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Methodological and Ideological Options

Bridging the Gap Between National and Ecosystem Accounting Application in Andalusian Forests, Spain

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ABSTRACT

National accounting either ignores or fails to give due values to the ecosystem services, products, incomes and environmental assets of a country. To overcome these shortcomings, we apply spatially-explicit extended accounts that incorporate a novel environmental income indicator, which we test in the forests of Andalusia (Spain). Extended accounts incorporate nine farmer activities (timber, cork, firewood, nuts, livestock grazing, conservation forestry, hunting, residential services and private amenity) and seven government activities (fire services, free access recreation, free access mushroom, carbon, landscape conservation, threatened biodiversity and water yield). To make sure the valuation remains consistent with standard accounts, we simulate exchange values for non-market final forest product consumption in order to measure individual ecosystem services and environmental income indicators. Manufactured capital and environmental assets are also integrated. When comparing extended to standard accounts, our results are 3.6 times higher for gross value added. These differences are explained primarily by the omission in the standard accounts of carbon activities and undervaluation of private amenity, free access recreation, landscape and threatened biodiversity ecosystem services. Extended accounts measure a value of Andalusian forest ecosystem services 5.4 times higher than that measured using the valuation criteria of standard accounts.

1. Introduction

Gross value added, as measured by the standard System of National Accounts, is generally regarded as sketchy at best due to its inadequate valuation of the individual contribution of ecosystem services to the supply of goods and services produced in a country, region or landscape (Council of Europe, 2000; European Commission et al., 2009). This has spurred governmental institutions and scientific experts to attempt to develop an accounting framework that addresses the shortcomings of the System of National Accounts and their standard satellite Economic Account for Forestry for building full economic ecosystem accounting. The latter focuses on farmer market product production account using

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gross value added as balancing item (European Communities, 2000).

The main academic and statistical communities, led by the United Nations Committee of Experts on Environmental-Economic Accounting and other governmental institutions, have reached an agreement on certain issues (and are committed to agree on others by 2020) as regards the System of Environmental-Economic Accounting (Atkinson and Obst, 2017; Edens and Hein, 2013; Obst et al., 2016; United Nations et al., 2014a, 2014b; United Nations, 2017). Several international initiatives are pilot-testing the SEEA, including the "Wealth Accounting and Valuation of Ecosystem Services" of the World Bank (World Bank, 2016), and various ecosystem accounting case studies of forests and croplands at different scales (EFTEC, 2015; Keith et al., 2017; Remme et al., 2015; Sumarga et al., 2015).

With this background in mind, we developed and tested the Agroforestry Accounting System (AAS). This framework is based on the exchange value criterion favoured by the System of National Accounts (SNA) and the System of Environmental Economic Accounting-Experimental Ecosystem Accounting (SEEA-EEA). AAS and SEEA-EEA also share the concepts of ecosystem service and environmental asset, as well as the goal of measuring ecosystem services embedded in market and non-market products. The two main differences are that we propose to measure environmental income defined as the aggregated value of ecosystem services and the change in the value of natural wealth (technically, work in progress used adjusted to change of environmental net worth) and that we include exchange values for simulated markets.

We proceed as described below. In the second section, we present the accounting framework and the data used in our application to Andalusian forests. The third section presents the spatially-explicit results obtained, and compares them to those obtained using a slightly revised version of the standard accounts. The fourth section compares the characteristics of our study to those in previous literature, and discusses the strengths and weaknesses of our extended accounting framework. In the fifth section we present the conclusions.

2. Materials and Methods

2.1. Regional Application

We applied the extended accounts to the 4,386,432 ha of forests in the region of Andalusia, southern Spain. This region covers an area of 8,759,700 ha and sustains a population of 8.4 million people; these figures resembling those of other countries in Europe (e.g. Austria). The region has a rich biodiversity and a great variety of forest plants and wild animal species. The territory of Andalusia begins at sea level and rises to over 3400 m. It contains one of the places with the highest rainfall in Spain, in the Sierra de Grazalema (Cádiz), as well as an area with the lowest levels of precipitation: the Tabernas desert (Almería). The Andalusian forests represent one of the 25 biodiversity hotspots identified in the world (Myers et al., 2000). Hardwood forests account for 43% of the total forest area, coniferous forests 20%, eucalyptus plantations 4%, shrublands 28%, natural grassland 3% and other forests 2% (Fig. 1 and Supplementary Table S1). Extensive stockbreeding and the historic government plantations of coniferous and eucalyptus species in forest areas with low physical productivity have shaped the Mediterranean forest landscape into a rich mosaic of forest vegetations. However, the physical productivity of these forests is currently in decline because of diminishing silvicultural management and livestock grazing in steeper areas (Nieto-Romero et al., 2014; Campos et al., 2013, 2016).

2.2. Primary Data Sources

We have used data from a wide variety of sources, at different spatial scales, although the minimum scale at which all estimations have been geo-referenced is the vegetation-type tiles of the Forest Map of Spain (FMS). The primary data sources are: (i) natural growth function models of biophysical measurements for timber, cork, firewood and shrub vegetations and fruits (acorn, chestnut and pine nut) obtained from the literature and from our own estimates (Supplementary text S1–S2), (ii) the 86,546 tiles of the FMS (with tile sizes ranging from 48.3 average hectares for wooded surfaces to 57.1 average hectares for treeless areas), which are integrated with information from the plots of the Third National Forest Inventory (IFN3) of Andalusia (Supplementary text S3), (iii) hydrological data from the Andalusian government (Supplementary text S4), (iv) list of threatened wildlife species compiled by the authors along with maps of their distribution in Andalusia based on government and expert data (Supplementary text S5), (v) a phone survey on mushroom picking 4219 Andalusian households of which 267 respondents were mushrooms pickers (Supplementary text S6), (vi) a survey of 740 holders of Andalusian forest hunting reserves (Supplementary text S7), (vii) microeconomic data from 58 agroforestry farm case studies with an aggregate surface of 108,100 ha (Supplementary text S8), (viii) a contingent valuation survey of 765 non-industrial private forest landowners (Supplementary text S9.1), (ix) a contingent valuation survey of 4030 public visitors in nine key forest recreation areas (Supplementary text S9.2), (x) a choice experiment survey of 3214 adults (> 18 years old) from households in Andalusia and of 836 adults from households in the rest of Spain (Supplementary text S9.3), (xi) simulated exchange value modeling (Supplementary text S10), and (xii) public forest expenditure of the Andalusian government. The period during which we collected data was April 2008–June 2012, although all estimates are presented at 2010 dated prices.

2.3. Accounting Frameworks: Extended Accounts and Revised Standard Accounts

The AAS (extended accounts) valuation methods are consistent with SNA (standard accounts) and SEEA-EEA valuation approaches (see Section 2.4). The AAS covers 13 ecosystem services that are not explicit or not included in the SNA. The AAS incorporate nine farmer activities (timber, cork, firewood, nuts (pine-nuts and chestnuts)), livestock grazing (acorn, grass and browse), conservation forestry, hunting (substitute of non-market game grazing), residential services and private amenity, and seven government activities (fire services, free access recreation, free access mushroom, carbon, landscape conservation, threatened biodiversity and water yield). In our extended accounts, activities are differentiated into those that are the responsibility of the landowner (farmer) and those that are the responsibility of the government. They are also differentiated into private and public activities. The application only goes beyond the production boundary of SNA in the case of carbon activity.

To explicitly address ecosystem services in the standard accounts of our application, we integrate intermediate product (IP) in their final product consumption with the name of final product intra-consumption (FPic) in the supply side and the same value in the use side as own intermediate consumption (ICo) (European Commission et al., 2009: pp. 109–110). Due to this change, we use the term "revised" standard SNA, or SNAr. The SNAr allows comparing selected results for the different accounting approaches considered (see Results section and Supplementary text S11).

Given the ownership of forest products and their current and expected future uses, the factorial distribution of total income corresponds to the observed behaviors of the private economic agents in local markets, the government forest management and policy, and the public free access uses in current and future periods. We accept that the allocation of total income among the services provided by the production factors follows this order of priority (taking into account the first potential transaction as intermediate or final product): compensation of employees (labour cost), manufactured capital income and environmental income. Thus, it is necessary to estimate the total

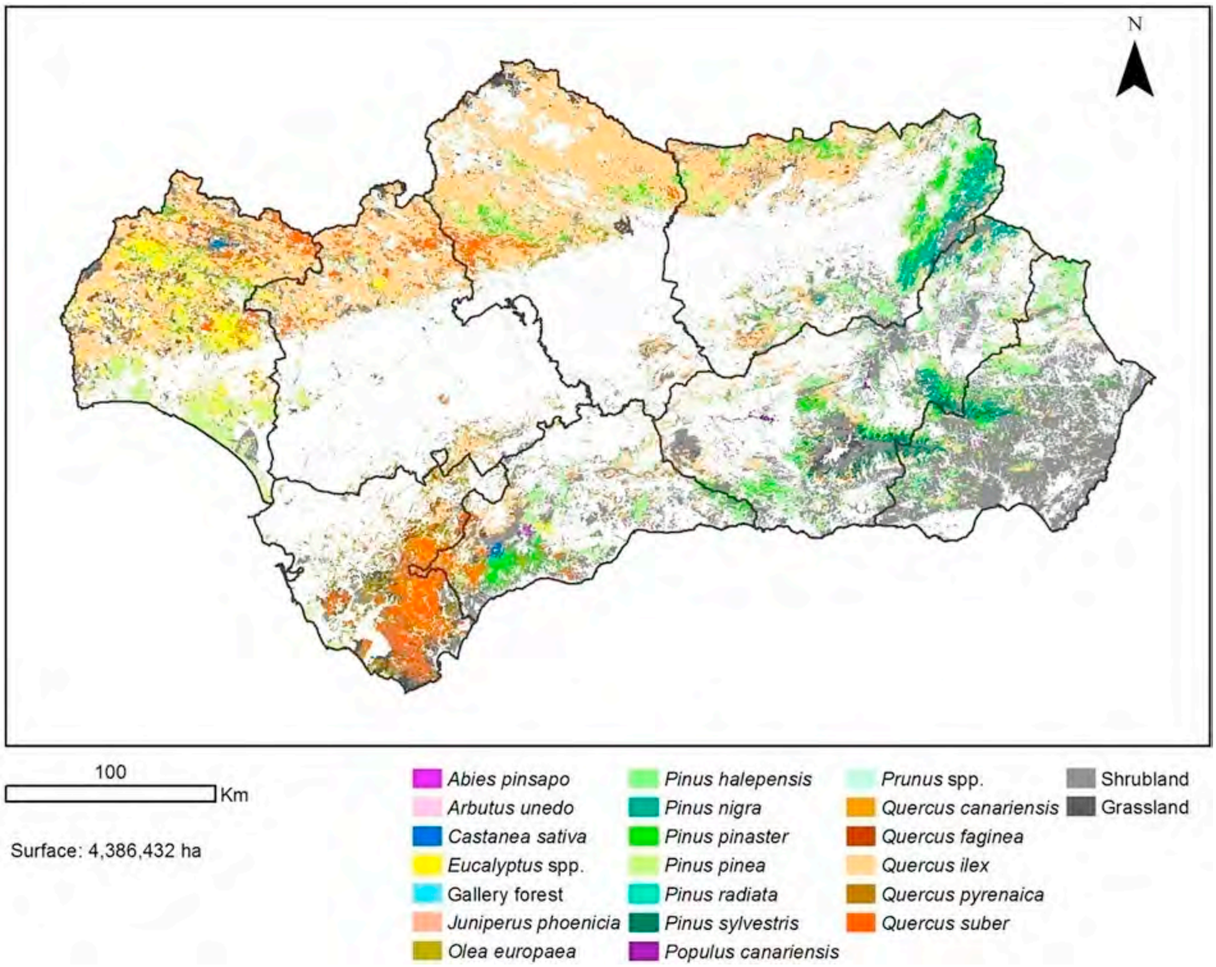

Fig. 1. Andalusian forest vegetation cover.

product, the market or imputed normal (e.g., long-term horizon public bonus discount rate) manufactured capital income, and the environmental income for each forest activity.

The total product (TP) function (F) of the forest extended accounts explicitly incorporates the environmental intermediate consumption (ICe) of work in progress used (WPeu) and the environmental fixed assets (EFA) as production factors:

$$TP \equiv F(WPeu, ICm, LC, EFA, FCm), \quad (1)$$

where ICm is manufactured intermediate consumption, LC is labour costs, and FCm is manufactured fixed capital.

2.3.1. Total Income

Extended accounts apply the concept of forest total income as the maximum consumption of forest products without diminishing their opening capital at the closing of the current period (European Communities, 2000: 87). An early description of our extended account framework, with an application at micro-scale, can be found in Campos (2000), Caparrós et al. (2003), Campos and Caparrós (2006), Campos et al. (2008), Ovando et al. (2016) and Oviedo et al. (2017). Details of recent advances in our extended account framework can be found in Campos et al. (2017a, 2017b) and Supplementary texts S1–S10, S12–S14, Tables S1–S16 and Figs. S1–S13 of this research.

Extended accounts estimate forest total income (TI) as the aggregation of net value added (NVA) and capital gain (CG) in a given period at producer and purchase prices (Campos et al., 2017a; Eisner, 1988; European Communities, 2000; Hicks, 1946; Krutilla, 1967; McElroy, 1976). Total income estimation requires production and capital balance residual values to be linked, which are, respectively, net operating margin (NOM) and capital revaluation (Cr) (Supplementary Fig. S13). To avoid double counting of capital income (CI), the capital gain (CG) estimate incorporates a capital gain adjustment (Cadj) (Campos et al., 2017a: SM 1). The AAS production account integrates the components that allow the net operating margin (NOM) to be estimated as its balancing item (total production minus total costs) (Supplementary Fig. S13 and Table S3). These AAS total income variables measured by each individual activity yield two relevant accounting identities: (i) net value added (operating income) and capital gain, and (ii) return allocation to production factors (for details see Campos et al., 2017a: SM 1):

$$TI = NVA + CG \quad (2)$$

$$TI = LC + CIm + EI, \quad (3)$$

where CIm is manufactured capital income and EI is environmental income.

2.3.1.1. Total product (TP).

This is classified as intermediate product (IP), which is used up in the same period by other forest activities in the same economic unit, and as final product (FP), which is separated into final product consumption (FPc) and gross capital formation (GCF) accumulated at the closing of the current period (Stone, 1984). GCF integrates natural growth (NG) standing at the closing of the period (Supplementary Tables S2–S3) and gross manufactured fixed capital formation (GFCFm):

$$TP = IP + FP \quad (4)$$

$$TP = IP + FPc + GCF \tag{5}$$

$$TP = IP + FPc + NG + GFCFm \tag{6}$$

2.3.1.2. Total cost (TC). This includes intermediate consumption (IC), labour cost (LC) and the consumption of manufactured fixed capital (CFC) at replacement price. Intermediate consumption (IC) stems from the forest intermediate product used by the forest activities as manufactured raw materials (RMm) and services (SSm) (both own and bought). In addition, IC includes environmental intermediate consumption (ICe) of work in progress used (WPu). Labour costs (LC) comprise only employees' compensation in this Andalusian forests application. To estimate the ecosystem services (ES) we differentiate between the ordinary total cost (TCo) originated from supplying the total product consumed (TPc) and the investment total cost (TCi) derived from the production of the gross fixed capital formation (GCF). TCi includes environmental consumption of fixed capital (CFCe) caused by forest carbon emission (SSe):

$$TC = IC + LC + CFC \tag{7}$$

$$TC = RMm + SSm + WPeu + LC + CFCm + SSe \tag{8}$$

$$TC = TCo + TCi \tag{9}$$

2.3.1.3. Forest capital (C). This is classified into environmental work in progress (WPe) and fixed capital (FC). The WPe incorporates current (standing trees) and future natural growth of trees alive in 2010. We term the former 'produced' (WPep) and the latter 'expected to be produced' (WPee) in the future considering the scheduled silviculture models (see Supplementary Fig. S1 and Table S2). The FC can be environmental fixed assets of land (EFAl), environmental fixed biological resources (EFAbr) and manufactured fixed capital (FCm). EFAl incorporates the growth of all future generations of trees that will replace the current generation in the future. Following a similar logic, EFAbr refers to the current period environmental fixed asset value of the standing fruit (acorn, pine nuts and chestnut), timber and cork producing trees with products harvested in multiple periods (e.g., cork and eucalyptus timber harvestings cycle are 9–10 years in Andalusia) until they finish their expected economic cycles as planned under the silviculture models (for details see Supplementary texts S1–S3). The current period cork and eucalyptus timber harvesting cycles are included in the stock of WPe. Total environmental asset (EA) reflects the discounted sum of the resource rent (RR) and is estimated as the sum of the environmental work in progress (WPe) and the environmental fixed asset (EFA):

$$C = WPe + FC \tag{10}$$

$$FC = EFAl + EFAbr + FCm \tag{11}$$

$$EA = WPe + EFAl + EFAbr \tag{12}$$

2.3.2. Environmental Income

Environmental incomes (EI) come from the services provided by environmental assets and are estimated by subtracting labour costs and market residual or imputed normal returns of manufactured capital from total income (see Eqs. (2) and (3) and Supplementary text S12). In the extended accounts, the EI components are the environmental net operating margin (NOMe) and the environmental asset gain (EAg). The challenge involved in these estimates is to measure the ordinary manufactured net operating margin (NOMmo) for each individual product. The ordinary environmental net operating margin (NOMeo) is estimated by subtracting the ordinary manufactured net operating margin (NOMmo) from the total ordinary net operating margin (NOMo). We assume that the NOMeo is non-negative, except for private amenity, carbon and public recreation products. Thus, we give a zero value to the NOMeo if Eq. (14) shows a negative value and we attribute this negative value to the NOMmo, which in this case is equivalent to the NOMo:

$$EI = NOMe + EAg \tag{13}$$

$$NOMeo = NOMo - NOMmon, \tag{14}$$

where NOMmon is normal manufactured net operating margin.

The three exceptions for which we admit the possibility of obtaining a negative NOMeo (private amenity, public recreation and carbon) have different explanations. In the case of private amenity and free access recreation, the assumed economic rationality is that the normal remuneration of manufactured capital must be guaranteed because in both activities the final consumption of its services is the main product; therefore, a negative NOMeo is possible if the NOMo is lower than the NOMmon.

In the case of forest carbon, the production account registers the fixation as final product consumption and the emission as environmental consumption of environmental fixed asset. However, these flows are not physically linked, so the difference between the fixation and the equivalent carbon emission can offer a positive or negative value. The farmer is not affected by carbon activity because he/she has the rights of free carbon emission and fixation under the current given institutional property rights in order to harvest the final woody products (timber, cork, firewood, and shrub (for details see Supplementary texts S1.7 and S3.3).

Environmental asset gain (EAg) components are environmental asset revaluation (EAr) and ad hoc instrumental adjustments (EAadj) of environmental withdrawal reclassifications (EAwrc). These withdrawals correspond to natural growth and carbon fixation valued at the opening of the current period. This instrumental reclassification avoids double counting when aggregating NOMe and EAg. More precisely, the accounting equations that estimate the environmental asset gain (EAg) and revaluations (EAr), both in the SEEA-EEA and the AAS do not include the EAwrc. That is, if we only consider registers in the asset balance or, alternatively, both in the production account and asset balance, the result of EI does not change. However, their allocation between environmental net operating margin and environmental asset gain would change.

Thus, the concepts defined by the SEEA-EEA of ES, environmental asset (EA) and environmental asset revaluation (EAr) allow the EI of the extended accounts (with work in progress and carbon fixation adjusted asset gain to avoid double counting) to be estimated. In this regard, the AAS methodology can be seen as a version of model B of the SEEA-EEA that provides the measurement of the EI as a novelty. The SEEA-EEA guidelines model B seems to be more suitable for accounting multiple biophysical and economic activity links. This approach offers the advantage of presenting an individual product function that incorporates all the factors of production (manufactured and environmental) of the two productive agents (farmer and government) considered to manage the economic activities of the forest. Model B favours simultaneous analysis of biophysical and economic results of the different private uses of the forest owners, together with the public uses directly managed by the government.

2.3.3. Ecosystem Services

In our extended accounts the concept of ecosystem services (ES) is restricted to the contribution of nature to the value of total products consumed directly or indirectly by humans during the period when they are extracted (e.g., when timber is harvested).

The value of an individual product consumed (TPc) represents the ordinary total cost and net operating margin (Eq. (15)):

$$TPc = ICmo + WPeu + LCo + CFCmo + NOMmo + NOMeo, \tag{15}$$

where ICmo is ordinary manufactured intermediate consumption, WPeu is intermediate consumption of environmental work in progress used (current period opening value of woody products harvested), LCo is ordinary labour cost, CFCmo is ordinary manufactured consumption of fixed capital, NOMmo is market or imputed normal return (the operating manufactured benefit obtained by the farmer or government in the current period from the product consumed) and NOMeo is ordinary environmental net operating margin (the operating environmental benefits obtained from nature based on farmer and government property rights). Among the full production factors of the product consumed in the above equation, WPeu and NOMeo are the components that show the contribution of nature to the TPc. That is, they represent the value of ecosystem services (ES). Rearranging Eq. (15), the value of ES is given by the next two identities:

$$ES = WPeu + NOMeo \tag{16}$$

$$ES = TPc - ICmo - LCo - CFCmo - NOMmo \tag{17}$$

The current period ecosystem service estimate does not show the contribution of nature to the expected potential future product consumption. In other words, current period ES does not refer to sustainable individual product consumption, except in the situation of economic and ecological steady state resource extraction. The current period natural growth accumulated in the forest, which will be used up as an input for future final product consumption, is not eligible as an ecosystem service in the current period. Thus, own-account environmental investment in the current period will be accounted in the future as a component of the ecosystem service. We solve the ES timing (temporization) problem of measuring the full contribution of nature to forest total product by the environmental income variable. The latter should be seen as the current period potential sustainable ecosystem service consumption that would sustain the forest environmental asset unchanged (La Notte et al., 2017: p. 32).

The environmental income Eq. (13) is instrumentally rearranged below to link it with current ecosystem services. We add and subtract to the right hand side in Eq. (13) WPeu to obtain two new EI identity components: the ES (Eq. (16)) and the WPeu adjusted to change of environmental net worth (CNWeadj) (Eq. (19)):

$$EI = ES + CNWeadj \tag{19}$$

$$CNWeadj = CNWe - WPeu \tag{20}$$

$$CNWe = NOMei + EAg \tag{21}$$

$$NOMei = NG - SSe \tag{22}$$

$$EAg = EAr + EAadj \tag{23}$$

$$EAr = EAc - EAo + EAw - EAe, \tag{24}$$

where NOMei is environmental investment net operating margin, CNWe is change of environmental net worth, EAc is closing environmental asset, EAo is opening environmental asset, EAw is withdrawals of environmental asset and EAe is entries of environmental asset.

2.3.4. Revised Value Added and Ecosystem Services of the Standard Accounts

In the standard accounts, the absence of manufactured and environmental costs linked to the omission of accumulated natural growth and the valuation of the manufactured gross fixed capital formation on own-account (GFCFm) at production cost lead to the ordinary net operating surplus (NOSo) coinciding with the total net operating surplus of the activity (NOS). Revising the gross and net values added (GVA_r/NVA_r) of the SNA applied to the Andalusian forests gives the revised gross and net operating surplus (GOSr/NOSr). The slight change in the conventional GOS and NOS consists of subtracting the stumpage values of the harvested environmental work in progress products (WPeu) of timber, cork and firewood in order to estimate the GOSr and NOSr. This change is effected to reclassify the WPeu standard accounts resource rent as an environmental cost of intermediate consumption when estimating the NOSr.

The standard measure of the revised final product (FPr) can be shown as the aggregate value of the production factors of labour, investment in manufactured capital and ecosystem services. The production and income generation accounts of the SNA and the SEEA-EEA are presented in a slightly modified form in the Results section (European Commission et al., 2009: Table 16.4, p. 336; United Nations, 2017: Table 8.2, p. 135). The revised gross value added (GVAr) is estimated by subtracting the WPeu from the standard gross value added (GVA_{SNA}):

$$FPr = ICm + LCm + CFCm + NOS, \tag{25}$$

$$NOS = NOSr + WPeu, \tag{26}$$

$$NOSr = NOSer + NOSm, \tag{27}$$

$$FPr = ICm + LCm + CFCm + NOSm + NOSer + WPeu, \tag{28}$$

$$ES = NOSer + WPeu = FPr - ICm - LCm - CFCm - NOSm, \tag{29}$$

$$GVAr = GVA_{SNA} - WPeu, \tag{30}$$

2.4. Forest Products Valuation

Extended account valuation methods are consistent with the SNA exchange value principle. However, we expand the valuation of public economic activities beyond production cost valuation practices in national accounting. Fig. 2 summarizes the valuation methods applied for measuring each individual product in our application. Sub-sections below summarize these methods.

2.4.1. Market Product Valuations

This section describes the activities in which products are traded in markets or not traded in markets but for which similar markets exist.

2.4.1.1. Timber, Cork, Firewood and Nuts (Pine Nuts and Chestnuts). These are harvested products and natural growth accumulated at the closing of the period (except for nuts, for which natural growth is irrelevant as the product does not last beyond an accounting period). Total product consumed is estimated by multiplying the quantity of harvested product by its road-side producer price. Natural growth value is estimated by multiplying the quantity of woody accumulated natural growth in the current period by its environmental price (defined as unitary resource rent). Estimating the physical quantity of natural growth of woody products requires scheduled silviculture modeling per individual species, age and site environmental conditions (see Supplementary text S1 to S3).

2.4.1.2. Grazing. This is the resource rent from forage unit consumption (assuming that the environmental asset gain of grazing is null). The products are acorn and grass (including browse and other fruits), which are intermediate products used up as own intermediate consumption by the livestock activity (outside forest accounts in this application). Acorn product consumption is estimated as the part of holm oak biological acorn yield, estimated through forest site empirical modeling that is grazed (consumed) by livestock (Supplementary text S8). We model livestock total physical consumption of fodder and estimate physical forage units grazed as the residual quantity resulting from subtracting supplemented fodder consumption from total fodder consumption. Grazing market lease prices are estimated from the survey of 765 non-industrial private forest landowners (Supplementary text S9.1) and manufactured costs of grazing from a sub-sample of the forest farm case studies (Supplementary text S8). Grass and browse grazing forage units are valued as the physical quantity of grazing forage units times grazing lease price (Campos et al., 2016).

2.4.1.3. Hunting. Game species are legally a public environmental asset for which the landowner has the exclusive right to market hunting captures. Thus, in practice, the heads of game expected to be hunted is a private good, even before the capture occurs, and the hunting environmental asset is embedded in the market price of the forest

Class	Unit	Quantity	Price
Timber and firewood natural growth	m^3	IFN3/F	M/NPV
Cork natural growth	kg	IFN3/F	M/NPV
Acorn yield	kg	IFN3/F/S	S/NPV
Grass	kg	F/S	S/NPV
Game inventory	he	F/AMAYA	S/NPV
Game captures	he	CMAYOT/F	M/E/NPV
Private amenity	ha	S	S/CVM/NPV
Land	ha	S	S/CVM/NPV
Mushroom	kg	S	S/M/NPV
Carbon	t	IFN3/F	M/NPV
Regulated water yield	m^3	AMAYA/HPM	HPM
Public recreation	vi	CEM/CVM	CVM/F/SEV
Landscape	ha	CEM/F	CEM/F/SEV
Threatened biodiversity	N	CMAYOT	CEM/F/SEV
Government expenditures	ha	S/CMAYOT	S/M

Fig. 2. Methods applied to value forest products in Andalusia.
Abbreviations: AMAYA is Environment and Water Agency of Andalusia, he is game animal head, ha is hectare, CMAYOT is department of environment and territory planning of Andalusia, CEM is Choice experiment method, S is *ad hoc* survey, F: production function, IFN3 is third national inventory, kg is kilogram, M is market, m^3 is cubic meter, HPM is hedonic price method, N is number of threatened biological species, t is metric ton, vi is visit, CVM is contingent valuation method, NPV is net present value and SEV is simulated exchange value.

property. We consider that hunting captures valued at their environmental prices represent a proxy substitute for forest game fodder grazing (Supplementary text S7 and Table S10). Intermediate products of hunting are valued, assuming a steady state of the animal population, by physical captures times the environmental market price of the captured game (Martínez-Jauregui et al., 2016).

2.4.1.4. Landowner Residential House. This is an activity devoted exclusively to support the self-consumption of private amenities by the non-industrial landowner. It is an intermediate product valued at the observed market real estate lease price in the area. This product is used up as own intermediate consumption by the private amenity activity of the family non-industrial landowner.

2.4.1.5. Mushroom Picking. This is the resource rent appropriated by recreational mushroom gatherers during the accounting period. Wild mushrooms are legally a private environmental asset but, in practice, in Andalusian forests they are a public good gathered under free access in public and private properties (private landowners have difficulties in enforcing access restriction so that in practice they allow free access to their properties for mushroom picking). Therefore, the mushroom environmental asset is not embedded in the forest market price and we consider it a public activity. The final products associated with mushrooms are the aggregate value of mushroom-picking (harvest) valued at imputed market price (from local markets) and government gross manufactured fixed capital formation valued at production cost (Supplementary text S6). Mushroom picking only has government management manufactured costs. We assume that the opportunity cost for mushroom picking leisure time is zero. We also assume a steady scenario for mushroom management. Mushrooms are collected by public recreational visitors in public and private properties and almost all mushrooms collected are self-consumed. There is a local competitive market for mushrooms that is the source of the market prices imputed to mushrooms. The resource rent in the current period is estimated as the physical quantity of mushrooms collected times the imputed market price minus governmental manufactured costs (see Supplementary material S6). In the assumed context of the steady state of the environmental asset, the resource rent tends to coincide with the environmental income.

2.4.1.6. Carbon Fixation and Emission. Carbon fixation and emission are valued using the European Union Emissions Trading Scheme price for carbon allowances as a proxy, although the observed price is reduced to take into account the impact that the inclusion of forest carbon activity would have on carbon prices (for details see Supplementary texts S1.7 and S3.3).

2.4.1.7. Landowner Conservation Forestry and Government Fire Services. Conservation forestry activity refers to silvicultural work services, under the landowner's responsibility and compensated through government payments to landowners, which have the primary purpose of being used up in the current period as inputs (own intermediate consumption) to maintain and/or enhance public landscape conservation. They are valued at government ordinary production cost (Ovando et al., 2016). Government fire services refer to firefighting and public forest trail work services.

2.4.2. Non-market Product Valuations

This section describes the activities associated with products that are not traded in markets, and for which no similar markets exists. In all cases, except for water (see below), we apply the Simulated Exchange Value (SEV) method. That is, we simulate the entire market (demand and supply) to determine, within a context of a partial equilibrium analysis, what the marginal price and quantity of the final product would be if the product had been traded in the market. While non-market valuation alone estimates demand and usually focuses on consumer surplus, the simulated exchange value method determines which part of this consumer surplus would be internalized in a potentially implemented market (Caparrós et al., 2017 and Supplementary text S10). We applied the SEV method to four non-market forest products: public recreation, threatened biodiversity, landscape conservation and private amenities. We did not check whether a partial equilibrium framework is appropriate as this is beyond the scope of our study. However, note that this is a common practice in standard accounts when simulated values are used.

2.4.2.1. Public Recreation. This is the final consumption of recreational services of the forest free of charge. Visitors enjoy free access recreation in Andalusian forests in recreational areas and hiking trails that are provided by the public administration in its properties. However, as free-access is not a legal right, but a de facto situation, a scenario in which visitors would need to pay for access is feasible. In this context, the final product consumption is captured by the visitors (Caparrós et al., 2017). We valued this final product consumption through two non-market valuation face-to-face surveys: a survey of free-access forest visitors in Andalusia (4030 questionnaires), and a survey of households (3214 questionnaires in Andalusia and 836 questionnaires in the rest of Spain). The number of visits to different forest areas in Andalusia is estimated from the household survey. No public recreation consumption is assigned to areas that did not receive visits according to this survey. The monetary value of public recreation is based on the visitor's willingness to pay for one particular forest area using a single-bounded contingent valuation question. A conditional logit function with two alternatives was estimated based on a contingent valuation survey conducted among visitors to 9 selected forest areas (Supplementary text S9.2). Using the particular forest area as an explanatory variable, the function estimates the probability that a visitor would pay a specific amount of money to access the area (for forest areas with visitors but not included in the 9 areas investigated, we use the values of the most similar area investigated). Determining this probability and the number of visitors during the initial non-payment situation we estimate one Marshallian demand function for each relevant forest area (assuming no income effects to simplify). With respect to market structure, the forest areas are assumed to operate under monopolistic competition in the short run (because they are similar, although sufficiently differentiated goods). Adding the assumption that costs are constant, the simulated exchange value is given by the price that would maximize the revenue in each natural area. However, to simplify the calculations we use the median willingness to pay obtained times half of the total annual visits to each forest area identified as receiving free-access visits, as this is a reasonable approximation (for details see Supplementary text S10.1 and Caparrós et al. (2017)).

2.4.2.2. Threatened Wild Biodiversity. The threatened biodiversity product can be defined as the maximum amount that could be internalized out of the passive consumers' willingness to pay (WTP) to ensure that none of the wildlife species under threat in the region of Andalusia will be lost forever. This is estimated by assuming a payment, additional to the current government cost, to manage threatened biodiversity over the next 30 years without loss of unique species. This value has been measured together with the landscape conservation value by using a choice experiment survey and the simulated exchange value method, although values of landscape conservation and existence of wild biological biodiversity have been differentiated (Supplementary texts S9.3, S10.2 and S14). As detailed in the Supplementary text S10.2, these values were estimated using a single probability function based on a mixed logit model and then finding the value that maximizes the revenue from the simulated payment for ecosystem services scheme. We estimate the final product consumptions as the aggregate value of government ordinary total cost plus the simulated exchange value for the landscape conservation and threatened biodiversity services.

2.4.2.3. Landscape Conservation. We defined landscape conservation activity as the final product of landscape service consumed by the Andalusian population, represented as the maximum amount that could be internalized out of the passive consumers' willingness to pay (WTP) to ensure that the current main tree vegetations of Andalusian forests will maintain their current area in the long-term (about 30 years). As already mentioned, this value has been measured together with the threatened biodiversity value by using a choice experiment and the same valuation criteria.

2.4.2.4. Private Amenity. This represents the exclusive services which are self-consumed by non-industrial forest landowners associated with private land ownership (Oviedo et al., 2015, 2017). While the consumption of this final product is not traded in a formal market, its asset value is part of the market price of the land. In public farms these products are not actively consumed but would affect the market price of the land due to the willingness to pay of potential private buyers and investors for the self-consumption of these services. We estimate the private amenity product using the results of a single-bounded contingent valuation (CV) question included in the survey of 765 non-industrial private forest landowners. Landowners were asked whether they would accept, or not, a specific annual amount of money from an alternative investment in order to give up their property and therefore their land amenities (Supplementary text S9.1).

2.4.2.5. Water Yield. Water yield activity is defined as the water resource rent appropriated by landowners of irrigated agricultural farms. The final product with an economic value of forest water activity is made up of the superficial water run-off and superficial springs that reach a regulated reservoir in Andalusia and is used for irrigation (85%), and industry and household consumptions (15%), excluding the quantity of water released as ecological flow. We apply the Soil and Water Assessment Tool (SWAT) to simulate numerically the natural water balance of 44 hydrological response units (reservoirs) for all the tiles in the Spanish National Forest Map corresponding to Andalusia (Supplementary text S4). The environmental price of regulated water is estimated using the hedonic price incorporated into the price of the land with water concessions for irrigated crops in the basin of the Guadalquivir River (Berbel and Mesa, 2007). This final product consumption for water is valued by its environmental price times the quantity used up by irrigated crops and other industry and household consumptions. We have not identified government costs for forest water yield.

3. Results

This section presents the results of the extended accounts applied to the forests in Andalusia. We also compare the extended accounts (AAS) results to those estimated by applying the standard economic account for forestry (EAF) and a slightly modified version of the system of national accounts (these modifications are detailed in Supplementary text S11 and are needed to permit a consistent comparison). As previously explained, we refer to this modified version of the SNA as 'revised standard accounts (SNAr)' (see Supplementary text S11).

According to the extended account results, total opening forest capital comprised 94% environmental assets and 6% manufactured capital, with farmer and government activities sharing 50% of this total opening capital (Table 1). Total manufactured capital was evenly distributed between farmer and the government, with the latter holding 18% of manufactured capital (Table 1). The capital balance shows devaluation (negative capital revaluation) of fixed capital at the closing of the period of −509.6 million euros, with a drop in manufactured and land amenity price capitals contributing, respectively, −132,5 and −686,1 million euros to this devaluation of fixed capital (Table 2 and Supplementary Table S2). In 2010 in Spain there was a notable decline in land and construction prices, which explains the fall in the value of manufactured capital, even after depreciation has been taken into account (depreciation at the replacement price has been estimated for all tangible and intangible manufactured investments).

We present the balance and production extended accounts indicators in Table 3, adapting the SNA and SEEA-EEA summary

Table 1
Extended opening capital of Andalusian forests (2010).

Class	Environmental asset			Manufactured capital			Opening capital		
	Farmer	Government	Total	Farmer	Government	Total	Farmer	Government	Total
	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)	(€·10^6)
Timber	1387		1387	226		226	1613		1613
Cork	1023		1023	12		12	1035		1035
Firewood	322		322	0		0	322		322
Nuts	23		23	0		0	23		23
Grazing	2058		2058	58		58	2116		2116
Conservation forestry				127		127	127		127
Hunting	767		767				767		767
Residential				1600		1600	1600		1600
Amenity	14,355		14,355				14,355		14,355
Fire services					196	196		196	196
Recreation		5941	5941		218	218		6159	6159
Mushrooms		1414	1414		5	5		1419	1419
Carbon		3172	3172					3172	3172
Landscape		4928	4928		13	13		4937	4941
Biodiversity		1676	1676		26	26		1702	1702
Water		4132	4132		0	0		4132	4132
Total	19,934	21,263	41,197	2023	458	2481	21,958	21,717	43,679

production, generation, accumulation and balance extended accounts (United Nations, 2017: Table 8.2, p. 135) and SNA (European Commission et al., 2009: Tables 16.4–16.5, pp. 336, 338–339). Full balance and production extended accounts are presented in Supplementary Tables S2–S3. We now go on to describe the logic of the results presented in Table 3.

Firstly. Row 1 shows the total products consumed with and without embedded ecosystem services by farmer and government activities. Only conservation forestry, residential service and fire service activities have no potential current or future ecosystem services embedded in their product consumed. Nevertheless, these three manufactured activities supply intermediate products to be used as own intermediate consumption (ICmo) by other farmers (private amenity) and by the government (public recreation, landscape and biodiversity) activities, which have ES embedded. Rows 2–6 present the shared values of individual production factors that contribute to the values of TPc (ES, ICmo, LCo, CFCmo and NOMmo). Row 7 refers to the ordinary net value added (NVAo) that accrues from the products consumed. Ordinary refers to the NVAo generated only from total product consumed, that is, it excludes the activity investment net value added (NVAi) originated by the production of own account gross capital formation (GCF). Row 8 is GCF and rows 9–12 present the same logic as rows 2–6 applied to GCF products. Row 13 is NVAi. Row 14 presents the net value added (NVA) of full activities as the aggregation of the values of production and generation income accounts (see European Commission et al., 2009: Tables 16.4–16.5, pp. 336, 338–339). This is similar to Table 8.2: "Simplified sequence of accounts for ecosystem accounting" in the recent SEEA-EEA TR report (see United Nations, 2017: Table 8.2, p. 135).

Secondly. Rows 15–17 summarize the estimate of capital gain as the total income component that accrues from capital balance (see Table 3 and Supplementary Table S3). Rows 18–19 measure the change in environmental net worth (CNWe) and an instrumental WPeu and carbon FPc adjusted change in environmental net worth (CNWeadj). This adjustment makes it possible to measure EI as the ES value plus CNWeadj (Table 4). *Finally*, row 20 presents the allocation to the total income between manufactured (TIm) and nature (EI) production factors.

Farmer private amenity self-consumption stands out with respect to other forest products, with a final product value 25 times greater than that of final products sold (timber, cork, firewood and nuts) (Supplementary Table S3). The management of Andalusian forest oriented towards the consumption of non-market amenity products by non-industrial private landowners is explained partly by a dominance of private ownership (73% private versus 27% public) and partly by private landowners' preferences towards recreational, lifestyle and leisure-related motivations for owning a forest property (Oviedo et al., 2017). Although the contribution of most public non-market products is not particularly noteworthy when considered individually, when considered all together (e.g. public recreation, landscape and threatened biodiversity) the value slightly exceeds the contribution of private amenity to total income (Tables 3 and Supplementary Table S3).

The gross value added of the forest differs dramatically between extended and revised standard accounts: this figure is 3.6 times higher when estimated using extended accounts (Table 4). This difference is mainly explained by the omission of carbon activity and environmental net operating margin of non-market products consumed (private amenity, threatened biodiversity, public recreation and landscape) in standard accounts. Extended accounts estimate a gross value added that is 11.4 times higher than that estimated by the standard economic account for forestry (EAF) (IECA, 2015). While extended accounts estimate capital gains of −601.8 million euros (that is, capital losses), mainly due to the depreciation of environmental assets of land in 2010 (Table 4), standard accounts do not measure forest capital gains. Gross capital formation is 47.4 million euros in standard accounts and 85.361 million euros in extended accounts (Table 3 and Supplementary Table S3), as the latter incorporate the natural growth of timber and cork activities. Total income of Andalusian forest, which adds capital gain to the net value added, can only be measured by extended accounts and reaches a value of 1685.8 million euros in 2010 (Tables 3, 4).

The gross value added as measured by the standard EAF represents only 0.1% of total gross value added for the region of Andalusia and 3.2% of the gross value added (GVA) of the primary sector in Andalusia (European Communities, 2000; IECA, 2015). When applying extended accounts, the forest GVA contributions rise to 0.5% for the standard accounts and 35.4% of the primary sector GVA for the region, respectively (Table 4 and IECA, 2015). As can be seen, the implications for the primary sector are immense.

Environmental income accounts for 84% of total income (Tables 3, 4). The largest share of this environmental income comes from farmer private amenity (28%) and implicitly in EAF market products (17%), and is followed by water (20%), carbon (12%), landscape (10%), public recreation (7%), threatened biodiversity (3%) and mushroom picking (3%) (Table 4). Fig. 3 presents a group of maps showing spatially-explicit estimates of this environmental income by individual product.

Table 2
Extended capital balance of Andalusian forests (2010).

Class	1. Opening capital	2. Capital entries				3. Capital withdrawals					4. Capital revaluation	5. Closing capital
		2.1 Bought	2.2 Own	2.3 Other	2.4 Total	3.1 Used	3.2 Destructions	3.3. Reclassification	3.4 Other	3.5 Total		
	(Co)	(Ceb)	(Ceo)	(Ceot)	(Ce)	(Cwu)	(Cwd)	(Cwrc)	(Cwot)	(Cw)	(Cr)	(Cc)
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Environmental asset (EA)	41,197,177	0	37,953	224,578	262,531	30,476		254,885	65,830	351,191	−269,294	40,839,224
1.1 Farmer	19,934,484	0	37,953	0	37,953	30,476		36,848	0	67,324	−497,192	19,407,921
1.1.1 Timber	1386,694		14,665		14,665	7632		14,238		21,869	91,001	1470,490
1.1.2 Cork	1023,115		22,790		22,790	22,496		22,126		44,623	79,854	1081,137
1.1.3 Firewood	321,550		499		499	348		484		833	14,321	335,537
1.1.4 Nuts	22,767										791	23,559
1.1.5 Grazing	2058,198										2982	2061,180
1.1.6 Hunting	767,102										0	767,102
1.1.7 Amenity	14,355,058										−686,140	13,668,917
1.2 Government	21,262,693	0	0	224,578	224,578	0	0	218,037	65,830	283,867	227,898	21,431,302
1.2.1 Recreation	5941,174										0	5941,174
1.2.2 Mushrooms	1414,138										0	1414,138
1.2.3 Carbon	3171,608			224,578	224,578			218,037	65,830	283,867	227,898	3340,217
1.2.4 Landscape	4928,297										0	4928,297
1.2.5 Biodiversity	1675,544										0	1675,544
1.2.6 Water	4131,933										0	4131,933
2. Manufactured (Cm)	2481,494	1862	47,407		49,269				6		−132,553	2398,205
2.1 Farmer	2023,794	0	19,264	0	19,264						−101,067	1941,991
2.1.1 Plantations	224,453		19,264		19,264						525	244,242
2.1.2 Constructions	1799,341										−101,592	1697,749
2.2 Government	457,699	1862	28,144	0	30,006				6	6	−31,486	456,213
2.2.1 Plantations	0		71		71						−1	70
2.2.2 Constructions	380,610		20,637		20,637						−24,026	377,220
2.2.3 Equipment	14,111	1862			1862				6	6	−677	15,290
2.2.4 Others	62,979		7436		7436						−6782	63,633
Total (C)	43,678,671	1862	85,361	224,578	311,801	30,476	0	254,885	65,836	351,197	−401,847	43,237,428

Table 3
Summary production, regeneration, accumulation and capital balance extended accounts applied in Andalusian forests (2010).

Class	Timber	Cork	Firewood	Nuts	Grazing	Conservation forestry	Hunting	Residential	Amenity
	1	2	3	4	5	6	7	8	9
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Total product consumption (TPc)	19,509	49,147	2325	2868	66,608	34,673	26,418	51,508	1134,735
2. Ecosystem services (ES)	7632	22,496	1359		33,334		26,418		1083,227
2.1 Environmental work in progress used (WPeu)	7632	22,496	348						
2.2 Ordinary environmental net operating margin (NOMeo)			1010		33,334		26,418		1083,227
3. Ordinary manufactured intermediate consumption (ICmo)	24,562	23,926	319	2535	1681	11,688		2732	51,508
4. Ordinary labour cost (LCo)	117,628	4836	486	16,059	9411	21,584		11,023	
5. Ordinary manufactured consumption of fixed capital (CFCmo)	5302		7	347	3166	1210		19,779	
6. Ordinary manufactured net operating margin (NOMmo)	−135,615	−2112	155	−16,073	19,016	191		17,974	
7. Ordinary net value added (NVAo)	−17,987	2724	1651	−13	61,762	21,775	26,418	28,997	1083,227
8. Gross capital formation (GCF)	14,665	22,790	499			19,264			
8.1 Manufactured (GCFm)						19,264			
8.2 Environmental (GCFe)	14,665	22,790	499						
9. Investment manufactured intermediate consumption (ICmi)						6767			
10. Investment labour cost (LCi)						12,497			
11. Investment manufactured consumption of fixed capital (CFCi)									
11.1 Manufactured (CFCmi)									
11.2 Environmental (CFCe)									
12. Investment net operating margin (NOMi)	14,665	22,790	499						
12.1 Manufactured (NOMmi)									
12.2 Environmental (NOMei)	14,665	22,790	499						
13. Investment net value added (NVAi)	14,665	22,790	499			12,497			
14. Net value added (NVA)	−3322	25,514	2150	−13	61,762	34,271	26,418	28,997	1083,227
14.1 Labour cost (LC)	117,628	4836	486	16,059	9411	34,080		11,023	
14.2 Net operating margin (NOM)	−120,950	20,679	1664	−16,073	52,351	191	26,418	17,974	1083,227
15. Capital gain (CG)	77,676	57,318	13,845	1010	4167	1101		−74,538	−686,140
15.1 Manufactured (CGm)	913	−409	8	219	1185	1101		−74,538	
15.2 Environmental (EAg)	76,763	57,728	13,837	791	2982				−686,140
16. Environmental asset revaluation (EAr)	91,001	79,854	14,321	791	2982				−686,140
17. Environmental asset adjustment (EAadj)	−14,238	−22,126	−484	0	0				
18. Change of environmental net worth (CNWe)	91,428	80,518	14,336	791	2982				−686,140
19 WPeu adjusted change of environmental net worth (CNWeadj)	83,796	58,022	13,987	791	2982				−686,140
20. Total income (TI)	74,354	82,833	15,994	997	65,928	35,372	26,418	−45,542	397,087
20.1 Manufactures total income (TIm)	−17,074	2315	649	206	29,613	35,372		−45,542	
20.2 Environmental (EI)	91,428	80,518	15,346	791	36,316		26,418		397,087

Class	Farmer	Fire services	Recreation	Mushrooms	Carbon	Landscape	Biodiversity	Water	Government	Total
	10 = Σ1–9	11	12	13	14	15	16	17	18 = Σ11–17	19 = 10 + 18
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Total product consumption (TPc)	1387,792	170,930	202,713	43,093	224,578	384,717	75,303	277,649	1378,983	2766,776
2. Ecosystem services (ES)	1174,466		94,580	40,938	224,578	149,015	40,254	277,649	827,014	2001,480
2.1 Environmental work in progress used (WPeu)	30,476									30,476
2.2 Ordinary environmental net operating margin (NOMeo)	1143,989		94,580	40,938	224,578	149,015	40,254	277,649	827,014	1971,004
3. Ordinary manufactured intermediate consumption (ICmo)	118,952	50,649	14,584	121		206,258	6638		278,250	397,201
4. Ordinary labour cost (LCo)	181,027	108,062	17,323	266		18,439	14,452		158,543	339,569

(*continued on next page*)

Table 3 (*continued*)

Class	Farmer	Fire services	Recreation	Mushrooms	Carbon	Landscape	Biodiversity	Water	Government	Total
	10 = Σ1–9	11	12	13	14	15	16	17	18 = Σ11–1-7	19 = 1-0 + 18
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
5. Ordinary manufactured consumption of fixed capital (CFCmo)	29,811	11,985	7268	114		3322	2934		25,623	55,434
6. Ordinary manufactured net operating margin (NOMmo)	−116,463	235	68,958	1654		7683	11,024		89,554	−26,909
7. Ordinary net value added (NVAo)	1208,553	108,297	180,861	42,858	224,578	175,136	65,731	277,649	1075,111	2283,664
8. Gross capital formation (GCF)	57,217	15,904	4983	145		2895	4216		28,144	85,361
8.1 Manufactured (GCFm)	19,264	15,904	4983	145		2895	4216		28,144	47,407
8.2 Environmental (GCFe)	37,953									37,953
9. Investment manufactured intermediate consumption (ICmi)	6767	5075	1437	45		898	1317		8772	15,540
10. Investment labour cost (LCi)	12,497	10,829	3547	100		1997	2899		19,371	31,868
11. Investment manufactured consumption of fixed capital (CFCi)					65,830				65,830	65,830
11.1 Manufactured (CFCmi)										
11.2 Environmental (CFCe)					65,830				65,830	65,830
12. Investment net operating margin (NOMi)	37,953				−65,830				−65,830	−27,876
12.1 Manufactured (NOMmi)									0	0
12.2 Environmental (NOMei)	37,953				−65,830				−65,830	−27,876
13. Investment net value added (NVAi)	50,450	10,829	3547	100	−65,830	1997	2899		−46,459	3991
14. Net value added (NVA)	1259,003	119,125	184,408	42,958	158,748	177,133	68,630	277,649	1028,652	2287,656
14.1 Labour cost (LC)	193,523	118,890	20,870	366		20,436	17,352		177,914	371,437
14.2 Net operating margin (NOM)	1065,480	235	163,538	42,592	158,748	156,698	51,279	277,649	850,739	1916,219
15. Capital gain (CG)	−605,562	−8901	930	−112	9861	1577	369		3724	−601,838
15.1 Manufactured (CGm)	−71,522	−8901	930	−112		1577	369		−6136	−77,659
15.2 Environmental (EAg)	−534,040				9861				9861	−524,179
16. Environmental asset revaluation (EAr)	−497,192				227,898				227,898	−269,294
17. Environmental asset adjustment (EAadj)	−36,848				−218,037				−218,037	−254,885
18. Change of environmental net worth (CNWe)	−496,087				−55,969				−55,969	−552,056
19 WPeu adjusted change of environmental net worth (CNWeadj)	−526,563				−55,969				−55,969	−582,532
20. Total income (TI)	653,441	110,224	185,337	42,846	168,609	178,711	69,000	277,649	1032,377	1685,818
20.1 Manufactures total income (TIm)	5538	110,224	90,758	1908		29,696	28,746		261,331	266,869
20.2 Environmental (EI)	647,903		94,580	40,938	168,609	149,015	40,254	277,649	771,045	1418,948

Source: on elaboration after SEAA-EEA (United Nations, 2017: Table 8.2, p. 135) and SNA (European Commission et al., 2009: Tables 16.4–16.5, pp. 336, 338–339).

Additional maps with detailed spatially-explicit results are available at http://vicaf.cchs.csic.es (access user name: guest1, and password: Hal024Euc61Pi23f).

The value of ecosystem services represents 72% of total product consumption, of which 59% is contributed by farmer products (with commercial products constituting 5% and private amenity 54%) and 41% by government products (water 14%, carbon 11%, landscape 8%, recreation 5%, threatened biodiversity 2% and mushroom picking 2%) (Tables 3–5). Following the standard classification of ecosystem services (Haines-Young and Potschin, 2013), the estimated values break down into 20% for provisioning services, 21% for regulating services and 59% for cultural services (Table 5). Fig. 4 shows a map of spatially-explicit values of these forest ecosystem services. Extended accounts, with their implementation of simulated exchange values, measure a value for Andalusian forest ecosystem services which are 5.4 times higher than that estimated using the valuation criteria of standard accounts.

4. Discussion

4.1. Comparison With Previous SEEA-EEA Selected Applications

In this subsection we compare the concept and valuation criteria of the ecosystem services estimated in our extended accounts approach with four other forest and cropland ecosystem service valuation case studies that applied the SEEA-EEA guidelines (Fig. 5). The studies are characterized according to location, size of studied area, types of landscapes, measured ecosystem services and valuation methods used (Fig. 5).

There are both coincidences and discrepancies among these studies with regard to the concept of ecosystem services and the valuation methods employed for the same type of ecosystem service. The services valued are not all of those which are present in the landscapes of these case studies and differ notably from one to another, especially for cultural and regulating ecosystem services (see Fig. 5). All the case studies measure the ecosystem services embedded in forest products consumed in the accounting period and are valued in accordance with their resource rents. In addition, our case study values the natural growth of woody products and the net growth of the settled game species accumulated in the forest at the closing of the current period.

Public recreational services consumed by free access visitors are valued by the resource rent of the offsite recreational services appropriated by the tourist industries in the case studies of Central Calimatan (Sumarga et al., 2015), Limburg (Remme et al., 2015) and Central Highlands (Keith et al., 2017). In the United Kingdom (EFTEC, 2015), free access recreational services are valued by the consumer surplus derived from a meta-analysis of stated preference surveys in UK woodlands. Only in our case-study is on-site free access recreational service enjoyed by visitors valued according to its resource rent obtained after applying the simulated exchange value method.

Several ecosystem services are valued using the alternative production function technology: (i) differential costs of water yield in Limburg and Central Highlands and (ii) cost of mitigation of carbon release in the UK. Our study values the ecosystem provisioning services of forest water yield appropriated by farmers of irrigated land by their environmental price (unit resource rent) estimated from the hedonic price of the water used from the public reservoirs. The forest water resource rent is embedded in the irrigated agricultural products.

Economic accounts are more developed in the Central Calimatan and Limburg case studies as well as in our case study. The development of national extended accounts is essential to clearly establish the interactions between activities of the same economic unit and with other economic units. In the absence of a complete SNA-type-wide system with geo-referenced attributes and individual product accounts, the omissions and double accounting of ecosystem services and assets may be aggravated by the difficulties of modeling the dynamics of productive interactions between products, ecosystem services and assets. The incorporation of intermediate products by the extended accounts applied in Andalusia mitigates to a large extent these problems.

The case studies cited above rely almost exclusively on existing data, which limits considerably the scope of the applications. This limitation does not apply to our case study, as the regional government of Andalusia funded the research needed to produce new data and provided some of the primary information not accessible for public use.

4.2. Extended Account Strengths and Weaknesses

The contribution of our extended accounts is threefold. *Firstly*, extended accounts improve upon standard accounts in that they explicitly measure the environmental asset variations and natural growth used and in that they treat manufactured capital and environmental assets in an integrated way. This entails: (i) explicitly considering the 'own work-in-progress' used up (e.g. standing timber or cork harvested) in the current period, but grown in previous periods, as intermediate consumption, which avoids attributing the product from a previous period as income from the current period; (ii) measuring both environmental fixed asset services (e.g. land and standing biological resources), and the intermediate consumption of 'own environmental services' (e.g. carbon emission) as production function factors, allowing for a consistent integration of these values into the ecosystem extended accounts; and (iii) calculating environmental income as environmental asset gain plus environmental net operating margin, thus making this estimate consistent with the concept of total income and SNA valuation criterion.

Secondly, we apply the simulated exchange value (SEV) at regional scale, a method that aims to simulate market values for non-market ecosystem products for which no similar market exists (e.g., private amenity, public recreation, landscape and threatened biodiversity). Despite the existence of well-developed literature on non-market valuation methods and an increasing interest in extending the production boundary of standard accounts to non-market products (Atkinson and Obst, 2017; Obst et al., 2013, 2016), most valuation studies tend to focus only on the demand for non-market products and the associated consumer surplus (Bishop et al., 2017). This approach does not produce values that can be consistently aggregated to the exchange values observed in markets and incorporated into standard accounts. To overcome this difficulty, the SEV method simulates the entire market, using non-market valuation methods to estimate demand and market data to estimate supply. This allows us to consistently integrate and compare values of market products such as timber, with values of non-market products such as public recreation, both estimated based on consumer preferences (Caparrós et al., 2003, 2017; Howarth and Farber, 2002). This is not only of theoretical interest but also has significant practical implications, improving upon the government production cost base valuation criterion applied to public non-market products in standard accounts. It is also more consistent than previous approaches that aggregated consumer surplus estimates and market values, such as the pioneering valuation of Earth ecosystem services by Costanza et al. (1997, 2014a, 2014b) and the UK National Ecosystem Assessment (UK NEA) (Bateman et al., 2013a, 2013b).

Thirdly, our extended accounts measure the economic value of ecosystem services and environmental income for each activity in the forest, offering relevant information for all agents interested in the interaction between ecosystem assets and services and a country's economy. These individual values cannot be measured by standard accounts.

If only economic ecosystem accounts are considered, the conceptual production and capital accounts in our framework are similar to the SEEA-EEA supply and use account and the SEEA-CF asset balance (United Nations et al., 2014a, 2014b). Both accounting approaches coincide as regards the concepts of ecosystem services and their assets valued at their observed, imputed or simulated exchange value. The

Table 4
Extended and standard accounts indicators comparison in Andalusian forests (2010).

Class	Timber	Cork	Fire-wood	Nuts	Grazing	Conservation forestry	Hunting	Residential	Amenity
	1	2	3	4	5	6	7	8	9
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
Extended accounts indicators (AAS)[a]									
1. Gross value added (GVA)	1979	25,514	2157	334	64,928	35,481	26,418	48,776	1083,227
2. Net value added (NVA)	−3322	25,514	2150	−13	61,762	34,271	26,418	28,997	1083,227
3. Capital gain (CG)	77,676	57,318	13,845	1010	4167	1101		−74,538	−686,140
4. Capital income (CI)	−43,274	77,997	15,509	−15,062	56,517	1292	26,418	−56,565	397,087
4.1. Environmental income (EI)	91,428	80,518	15,346	791	36,316		26,418		397,087
4.1.1 Ecosystem services (ES)	7632	22,496	1359		33,334		26,418		1083,227
4.1.2 WPeu adjusted change of environmental net worth (CNWeadj)	83,796	58,022	13,987	791	2982				−686,140
4.2. Manufactured income (CIm)	−134,702	−2521	163	−15,853	20,202	1292		−56,565	
5. Total income (TI)	74,354	82,833	15,994	997	65,928	35,372	26,418	−45,542	397,087
Standard account revised indicators (SNAr)[a]									
1. Final product (FPr)	14,846	26,060	2325	2868	66,608	53,937	26,418	51,508	51,508
1.1 Final product consumption (FPcr)	14,846	26,060	2325	2868	66,608	34,673	26,418	51,508	51,508
1.2. Gross fixed capital formation (GFCFm)						19,264			
2. Ecosystem services (ES)	7632	22,496	1359		33,334		26,418		
2.1 Work in progress used (WPeu)	7632	22,496	348						
2.2 Revised net operating surplus (NOSer)			1010		33,334		26,418		
3. Intermediate consumption (ICm)	19,900	840	319	2535	1681	18,456		2732	51,508
4. Labour cost (LC)	117,628	4836	486	16,059	9411	34,080		11,023	
5. Consumption of fixed capital (CFCm)	5302		7	347	3166	1210		19,779	
6. Manufactured net operating surplus (NOSm)	−135,615	−2112	155	−16,073	19,016	191		17,974	
7. Gross value added revised (GVAr)	−12,685	2724	1658	334	64,928	35,481	26,418	48,776	
8. Conventional gross value added (GVA)	−5054	25,221	2007	334	64,928	35,481	26,418	48,776	
9. Conventional net operating surplus (NOS)	−127,983	20,385	1514	−16,073	52,351	191	26,418	17,974	
Economic account for forestry (EAF)[b]									
1. Final product (FP)									
2. Intermediate consumption (IC)									
3. Gross value added (GVA)									
4. Labour cost (LC)									
5. Gross operating surplus (GOS)									
Accounting systems indicators comparison									
GVA_{AAS}/GVA_{SNA}	−0.2	9.4	1.3	1.0	1.0	1.0	1.0	1.0	
GVA_{AAS}/GVA_{EAF}									
ES_{AAS}/ES_{SNA}	1.0	1.0	1.0		1.0		1.0		

Class	Farmer	Fire services	Recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Government	Total
	10 = Σ1–9	11	12	13	14	15	16	17	18 = Σ 11–17	19 = 1-0 + 18
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
Extended accounts indicators (AAS)[a]										
1. Gross value added (GVA)	1288,814	131,110	191,676	43,072	224,578	180,455	71,564	277,649	1120,105	2408,919
2. Net value added (NVA)	1259,003	119,125	184,408	42,958	158,748	177,133	68,630	277,649	1028,652	2287,656
3. Capital gain (CG)	−605,562	−8901	930	−112	9861	1577	369		3724	−601,838
4. Capital income (CI)	485,807	−8666	164,467	42,480	168,609	158,275	51,648	277,649	854,463	1314,381

(continued on next page)

Table 4 (*continued*)

Class	Farmer	Fire services	Recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Government	Total
	10 = Σ1–9	11	12	13	14	15	16	17	18 = Σ 11–17	19 = 1-0 + 18
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
4.1. Environmental income (EI)	647,903		94,580	40,938	168,609	149,015	40,254	277,649	771,045	1418,948
4.1.1 Ecosystem services (ES)	1174,466		94,580	40,938	224,578	149,015	40,254	277,649	827,014	2001,480
4.1.2 WPeu adjusted change of environmental net worth (CNWeadj)	−526,563				−55,969				−55,969	−582,532
4.2. Manufactured income (CIm)	−162,096	−8666	69,888	1542	0	9260	11,394		83,418	−104,568
5. Total income (TI)	653,441	110,224	185,337	42,846	168,609	178,711	69,000	277,649	1032,377	1685,818
Standard account revised indicators (SNAr)[a]										
1. Final product (FPr)	296,080	186,834	51,134	43,238		32,951	28,168	236,002	578,328	874,407
1.1 Final product consumption (FPcr)	276,816	170,930	46,151	43,093		30,056	23,952	236,002	550,185	827,000
1.2. Gross fixed capital formation (GFCFm)	19,264	15,904	4983	145		2895	4216		28,143	47,407
2. Ecosystem services (ES)	91,239			40,938				236,002	276,940	368,179
2.1 Work in progress used (WPeu)	30,476									30,476
2.2 Revised net operating surplus (NOSer)	60,762			40,938				236,002	276,940	337,703
3. Intermediate consumption (ICm)	97,969	55,724	8453	166		9193	7883		81,419	179,389
4. Labour cost (LC)	193,523	118,890	20,870	366		20,436	17,352		177,914	371,437
5. Consumption of fixed capital (CFCm)	29,811	11,985	7268	114		3322	2934		25,623	55,434
6. Manufactured net operating surplus (NOSm)	−116,463	235	14,543	1654		0	0		16,432	−100,031
7. Gross value added revised (GVAr)	167,634	131,110	42,681	43,072		23,758	20,285	236,002	496,909	664,543
8. Conventional gross value added (GVA)	198,110	131,110	42,681	43,072		23,758	20,285	236,002	496,909	695,019
9. Conventional net operating surplus (NOS)	−25,224	235	14,543	42,592		0	0	236,002	293,372	268,148
Economic account for forestry (EAF)[b]										
1. Final product (FP)	428,938									428,938
2. Intermediate consumption (IC)	217,928									217,928
3. Gross value added (GVA)	211,010									211,010
4. Labour cost (LC)	186,380									186,380
5. Gross operating surplus (GOS)	24,630									24,630
Accounting systems indicators comparison										
GVA_{AAS}/GVA_{SNA}	7.7	1.0	4.5	1.0		7.6	3.5	1.2	2.3	3.6
GVA_{AAS}/GVA_{EAF}	6.1									11.4
ES_{AAS}/ES_{SNA}	12.9			1.0				1.2	3.0	5.4

[a] Source: own elaboration.
[b] Source: IECA (2015).

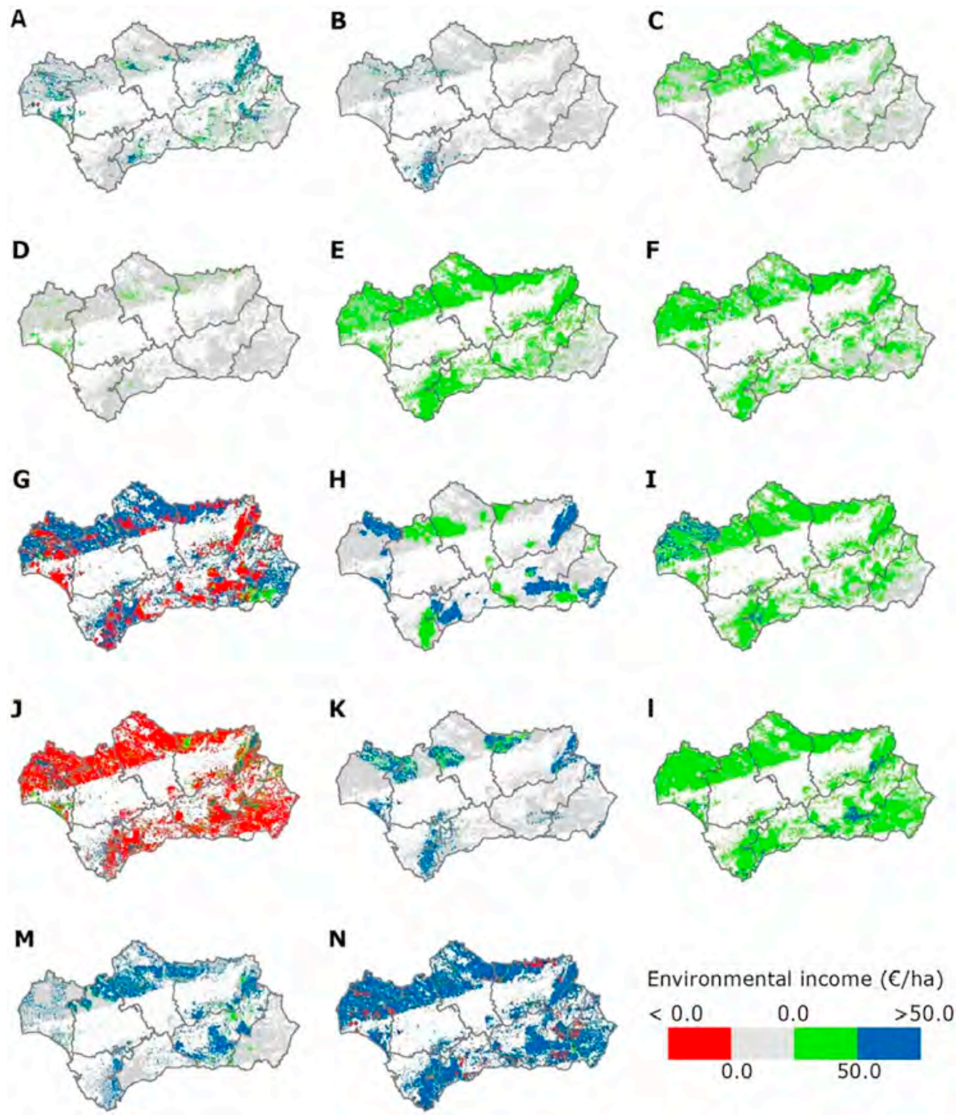

Fig. 3. Maps of environmental incomes of Andalusian forests (2010).
Abreviations: **A** is timber, **B** is cork, **C** is firewood, **D** is nuts, **E** is grazing, **F** is hunting, **G** is private amenity, **H** is public recreation, **I** is mushrooms, **J** is carbon, **K** is landscape, **L** is biodiversity, **M** is water and **N** all products.
Note: the value 0.0 denotes a value below 0.01 €/ha.

Table 5
Ecosystem services consumed in Andalusian forest (2010).

Class	Farmer	Government	Total
	(€ 10^3)	(€·10^3)	(€·10^3)
1. Provisioning services	91,239	318,587	409,826
Timber	7632		7632
Cork	22,496		22,496
Firewood	1359		1359
Nuts	0		0
Grazing	33,334		33,334
Hunting	26,418		26,418
Free access mushrooms		40,938	40,938
Water		277,649	277,649
2. Regulating services	0	413,847	413,847
Carbon		224,578	224,578
Landscape		149,015	149,015
Biodiversity		40,254	40,254
3. Cultural services	1083,227	94,580	1177,807
Private amenity	1083,227		1083,227
Free access recreation		94,580	94,580
Total	1174,466	827,014	2001,480

SEEA-EEA supply and use account in model B can be seen as a subset of our broader AAS forest production account. The concept of environmental asset revaluation is similar in both ecosystem accounting approaches. The main difference between the AAS and the SEEA-EEA is that the environmental income concept is not included in the SEEA-EEA but is central in our framework. This concept measures the potential maximum sustainable forest ecosystem services that people could consume from forests without a decline in the real value of forest WPeu adjusted to the change in environmental net worth (CNWeadj) during the accounting period (Eq. (20)). In other words, environmental income is consistent with the SEEA-EEA concept of sustainable ecosystem services (La Notte et al., 2017). We agree that it is not always possible to derive the current biophysical sustainability of forest ecosystem from the environmental income. However, we have valued the environmental asset (EAc) at the closing of the current period by modeling the forecast sustainable biophysical management of the Andalusian forests (see Supplementary texts S1-S2-S3-S13) both by farmers and government. The change in environmental net worth (CNWe) we have defined as an environmental asset gain (EAg) adjusted to environmental net investment (Eq. (21)) is the key economic indicator required in order to

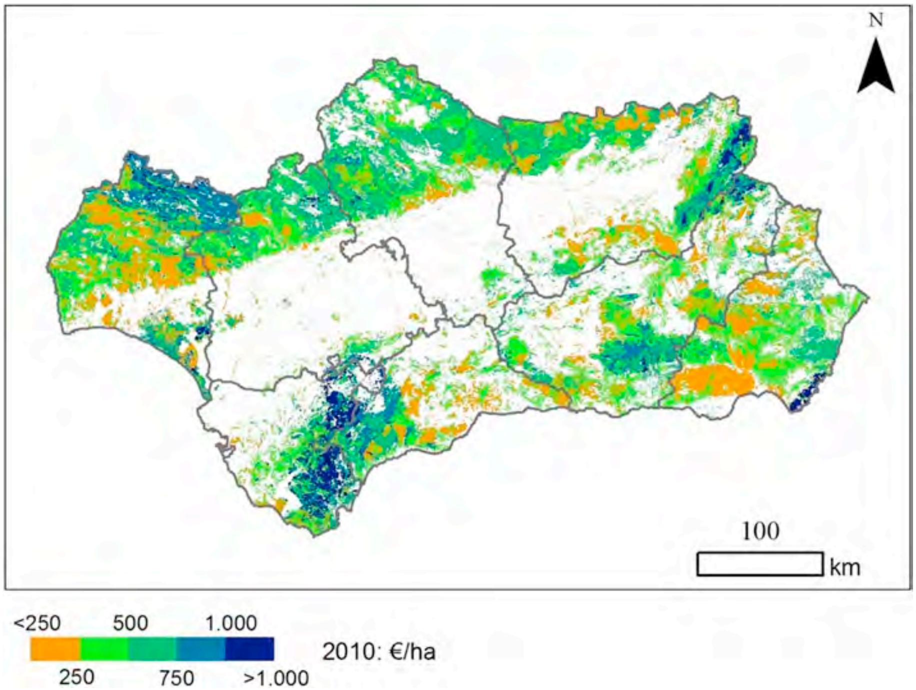

Fig. 4. Map of total ecosystem service values for Andalusian forests.

measure environmental income in the current period.

All the varied income and capital concepts of the AAS are consistent with the SNA and/or SEEA-EEA methodologies (European Commission et al., 2009: Tables 16.4–16.5 pp. 336, 338–339; United Nations, 2017: Table 8.2, p. 135). Although the latter do not measure environmental income (EI) and total income (TI), they do incorporate, either explicitly or implicitly, the variables that would allow its measurement (see Tables 1–5 and Supplementary Tables S2–S3). McElroy (1976) showed that SNA incorporate capital gain into the measurement of depreciation for measuring net domestic product. The depreciation valuation criterion at replacement price is a true implementation of the capital gain concept for fixed manufactured capital valuation into standard accounts. Another example is the livestock gross capital formation measured as stock variations in the current period.

However, standard accounts omit several concepts that we measure, and our evaluation criteria, while consistent with standard accounting principles, are not identical to those used in standard accounts either. The standard accounts net operating surplus (NOS) omits the final product of natural growth (NG) and the intermediate consumption of environmental work in progress used up (WPeu) in the timber, cork and firewood products. These standard production account omissions cause a NOS temporization bias measurement problem (McElroy, 1976). As already mentioned, public final product consumption of free access recreation, landscape conservation and threatened biodiversity are valued at ordinary production cost in standard accounts. The standard accounts measure forest water at production cost and, therefore, do not measure the final product of forest water (which equals its environmental income) embedded in the irrigated crops and other regulated commercial uses of water. The final product of forest carbon uptake and intermediate consumption emission are not considered in standard accounts. The standard production account for forestry used by the EAF does not include labour compensation separated from intermediate consumption of those services provided by forestry enterprises, and EAF also excludes the government forest expenditures and public forest

Class	Remme et al. (2015)	Sumarga et al. (2015)	EFTEC (2015)	Keith et al. (2017)	This study
Region/country	Limburg province, the Netherlands	Central Calimatan province, Indonesia	United Kingdom	Central Highlands of Victoria, Australia	Andalusian region, Spain
Landscape	Forest and crop lands	Forest and crop lands	Woodlands	Forests and crop lands	Forests
Area (ha)	222,000	15,350,000	2,780,000	735,655	4,386,432
Ecosystem services	Crop production, fodder production, drinking water production, air quality regulation, carbon sequestration, nature tourism and commercial hunting	Wood, palm oil, rattan, paddy rice, carbon sequestration, [in site tourism industry] nature recreation, and wildlife habitat	Wood, carbon and recreation [off site tourism industry]	Wood, vegetation carbon sequestration, water yield, and recreational amenity of tourism industry	Wood, cork, firewood, chestnut, pine nuts, acorn, grazed grass and browse, commercial hunting, mushrooms, tree and shrub carbon, private amenity, water yield, on site open access recreation, landscape conservation, threatened biodiversity
Valuation methods	RR, RC, ADCM	RR, REC	TSP, TGF, M, NCS, MAF, NTM	TSP, RR, RC, AP	TSP, RR, M, EU ETS, SEV, HPM, CVM, CEM

Fig. 5. Forest and cropland ecosystem service estimates in SEEA-EEA selected case studies.
Abbreviations: TSP is wood stumpage price as unitary resource rent price, RC is replacement cost, RR is resource rent, AP is government carbon auction price, M is market price, SEV is simulated exchange value, HPM is hedonic price method, CVM is contingent valuation method, CEM is choice experiment method, TGF is trip-generating function, EU ETS is carbon European Union Emissions Trading Scheme, NCS is net consumer surplus, MAF is meta-analysis function, NTM is non traded market price, REC is species reintroduction annualized government cost, ADCM is avoided damage cost method.

products (European Communities, 2000).

With regard to the shortcomings, there may be a conceptual inconsistency in our estimation of ES for forestry activity as we estimated a positive resource rent of the woody products harvested and a negative manufactured net operating margin, despite prioritizing the remuneration of the manufactured investment over the residual resource rent. The reason for this is that the ordinary costs of extracting the woody products are greater than the difference between the market stumpage price (used to estimate the residual resource rent) and the road-side price of the harvested products (used to estimate the total margin of this activity). If this negative differential margin of woody product extractions remains stable over time, we should accept that the extractions undertaken directly by the forest owner generate intermediate products of non-commercial services of the forestry activity, which are re-employed as inputs of intermediate consumption by other activities within the economic unit (e.g., private amenity and landscape conservation) (Raunikar and Buongiorno, 2006). By ignoring these farmer non-commercial intermediate services, we may be underestimating the manufactured margin from forestry activity and overestimating the margin of the activities that re-employ these non-commercial intermediate services. Raunikar and Buongiorno (2006) previously noted that non-industrial forest owners may incur voluntary monetary opportunity costs to satisfy a greater self-consumption of amenities in the case of private family owners and the improvement of the production of public goods and services in the case of institutional owners. The monetary opportunity cost of private family owners can be conceptualized as an intermediate product of forestry services that would be an input of own manufactured intermediate consumption of the production function of private amenity.

Although our application presents the valuation of a wide variety of forest ecosystem services and activities, we did not include soil erosion, pollination or air filtration. Future research should address these shortcomings. Although we incorporated water in our analysis, future research should also address some of the limitations of our study. For example, despite its importance we have not valued the effect of forests on groundwater recharge, due to: (i) the difficulty involved in identifying what fraction of groundwater recharge is effectively used; and (ii) difficulties in determining its value, since the extraction costs vary largely and very little information is available. Furthermore, a dense vegetation cover (not necessarily trees) is the best protection against soil erosion, and therefore against excessive sediment and associated pollutants in water bodies. Despite the potential relevance of this effect, we have not included it in our case study.

An additional shortcoming of both the extended and standard accounts is that forest total income does not include the environmental income embedded in all national industries and household consumptions. One example is the case of environmental income obtained by the tourism industry in surrounding natural areas when these areas increase the value of the marketed services of local hostelry (Remme et al., 2015).

Finally, several assumptions have influenced our results. The effects of the discount rate on asset values are the clearest example. That said, measuring income entails valuing known economic facts as well as unknown expected future economic facts, and standard accounts are not free of these assumptions either.

4.3. Policy Matters

The breakdown of ecosystem services into individual products has great potential for policies allocating funds to enhance these ecosystem services in different regions and/or countries. It would be of help, for example, in implementing a payment scheme for ecosystem services, such as those being implemented in many developing countries, or in designing agri-environmental measures, such as those from the Common Agricultural Policy in Europe. These programs could be based on compensating landowners for potential losses on their investments in manufactured (man-made) capital derived from environmentally-oriented forest management practices. Spatially-explicit forest total income estimates, such as those obtained from our extended accounts, could be key tools for making public spending more efficient; e.g. by concentrating resources in areas offering higher income (both market and non-market). They would also be helpful in assessing the economic feasibility of managing the natural environment by considering value changes in environmental assets.

Estimating simulated exchange values for non-market products would also allow us to make consistent comparisons of forest ecosystem services and income among countries, regardless of the ways that people access consumption. For example, although recreational visits to national parks in one country may be charged while in another country they may be free-access, the income generated could be consistently measured through extended accounts, with the only variation being who receives the income in each case. By contrast, standard accounts would record the market price in the first case, but only production costs in the second case, thus leading to inconsistency in the ways that total income is measured.

We believe that EI is of importance to policy making because it integrates the two key residual flows that come from the ecosystem environmental production and capital balance account. The advantage of EI over ES is that it represents the contribution of the ecosystem to present and future consumption of forest products. ES are only part of the economic contribution of the ecosystem to the consumption of forest products.

5. Concluding Remarks

Our research presents the conceptual challenges and practical difficulties of applying extended accounts to forests on a national or regional scale. The detailed extended accounts results are empirically relevant for one region, but they are equally relevant as an example of the results that could be obtained for different ecosystems around the world. Our application constitutes the first attempt at spatially-explicit measuring of multiple ecosystem services and their environmental incomes from forests at a regional scale (Andalusia, Spain). We also provide evidence of the feasibility of building an ecosystem accounting approach consistent with the exchange value criteria of the standard accounts for both market and non-market products. A generalized application of the extended accounts and the simulated exchange value method would allow us to compare ecosystem services and their environmental assets and incomes among ecosystems, regions, and countries in a consistent manner, while maintaining the exchange value principle of standard accounts.

The main message is that a complete framework of production and capital accounts of forest ecosystems should be applied to measure the total income and its factorial distribution. In this context, the need to incorporate measures of income and capital for each activity of the forest ecosystem requires the measurement of intermediate product, attributing its own intermediate consumption counterpart among the activities that use it. The public goods and services produced present links to the accounts of landowners through the former intermediate consumption. In our application we try to measure all the consumptions observed onsite in the forest, as well as one that is displaced: regulated forest water, whose environmental asset is appropriated by the landowner of irrigated land outside the forest.

Our results reveal that if we do not overcome the omission and ‘dislocation’ of products associated with standard accounts and their satellite EAF when applied to ecosystems, we risk making a substantial undervaluation of forest non-market ecosystem services and their environmental assets.

Due to this network of biophysical and economic links among forest ecosystem activities means, government agendas will be challenged to elaborate a system of extended accounts that can be implemented at a tolerable cost by 2020. In the actual application of the current SEEA-

EEA guidelines, we have found no cases in forest areas of similar size and variety of forest vegetation to that of Andalusian forests with individual products subject to measurement of total and environmental incomes.

The incorporation of the WPeu adjusted to change in net worth (CNWeadj) allows us to link environmental income with potential economic sustainability in the current period. However, we cannot separate the condition of economic sustainability from the critical physical threshold of the environmental asset. When a critical degradation threshold of the physical endowment of the natural asset is not surpassed, the economic sustainability attributed to environmental income has consistent economic and biophysical meanings. Our environmental income indicator shows sustainable product consumption without decline or degradation of their environmental assets, under the assumptions of a steady state of institutions, prices, technology and natural fertility. As argued above, we believe that the forthcoming SEEA-EEA guidelines should incorporate this indicator.

There is still a long way to go before standard accounts will be able to incorporate all the improvements tested in this application of extended accounts. The main limitation is government lag in implementing a suitable supply of primary statistical data on ecosystem services and assets. However, we believe that the scale of the application and the relevance of the figures obtained show that spatially-explicit national total income figures for forest ecosystems beyond strict market transactions can be generated. The methods and data collection protocols from our extended accounts are well-developed and could be put into practice by statistical offices if resources were made available. This is a path worth pursuing if we want to develop an accounting framework that effectively reflects stock variation, ecosystem services, and natural resource use in economic activities.

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Declarations of Interest

None.

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Author Contributions

Design of data collection, modeling and analysis of: (1) ecosystem accounting by P.C., A.C., J.L.O. and P.O, (2) valuation surveys by J.L.O., B.A.F., A.C., M.S. and P.C., (3) woody, acorns, nuts and carbon products by G.M, L.D.B., P.O., M.P.T., A.C., P.C. and C.R., (3) hunting by C.H., M.M.J., M.S., P.C., J.C. and J.T.P., (4) mushroom by F.M.P., P. de F., J.A. and P.C.,(5) threatened biodiversity by M.D. and E.D.C., (6) and water by S.B., R.S.N. and P.C. A.A., E.A., B.M. and C.F. prepared the data and provided research support. Authors contributed to the supplementary information on the areas for which each has been credited above.

Appendix A. Supplementary Material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.ecolecon.2018.11.017.

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