Land Use Policy 99 (2020) 104984

Contents lists available at ScienceDirect

Land Use Policy

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

Measuring environmental incomes beyond standard national and ecosystem accounting frameworks: testing and comparing the agroforestry Accounting System in a holm oak *dehesa* case study in Andalusia-Spain

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

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

A R T I C L E I N F O

Keywords:
Working landscape environmental policy
ecosystem accounting
total product consumption
ecosystem services
environmental assets
adjusted change of environmental net worth

A B S T R A C T

The standard System of National Accounts (SNA) omits the costs of the environmental inputs from nature and the environmental fixed asset degradation from the national/sub-national natural working landscapes. The United Nations Statistic Division (UNSD) is currently drafting the standardization of the Experimental Ecosystem Accounting (EEA), as part of the System of Environmental-Economic Accounting (SEEA). The EEA- aims to mitigate some of the limitations of the SNA by extending the concept of economic activity and explicitly incorporating ecosystem services and environmental assets provided by nature in the estimates of net value added, adjusted according to the costs of the environmental inputs consumed and the environmental fixed asset degradations of ecosystem. However, the NVAad proposed in the ongoing draft of the EEA is inconsistent in that it omits the manufactured costs of the public economic activities of the new government institutional sub-sector of the ecosystem trustee. In addition, the ongoing methodological guidelines of the EEA do not propose to estimate the environmental income. This implies that there is not a single indicator that integrates the ecosystem services obtained and the evolution of the environmental assets in the natural working landscapes in which the private and public activities are valued. The objective of this research is to discuss conceptually and compare the measurements of ecosystem services and environmental incomes in the extended Agroforestry Accounting System (AAS), and in refined versions of the official SNA and the ongoing EEA methodologies, through a case study of privately-owned holm oak *dehesas* working landscapes in Andalusia-Spain. This comparison shows that the refined SNA and the refined EEA in their current state of development do not allow the complete visualization of the environmental income contribution to the total income of the natural working landscapes. We also discuss the advances provided by the AAS extended accounting methodology that would be relevant for the EEA next improvements.

1. Introduction

The scientific debate on economic ecosystem accounting is a multidisciplinary and interdisciplinary challenge of enormous complexity. In particular, the debate over the economic valuation of human consumption of the natural working landscape products from agroforestry farms generates ethical and technical issues surrounding which there is much discrepancy.

Only recently did the United Nations Statistics Division (UNSD), the official body responsible for the SNA (European Commission et al., 2009), and the governments, start addressing these shortcomings in the standard SNA through the ongoing standardization of the System of Environmental Economic Accounting (SEEA). The official SEEA is composed of the Central Framework (SEEA-CF) (United Nations et al., 2014a) and the still-in-process satellite Experimental Ecosystem Accounting (SEEA-EEA) (United Nations et al., 2014b). The SEEA-EEA (henceforth EEA) constitutes the current conceptual framework for the measurement of ecosystem services and environmental assets linked with the standard SNA (FAO, 2017; Hein et al., 2020a; Obst et al., 2016, Obst et al., 2019; ONS and DEFRA, 2017; United Nations et al., 2014a, United Nations et al., 2014b; United Nations, 2017; UNSD, 2020a, UNSD, 2020b).

* Corresponding author at: Spanish National Research Council (CSIC), Institute of Public Goods and Policies (IPP), C/ Albasanz, 26-28, E-28037 Madrid, Spain.
E-mail address: pablo.campos@csic.es (P. Campos).

https://doi.org/10.1016/j.landusepol.2020.104984
Received 6 November 2019; Received in revised form 30 July 2020; Accepted 31 July 2020
Available online 21 August 2020

There are scarce experimental academic and national statistical office applications at national/subnational ecosystem type scales that extend the standard SNA (Hein et al., 2020a, 2020b; Keith et al., 2017; Obst, 2019; Remme et al., 2015; Sumarga et al., 2015). In the context of the ongoing debate surrounding ecosystem accounting, our extended Agroforestry Accounting System (AAS) methodology aims to overcome the limitations of the standard NVA (Campos et al., 2019a, 2020a, 2020b, 2020c). We advocate the measurement of total environmental income[1] of the ecosystem types with reference to the specific natural landscape and territorial economic unit of individual farms in accordance with the total income of society (Eisner, 1989; Hicks, 1946; Krutilla, 1967; McElroy, 1976; Stone, 1984).

Among the shortcomings of the standard System of National Accounts (SNA) net value added (NVA) are the omission of the explicit measurement of the environmental income of the economic activities of the natural working landscapes. The environmental income is defined as the aggregate value of the environmental net operating margin and the environmental asset gains of the natural working landscape area valued. This limitation of the SNA means that the standard NVA does not reflect the real total income contributed by a natural working landscape area to society (Campos et al., 2013, 2020a). However, we need to estimate the total income of society and its factorial distribution for farms, and therefore determine the significance of the residual values of the environmental incomes and assets in order to assess the options for biological and economic sustainability of ecosystem types at individual farm scale, linking the trade-offs between private and public economic activities with natural base production functions (Campos et al., 2019b).

The debate among expert, scientific institutions on the national/subnational application of the EEA also highlights the challenge of making visible the environmental incomes that accrue from the management of ecosystem environmental assets at farm scale (Campos et al., 2017, 2019b, 2020d; Cavendish, 2002; Lammerant, 2019; Marais et al., 2019; Obst et al., 2019; Ovando et al., 2016; Oviedo et al., 2017; Sjaastad et al., 2005).

Articles concerning the conceptual development and applications of the Experimental Ecosystem Accounting (EEA) tend to focus on a single ecosystem service and/or the respective environmental asset of the product (good or service) valued, although they sometimes present valuations of several products within a single natural landscape. The majority of these articles on applications of the EEA do not estimate the value added of the product consumed. In other words, these articles are often elusive as regards showing that they are measuring ecosystem services without bias resulting from the omission of manufactured costs and products of activities without market prices.

In academic and technical report literatures ecosystem services and environmental incomes are considered to have plural meanings, encompassing from the consumer surplus to the resource rent concepts. This research attempts to extend this latter perspective by integrating ecosystem services in both the values of the extended total products consumed and the environmental income in an ecosystem accounting area, in a specific period.

The main objectives of this research are, firstly, to extended the concepts and measurements of the environmental incomes, under our own refined standard System of National Accounts (rSNA) and the refined System of Environmental Economic Accounting-Environmental-Experimental Ecosystem Accounting (SEEA-rEEA) approaches and, secondly, to conduct a comparison by testing them with our Agroforestry Accounting System (AAS) in a case study of open woodland working landscapes of a real farm.

[1] We interpret "environmental profit and loss" (Lammerant, J., 2019: p. 11) and "extended profit and loss" (Obst, 2019; p. 16) in the production and balance accounts of corporations as conceptually synonymous with 'environmental income'.

We apply the above economic accounting frameworks to 16 privately-owned mixed holm oak *dehesas* in Andalusia-Spain (henceforth *dehesa* case study) with a total area of 9,032 hectares (Campos et al., 2020d: Table A1, p. 28). The *dehesa* case study is of an open woodland agroforestry farm, in which the area covered by holm oak (*Quercus ilex* L.) predominates, and where the livestock and game species shape the open woodlands (Montero et al., 2017)[2] . This research requires the measurement of multiple bio-physical and economic functional interactions among the aggregate environmental incomes of the farmer, government and average farm values. In these measurements, the valuations of final products consumed are based on the interactions associated with the intermediate products of single activity production functions for the 19 economic activities of the *dehesa* valued, 11 of which provide ecosystem services and 12 environmental incomes in the 2010 period. The farmers (landowners) have the property rights of 12 private economic activities (timber, cork, firewood, industrial nuts, grazing (grass, acorn, browse, wild fruit), conservation forestry services, hunting recreation services, commercial recreation services, landowner residential services, livestock, agricultural crops and amenity service auto-consumption) and the government is the collective owner of 7 public economic activities (fire services, public recreation services, mushrooms, carbon, landscape conservation services, threatened wild biodiversity preservation services, water supply stored in lowland watershed government reservoirs).

Based on the previously identified total income and total capital measured by the AAS approaches (Campos et al., 2020d), this *dehesa* case study tackles the development of the SEEA-rEEA (henceforth rEEA) in order to measure and compare its ecosystem services and environmental incomes with those of the AAS methodology. One of the main novelties of this *dehesa* case study is that we present real results incorporating the simulated transaction prices of public final product consumption revealed and stated by consumer willingness to pay (WTP). This allows us to make a more robust comparison of the environmental-economic results obtained with our refined official rSNA and rEEA and those of the AAS approaches for the first time in a privately-owned holm oak open woodland *dehesa* case study.

The conceptual development and results show that the official rSNA and rEEA do not make visible the contribution of the total environmental incomes of natural working landscapes to the total income of society which, as shown in this research, is estimated with greater consistency by the AAS methodology in the privately-owned *dehesa* case study.

The study continues in the second section with brief characterizations of the economic rationales of the landowners, the government and the specific consumers in the *dehesa* case study, along with a conceptualization of the estimates of integrated environmental incomes in the rSNA, rEEA and AAS approaches. The third section describes environmental-economic results for the 2010 period, firstly for the AAS method and secondly, we compare the results for the three accounting methods. The fourth section discusses the conceptual perspectives and results from the *dehesa* case study: firstly, the limitation of the rSNA and rEEA methods compared with the advances of the AAS approach, and secondly, we highlight the pending challenges to be overcome by environmental ecosystem accounting from the perspective of measuring the environmental income integrated in the total income of natural working landscapes. The fifth section presents the policy implications: firstly those relating to the government, in the design and implementation of the EEA and associated utilities with the aim of determining the true economic contribution of the ecosystem types to the

[2] According to the Andalusian regional government legal definition of the *dehesa* in terms of vegetation and agrarian uses, the canopy cover of the open woodlands of Mediterranean species should not exceed 75% and these woodlands should make up at least 50% of the total surface area of the farm (BOJA, 2010).

products consumed and accumulated in the period in which the total income of the natural working landscape is measured; secondly, it describes how the concept of fair compensation can be estimated by considering the results for a type of environmental ecosystem accounting such as the AAS. Section six concludes with a summary of the advances in the AAS methodology and of its possible applications in the development of voluntary concerted actions between the private and public agents with the purpose of mitigating the degradation of the environmental assets derived from the economic activities while at the same time maintaining the consumption of the private and public products of the natural working landscapes.

2. Concepts and integration of the environmental accounting frameworks

Due to the absence of a government standard economic ecosystem accounting stystem, in the development of the accounting approaches applied here to the dehesa case study, we are obliged to create our own organisations for the accounting records and definitions of economic variables omitted in the rSNA and rEEA approaches. With regard to the most important terms used in this dehesa case study, although we have attempted to define those which are less common in the literature, we may have overly eluded the use of certain concepts from the point of view of the average reader not expertly knowledgeable in such valuations. Where this is the case we recommend that the reader consults our previous publications (Campos et al., 2019b, 2020a, 2020b, 2020c, 2020d).

The criterion governing the structure of ecosystem accounting for an individual product consumption is based on its direct and/or indirect consumption in the period and that which is expected to be consumed in the infinite future by people. The ecosystem service value is embedded in the product consumption, and its perpetual flow of discounted future consumption give the environmental asset value, by convention, at the closing of the period. It should be noted that the valuation of the environmental assets is subsidiary to the consumption of their flows of services by people, while the bio-physical assets are the ultimate basis for the biological sustainability of the ecosystems. For this reason, the economic valuation of ecosystem services based on consumer preferences should also be subsidiary (under the collective ethic of the precautionary principle) to operating above the bio-physical thresholds (biological Safe Minimum Standard) considered sufficient to avoid or at least mitigate the uncertain risk as regards possible irreversible consequences of the economic activities (Berrens, 2001; Campos and López, 1998).

2.1. Total product consumption

The value of the total product consumption (TPc) of an economic activity in a period is given by a biophysical-economic production function which depends, among other things, on the local labour market, the property rights over the extraction and the transmission of rights of use of natural landscapes to third parties (Anderson and McChesney, 2003).

In Campos et al. (2020c) we define the economic concepts of 'activity' and 'product' which we employ in this *dehesa* case study, although without describing the explicit links with the concept of total economic value, which we explain below. The name that we give to an economic activity corresponds to that of the main economic product, although there are normally secondary products associated with a given economic activity.

The economic valuation only relates to those products consumed by people directly or indirectly from the types of ecosystem services that have been appropriated and which, given their scarcity, generally require human production factors to produce them. Only the scarce ecosystem products managed by private and public (including government) economic agents can be subject to economic valuation, based on the individual preferences of citizens and, in situations where there is a high risk of irreversibility due to the loss of a unique genetic variety, government collectives expressed by direct public spending on the management of quasi-option passive use (existence) value.

The environmental assets of the ecosystems of the holm oak *dehesa* case study provide multiple economic goods and services which contribute to the supply of the total product consumption according to the human demand. To estimate the contributions of the *dehesa* ecosystem services it is necessary to consider the presence of human consumption of goods and services, whether individual or collective, in the current period and/or future periods, along with the assignment of individual or collective property rights over the product. The contribution of human production factors (remunerated labour and/or manufactured capital) in certain natural products is not necessary in order to define the concepts of their economic product consumption.

The existence of an economic value for the total product consumed (TPc_j) of an activity only requires its appropriation by an individual or institution and the economic contribution of, at least, one production factor belonging to one of the five production function classifications (Eq. 1):

$$TPc_j \equiv F_j\ (ICmo_j,\ WPeu_j,\ LCo_j,\ FCm_j,\ EFA_j) \quad (1)$$

where j is the economic activity, F is the production function, ICmo is ordinary manufactured intermediate consumption of raw materials and services, WPeu is ecosystem environmental work in progress used, LCo is ordinary labor compensation of employees and self-employed labour, FCm is manufactured fixed capital and EFA is environmental fixed asset.

The first step in implementing the economic environmental ecosystem accounting is to estimate the economic value of the intermediate and total final product consumption generated by the single economic activity for which complete data is available for the period, when their total income is estimated in the ecosystem accounting area (Fig. 1). We interpret 'complete data' as meaning that all the total product consumption (goods and services) associated with the different stages of production of the main product of the economic activity are valued and registered explicitly in the production account, to which we attribute exclusively the total cost and the ordinary net operating margin, which complete its total product consumption transaction or imputed production cost value.

The most obvious reason for which people state their willingness to pay (WTP) in order to appropriate the active use of a product is to satisfy their consumption requirements in the current and/or future periods (Fig. 1).

We define active use as the observed or stated/revealed WTP for the current benefit associated with assuring the consumption of the product in the current period and the appropriation of the accumulated ecosystem product in future periods.

People may also pay for the passive use benefit of assuring the persistence in the future of the consumption of goods and services with current active uses. We define the ordinary passive use option as the consumer marginal WTP for the current benefit associated with assuring management which guarantees that current ecosystem services will continue to be produced over a given time horizon (e.g. 30 years). This ordinary passive use option arises when the current generations are concerned about the future supply of a given service, the persistence and/or desired supply of which they prefer not to be put at risk. The ordinary passive use option is reflected in the willingness of current generations to incur an additional ecosystem management cost as a means to assure that the desired amount of the environmental asset is reached in the future. The compensation is justified either by the decline in the supply of ecosystem services, caused by the current management, or because a future offer of these services either similar to or greater than that currently available is desired.

Individuals may also express WTP for the benefit associated with

Intermediate and final products		Final products	
Active uses		Passive ordinary option use	Passive quasi-option use
Final products	Intermediate products	Final products	
1. Definitions of final and intermediate total products			
The finished final product consumed by people or by other economic activities of ecosystems different from the one that produced it. The work in progress and finished long-lasting products accumulated in the ecosystem until harvesting or consumption of the aliquot part of the periodic depreciation in the case of long-lasting product.	Goods and services produced that are used in the same period as own ordinary intermediate consumption in obtaining the final product consumptions in the same ecosystem	Willingness of users to assume a payment to guarantee the consumption of the service by themselves or third parties in the future.	Willingness of interested people to assume a payment to guarantee the future existence of the service irrespective of its active use.
2. Intermediate and final consumptions of total products			
Timber , cork , firewood , industrial nuts , hunting meat and recreation services , commercial recreation services , livestock , agricultural crops , amenity service auto-consumption , public recreation services , mushrooms, carbon , , water supply stored in lowland watershed government reservoir .	Grazing (grass, acorn, browse, wild fruit), conservation forestry services, landowner residential services, fire services, government service compensation, landowner amenity service auto-consumption.	Landscape conservation services	Threatened wild biodiversity preservation services.

Fig. 1. Intermediate and final consumptions of total products for the *dehesa* case study in Andalusia.

contributing towards mitigating the decline and/or loss of habitats and unique, non-reproducible species threatened with extinction if appropriate preservationist management is abandoned in the future. We define the quasi-option passive use (existence value) as the consumer WTP for the benefit currently perceived by assuring a management that guarantees that the current number of wild biological species threatened with extinction will not increase over a given future time horizon (e.g. 30 years).

The concept of ecosystem existence value has given rise to much ongoing scientific controversy concerning the difficulty involved in valuing this unusual concept of quasi-option passive use. Economic science bases the existence value on the observation that the individuals and institutions that represent them spend economic resources either individually or collectively, in an attempt to avoid the complete disappearance of natural habitats and/or varieties of biological species (once gone they cannot be reproduced by human industrial means).

The consumption of the final product of the ordinary passive use landscape conservation service has an inevitably subjective delimitation. We adopt the criterion of estimating the additional amount which Spanish consumers surveyed at their homes are WTP at a given annual rate over a period of 30 years, on top of the ordinary total cost borne by the government in the current period. In return, the government guarantees that the landscape ecosystem services will not decline over a time horizon of the next 30 years. In the choice experiment scenarios, the more than 3,000 respondents to the survey are presented with alternatives for landscape conservation and preservation without loss of threatened wild biodiversity (Campos et al., 2019a). Our separate estimation of landscape and threatened wild biodiversity services requires mathematical procedures which lead to the splitting of the different estimates of consumer marginal WTP for the same quantity and quality of public landscape services and threatened wild biodiversity.

The economic values of the active and passive uses which make up the total product consumption of ecosystem goods and services are additive, although double counting errors and heterogeneity of product values may arise if the criteria of double entry and exchange value are not taken into account in the residual valuations of the ecosystem services and environmental incomes of the economic activities of the farm (Campos et al., 2019b, 2020d).

In developing the rEEA and AAS we carry out the valuation of the final product consumption on the basis of the exchange prices applied by the standard SNA and we extend the transaction price to the simulation of markets for the consumption of products without market prices (for details see Campos et al., 2020d).

2.2. Environmental income

2.2.1. Conditioned sustainable environmental income

Although the concept of ecological sustainability is a broader concept than the term biological sustainability, we have used both concepts synonymously in this research since we assume future scheduled management of the *dehesa,* which satisfies the preferences of the consumers and guarantees the preservation of the natural biophysical environment, assuming the absence of irreversibility. We also assume there are no current notable losses in soil fertility or water quality caused by livestock, game or superficial ploughing in the Spanish *dehesa*, although certain controlled animal management with residual water filtration could affect water quality further down the watershed.

Biological sustainability is defined by biological variables which are independent of the total income sustainability which defines economic sustainability. Our conceptualizations and applications of the rSNA, rEEA and AAS frameworks in the *dehesa* case study assume the absence of land use change and also that the biophysical amounts of unique varieties of environmental assets over complete reproductive cycles are above the threshold of significant risk of extinction according to the expert scientific natural resource subjective criterion of the stated Safe Minimum Standard (SMS). In this circumstance, the scheduled future biological sustainability of natural resource management assures the preservation of all the wild biological species currently present in the *dehesa* case study (for details see 2010 period biophysical measurements in Campos et al., 2020d: Table A4, pp. 29-30). Given the assumed future biological sustainability of the case study *dehesa*, here we only tackle the concept and measurement of the economic ecosystem service and conditioned sustainable environmental income integrated in a consistent manner with total income theory.

We define the concept of conditioned sustainable environmental income subject to the fulfilment of two conditions at the closing of the accounting period. The first, a biological condition, refers to the renewable environmental asset biophysical critical minimum volume given by its SMS, represented by a unique wild genetic variety, necessary in the natural habitats where it reproduces and grows in the wild to guarantee that the risk of extinction as a consequence of the economic activities is avoided. The second, an economic condition, is that once the first condition of exceeding a SMS of stock at the closing of the period has been met, the aggregate total income at social price of the economic activities for the ecosystem type and/or spatial unit estimated in the current period must be equal to or above that estimated in the preceding accounting period.

The corollary of meeting both conditions is that any combination of values for the labour, manufactured capital and environmental asset incomes that make up the total income will be economically and biologically sustainable. If the biological condition is met but not the economic condition, then there will be biological sustainability but the total income will not be sustainable. If neither condition is met, then the economic activity will not be sustainable economically or biologically.

2.2.2. Environmental income residual measurement

Based on the results for the production, income generation and capital balance accounts of the AAS methodology, we constructed the sequence of accounting registers for the rSNA, the rEEA and the AAS, which measure the environmental incomes of the individual activities, farmer, government and aggregate activities in the *dehesa* case study (Campos et al., 2020d). The AAS results are of particular interest as they highlight the insufficiency of the rSNA and rEEA valuations in the preliminary development phase of the latter. In this *dehesa* study no adjustments are made to the ordinary net value added or the ordinary net operating margin according to consumption of environmental fixed assets (ecosystem degradation) because they are not embedded in the consumption of total products. However, the ecosystem degradation is implicitly recorded as it is integrated in the change of the environmental asset estimated for the period.

The environmental incomes in the *dehesa* case study allow the integration of the environmental ecosystem accounts within the general framework of the standard SNA principle of transaction value and effective total product consumption by people for the period, which provide the basis for environmental ecosystem accounting. In this research, the existence of environmental income for the period is conditioned by the institutional land ownership types and consumer preferences at global and local scales according to their residual value estimate once the labour cost and manufactured capital investment operating margin (benefit services) have been paid.

The environmental income is estimated directly as the sum of the balancing items of the environmental net operating margin and the environmental asset gain (Campos et al., 2020d). However, in this case we want to reclassify both components of the environmental income into their equivalents of ecosystem service and adjusted change in environmental net worth:

$$EI = ES + CNWead \tag{2}$$

No discrepancies exist in expert scientific literature on environmental accounting as regards the concept of environmental income, defined as the contribution of nature to the total income of a natural area. However, the absence of a definition of environmental income in the standard SNA and EEA has meant that, in practice, multiple terms continue to be used such as environmental income (Cavendish, 2002), value added (Sjaastad et al., 2005; Vedeld et al., 2004), ecosystem income (Fenichel et al., 2018) or sustainable potential flow, without distinguishing whether they refer to ecosystem services or environmental income (La Notte et al., 2019a, 2019b).

2.2.2.1. Ecosystem services

Ecosystem services. Once the total income for the *dehesa* case study has been estimated using the AAS method (Campos et al., 2020d), we organize the structure of the registers of environmental ecosystem accounting starting with the working landscape total product consumption (TPc_j):

$$TPc_j = ICmo_j + WPeu_j + LCo_j + CFCmo_j + NOMmo_j + NOMeo_j \tag{3}$$

where j is economic activity, $ICmo_j$ is ordinary manufactured net operating margin, $WPeu_j$ is environmental work in progress used, LCo_j is ordinary labor cost, $CFCmo_j$ is manufactured consumption of fixed capital, NOMmo is ordinary manufactured net operating margin and NOMeo is ordinary environmental net operating margin.

The single activity total product consumption components give the estimates of ordinary gross value added (GVAo), ordinary net value added (NVAo), ordinary net operating margin (NOMo) and ecosystem service (ES):

$$GVAo_j = TPc_j - ICmo_j - WPeu_j \tag{4}$$

$$NVAo_j = GVAo_j - CFCmo_j \tag{5}$$

$$NVAo_j = LCo_j + NOMo_j \tag{6}$$

$$NOMo_j = NOMmo_j + NOMeo_j \tag{7}$$

$$ES_j = WPeu_j + NOMeo_j \tag{8}$$

The concepts of ecosystem services and environmental incomes in the ecosystem accounting area steady state management give similar economic figures, but they usually differ when over/under use of natural resources exists.

2.2.2.2. Adjusted changes in the environmental net worth

Adjusted changes in the environmental net worth. Among the components of the adjusted changes in the environmental net worth are the following: natural growth of woody work in progress inventoried at the opening and closing of the period; degradation of fixed environmental assets (in this study only carbon emission is entered in the production account) and environmental asset gains. The latter come from revaluations of environmental assets less the adjustments in environmental assets to avoid double counting. The revaluations of the environmental assets are due to the reduction, by one period, of the time remaining until the extraction of the woody products in progress inventoried, at the opening and at the closing of the period (except those included in the natural growth), and the changes in the future biological productivity of the woody products:

$$CNWead = NOMei + EAg - WPeu \tag{9}$$

$$NOMei = NG - CFCe \tag{10}$$

$$EAg = EAr - EAad \tag{11}$$

$$EAr = EAc - EAo + EAw - EAe \tag{12}$$

$$EAad = WPeuw/(1+r) + FPcca/(1+r) \tag{13}$$

where NOMei is environmental net operating margin investment, EAg is environmental asset gain, WPeu is environmental work in progress used, NG is natural growth at the closing of the current period less expected future simulated catastrophic forest fire losses, CFCe is consumption of environmental fixed asset (carbon emission), EAr is environmental asset revaluation, EAad is environmental asset adjustment, EAc is closing environmental asset, EAo is opening environmental asset, EAw is environmental asset withdrawal, EAe is environmental asset entry, WPeuw/(1 + r) is environmental work in progress used valued at the opening environmental price and FPcca/(1 + r) is carbon final product consumption (carbon fixation) valued at the imputed market price (in this *dehesa* case study this coincides with marker price) at the closing of the current period.

2.3. Integration of ecosystem accounting frameworks

In this research, given the lack of fully developed environmental-economic accounts in the official EEA methodology, we have developed our own refined version of the official EEA (rEEA) applied to the institutional sectors of the farmer (landowner) and the government ecosystem trustee (UNSD, 2020b). Our comparison of the concepts and results of our extended Agroforestry Accounting System (AAS) and our refined version of the standard SNA (rSNA) is hampered by the fact that the definitions of the incomes and ecosystem services are not homogeneous, as evidenced by the omission of manufactured costs in the activities of the new institutional sector of the ecosystem trustee under the rEEA. The rEEA consists of incorporating the government activities, which embed the ecosystem services with and without manufactured costs valued according to the final product consumed at imputed market price (mushrooms, water and carbon) and declared simulated transaction price (landscape and threatened wild biodiversity), in the ecosystem trustee institutional sector (UNSD, 2020b: para. 11.55, p. 14). Although there is no final decision about whether or not to include manufactured costs in the institutional government sub-sector of ecosystems trustee (in total or partially), we have decided to assume that manufactured costs will not be included in the final version, in order to highlight the consequences that such a decision would have. We also include a brief comparison of the AAS and the refined System of National Accounts (rSNA) with the main aim of comparing the environmental incomes measured by the rSNA, rEEA and AAS methodologies applied in the *dehesa* case study.

Fig. 2 presents the presence/absence of accounting records which, based on the standard System of National Accounts (SNA)[3] applied to the agroforestry activities of the farms at national/sub-national scale, lead us (after successive modifications) first to the rSNA, then to the rEEA and finally to the AAS.

The production accounts for total product consumption in the case of the farmer under the SNA and rSNA methods contain the same values, reclassified so that we present a refined version which allows greater homogeneity with the records under the rEEA and AAS methods applied in this Andalusian *dehesa* case study. We reclassify the ordinary net operating surplus in the SNA as the ordinary net operating margin in the rSNA, removing the manufactured and environmental work in progress used from the net operating surplus and recording them as intermediate consumption. The consequence of this change is that it avoids the inconsistency in the SNA of including work in progress used as income instead of considering it as a cost, as in the rSNA. The rSNA splits the ordinary net mixed income in the SNA into ordinary net operating margin and ordinary self-employed labour compensation.

The non-financial production and balance accounts of the SNA should not differ conceptually from the farm accounts. However, the differences between these farm accounting frameworks and that of the SNA are: (i) that the SNA ignores natural growth (NG) in the estimation of own account gross capital formation for the period and considers the intermediate consumption of work in progress used (WPeu) standing at the opening of the period as a component of the net operating surplus (NOS); and (ii) that the SNA does not measure changes in the environmental assets (CEA) and adjusted changes in environmental net worth (CNWead) in the balance account. Although both systems claim to measure the income of the economic activities (at regional/national scale in the case of the SNA and at farm scale in the case of farm accounting), the farm accounting differs from the SNA in that it explicitly or implicitly takes into account the adjusted change in net worth to the market beyond the legal regulations. However, both accounting approaches ignore the environmental incomes and environmental assets from public goods and services.

In the opening capital of the balance account we count the manufactured capital of livestock work in progress from the preceding period, and we also simultaneously register it in the withdrawal from the balance account as manufactured work in progress used (WPmu) included in the intermediate consumption of the production account, since we do not follow the rSNA criterion of registering it under inventory change in gross capital formation. These differences in accounting approach do not affect the estimation of the net values added in the three accounting methodologies applied.

An overvaluation of the ordinary net operating surplus is incurred in the SNA compared with the ordinary net operating margin in the rSNA, rEEA and AAS frameworks. This is due to the inclusion in the ordinary net operating surplus of the work in progress used (WPu), the latter being an input from the inventory at the opening of the period (work in progress produced in previous years), and it is not considered by the SNA as intermediate consumption of the economic activities in the period. In contrast to the SNA criterion, the criterion of the rSNA, rEEA and AAS as regards the ordinary net operating margin NOMo is to exclude the work in progress used. The ordinary net operating surplus in the SNA differs from that of the rSNA ordinary net operating margin as shown in Eq. 14:

$$NOMo_{bp,rSNA} = NOSo_{bp,SNA} + NOSo_{bp,NMI} - WPu \tag{14}$$

where $NOMo_{bp,rSNA}$ is the rSNA ordinary net operating margin at basic prices, $NOSo_{bp,SNA}$ is the SNA ordinary net operating surplus at basic prices, $NOSo_{bp,NMI}$ is the SNA net mixed income (NMI) ordinary net operating surplus at basic prices and WPu is the work in progress used.

The SNA and the rSNA estimate the ordinary net value added of the commercial activities of the farmer at basic prices. As a consequence of the reclassification and splitting of the SNA total product consumption account records in this *dehesa* case study, we eliminate the bias towards overvaluation of the SNA net value added by the amount corresponding

[3] The SNA final product consumption at basic prices refers to the exclusion of the own-account gross capital formation of the farmer, the components of which are the intermediate consumption investment and gross value added investment.

Class	SNA	rSNA			rEEA			AAS		
Institutional sectors/farm	Farmer	Farmer	Government	*Dehesa*	Farmer	Ecosystem	*Dehesa*	Farmer	Government	*Dehesa*
Intermediate product of raw materials		$IRMg_{pp}$		$IRMg_{pp}$	$IRMg_{pp}$		$IRMg_{pp}$	$IRMg_{pp}$		$IRMg_{pp}$
Commercial intermediate product of services		$ISSc_{pp}$	$ISSc_{pp}$	$ISSc_{pp}$	$ISSc_{pp}$		$ISSc_{pp}$	$ISSc_{pp}$	$ISSc_{pp}$	$ISSc_{pp}$
Non-commercial intermediate product of services compensation		$ISSncc_{bp}$		$ISSncc_{bp}$	$ISSncc_{bp}$		$ISSncc_{bp}$	$ISSncc_{bp}$		$ISSncc_{bp}$
Non-commercial intermediate product of amenity services auto-consumption					$ISSnca_{sp}$		$ISSnca_{sp}$	$ISSnca_{sp}$		$ISSnca_{sp}$
Final product consumption	FPc_{bp}	FPc_{pp}	$FPc_{pp/pc}$	$FPc_{pp/bp}$	$FPc_{pp/sp}$	$FPc_{pp/sp}$	$FPc_{pp/sp}$	$FPc_{pp/sp}$	$FPc_{pp/sp}$	$FPc_{pp/sp}$
Ordinary manufactured intermediate consumption bought	$ICmob_{pp}$	$ICmob_{pp}$	$ICmob_{pp}$	$ICmob_{pp}$	$ICmob_{pp}$		$ICmob_{pp}$	$ICmob_{pp}$	$ICmob_{pp}$	$ICmob_{pp}$
Own ordinary commercial intermediate consumption of services		$SScoo_{pp}$	$SScoo_{pp}$	$SScoo_{pp}$	$SScoo_{pp}$		$SScoo_{pp}$	$SScoo_{pp}$	$SScoo_{pp}$	$SScoo_{pp}$
Own ordinary non-commercial intermediate consumption of services			$SSncooc_{bp}$	$SSncooc_{bp}$	$SSncooa/c_{bp/sp}$		$SSncooa/c_{bp/sp}$	$SSncooa/c_{bp/sp}$		$SSncooa/c_{bp/sp}$
Environmental work in progress used		$WPeu_{ep}$		$WPeu_{ep}$	$WPeu_{ep}$		$WPeu_{ep}$	$WPeu_{ep}$		$WPeu_{ep}$
Ordinary manufactured work in progress used		$WPmuo_{pp}$		$WPmuo_{pp}$	$WPmuo_{pp}$		$WPmuo_{pp}$	$WPmuo_{pp}$		$WPmuo_{pp}$
Ordinary manufactured consumption of fixed capital	$CFCmo_{rp}$	$CFCmo_{rp}$	$CFCmo_{rp}$	$CFCmo_{rp}$	$CFCmo_{rp}$		$CFCmo_{rp}$	$CFCmo_{rp}$	$CFCmo_{rp}$	$CFCmo_{rp}$
Ordinary labour compensation of employees	$LCeo_{pp}$	$LCeo_{pp}$	$LCeo_{pp}$	$LCeo_{pp}$	$LCeo_{pp}$		$LCeo_{pp}$	$LCeo_{pp}$	$LCeo_{pp}$	$LCeo_{pp}$
Ordinary labour compensation of self-employed		$LCseo_{bp}$		$LCseo_{bp}$	$LCseo_{bp}$		$LCseo_{bp}$	$LCseo_{bp}$		$LCseo_{bp}$
Ordinary net operating surplus	NOS_{bp}									
Ordinary net mixed income	$NMIo_{bp}$									
Ordinary manufactured net operating margin		$NOMmo_{bp}$	$NOMmo_{bp}$	$NOMmo_{bp}$	$NOMmo_{sp}$		$NOMmo_{sp}$	$NOMmo_{sp}$	$NOMmo_{sp}$	$NOMmo_{sp}$
Ordinary environmental net operating margin		$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$	$NOMeo_{ep}$
Total product consumption		TPc_{bp}	TPc_{bp}	TPc_{bp}	TPc_{sp}		TPc_{sp}	TPc_{sp}	TPc_{sp}	TPc_{sp}
Ordinary net value added	$NVAo_{bp}$	$NVAo_{bp}$	$NVAo_{bp}$	$NVAo_{bp}$	$NVAo_{sp}$	$NVAo_{sp}$	$NVAo_{sp}$	$NVAo_{sp}$	$NVAo_{sp}$	$NVAo_{sp}$
Ecosystem service		ES_{bp}	ES_{bp}	ES_{bp}	ES_{sp}	ES_{sp}	ES_{sp}	ES_{sp}	ES_{sp}	ES_{sp}
Change in environmental asset		CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}	CEA_{ep}
Adjusted change in environmental net worth		CNWead	CNWead	CNWead	CNWead	CNWead	CNWead	CNWead	CNWead	CNWead
Environmental income		EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}	EI_{ep}

Fig. 2. Stylized accounting frameworks total product consumptions and environmental incomes for the *dehesa* case study in Andalusia. Abbreviations: SNA is System of National Accounts, rEEA is refined Experimental Ecosystem Accounting, AAS is Agroforestry Accounting System, pp in producer price, pc is production cost, sp is simulated exchange price rp is replacement price, bp is basic price, ep is environmental price.

to the omission of the work in progress used. Thus, this allows homogeneous comparison of the rSNA estimation of the net operating margin with that of the rEEA and AAS, although it does not avoid other biases such as those associated with the valuation at production cost of final products consumed without market prices and the omission of activities lacking manufactured cost production function.

A conceptual change in the definition of the activity is the appearance of the non-commercial activity of private amenity in the rSNA. This change means that in the residential service activity the consumption of the final product of auto-consumed service recorded in the SNA is reclassified as commercial intermediate product of the service of private amenity auto-consumption. The private amenity activity records the non-commercial intermediate consumption of the amenity auto-consumption service and, at the same value, records the consumption of the final product of amenity auto-consumption. The qualitative importance of the reclassification of the auto-consumption of the final product consumption of residential service in the SNA and rSNA frameworks is the appearance of the new private amenity activity without modifying the net values added of the farmer activities and the consequent zero value added of the private amenity activity valued by the rSNA. The economic importance will become apparent on changing the valuation criteria for the consumption of final products without market prices in the rEEA and AAS methodologies by applying stated marginal WTP of landowners.

The private amenity auto-consumption service by the owners has been estimated according to the maximum value stated by the non-industrial private owners which they are willing to forsake in income with respect to the prospect of selling their property, in order to invest in a business which involves purely financial return and a similar risk to the investment in their large silvo-pastoral and agroforestry property (Campos et al., 2019a; Oviedo et al., 2015, 2017). A survey of the owners in Andalusia through more than 800 questionnaires has allowed us to group the farms and provide values for the amenity according to vegetation type and zone in which the farm is located. The most controversial assumption is that the average value for the landowners in the same group of *dehesas* is a value compatible with the concept of transaction price. This is the case if we consider that each farm has a unique environmental asset price and therefore that the market for the *dehesa* land is unique to each property. Hence, if the property is sold, the owner would receive from the buyer the value attributed to the maximum willingness to pay (WTP) for the auto-consumption of the private amenity provided by the farm. There is notable uncertainty in this assumption, hence our valuation of the private amenity auto-consumed by the owners could be a maximum possible value, although in practice it may be that the price that could be offered for the environmental asset of the amenity in a real market transaction would be lower than the value derived from the owner's willingness to pay.

Another economic difference between the SNA and rSNA methods is the incorporation of the government institutional sector economic activities affecting the studied *dehesas* which come from the general government institutional sector in the SNA. The rSNA estimates the economies for the total product consumption of the *dehesa* for the private as well as public economic activities managed by the farmer and government institutional sectors, respectively. No changes are made to the valuation criteria of the government accounts associated with activities affecting the *dehesa* case study. The changes introduced in the rSNA with respect to the SNA affect the reclassification of the records, according to the homogenization of the comparison of ecosystem service and environmental income variables along with the economic changes associated with the incorporation of the government as institutional sector in representation of the public goods and services in the *dehesa* case study. This change in the *dehesa* economy due to the inclusion of the government does not modify the net value added, and it avoids the omission of the public economy of the *dehesa* in the official SNA methodology.

Another operationally important reclassification in the rSNA is the measurement of intermediate product/own ordinary intermediate consumption, which is required for the estimation of ecosystem services and environmental incomes of the individual activities in this *dehesa* case study. Although there is no conceptual innovation associated with these records since they are recognized in the SNA, in practice they are not recorded since there are no separate measurements of net values added for final product consumptions but rather, the SNA presents them separately at national/subnational scale for agriculture (including

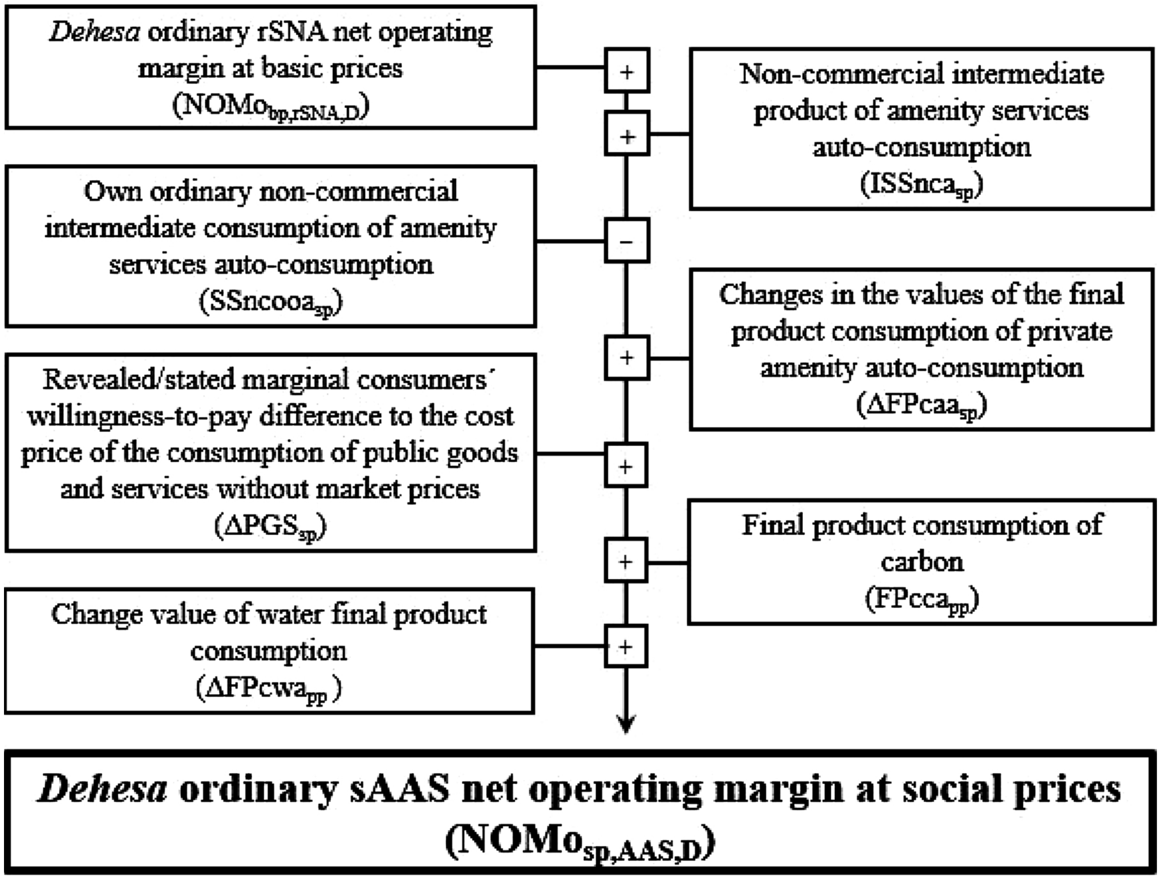

Fig. 3. Integration of the rSNA ordinary net operating margin in the AAS for the *dehesa* case study in Andalusia.

livestock and game activities) and forestry (European Communities, 2000) (readers interested in further technical details of the rSNA can refer to the Supplementary text S1).

We have developed and applied the rEEA on the basis of the rSNA records, introducing changes to the definition of economic activity and in the price of the consumption of products without market prices. We extend the definition of economic activity with the only conditions of observing the consumption appropriated either individually or collectively and of having verified the revealed and stated individual's willingness to pay (WTP) in formal or simulated markets for the products which they consume in the current period or expect to consume in infinite future periods (Campos et al., 2019a). The 19 activities valued in this case study meet these conditions, although we recognize the possible controversial character of the economic activity which we attribute to forest carbon in this *dehesa* study. It may surprise some readers that the only activity not considered explicitly or implicitly in the SNA and rSNA methodologies is the forest carbon activity.

We have incorporated the farmer and the government institutional sectors in the rSNA, splitting the values of the ecosystem services and environmental incomes. The change in the valuation of the consumption of final products without market prices is due to the substitution of the production cost price applied in the rSNA for the simulated price stated/revealed by consumers applied in the rEEA. This change to the type of price in final products without market price has an important effect in the rEEA of mitigating the bias in the valuations of ecosystem services and environmental income in the rSNA.

We have incorporated the physical private non-industrial farmer voluntary economic operating opportunity cost in the rEEA. We register this simulated implicit opportunity cost as a non-commercial intermediate product of amenity services auto-consumption and its counterpart entry of ordinary own non-commercial consumption of the private amenity auto-consumption service.

Our inclusion of the ecosystem trustee institutional sector in the rEEA in place of the government institutional sector in the rSNA is not consistent with environmental income theory (Angelsen et al., 2014: Cavendish, 2002; Krutilla, 1967; Sjaastad et al., 2005). This limitation is due to the fact that, by definition, the new ecosystem "trustee" institutional sector omits the manufactured production costs incurred by the government in creating the offer of public goods and services consumed (UNSD, 2020b). In our interpretation of the possible development of the rEEA, in the absence of a complete official development for illustrative purposes (Atkinson and Obst, 2017), which the SNA *does* have (European Commission et al., 2009), we have opted to consider that the rEEA incorporates all the government economic activities in the *dehesa* case study which incorporate resource rent in the total products of their activities. Although the rEEA we have developed is a notable advance on the rSNA, it still has certain inconsistencies with respect to ordinary operating income theory in the valuations of the net operating margins and the net value added of the ecosystem institutional sector (readers interested in further technical details of the rEEA can refer to Supplementary text S2).

The inconsistencies of the rEEA referred to above are overcome in our AAS by substituting the ecosystem institutional sector of the rEEA for the government institutional sector (including Spanish National and Andalusia regional governments) specific to the *dehesa* case study, thus avoiding the omission of the ordinary manufactured costs incurred by the government in creating the offer of public goods and services consumed.

The AAS estimates of the net operating margins and the net values added of the farmer and government total products consumed in this *dehesa* case study are fully consistent with the theory of environmental income and environmental asset of the ecosystems, and as such, the AAS estimates of ecosystem services and environmental incomes avoid

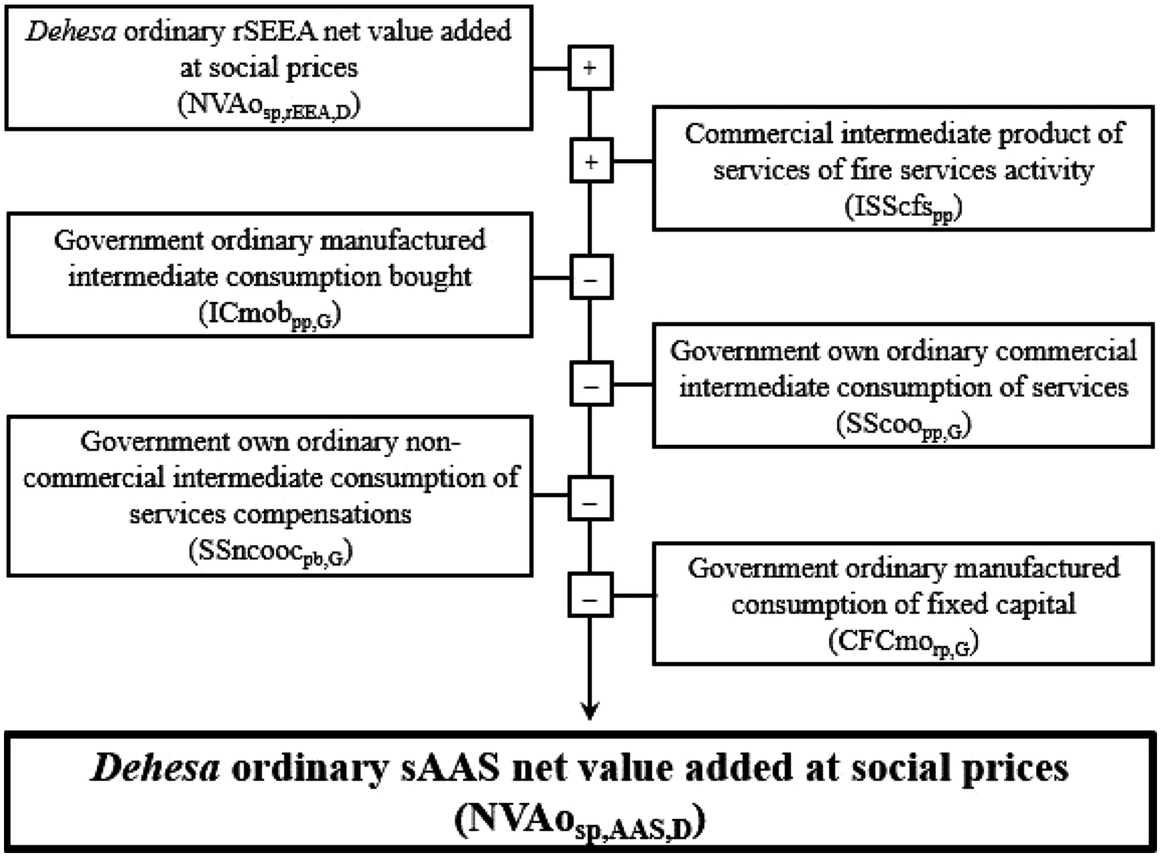

Fig. 4. Integration of the rEEA ordinary net value added in the AAS for the *dehesa* case study in Andalusia.

the previously discussed bias associated with the rSNA and rEEA methods.

Our AAS incorporates the government institutional sector as collective owner of the public economic activities. We consider the AAS total product consumption of (i) fire services measured at production cost, (ii) mushrooms, water and carbon at market prices, and (iii) recreation, landscape and biodiversity at the simulated transaction marginal price of consumers' stated willingness to pay (WTP).

In the rEEA we have kept the government ecosystem trustee institutional sector, adding to it the public final product consumption with manufactured costs but omitting the recording of government manufactured costs. The homogenous development of the abovementioned records of total product consumption in the approaches applied, allow us to integrate the variables of the rSNA and SEEA in the AAS, since the latter is the most complete and robust of these methodologies. For illustrative purposes we present the integration of the ordinary net operating margin of the rSNA (Fig. 3) and the ordinary net value added of the rEEA (Fig. 4) in the AAS (readers interested in further technical details of the AAS can refer to Supplementary text S3).

3. Economic results comparison

In this *dehesa* case study it is assumed that we know the total income and total capital values derived from the rSNA, rEEA and AAS methodologies applied to the 16 holm oak *dehesas* in this case study (Campos et al., 2020d). Since the aim of this research is to compare the environmental incomes measured by the three accounting methodologies, it is sufficient to have the records of the total product consumption and the environmental asset balance accounts.

We have incorporated the changes in physical productivity of timber, cork, firewood and acorns based on individual tree modelling of the species recorded by diameter class in the official National Forestry Inventory (MMA, 2008) as well as our own in some of the single *dehesas* (Campos et al., 2020d). Thus, the valuations of closing environmental assets depend on scheduled sustainability according to biological models of future management of the natural resource physical yields and extractions (Campos et al., 2019a: Supplementary texts S1-S2, pp. 11-19 [4]).

We have assumed that the prices do not vary in the future and we apply a real discount rate of 3%, without distinction, for the expected anticipated values of the future infinite streams of individual activity resource rents of farmer and government total product consumption (Campos et al., 2020d).

3.1. Opening commercial and non-commercial environmental assets

The *dehesa case* study in this research evidences the predominant weight of the environmental assets in the total capital. Although it is reasonable to assume that some breeds of threatened autochthonous livestock could offer passive use services of legacy and existence values to consumers, we have not valued such services, hence the livestock census in this study is valued only for its fixed biological manufactured capital and work in progress.[5]

The results for the valuations of the environmental assets reveal that

[4] The bio-physical flows and stocks, including accumulated natural growth and extractions in the 2010 period have been published in Campos et al. (2020d).

[5] We have not produced a land-owner survey which separates amenity services according to the single products in their *dehesas*. It is reasonable to expect that for a large proportion of the landowners their real opportunity cost incurred in the livestock activity will be lower than their marginal willingness to pay for the auto-consumed amenity service provided by the livestock. This information requires *dehesa* owners to respond to a choice experiment type study, which we have not conducted.

Table 1
Comparison of accounting framework opening capital indexes for commercial and non-commercial activities and *dehesa* case study in Andalusia (2010).

Class	Commercial activities			Non-commercial activities				*Dehesa*
	Woody products	Non-woody products	Total	Ame-nity	Land-scape	Others	Total	
1. Opening environmental asset (EAo)								
rSNA/AAS	1.00	1.00	1.00	1.00	0.00	0.62	0.76	0.82
rEEA/AAS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.1 Work in progress (WP)								
rSNA/AAS	1.00	1.00	1.00					1.00
rEEA/AAS	1.00	1.00	1.00					1.00
1.2 Environmental fixed asset land (EFAl)								
rSNA/AAS	1.00	1.00	1.00	1.00	0.00	0.62	0.76	0.80
rEEA/AAS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.3 Environmental fixed asset biological resources (EFAbr)								
rSNA/AAS	1.00	1.00	1.00					1.00
rEEA/AAS	1.00	1.00	1.00					1.00
2. Manufactured capital (FCm)								
rSNA/AAS	1.00	1.00	1.00		1.00	1.00	1.00	1.00
rEEA/AAS	1.00	0.97	0.97		0.00	0.00	0.00	0.93
3. Opening capital (Co)								
rSNA/AAS	1.00	1.00	1.00	1.00	0.01	0.63	0.76	0.85
rEEA/AAS	1.00	0.98	0.99	1.00	0.99	0.98	0.99	0.99

grazing is not the main asset, but rather, the private amenity services auto-consumed by the non-industrial land owners. However, the private amenity service requires the presence of livestock herding and/or hunting activities, whereby the owners of the livestock incur voluntary opportunity costs which we assign as a non-commercial intermediate product of service of the livestock to ensure greater enjoyment of the amenities which their *dehesa* provides (see detailed analysis of the capital balance in Campos et al., 2020d). As expected, the three accounting methodologies coincide in their valuations of the capital of the commercial and non-commercial activities of mushrooms which, subsequent to their harvesting by recreational gatherers, present market prices. The rSNA, rEEA and AAS methodologies differ in the non-commercial activities, with the exception of carbon and water, in the rEEA and AAS, with carbon being the only public product which is omitted in the rSNA valuation (Tables 1 and A1).

There has been no degradation in the future physical productivities of *dehesa* economic activities, where long-term-horizon scheduled sustainable biological modelling is considered (Campos et al., 2019a, 2020d). Thus, when estimating the changes in environmental assets at environmental price (unit resource rent) discounted at the closing of the period, a greater environmental asset value is obtained for each individual activity than that at the opening of the period, except for grazing, private amenity and carbon environmental assets. The negative environmental asset change in the case of the private amenity is due to the market land price decrease in the 2010 period.

3.2. Agroforestry Accounting System environmental incomes

Fig. 5 shows the aggregate *dehesa* total environmental incomes measured by the AAS (see the rSNA and the rEEA aggregate *dehesa* total environmental incomes presented in Fig. A1 and Fig. A2), broken down into ecosystem services and adjusted change in environmental net worth.

In these applications of the AAS and rEEA at social price[6] to the *dehesa* case study, the valuation at social price is done by recording the ISSnca on the intermediate product side, and the own ordinary non-commercial intermediate consumption of services (SSncoo) on the cost side. The latter arise from the use (intra-consumption) of the ISSnca imputed to the individual activities of the farmers.

In this application of the AAS to the *dehesa* case study, the ecosystem services contribute 54.8%, 65.9% and 59.6% respectively to the adjusted final product consumption (FPcad)[7] of the farmers, government and total (Table 2). Table 2 shows that the final product consumption of mushrooms, recreational services, landscape conservation services and preservation of threatened wild biodiversity services exceed those of their respective ecosystem services. Only in the cases of the public products of carbon and economic water retained in public reservoirs do the values of their final product consumption coincide with the respective values of their ecosystem services. This is due to the absence of manufactured costs in these two economic activities (see Table 2 and Campos et al., 2019a: Supplementary texts S1.7 and S4).

The accounting rule is to assign the manufactured costs to the aims which produce them. We assume that the costs of thinning, periodical pruning and other maintenance costs are attributed to the conservation forestry activity. Evidently, these manufactured costs could favour other products in the *dehesa*, and we consider them to be “free” input production factors.

As regards the AAS government institutional sectors in the *dehesa* case study, it can be seen that farmers contribute 43.3% to ordinary total net value added, 51.9% to total ecosystem services and 34.9% to total environmental income (Table 2).

Given that the holm oak is a fruiting tree species, the silviculture applied promotes an open canopy cover through early thinning and periodical pruning to encourage acorn production, grass and browse grazed by livestock, game species and other wild fauna. In this *dehesa* case study, the ecosystem service of grazing accounts for 38.7% of the ecosystem service provision of farmers measured by the AAS (Table 2).

The main individual ecosystem service of the *dehesa* is auto-consumption of the private amenity. The *dehesa* private non-industrial farmer implicitly incurs own ordinary manufactured intermediate consumption of services (SSooa) for the amenity activity, which represents 57.3% of the final product auto-consumption of the amenity (FPcaa). The SSooa rises in accordance with the use of landowner

[6] The rSNA does not incorporate own ordinary non-commercial intermediate consumption of services arising from the opportunity costs of the holm oak *dehesa* case study activities valued. This is why the results for both farmers and government are presented at basic prices in the rSNA (see Campos et al., 2020d for price definitions).

[7] Excludes final product consumption of conservation forestry, residential, commercial services, livestock and fire services activities.

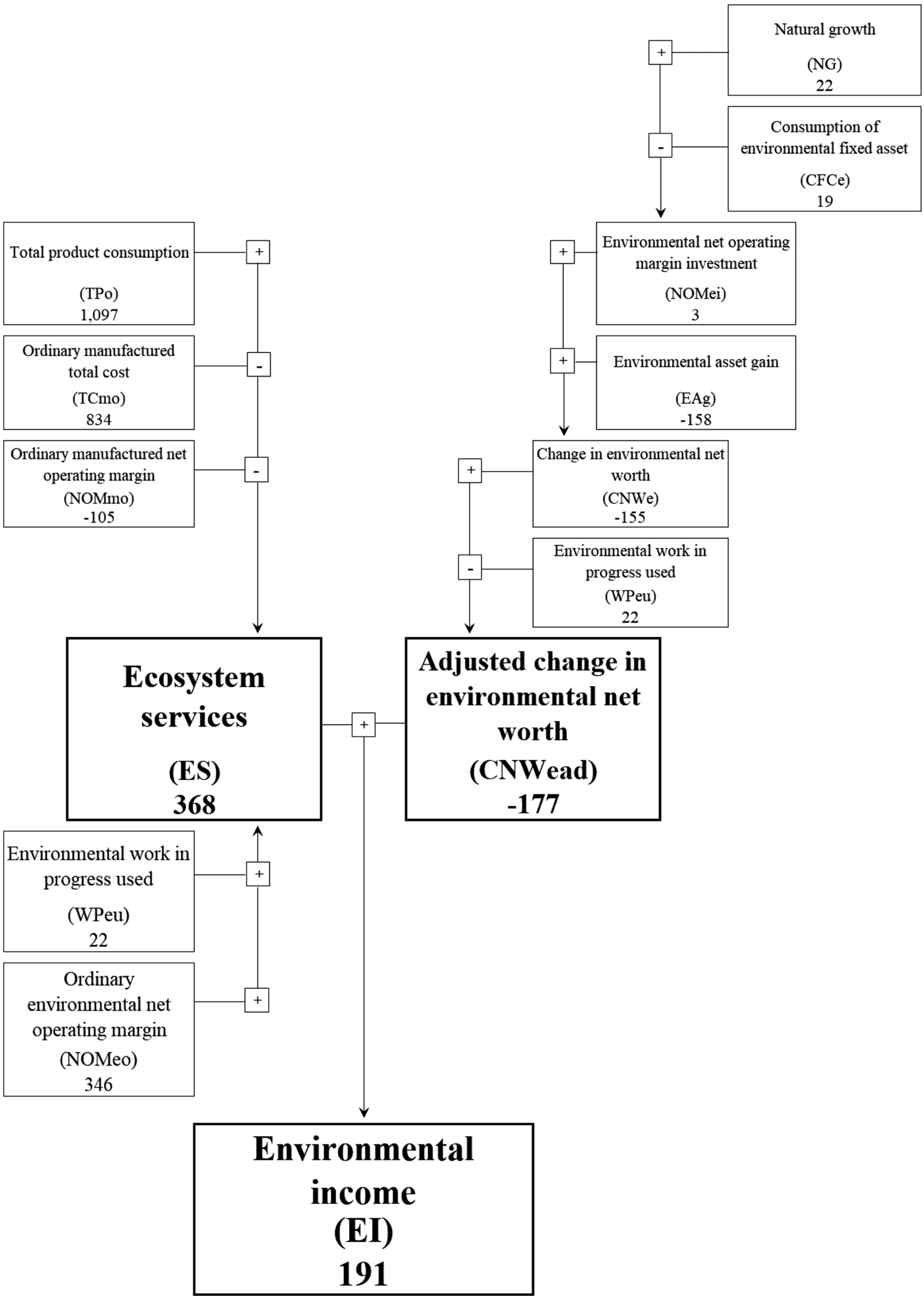

Fig. 5. AAS environmental income for the *dehesa* case study in Andalusia (2010: €/ha).

residential dwelling services (SScooa) and voluntary manufactured opportunity costs incurred (SSncooa). The cultural ecosystem service of the amenity makes up 42.7% of the FPcaa and 66.0% of farmer total ecosystem services respectively (Table 2).

Table 2 shows that, although the mixture of holm oak woodland with conifer species and cork oak make up 0.8% of the total area of the *dehesa*, the harvested products of timber and cork contribute marginally to the total final product consumption (FPc) and ecosystem services (ES) of the farmers, accounting for 2.5% and 4.2% respectively.

The government institutional sector public activity of forest services

Table 2
AAS stylized sequence of environmental income measurements for the *dehesa* case study in Andalusia (2010: €/ha).

Class	Farmer										
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
Production and generation of income accounts											
1.Total product consumption (TPc_{AAS})	**0.4**	**17.9**	**11.5**		**40.9**	**2.1**	**105.3**	**10.1**	**18.1**	**291.5**	**4.0**
1.1 Intermediate products (IP_{AAS})	0.4	4.4	1.6		40.3	2.1	75.6		14.0	111.7	0.8
1.1.1 Intermediate product SNA (IP_{rSNA})					27.6	1.6	18.0		14.0	33.9	0.8
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)	0.4	4.4	1.6		12.7	0.5	57.5			77.8	
1.2 Final product consumption (FPc_{AAS})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.1 Final product consumption SNA (FPc_{rSNA})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Final product consumption non SNA ($Fpc_{non\text{-}rSNA}$)											
2. Ordinary total intermediate consumption (ICo_{AAS})	**0.1**	**8.8**	**3.1**		**5.9**	**0.4**	**55.6**	**7.1**	**1.6**	**334.5**	**2.7**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)	0.1	0.7	1.0		5.9	0.4	21.1	7.1	1.6	146.6	2.7
2.2 Own intermediate consumption ($ICmoo_{AAS}$)							22.9			21.5	
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)							22.9			21.5	
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)											
2.3 Manufactured work in progress used (WPmuo)										166.4	
2.4 Environmental work in progress used (WPeu)		8.1	2.1				11.6				

(*continued on next page*)

Table 2 (*continued*)

Class	Farmer										
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
3. Ordinary gross value added (GVAo$_{AAS}$)	**0.3**	**9.1**	**8.3**		**35.0**	**1.7**	**49.7**	**3.0**	**16.5**	**-43.0**	**1.3**
4. Ordinary consumption of fixed capital (CFCo$_{AAS}$)	**0.1**	**0.5**	**0.2**		**2.6**	**0.1**	**7.7**	**4.2**	**13.8**	**14.8**	**2.6**
5. Ordinary net value added (NVAo$_{AAS}$)	**0.2**	**8.6**	**8.1**		**32.4**	**1.6**	**41.9**	**-1.2**	**2.7**	**-57.8**	**-1.3**
5.1 Labor cost (LCo$_{AAS}$)	0.2	8.1	3.2		5.1	1.2	19.8	5.6	8.2	44.0	3.9
5.1.1 Compensation of employees SNA (LCoe$_{rSNA}$)	0.2	8.1	2.0		5.1	1.2	19.4	5.6	8.0	42.6	3.9
5.1.2 Imputed compensation of self-employed non-SNA (LCose$_{AAS}$)			1.2				0.3		0.1	1.4	
5.2 Net operating margin (NOMo$_{AAS}$)	0.0	0.5	4.9		27.3	0.4	22.2	−6.8	−5.5	−101.8	−5.2
5.2.1 Manufactured net operating margin (NOMmo$_{AAS}$)	0.0	0.5	4.9		2.1	0.4	4.1	−6.8	−5.5	−101.8	−5.2
5.2.2 Environmental net operating margin (NOMeo$_{AAS}$)					25.2		18.0				
6. Ecosystem services (ES$_{AAS}$)		**8.1**	**2.1**		**25.2**		**29.7**				
Changes in balance accounts											
7. Changes in environmental asset (CEA$_{AAS}$)	**1.6**	**57.7**	**6.9**	**0.0**	**-2.9**						
8. Adjusted changes in environmental net worth (CNWead$_{AAS}$)	**1.6**	**57.7**	**6.9**	**0.0**	**-3.0**		**-0.3**				
9. Environmental income (EI$_{AAS}$)	**1.6**	**65.8**	**9.1**	**0.0**	**22.2**		**29.4**				

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
Production and generation of income accounts											
1.Total product consumption (TPc$_{AAS}$)	**295.2**	**796.9**	**31.5**	**23.7**	**13.3**	**49.5**	**90.2**	**9.9**	**81.9**	**300.0**	**1,097.0**

(*continued on next page*)

Table 2 (*continued*)

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
1.1 Intermediate products (IP_{AAS})		251.1	31.5							31.5	282.6
1.1.1 Intermediate product SNA (IP_{rSNA})		96.1	31.5							31.5	127.5
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)		155.0									155.0
1.2 Final product consumption (FPc_{AAS})	295.2	545.8		23.7	13.3	49.5	90.2	9.9	81.9	268.6	814.4
1.2.1 Final product consumption SNA (FPc_{rSNA})	14.0	264.7		7.1	13.3		77.1	4.8	69.6	171.8	436.5
1.2.2 Final product consumption non SNA ($Fpc_{non\text{-}rSNA}$)	281.1	281.1		16.7		49.5	13.1	5.1	12.3	96.8	377.9
2. Ordinary total intermediate consumption (ICo_{AAS})	**169.1**	**588.9**	**10.2**	**2.3**	**0.1**		**69.9**	**1.5**		**84.0**	**672.9**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)		187.2	10.2	1.4	0.1		1.8	1.5		14.9	202.1
2.2 Own intermediate consumption ($ICmoo_{AAS}$)	169.1	213.5		1.0			68.1			69.1	282.6
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)	14.0	58.4		1.0			68.1			69.1	127.5
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)	155.0	155.0									155.0
2.3 Manufactured work in progress used (WPmuo)		166.4									166.4
2.4 Environmental work in progress used (WPeu)		21.8									21.8
3. Ordinary gross value added ($GVAo_{AAS}$)	**126.1**	**208.0**	**21.2**	**21.4**	**13.2**	**49.5**	**20.3**	**8.5**	**81.9**	**216.1**	**424.1**
4. Ordinary consumption of fixed capital ($CFCo_{AAS}$)		**46.6**	**1.0**	**1.2**	**0.0**		**2.1**	**0.4**		**4.8**	**51.4**
5. Ordinary net value added ($NVAo_{AAS}$)	**126.1**	**161.4**	**20.2**	**20.2**	**13.2**	**49.5**	**18.2**	**8.0**	**81.9**	**211.3**	**372.7**
5.1 Labor cost (LCo_{AAS})		99.3	20.2	3.6	0.1		5.1	2.9		31.8	131.1

(*continued on next page*)

Table 2 (*continued*)

Class	Farmer		Government							Dehesa
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
5.1.1 Compensation of employees SNA ($LCoe_{rSNA}$)		96.2	20.2	3.6	0.1		5.1	2.9		31.8	128.0
5.1.2 Imputed compensation of self-employed non-SNA ($LCose_{AAS}$)		3.1									3.1
5.2 Net operating margin ($NOMo_{AAS}$)	126.1	62.1	0.0	16.7	13.1	49.5	13.1	5.1	81.9	179.5	241.5
5.2.1 Manufactured net operating margin ($NOMmo_{AAS}$)		−107.2	0.0	1.0	0.5		0.2	0.8		2.5	−104.7
5.2.2 Environmental net operating margin ($NOMeo_{AAS}$)	126.1	169.3		15.6	12.6	49.5	13.0	4.3	81.9	176.9	346.2
6. Ecosystem services (ES_{AAS})	**126.1**	**191.1**		**15.6**	**12.6**	**49.5**	**13.0**	**4.3**	**81.9**	**176.9**	**368.1**
Changes in balance accounts											
7. Changes in environmental asset (CEA_{AAS})	**-187.7**	**-124.2**				**-3.2**				**-3.2**	**-127.4**
8. Adjusted changes in environmental net worth ($CNWead_{AAS}$)	**-187.7**	**-124.6**				**-52.7**				**-52.7**	**-177.3**
9. Environmental income (EI_{AAS})	**-61.6**	**66.5**		**15.6**	**12.6**	**-3.2**	**13.0**	**4.3**	**81.9**	**124.2**	**190.8**

(fire fighting) is carried out either using government means or through contracted third party services. It is assumed to have the attributes of an activity since it is possible to value the intermediate product of services according to the manufactured cost of production and it is considered own intermediate consumption of services of the public activity of landscape conservation services (see details in Campos et al., 2020a: Supplementary text S3.4, p. 12; Ovando and Campos, 2016).

The government final products consumption of landscape (FPcla) and water supply (FPcwa) under the AAS are the largest individual public products, accounting for 64.1% of the government total final products consumption and 53.6% of government ecosystem services (Table 2). While water activity does not incur manufactured cost, the landscape activity manufactured total ordinary cost represents 85.4% of the FPcla and the landscape ecosystem service accounts for 14.4% of the FPcla (Table 2).

Recreation, mushrooms, carbon and threatened wild biodiversity ecosystem services comprise 30.6% of the government final product consumption under the AAS. Farmer and government activity ecosystem services contribute 35.0% and 65.9% to their respective final product consumptions.

Environmental income is the key threshold indicator of the maximum value of economic sustainable ecosystem service for the period. A negative adjusted change in environmental net worth of an individual product in the period, as is the case in the *dehesa* for grazing, hunting, amenity and carbon, indicates overconsumption and often the decline in the environmental asset[8] . Table 2 and Fig. 5 show a total ecosystem service in the *dehesa* case study of 1.9 times the total environmental income. This ecosystem service overconsumption for the period is precisely due to negative adjusted change in environmental net worth of grazing, hunting, amenity and carbon (Table 2 and Fig. 5).

3.3. Integration of environmental incomes in the accounting frameworks

The economic results in Tables 2, A2-A3 show the AAS, rSNA and rEEA stylized sequence of net value added, ecosystem services and environmental incomes recorded according to our own development of Obst et al. 2019 (Table 6, p. 33), which we have applied to the holm oak *dehesa* case study in Andalusia. We estimate the individual activity, aggregate farmer and government institutional sector ecosystem services and environmental incomes, as well as those for the *dehesa* as a whole from the total production and total capital balance accounts data published in Campos et al. (2020d).

In the holm oak *dehesa* case study we focus the comparisons of the results for the rSNA at basic prices and the rEEA and AAS at social prices on the aggregate values for ordinary net value added, ecosystem service, change in environmental asset, adjusted change in environmental net worth according to environmental work in progress used. These results are presented per individual activity and for the economic activities of the farmer, government and those of the *dehesa* as a whole.

The *dehesa* ecosystem service under the rEEA is larger than that of the AAS because the rEEA omits the ordinary total cost incurred by the government in the management and regulation of total product consumption. It is considered that the rEEA overvalues public ecosystem services, except for water and carbon because these products do not have ordinary manufactured costs. In the case of public activities where no manufactured costs are incurred, the ecosystem service estimates of the rEEA and AAS coincide. In this *dehesa* case study, this is the case for the water and carbon activities.

If we assume that the AAS gives consistent total environmental income estimates, then the rSNA undervalues the positive estimates of ordinary net value added, ecosystem services and environmental incomes (Table 3 and Figs. 6–7). The rSNA also undervalues the negative result of the adjusted change in environmental net worth (Tables 3 and A2). As the rEEA ignores the government manufactured costs of public activities it is to be expected that it will overvalue the government ecosystem services and incomes (Tables 3 and A3). However, the rEEA and AAS give the same estimate of adjusted change in environmental net worth. It should be emphasized that the economic activities most affected by our rSNA and rEEA applications are those of amenity and landscape.

In this *dehesa* case study, the adjusted change in environmental net worth and change in environmental asset differ with regard to the grazing, hunting and carbon activity (Kay et al., 2019). This is due to our assumption that carbon emission involves consumption of environmental fixed asset. That is, carbon emission is not embedded in the ordinary final product (carbon fixation).

Table 3 and Figs. 6–7 shows the aggregate results for the farmer and government institutional sectors in the *dehesa* case study. Although the comparisons of the aggregate results lack conceptual consistency in the rSNA and rEEA official accounting frameworks as opposed to the robust total income measurement of the AAS, they are of interest because they highlight the limitations of the rSNA and rEEA in terms of measuring the differences in the values estimated by the accounting frameworks compared as regards the results for the incomes and ecosystem services of the 19 economic activities of the *dehesa* case study valued in this work. The comparisons are robust as they indicate the degree of error in the rSNA and rEEA measurements in contrast to the consistent measurements under the total income concept of the AAS.

The results of the indexes compared for the ecosystem services and incomes in the rSNA and rEEA methodologies in comparison to the AAS methodology reveal similar commercial values, except for the ordinary net value added in the rEEA, due to the omission of the fire service activity (Tables 4 and A4).

The non-commercial indexes in Table 4 and absolute values in Table A4 show notable under-valuations in the rSNA and overvaluations in the rEEA. The rSNA undervaluation is due to the omission of the carbon activity and the valuation of final public products without market prices at production cost. The bias towards overvaluations in the rEEA is due to the omission of the manufactured cost in the ecosystem trustee institutional sector activities.

The individual activity economic ecosystem sustainability index in Table 5 shows values of more than one, except for the amenity and carbon activities. The interpretation of the meaning of economic unsustainability of the amenity in the period lacks biophysical significance and is due exclusively to the inter-annual volatility of the variation in land prices[9] . In the case of the carbon activity, the overconsumption is due to the convention of attributing emission to negative environmental asset formation (consumption of environmental fixed assets), since the environmental income is slightly positive (Tables 2–5)

The comparison of the results of the ecosystem accounting framework applications reveals that it is conceptually and functionally possible (and consistent with the standard SNA transaction value criterion) to make visible the AAS valuations and extensions to the SNA and EEA embraced in the rSNA and rEEA. This can be achieved while maintaining the valuations of products with market price at observed market prices and at production cost in the case of consumption of products without market prices in the rSNA, and at simulated transaction prices in this case of consumption of products without market prices in the

[8] Although the change in the value of the environmental asset is a real measurement, this may not be the case for the adjusted change in environmental net worth. The latter incorporates the instrumental environmental asset gain estimate. By correcting the overvaluation of the ordinary environmental net operating margin, the adjustment of the environmental asset explains the potential simultaneous existence of a positive change in environmental asset and negative adjusted change in environmental net worth, as is the case of carbon in this holm oak *dehesa* case study (Table 2 and Fig. 5).

[9] In the period 1994-2010 the *dehesa* market land price increased at the annual cumulative real rate variation of 3.4% (Ovando et al., 2016).

rEEA and AAS.

With respect to the simplified system of accounts of Obst et al., 2019 (Table 6, p. 33), the extensions to the ecosystem accounting frameworks compared involve reclassifications and the incorporation of new variables along with the government institutional sector in the rSNA. These *dehesa* case study results reveal that environmental income from individual products for the period can occur in parallel with the sustainability of economic ecosystem services.

4. Discussion

4.1. Summary of accounting framework results

In this *dehesa* case study, we have applied the rSNA, rEEA and AAS methodologies at the micro scale of *dehesas* with the aim of experimentally exploring their accounting structures and results, although we are unable to gauge the representativeness of the results obtained. The economic results from the group of *dehesas* studied should not be considered representative of the Spanish *dehesas* as a whole, not even of the group of large *dehesas* which most of those studied belong to (only 3 of the 16 being less than 200 hectares in size) (Campos et al., 2020c: Table 1, p. 18). However, the case study can be considered illustrative of the present economic management trends in large Spanish *dehesas*.

Despite the fact that the estimated economic results for the case study *dehesas* might not be statistically representative of the *dehesas* as a whole, they do provide sufficient information to favour public policy on the conservation of the natural environment. Our results show that the group of large private *dehesa* owners, that is, farms of more than 200 hectares which make up 66% of the total area of *dehesas* in Spain, display an investor rationale conditioned by their demands for autoconsumption of their final products of private amenity services. This affirmation, based on the results from our case study, is of importance for the design of public policies on the conservation of the *dehesa* working landscape and the preservation of wild as well as domestic genetic varieties of the controlled biota.

In Campos et al. (2020a,b) we have scaled up the results for the contributions of environmental incomes, ecosystem services and environmental assets to land-use tile scale for holm oak open woodlands in Andalusia. However, these results are not comparable in absolute terms with those of this *dehesa* case study, since the *dehesas* contain a greater proportional contribution of areas of other species of trees, shrublands and grasslands (Campos et al., 2020a, Supplementary table S1; 2020d: Table A4) and, in addition, the holm oak open woodlands omit the hunting, livestock and agricultural crop activities (Campos et al., 2020a,b).

The consumption of manufactured fixed capital of plantations is not included in the timber, cork, firewood and grazing (acorns) activities. Since the plantations come from government compensation as part of the public landscape conservation service, we register them under an activity that we designate 'conservation forestry' (Campos et al., 2019a, 2019b, 2020d; Ovando et al., 2016). The use of manufactured fixed capital equipment is imputed in the intermediate consumption of services paid for by the farmer to contracted farm services.

As regards the updating of the mainstream economic concepts of ecosystem services and environmental assets in the holm oak *dehesa* case study, we acknowledge the general agreement that standard SNA economic activities should be refined to incorporate non-market total products and incomes at national/sub-national (including individual farm) scale. Resource rent, as the transaction value of the ecosystem services for the period and, all else being equal, their future discounted flows, should give the environmental asset values for the period

In this *dehesa* case study, the net present values of future ecosystem services that will accrue from timber, cork and firewood extractions will be lower than the net present values of future natural growths (net of the expected normal historical rate of tree destruction by forest fire). Taking into account these expected events, the net present value of the future net increment in the woody work in progress environmental asset gives a positive value for the adjusted change in environmental net worth. The above assumptions imply that, given that the environmental incomes from timber, cork and firewood exceed their respective ecosystem services, it is consistent to conceptualize the ecosystem services for the period as biologically sustainable values.

The ecosystem services of recreation, mushrooms, water, landscape and wild threatened biodiversity economic activities will remain constant in real terms in future periods.

It is reasonable to assume that the ecosystem services and the environmental income from commercial woody products will have the same values regardless of the ecosystem accounting framework applied. This is not the case for the ecosystem services embedded in the consumption of final products without market prices due to the fact that their ecosystem services and environmental incomes have been omitted completely in the rSNA and the ecosystem institutional sector in the rEEA does not include manufactured cost of the consumption of final public goods and services.

The integration of the Common International Classification of Ecosystem Services (CICES) in the environmental ecosystem accounting (EEA) in a manner consistent with the SNA is still pending, this situation being due to the standardization of the EEA economic accounts, which is also pending. The most recent draft guidelines of the EEA, currently in global consultation phase, are limited to grouping the ecosystem services assigned to the ecosystem-type categories into cultural, regulating-supporting and provisioning (UNSD, 2020a). We understand that *dehesas* would fall into ecosystem type T2.1 in level 3 of the IUCN ecosystem classification. In a previous publication comparing the rSNA and AAS we presented the grouping of ecosystem services of the economic activities into the three categories of the CICES classification (Campos et al., 2020d: Table 3, p. 22), as applied in the EEA (UNCD, 2020a).

4.2. Strengths and weaknesses of the AAS environmental income results

Our *Agroforestry Accounting System* (AAS) methodology is universal and integrates the measurement of any private or public activity which can only be carried out by the economic agents of the owner and government institutional sectors, respectively. Furthermore, it is only these economic agents who incur risks associated with not knowing in advance the returns on their investments in terms of operating capital income (net operating margin) and capital gain.

The measurement of environmental income refers to the economic activities of the 2010 period and the continuation of the activities with current uses in the future. In exceptional cases, new forthcoming events can be included as long as they are certain to be incorporated in the transactions of the land at the closing of the period.

We have mentioned the results with regard to the real economic events which have occurred in the *dehesa* case study during the 2010 period. If this were an implicit contractual relationship between private individuals, the institutional sector that would register the economic events would be the economic activities of the owner. In simple terms, what would be happening is that an institution or private individual would be "purchasing" the active or passive consumption of a final product generated by one or more private activities of the exclusive property of the owner. The extended economic accounts of the activities involved in the implicit purchases of consumers would register the corresponding possible incomes, ecosystem services and environmental assets originating in the payment of private individuals and institutions. In other words, conceptually, the AAS methodology integrates all the economic activities of a territorial unit and all the economic agents (including consumers and the legal regulation which provides legal certainty of property rights to the intervening parties in the trading of consumptions and accumulation of products in the period).

The incomes of the owners are not affected by measurement under the rEEA and AAS methodologies since all the private activities subject to economic valuation are taken into consideration. However, public activities which we attribute to the government institutional sector such as the gathering of plants (e.g., asparagus, desert truffles) and animals (e.g. snails), which probably have lower, albeit unknown, economic importance, are not taken into consideration. In contrast, the resource rent of hotel and restaurant services, again unknown, could be of greater importance as they may be benefitting free of charge from the appropriation of public ecosystem services embedded in the value of the goods and services consumed by visitors who are supplied by these industries in the area surrounding the *dehesas*.

Similarly, the economic withdrawals of government environmental fixed assets have not been estimated (e.g. silting up of reservoirs, with part of the material finally ending up in cultivated croplands river beds and the sea), nor has the global effect of carbon dioxide emitted by the livestock. In a single period, we have not been able to estimate the effects of land use change. The greatest uncertainties in our valuations in this *dehesa* case study are those associated with the estimation of the consumption of final products without market prices of the private amenity service, the landscape conservation service, the threatened wild biodiversity service and the global warming mitigation effect of the carbon activity. Even greater than the uncertainty associated with the product valuations is that related to the valuations of the environmental assets (Campos, 2010).

The carbon global warming mitigation service presents greater uncertainty as the *dehesa* case study would require the simulation of the global distribution of government ownership of the natural capital of the atmosphere (see Supplementary text S4).

We do not have up to date economic information at our disposal on non-government organisations (NGOs) operating as owners or donors financing economic investments as part of *dehesa* management. We have not included public *dehesas* in the analysis as the management rationale would differ from that of the private *dehesas*. Nevertheless, we *do* have compensation and donation data relating to six public *dehesas* in Andalusia (Campos et al., 2020a: Supplementary text S4.2: Table ST5, p. 25). However, cultural landscape conservation in open woodlands of oak species depends mainly on the management of conservation forestry treatments and animal (domestic livestock and game) activities of private owners, since public owners only account for 12% of the total area of oak open woodlands in the west and centre of Spain, mainly composed of holm oaks (Campos et al., 2017: p. 1, Table 1). In Andalusia, public owners possess 9% of holm oak open woodlands (Campos et al., 2020a: Supplementary text S4.2: p. 25).

By placing the emphasis of the discussion on environmental and economic aspects it may seem that we have passed over the social aspects of employment of individuals and the fulfilment of the preferences of non-profit institutions and public consumers. In this research, the non-governmental organisations (NGOs) are not taken into consideration even though they play an important role in the defence of the natural environment of Spanish *dehesas* (see involvement of NGOs in direct *dehesa* management in Campos et al. (1996). However, human labour and the consumers are expressly quantified and their preferences documented in our published surveys (Oviedo et al., 2016) as well as in the results of this research. In terms of employment, the *dehesas* account for a relatively low contribution to total income (Campos et al., 2020d). *Dehesas* of 200 hectares or more account for 64% of the total 112,387 of Spanish *dehesas* (Campos et al., 2020a: Supplementary text S1, Table ST2, p. 7), and the greatest likelihood of environmental efficiency and lowest costs of government compensation in terms of biological conservation is concentrated in 64% of the total area of the large *dehesas* referred to. *Dehesas* of less than 200 hectares have an average area of 12 hectares, which represent economic complements for owners with diverse rationales, from abandonment of production to donation of use to family or others. We do not have biophysical information on this 36% of the *dehesa* area in the hands of small and medium landowners (Campos et al., 2020a: Supplementary text S1, Table ST2, p. 7).

4.3. On the economic concept of environmental asset

As regards the environmental ecosystem accounting, the environmental income of society, not the environmental asset, is the most important synthetic indicator in the economic valuation of ecosystems types, such as that of this *dehesa* case study. In other words, if we follow the path of active and passive human uses in an ecosystem working landscape we can identify the goods and services that originate the total environmental income of society in a determined time and ecosystem accounting area. Then, the current and future consumption of an ecosystem by current generations provide the basis for the economic valuation of its total environmental income (Campos, 2010).

From an economic perspective the environmental asset (natural capital) is a virtual concept with a volatility and a subjectivity which ranges from being almost inscrutable in the case of the economic services of threatened unique natural variety which is not reproducible through human engineering, to the quasi-market value of the public environmental asset of the free access recreation service. The possible robustness of a subjective economic valuation of an environmental asset depends on the observation of the economic product consumption by humans, irrespective of whether this human consumption of goods and services is through a formal market transaction or an implicit revealed or stated transaction of active and passive consumptions.

4.4. Environmental ecosystem accounting challenges

Notable asymmetry exists between the accounting practices in informal[10] private farm accounting and the SNA with regard to the valuation of flows and non-financial stocks of a territorial business farm unit. In farm accounts, the important indicator for guiding decision-making is the total capital income, which in turn comprises the operating profit (hereafter ‘net operating margin’) and the capital gain. In other words, farmers, in practice, take into account both production and balance (stock) accounts to avoid bias in the estimation of the total capital income accrued from their investments in manufactured capital and environmental assets in a period (e.g., the year 2010 in the results for these *dehesa* farms s).

The message to be taken from the informal farm accounting practices, is that rSNA should tend towards assuming the informal accounting practice of farms and extend the same accounting rule at a scale larger than the farm to regulated public production and/or that managed by the government institutional sector using the same territorial unit in which the farm operates.

Environmental economic accounting integrated in the extended accounts of society, as in the AAS methodology at farm scale, is a challenge as yet to be resolved for numerous conceptual and instrumental reasons. As regards conceptual issues, the valuations of final product consumption without market price and the delimitation of the concept of total income are those attracting most academic controversy. As for instrumental problems, these include the absence of national/sub-national government standardization of a glossary of terms[11] to mitigate the current polysemic labyrinth and the lack of a developed structure of the economic ecosystem accounts linked to the SNA.

Certain challenges still need to be addressed in the economic ecosystem accounting frameworks. Among the most difficult of these from a scientific perspective is the measurement of values for cultural landscape conservation, threatened biodiversity and the global environmental assets of migrating birds and game species. In relation to the gaps which exist in the measurement by the rSNA and rEEA of the

[10] The term ‘informal’ is used here in the sense that it is not required by government legislation.

[11] In this study we use the terms economic ecosystem accounting, ecosystem service and environmental asset as synonymous of experimental environmental accounting, resource rent and ecosystem environmental asset, respectively.

Table 3
Comparison of environmental incomes of the farmer, government, ecosystem trustee and the *dehesa* case study in Andalusia under the different accounting frameworks (2010: €/ha).

Class	rSNA			rEEA			AAS		
	Farmer	Government	*Dehesa*	Farmer	Ecosystem trustee	*Dehesa*	Farmer	Government	*Dehesa*
Production and generation of income accounts									
1. Total product consumption (TPc)	**360.8**	**203.3**	**564.1**	**796.9**	**268.6**	**1,065.5**	**796.9**	**300.0**	**1,097.0**
1.1 Intermediate products (IP)	96.1	31.5	127.5	251.1		251.1	251.1	31.5	282.6
1.1.1 Intermediate product SNA (IP_{rSNA})	96.1	31.5	127.5	96.1		96.1	96.1	31.5	127.5
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)				155.0		155.0	155.0		155.0
1.2 Final product consumption (FPc)	264.7	171.8	436.5	545.8	268.6	814.4	545.8	268.6	814.4
1.2.1 Final product consumption rSNA (FPc_{rSNA})	264.7	171.8	436.5	264.7	82.9	347.6	264.7	171.8	436.5
1.2.2 Final product consumption non rSNA ($Fpc_{non\text{-}rSNA}$)				281.1	185.7	466.8	281.1	96.8	377.9
2. Ordinary total intermediate consumption (ICo)	**434.2**	**84.0**	**518.2**	**588.9**		**588.9**	**588.9**	**84.0**	**672.9**
2.1 Manufactured intermediate consumption bought SNA ($ICmob_{rSNA}$)	187.2	14.9	202.1	187.2		187.2	187.2	14.9	202.1
2.2 Own intermediate consumption (ICmoo)	58.4	69.1	127.5	213.5		213.5	213.5	69.1	282.6
2.2.1 Own intermediate consumption rSNA ($ICmoo_{rSNA}$)	58.4	69.1	127.5	58.4		58.4	58.4	69.1	127.5
2.2.2 Own intermediate consumption non rSNA ($ICmoo_{non\text{-}rSNA}$)				155.0		155.0	155.0		155.0
2.3 Manufactured work in progress used (WPmuo)	166.4		166.4	166.4		166.4	166.4		166.4
2.4 Environmental work in progress used (WPeu)	21.8		21.8	21.8		21.8	21.8		21.8
3. Ordinary gross value added (GVAo)	**-73.4**	**119.3**	**45.9**	**208.0**	**268.6**	**476.6**	**208.0**	**216.1**	**424.1**
4. Manufactured consumption of fixed capital SNA ($CFCmo_{rSNA}$)	**46.6**	**4.8**	**51.4**	**46.6**		**46.6**	**46.6**	**4.8**	**51.4**
5. Ordinary net value added (NVAo)	**-120.1**	**114.5**	**-5.5**	**161.4**	**268.6**	**429.9**	**161.4**	**211.3**	**372.7**
5.1 Ordinary labor cost (LCo)	99.3	31.8	131.1	99.3		99.3	99.3	31.8	131.1
5.1.1 Compensation of employees rSNA ($LCoe_{rSNA}$)	96.2	31.8	128.0	96.2		96.2	96.2	31.8	128.0
5.1.2 Imputed compensation of self-employed non-SNA ($LCose_{non\text{-}rSNA}$)	3.1		3.1	3.1		3.1	3.1		3.1
5.2 Ordinary net operating margin (NOMo)	−219.3	82.7	−136.6	62.1	268.6	330.7	62.1	179.5	241.5
5.2.1 Ordinary manufactured net operating margin (NOMmo)	−262.5	0.5	−262.0	−107.2		−107.2	−107.2	2.5	−104.7
5.2.2 Ordinary environmental net operating margin (NOMeo)	43.2	82.2	125.4	169.3	268.6	437.9	169.3	176.9	346.2
6. Ecosystem services (ES)	**65.0**	**82.2**	**147.2**	**191.1**	**268.6**	**459.7**	**191.1**	**176.9**	**368.1**
Changes in environmental asset									
7. Change in environmental asset (CEA)	**-124.2**		**-124.2**	**-124.2**	**-3.2**	**-127.4**	**-124.2**	**-3.2**	**-127.4**
8. Adjusted change in environmental net worth (CNWead)	**-124.6**		**-124.6**	**-124.6**	**-52.7**	**-177.3**	**-124.6**	**-52.7**	**-177.3**
9. Environmental income (EI)	**-59.6**	**82.2**	**22.6**	**66.5**	**215.9**	**282.4**	**66.5**	**124.2**	**190.8**

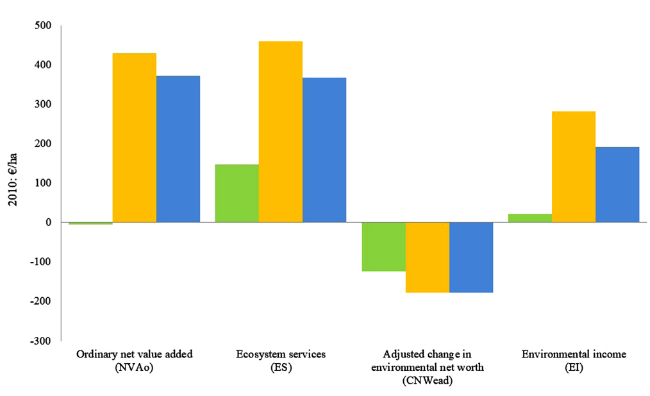

Fig. 6. Comparison of environmental-economic indicators for the *dehesa* case study in Andalusia under the different accounting frameworks (2010: €/ha).

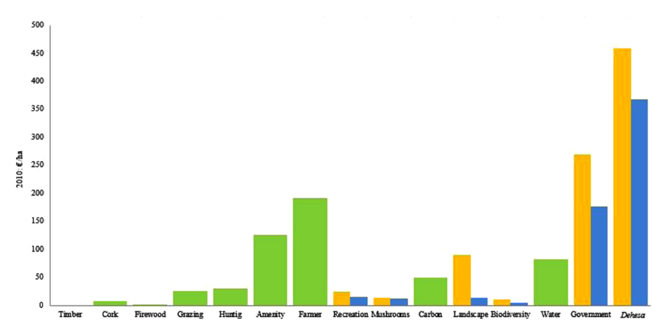

Fig. 7. Comparison of ecosystem services of single activities for the *dehesa* case study in Andalusia under the different accounting frameworks (2010: €/ha).

contribution of nature to the total income of society from agroforestry ecosystems, the AAS methodology overcomes these shortcomings.

5. Policy implications

The accounting methodologies applied to the *dehesa* study bring

Table 4
Comparison of environmental income indexes for commercial and non-commercial activities and the *dehesa* case study in Andalusia under the different accounting frameworks (2010).

Class	Commercial activities			Non-commercial activities				*Dehesa*
	Woody products	Non-woody products	Total	Ame-nity	Land-scape	Others	Total	
1. Ordinary net valued added (NVAo)								
rSNA/AAS	0.62	−2.86	−1.80	0.00	0.28	0.52	0.30	−0.01
rEEA/AAS	1.00	0.48	0.64	1.00	4.96	1.03	1.24	1.15
2. Ordinary net operating margin (NOMo)								
rSNA/AAS	−0.19	3.14	3.43	0.00	0.00	0.50	0.27	−0.57
rEEA/AAS	1.00	1.00	1.00	1.00	6.86	1.07	1.29	1.37
3. Ecosystem services (ES)								
rSNA/AAS	1.00	1.00	1.00	0.00	0.00	0.50	0.27	0.40
rEEA/AAS	1.00	1.00	1.00	1.00	6.95	1.09	1.30	1.25
4. Changes in environmental asset (CEA)								
rSNA/AAS	1.00	1.00	1.00	1.00		0.00	0.98	0.98
rEEA/AAS	1.00	1.00	1.00	1.00		1.00	1.00	1.00
5. Adjusted change in environmental net worth (CNWead)								
rSNA/AAS	1.00	1.00	1.00	1.00		0.00	0.78	0.70
rEEA/AAS	1.00	1.00	1.00	1.00		1.00	1.00	1.00
6. Environmental income (EI)								
rSNA/AAS	1.00	1.00	1.00	3.05	0.00	0.74	−1.68	0.12
rEEA/AAS	1.00	1.00	1.00	1.00	6.95	1.13	2.46	1.48

Table 5
Comparison of the economic ecosystem service sustainability index by individual activity, institutional sectors and the *dehesa* case study in Andalusia under the different accounting frameworks (ESSI: 2010).

Class	rSNA	rEEA	AAS
1. Farmer	−0.92	0.35	0.35
1.1 Timber	0.00	0.00	0.00
1.2 Cork	8.15	8.15	8.15
1.3 Firewood	4.24	4.24	4.24
1.4 Nuts	0.00	0.00	0.00
1.5 Grazing	0.88	0.88	0.88
1.6 Hunting	0.99	0.99	0.99
2. Government*/Ecosystem*	1.00	0.80	0.70
2.1 Recreation		1.00	1.00
2.2 Mushrooms	1.00	1.00	1.00
2.3 Landscape		1.00	1.00
2.4 Biodiversity	0.00	1.00	1.00
2.5 Water	1.00	1.00	1.00
Dehesa	0.15	0.61	0.52

Abbrevation: ESSI is economic ecosystem service sustainability index

* Institutional sector of government is used in rSNA and AAS and ecosystem trustee is used in rEEA.

together all these aspects to inform the design of government policies implemented in the natural environment. From the perspective of government political agendas, the importance of the methodologies applied here is their role as tools, which contribute to the production of important scientific data applied universally to the management of the natural environment and allow a greater understanding of the contribution of nature to the total income of society. In this regard, it is worth remembering the words of G. H. Brundtland in her vision of the role of scientific information in political actions: "Politics that disregard science and knowledge will not stand the test of time. Indeed, there is no other basis for sound political decisions than the best available scientific evidence. This is especially true in the fields of resource management and environmental protection" (Brundtland, 1997: pp. 457). Given that the environmental income comprises a substantial part of the income of owners and consumers of public products (Krutilla, 1967), scientific knowledge regarding its consumption by private and public beneficiaries is of undeniable importance for the design of public policies, which are both environmentally and socially efficient and have a lasting effect.

Our research reveals that the consumer-investor rationale of the non-industrial private owners implies preference for the consumption of private amenity services, leading to the degradation of the woodland environmental asset. The corollary of this lack of investment rationale of the owner is that, as they are not obliged to assure sufficient regeneration of the trees, the practice of grazing compensation by governments should include the mitigation of density loss in holm oak woodlands in the design of the Common Agricultural Policy of the European Union as well as the national policies of the member states.

The design and implementation of the future standard environmental ecosystem accounting (EEA) approach are the responsibility of the national central government statistical office and may include the following extended economic measurements: consumer marginal willingness to pay for the consumption of public products; ecosystem services, environmental assets, changes in environmental assets and should incorporate fair compensation, environmental income and tolerable social cost for the preservation of threatened unique natural habitats and biological species. These environmental-economic accounting outcomes provide valuable data to inform national and subnational government nature conservation policy, taking into account current and future preferences of society (European Commission, 2011, 2016, European Commission, 2020; Terama et al., 2016; United Nations, 2012).

Public policy and private partnership governances for the preservation of threatened unique natural variety which is not reproducible through human engineering should be designed and implemented outside the general system of transaction prices observed in the market and simulated prices for revealed or stated consumption by individuals of current generations. In the presence of an irreversibility problem, as is the case of a species in danger of extinction, it is not the consumers that determine decision making with regard to the conservation of the species. In such circumstances it is not the economic benefit of conservation but rather the precautionary principle (risk avoidance) along with the social tolerable cost which will influence the final decisions of the economic actors. It is expected that the interested actors will defend the conservation of a threatened species and the political decision makers will heed that demand as long as the economic cost of the conservation is acceptable to society, irrespective of the usefulness to the latter in terms of the preservation of the threatened species (Campos and López, 1998).

The current dominant preferences in European society and Spanish society in particular are reflected in environmental preference surveys, in which Spaniards declare their willingness to pay for the conservation of the cultural landscape of the *dehesas* and threatened biodiversity (Oviedo et al., 2016). These demands of Spanish society provide a robust basis for the implementation of taxes on the general population as well as specific taxes and/or entry fee on recreational users of *dehes*a areas in order to bring in funds to finance actions. European Union legislation has implemented territorial contracts which provide another avenue of funding originating in the general budget for concerted action, and which have so far not been implemented by the Spanish government and autonomous communities with the vigour that usually accompanies the design of new environmental policies on the conservation of the natural environment. The paralysis in the agreed compensations for the management of *dehesa* regeneration is not unrelated to the prejudice which still exists in the discourse of certain political groups which are not in favour of spending public money on compensations to large *dehesa* owners for investment in the restoration of biophysical resources. The problem in this regard is that it tends to be the large *dehesas* which possess the richest biodiversity of the Spanish *dehesas* (Díaz et al., 1997, 2020). It is necessary to provide society with biophysical and economic information on the *dehesas* in order to promote responsible attitudes among the political class and other stakeholders.

At the current stage of global consultation of the EEA guidelines, one policy challenge is "to explore the current state of play and opportunities for alignment between the public and private sectors when it comes to the EEA" (Lammerant, 2019: p. 1). Thus, the sustainable management aspect of renewable environmental assets should encourage concerted action on management plans between farmer and the government. In the case of the *dehesa* case study, as long as the amounts of individual physical environmental assets remain above the conservation threat threshold of Safe Minimum Standard, these contracts between farmer and government could be agreed based on previous knowledge of the preferences of the owners as regards compensation of auto-consumption of private amenities and the effective economic demands by public consumers (represented by the government) for the consumption of total products, dependent on the management of cultural landscapes of the privately-owned non-industrial holm oak *dehesas*.

All three accounting systems applied in the *dehesa* case study are valid for revealing the voluntary opportunity cost of the owners, but only the rEEA and AAS can be used to estimate the government fair compensation for the production of public goods and services by the farmers, who incur non-voluntary opportunity costs. This aspect of the methodologies applied to the *dehesa* in terms of providing improved scientific information for the design and application of economic incentives for the enhancement of environmental assets is of particular interest (see Supplementary text S5).

One critical aspect when attempting to reach agreement on compensation for maintaining/improving sustainability is the legitimacy of the compensation according to the initial economic property rights of the owners and public consumers prior to the agreement. Public compensation is legitimate if it is based on reciprocation for the loss of economic value of a previous legal use which will be lost in the future and/or loss of profit from a private manufactured investment due to a new action aimed at improving/mitigating potential abandonment, which favours the future offer of public products.

We have addressed the conceptualization of government "fair compensation" applied to the integration of the private activities of the farmer and the public activities of the government in Campos et al. (2020c), although it can be applied universally. Therefore, it can also be applied to concerted action rights in partnership mechanisms between private individuals or institutional owners and buyers in the *dehesas*, both for the management of new activities which extend the market of environmentally based private goods and services as well as free access public services (see Supplementary text S5).

The government strategies for biodiversity conservation, such as the example of the communication from the European Commission (European Commission, 2020), tend to be declarations of good intentions so that they are made known to national governments although the latter are not obliged to allocate budgets in order to put them into practice. With the exception of certain spending programmes linked to the conservation of species in danger of extinction, there is no allowance in the budget of the European Commission for the management of domestic or wild biodiversity in natural areas beyond wild species in danger of extinction. In this respect, each European Union member state depends on its own public or private financial resources.

The practical interest of environmental ecosystem accounting, such as the AAS approach, is that they give economic significance to the cost of interventions by public administrations (governments) in terms of total income of society, since environmental-economic accounts provide measurements of the final production of goods and services without market prices consumed, which must be bought by individuals directly through private concerted actions with the owners or indirectly through compensation of fees for services consumed and general taxes paid by all taxpayers.

The EEA should be a system of extended accounts, like the AAS, which can be used to facilitate government regulation of sustainable practices from the perspective of economic management of natural resources at farm scale.

The concept of owner voluntary opportunity cost favours greater economic efficiency and equity of policies for public compensation in cases where investment by the owners promoting the conservation of the cultural landscape of the farms leads to loss of potential income. Extended accounts like the EEA and AAS are tools which allow us to improve our understanding of the biophysical and economic realities of the contributions of current and future programmed management of the farms while also supporting decision making on the improvement and restoration of declining environmental assets. The design and future implementation of the standard EEA by governments beyond 2021 are of high current interest and have important implications for public environmental policy on the natural environment and economic management by the owners (European Commission, 2011, 2020; CBD, 2010).

The implications of the accounting systems applied with regard to owner and government economic management are conceptually accepted by both actors responsible for private and public *dehesa* management and, in general, by public consumers of the final products (Álvarez-Farizo et al., 2016; BOJA, 2010; García, 2011; MAPA, 2008; Oviedo et al., 2015, 2016; Senado, 2010). The main problem associated with the implementation of ecosystem economic statistics based on total income theory at farm scale is that it requires the production of new data on the stocks and flows, both biophysical and economic, using a wide range of techniques which will necessitate new public budgets.

Governments have still not approved the standard ecosystem accounts, without which there will be no new government budgets for the implementation of environmental income and environmental asset measurements by the offices for statistics. The lack of a standard manual for environmental ecosystem accounting in the UNSD after more than fifteen years of debate explains the delay between the signing of agreements by numerous governments and the current poor development of experimental implementations of the EEA guidelines by the national offices for statistics (Atkinson and Obst, 2017; Hein et al., 2020a: UNSD, 2020b).

6. Concluding remarks

Our aim in this research is to refine the EEA through the real applied novelty of measuring the public environmental income of holm oak open woodland farms in a way that is consistent with the concept of total income of society. We propose the standardization of the rEEA by (i) extending the SNA through new economic activities only depending on environmental production factors, (ii) incorporating the intermediate products derived from the opportunity costs, and (iii) by substituting the valuation of final products without market prices at cost price in the SNA by a valuation founded on simulated prices based on the consumers' willingness to pay.

In this *dehesa* case study we have focused attention on the economic rationale of amenity consumption by private owners and the rationale of the government, interested in sustainable management of biological environmental assets. We have not included other non-profit institutional organizations in this *dehesa* case study, such as public owners and NGOs, which can contribute to the donation of non-commercial intermediate products of services in order to ensure the continuity/improvement of nature based public products.

We have shown that since the accounting systems compared are based on the exchange value stated/revealed by the consumers through their consumption of the final products, they are applicable regardless of the territorial unit size considered.

The results of the *dehesa* case study application show that it is possible to generate scientific knowledge on the contribution of nature to the total income of society. The comparisons of our own rSNA and rEEA versions of the official SNA and EEA methodologies reveal the distances that separate them from the AAS methodology, which estimates the environmental income integrated in a consistent manner with the total income of society, even though we recognize that the valuations of the environmental incomes from consumptions of products without market prices are still preliminary and require future applied development for possible improvement. It is particularly important that the lesson drawn from the comparison of the environmental income results is taken into account in the design of the EEA manual currently in the process of standardization by the United Nations Statistics Division.

The results provided in this article reveal that the EEA proposal currently under discussion needs to be further improved to reveal the economic contribution of nature to the total income from the natural environment enjoyed by society. This conclusion is important with regard to the design of public policy and good practices in farm management by the owners, supported by the best understanding of the biophysical and economic contributions of nature in order to conserve the greatest possible number of unique natural varieties for the future, while also favouring the sustainable use of natural resources, which should be the case when the social cost is tolerable for current generations. One of the most consistent arguments in favour of implementing ecosystem accounting at individual farm scale refers to the fact that the voluntary opportunity cost of the individual activities of the owners can only be estimated at individual farm scale. It follows therefore that the rEEA applied to an ecosystem type at national/subnational scale must be based on prior application at farm scale in order to provide consistent values for the ecosystem services and environmental assets of the economic activities, when the owners and the government incur voluntary opportunity costs. In other words, the ecosystem accounting methodology must value the net operating margin of the individual activities at social prices, since their estimation at basic prices can lead to biased valuations of the ecosystem services.

Finally, concerted action by both the owners and the government as regards public compensation for additional production of public goods and services, based on scientific knowledge, could increase the likelihood of acceptance by active public consumers (e.g. recreation services) and passive consumers (e.g. landscape services). However, for the moment, the sustainable governance expressed in government agendas is still pending, awaiting future approval of the ecosystem accounting frameworks and associated new budgets for the government office of statistics, in order to produce harmonized farm-type ecosystem accounts at individual activity scale, suitable for providing the scientific information. This could legitimize, in the eyes of society, agreements between governments and farms, which manage threatened renewable environmental assets and, where possible, improve the provision of environmental goods and services under conditions of biological and economic sustainability.

7. Author Contributions

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

Funding sources

This research has received financial support from the RECAMAN, VAMSIL and MAIA projects.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgments

The authors thank the Agency for Water and Environment of the Regional Government of Andalusia for the financial and field work support for the REnta y CApital de los Montes de ANdalucía (RECAMAN) project (Contract NET 165602), the Valoraciones de servicios y activos de AMenidades privadas de fincas SILvopastorales (VAMSIL) project of CSIC (ref.: 201810E036) and the Mapping and Assessment for Integrated ecosystem Accounting (MAIA) project of EU call H2020-SC5-2018-1 (Grant Agreement Nr. 817527). We acknowledge the contributions of Eloy Almazán and Begoña Álvarez-Farizo and other colleagues in the framework of the RECAMAN projects to the methods and results presented in this article. We thank Adam B. Collins for translating and reviewing the final English version of this paper.

Appendix A

Table A1
Comparison of opening capital for commercial and non-commercial activities and the *dehesa* case study in Andalusia under the different accounting frameworks (2010: €/ha).

Class	Commercial activities			Non-commercial activities				*Dehesa*
	Woody products	Non-woody products	Sub-total	Amenity	Landscape	Others	Sub-total	
1. Opening environmental asset (EAo)								
rSNA	1,081.9	1,353.8	2,435.7	3,051.7		1,886.1	4,937.8	7,373.5
rEEA	1,081.9	1,353.8	2,435.7	3,051.7	438.1	3,049.6	6,539.4	8,975.1
AAS	1,081.9	1,353.8	2,435.7	3,051.7	438.1	3,049.6	6,539.4	8,975.1
1.1 Work in progress (WP)								
rSNA	181.6	35.7	217.2					217.2
rEEA	181.6	35.7	217.2					217.2
AAS	181.6	35.7	217.2					217.2
1.2 Environmental fixed asset of land (EFAl)								
rSNA	60.5	1,257.0	1,317.5	3,051.7		1,886.1	4,937.8	6,255.3
rEEA	60.5	1,257.0	1,317.5	3,051.7	438.1	3,049.6	6,539.4	7,856.9
AAS	60.5	1,257.0	1,317.5	3,051.7	438.1	3,049.6	6,539.4	7,856.9
1.3 Environmental fixed asset of biological resources (EFAbr)								
rSNA	839.8	61.1	900.9					900.9
rEEA	839.8	61.1	900.9					900.9
AAS	839.8	61.1	900.9					900.9
2. Manufactured fixed capital (FCm)								
rSNA	4.5	1,601.7	1,606.2		2.3	74.2	76.5	1,682.7
rEEA	4.5	1,553.2	1,557.7					1,557.7
AAS	4.5	1,601.7	1,606.2		2.3	74.2	76.5	1,682.7
3. Opening capital (Co)								
rSNA	1,086.4	2,955.5	4,041.9	3,051.7	2.3	1,960.3	5,014.3	9,056.2
rEEA	1,086.4	2,907.0	3,993.4	3,051.7	438.1	3,049.6	6,539.4	10,532.8
AAS	1,086.4	2,955.5	4,041.9	3,051.7	440.4	3,123.8	6,615.9	10,657.8

Table A2
rSNA stylized sequence of environmental income measurements for the *dehesa* case study in Andalusia (2010: €/ha).

Class	Farmer										
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
Production and generation of income accounts											
1.Total product consumption (TPc_{rSNA})		**13.5**	**9.8**		**28.2**	**1.6**	**47.8**	**10.1**	**18.1**	**213.7**	**4.0**
1.1 Intermediate products (IP_{rSNA})					27.6	1.6	18.0		14.0	33.9	0.8
1.1.1 Intermediate product SNA (IP_{rSNA})					27.6	1.6	18.0		14.0	33.9	0.8
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)											
1.2 Final product consumption (FPc_{rSNA})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.1 Final product consumption SNA (FPc_{rSNA})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Final product consumption non SNA ($Fpc_{non\text{-}rSNA}$)											
2. Ordinary total intermediate consumption (ICo_{rSNA})	**0.1**	**8.8**	**3.1**		**5.9**	**0.4**	**55.6**	**7.1**	**1.6**	**334.8**	**2.7**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)	0.1	0.7	1.0		5.9	0.4	21.1	7.1	1.6	146.9	2.7
2.2 Own intermediate consumption ($ICmoo_{rSNA}$)							22.9			21.5	
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)							22.9			21.5	
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)											
2.3 Manufactured work in progress used (WPmuo)										166.4	
2.4 Environmental work in progress used (WPeu)		8.1	2.1				11.6				
3. Ordinary gross value added ($GVAo_{rSNA}$)	**-0.1**	**4.7**	**6.7**		**22.3**	**1.2**	**-7.9**	**3.0**	**16.5**	**-121.1**	**1.3**
4. Ordinary consumption of fixed capital ($CFCo_{rSNA}$)	**0.1**	**0.5**	**0.2**		**2.6**	**0.1**	**7.7**	**4.2**	**13.8**	**14.8**	**2.6**
5. Ordinary net value added ($NVAo_{rSNA}$)	**-0.2**	**4.2**	**6.5**		**19.7**	**1.1**	**-15.6**	**-1.2**	**2.7**	**-135.9**	**-1.3**
5.1 Labor cost (LCo_{rSNA})	0.2	8.1	3.2		5.1	1.2	19.8	5.6	8.2	44.0	3.9

(*continued on next page*)

Table A2 (*continued*)

Class	Farmer										
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
5.1.1 Compensation of employees SNA (LCoe$_{rSNA}$)	0.2	8.1	2.0		5.1	1.2	19.4	5.6	8.0	42.6	3.9
5.1.2 Imputed compensation of self-employed (LCose$_{rSNA}$)			1.2				0.3		0.1	1.4	
5.2 Net operating margin (NOMo$_{rSNA}$)	−0.4	−3.9	3.2		14.6	−0.1	−35.4	−6.8	−5.5	−179.9	−5.2
5.2.1 Manufactured net operating margin (NOMmo$_{rSNA}$)	−0.4	−3.9	3.2		−10.6	−0.1	−53.4	−6.8	−5.5	−179.9	−5.2
5.2.2 Environmental net operating margin (NOMeo$_{rSNA}$)					25.2		18.0				
6. Ecosystem services (ES$_{rSNA}$)		**8.1**	**2.1**		**25.2**		**29.7**				
Changes in balance accounts											
7. Changes in environmental asset (CEA$_{rSNA}$)	**1.6**	**57.7**	**6.9**	**0.0**	**-2.9**						
8. Adjusted changes in environmental net worth (CNWead$_{rSNA}$)	**1.6**	**57.7**	**6.9**	**0.0**	**-3.0**		**-0.3**				
9. Environmental income (EI$_{rSNA}$)	**1.6**	**65.8**	**9.1**	**0.0**	**22.2**		**29.4**				

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
Production and generation of income accounts											
1.Total product consumption (TPc$_{rSNA}$)	**14.0**	**360.8**	**31.5**	**7.1**	**13.3**		**77.1**	**4.8**	**69.6**	**203.3**	**564.1**
1.1 Intermediate products (IP$_{rSNA}$)		96.1	31.5							31.5	127.5
1.1.1 Intermediate product SNA (IP$_{rSNA}$)		96.1	31.5							31.5	127.5
1.1.2 Intermediate product non-SNA (IP$_{non\text{-}rSNA}$)											
1.2 Final product consumption (FPc$_{rSNA}$)	14.0	264.7		7.1	13.3		77.1	4.8	69.6	171.8	436.5
1.2.1 Final product consumption SNA (FPc$_{rSNA}$)	14.0	264.7		7.1	13.3		77.1	4.8	69.6	171.8	436.5
1.2.2 Final product consumption non SNA (Fpc$_{non\text{-}rSNA}$)											

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Table A2 (*continued*)

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
2. Ordinary total intermediate consumption (ICo_{rSNA})	**14.0**	**434.2**	**10.2**	**2.3**	**0.1**		**69.9**	**1.5**		**84.0**	**518.2**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)		187.2	10.2	1.4	0.1		1.8	1.5		14.9	202.1
2.2 Own intermediate consumption ($ICmoo_{rSNA}$)	14.0	58.4		1.0			68.1			69.1	127.5
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)	14.0	58.4		1.0			68.1			69.1	127.5
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)											
2.3 Manufactured work in progress used (WPmuo)		166.4									166.4
2.4 Environmental work in progress used (WPeu)		21.8									21.8
3. Ordinary gross value added ($GVAo_{rSNA}$)		**-73.4**	**21.2**	**4.7**	**13.2**		**7.2**	**3.3**	**69.6**	**119.3**	**45.9**
4. Ordinary consumption of fixed capital ($CFCo_{rSNA}$)		**46.6**	**1.0**	**1.2**	**0.0**		**2.1**	**0.4**		**4.8**	**51.4**
5. Ordinary net value added ($NVAo_{rSNA}$)		**-120.1**	**20.2**	**3.6**	**13.2**		**5.1**	**2.9**	**69.6**	**114.5**	**-5.5**
5.1 Labor cost (LCo_{rSNA})		99.3	20.2	3.6	0.1		5.1	2.9		31.8	131.1
5.1.1 Compensation of employees SNA ($LCoe_{rSNA}$)		96.2	20.2	3.6	0.1		5.1	2.9		31.8	128.0
5.1.2 Imputed compensation of self-employed ($LCose_{rSNA}$)		3.1									3.1
5.2 Net operating margin ($NOMo_{rSNA}$)		−219.3	0.0		13.1		0.0	0.0	69.6	82.7	−136.6
5.2.1 Manufactured net operating margin ($NOMmo_{rSNA}$)		−262.5	0.0		0.5		0.0	0.0		0.5	−262.0
5.2.2 Environmental net operating margin ($NOMeo_{rSNA}$)		43.2			12.6				69.6	82.2	125.4
6. Ecosystem services (ES_{rSNA})		**65.0**			**12.6**				**69.6**	**82.2**	**147.2**
Changes in balance accounts											
7. Changes in environmental asset (CEA_{rSNA})	**-187.7**	**-124.2**									**-124.2**

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Table A2 (*continued*)

Class	Farmer		Government								D*ehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
8. Adjusted changes in environmental net worth ($CNWead_{rSNA}$)	**-187.7**	**-124.6**									**-124.6**
9. Environmental income (EI_{rSNA})	**-187.7**	**-59.6**			**12.6**				**69.6**	**82.2**	**22.6**

Table A3
rEEA stylized sequence of environmental income measurements for the *dehesa* case study in Andalusia (2010: €/ha).

Class	Farmer									
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
Production and generation of income accounts											
1.Total product consumption (TPc_{rEEA})	**0.4**	**17.9**	**11.5**		**40.9**	**2.1**	**105.3**	**10.1**	**18.1**	**291.5**	**4.0**
1.1 Intermediate products (IP_{rEEA})	0.4	4.4	1.6		40.3	2.1	75.6		14.0	111.7	0.8
1.1.1 Intermediate product SNA (IP_{rSNA})					27.6	1.6	18.0		14.0	33.9	0.8
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)	0.4	4.4	1.6		12.7	0.5	57.5			77.8	
1.2 Final product consumption (FPc_{rEEA})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.1 Final product consumption SNA (FPc_{rSNA})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Final product consumption non SNA ($Fpc_{non\text{-}rSNA}$)											
2. Ordinary total intermediate consumption (ICo_{rEEA})	**0.1**	**8.8**	**3.1**		**5.9**	**0.4**	**55.6**	**7.1**	**1.6**	**334.5**	**2.7**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)	0.1	0.7	1.0		5.9	0.4	21.1	7.1	1.6	146.6	2.7
2.2 Own intermediate consumption ($ICmoo_{rEEA}$)							22.9			21.5	
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)							22.9			21.5	
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)											
2.3 Manufactured work in progress used (WPmuo)										166.4	
2.4 Environmental work in progress used (WPeu)		8.1	2.1				11.6				
3. Ordinary gross value added ($GVAo_{rEEA}$)	**0.3**	**9.1**	**8.3**		**35.0**	**1.7**	**49.7**	**3.0**	**16.5**	**-43.0**	**1.3**
4. Ordinary consumption of fixed capital ($CFCo_{rEEA}$)	**0.1**	**0.5**	**0.2**		**2.6**	**0.1**	**7.7**	**4.2**	**13.8**	**14.8**	**2.6**
5. Ordinary net value added ($NVAo_{rEEA}$)	**0.2**	**8.6**	**8.1**		**32.4**	**1.6**	**41.9**	**-1.2**	**2.7**	**-57.8**	**-1.3**
5.1 Labor cost (LCo_{rEEA})	0.2	8.1	3.2		5.1	1.2	19.8	5.6	8.2	44.0	3.9

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Table A3 (*continued*)

Class	Farmer										
	Tim-ber	Cork	Fire-wood	Nuts	Gra-zing	Cons. forestry	Hun-ting	Comm. recreation	Resi-dential	Live-stock	Agri-culture
5.1.1 Compensation of employees SNA ($LCoe_{rSNA}$)	0.2	8.1	2.0		5.1	1.2	19.4	5.6	8.0	42.6	3.9
5.1.2 Imputed compensation of self-employed ($LCose_{rSNA}$)			1.2				0.3		0.1	1.4	
5.2 Net operating margin ($NOMo_{rEEA}$)	0.0	0.5	4.9		27.3	0.4	22.2	−6.8	−5.5	−101.8	−5.2
5.2.1 Manufactured net operating margin ($NOMmo_{rEEA}$)	0.0	0.5	4.9		2.1	0.4	4.1	−6.8	−5.5	−101.8	−5.2
5.2.2 Environmental net operating margin ($NOMeo_{rEEA}$)					25.2		18.0				
6. Ecosystem services (ES_{rEEA})		**8.1**	**2.1**		**25.2**		**29.7**				
Changes in balance accounts											
7. Changes in environmental asset (CEA_{rEEA})	**1.6**	**57.7**	**6.9**	**0.0**	**-2.9**						
8. Adjusted changes in environmental net worth ($CNWead_{rEEA}$)	**1.6**	**57.7**	**6.9**	**0.0**	**-3.0**		**-0.3**				
9. Environmental income (EI_{rEEA})	**1.6**	**65.8**	**9.1**	**0.0**	**22.2**		**29.4**				

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
Production and generation of income accounts											
1.Total product consumption (TPc_{rEEA})	**295.2**	**796.9**		**23.7**	**13.3**	**49.5**	**90.2**	**9.9**	**81.9**	**268.6**	**1,065.5**
1.1 Intermediate products (IP_{rEEA})		251.1									251.1
1.1.1 Intermediate product SNA (IP_{rSNA})		96.1									96.1
1.1.2 Intermediate product non-SNA ($IP_{non\text{-}rSNA}$)		155.0									155.0
1.2 Final product consumption (FPc_{rEEA})	295.2	545.8		23.7	13.3	49.5	90.2	9.9	81.9	268.6	814.4
1.2.1 Final product consumption SNA (FPc_{rSNA})	14.0	264.7			13.3				69.6	82.9	347.6
1.2.2 Final product consumption non SNA ($Fpc_{non\text{-}rSNA}$)	281.1	281.1		23.7		49.5	90.2	9.9	12.3	185.7	466.8

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Table A3 (*continued*)

Class	Farmer		Government								*Dehesa*
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
2. Ordinary total intermediate consumption (ICo_{rEEA})	**169.1**	**588.9**									**588.9**
2.1 Manufactured intermediate consump. bought SNA ($ICmob_{rSNA}$)		187.2									187.2
2.2 Own intermediate consumption ($ICmoo_{rEEA}$)	169.1	213.5									213.5
2.2.1 Own intermediate consumption SNA ($ICmoo_{rSNA}$)	14.0	58.4									58.4
2.2.2 Own intermediate consumption non SNA ($ICmoo_{non\text{-}rSNA}$)	155.0	155.0									155.0
2.3 Manufactured work in progress used (WPmuo)		166.4									166.4
2.4 Environmental work in progress used (WPeu)		21.8									21.8
3. Ordinary gross value added ($GVAo_{rEEA}$)	**126.1**	**208.0**		**23.7**	**13.3**	**49.5**	**90.2**	**9.9**	**81.9**	**268.6**	**476.6**
4. Ordinary consumption of fixed capital ($CFCo_{rEEA}$)		**46.6**									**46.6**
5. Ordinary net value added ($NVAo_{rEEA}$)	**126.1**	**161.4**		**23.7**	**13.3**	**49.5**	**90.2**	**9.9**	**81.9**	**268.6**	**429.9**
5.1 Labor cost (LCo_{rEEA})		99.3									99.3
5.1.1 Compensation of employees SNA ($LCoe_{rSNA}$)		96.2									96.2
5.1.2 Imputed compensation of self-employed ($LCose_{rSNA}$)		3.1									3.1
5.2 Net operating margin ($NOMo_{rEEA}$)	126.1	62.1		23.7	13.3	49.5	90.2	9.9	81.9	268.6	330.7
5.2.1 Manufactured net operating margin ($NOMmo_{rEEA}$)		−107.2									−107.2
5.2.2 Environmental net operating margin ($NOMeo_{rEEA}$)	126.1	169.3		23.7	13.3	49.5	90.2	9.9	81.9	268.6	437.9
6. Ecosystem services (ES_{rEEA})	**126.1**	**191.1**		**23.7**	**13.3**	**49.5**	**90.2**	**9.9**	**81.9**	**268.6**	**459.7**
Changes in balance accounts											
7. Changes in environmental asset (CEA_{rEEA})	**-187.7**	**-124.2**				**-3.2**				**-3.2**	**-127.4**

(*continued on next page*)

Table A3 (*continued*)

Class	Farmer		Government								Dehesa
	Amenity	Total	Fire services	Recrea-tion	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Total	
8. Adjusted changes in environmental net worth (CNWead$_{rEEA}$)	**-187.7**	**-124.6**				**-52.7**				**-52.7**	**-177.3**
9. Environmental income (EI$_{rEEA}$)	**-61.6**	**66.5**		**23.7**	**13.3**	**-3.2**	**90.2**	**9.9**	**81.9**	**215.9**	**282.4**

Table A4
Comparison of environmental incomes for commercial and non-commercial activities and the *dehesa* case study in Andalusia under the different accounting frameworks (2010: €/ha).

Class	Commercial activities			Non-commercial activities				*Dehesa*
	Woody products	Non-woody products	Sub-total	Ame-nity	Land-scape	Others	Sub-total	
1. Ordinary net valued added (NVAo)								
rSNA	10.4	−110.3	−99.8		5.1	89.3	94.3	−5.5
rEEA	16.9	18.3	35.3	126.1	90.2	178.4	394.7	429.9
AAS	16.9	38.6	55.5	126.1	18.2	172.9	317.2	372.7
2. Ordinary net operating Margin (NOMo)								
rSNA	−1.0	−218.3	−219.3		0.0	82.7	82.7	−136.6
rEEA	5.4	−69.5	−64.0	126.1	90.2	178.4	394.7	330.7
AAS	5.4	−69.5	−64.0	126.1	13.1	166.3	305.6	241.5
3. Ecosystem services (ES)								
rSNA	10.2	54.8	65.0			82.2	82.2	147.2
rEEA	10.2	54.8	65.0	126.1	90.2	178.4	394.7	459.7
AAS	10.2	54.8	65.0	126.1	13.0	164.0	303.0	368.1
4. Changes in environmental asset (CEA)								
rSNA	66.3	−2.8	63.5	−187.7			−187.7	−124.2
rEEA	66.3	−2.8	63.5	−187.7		−3.2	−190.9	−127.4
AAS	66.3	−2.8	63.5	−187.7		−3.2	−190.9	−127.4
5. Adjusted change in environmental net worth (CNWead)								
rSNA	66.3	−3.2	63.1	−187.7			−187.7	−124.6
rEEA	66.3	−3.2	63.1	−187.7		−52.7	−240.4	−177.3
AAS	66.3	−3.2	63.1	−187.7		−52.7	−240.4	−177.3
6. Environmental income (EI)								
rSNA	76.5	51.6	128.1	−187.7		82.2	−105.5	22.6
rEEA	76.5	51.6	128.1	−61.6	90.2	125.7	154.3	282.4
AAS	76.5	51.6	128.1	−61.6	13.0	111.3	62.6	190.8

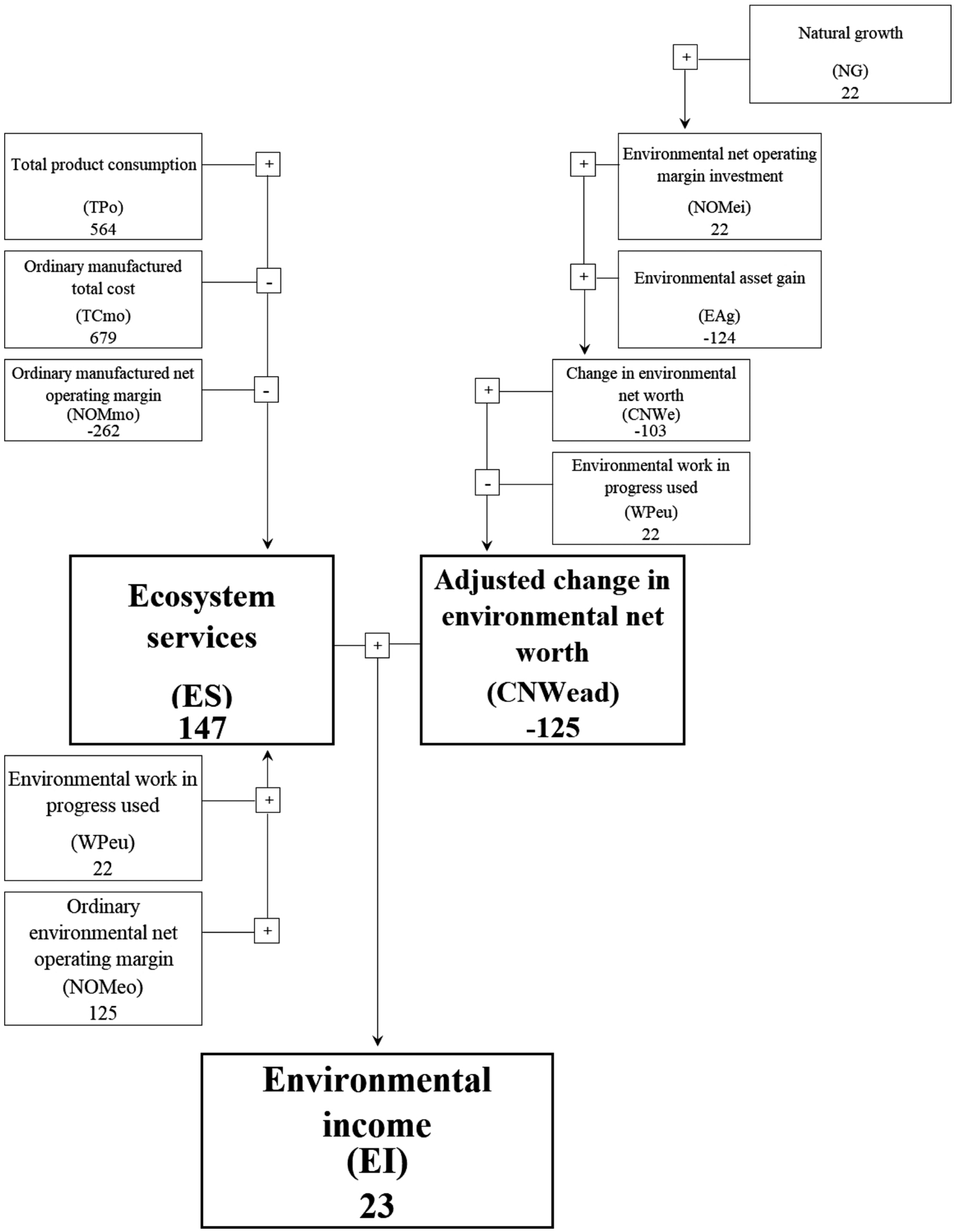

Fig. A1. rSNA environmental income for the *dehesa* case study in Andalusia (2010: €/ha).

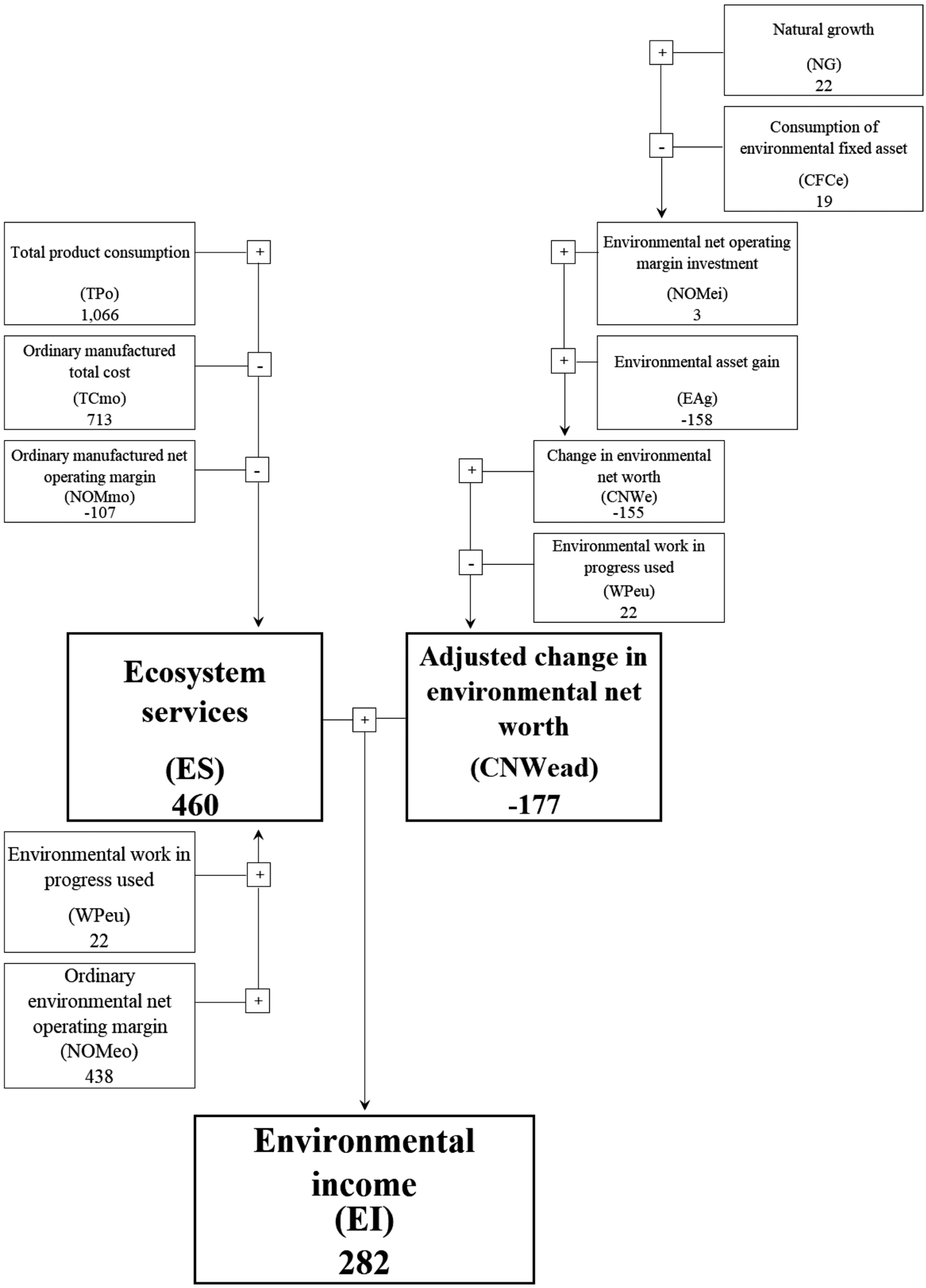

Fig. A2. rEEA environmental income for the *dehesa* case study in Andalusia (2010: €/ha).

Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104984.

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