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The role of non-commercial intermediate services in the valuations of ecosystem services: Application to cork oak farms in Andalusia, Spain

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ABSTRACT

This research applies and compares the Agroforestry Accounting System (AAS) and the lightly revised System of National Accounts (SNA) in five cork oak farms in Andalusia, Spain, in 2010. We value eighteen economic activities, eleven of which are managed by individual farmers and seven of which are overseen by government. Our objectives are to measure and compare ecosystem services (ES), gross value added (GVA) and environmental income (EI). The comparison takes into account the valuation of products at producer, basic and social prices. Our most noteworthy novelty is that the AAS proposal incorporates the environmental income as a variable which serves as a reference value for the condition of economic sustainability of ecosystem service consumption. Our results show that ES and GVA estimates vary depending on the omission/measurement of auto-consumed/donated non-commercial intermediate services and nature based activity with zero ES value represents nature's free physical service contribution to the farms net value added. Farms AAS ecosystem services at social prices contribute to 64% of final product consumption, and ES at basic prices represent 1.2 times the ES at social prices. Farm revised SNA ecosystem services at basic prices are 0.5 times the AAS ecosystem services at social prices.

1. Introduction

Statistical institutions recognize the importance of valuing ecosystem services and their environmental assets as well as incorporating them in, or at least linking them, to the System of National Accounts (SNA) by 2020 (European Commission, 2011; United Nations, 2012). The explicit measurement of ecosystem services continues to be a challenge that must be overcome through the development of extended accounts (Atkinson and Obst, 2017; Edens and Hein, 2013; European Commission, 2016; La Notte et al., 2017; Obst et al., 2016). While the System of Environmental–Economic Accounting 2012–Central Framework-SEEA-CF is a standard for environmental asset balance linked to individual nature base commercial products (United Nations et al., 2014a), there are still no governmental standard extended accounts for ecosystem services and their environmental assets beyond the SNA (henceforth standard accounts) economic activities boundaries (Campos et al., 2019; Eigenraam and Obst, 2018; La Notte et al., 2019a, 2019b). Preliminary guidelines discussion can be found in the System of Environmental–Economic Accounting 2012–Experimental Ecosystem Accounting-SEEA-EEA (United Nations et al., 2014b) and more recently, the technical recommendations developed by the United Nations (2017). These publications depict the criteria for valuing the contributions of ecosystem services to direct and indirect single economic product consumption, with the aim of connecting them to the standard accounts. Nevertheless, the SEEA-EEA discussion is still open to extending the scope of environmental-economic flows and stocks beyond the production function boundary of the standard accounts.

To date, there are very few published studies that apply SEEA-EEA and include economic valuations for different ecosystem services from agricultural and forestry lands at any spatial scale (Campos et al., 2017, 2019; EFTEC, 2015; La Notte et al., 2017; Maes et al. 2016; Remme et al., 2015; Ogilvy et al., 2018; Sumarga et al., 2015, Keith et al., 2017). Some scholars have estimated the willingness of non-industrial landowners to accept monetary losses (opportunity costs) from their preferred ways of managing their forests and woodlands and economic activities, in exchange for, in the case of private owner, greater auto-consumed private amenities, or in the case of non-industrial institutional owners, the consumption of public final services and/or land improvements (Masiero et al., 2019; Raunikar and Buongiorno, 2006; Scarpa et al., 2000). The Agroforestry Accounting System (henceforth extended accounts) that we apply to the studied farms, measures the auto-consumed/donated intermediate services (ISSncoa/d), which are ignored by the standard accounts and were measured partially for the first time by applying extended accounts in Campos et al. (2017).

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Measuring the ISSnca/d in the original activities and attributing the own auto-consumed/donated intermediate consumption of services (SSncoa/d) to activities that use them goes beyond the standard accountś valuation criteria and production boundary. Our extended accounts applied to economic activities of the studied farms, exclusively consider farmer and government institutional sectors (Campos et al., 2019; Eigenraam and Obst, 2018).

This research develops and tests the extended accounts and the revised SNA (henceforth revised standard accounts) in five non-industrial, privately-owned, cork oak farms case studies (henceforth farms) in Andalusia, Spain. However, because there is a primarily illustrative aim to this application, the results for the farms should not necessarily be considered statistically representative of the 248,015 ha of Andalusian cork oak woodlands (207,839 ha privately-owned and 40,175 ha publicly-owned).

In the farms, the eleven farmers' economic activities that are considered are timber, cork, firewood, nuts, livestock grazing, forestry conservation services, wild game hunting, livestock, residential services, agricultural crops and private amenity. The motivation underlying the management of farmer activities may partially differ between that of a family owner, who shows a mixed amenity consumption-monetary benefit rationale, and that of a non-industrial private institutional landowner, who may incorporate social preferences in regards to ecosystem services and environmental assets, such as sustainability and equity concerns. The government acts as a collective owner that operates seven public economic activities, producing non-market public goods and services, consumed freely by public users, such as public free-access recreation, landscape conservation services and threatened wild biodiversity services. In addition, the government holds the property rights for public quasi-market activities, offering free goods and services such as a fire services, mushroom picking, carbon services of global warming mitigation and natural water yield.

The objectives of this research are to compare extended and revised standard accounts measurements of ecosystem services (ES), gross value added (GVA) and environmental income (EI). Our comparisons take into account both, (i) the individual activity and the activities of the farmer, government, and farm, and, (ii) product consumptions valued at producer, basic and social prices. We measure the total product consumption at the social price of the firewood, grazing, conservation forestry, hunting and livestock activities. The extended accounts use total income theory to consistently calculate the ES, GVA and EI in the accounting period. The EI is defined as the potential maximum sustainable economic exchange value of actual ecosystem service consumption in the accounting period that does not cause environmental asset to decline, if indefinite future physical productivity also does not decline, other things being equal.

Our main contribution is that the extended accounts apply to these studied farms are mostly consistent with farm version of the SEEA-EEA guidelines linked with revised standard accounts, except for the issues that the extended accounts incorporate simulated exchange values, the opportunity cost and the carbon activity that are omitted by the revised standard accounts. However, these omissions are a statistical convention rather than a scientific consistency controversy, given the current SNA methods (European Commission et al., 2009). As far as we know, no case studies applying extended accounts have been published integrating the farm or regional spatial units, landowner and government economic activities results applying both simulated exchange values and social prices incorporated into the total product consumption estimate.

The more relevant results of our application are that (i) farmer and government ES, GVA and EI estimates vary depending on the omission/measurement of ISSnca/d and SSncoa/d, and (ii) single nature base activity with zero ES value represents the naturés free physical service contribution in enabling the farmers and government to generate labor compensation for workers and/or manufactured net operating margin for landowners.

2. Concepts and accounting frameworks

2.1. Integrating the standard into the extended accounts at farm scale

Our extended accounts depart from the definition of total income "as being the total of the consumption [farm product consumption minus intermediate consumption] and change in the value of assets [net worth] held over a given period, and other things being equal [in the farms at closing accounting period]" (European Communities, 2000: p. 87). This total income concept could therefore potentially be measured by the standard accounts, even though in practice the standard accounts do not estimate the farmś national total income. However this would not be the case with regard to the valuation criteria of non-market final products, since the standard accounts value these final goods and services at production cost and not using the simulated exchange value, as in our extended accounts. The latter broadens the concept of economic activity depicted in standard accounts and suggests that the contribution of environmental factors of production (which nature offers us for free) are the only factors of production necessary to be eligible as a single economic activity. This production function concept marks the difference between the definitions of economic activity in the extended accounts in contrast to the standard accounts, which only recognizes economic activities as those that generate products with the contribution of at least one manufactured production factor. We note that of all the activities in our studied farms, only the carbon activity has no manufactured production factors or self-employed labor cost.

In the extended production accounts, the net operating margin at social prices ($NOM_{sp,E}$) includes: (i) the revised standard accounts net operating margin at basic prices ($NOM_{bp,Sr}$) (for details see Supplementary text S1), (ii) the ISSnca/d and the SSncoa/d, (iii) the change in value of the final product of the private amenity (ΔFPpa), by substituting the standard accounts value at the cost of the residential service for the extended accounts private amenity landowner willingness to pay (Oviedo et al., 2017), (iv) the change in value of the non-market public final goods and services (ΔPGS) consumption (recreation, landscape and threatened biodiversity) caused by replacing the standard account's valuation at the production cost with the extended account's simulated exchange values at producer prices, (v) the final product of carbon fixation (FPca) omitted by the standard accounts, and (vi) the consumption of environmental fixed asset of carbon emission (SSe):

$$NOM_{sp,E} = NOM_{bp,Sr} + ISSnca/d - SSncoa/d + \Delta FPpa + \Delta PGS + FPca - SSe \quad (1)$$

where subscript E is extended accounts and subscript Sr is revised standard accounts.

The values of ISSnca/d and SSnca/d are only equal within the aggregate farm value and not for the respective values of the single activities. The private amenity values in the extended accounts are estimated through a survey on owners' willingness to pay in the geographic areas around each farm case study (Campos et al., 2019; Oviedo et al., 2017). Some valuations of the public goods and services in the extended accounts are made at imputed market price, such as those for the water, mushrooms and carbon final products (Campos et al., 2019), and others are at simulated exchange values, such as those for the recreational, landscape and threatened biodiversity final products (Campos et al., 2019; Caparrós et al., 2017).

The single and aggregate ecosystem services of the farms at basic prices and producer prices can vary in their valuations. When opportunity costs are present in certain activities, the omission of ISSnca/d in the revised standard accounts leads to the overvaluation of the ecosystem services for those activities, which incorporate SSncoa/d. This omission also leads to an undervaluation of the gross value added of the activities that produce the ISSnca/d.

2.2. Extended accounts as agro-forestry farm experimental SEEA-EEA model B

The extended accounts applied to farms are conceptually similar to extended version of the SEEA-EEA model B, which considers an ecosystem as an environmental production factor and not as an independent institutional sector. We use the SEEA-EEA market observed and simulated transaction prices. The extended accounts differ from the SEEA-EEA in that it provides the ISSnca/d as an intermediate product and as a new indicator of environmental income. Both methodologies contain similar concepts of monetary ecosystem services, environmental assets and the environmental asset revaluation (EAr). The primary new variable introduced is the environmental income (EI), which is not conceptual but practical, since EI is the total yearly returns on environmental assets. Estimating the components of EI does not require new concepts (or anything additional to the SEEA-EEA), since the main parts of this calculation are the ES, NG and EAr, which are already measured by the SEEA-EEA. However, there may be practical differences in the measurements of the EAr, because the SEEA-EEA does not incorporate natural growth in the supply side of production account. These differences are corrected in the environmental asset gain (EAg) of our extended accounts by subtracting the opening value for natural growth (NGo) from the estimates of the EAr.

Furthermore, our accounting concepts of ecosystem services and environmental assets are consistent with the exchange value criterion in the SEEA-EEA. The production and capital balance accounts in the extended accounts incorporate the SNA accounts (European Commission et al., 2009: Tables 16.4 and 16.5, pp. 336–339). Our extended accounts consider also the SEEA-EEA production and regeneration of income accounts (Campos et al., 2019; Edens and Hein 2013; United Nations et al., 2014b: Annex 6.1, Table 6.1, p. 144; United Nations, 2017: Table 8.2, p. 135). The environmental income approach is conceptually consistent, although not totally in the practice, with the SNA and SEEA-EEA frameworks, since the capital gain (CG) is implicitly included in the consumption of manufactured fixed capital (CFCm), valued at the replacement cost that is applied in the SNA (McElroy, 1976, p. 222). Also, the net variation in the livestock inventory is recorded as gross capital formation in the SNA. The fact that the SNA and the SEEA- EEA do not estimate environmental income is due to standardized governmental practices rather than a theoretical inconsistency within the concept of total social income.

2.3. Micro farm and macro landscape spatial unit data sources

The extended accounts and SEEA-EEA could be applied to any territorial scale by starting from a specific micro unit of a property and adding each relevant macro data scale, up until the maximum spatial scale of the nation's territorial boundaries. Recent applications at the micro and macro scale of extended accounts and SEEA-EEA frameworks show that there are no conceptual ecosystem service and incomes differences between the two scales (Campos et al., 2017, 2019; Ogilvy et al., 2018). Micro farm and macro landscape vegetation spatial unit data enable the measurement of single ecosystem services and incomes of any ecosystem type, at farm and other bigger spatial unit scales.

The farm is the basic spatial unit where single farmer and government economic activities are linked by their production of intermediate products and own intermediate consumption across many single farm activities. The farm is the unique basic economic independent unit that allows for the consistent measurement of the landowner voluntary accepted monetary opportunity costs linked with the farmer amenity activity, the public landscape activity, and other government activities.

Beyond the micro farm scale, macro scale data are needed to measure farm imputed economic data in order to obtain representative economic values gathered from surveys on livestock grazing lease, hunting lease, mushrooms collection, the public recreation actual demand, wild threatened biodiversity services, as well as from spatial single vegetation type bio-economic models, and hydrological models linked to vegetations types and government spending. The goal of this data collection will be to transfer and apply these values to the farm scale, in a manner that is consistent with the farm total income concept.

The compilation of spatially referenced micro and macro data are necessary for valuing the actual economic ecosystem services and the environmental income in the accounting period. Prior to the beginning of this research, we knew the value of consumption of final goods and services without market prices, estimated at producer prices (Campos et al., 2019; Oviedo et al., 2017). These products were valued through the application of diverse methods of environmental valuation, at the scale of the Spanish Forest Map (SFM) tiles, by the type of dominant forest vegetation, and the results have been transferred to the scale of the cork oak farmś vegetations and specific land uses (Fig. S1; Campos et al., 2019; Caparrós et al., 2017; Ovando et al., 2015, 2016; Oviedo et al., 2017).

The opening stocks, intermediate and final product consumption, and physical production accumulation (the gross capital formation) in the accounting period are associated with the relevant area needed for the type of vegetation and land uses of that area. Based on the available information, some products are attributed to a specific farm area (timber, cork, firewood, acorn, carbon and water), and others to the area exclusively used by a single farm (grazing of grass, browse and acorn, and hunting, recreation, mushroom, landscape and biodiversity).

Final public goods of mushroom gathering and production of water are valued by their market prices and they are attributed to the single farm that their location pertains to (Beguería et al., 2015; Martínez-Peña et al., 2015). We adapt the bio-economic models in Campos et al. (2019) and apply them to the farms' yield functions for natural growth of timber, cork, firewood and settled inventoried game species (Campos et al., 2019; Ovando et al., 2015; Herruzo et al., 2016). We use the grazing consumption by livestock and game species developed by Carranza et al. (2015) and Campos et al. (2016).

The goods and services of the farm measured in physical units refer to the area that is necessary to sustain them and not to the total area of the farm. This is not the case with our economic valuation of sustainable ecosystem services at the farm scale, which present the average monetary results of individual ES for the total farm, and is also different from the classification of ecosystem services in KIP-INCA project, where the government institutional sector is not integrated at farm scale (La Notte et al., 2019b: Fig. 5).

2.4. Extended accounts institutional sectors and economic activities

The private ownership and public collective rights over the consumption and transfer of products in the cork oak farms case studies underline the condition of joint private and public economic capitals and the ownership of income (Anderson and McChesney, 2003). In terms of the economic activities, property rights are simultaneously shared by landowners, which are physical persons or institutions, and the government, which represents society as a whole.

The summary of production and income generation extended and standard accounts of the activities considered are included in both accounting frameworks, except for the carbon activity which is only recognized in the extended accounts. The columns of the above cited accounts show the single activities attributed to their respective institutional sectors of farmer and government. The concepts of product, cost and income presented in the rows of the overall accounts summary follow the terminology used in the SNA.

We apply our extended production account to the single activities of the owner and the government so that they are linked to each farm. To do so, we record the production and capital balance account results for each farm and then combine them to determine an aggregate value in order to establish an average across all of the five farms case studies.

The production function of a product in the extended accounts is sufficient as long as the activity ownership is attributed exclusively to the owner or to the government. The production function incorporates consumption in the actual accounting period or accumulated products as part of the capital stock of the farm for use as a production factor of products that will be consumed in the future. There are cases in which the production factors of certain products may only be environmental. In such circumstances the simulated assignment of ownership to the government in its role as the collective owner of public goods and services consumed by people for free, is considered an economic activity.

An activity is defined by at least one product and may contain several products which fill production and capital balance accounts. Farm total products (TP) taken into account by revised standard[1] and extended accounts are limited to the accounting period intermediate product (IP) and final product (FP), valued at basic and social prices observed in formal or simulated markets (European Commission et al., 2009: pp. 109-110; Eisner, 1989; Stone, 1984). The consumption of final products (FPc) are products that leave the farm in the accounting period to be either consumed or employed as an input to the production of another economic unit different from the one that produced it. Gross capital formations (GCF) are accumulated products at the closing of the accounting period to be consumed in future production processes on the farms as intermediate consumption or consumption of fixed capital.

Our definition of economic activity provides the basis for the choice of products considered in the farms, because exclusive ownership is assigned to the property owner or the government. The production function of single total product consumption (TPc_{sp}) contains all of the natural and manufactured production factors that contribute to its economic value for each farm (Edens and Hein, 2013; Campos et al., 2019). Our farm applications enhance the total product function by incorporating the production factors of environmental intermediate consumption, work in progress used (WPeu), manufactured intermediate consumption (ICm), labor cost (LC), environmental fixed asset (EFA) and manufactured fixed capital (FCm) (for detail see Supplementary text S2):

$$TP \equiv F(WPeu, ICm, LC, EFA, FCm) \tag{2}$$

In the extended and revised standard accounts, single activities and products are attributed to their respective total costs (TC) (see Supplementary texts S1-S2). The production function allows us to discern the relative contributions of the production factors to the value of the farm's total products.

2.5. Famers auto-consumed and donated non-commercial intermediate services

The "opportunity cost, usually expressed as the difference in the NPVs [net present value] of various options, is the cost of a benefit that could have been received but which has been given up to pursue a certain course of action" (Masiero et al., 2019: p. 52). In our farm case studies, the monetary opportunity costs incurred by the farmers have been measured by comparing it to the greater monetary benefits that could have been obtained by the same investment in non-agrarian alternative assets (e.g. medium-long term public debt). In these farms, we assume that non-industrial land owners voluntarily accept the monetary opportunity costs incurred due to changes in grazing, hunting and livestock managements that favor the supply of the private amenity auto-consumption and public products, such as landscape conservation services (Masiero et al., 2019; Ovando et al., 2016: Oviedo et al., 2017; Raunikar and Buongiorno, 2006; Scarpa et al., 2000). We attribute ISSnca/d as well its counterpart, the value of the SSncoa/d, for each single activity that incurs a voluntary opportunity cost.

Our estimate of the ISSnca/d unfolds step-by-step, as follows. First we estimate the ordinary normal net operating margin (NOMmon) (eq. (3)) of the individual activity, directly derived from the normal private profitability rate (r)[2] multiplied by the ICMmo. The latter is estimated considering the average manufactured investment of the period immobilized in the individual activity. The annual period average (permanent) manufactured investment is weighed by the constant (c) type of manufactured working capital items (for details see Supplementary text S3):

$$NOMmon = r * IMCmo \tag{3}$$

We measure IMCmo assuming a constant, regular expenditure (e.g., c = 0.5) on manufactured ordinary working capital (WCmo) (Eqs. 4–5), a new investment on purchased fixed manufactured capital (Cmeb), sales of final products (FPs) and sales of manufactured capital (Cmwos) during the period:

$$IMCmo = FCmo + WCmo + c * Cmeb - c * FPs - c * Cmwos \tag{4}$$

$$WCmo = c * ICmob + c * LCeo \tag{5}$$

where FCmo is opening manufactured fixed capital and ICmob is bought (purchased) ordinary manufactured intermediate consumption.

This research measures ISSnca/d from grazing, hunting and livestock activities and attributes the SSncoa/d to private amenity and landscape conservation services activities. An additional non-commercial compensated intermediate service (ISSncc)[3] exists as a result of government compensation to the farmers (i.e. in the form of subsidies on products), which favors and promotes landscape conservation activity. Farms also produce commercial intermediate service (ISSc), and use the latter as own commercial intermediate consumption of service (SSco).

The farms total intermediate services (ISS) are calculated by the sum of the ISSc and non-commercial intermediate services (ISSnc) services. The counterpart of the latter is the own intermediate consumption of services (SSo) as the sum of SSco and own non-commercial intermediate consumption of service (SSnco).

The purpose of registering the monetary opportunity cost in farm activity valuations, is that its inclusion as ISSnca/d of the activity which generate them, and as SSncoa/d of the activity which consumes them, results in a variation in the value of the ecosystem services of the activities that consume SSncoa/d, at social prices (ES_{sp}) in comparison with their valuation at basic prices (ES_{bp}).

2.6. Concept of social price

The consistent valuation of farm gross value added (GVA) in the extended and revised standard accounts is at producer prices, and represents the real or imputed producer prices. The estimates at basic and social prices are those which correspond to the measurements of GVA for the individual activity, and the activities of the farmer, government and farm. However, revised standard accounts do not use simulated producer prices, but instead apply production cost prices to value final public product consumption without market prices.

The standard accounts at any spatial scale estimate the gross value added at producer prices (before incorporating net operating subsidies on products and unitary opportunity cost) and at basic prices (after adding the unitary government compensation to the producer price). The extended accounts offer an additional social price after adding the unitary opportunity cost to the basic price of a single activity.

We define the producer price of a product as its unitary exchange

[1] In this farm application, our revised standard account (supply and use account in the terminology of the SEEA-EEA) is different from government standard accounts because it includes natural growth (NG) in the supply side and the own intermediate consumption of environmental work in progress used (WPeu) in the use side.

[2] We apply a 3% private rate of return in these case study farms.

[3] We have not estimated taxes on product, subsidies on other production and taxes on other production.

value observed in formal or simulated markets, where the latter occurs when the product is not actually traded in real markets. For this research, based on data of the marginal willingness to pay declared by consumers and landowners, we apply the simulated exchange value method to estimate the producer price of the single product (Campos et al., 2019; Caparrós et al., 2017; Oviedo et al., 2017). We incorporate the environmental price of WPeu and NG when valuing the resource rent (Campos et al., 2017, 2019; Martínez-Jauregui et al., 2016).

Farmer and government activity ecosystem services and gross value added of the extended accounts are based on the social prices of formal and simulated markets of total product consumption and of accumulated products which will be consumed in the future. This principle of economic accounting valuation underlies the reason that the aggregate gross value added of the farms does not change when we alter the type of prices applied to individual total product consumption. Therefore, the incorporation of intermediate products and own intermediate consumption does also not influence the estimation of gross value added of the farms. However, farmer and government ecosystem services and gross value added depend on the type of price considered. Consequently, there is an undervaluation of gross value added of the activities that produce the ISSnca/d omitted, and an overvaluation of ecosystem services of activities that consume the SSnca/d omitted (for details see Supplementary text S4):

$$TPc_{bp} = TPc_{pp} + ISSncc \quad (6)$$

$$TPc_{sp} = TPc_{bp} + ISSnca/d \quad (7)$$

2.7. Total income

The total income is the variable on which we base the structure of extended production and capital balance accounts of farmer, government and farm single activity, and its factorial distribution across labor, manufactured capital and environmental assets (Fig. 1). We first measure the total income accounting identity given by the net value added (NVA) and the capital gain (CG) balancing items (Fig. 1). After measuring this first TI identity, it can be used to derive another expression. Thus, a second TI identity is directly related to consumption (total product consumption minus intermediate consumption) and change in net worth (see details in Supplementary text S2). A third TI identity shows its factorial allocation across labor costs (LC) and capital income (CI) (Fig. 1), which is the sum of manufactured capital income (CIm) and the environmental income (EI).

Fig. 1 depicts the total income breakdown as the NVA, and CG and its factorial allocation amongst LC, CIm and EI. The components of the total product consumption at social prices (TPc_{sp}) are classified according to whether they are intermediate raw materials (IRM), intermediate services (ISS), final products sold (FPs), auto-consumption (FPa), public goods and services (PGS) and other consumption of final products (FPo). The intermediate product (IP) equals with own intermediate consumption (ICo). The change of environmental net worth (CNWe) is depicted as the own-account gross capital formation (GCF) minus consumption of fixed capital (CFC) and by adding the capital gain (CG). The total income (TI) is also estimated as the TPc_{sp} minus the IC and adding the CNWe (see details in Supplementary text S2).

Once TI has been measured, and assuming that the remuneration for employees' labor cost (LC) and manufactured capital income (CIm) is prioritized at the stage of the first intermediate or final product transaction,[4] if a positive monetary residual value remains, this residual value is the environmental income (EI). The EI is depicted in Fig. 1 as the value of the environmental net operating margin (NOMe) plus the environmental asset gain (EAg), and in Fig. 2 as ecosystem services plus environmental work in progress used (WPeu) adjusted to change of environmental net worth (CNWead).

2.8. Ecosystem services

The concept of ecosystem service has diverse meanings among the different scientific disciplines. In main-stream environmental accounting economics, the concept refers to the contribution of nature to the exchange value of a final product (FPc_{sp})[5] directly or indirectly consumed by people in the accounting period (Atkinson and Obst, 2017; Edens and Hein, 2013; EFTEC, 2015; Haines-Young and Potschin, 2013; Howarth and Farber, 2002; La Notte et al., 2017, 2019a,b; Obst et al., 2016; United Nations et al., 2014b; United Nations, 2017). However, there is still controversy around its application due to different views on how much the concept of economic activity should be extended to the national accounting context, and on the consistency of the valuation of products without a market price (Campos et al., 2019; Caparrós et al., 2017; La Notte et al., 2019a, 2019b; Remme, et al., 2015; ONS and Defra, 2017; Oviedo et al., 2017; Sumarga et al., 2015; Sutton et al., 2016). Different valuation concepts are sometimes applied to the valuation of ecosystem services, such as products valued at market price and measurements of welfare estimates using non-market valuation techniques (Bateman et al., 2013; Costanza et al., 1997; La Notte et al., 2017; Vojinovic et al., 2017). This implies that some valuations of ecosystem services are not based on a consistent integration of market product exchange values with non-market product estimates.

Our interest in the estimation of the ecosystem services (ES) leads us to place emphasis on the intermediate and final products consumption in the accounting period (Fig. 2). The concept of actual ecosystem service at social price (ES) applied to the farms measures the exchange value contribution of nature embedded in the single total product consumption at social prices (TPc_{sp})[6] in the accounting period. To estimate the TPc_{sp}, we extend the scope of standard accounts total product consumption at basic prices (TPc_{bp}) by adding ISSnca/d. The TPc_{sp} excludes the gross capital formation (GCF). The natural growth (NG) does not affect consumption in the accounting period. The consumption of environmental fixed asset of carbon emission (SSe) does not affect the ordinary total cost (TCo), although it does affect the environmental investment cost of carbon emissions (SSe) from the farms in the accounting period, because it is considered a degradation of carbon environmental fixed assets (for details see Supplementary text S5, Campos et al., 2019):

Thus, from our extended accounts, an ecosystem service at social prices (ESsp) is formed by environmental work-in- progress used (WPeu) and the ordinary environmental net operating margin ($NOMeo_{sp}$). The WPeu is valued at the opening of the accounting period at its environmental price (unitary resource rent) as environmental intermediate consumption incorporated into the TPc_{sp}. The $NOMeo_{sp}$ valued at the social price refers to the environmental fixed asset operating benefit embedded in the TPc_{sp}.

The total product consumption at social price (TPc_{sp}) is separated into final product consumption (FPc) and intermediate products (IP), both IRM and ISS (Fig. 2). The single TPc_{sp} may have four ordinary production factors ($ICmo_{sp}$, LCmo, CFCmo and WPeu) and two net operating margins ($NOMmo_{sp}$ and $NOMeo_{sp}$) (Fig. 2, Eqs. 8–9). We rearrange both sides of eq. (8) to show the ecosystem services (Es_{sp})

[4] As example: the cork stripped first potential transaction is their stumpage price and the second potential transaction is after harvesting their farm gate price.

[5] .This definition may result in ES overvaluation if only the consumption of farm final products is considered without measuring ES pending on the first transaction at intermediate product stage.

[6] ES at full farm activities is embedded in the final product consumption. However, ES for a single product first transaction could occur as intermediate products. Thus, the latter is necessary to be considered for consistently measuring and allocating single ES by famer, government and farm activities.

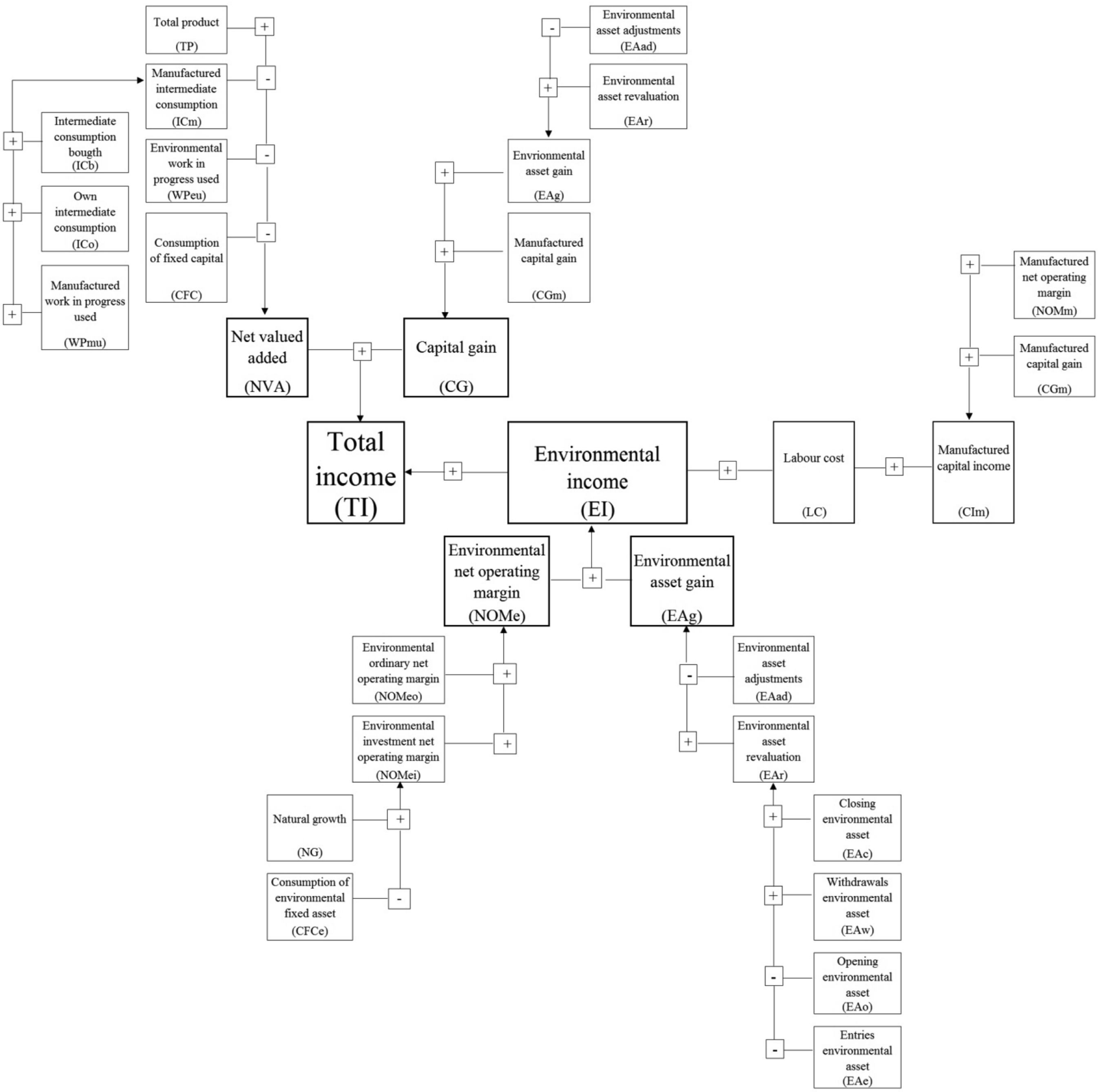

Fig. 1. Extended accounts total income at social prices.

Eqs. 10–11[7]:

$$TPc_{sp} = ICmo_{sp} + LCo + CFCmo + NOMmo_{sp} + NOMeo_{sp} + WPeu \quad (8)$$

$$TPc_{sp} = ICmo_{sp} + LCo + CFCmo_{sp} + NOMmo_{sp} + ES_{sp} \quad (9)$$

$$ES_{sp} = TPc_{sp} - ICmo_{sp} - LCo - CFCmo - NOMmo_{sp} \quad (10)$$

$$ES_{sp} = WPeu + NOMeo_{sp} \quad (11)$$

The operative challenge to measure ES is to separate ordinary net operating margin (NOMo) into NOMeo and NOMmo. The latter could be a residual value if NOMeo is previously given (e.g., this research estimates for cork, grazing and hunting) or a normal manufactured immobilized capital return if NOMeo is measured as residual value (e.g., this research estimates for private amenity, recreation, landscape and biodiversity).

2.9. Environmental income

We define a farm single environmental income at social price (EI_{sp}) as the maximum potential sustainable economic ecosystem service (resource rent) in the accounting period. The extended production and balance accounts EI_{sp} components are the environmental net operating margin ($NOMe_{sp}$) and the environmental asset gain (EAg) (Fig. 1, Campos et al., 2019):

[7] The ICmo is the aggregated value of ordinary raw materials (RMmo) and ordinary services (SSmo). The sum of CFCo and NOMmon represents the user cost of manufactured immobilized capital (IMCmuc).

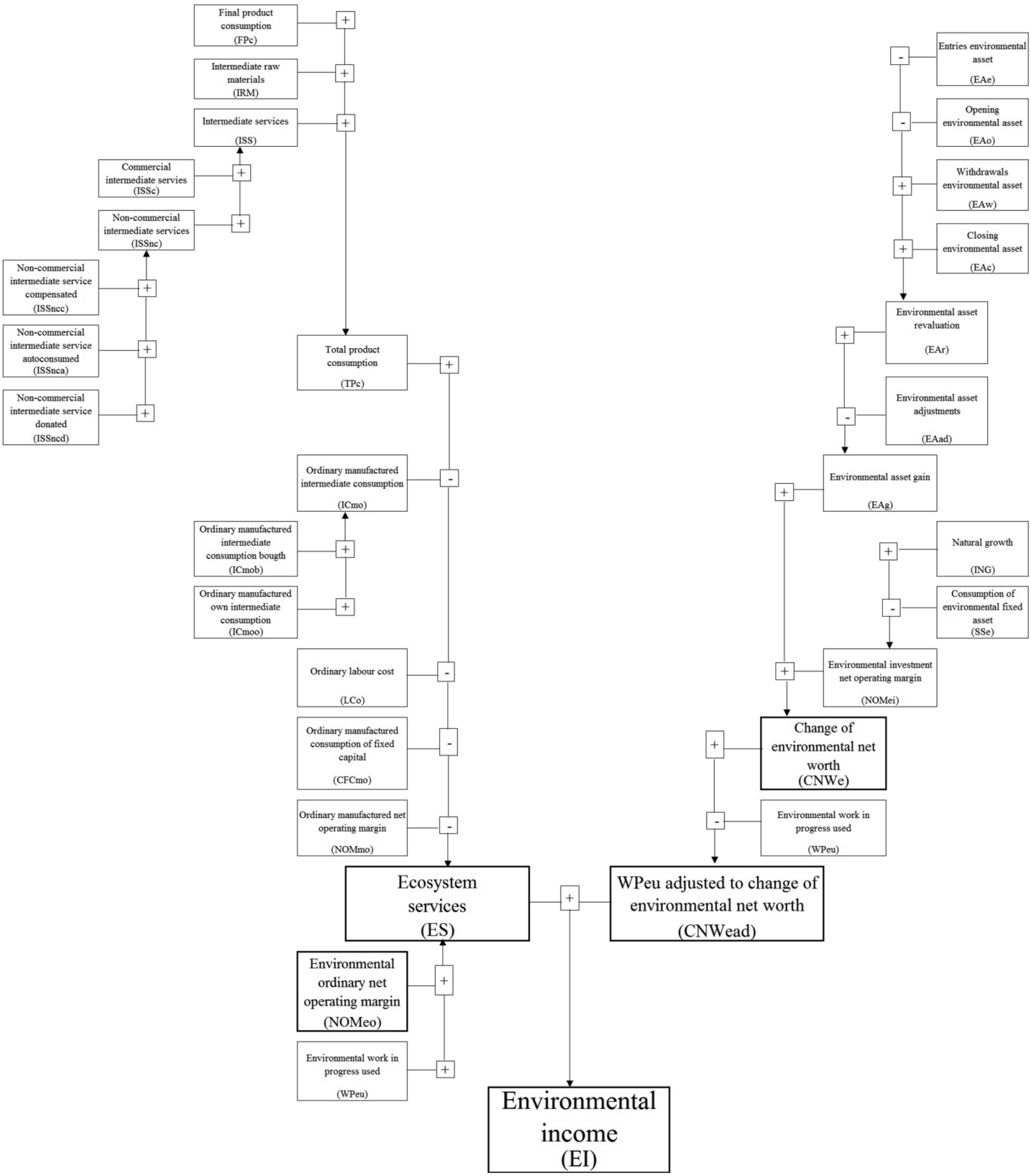

Fig. 2. Extended accounts environmental income at social prices.

$$EI_{sp} = NOMe_{sp} + EAg \quad (12)$$

We concentrate on the breakdown and reorganization of the estimation of environmental income (EI_{sp}) explicitly dependent on actual ecosystem services at social prices (ES_{sp}) in each single product valued at farm site (Fig. 2). This aim includes measuring the change of environmental net worth (CNWe). The estimation of CNWe does not depend on the actual ecosystem services, but is related to the closing environmental assets[8], and other estimated variables at the closing accounting period. Environmental asset gain (EAg) is due to the expected (discount effect) and unexpected (extraordinary destructions) environmental asset revaluation (EAr) and accounting instrumental adjustment (EAad) at the closing of accounting period.[9] The EAg is differentiated from the CNWe, because it incorporates the environmental investment net operating margin (NOMei).

Furthermore, the new identity of EI as the sum of ES_{sp} and the change of environmental net worth adjusted (CNWead) (Fig. 2), is derived by adding and subtracting the work-in-progress used (WPeu) from the components of $NOMe_{sp}$ and EAg described above. The extended accounts measure the CNWe for the accounting period as the EAg plus NOMei, which is the natural growth (NG) minus the carbon emissions (SSe) equivalent to consumption of environmental fixed assets (CFCe) (Figs. 1 and 2, for details see Campos et al., 2017, 2019, Supplementary text S2). Because $NOMe_{sp}$ is the sum of ordinary ($NOMeo_{sp}$) and investment (NOMei) net operating margins, the CNWe (eq. (13)) and EI_{sp} (eqs. 14–15) can be obtained:

$$CNWe = NOMei + EAg \quad (13)$$

$$EI_{sp} = NOMeo_{sp} + CNWe \quad (14)$$

$$EI_{sp} = ES_{sp} + CNWead \quad (15)$$

The CNWead reveals valuable connections between EI and actual ES (Figs. 1 and 2). If CNWead is zero or a positive value, total product consumption does not deplete and/or degrade its economic environmental assets in the accounting period (Campos et al., 2019)

In the cork oak farms case studies the CNWe[10] is carried out assuming a future steady state scenario of prices, environmental conditions and technology, while the physical natural growth of woody products follows the evolution of the natural growth of the trees subject to the scheduled conservation forestry plan, at the time of the valuation of the farm's environmental assets (Campos et al., 2017, 2019). The EI_{sp} results of this data, not only represent the concept of the maximum potential economic sustainable ES in the accounting period, but also possibly the potential physical maximum sustainable ES_{sp} extraction, since the closing environmental asset (EAc) corresponds with the scheduled future sustainable biophysical growth and extraction scenarios (Campos et al., 2019; Ogilvy et al., 2018).

The extended accounts measure closing environmental assets of cork oak farms under four assumptions concerning scheduled future managements: (i) the actual single activity managements (i.e. forest management according to the species) are maintained in the future without technical innovation and productivity changes; (ii) the yearly physical natural resources harvested (timber, cork, firewood, acorns, shrub and hunting) change according to the biological modeling functions; (iii) there is a scheduled scenario that guarantees that actual biological cycle of the trees, shrubs and hunting will be followed by further identical cycles of regeneration (either natural or induced by human intervention) to provide for the indefinite persistence of the state and condition of the biotic environmental assets, and (iv) the absence of irreversible losses of biological or cultural assets in the cork oak farms (Campos et al., 2019: 235). The light decline of closing environmental asset is due to private amenity, without being affected by physical natural resource productivities.

3. Results

The five cork oak farms[11] case studies have a mean size of 1104 ha (Tables 1 and S1; Fig. S1). We measure the farms average physical indicators that refer to their specific areas and economic results for the individual activity and the activities of the farmer, government, and farm of the 2010 accounting period. These farms tree vegetation and other land uses include mainly open woodlands, with a canopy covers of 43.2% (Table S1), forests, shrublands, grasslands and others uses (Table 1).

3.1. Cork oak farms case studies data sources

The data on farmer and government economic managements of the cork oak farms were gathered in-situ in 2009 and 2010 through agreements signed with the landowners guaranteeing confidentiality in the use of the data from the farms. We developed the modeling of natural growth and the silviculture applied according to own forest inventories at the farms complemented by data from the third Spanish National Inventory. Growth dynamics and game species captures were based on data from previous research by the authors as well as information on hunting captures in farms provided by the Andalusian government. The hydrological modeling by the authors was based on information from the Andalusian public hydrographic basin agency. The information on government public goods and services with no market prices was obtained through the following sources (Campos et al., 2019): (i) a contingent valuation survey of 765 non-industrial private forest landowners of silvo-pastoral farms to value private amenities (Oviedo et al., 2015), (ii) a phone survey on mushroom picking to 4219 Andalusian households of which 267 respondents were mushroom pickers, (iii) a contingent valuation survey of 4030 public visitors in nine key forest recreation areas, (iv) a choice experiment survey of 3214 adults ($>$ 18 years old) from households in Andalusia and of 836 adults from households throughout the rest of Spain. These data were also obtained during 2010. The methodological procedures for obtaining the information described beyond the farms have been published in Campos and Caparrós (2016), Campos et al. (2019), and those that describe the process of the information from farm can be accessed in Ovando et al. (2015, 2016) (Fig. S2).

All the above data allow us to estimate different environmental stocks and flow prices pending on the production process stages from environmental asset withdrawals of environmental work in progress used, stumpage prices and farm gate final good and service consumption.

3.2. Summary of physical indictors

Tables S2 and S3 and Fig. S3 show a selection of physical indicators directly linked with the farms' income and capital results. In 2010, employee labor was 19 hours per hectare (Table S2). Livestock equivalent cow unit stocking rate was 0.1 per hectare, to which bovine species account for 70%. Bovine births heads, sales, and depletion (aging) were, respectively, 3.7, 4.5 and 1.1 per 100 hectares (Table S3). Game species consume a significantly higher amount of grazing fodder than livestock in the farm case studies. Free fodder indicates that the

[8] EAc represents discounted expected future indefinite potential ecosystem services extractions.

[9] There is in the estimate of EAg an instrumental reclassification of natural growth expected at opening (NGo) to NG produced at closing (NGc). These two instrumental withdrawal and entry capital balance reclassifications are accounting adjustment (EAad) to avoid double counting of natural growth.

[10] The CNWe concept is the environmental component of the standard accounts change in net worth (McElroy, 1976).

[11] One of the farms is owned by a private non-profit institution and four farms are family-owned properties (Table 1).

Table 1
Cork oak farms case studies vegetation covers and other land uses in Andalusia, Spain (2010).

Class	Farm F1	Farm F2	Farm F3	Farm F4	Farm F5	Farms F1-F5	
	ha	ha	ha	ha	ha	ha	%
1. Useful agrarian land	500	1438	1036	975	1532	5481	99.5
1.1 Open woodland	500	903	848	820	1430	4500	81.7
Quercus ilex					*671*	*671*	*12.2*
Quercus suber	*447*	*758*	*574*	*632*	*711*	*3122*	*56.7*
Other oaks	*52*	*110*	*32*	*81*	*48*	*323*	*5.9*
Wild olive		*34*	*243*	*107*		*384*	*7.0*
1.3 Shrubland[(1)]		334	163	147	65	*710*	12.9
1.4 Grassland		137	5	4		*146*	2.6
1.5 Other forests[(2)]		64	20	5	37	*126*	2.3
2. Others[(3)]	4	5	6	4	10	*30*	0.5
3. Total	504	1443	1042	980	1542	5512	100.0

Notes: [(1)]Includes shrubland and shrubland and grassland. [(2)]Includes riparian forests, other species and mix oaks-conifers forests. [(3)]Infrastructure an unproductive surface.
Farm average size: 1104 hectares.

market does not pay a leasing price for this grazing consumption mainly by game species. Acorns have been measured by cork and holm oak production function modeling and adjusted for each farm case study in order to attribute them the consumption of livestock and game species pending on farm managements (Campos et al., 2019). Average acorn productivity on the farms is 200 kg/ha (Table S3). Animal feeding with fodder supplement is important for livestock and negligible for game species (Fig. S3).

It is remarkable that physical natural growth of cork was 1.25 times the amount harvested, and firewood natural growth was 22.2 times the amount harvested by holm oak pruning. Carbon fixation is 5.4 times emissions. Shrubs account for 38.6% of total net carbon fixation. Water runoff is 2802.5 m^3/ha and year. Only 18.1% of the latter final water yield from these farms was put to commercial use for irrigation (85%) or industrial and household uses (15%). Recreational visits to the natural area of the farms were measured at 4.8vi/ha and year and finally, There are 1.7 threatened wild species per 100 hectares (Table S3).

3.3. Extended accounts capital balance

The opening capital of the actual period mainly comprises of work in progress environmental assets (WPeo) and fixed environmental assets (EFAo) (Tables 2-S4-S5). These environmental assets (EAo) account for 90.4% of the total opening capital (Co) (Tables 2-S4-S5). The activities which contribute the most are, in order of importance, landscape, cork and private amenity, which make up 64.7% of the total EAo (Tables 2-S4-S5). The environmental asset values for the farmer and the government are similar. This result confirms the condition of joint private and public economic property rights to the environmental assets of the farms case studies.

The environmental asset withdrawals used represent the extractions of work in progress used of cork, firewood and hunting captures (Tables 2-S5). The environmental asset owns entries represent the natural growths of woody products and inventoried settled hunting species. Reclassification and other withdrawals are accounting instrumental records that are need in order to avoid double counting double counting when measuring total income.

The environmental assets of work in progress and fixed biological resources present substantial revaluation of cork because of the reduction of one year in the discounted time for natural cork growth (Tables 2-S5-S6). In contrast, the opposite occurs in the case of the private amenity, with a drop in land prices which we attribute in its entirety to the fall in prices of future consumption of amenities (Tables 2-S5). For all the farm activities as a whole the revaluation of the environmental asset totals €122.6/ha (Tables 2-S5). In the 2010 accounting period there was a notable drop in the prices of manufactured fixed capital which caused a devaluation of the manufactured fixed capital of -€59.6/ha (Table 2). The result of these revaluations, both positive and negative for both types of capital, is a capital revaluation of € 63.0/ha (Tables 2-S5).

3.4. Extended accounts total income

The total income measurement of the farms in the account period is presented in Fig. 3:

a) The top left of Fig. 3 shows the TPc_{sp} components of intermediate product (IP) of raw material (IRM) and services (ISS) and final product consumption (FPc). Those which stand out in their contribution to the $TPc_{sp,}$ are the PGS, FPs, FPa and ISS. The farms total product consumption incorporates the double counting of intermediate products (IP), which corresponds to the own ordinary intermediate consumption (ICoo) that is embedded in the final product consumption.
b) The upper right of Fig. 3 shows the components of intermediate consumption. Own intermediate consumption (ICo) equals with the intermediate product (IP).
c) The Fig. 3 presents the estimate of the change of net worth (CNW) as the own-account GCF, minus the CFC, plus the CG,(which was a negative value in this accounting period). Fig. 3 presents the capital gain (CG) separated between manufactured capital gains (CGm) and environmental asset gain (EAg).
d) The factorial distribution of the total income (TI) is presented in Fig. 3. In the lower right of the Fig. 3, there is a breakdown of TI factorial distribution between compensation of employees (LC) and capital income (CI). The latter is separated into its components of manufactured capital income (CIm) and environmental income (EI).

3.5. Auto-consumed and donated non-commercial intermediate services

Some individual activities incorporate the ISSnca/d and their counterpart of SSncoa/d, respectively, into the total product consumption at social prices (PTc_{sp}) and the own intermediate consumption (ICo), makes it possible to estimate the ecosystem services (ES_{sp}).

We estimate the ordinary net operating margin at basic price ($NOMo_{bp,E}$) and the total immobilized capital (IMC) that we use in the measurements of the profitability rates of the individual activities (Table S7). We separate the portion of the IMC corresponding to the ordinary manufactured immobilized capital (IMCmo) used in the generation of the total products consumed (Table S8), with the exception of the amenity and carbon activities that do not incur in IMCmo. Known the $NOMo_{bp,E}$ and the IMCmo of the individual activities we estimate

Table 2
Cork oak farms case studies extended accounts capital balance in Andalusia, Spain (2010: €/ha).

Class	1. Opening capital	2. Capital entry				3. Capital withdrawal						4. Capital revaluation	5. Closing capital
	(Co)	2.1 Bought (Ceb)	2.2 Own (Ceoo)	2.3 Other (Ceot)	2.4 Total (Ce)	3.1 Used (Cwu)	3.2 Sales (Cws)	3.2 Destructions (Cwd)	3.3. Reclasification (Cwrc)	3.4 Other (Cwot)	3.5 Total (Cw)	(Cr)	(Cc)
1. Environmental asset (EA)	15,110.5		73.5	66.6	140.1	191.5			112.2	17.3	321.0	122.6	15,052.2
1.1 Farmer	7662.1		73.5	2.2	75.6	191.5			49.6	5.6	246.6	114.7	7605.7
Timber	*0.3*		*0.0*		*0.0*				*0.0*		*0.0*	*0.0*	*0.4*
Cork	*3524.8*		*55.8*		*55.8*	*176.9*			*49.6*		*226.5*	*379.1*	*3733.2*
Firewood	*13.1*		*0.0*		*0.0*	*0.0*			*0.0*		*0.1*	*0.6*	*13.7*
Nuts	*0.0*											*0.0*	*0.0*
Grazing	*960.0*											*1.5*	*961.5*
Hunting	*634.7*		*17.6*	*2.2*	*19.8*	*14.5*				*5.6*	*20.1*	*0.3*	*634.7*
Amenity	*2529.0*											*−266.9*	*2262.2*
1.2 Government	7448.5			64.4	64.4				62.6	11.8	74.3	7.9	7446.5
Recreation	*894.5*												*894.5*
Mushrooms	*551.6*												*551.6*
Carbon	*592.4*			*64.4*	*64.4*				*62.6*	*11.8*	*74.3*	*7.9*	*590.4*
Landscape	*3716.4*												*3716.4*
Biodiversity	*785.8*												*785.8*
Water	*907.6*												*907.6*
2. Manufactured (FCm)	1604.4	11.3	327.0	0.7	338.9	198.0	34.9	4.8		30.1	267.8	−59.6	1615.9
2.1 Farmer	1429.4	11.3	235.7	0.7	247.7	198.0	34.9	4.8		30.1	267.8	−51.7	1357.6
Plantations													
Constructions	*872.7*											*−36.2*	*836.6*
Equipments	*74.8*	*4.9*			*4.9*							*−14.8*	*65.0*
Livestock	*481.9*	*6.4*	*235.7*	*0.7*	*242.7*	*198.0*	*34.9*	*4.8*		*30.1*	*267.8*	*−0.7*	*456.1*
Agriculture													
2.2 Government	174.9		91.3		91.3							−7.9	258.3
Plantations													
Constructions	*127.1*		*9.7*		*9.7*							*−8.9*	*127.9*
Equipments	*43.8*											*0.6*	*44.3*
Others	*4.1*		*81.5*		*81.5*							*0.4*	*86.1*
Capital (C)	16,714.9	11.3	400.4	67.2	479.0	389.5	34.9	4.8	112.2	47.5	588.8	63.0	16,668.1

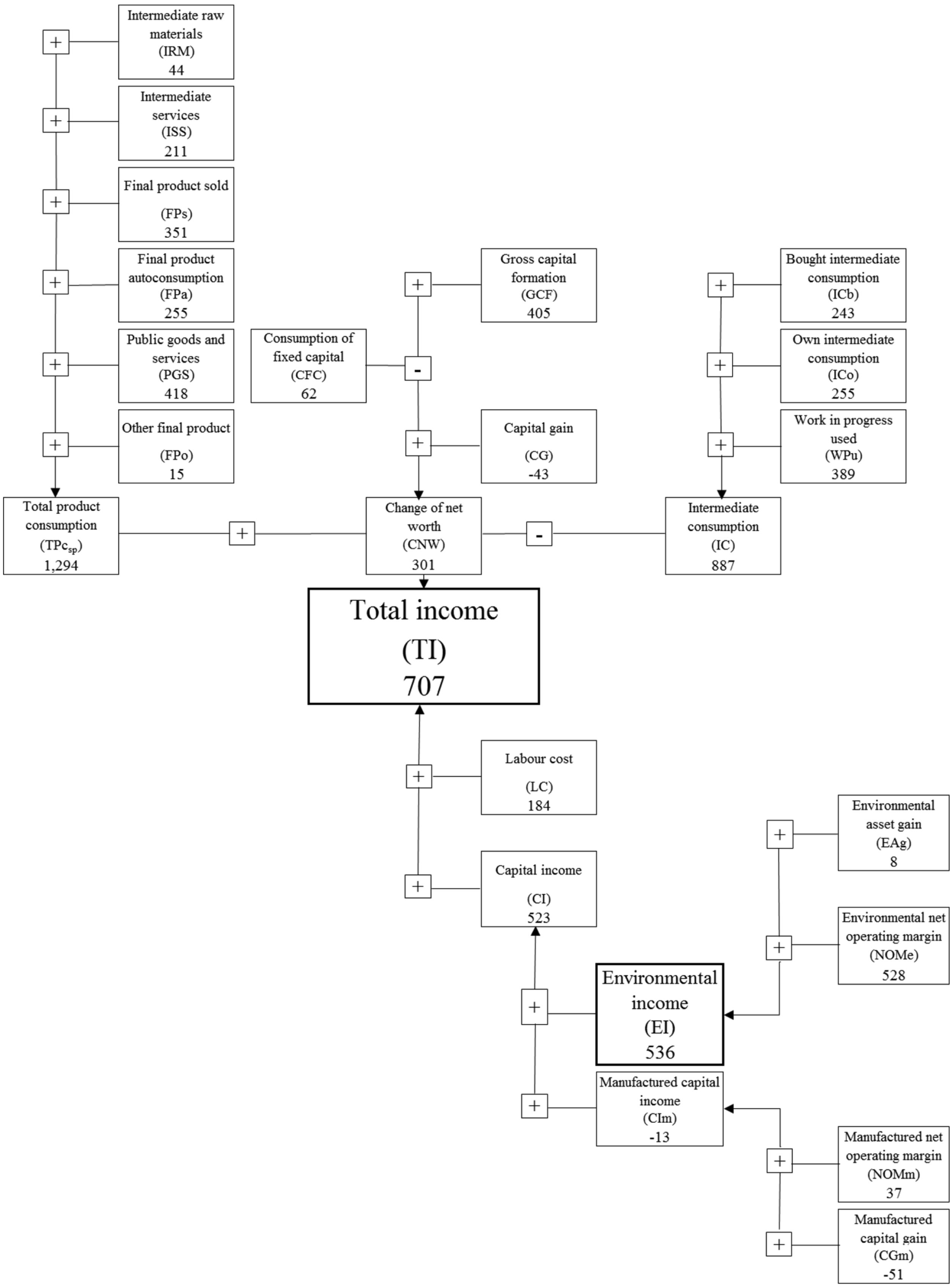

Fig. 3. Cork oak farms case studies extended accounts total income results at social prices in Andalusia, Spain (2010: €/ha).

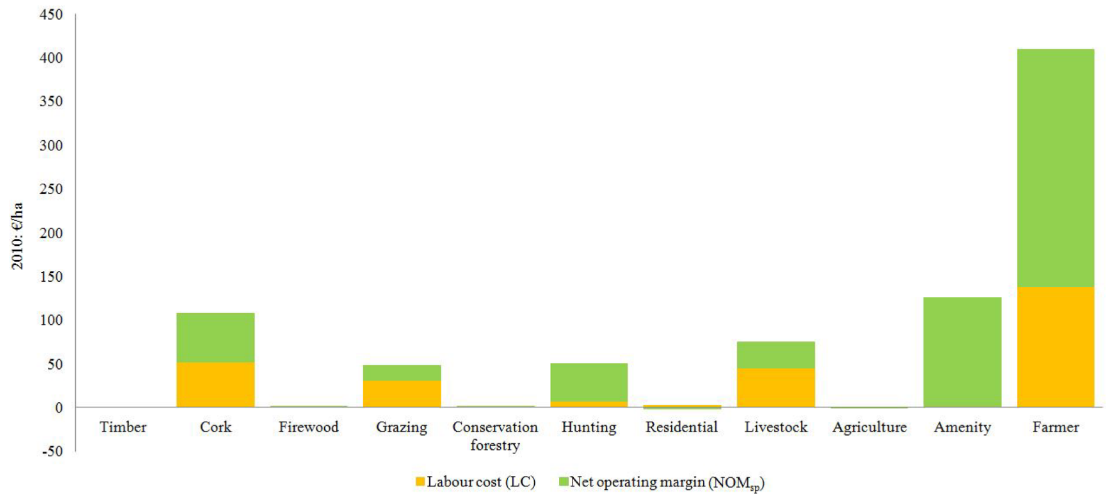

Fig. 4. Cork oak farms case studies farmer extended accounts net value added at social prices in Andalusia, Spain (2010: €/ha).

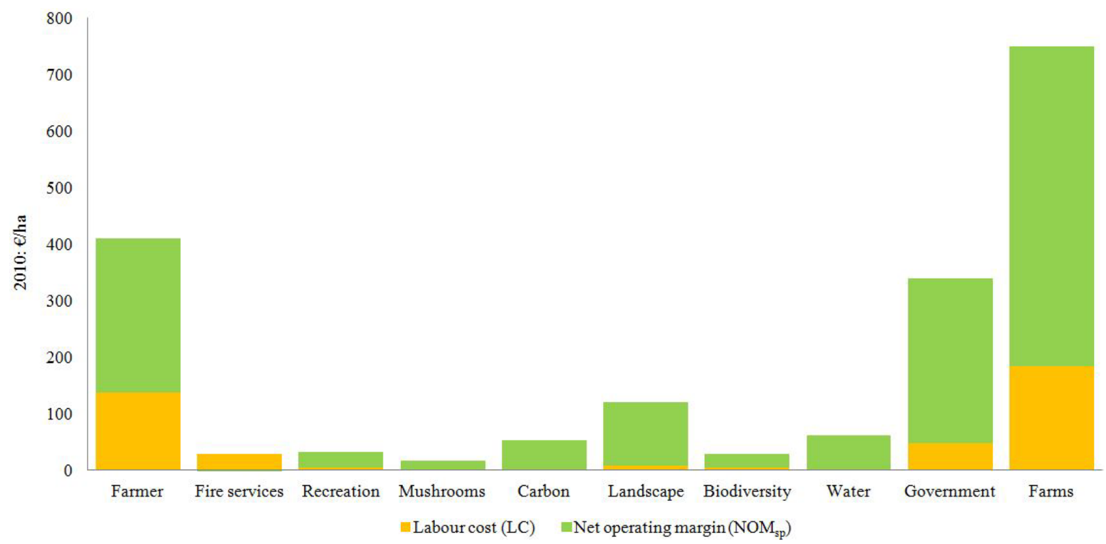

Fig. 5. Cork oak farms case studies extended accounts net value added at social prices in Andalusia, Spain (2010: €/ha).

the ISSnca/d (for details see Supplementary text S3).

The landowner activities that contribute the most ISSnca/d, in the order of most to least value contributed, are livestock, hunting, grazing and lastly, firewood (Fig. S4, Table S9). The SSncoa/d is attributed, respectively, to private amenity activity for the most part, but also to landscape conservation activity (Fig. S5, Table S9).

3.6. Extended accounts net value added at social price

Fig. 3 offers the measurements of total product (TP) and intermediate consumption (IC) in order to estimate the gross value added at the social price (GVAsp). The net value added at the social price ($NVA_{sp,}$) for the individual activity, and the activities of the farmer, government and farms, is derived by subtracting the consumption of fixed capital (CFC) from the GVA_{sp} (Figs. 4 and 5, Tables S9-S10-S11). NVA_{sp} are operating incomes of both labor (LC) and net operating margin at social prices (NOM_{sp}) (Figs. 4 and 5). The NOM_{sp} is classified in ordinary manufactured net operating margin (NOMo) and investment net operating margin (NOMi) and both manufactured (NOMm) and environmental (NOMe) (see Tables S10-S11).

In the extended accounts the highest contribution to farms net value added at social prices ($NVA_{sp,F}$) is the private amenity. The next highest is landscape services followed by cork, livestock, water yield, carbon, grazing, hunting and threatened wild biodiversity. The farms environmental net operating margin ($NOMe_{sp,O}$) at social prices contributes to 70.4% of farms NVA_{sp} (Table S9, Figs. 4 and 5). Most labor cost (LC) is attributed to farmer activities, contributing 35.5% to farmer $NVA_{sp,O}$ (Table S9).

3.7. Ecosystem services

Tables S10-S12 present a breakdown of ordinary total cost (TCo) and ordinary net operating margin (NOMo), which provides the value of the total product consumption (TPc_{sp}). Farms extended accounts ES at social prices contribute to 64% of TPc_{sp}.

Cork is the largest single contributor to ES, followed by amenity, landscape, carbon and water (Fig. 6, Tables S10-S11-S12). The consumption of these five products accounts for 81.7% of total ES. Livestock grazing makes a lower contribution to the ES, even when the hunting ES is considered a subrogated value of game grazing; total livestock grazing is €16.6/ha (Fig. 6, Tables S10-S11-S12).

When applying the ES_{sp} classification of provisioning, regulating and cultural services (Haines-Young and Potschin, 2013), the largest contribution is by provisioning services (47%), followed by regulating (30%) and cultural services (23%) (Table S12).

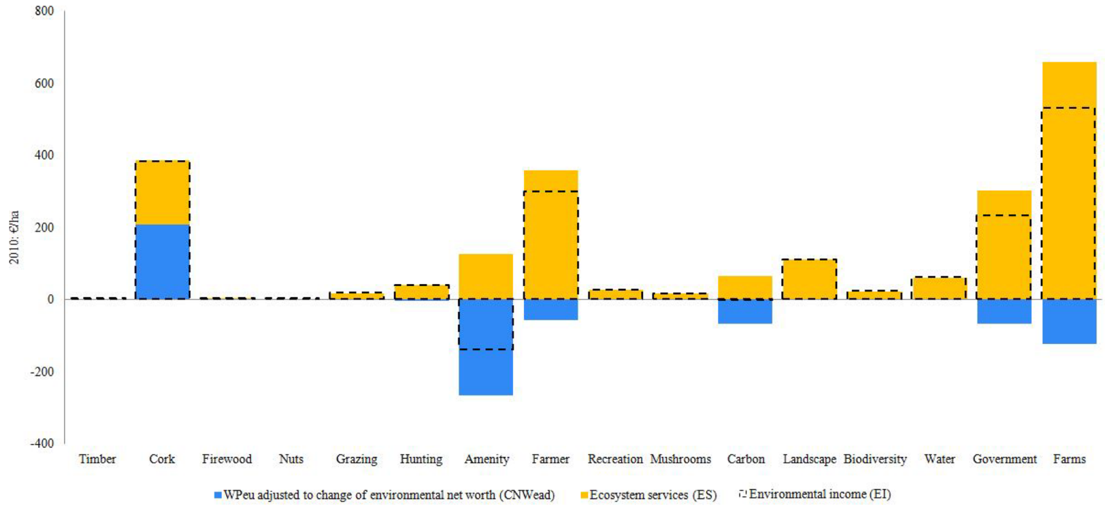

Fig. 6. Cork oak farms case studies extended accounts environmental income at social prices in Andalusia, Spain (2010: €/ha).

3.8. Environmental income

In Fig. 3 the environmental income (EI) is presented as the aggregate value of the environmental net operating margin (NOMe) and the environmental asset gain (EAg) derived directly from the estimates of the extended production and capital balance accounts. The EAg is separated into revaluation (EAr) and accounting instrumental adjustments (EAad) to avoid double accounting of the environmental income as the natural growth for the accounting period that has already been entered in the production account (Tables S10-S11-S12). The ecosystem services are presented in Tables S10-S11 as WPeu and NOMeo, and ES is showed linked to the environmental income (Fig. 6, Tables S11-S12). We have estimated the WPeu adjusted to CNWe to measure the adjusted change of environmental net worth (CNWead).

Fig. 6 depicts the EI and their components of ES and CNWead for the individual activity, and the activities of the farmer, government and farms. EI has positive value in all single activities, except in private amenity activity. The activities with the highest contributions to EI are cork, landscape, water supply and hunting (Fig. 6). Although there are the same values for ES and EI by single activity when it CNWead is zero value, in the accounting period this it is not the case for cork, amenity and carbon activities in *dehesas* case studies (Fig. 6).

Amenity and carbon present negative values of CNWead in this accounting period. The former is due to the land price depreciation and the latter because low present value of natural growth due their multi-period of cork stripping. Multi-period cork extractions can offer ecosystem service values which differ from their environmental income because of over/under harvestings (WPeu) with respect to their natural growth (NG) in the accounting period (Tables S3-S11). This difference in the case of cork is explained by the fact that cork is harvested at 9 to 10 year intervals but cork ES are only recorded in the year in which harvesting takes place. In contrast, the cork EI component of CNWead is always recorded in the accounting period.

The negative variation in land prices that occurred in 2010 in Andalusia caused the value of the amenity EI to be negative, in contrasts with the positive figures of ES. The reason for this difference is that ES is not affected by change in environmental net worth.

3.9. Sensitive analysis to prices and accounting frameworks of ES and GVA

The results for ecosystem services (ES) and gross values added (GVA) under different prices and both the extended accounts (E), and revised standard accounts (Sr) are show in Tables S10-S11-S12-S13-S14.

We focus on the comparisons of the indices of ES and GVA for the individual activity, and the activities of the farmer, government and farms (Table 3). These indices could change because the application of different accounting frameworks (extended and revised standard accounts) and prices (producer, basic and social prices).

Table 3 shows that the ES of the owner's commercial products do not vary with the prices or when different accounting methodologies are applied. However, changes in prices and accounting methodologies do affect the ES indices of the private self-consumption amenity of the owner and public goods and services, with the exceptions of mushroom harvesting and consumption of the final public water used on irrigated farms offsite of the farms case studies. It should be noted that revised standard accounts by definition do not estimate the ES of final products consumed without market price (recreation, landscape, biodiversity and carbon). The ES of final water consumed by industries, the service sector and households does not vary due to the water law that mandates that the income of the resource must be zero. Extended accounts show that the ES of the farm at basic price is 1.2 times the ES measured at social price and 1.3 times the ES of the farmer at social price. The ES of the government does not observe variation because the donations of intermediate services consumed by the activity of landscape have an insignificant value.

Comparisons of ES measurements at basic prices by the revised standard accounts and at social prices by the extended accounts show significant differences. The ES of the farms measured by the standard accounts are 0.5 times greater than those offered by the extended accounts. ES of the farmer of the standard accounts are 0.7 times the ES of the extended accounts, but those of the government of standard accounts are only 0.2 times that of the extended accounts.

Tables 3-S14 show that the farm farmer and government GVA, of extended accounts do not vary with the change in valuation from basic prices to social prices; however, the GVA of famer activities affected by ISnca/d and their counterparts SSncoa/d do change. The GVA of government activities do not vary because the contribution of own donated non-commercial intermediate consumption of services (SSncod) used in the production of public goods and services without market prices is negligible. The GVA of the farmer valued at producer prices (pp) is 0.9 times that of the farmer at social prices (sp). In the case of the government the GVA at pp is 1.1 times that offered at sp (Tables 3-S14).

In the standard accounts, the change in valuation from producer prices to basic prices, modifies the GVA of the farmer and the government, but has no effect on the GVA of the farms. The farmer's GVA at pp is 0.7 times the corresponding bp. In the case of the government the GVA at pp is 1.3 times that offered by the bp (Tables 3-S14).

Additionally, there are more significant differences between GVA measurements at the basic price by the revised standard accounts and at

Table 3
Cork oak farms case studies extended and revised standard accounts ecosystem services and gross value added indices comparisons in Andalusia, Spain (2010).

Class	Timber 1	Cork 2	Firewood 3	Nuts 4	Grazing 5	Conserv. forestry 6	Hunting 7	Residential 8	Livestock 9	Agriculture 10	Amenity 11	Farmer 12 = Σ1-11
Ecosystem services (ES)												
$ES_{pp,E}/ES_{sp,E}$	0.0	1.0	1.0	0.0	1.0		1.0				1.9	1.3
$ES_{bp,E}/ES_{sp,E}$	0.0	1.0	1.0	0.0	1.0		1.0				1.9	1.3
$ES_{bp,Sr}/ES_{sp,E}$	0.0	1.0	1.0	0.0	1.0		1.0					0.7
$ES_{pp,Sr}/ES_{pb,Sr}$	0.0	1.0	1.0	0.0	1.0		1.0					1.0
Gross value added (GVA)												
$GVA_{pp,E}/GVA_{sp,E}$	1.0	1.0	0.3	0.0	0.8	1.0	0.0	1.0	0.0	1.0	1.9	0.9
$GVA_{bp,E}/GVA_{sp,E}$	1.0	1.0	0.3	0.0	0.8	1.0	0.0	1.0	0.4	1.0	1.9	1.0
$GVA_{bp,Sr}/GVA_{sp,E}$	1.0	1.0	0.3	0.0	0.8	1.0	0.0	1.0	−0.4	1.0		0.3
$GVA_{pp,Sr}/GVA_{bp,Sr}$	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	2.1	1.0		0.7

Class	Fire services 13	Recreation 14	Mushrooms 15	Carbon 16	Landscape 17	Biodiversity 18	Water 19	Government 20 = Σ13-19	Farms 21 = 12 + 20
Ecosystem services (ES)									
$ES_{pp,E}/ES_{sp,E}$		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2
$ES_{bp,E}/ES_{sp,E}$		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2
$ES_{bp,Sr}/ES_{sp,E}$			1.0				0.9	0.2	0.5
$ES_{pp,Sr}/ES_{pb,Sr}$			1.0				1.0	1.0	1.0
Gross value added (GVA)									
$GVA_{pp,E}/GVA_{sp}$	1.0	1.0	1.0	1.0	1.4	1.0	1.0	1.1	1.0
$GVA_{bp,E}/GVA_{sp,E}$	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0
$GVA_{bp,Sr}/GVA_{sp,E}$	1.0	0.2	1.0		0.1	0.2	0.9	0.3	0.3
$GVA_{pp,Sr}/GVA_{bp,Sr}$	1.0	1.0	1.0		4.8	1.0	1.0	1.3	1.0

Abbreviations: The subscript pp is producer prices, the subscript bp is basic prices, the subscript sp is social prices, the subscript E is the extended accounts and the subscript Sr is the revised standard accounts.

social prices by the extended accounts. The GVA of the farms measured by the standard accounts (Sr) are 0.3 times than those offered by the extended accounts (E). GVA of the farmer of the standard accounts are 0.7 times the GVA of the extended accounts, and those of the government of standard accounts are only 0.3 times that of the extended accounts (Tables 3-S14).

3.10. Farmer extended accounts actual profitability rates at social prices by activities

It is necessary to describe the farmeŕs rates of profitability instead of the government's, since the value of the environmental assets of public activities in this case is obtained by discounting their respective resource rent. In the cork oak farm case studies, we apply the discount rate of 3%. Plus, we estimated the rates of current operating profitability and capital gain for single as well as the average aggregate value for all the farm activities as a whole (Fig. S6; Table S15).

In regards to the farmer activities, the current operating profitability rate at social prices is positive and the capital gain is slightly positive. The rates for single activities range considerably, with a 9.1% profitability rate for cork as the highest current rate amongst all single activities. The rate of capital gain takes into account the price of land variation, which is attributed to amenity activity. In 2010 the rate of variation in the estimated price of land of the cork oak farms was −3.40% (Ovando et al., 2016: 45). For all the farmer activities in these case studies, the current farmer capital gain is 0.1%. The current total farmer profitability rate is 3.1% (Table S10).

We estimate the real rate of return by replacing the actual rate of variation in the land price applied when measuring the actual rate of return, with the real rate of change in land price for the period 1994–2010, which we estimated at 3.41% (Ovando et al., 2016: 45). This real rate, based on the expectation that past trends will be maintained in the future, gives a competitive 8.9% real profitability rate for the cork oak agroforestry farm case studies (Table S15).

4. Discussion

4.1. Linking ecosystem services and environmental income

From an economic perspective, our definition of sustainable ecosystem service of a single environmental asset ensures that its value does not exceed the value of environmental income in the accounting period. Our economic definition of sustainable ES does not prevent the decline of the physical endowments below the threshold. However, it was constructed keeping in mind government regulations of extractions of natural resources and land use that aim to maintain the physical natural resources endowment above the threshold of preservation, which would guarantee the ecologically sustainable consumption of ecosystem services indefinitely. The definition of a sustainable ecosystem service from the economic and physical perspectives simultaneously is required in order to permanently maintain the natural resource endowments and the physical productivity of environmental assets above the critical threshold which would sustain their preservation indefinitely.

Although our definition of sustainable environmental-economic ecosystem services is conceptually similar to that of other academic experts and statistical institutions (La Notte et al., 2019a; United Nations et al., 2014b; United Nations, 2017), there are some differences, which can possibly be understood in light of the lack of standardization of the SEEA-EEA environmental income concept and other variations amongst statistical conventions. For example, the definition of "the concept of *ecosystem services potential flow* (ES potential flow) as the maximum flow of services that the ecosystem type can provide while ensuring its provision through time" (La Notte et al., 2019a: 119) is similar to our concept of environmental income as the maximum potential environmental-economic sustainable ES. However, the measurement of our EI may differ from the ES potential flow. The latter is "defined as such, the difference between the ES potential flow and the [ES] actual flow provides an indication of how sustainably or unsustainably the [ecosystem] service is being used" (La Notte et al., 2019a: 119).

Furthermore, the concept of ES does not provide sufficient information on possible future changes in the resource rent of the ecosystem. The trends of product consumption in monetary terms do not necessarily indicate that the ecological functions of the ecosystem will be maintained in the desired conditions in the future. Hypothetically, it is possible that in a specific situation and point in time in the future, an ES contribution to the consumption of ecosystem products could induce the depletion or degradation of the ecosystemś ecological integrity. In contrast, it is also possible that the ES contribution to the product consumption is zero, which could allow for long-term conservation of the integrity of the ecosystemś ecological functions. The accumulated natural growth of woody products and game species at the closing of the accounting period, the annual cycle of herbaceous growth extracted, and the environmental work in progress used are economic variables that are incorporated into the measurement of the environmental net operating margin (NOMe). The environmental asset gain (EAg) provides the revaluation of environmental assets (EAr) as well as the withdrawal, destructions and degradations of the environmental asset at the closing of the accounting period. The EI components, NOMe and the EAg, provide a reliable implicit indication of the biophysical productivity for the actual period and on the expected future trends of the environmental asset ecosystem service yields. The environmental income (EI) is the economic variable which signifies naturés contribution to the total income of the ecosystem. However, the economic sustainability indicated by the EI does not guarantee the ecological sustainability of the farm, since the economic sustainability is the result of the physical quantity of the product consumption multiplied by its environmental price. The variations, both positive and negative, in the physical production and prices of the products, may result in a situation where both ecological decline and economic sustainability exist simultaneously. The advantage of the EI indicator is that it obliges us to estimate the future flow of physical production and therefore allows us to determine the meaning of ecological sustainability and economic sustainability separately, and then link them in the EI concept. The estimation of environmental income for the components of the actual ES and the CNWead makes it possible to directly integrate the EI in total income, in a manner that is consistent with the SNA principles of transaction value and total income (McElroy, 1976).

4.2. The meanings of depletion, degradation and change of environmental net worth

The SEEA-EEA consider the adjustment of environmental intermediate consumption (depletion) and of the consumption of environmental fixed asset (degradation) as adjustments of net value added (NVAad) and net operating surplus (NOSad) (United nations, 2017: Table 8.2, p. 135). These adjustments are not performed in the AAS due to the definition of a production function F which incorporates the natural growth (NG) and the environmental intermediate consumption (WPeu). We have only incorporated the degradation of the environmental asset of atmospheric carbon equivalent in the production account, represented by the consumption of environmental fixed asset from the emission of forest carbon through the extraction of cork, firewood and shrub in the estimations of net value added (NVA) and net operating margin (NOM). In other words, although there is no conceptual discrepancy, there is a difference in the way in which the environmental flows are organized.

The potential omission of environmental flows of "supply and use" in the production and income generation accounts of the SEEA-EEA and extended accounts affect the net operating surpluses/margins but would have no effect on the measurement of environmental income since they incorporate the values of the omissions in the revaluations and destructions of the environmental asset balance. The SEEA-EEA measures these environmental variables without integrating them into a single concept of environmental income. Thus, the SEEA-EEA measures ecosystem services and degradation adjusted net value added variables, being extended accounts and SEEA-EEA the ecosystem services the same value, then SEEA-EEA can only to estimate environmental income if the CNWead measured by AAS is null.

The interpretation of the environmental income flow component of CNWe must take into account the adjustment subtracting the natural growth values at the opening of the actual period from the revaluation of the environmental assets. As they have been counted as natural growth in accordance with their full value at the close of the period in the accumulated final product (timber, cork and firewood) and in the final product consumption (carbon fixation) in order to estimate the net environmental margin, we should correct the capital gains of the environmental assets by subtracting the natural growth values embedded in the environmental assets at the opening of the period from the environmental asset revaluations. In this way, we avoid double accounting of the environmental income from natural growth. This is the reason why the CNWe of carbon is negative in the actual period. In the case of the amenity, the notable negative value of the CNWe is due to the decline in land prices in 2010 which was not foreseen at the opening of the period.

4.3. Profitability and natural regeneration of Spanish cork oaks farms

Existing information with regard to the natural regeneration of the cork oaks in the Spanish *Dehesa* reveals a marked physical degradation leading to a gradual decline in physical productivity of cork extraction and points to non-sustainability of the biological management of cork oaks at *Dehesa* scale in the west and southwest of Spain (Aronson et al., 2009; Bugalho et al., 2011; Campos et al, 2007, 2008; Coelho and Leitão, 2013). A government technical report estimated a decade ago that in 93% of the experimental tiles of cork oak forest in Andalusia, cork oak regeneration was null (MAPA, 2008: Table 126, p.200). Furthermore, from an economic perspective, the scarce scientific information available suggests that cork yield is competitive compared to the profitability of public debt or investment in low risk assets in the stock market (Campos, 1999: Coelho and Campos, 2009). However, there is an overvaluation of the income from cork extracted from Spanish cork oaks as a whole due to the omission of the consumption of fixed environmental assets in the costs considered in the standard accounts. If the estimated replacement costs of the aged cork oaks were taken into account, the sustainable environmental income of the cork would disappear at market prices (Campos et al., 2003).

What is the apparent paradox between the biological degradation of the cork oak forest and obtaining of real competitive rates of return? There is no hidden mystery and the new owners of cork oak farms know that they pay a price for the purchase of a cork oak farm that is usually double the price justified by the profits from commercial products. The buyer of a cork oak farm today generally seeks to satisfy their demand for the enjoyment of private amenities. In other words, today, the private family owners of a cork oak farm pay the commercial opportunity cost of auto-consumption of environmental services exclusively enjoyed in their cork oak farm (Oviedo et al., 2017).

4.4. Policy implications

The monetary valuation of the economic activities ecosystem services and the environmental income are always conditioned by property rights that dictate access to the appropriation of goods and services provided by nature. In these cork oak farms case studies only employee labor is used. This is not the actual fact in most of the Spanish *dehesas* properties, were 96% of farms have less than 200 ha and in these *dehesas* size the labor force is frequently made-up of family members and thus self-employed workers, which generates a net mix income in farm standard account. In the contexts in which self-employed workers have free access to land uses, it is possible to arbitrarily separate the only ordinary environmental net operating margin, ordinary manufactured net operating margin and imputed self-employed workers compensation from the farm net mix income. In situations where it is possible to attribute an opportunity cost to self-employed labor, it may be acceptable to assume a residual price for self-employed labor by comparison with the price for the same task undertaken by a salaried worker, weighted according to a correction factor of less than one unit (marginal productivity is assumed to be lower for self-employed labor) (Ovando et al., 2016). The problem which may arise with the imputation of the residual value for self-employed labor is the absence of economic value of the environmental income due to giving preference to remuneration for human labor over the income from nature, which only makes economic sense as a payment for the excess beyond remuneration for human labor and immobilized manufacture capital. In this situation, the important variable is the net value added because it reflects the manufactured income generated by production factors when one of them, such as the land in this case, "is worth nothing". However, this situation of gratuity in the appropriation of natural resources by the workers and/or farmer is a necessary condition for the existence of labor compensation and/or manufactured capital income. In other words, the economic activity can take place thanks to the fact that the farmer does not have to pay for the free (null economic value) actual ecosystem services.

The implication that can be drawn from the above reflection in regards to the significance of the environmental income is that there are situations where it is the value added, and not the environmental income, that is the key economic variable in public policies concerned with the management and conservation of natural resources. However, it remains the case that in a context where there is market wage rate, as in our case studies, sustainable economic management must take into account scheduled future sustainable biophysical indicators scenarios.

Beyond the competitive return of the Spanish cork oak farms, the myopia of the farm market that encouraged family ownerś investments mainly for the auto-consumption of amenities, with a forfeit of the long-term regeneration of the landś biological tree and soil varieties , is a challenge that must be overcome by the government, as the collective owner in the name of the actual society, of the coming generations of public good and services of Spanish cork oak farms. These goods and services must include conservation of the cultural landscape in a good ecological condition along with the unique biological variety under threat. Consequently, it is government policies that must address the conservation of the cultural landscape of the Spanish cork oak farms, not only the biophysical aspects, but also the historical built heritage and historical uses which inform the legacy recognized by the global society. In this case, the reference to society goes beyond the Iberian countries and must include member countries of the European Union.

Government statements on the need to implement ecosystem accounts incorporate the purpose of linking biodiversity conservation with the equitable distribution of benefits to local people from the sustainable management of landscapes multiple uses (European Commission, 2011; Masiero et al., 2019; United Nations, 2012). Thus, equity is a public policy criterion that must be considered as part of the sustainable management of the environmental assets of the Spanish cork oak farms. The incorporation of government compensation, owner opportunity costs, commercial intermediate services of government management, and consumer willingness to pay in the product consumption means that we have a social responsibility to share out these payments appropriately in order to promote sustainability in the management of Spanish cork oak farmś environmental assets.

5. Concluding remarks

The ES provides an indication of the importance of the cork oak farmś consumption of its economic products by actual generations. The EI tells us which part of the consumption is supported by actual and future resource rents of the cork oak farms. It may be said that the EI provides robust information on actual and expected future consumption of ES, thus incorporating options for future consumption of ES by actual generations and those to come. The advantage of the EI over the ES is that the former represents the contribution of the ecosystem to present and future farm product consumptions. Thus, it can be understood that the ES is only part of the economic contribution of the cork oak farms to the actual consumption of farm products.

Our cork oak farm application has highlighted the importance of auto-consumed intermediate services of single activities in valuing ecosystem services and gross valued added of farmer and farms private amenities. In particular, our inclusion of non-commercial intermediate services and their counterpart of own intermediate consumption of services has proven to be a necessary in avoiding bias in the valuation of single ecosystem services and total environmental income. The measurement of environmental income is a key challenge to forecasting sustainable management of ecosystem services and environmental assets. The main economic challenge faced by landowners, governments and consumers in regards to the conservation and improvement of the environmental assets of farms is how to distribute the payment of the intermediate services produced by private activities amongst each other in order to favour the consumption of private amenity and public final product consumption by actual and future generations.

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Declaration of Competing Interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

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