (vi) environmental accounts must be implemented by governments according to types of ecosystems at global, national, regional and local scales to ensure the mitigation of losses of threatened and shared biological and cultural varieties, and (vii) new technologies are key production factors in the improvement of economic growth and their impact on environmental assets must be incorporated in the valuation of economic progress, in both its effects on benefits and environmental costs, through new indicators such as environmental income, and others that can be incorporated into the refined standard national accounts and the extended accounts.

The application of the extended accounts to a complex ecosystem (e.g. the COW) allows an insight into the general public utility of the implementation of an environmental-economic ecosystem accounting system like the AAS. Public policies for the preservation of threatened unique wild genetic variety is based on the precautionary principle and government policy conditioned by the tolerable social cost of avoiding and/or mitigating the loss of unique diversity forever.

6.4. Uncertainty of the assumptions on the future cork oak open woodland economy

The assumptions established to estimate the values of the environmental assets at the closing of the period may not be met in the case of the cork oak open woodlands of Andalusia. Depending on the reason for and the qualitative effects of the change, we consider that it could be due to the following key future events:

In large areas, even if the cork oaks regenerate naturally, the loss of overripe cork oaks that occurs as a result of deaths from natural causes could make it difficult to conserve the wild fauna which depend on the hollows in the trunks of the ancient cork oaks.

It is unlikely that the resource rent (environmental price) of cork will decrease, and consequently, the environmental asset of the raw material could be maintained or even increased in the coming decades. In the period 1994–2000, more than 83,000 ha of cork oaks were repopulated in western, central and southwestern Spain, which represents nearly a fifth of the surface area of Spanish cork oaks (Ovando et al., 2007:Table 1, p. 175).

The resource rent of the pastures consumed by livestock tends to disappear and will depend on the replacement of livestock species. The income from grazing associated with hunting species, represented by the resource rent from captures valued at their environmental price, may increase. It is probable that the net effect as regards animal grazing is a reduction in the resource rent of the pastures and consequently, of their environmental assets.

It is quite likely that the ecosystem services of the private amenities will follow a trend of real growth increase, since large cork oak woodlands tend to be among the most valued, both by non-industrial owners and potential buyers who demand the consumption of private amenities. The environmental asset of the private amenity will tend to grow and contribute above half the market price of land in most areas of Spanish cork oak woodland.

Although social groups calling for a ban on hunting are increasing in Spain, it is unlikely that this will occur, except in certain protected wilderness areas in National parks, where it is now managed on a temporary basis. If there were to be a decrease in hunting captures in certain cork oak woodland wilderness areas, it could have harmful effects on health of the ecosystem, as competing wildlife could be displaced without alternative natural habitats to resettle.

It is unlikely that the current level of government compensation for livestock will decline, and as a result, the favorable effects that livestock have on owner amenities, domestic biological variety and cultural landscape conservation services will allow continued improvements in their contributions to labor income, return on owner investments and free consumption by the public.

Public owners are likely to increase donations of intermediate and final products because of increased manufactured investment in commercial forestry, hunting and livestock activities.

7. Concluding remarks

We refine the standard accounts (rSNA) to render ecosystem services and incomes measured comparable with those of the extended accounts (AAS). Thus, we avoid the income timing bias that occurs when applying the standard accounts (SNA) and leads to the omission of natural growth and the cost of the standing environmental work in progress used (WPeu) of woody products and game species in the SNA. The AAS and the rSNA are methodologies which are applicable to any basic spatial unit (BSU) and ecosystem type.

The results for the COW land-cover tiles, as basic spatial units in the AAS application, reveal that the omission of hunting and livestock activities leads to different income results at producer, basic, and social prices. This is because the own non-commercial intermediate consumption of services (SSncoo) that come from the hunting and livestock activity non-commercial intermediate production of services (ISSnco) is registered on the use side of the AAS production account. Otherwise, when the AAS is applied to farms as the basic spatial unit, the results for all the activities as a whole are the same at producer, basic, and social prices. The implication of these results is that the SSncoo and ISSnc should be measured at farm BSU and then scaled up to the COW land-cover tile BSU.

We have shown that, under both accounting systems, the complete production and capital accounts of the economic activities valued in the COW are required to estimate the specific contributions of nature to the social total income of the period. This total contribution of nature could be represented by a synthetic total environmental income (EI) indicator, which can be broken down into other components such as ecosystem services (ES) and the adjusted change of environmental assets (CNWead) in the period. In this research we present a systematic conceptualization and application of the extended accounts to the cork oak open woodlands of Andalusia. This is based on micro and macro data at present partially available on the physical data from the official national forest inventory (NFI3) for the Andalusian region of Spain. The application of these accounting frameworks reveals the feasibility of integrating (in a manner consistent with theory) the wide variety of products, both consumed and accumulated in the COW in the period, through a normalized single indicator of environmental income integrated with the measurement of the COW total income. The measurement is the joint result of multiple physical and monetary indicators that link the contributions of possible sustainable ecosystem services to the current consumption of cork oak open woodland products, with a periodic adjustment of the latter according to the change in the environmental asset. In general, the measurement of a sustainable ecosystem service indicator would require the adjusted change in environmental net worth according to environmental work in progress used in the period to be taken into account.

However, a standard protocol for ecosystem accounts that proposes the measurement of total environmental income has still not been made available. A future standard protocol for environmental income would serve as a reference indicator to measure ecological and economic sustainability of current and future management of the natural and cultural assets of ecosystems. However, in the presence of individual biophysical endowments on the critical threshold of physical ecosystem stocks, environmental income is not an indicator that can provide unequivocal information on the ecological sustainability of the management of individual ecosystem assets. In these circumstances, it is necessary to design biophysical management beyond economic

sustainability on the basis of consumer preferences.

CRediT authorship contribution statement

Pablo Campos: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Visualization, Writing - original draft, Writing - review & editing. **Alejandro Álvarez:** Data curation, Formal analysis, Visualization, Writing - review & editing. **José L. Oviedo:** Funding acquisition, Supervision, Writing - review & editing. **Bruno Mesa:** Data curation, Formal analysis, Writing - review & editing. **Alejandro Caparrós:** Funding acquisition, Supervision, Writing - review & editing. **Paola Ovando:** Funding acquisition, Supervision, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2020.106551.

References

Alfsen, K.N., Greaker, M., 2006. From natural resources and environmental accounting to construction of indicators for sustainable development. Statistics Norway, Research Department, Discussion Papers No. 478, p. 30. https://www.ssb.no/a/publikasjoner/pdf/DP/dp478.pdf. (Accessed 10 December 2019).

Atkinson, G., Obst, C., 2017. Prices for ecosystem accounting. WAVES. https://www.wavespartnership.org/sites/waves/files/kc/Prices%20for%20ecosystem%20accounting.pdf. (Accessed 2 October 2018).

Campos, P., Ovando, P., Mesa, B., Oviedo, J.L., 2016. Environmental income of livestock grazing on privately owned silvopastoral farms in Andalusia, Spain. J. Land. Degrad. Dev. 29 (2), 250–261. https://doi.org/10.1002/ldr.2529.

Campos, P., Mesa, B., Álvarez, A., Castaño, F.M., Pulido, F., 2017. Testing extended accounts in scheduled conservation of open woodlands with permanent livestock grazing: Dehesa de la Luz Estate case study, Arroyo de la Luz, Spain. Environments 4 (4), 1–38. https://doi.org/10.3390/environments4040082.

Campos, P., Caparrós, A., Oviedo, J.L., Ovando, P., Álvarez-Farizo, B., Díaz-Balteiro, L., Carranza, J., Beguería, S., Díaz, M., Herruzo, A.C., Martínez-Peña, F., Soliño, M., Álvarez, A., Martínez-Jáuregui, M., Pasalodos-Tato, M., de Frutos, P., Aldea, J., Almazán, E., Concepción, E.D., Mesa, B., Romero, C., Serrano-Notivoli, R., Fernández, C., Torres-Porras, J., Montero, G., 2019a. Bridging the gap between national and ecosystem accounting application in Andalusian forests, Spain. Ecol. Econ. 157, 218–236. https://doi.org/10.1016/j.ecolecon.2018.11.017.

Campos, P., Oviedo, J.L., Álvarez, A., Mesa, B., Caparrós, A., 2019b. The role of non-commercial intermediate services in the valuations of ecosystem services: Application

to cork oak farms in Andalusia. Spain. Ecosyst. Serv. 39. https://doi.org/10.1016/j.ecoser.2019.100996.

Campos, P., Álvarez, A., Mesa, B., Oviedo, J.L., Ovando, P., Caparrós, A., 2019c. Uncovering the hidden ecosystem services embedded in environmental incomes: Testing experimental extended accounts in dehesas of holm oak woodlands, Andalusia-Spain. Instituto de Políticas y Bienes Públicos (IPP) CSIC, Working Paper 2019-03, 91 pp. http://ipp.csic.es/sites/default/files/content/workpaper/2019/2019_03_IPPwp_Campos.pdf. (Accessed 1 October 2019).

Campos, P., Álvarez, A., Oviedo, J.L., Ovando, P., Mesa, B., Caparrós, A., 2020a. Income and ecosystem service comparisons of refined National and Agroforestry Accounting frameworks: Application to holm oak open woodlands in Andalusia, Spain. Forests 11 (185). https://doi.org/10.3390/f11020185.

Campos, P., Álvarez, A., Oviedo, J.L., Ovando, P., Mesa, B., Caparrós, A., 2020b. Refined Systems of National Accounts and Experimental Ecosystem Accounting versus the simplified Agroforestry Accounting System: Testing in Andalusian holm oak open woodlands. Forests 11 (393). https://doi.org/10.3390/f11040393.

Caparrós, A., Oviedo, J.L., Álvarez, A., Campos, P., 2017. Simulated exchange values and ecosystem accounting: Theory and application to recreation. Ecol. Econ. 139, 140–149. https://doi.org/10.1016/j.ecolecon.2017.04.011.

DGCN (Dirección General de Conservación de la Naturaleza), 2008. Mapa Forestal de España 1:50.000. Ministerio de Medio Ambiente, Madrid. https://www.miteco.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/mfe50.aspx. (Accessed 11 July 2019).

Díaz, M., Concepción, E.D., Oviedo, J.L., Caparrós, A., Farizo, B.A., Campos, P., 2020. A comprehensive index for threatened biodiversity valuation. Ecol. Ind. 108. https://doi.org/10.1016/j.ecolind.2019.105696.

EFTEC, 2015. Developing UK natural capital accounts: woodland ecosystem accounts. Department for Environment, Food and Rural Affairs (Defra), Economics for the Environment Consultancy Ltd. London, p. 97. http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18909. (Accessed 14 September 2017).

Eigenraam, M., Obst, C., 2018. Extending the production boundary of the System of National Accounts (SNA) to classify and account for ecosystem services. Ecosyst. Health Sustain. 4 (11), 247–260. https://doi.org/10.1080/20964129.2018.1524718.

European Commission, International Monetary Fund, Organization for Economic Co-operation and Development, United Nations, World Bank, 2009. System of National Accounts 2008 (SNA 2008). New York, p. 722. http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf. (Accessed 11 July 2019).

European Commission, 2011. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM(2011) 244 final. Brussels, p. 17. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN. (Accessed 23 January 2018).

European Commission, 2016. Report on phase 1 of the knowledge innovation project on an integrated system of natural capital and ecosystem services accounting in the EU (KIP-INCA Phase 1 report). http://ec.europa.eu/environment/nature/capital_accounting/pdf/KIP_INCA_final_report_phase-1.pdf. (Accessed 11 July 2019).

European Communities, 2000. Manual on the Economic Accounts for Agriculture and Forestry EEA/EAF 97 (Rev. 1.1). EC, EUROSTAT, Luxembourg, 172 pp. http://ec.europa.eu/eurostat/documents/3859598/5854389/KS-27-00-782-EN.PDF/e79eb663-b744-46c1-b41e-0902be421beb. (Accessed 14 September 2017).

Keith, H., Vardon, M., Stein, J.A., Stein, J.L., Lindenmayer, D., 2017. Ecosystem Accounts define explicit and spatial trade-offs for manging natural resources. Nat. Ecol. Evol. 1 (11), 1683–1692. https://doi.org/10.1038/s41559-017-0309-1.

Koop, J.R., Smith, V.K., 1993. Understanding Damage to Natural Assets, in: Koop, J. R., Smith, V. K. (Eds.), Valuing Natural assets - The economics of natural resource damage assessment. Resources for the Future, Washington D.C., pp. 6–20.

Krutilla, J.V., 1967. Conservation reconsidered. Am. Econ. Rev. 57 (4), 777–786.

La Notte, A., Vallecillo, S., Marques, A., Maes, J., 2019a. Beyond the economic boundaries to account for ecosystem services. Ecosyst. Serv. 35, 116–129. https://doi.org/10.1016/j.ecoser.2018.12.007.

La Notte, A., Vallecillo, S., Maes, J., 2019b. Capacity as "virtual stock" in ecosystem services accounting. Ecol. Ind. 98, 158–163. https://doi.org/10.1016/j.ecolind.2018.10.066.

Lammerant, J., 2019. State of play of business accounting and reporting on ecosystems. Forum of Experts 26-27th June, New York, p. 13. https://seea.un.org/sites/seea.un.org/files/1._johan_lammerant_state_of_play_of_business_accounting_and_reporting.pdf. (Accessed 17 December 2017).

Martinez-Jauregui, M., Herruzo, C., Carranza, J., Torres-Porras, J., Campos, P., 2016. Environmental price of game animal stocks. Hum. Dimens. Wildl. 21 (1), 1–17. https://doi.org/10.1080/10871209.2016.1082682.

Masiero, M., Pettenella, D., Boscolo, M., Barua, S.K, Animon, I., Matta, J.R., 2019. Valuing forest ecosystem services: a training manual for planners and project developers. Forestry Working Paper 11. FAO, Rome, 216 pp. Licence: CC BY-NC-SA 3.0 IGO.

McElroy, M.B., 1976. Capital gains and social income. Econ. Inquiry XIV 221–240.

Montero, G., Pasalodos-Tato, M., López-Senespleda, E., Ruiz-Peinado, R., Bravo-Oviedo, A., Madrigal, G., Onrubia, R., 2015. Modelos de selvicultura y producción de madera, frutos y fijación de carbono de los sistemas forestales de Andalucía, in: Campos, P., Díaz-Balteiro, L. (Eds.), Economía y selviculturas de los montes de Andalucía. Memorias científicas de RECAMAN. Vol 1, memoria 1.2, Editorial CSIC, Madrid, pp. 153–396. http://libros.csic.es/product_info.php?products_id=987. (Accessed 27 April 2018).

Mountford H., 2011. OECD Green Growth Strategy & Resource Policy. ESDN Conference, 27-29 June 2011. Szentendre, p. 19. http://www.sd-network.eu/pdf/conferences/2011_szentendre/presentations/Mountford.pdf. (Accessed 11 June 2019).

Ogilvy, S., Burritt, R., Walsh, D., Obst, C., Meadows, P., Muradzikwa, P., Eigenraam, M., 2018. Accounting for liabilities related to ecosystem degradation. Ecosyst. Health

Sustainability 4 (11), 261–276. https://doi.org/10.1080/20964129.2018.1544837.

Ovando, P., Campos, P., Montero, G., 2007. Forestaciones con encina y alcornoque en el área de la dehesa en el marco del Reglamento (CE) 2080/92 (1993–2000). Revista Española de Estudios Agrosociales y Pesqueros 214, 173–186.

Ovando, P., Campos, P., Oviedo, J.L., Montero, G., 2010. Private net benefits from af-foresting marginal cropland and shrubland with cork oaks in Spain. For. Sci. 56 (6), 567–577. https://doi.org/10.1093/forestscience/56.6.567.

Ovando, P., Campos, P., Oviedo, J.L., Caparrós, A., 2016. Ecosystem accounting for measuring total income in private and public agroforestry farms. For. Policy Econ. 71, 43–51. https://doi.org/10.1016/j.forpol.2016.06.031.

Ovando, P., Beguería, S., Campos, P., 2019. Carbon sequestration or water yield? The effect of payments for ecosystem services on forest management decisions in Mediterranean forests. Water Resour. Econ. 28. https://doi.org/10.1016/j.wre.2018.04.002.

Oviedo, J.L., Huntsinger, L., Campos, P., 2017. Contribution of amenities to landowner income: Case of Spanish and Californian hardwood. Rangeland Ecol. Manage. 70, 518–528. https://doi.org/10.1016/j.rama.2017.02.002.

Raunikar, R., Buongiorno, J., 2006. Willingness to pay for forest amenities: The case of non-industrial owners in the south central Unite States. Ecol. Econ. 56, 132–143. https://doi.org/10.1016/j.ecolecon.2005.01.013.

Remme, R.P., Edens, B., Schröter, M., Hein, L., 2015. Monetary accounting of ecosystem services: a test case for Limburg Province, the Netherlands. Ecol. Econ. 112, 116–128. https://doi.org/10.1016/j.ecolecon.2015.02.015.

Stone, R., 1984. The accounts of society. Nobel Memorial Lecture, 8 December, 1984. https://www.nobelprize.org/uploads/2018/06/stone-lecture.pdf. (accessed 2 October 2018).

Sumarga, E., Hein, L., Edens, B., Suwarno, A., 2015. Mapping monetary values of ecosystem services in support of developing ecosystem accounts. Ecosyst. Serv. 12, 71–83. https://doi.org/10.1016/j.ecoser.2015.02.009.

United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organization for Economic Cooperation and Development, World Bank, 2014a. System of Environmental– Economic Accounting 2012 –Central Framework [SEEA-CF]. United Nations, New York, p. 378. https://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf. (Accessed on 11 July 2019).

United Nations, European Commission, Food and Agriculture Organization of the United Nations, Organization for Economic Co-operation and Development, World Bank Group, 2014b. System of Environmental Economic Accounting 2012— Experimental Ecosystem Accounting [SEEA-EEA]. United Nations, New York, p. 198. http://ec.europa.eu/eurostat/documents/3859598/6925551/KS-05-14-103-EN-N.pdf. (Accessed on 11 July 2019).

United Nations, 2017. Technical Recommendations in support of the System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting, pp. i-xiii + 1–180. https://seea.un.org/sites/seea.un.org/files/technical_recommendations_in_support_of_the_seea_eea_final_white_cover.pdf. (Accessed 17 December 2018).

van de Ven, P., Obst, C., Edens, B., 2019. Discussion Paper 5.3: Accounting Treatments When Integrating Ecosystem Accounts in the SNA. SEEA EEA Revision. Version Date: 22 November 2019. Expert Consultation. Working Group 5: Valuation and Accounting Treatments. Department of Economic and Social Affairs Statistics Division/United Nations, New York. p. 19. https://seea.un.org/sites/seea.un.org/files/documents/EEA/dp5.3_accounting_treatments_22nov2019.pdf. (Accessed on 20 January 2020).