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Total income and ecosystem service sustainability index: Accounting applications to holm oak *dehesa* case study in Andalusia-Spain

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ABSTRACT

This research develops the novel concept of an economic ecosystem service sustainability index from the perspective of total income theory, and presents its empirical application at the spatial unit scale of the agroforestry farm. This paper compares the results accrued from applying the refined standard System of National Accounts (rSNA) and the authors' Agroforestry Accounting System (AAS). The AAS extends the rSNA to capture economic activities without manufactured production costs and substitutes the production cost valuations for exchange values revealed/stated by consumer willingness to pay for consumption of final products without market prices, the aim being to provide more comprehensive figures for total and environmental incomes of the agroforestry farms. Both accounting frameworks are applied to a case study of sixteen large, non-industrial, privately-owned holm oak *dehesas* (agroforestry farms) in Andalusia-Spain. This *dehesa* application provides estimates for the economic ecosystem service, total income factorial allocation, total capital and economic ecosystem service sustainability index for the aggregate and individual economic activities of the *dehesa*, distributed between accounts for the farmer and government institutional sector economic activities. The AAS explicit measurements of the hidden rSNA ecosystem services and environmental incomes of the *dehesa* allow us to further our scientific understanding of the current and future contributions of environmental income from nature to the total income of society as well as to provide information to the policy makers so that action can be taken to mitigate the depletion and degradation of environmental assets. This *dehesa* application reveals that environmental income measured by the AAS accounts for 67 % of total income in 2010. The *dehesa* AAS and rSNA ecosystem services share 34 % and 26 % of total product consumptions, respectively. Coupled with the AAS economic ecosystem service sustainability index of 0.5 and the rSNA economic ecosystem service sustainability index of 0.2, these figures indicate total product over-consumption in 2010. The *dehesa* case study shows that the AAS ecosystem services and environmental incomes are 2.5 and 8.4 times higher than those of the rSNA, respectively. Once the theoretic robustness of non-market product consumption simulated transaction value is accepted, as in the AAS methodology, the expected official economic ecosystem accounting framework will mainly depend on its ongoing standardization by the United Nations Statistical Division and implementation by individual governments. Thus, the challenge of standardizing and implementing such a framework is more closely linked to governmental policy measures than to the current scientific weakness of non-market product consumption valuations.

1. Introduction

The objectives of this agroforestry farm study are to measure the total income and to conceptualize the economic ecosystem service sustainability index at *dehesa* scale. We define total income as the maximum possible total product consumption by individuals, generated in the current period without reducing the total capital at the closing of the period (European Communities, 2000: p. 87; Hicks, 1946; Krutilla, 1967; McElroy, 1976). The economic ecosystem service sustainability index is the coefficient between environmental income and ecosystem services. We define environmental income as nature's contribution to the total income of an activity that results from adding to the ecosystem services the adjusted change in environmental net worth according to environmental work in progress used in the current period (Campos

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et al., 2019a, 2019b; Cavendish, 2002: p. 53).

This *dehesa* study takes into account the Andalusian government's definition of the *dehesa* as an agroforestry farm spatial unit "constituted for the most part by open woodland, subject to a system of land use and management based mainly on extensive livestock that uses grass, non-industrial fruits and browses, as well as other forestry, hunting or agricultural uses" (BOJA, 2010: 4, article 2b). The *dehesa* open woodland ("*formación adehesada"*) is a "forested land occupied by a tree stratum, with a canopy cover fraction (soil surface area covered by the projection of the tree crowns) between 5% and 75 %, mainly comprised of holm oaks (*Quercus ilex* L.), cork oaks (*Quercus suber* L.), Portuguese oaks (*Quercus faginea* Lam.) or wild olive trees (*Olea europaea* L.), and occasionally other types of trees, which allow for the development of a herbaceous stratum, which can be utilized by livestock or hunting species" (BOJA, 2010: 4, article 2a). The holm oak is a wild fruit tree that provide acorns upon which a variety of wildlife and domestic livestock depend. Consequently, its healthy conservation has become a cause for concern for diverse groups of society, academic institutions and public administrations interested in mitigating the loss or degradation of these Mediterranean habitats (Alagona et al., 2013; Alejano et al., 2011; Campos et al., 2013; Senado, 2010; Pinto-Correia et al., 2013; Pulido and Picardo, 2010; Urbieta et al., 2011). Holm oak is a defining element of Mediterranean landscapes, and one of the main species forming the traditional *dehesa* agrosilvopastoral systems. Stakeholders addressing the implications of natural conservation of *dehesas* for the results of the economic management of farmer and government activities are concerned because the results of these activities shape the natural landscape.

Holm oak conservation is currently compromised. About 75 % of the experimental plots in which natural regeneration is measured, reveal that regeneration of holm oak trees is null or scarce (MAPA, 2008). Despite the fact that the ecological sustainability of Andalusian holm oak woodlands (HOW) is assured in the short term given the large extension of these woodlands (more than 1.4 million hectares), this might not hold in the long term. The notable loss in density of adult holm oak trees in areas dominated by holm oak open woodland (Montero, 2017) may be of importance in the long term, unless the natural or assisted regeneration of woodlands is facilitated in areas where tree recruitment has become scarce or holm oaks are degraded.

A reduction in acorn yield in holm oak woodlands, along with the reduction in the area covered by this species, could affect wild species through the trophic chain. Moreover, it could also have a cascade effect on the provision of multiple goods and services that are consumed by humans as final products, hence reducing the overall contribution of holm oaks to total income and, to a large extent, the environmental income of these woodlands. The effect of holm oak woodland productivity decline and degradation on consumer wellbeing will entail both active and passive use values of holm oak woodlands, including final consumption of landscape conservation services and the preservation of endangered wild species services (Díaz et al., 2020).

The above mentioned multiple uses of the *dehesa* are the sources of a wide variety of incomes for the farmer, generated by the commercial and non-traded total product consumptions that motivate the management decisions in their *dehesa*, while the income and the ecological sustainability of the *dehesas* themselves are the variables that should dictate the decision-making criteria of the government. This is not the case when the management of unique, non-replaceable things in nature that are in danger of total extinction are concerned. In this case, the government should be guided by the principle of tolerable social cost, total loss of income being acceptable if the case arises (Norton, 1987).

The holistic approach of considering the market and non-market total product of the agroforestry farm together is not taken into account in the official standard accounts for agriculture and forestry (European Commission, 2009; European Communities, 2000). The accounting perspective that we are interested in developing and applying at *dehesa* scale allows total income to be estimated through broadening the narrow limits of the official net value added for the farmer institutional sector as estimated by the System of National Accounts (SNA) (European Commission, 2009; European Communities, 2000).

This *dehesa* study applies the refined System of National Accounts (henceforth rSNA) and the Agroforestry Accouting System (AAS), taking into account the property rights associated with the activities of the farmer and government institutional sectors. An accounting model is proposed which allows the products (outputs) and production costs to be distributed between just two institutional sectors, and unlike the official SEEA-EEA manual currently in the process of standardization (UNSD/DESA, 2020), in our AAS, nature (the ecosystem) is not considered an institutional sector. We consider that nature is not an economic agent (institutional sector), but rather a production factor for farmer and government economic activities. The environmental work in progress used and environmental income are, respectively, the intermediate consumption product and the environmental asset services, accrued from the ecosystem. This ecosystem concept as production factors of nature has the advantage of direct integration in the farmer/government production and capital accounts. The Agroforestry Accounting System (AAS) simulated transaction price valuation criterion for consumption of the final product without market prices differs from the production cost criterion of the rSNA. We integrate the economic variables of the rSNA in a consistent manner in the AAS by overcoming this rSNA valuation bias (Campos et al., 2017, 2019a, 2019b, 2019c, 2020; Caparrós et al., 2017; European Commission, 2009; Ovando et al., 2016; Oviedo et al., 2017).

Total income is the variable that regulates the structure of the production account and the capital account in the two abovementioned accounting frameworks; thus, the formal structure of these methodologies is applicable to any economic unit and territorial scale. We are aware of the difficulty involved in transmitting environmental-economic variables that depend on a subjective concept such as that of total income, which we present as the variable governing the decisions taken by the farmer and government which will shape the future *dehesa* landscapes (Council of Europe, 2000), except where a unique natural variety is in danger of extinction. As far as possible, we try to mitigate the inherent difficulty involved in understanding terms plagued with multiple meanings. We believe that the most appropriate response to this polisemic labyrinth is to define the jargon we use.

Thus, environmental income is the largest possible reference value for the economically sustainable ecosystem service. This is the case if we program in advance an infinite succession of biological regeneration management practices that guarantee the conservation of all biophysical and economic flows without decreasing the environmental asset. We value an environmental asset as the environmental price of a transaction, at a given point in time (e.g., December 31), of the sum of ecosystem services that are expected to contribute in perpetuity to the total product consumption values. These environmental assets are measured by programmed management of the single activity and a subjective discount rate (e.g., a private real rate of 3%). We define ecosystem service as nature's habitat value contribution to the transaction value of human total product consumption generated in the ecosystem type in the current period (United Nations, 2017: p. 75). The concept of economic ecosystem service applied here does not detract from that applied to ecosystem services in ecology. The challenge is more to uncover the ecosystem services that contribute to the total product consumption and environmental assets generating the environmental incomes from multiple farmer and government economic activities in *dehesas* (Campos et al., 2019a, 2019b, 2020).

In this *dehesa* study, we distinguish between the economic sustainability given by an economic ecosystem service sustainability index value equal to or greater than one and the ecological sustainability of the natural landscape. We define the ecological sustainability as the Safe Minimum Standard (critical threshold of the bio-physical endowment that avoids the extinction of a unique non-reproducible natural variety by human intervention) for both the wild biological population

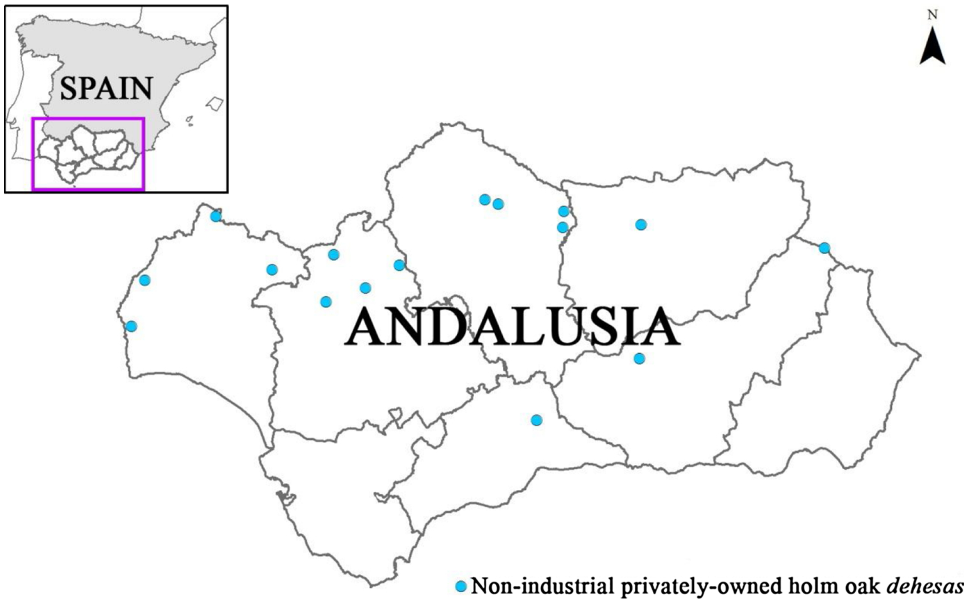

Fig. 1. Location map of non-industrial privately-owned Andalusian holm oak *dehesa* case study.

and its natural breeding habitat, guaranteeing its self-regeneration through a succession of infinite natural regeneration cycles.

We compare the results for economic ecosystem services, incomes and ecosystem service sustainability indexes by applying a refined System of National Accounts (rSNA) and the authors' Agroforestry Accounting System (AAS) to sixteen large, non-industrial, privately-owned holm oak *dehesa* case study in Andalusia (henceforth *dehesa* study) (Fig. 1). This *dehesa* study considers 19 economic activities, 12 of which correspond to the farmers (timber, cork, firewood, nuts, grazing, conservation forestry, hunting, commercial recreation, residential service, livestock, agriculture and private amenity) and 7 to the government (fire services, public recreation, mushrooms, carbon, landscape conservation services, threatened wild biodiversity preservation services and water supply). All *dehesa* economic activities are integrated in the production (including SNA generation of income account) and capital (including SNA balance sheet) accounts.

Few study have integrated the measurements of total income and total capital at *dehesa* scale and we are not aware of any literature by other authors on agroforestry accounting which includes the government activities. The rSNA and AAS applied in previous publications consider neither the concept of ESSI nor the holm oak *dehesa* (HOD) capital, income and ecosystem service valuations at social prices (Campos et al., 2016, 2017, 2019a, 2019b, 2020; Caparrós et al., 2017; Ovando et al., 2016; Oviedo et al., 2017). The first application of the AAS at social prices to the farmer institutional sector is described in Campos et al. (2017). In this *dehesa* study, we define the social price as the net operating margin of the activity at basic prices plus/less intermediate product/consumption accruing from owner voluntary opportunity cost. Campos et al. (2017) was the first study in which the AAS at social prices was applied to farmer activities in a publicly-owned holm oak *dehesa* although the value of ecosystem services associated with government economic activities were not estimated apart from that of carbon emission. In Campos et al. (2019b), the rSNA and AAS at social prices were applied to famer and government economic activities in five non-industrial privately-owned cork oak *dehesa* case study in Andalusia.

The operative advancement of this study is the fact that it is the first time that the results of the rSNA and AAS approaches gauging the social prices of farmer and government activities have been applied to privately-owned holm oak *dehesa* case study.

We estimate the total capital, environmental asset, total income, net value added, ecosystem service, environmental income, adjusted change of environmental net worth and economic ecosystem service sustainability index at the single activity, farmer, government and *dehesa* spatial unit scale. This *dehesa* study provides an economic ecosystem service sustainability index that is applied, for the first time, to the holm oak *dehesa*. In Campos et al. (2020), the economic ecosystem service sustainability index is applied to Andalusian holm oak open woodlands. The characteristic of the *dehesa* (farm) is that it is both a territorial unit and an economic unit with multiple Mediterranean oak-tree species as well as treeless land (shurblands, grasslands and herbaceous croplands). In this *dehesa* study, the treeless land uses are negligible. In these rSNA and AAS applications, the single *dehesa* is the independent economic unit, which makes it possible to measure the economic value of a single product and its economic interactions alongside other *dehesa* activities by measuring the intermediate product and own intermediate consumption.

In order to avoid overvaluation bias of ecosystem services when they are estimated at producer or basic prices (Campos et al., 2019a: 234), the farm-scale applications should estimate ecosystem services at social prices, as in the AAS approach. Therefore, the application of the AAS at social prices in this privately-owned *dehesa* study requires estimates of both the non-commercial intermediate product of services (ISSnc) from government compensation (ISSncc) and opportunity costs incurred voluntarily by non-industrial private farmers due to amenity auto consumption (ISSnca). The rSNA approach does not accept the accounting registers of manufactured non-commercial intermediate products of the services of amenity auto-consumption (ISSnca) and donation (ISSncd). The counterpart registers of ISSncc/d are ordinary own intermediate consumption of service compensation (SSncooc) and amenity auto-consumption (SSncooa), respectively. This application of the rSNA to the *dehesa* measures net value added at basic prices. Thus, only the AAS approach measures net value added incomes at social prices.

The study continues in Section 2 with a brief review of the literature on ecosystem services and environmental income applications of recent agroforestry accounts at *dehesa* scale. Section 3 summarizes the most relevant aspects of the rSNA and AAS methodologies applied to the *dehesa*. Section 4 then presents the physical and economic results of the *dehesa* case study and compares the results of integrating the rSNA in the AAS framework. Section 5 discusses the comparative results of the rSNA and AAS and the policy implications of the results in terms of the hypothetical government implementation of an agroforestry account system, such as those applied in this study. Finally, section 6 concludes with the main results and findings stemming from the study.

2. Brief review of the literature on agroforestry economic accounting

Although the debate in scientific circles and government institutions regarding the standardization of environmental accounts has been going on for more than two decades, we still do not have a regulatory agreement in the form of a manual for economic ecosystem accounting (EEA) (United Nations, 2017). In the last decade, governments have made a commitment to a standard manual for ecosystem accounting by the United Nations Statistical Division (UNSD), although the UNSD expects it to be a satellite methodology of the standard System of National Accounts (SNA) (European Commission, 2011; CBD, 2010; United Nations, 2012). The United Nations et al. (2014a, 2014b) manual on EEA is currently being revised, with the aim of it being adopted by the United Nations Statistic Division (UNSD) as an internationally agreed standard in spring 2021. The EEA framework considers the ecosystem services as final products. It is this subjective assumption that has led to the odd EEA convention of incorporating the ecosystem as a new institutional sector rather than incorporating it in that of the government (van de Ven et al., 2019: Table 2, model C, p. 10).

Until now, advances in the standardization of economic ecosystem accounting have mainly been with regard to the valuation criteria for consumptions of final product without market price (United Nations et al., 2014a, 2014b; United Nations, 2017; van de Ven et al., 2019). These advances affect the transaction value adopted for consumption of final products without market price in substitution place of applying the SNA production cost in the case of these public products, which consumers enjoy with no direct cost to them. However, the standardization of embedded ecosystem services and changes in the environmental assets in the environmental income of the ecosystems is still at a preliminary stage. As regards the development of frameworks for the production account (including the income generation account of the standard SNA) and capital account (including the standard SNA balance sheet), there has been little progress and at this moment this is still a challenge that has to be addressed (Atkinson and Obst, 2017. van de Ven et al., 2019). Even further behind is the standardization of the ecosystem accounts at farm scale for agroforestry land uses. Nevertheless, the scientific community continues to advocate the application of standardized EEA at farm scale at some future point in its development (Campos et al., 2019b; Lammerant, 2019; Marais et al., 2019).

The European Union estimates the net value added of farmer agroforestry activities at national scale or sub-national agroforestry farms through the satellite methodology of the SNA Manual on the Economic Accounts for Agriculture and Forestry (EAA/EAF) (European Communities, 2000).

The EAA/EAF methodology used to estimate the net value added for national/subnational agroforestry farms presents certain inconsistencies with respect to the theoretical concept of net value added (operating income) which it should represent due to the fact that: (i) it values the consumption of final products without market price according to the manufactured production cost, (ii) it includes the woody work in progress extracted (intermediate consumption) in the net operating surplus, (iii) it omits the natural growth of biological resources, (iv) it omits the non-commercial intermediate products of services of private amenity auto-consumption and donations, respectively, of non-industrial and institutional owners, as well as omitting own ordinary non-commercial intermediate consumption, (v) it misplaces the economic activities conducted in the national or sub-national agroforestry farms in the general government institutional sector.

The economic valuations of ecosystem services for agroforestry land uses at national scale usually refer to the data for single consumption of final products included in the standard SNA. In some cases, the single ecosystem service concept estimate of a SNA product is beyond the contribution to final product consumption. Vallecillo et al. (2019: pp. 19–23) value a group of 13 herbaceous agricultural products from official SNA statistics and apply a “solar energy Joule (se) metric” coefficient ($EcoCon_{crops}$) to estimate the contribution of ecosystem services to their respective final product consumption valued at basic prices. This physical coefficient is inconsistent as regards deriving economic transaction values. In addition, to estimate these values, even where the $EcoCon_{crops}$ are assumed, it is necessary to break down the net mixed income (NMI) of the official agricultural statistics into self-employment compensations (LCse) and net operating surplus. Net mixed income in the official EAA/EAF has not been separated using a subjective procedure (Ovando et al., 2016; Oviedo et al., 2017). Therefore, the failure to estimate the contribution of economic ecosystem service coefficients to agricultural product consumption leads to an overvaluation of ecosystem services in terms of the amount of compensation for self-employed labor which is not separated from the mixed income.

Vallecillo et al. (2019) estimate the ecosystem service of timber according to the physical (biomass) increase in the period multiplied by the roadside (farm gate) price of the harvested timber minus the manufactured costs of forestry and extraction (resource rent unit price). This estimate of the timber ecosystem service is inconsistent with the definition of ecosystem services as the contribution to the value of the timber final product consumption. The physical increase in timber should be valued by the environmental price of extraction discounted in accordance with the number of periods that remain until its programmed future extraction.

There have been no publications involving the application of agroforestry accounting methodologies at farm scale which take into consideration the valuation of ecosystem services and the environmental assets of farmers and government, with the exception of our AAS application in Campos et al. (2019b). Marais et al. (2019) present a qualitative study of agroforestry accounts for farmers which goes beyond those of the commercial products, incorporating auto-consumption of final products without market prices embedded in the market price of the land as well as changes in the environmental assets. The SEEA-EEA methodology developed in van de Ven et al. (2019) considers the ecosystem as a new institutional sector (van de Ven et al., 2019: Table 2, model C, p.10). In our application of the AAS methodology to the *dehesa* we have taken a different line and chosen to recover the government institutional sector, considering the ecosystem as a possible production factor of both farmer and government activities in the *dehesa*.

A study by Gaspar et al. (2007) is the only one by other authors, as far as we know, to have applied the EAA/EAF. Gaspar et al. (2007) extended the EAA/EAF to measure the total capital of the farm with the farmer capital valuation in a sample of sixty-nine *dehesas,* differentiated according to five groups of predominant livestock species in the Extremadura region. The data for the study by Gaspar et al. (2007) came from *in situ* structured questionnaires completed by *dehesas* owners or managers during the years 2003 and 2004. The fourth group of *dehesas* identified in the study by Gaspar et al. (2007) comprising ten *dehesas*, is that which comes closest, in terms of average farm size and predominance of holm oak trees, to those in our study of sixteen holm oak *dehesas* in Andalusia. Gaspar et al. (2007), in accordance with the standard EAA/EAF, estimate the farmer commercial net value added at basic prices but do not estimate the natural growth or environmental work-in-progress used. Furthermore, Gaspar et al. (2007) do not separate net mixed income into imputed self-employed labor compensation ($LCse_{NMI}$) and net operating surplus (NOS_{NMI}), despite the relevance of the $LCse_{NMI}$ in their group four type *dehesas* (Gaspar et al., 2007: p. 157, Table 2). In their estimate of farmer net value added for the commercial activities of the *dehesa* ($NVA_{EAA/EAF}$), Gaspar et al. (2007) omit the measurement of the private amenity ordinary environmental net operating margin (NOMeoa).

We have applied the AAS to the farmer institutional sector at agroforestry *dehesa* scale in a previous study of Spanish *dehesas*, Portuguese *montados*, Tunisian cork oak agroforestry farms and Californian ranches (Campos and Riera, 1996; Campos et al., 2008, 2017, 2019b, Coelho, and Campos, 2009; Ovando et al., 2016; Oviedo et al., 2017). Campos et al. (2019b) apply the AAS to a group of five cork oak *dehesas* (COD) in Andalusia, presenting the measurements for individual activities, farmer, government and *dehesa* total income, environmental income, ecosystem service, environmental asset and other economic results. In Ovando et al. (2016), we present aggregate results for a group of twenty-four private *dehesas* in Andalusia without differentiating between the oak vegetation present in each one. In the *dehesa* study by Ovando et al. (2016), we do not present estimates for ecosystem services, environmental assets, adjusted change in environmental net worth or other economic results.

This holm oak *dehesa* study is very similar to that of Campos et al. (2019b), except for the incorporation of the new concept of economic ecosystem service sustainability index (ESSI) and the imputed self-employed labor compensation (LCse). However, the procedure applied to separate net mixed income into imputed self-employed labor compensation and net operating surplus (or margin) was applied in Campos et al. (2008, 2017), Ovando et al. (2016) and Oviedo et al. (2017).

3. Accounting frameworks applied to holm oak *dehesa* case study

In this section, we address the challenge of mitigating the polysemic labyrinth in the literature concerning valuations of ecosystem services, environmental assets and environmental incomes. In this *dehesa* study we focus on defining the meanings of the terms we assign to the economic-environmental variables and analyze the differences and similarities to those of our refined System of National Accounts (rSNA).

We summarize the most important concepts of the AAS and rSNA approaches applied to the *dehesa* in order to facilitate the comprehension of the text by the reader without the need to refer to previously published literature (Campos et al., 2016, 2017, 2019a, 2019b, 2020; Caparrós et al., 2017; Ovando et al., 2016; Oviedo et al., 2017) (see additional accounting methodology developments applied in this *dehesa* study in Supplementary materials: texts S1-S4, Figs. ST1-ST6 and Tables ST1-ST3).

3.1. The institutional settings of the dehesa

3.1.1. Economic property rights, economic activities and institutional sectors

The exclusive property rights over the products consumed in the present, or expected to be consumed in the future, are the starting point from which the existence of products that can be exchanged between the entities that produce them and the consumers in a delimited agroforestry area are identified and exclusively attributed to the farmer or government (Anderson and McChesney, 2003: p. 1). Defining what a product is can be a controversial task, thus, we agree that a product is a good or service perceived by consumers directly or indirectly in the period that is produced or accumulated at period closing for use in the current period (as intermediate and final product consumption) or future periods (as gross capital formation). The economic activity for a main product is defined as containing the complete production and capital account records.

This *dehesa* study considers the institutional sectors of the farmers and the government. Households are considered to be independent economic units in the standard System of National Accounts (SNA), whereas in the rSNA and AAS applications to the *dehesas* in this study, public recreational open-access services and mushroom collection are considered to be produced by the two respective government activities (Campos et al., 2019a; European Commission, 2009).

The farmer is responsible for the management of his/her own activities based on exclusive private property rights. Our definition of public goods and services requires that the final product consumption and appropriation of such public products (goods or services) should be free for beneficiaries (Koop and Smith, 1993). This concept goes beyond the narrower definition of pure public goods (Maler et al., 2008). According to this definition, the government regulates and compensates the economic activities of farmers and directly manages public activities. When applied to *dehesa* study, the AAS values 12 farmer and 7 government activities. We classify the economic activities as commercial (timber, cork, firewood, nuts, grazing, conservation forestry, hunting, commercial recreation, residential service, livestock, agriculture and fire services) and non-commercial (private amenity, public recreation, mushrooms, carbon, landscape conservation services, threatened wild biodiversity services and water supply). The commercial activities are divided into those that produce products made from woody raw material (timber, cork, firewood) and those that produce other commercial non-woody products (nuts, grazing, conservation forestry, hunting, commercial recreation, residential, livestock, agriculture and fire services).

In the past, extensive livestock rearing has led to farmers shaping the cultural landscape of the *dehesas* to favor grazing productivity (including grass, browse, acorns and other non-industrial fruits). The relative importance of the multiple private goods and services of the *dehesa* has been changing in recent decades to favor a revaluation of big game hunting and private amenity final product consumptions (Campos and Mariscal, 2003; Ovando et al., 2015; Oviedo et al., 2015; Herruzo et al., 2016; Martinez-Jauregui et al., 2016). These economic changes have been motivated by the decline in livestock grazing, the expansion of hunting species in large *dehesas,* in areas of lower grazing productivity, and the purchase of *dehesas* by new farmers willing to accept lower monetary returns from livestock and hunting products in exchange for the enjoyment of private amenity service auto-consumption by the owner's family.

Why do livestock and hunting activities matter when estimating the values of ecosystem services beyond basic prices? They matter because, in this application of the AAS to privately-owned *dehesas*, these are the activities that generate the non-commercial intermediate products of services compensation (ISSncc) and private amenity auto-consumption (ISSnca). This ISSnca is due to the farmer voluntary opportunity cost incurred, usually in the manufactured investments in livestock and hunting activities[1] .

3.1.2. Mixed monetary and amenity auto-consumption rationale for manufactured investment in dehesa by non-industrial private farmers

Our analysis of the silvo-pastoral economies in this *dehesa* study assume that among the motivations of the farmers is the desire to continue their ownership of the land, in addition to expectations of real appreciation in the price of the land in the long term. In this *dehesa* study, the rationale of the non-industrial farmer is that of mixed investment, that is, they accept a lower than normal monetary margin in exchange for greater private amenity auto-consumption by the landowner's family, produced by the total capital investment in the *dehesa*. The value of the final product of the amenity auto-consumption of services (FPcaa) is estimated by the marginal willingness to pay of the group of private non-industrial farmers of the homogeneous landscape to which the owner's *dehesa* belongs. The FPcaa is not explicitly included in the list of farmer economic activities in the standard EAA/EAF. Instead, private amenity activity is implicitly valued according to its cost of production and included in the activity that directly generates the production cost. Conceptually, however, the FPcaa is consistent with the hidden market price of the environmental asset amenity, inseparable from the total land market price. The FPcaa in the *dehesas* of the west and southwest of Spain was valued through questionnaires completed by farmers in which the contingent valuation method is applied (Campos and Mariscal, 2003; Oviedo et al., 2015, 2017).

[1] Five farmer activities do not incur voluntary opportunity cost: nuts, commercial recreation, residential service, crops and private amenity.

The farmers assume risks associated with manufactured (man-made) capital investment decisions and voluntarily accept incurring monetary opportunity costs (Masiero et al., 2019; Raunikar and Buongiorno, 2006). It is assumed in this *dehesa* study that the non-industrial farmer (owner) manufactured investment opportunity costs (FVOC) incurred in the current period (year) generate a supply: the non-commercial intermediate products of the service of amenity auto-consumption (ISSnca). The ISSnca is estimated by the difference between the normal ordinary manufactured net operating margin (NOMmon) and the ordinary manufactured net operating margin at basic price ($NOMmo_{bp}$) of the single activities (timber, cork, firewood, grazing, conservation forestry, livestock, and hunting) in exchange for a higher level of private amenity final product consumption. Thus, the accounting counterpart of the ISSnca is the own ordinary non-commercial intermediate consumption of the service of amenity auto-consumption (SSncooa) on the cost side of the private amenity activity (for details see Supplementary text S1).

The *dehesa* farmers generally accept the normative aim of promoting conservationist methods in order to manage the *dehesas* in a manner that is "always sponsored from the productive point of view, in such a way that the interest is aimed at restoring the environmental balance with the business, allowing profitability that facilitates reinvestment in the environment [...,] actively organize[d] in the maintenance of the natural scenario where we develop our agroforestry activities, with the security of finding the economic return that our work needs" (García, 2011: p. 10).

For the non-industrial owners of Andalusia's *dehesas* there are generally multiple management purposes to be considered and they tend to prioritize family auto-consumption of amenities, assuming that they accept the monetary opportunity cost incurred for their manufactured investments in commercial activities. The farmer manufactured investment voluntary opportunity cost (FVOC) is defined as the accepted management choice by which the farmer does not receive a normal ordinary manufactured net operating margin, but rather, enjoys greater final product amenity auto-consumption in their *dehesa* property. The "[farmer manufactured capital investment voluntary] opportunity cost, usually expressed as the difference in the NPVs [net present values] of various options, is the cost of a [monetary] benefit that could have been received but which has been given up to pursue a certain course of action" (Masiero et al., 2019: p. 52).

The FVOC is estimated as the equivalent ordinary manufactured net operating margin of the manufactured investments that the farmer voluntarily gives up from the manufactured investment in the livestock and hunting commercial activities of their *dehesa* in exchange for a greater final product amenity auto-consumption (Oviedo et al., 2017). The FVOCs are registered twice, simultaneously as the non-commercial intermediate product of the amenity service auto-consumption (ISSnca) of the livestock and hunting activities and as own ordinary non-commercial intermediate consumptions of the amenity service auto-consumption (SSncooa) of the private amenity activity. The individual *dehesa* is the primary independent economic unit where the opportunity costs are born from the rationale of each individual farmer and must be observed from the results of the individual activities at the closing of the current period.

3.1.3. The meaning of intermediate product

The total product is composed of the total product consumption and gross capital formation of economic activities of the farmer (including both the landowner and livestock keeper) and the government in the *dehesa* study.

In this *dehesa* study, the intermediate product (IP) must be accounted for by estimating the net operating margin of the individual activities of each *dehesa* (independent economic unit). The total product consumption (TPc) contains double counting of IP because the IP, simultaneously, is registered as an own ordinary intermediate consumption (ICoo) which is embedded in the final product consumption (FPc)[2] .

[2] We asume TPc is higher than the ordinary total cost (TCo).

The rSNA and AAS approaches both measure the commercial intermediate services (ISSc) of the *dehesas*. These services stem from timber, cork, firewood, grazing, conservation forestry, residential and fire service activities. The SNA presents operating subsidies to owners as transfers without counterparts from the farmer to the citizens who pay them though their taxes. The AAS does not recognize the subsidies as transfers, but rather as government compensations to farmers for the additional generation of non-commercial intermediate products of services compensation (ISSncc) demanded by government as inputs of own ordinary non-commercial intermediate consumption of services compensation (SSnaooc) for the cultural landscape conservation activity. Compensations are registered twice, simultaneously as ISSncc of the activities that produce them and as SSncooc of the landscape activities that use them. SSncooc is embedded in the landscape activity final product consumption.

When all the economic activities of the farmer and government institutional sectors that take place in a *dehesa* during the current period are valued, both intra-institutional sector and inter-institutional sector transactions are cancelled in the estimations of total income. This is not the case, however, among the separate aggregate values of the institutional sectors and the activities affected by intra and inter-institutional exchanges. In the System of National Accounts (SNA), the flows that denote intra and inter-institutional transactions between single activities are the intermediate products (IP) of the activities that originate them. Their counterpart records for the activities that use them as inputs are called own ordinary intermediate consumption (ICoo). As regards extractions of woody products (timber, cork and firewood), these are harvested and produced in periods prior to the current one and therefore are not own ordinary intermediate consumption, although they are part of the intermediate consumption in the form of environmental work in progress used (WPeu). As examples, we describe the productive interdependencies of a farmer intra-sector-exchange (e.g., residential service) and a farmer-government inter-sector exchange (e.g., livestock intermediate service compensation-landscape conservation).

The farmer enjoys the residential services intended exclusively for their family's enjoyment of the private amenity services in their *dehesa*. We agree to isolate, as an economic activity, the production of the auto-consumption (by the farmer) of the commercial intermediate product of residential service (ISScrs) and we agree that its imputed market transaction value is the local rental price of the residential dwelling in the current period. We attribute the counterpart of this ISScrs to the amenity activity as own ordinary commercial intermediate consumption of residential service (SScrs). This intra-exchange between the two activities involved in the institutional sector is an example of the zero sum of the farmer net value added, but not of the amenity ecosystem service affected by its use of SScrs.

The farmers receive government compensation (operating subsidies less taxes on production) for improving grazing and yield of agricultural activities and in particular, for maintaining the increase in grazing livestock. This lessens the abandonment or reduction of livestock herd grazing, in turn mitigating and/or improving ecosystem services and income from the silvo-pastoral landscapes. In this case, if all of the other circumstances remain the same, the income of the farmer increases by the amount of compensated livestock intermediate production of services. Conversely, the income and ecosystem services of the government landscape activity decrease by the amount of own compensated intermediate consumption of services demanded by the landscape activity. On the other hand, the aggregate income of the farmers and the government is not altered in this simulated inter-exchange between the institutional sectors of the farmers and the government.

3.1.4. Prices

Embedded in its overall value, a product contains the individual values of its total production costs and the net operating margin at social price. The basic price (price at factor cost) represents the producer price (market price) plus the unitary value of the government compensations (operating subsidies net of taxes on production). We define the social price of a total product and operating incomes (net value added and net operating margin) as its basic prices by adding to the production account both the unitary value of the ISSnca registered on the supply side of the activity that generate the total product and the SSncooa on the cost side of the activity that used the SSncooa as input to generate the total product.

The aggregate values of products or incomes of a nation, region or any spatial unit generated in a period do no change depending on whether they are valued at basic prices or social prices. This is not the case for farmer and government activity products or incomes. The different types of prices influence the estimates of ecosystem services, the net value added by the farmer and government, including those of the individual activities affected by the production of ISSnc, and the ensuing SSncoo. In other words, the cancellations of ISSnc and SSnc effects only occur when all products and incomes of the spatial unit are taken into account.

The AAS replaces the valuation of non-market public products at production cost in the SNA with farmer and public consumer willingness to pay (simulated exchange value). The labor cost (LC) of the AAS coincides with that of the SNA, but the respective SNA operating surplus and AAS margin differ. The rSNA framework estimates ecosystem services and net value added at basic prices, and the AAS add social price (for details see Supplementary text S1).

In this *dehesa* study, we compare our refined System of National Accounts (rSNA) and Agroforestry Accounting System (AAS) at basic and social prices because the former presents biases in the valuations of the products and incomes of the activities affected by owner´s voluntary opportunity costs. However, in addition to social price refinement, we add the natural growth in the supply side and the environmental work in progress used in the cost side of the production account in our rSNA approach.

3.2. Refined System of National Accounts

Although the standard System of National Accounts (SNA) incorporates the institutional sector of the general government in the measurement of national or sub-national net value added, it does not include the activities of the government in the *dehesa* net value added. In practice, the SNA does not estimate total income, but estimates the NVA at basic prices and production costs for intermediate and final products for which market prices are not available. It does not estimate environmental assets and manufactured capital. The SNA does not separate the environmental work in progress used from the net operating surplus nor does it separate the net mixed income (NMI) into its net operating surplus and self-employed imputed compensation components. Moreover, the SNA does not estimate the ecosystem service and the change in the adjusted environmental net worth according to the environmental work in progress used. Consequently, the SNA does not measure the environmental income either. In this study these are all estimated by the rSNA and AAS.

The EAA/EAF approach estimates the overall net value added of the farmer commercial agroforestry activities at national or sub-national scale (European Communities, 2000). In this study of the *dehesa*, the rSNA methodology applied to the *dehesa* is our modified version of the official EAA/EAF methodology. The EAA/EAF approach which estimates the net value added of national or regional agroforestry farms presents several inconsistencies with regard to the theoretical concept of the operating income which it should represent due to the fact that: (i) it values the consumption of final products without market price according to the manufactured production cost, (ii) it includes the woody work in progress extracted (intermediate consumption) in the net operating surplus, (iii) it omits the natural growth of biological resources, (iv) it omits the non-commercial intermediate products of services of auto-consumption of the private amenity and donations, respectively, of the non-industrial and institutional owners, along with the omission of own ordinary non-commercial intermediate consumption, (v) it misplaces the economic activities of national and subnational agroforestry farms in the general government institutional sector.

We have refined the EAA/EAF by extending the farmer total product to include woody natural growth and future hunting captures, which are virtually inventoried in the period. We also incorporate the intermediate consumption of woody environmental work in progress and hunting captures for the period. We have extended the activities in the EAA/EAF approach to include government agroforestry activities in the *dehesa* which are included in the SNA among the economic activities of the general government institutional sector.

These virtual changes to the EAA/EAF methodology allow us to transform it into the rSNA approach. The EAA/EAF modifications incorporated into the rSNA resolve the bias resulting from the misplacement of the government activities in the EAA/EAF approach.

With regard to the satellite Economic Accounts for Agriculture and Forestry (EAA/EAF) methodology applied by government with the aim of measuring the net value added of commercial agroforestry activities in the *dehesa*, this official methodology contains concepts of total income, net value added and manufactured capital which are consistent with economic theory. We can even accept that the EAA/EAF (farmer System of National Accounts-SNA_F) pursues the estimation of farmer total income at basic price, although in practice it only partially measures, in an inconsistent manner, the net value added (European Communities, 2000: pp. 87–88). The SNA_F is applied to farmer activities on a spatial scale of greater administrative criterion than that of the *dehesa* study (municipality, province, region and nation) (European Communities, 2000). It does not measure farmer environmental income. The SNA_F does not measure the voluntary opportunity cost of farmer activities. In addition, the farmer SNA_F estimates the consumption of final products without market prices at production cost.

The SNA_F does not separate the net operating surplus of commercial activities into environmental surplus (NOSe) and manufactured surplus (NOSm) components. Likewise, the SNA_F does not separate net mixed income into operating surplus and imputed self-employed compensation. The investment environmental margin of the own account environmental gross capital formation (GCFe) is not estimated by the SNA_F due to the omission of natural growth and consumption of environmental fixed asset. These SNA_F omissions make it impossible to estimate farmer total labor compensation and total net operating margin. It is necessary to estimate the normal value of this latter margin in order to separate the residual value from the environmental net operating margin.

The SNA does not incorporate all capital gains from the farmer's commercial products and the government's manufactured fixed capital (the SNA only incorporates the measurement of livestock capital gain in total income). In summary, our refined SNA (rSNA) incorporates the values for (i) the compensated, auto-consumption and non-commercial intermediate product of services compensation (ISSncc) (ii) the natural growth (NG) in the own account gross capital formation (GCF), (iii) the environmental work in progress used (WPeu) in the intermediate consumption, and (iv) the own ordinary non-commercial intermediate consumption of services compensation (SSncooc) in the own ordinary intermediate consumption of services (SSoo).

The abovementioned changes to the EAA/EAF incorporated in the rSNA allow the total income and its factorial distribution to be estimated in labor cost (LC), manufactured capital income (CIm), environmental income and ecosystem services (Fig. 2) (see supplementary text S1 for further details).

3.3. Agroforestry Accounting System

In the AAS, we expand the SNA_F (EAA/EAF) methodology by incorporating (i) the economic activities of the government institutional

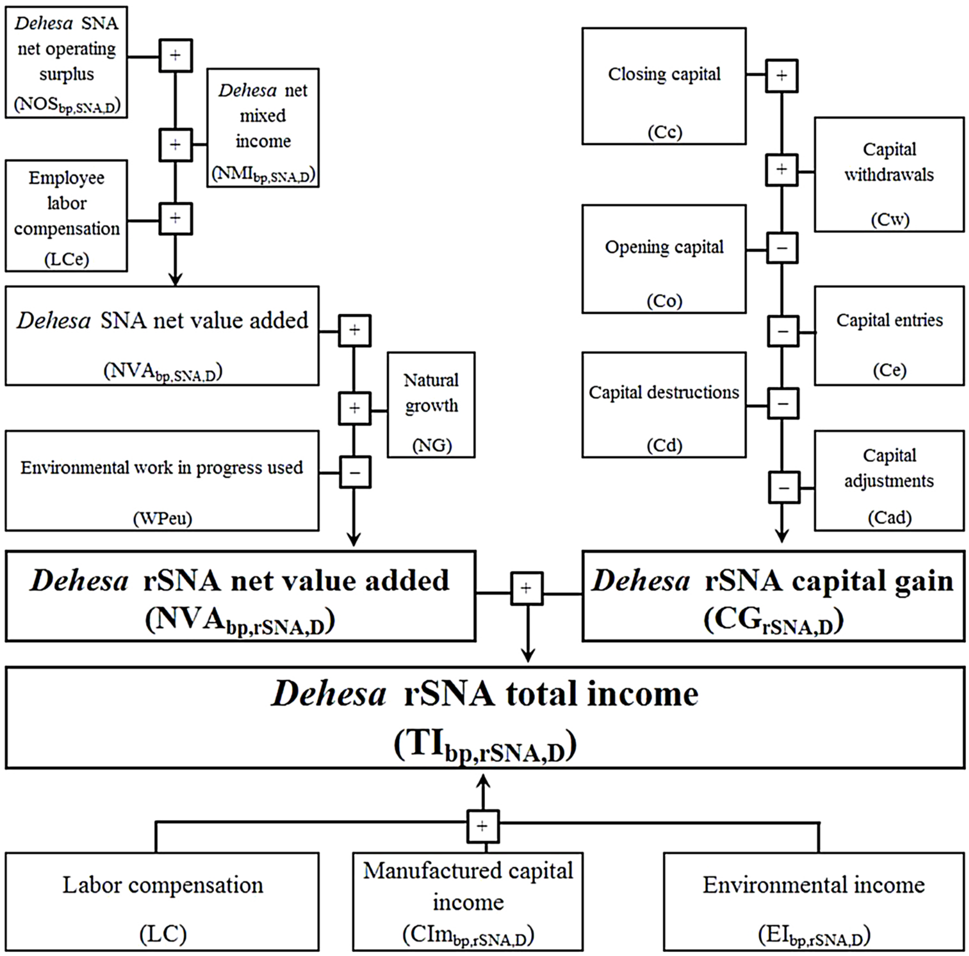

Fig. 2. *Dehesa* total income at basic prices under the refined System of National Accounts.
Abbreviations. SNA standard is System of National Accounts; bp is basic prices; D is *dehesa*; rSNA is refined System of National Accounts.

sector, which, in our definition, considers the activities included in the SNA within the general government institutional sector and which we attribute to the *dehesa*. In addition, the government institutional sector also includes the products collected by users which the SNA records in the households institutional sector, since they are not considered economic activities by the SNA, (ii) in our application of the AAS in the *dehesa* study we incorporate the carbon activity, (iii) the AAS values ecosystem services and net value added at social price, (iv) we define the social price by the aggregation at basic price (in our application this coincides with the price at factor costs) of the price derived from the farmer voluntary opportunity cost, (v) we apply an *ad hoc* subjective procedure to the refined SNA (rSNA) by separating the SNA_F net operating surplus (NOS) and net mixed income (NMI) into the environmental work in progress used (WPeu), manufactured net operating margin (NOMm), ordinary environmental net operating margin (NOMeo) and imputed self-employed compensation (LCse), and (vi) we replace the SNA valuations at production cost of transaction price obtained using various technical procedures, all of which are based on the consumers' willingness to pay for consumption of final products without market prices in the period. Based on these refined SNA (rSNA) and AAS extensions, we construct the *dehesa* production account (which includes the SNA income generation account) and the AAS capital account (which includes the SNA balance sheet). These accounts lead us to the quantifications of the AAS net value added of the *dehesa* at social price, with the rSNA estimating the net value added at the basic price. Due to these differences between the rSNA and the AAS, we consider our AAS as an extension of the rSNA without conceptual changes in total income and capital, although the latter statement may be controversial due to the conventions assumed on the limits of the concept of economic products and activities attributed to the *dehesa* institutional sectors of the farmers and the government.

The measurements of the AAS methodology are more consistent than those of the rSNA from the theoretical perspective of measuring the total income, ecosystem service and environmental income of *dehesas*.

3.3.1. *Total capital*

The total capital (C) represents the aggregate transaction values (observed in formal market or simulated through non-market valuation methods) of environmental assets (natural capital) and manufactured capital (produced by human intervention) used during the accounting period to obtain the total product.

In this *dehesa* study, total opening capital is the main capital production factor, because operating (working) capital shares a minor contribution to the total immobilized capital. Opening total capital (Co) consists of environmental asset (EAo) and manufactured capital (Cmo). The Cmo is estimated by its market replacement price adjusted according to a coefficient that denotes its state of depreciation (Campos et al., 2019a). The EAo is valued according to the discounted future resource rents (RR) (United Nations et al., 2014a). In this *dehesa* study, a normal real discount rate of 3% is assumed. Thus, the EAo represents the discounted exchange value of future expected product consumption quantity (q_c) times environmental prices (ep) (Campos et al., 2017, 2019a, 2019b). The environmental price is defined as the stumpage price less the unitary labor compensation, intermediate cost and manufactured capital user cost (consumption of manufactured fixed capital plus normal return of manufactured immobilized capital). In other words, environmental price is the resource rent price. This latter price is an economic rent, that is gifted by nature and appropriated by farmer or government. The standard System of Environmental Economic Accounting-Central Framework (SEEA-CF) only estimates the environmental asset of commercial products (United Nations et al., 2014a), while the AAS incorporates the *dehesa* study non-market carbon activity. We use, as does the SEEA-CF, the net present value in the AAS applications to the individual economic activities in the *dehesa* study. The environmental assets of amenity and water are the two exceptions to the use of the net present value in the calculation of the individual environmental assets. The amenity environmental asset is the share of the market price of the land corresponding to the private amenity as stated by the farmer (Campos et al., 2019a; Oviedo et al., 2017). The water environmental asset is estimated by the imputed (applying hedonic price) value of the water embedded in the market price of irrigated land (Campos et al., 2019a: Supplementary text S4, pp. 19–21).

The EAo is separated into environmental works in progress (WPeo) and environmental fixed assets (EFAo). The WPeo are the natural growths[3] of the biota produced (opening inventory) and expected to be produced in the *dehesa* study spatial unit for future consumption. They are valued by their discounted environmental prices, according to the remaining accounting periods up until the period in which the WPeu are harvested (Campos et al., 2017, 2019a). The discounted natural growth of biota that accumulates in the spatial unit destined for the production of future environmental flows (produced at the opening of the accounting period and expected to be produced in successive periods) is understood as the opening environmental fixed assets of biological resources (EFAbro). Besides the woody dominant biota, the EFAo also include expected future run-off surface water stored in watershed downstream governmental reservoirs, expected future collection of mushrooms and the expected future consumption of public recreation, landscape and biodiversity services valued at discounted environmental prices of future consumption (Campos et al., 2017, 2019a):

$$RR = q_c * ep \quad (1)$$

$$EAo = \sum_{s=t}^{\infty} \frac{RR}{(1+r)^{(s-t)}} \quad (2)$$

where r is the normal discount rate, s is the year of consumption of the product embedded the resource rent, and t is the current accounting period.

When applying the rSNA and AAS frameworks to the *dehesa* study, we estimated the closing environmental assets according to the scheduled future management aimed at physical and economic sustainability of the *biota* (for more detailed model development see Campos et al., 2019a: Supplementary texts S2-S3, pp. 11−19). We make four assumptions concerning scheduled future *dehesa* management: (i) the current management is maintained in the future with no further technical innovation; (ii) the physical productivity of the natural resources will change with the biological modeling functions; (iii) in the case of trees (i.e., timber, cork, firewood and acorns) shrub, and hunting products, the current biological cycle of the trees and shrubs will be followed by further cycles of regeneration (either natural or induced by human intervention) along with enough game species births to guarantee perpetual persistence in the condition of the biotic environmental assets, and (iv) the absence of irreversible losses of biological or cultural assets in the *dehesa* study (Campos et al., 2017, 2019a; Ovando et al., 2015).

Once the conditions of the infinite future programmed management described above have been met, then the environmental income becomes the maximum possible consumption of ecosystem services that does not diminish the value of either physical or economic environmental assets in the period. Other authors understand this concept as the "potential flux" of ecosystem services (La Notte et al., 2019a, 2019b).

The environmental assets excluded from the rSNA are those accrued from consumption of government final product without market prices (public recreation, landscape, biodiversity), while carbon activity is omitted.

The main difficulty involved in estimating the environmental asset gain (EAg) is that it requires the revaluation of environmental assets, as well as the associated accounting adjustments, which avoid possible double counting in the valuation of natural growths and final carbon product consumption. Valuing the change in environmental assets over the period is perhaps the most difficult task in the AAS application to the *dehesa* study. This requires us to forecast the environmental values of the future biota harvests inventoried and those products, including consumption of services, which will be produced and consumed in the infinite time horizon.

3.3.2. Total product

The total product of an activity can be composed of one or more products which are either completed (finished) or in work in progress phase at the end of the current period (year). The total product always requires complete records of its production account (including the factorial attributions of the net value added) and capital account (including the balance sheet of entries, withdrawals and capital revaluation for the current period). The functional classifications of the total product are: intermediate product, final product consumption and accumulation of final product (gross capital formation) at the closing of the period.

The transaction value of the total product is destined to the payment of intermediate consumption of raw materials and services, the depreciation of the normal use of fixed capital (durable goods), human labor compensation, the manufactured net operating margin of the investment in manufactured immobilized capital goods and the environmental net operating margin (the income of the environmental asset -natural capital- appropriated by its economic owner). The functional classification of the total product (TP) comprises the intermediate product (IP), final product consumption (FPc) and investment in own account gross capital formation (GCF). We break down the uses of total product as intermediate consumption (IC) into manufactured (ICm) and environmental work in progress product (WPeu), labor compensation (LC) into employees (LCe) and self-employed (LCse), normal consumption of fixed capital (CFC) into manufactured (CFCm) and environmental (CFCe) and the net operating margin (NOM) into ordinary environmental (NOMeo) and accumulated investment (NOMei). Fig. 3 presents the AAS components of the total product value of an activity, some of which are provided by nature, the ecosystem service (WPeu and NOMeo) and the environmental net operating margin of investment (NOMei) for the period.

The values of the total product and its uses are all known, with the exception of the ordinary environmental net operating margin. This requires a residual estimation of the balance equation between the total product (supply) and its uses as intermediate consumption, normal consumption of fixed capital, manufactured net operating margin and investment environmental net operating margin (Fig. 3).

The AAS measures the consumption of final products with market prices at observed or imputed formal market transactions prices. The AAS methodology applies the simulated exchange value revealed or stated by consumer willingness to pay in order to value the final product consumption without market prices. Consequently, the transaction value of the final product consumption applied by the AAS is derived from the prices that consumers have paid or would have been willing to pay if they had been required to purchase the products during the period (year) of its consumption.

[3] The natural growth in the accounting period is included in the environmental gross work in progress formation (GWPFe).

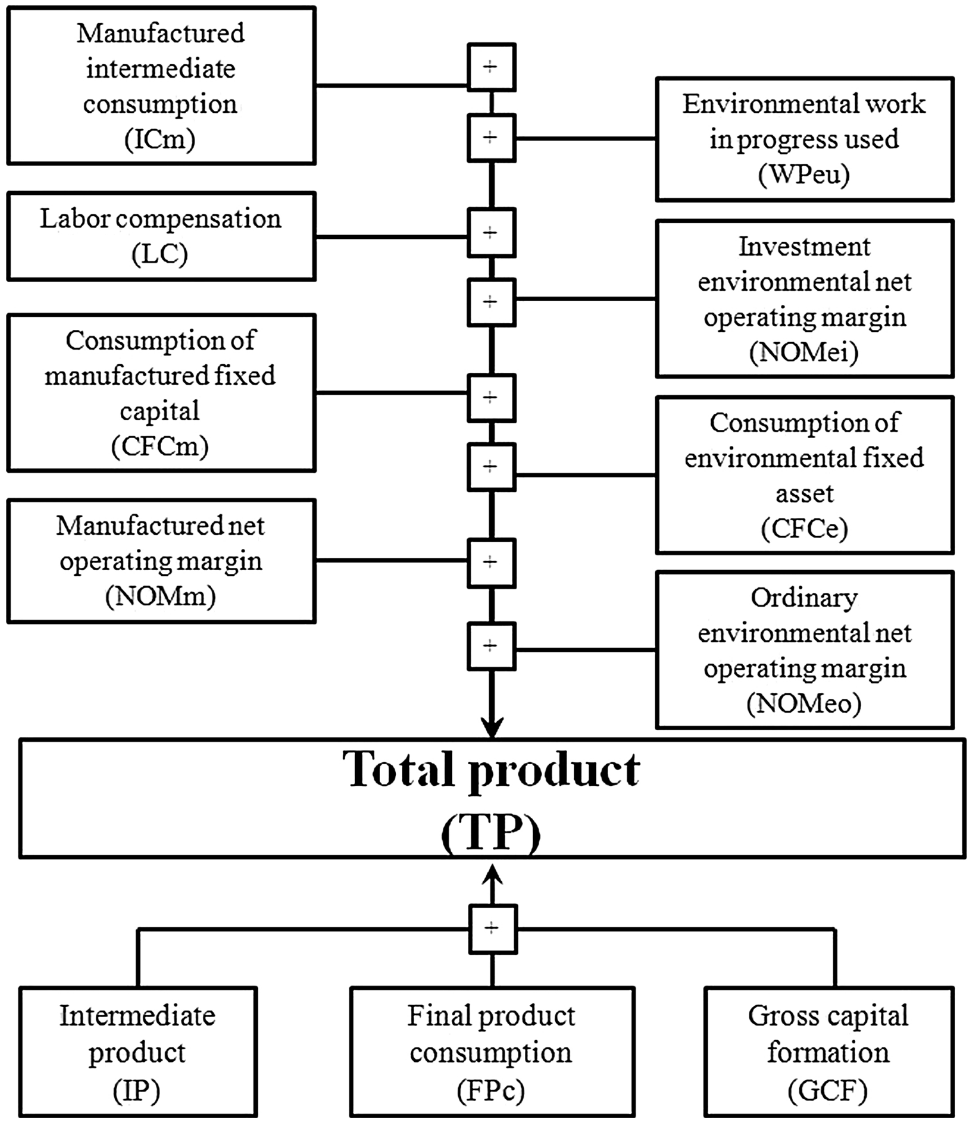

Fig. 3. Holm oak *dehesa* total product under the Agroforestry Accounting System.

However, within the AAS approach, some types of intermediate product consumption may be prone to subjective valuation bias derived from the discount rate used to estimate the non-commercial intermediate products of the services of amenity auto-consumption (ISSnca) and donation (ISSncd). Also, the valuation of the normal ordinary manufactured net operating margin of an economic activity may be biased, given the subjective estimate resulting from applying a normal rate of return to the manufactured immobilized capital (manufactured capital invested in an economic activity in the current period). This normal manufactured net operating margin is also assumed to be its upper bound value. Thus, the ordinary environmental net operating margin emerges with a value greater than zero in the presence of a residual ordinary manufactured net operating margin value higher than what is considered to be its normal value.

The possible bias that may arise from the inevitable subjective choice of the discount rate in the valuation of the ISSnca only affects the production accounts of economic activities involved in the supply side of those which produce the ISSnca and the use side of those activities that benefit from the ISSnca as SSncooa. The effects of the ISSnca, and their counterpart SSncooa, are nullified in the aggregate net value added and the total income of the *dehesa* study activities in the current period.

3.3.3. Total income

The concept of total income is at the heart of the theoretical conception of the standard System of National Accounts (SNA): "Income can be defined as the maximum amount which the beneficiary can consume over a given period without reducing the volume of his/her assets. It can also be defined as being the total of the consumption and change in value of assets held over a given period, all other things being equal, as income represents what *could have been* consumption" (European Communities, 2000: p. 87).

The SNA applications are limited to the estimation of the operating income represented by the net domestic product (henceforth net value added) from economic activities using manufactured production factors and it omits the measurement of capital gain.

The total income is the variable on which we base the structures of the AAS production and capital accounts of individual activities, farmers, governments and the *dehesas*. The construction of a complete system of accounts depends on the definition of the total product function, including the incorporation of the environmental work in progress used, the natural growth and the environmental asset gain (Fig. 4). The productive process of the period is recorded in the production account (includes the separation of the factorial allocation of net value added) from the individual activity and is generated as the first component of the total income, which is represented by the net

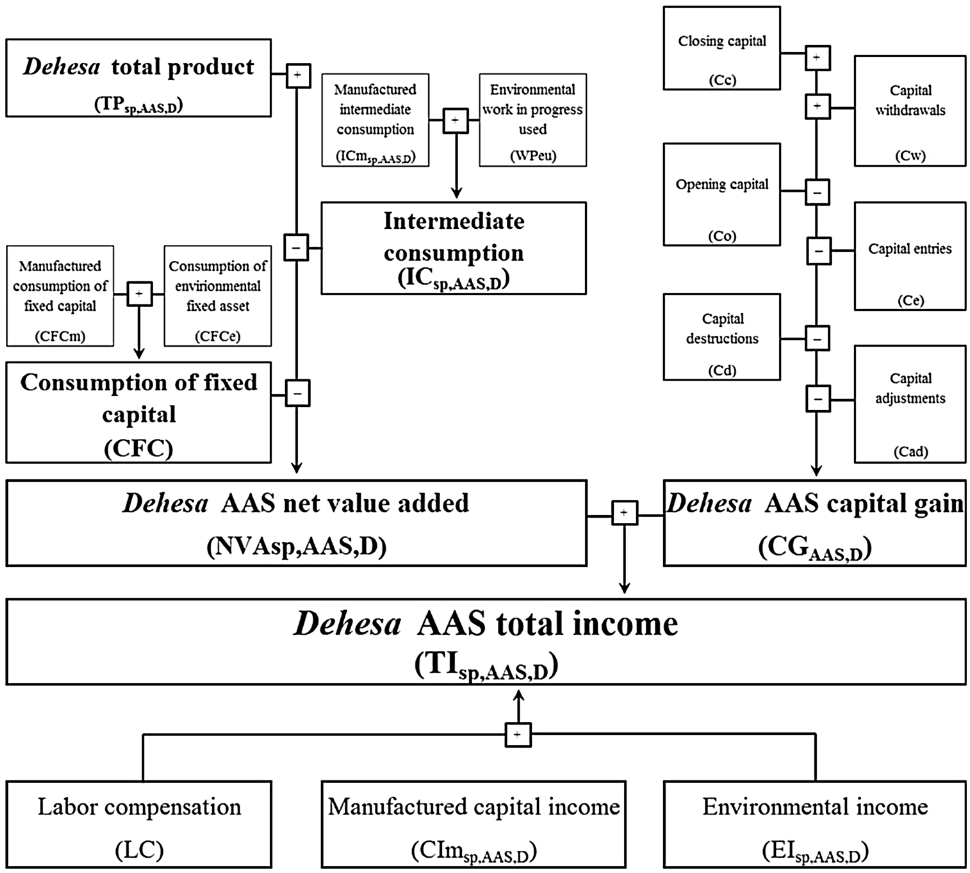

Fig. 4. Holm oak *dehesa* total income under the Agroforestry Accounting System.
Abbreviations: sp is social prices; AAS is Agroforestry Accounting System; D is *dehesa*.

value added (operating income). The capital account component of the total income is the capital gain. This is derived from the entries and withdrawals of the capital account (including balance sheet) as well as other effects, such as the discounting of standing work in progress expected to be harvested in the future and any other adjustments that are not detailed here (see details in Supplementary text S4).

It should be noted that the environmental income component of the net value added is dependent on the priority given to the payments of the production factor services in the following order: first, labor compensation, second, the manufactured normal ordinary net operating margin and third, ordinary environmental net operating margin. The residual value characteristic of environmental income makes its measurement unviable unless a consistent system of production and capital accounts is developed with the aim of measuring total income.

We reorganize the total income accounting components (Fig. 4) in order to present its factorial allocation across labor compensation and total capital income. The total capital income is the sum of net operating margin and capital gain along with the manufactured capital income and the environmental income. The environmental income represents the free contribution of nature to total income and environmental income is produced by nature, free of manufactured production cost. This environmental income in this *dehesa* study is appropriated by landowners and in the case of products of public activities, by the consumers through government final product consumption donations (Fig. 4). Fig. 4 presents the components of intermediate consumption and consumption of fixed capital that are deducted from the value of the total product, which offers the net value added as a result.

Fig. 4 shows the sequence of records derived from the capital account that give rise to the estimation of total capital gain (Cg). These records avoid double counting the measurement of capital income (Campos et al., 2017, 2019a, 2019b; McElroy, 1976; Ovando et al., 2015).

The AAS total capital gain is derived from capital revaluation minus the unexpected capital destruction and capital adjustments. The capital revaluation (Cr) is derived from the closing capital (Cc) and withdrawals (Cw) minus opening capital (Co) and entries (Ce) in the current period (Fig. 4). We need to correct the capital revaluation bias because the omission of extraordinary capital destruction (by subtracting withdrawals for capital destruction) is not expected in the valuation of the opening capital. In this *dehesa* study application of the AAS methodology, capital revaluation is also adjusted for double counting by subtracting the consumption of fixed capital from capital revaluation, along with both the opening period natural growth and carbon final product consumption. The instrumental adjustments (Cad) include the manufactured consumption of fixed capital and the instrumental adjustments of the natural growth and carbon final product consumption (fixation) at their opening environmental prices.

The manufactured capital gain is measured from the manufactured capital revaluation (including changes in prices of land improvements, plantations, constructions, equipment and intangible capitals) after taking into account the subtraction of manufactured capital destruction and, to avoid double counting of total income, the addition of the consumption of manufactured fixed capital net of change in manufactured capital replacement prices.

3.3.3.1. Net value added. The net value added (operating income) is the key variable indicating the additional value incorporated in the intermediate consumption of raw materials and services used to produce a single product. We break down each activity into their ordinary net value added (NVAo) and investment (NVAi). The NVAo is a component of the total product consumption (TPc) of the activity in the current period (year). The NVAi is a component of the own account accumulated final total product (gross capital formation) at the close of the period. Gross capital formation (GCF) is separated into: (i) accumulated final product of gross fixed capital formation (GFCF), which will deplete (depreciate) in aliquot parts (consumption of fixed capital) in successive future periods in which it contributes to the generation of total products consumed (harvests), and (ii) accumulated final product of gross work in progress formation (GWPF), which will be consumed all at once in future periods (e.g. when the woody products are harvested (WPeu)). We define ordinary net value added (NVAo) as the operating income that contributes to the value of the total product consumption, whereas we define investment net value added (NVAi) as the operating income embedded in gross capital formation less consumption of environmental fixed asset.

The net value added at social prices is measured as the balancing item of the production account (Figs. 3 and 4). The AAS gross value added at social prices is estimated by subtracting the intermediate consumption (IC) from the total product at social prices. The net value added is obtained from the total product minus the intermediate consumption. The net value added at social prices represents the labor compensations (to employees and self-employed) for production factor services and the net operating margin in the current period. The net operating margin is estimated as the residual variable that, within the production account, balances the total product with the total cost of the individual activities (Campos et al., 2017, 2019a, 2019b; Ovando et al., 2015, 2016; Oviedo et al., 2017).

The net operating margin is the capital income embedded in the values of total product at the closing of the current period, generated by the economic activities of the *dehesa,* all of which are managed by the farmer and the government (Figs. 3 and 4). Both the simulated separation of environmental net operating margin and that which is manufactured, can result in values of any sign in the first transactions, that is, the environmental net operating margin could have a negative value. This is not the case of the ordinary environmental net operating margin because, by definition, it is always equal to or higher than zero. By contrast, the environmental net operating margin of investment could have any value. The net operating margin (benefit) of the commercial products can be measured as residual or imputed value by observing product transactions in the markets. However, given that the amenity product is not marketed, the private amenity final product consumption has to be estimated through valuation methods for products without market prices (Campos and Mariscal, 2003; Oviedo et al., 2015, 2017).

3.3.3.2. Ecosystem service. The term "monetary ecosystem service" frequently appears in the System of Environmental Economic Accounting-Experimental Ecosystem Accounting (SEEA-EEA) (United Nations et al., 2014b). It seems to us that this expression, from the perspective of total income theory, is less clear than the "economic" term. In the literature, institutions and authors, regardless of their disciplinary field, employ the definition of ecosystem services that best suits their purposes. In this *dehesa* study, the economic ecosystem services are defined as the contributions made by the environmental assets (ecosystems) to the observed or simulated transaction values of products consumed directly or indirectly by individuals (Fig. 5).

The ecosystem service embedded in a product can be an environmental intermediate consumption (e.g., captures of inventoried game species) valued by its environmental price (unitary resource rent) and/or an ordinary environmental net operating margin (benefit as a type of resource rent). This is the ecosystem service concept accepted by the United Nations in its SEEA-EEA technical recommendations guide. Indeed, the guide explains "that flows of ecosystem services should be clearly differentiated from the goods and services [products] that are produced [with manufactured capital]. Thus, the ecosystem services represent the contribution of the ecosystem [environmental] assets to the production of those goods and services [products]" (United Nations, 2017: p. 75). This SEE-EEA perspective delimits the economic ecosystem services potentially embedded in the intermediate or final product consumption in the first real or simulated transaction of product consumption. However, it is still under debate whether ecosystem accounting could be extended, adding additional products to those currently included in the standard System of National Accounts (SNA), in future government ecosystem accounting methodology.

In this *dehesa* study, the ecosystem service (ES) represent the 'gift of nature' embedded in the total product consumed either directly or indirectly by individuals in the accounting period and produced with or without manufactured immobilized capital in each individual spatial unit (*dehesa*) and single activity (for details see Supplementary text S2-S3).

The ordinary net operating margin incorporates the values of ordinary manufactured net operating margin and ordinary environmental net operating margin. This latter margin provides a zero or higher value by definition. However, this *dehesa* study admits the short-term potential existence of a negative ordinary manufactured net operating margin for products, whereby their production functions use their own intermediate consumption as the only manufactured cost (e.g., private amenity activity).

The total product consumption does not provide information on either the natural growth accumulated at the closing of the accounting period in the *dehesas*, the consumption of environmental fixed asset or the environmental asset gain.

The ecosystem services only take into consideration the consumption of total products with estimates of positive residual results. The natural growth during the accounting period, accumulated in standing inventories at the closing of the period in the spatial unit, is not included in the current ecosystem service estimate as it does not contribute to the wellbeing of the consumers during the accounting period. Additionally, double counting of ecosystem services is incurred when the ecosystem services include the accumulated natural growth from previous periods (opening standing work in progress used) that are harvested in the current period. Thus, the definition of ecosystem services does not coincide with that of the environmental net operating margin. To avoid the limitation of the ecosystem service for the current period, which does not value the contribution of the ecosystem services (resource rents) to the consumption of products which are expected to be harvested in the future in the specific unit, the AAS methodology applied in this *dehesa* study advocates the measurement of the environmental income.

3.3.3.3. Environmental income. Much like an investor in companies listed on the stock market, a landowner who leases his *dehesa* will obtain both a land lease and an environmental asset gain from the revaluation of work in progress and an unanticipated change in the land price at the closing of current period. After deducting the land lease according to the manufactured costs incurred by the landowner, the ordinary environmental net operating margin is estimated as a residual value. The environmental net operating margin and the environmental asset gain are 'gifted' incomes provided by nature. In other words, these two incomes make up the total (natural) environmental income of the *dehesa* activities.

The environmental income corresponds to the maximum possible consumption of the total product without decreasing the environmental asset value at the closing of the period with respect to its value at the opening of the period. The AAS measures environmental income from the production account environmental net operating margin and the capital account (balance sheet) environmental asset (natural capital) gain. Our interest is to reorganize these two components of environmental income to link the environmental income at social price with the ecosystem services and the adjusted change of environmental net worth (CNWead). Figs. 4 and 6 present the accounting arrangements that show the separation of ecosystem services derived from total product consumption from adjusted changes in environmental net worth

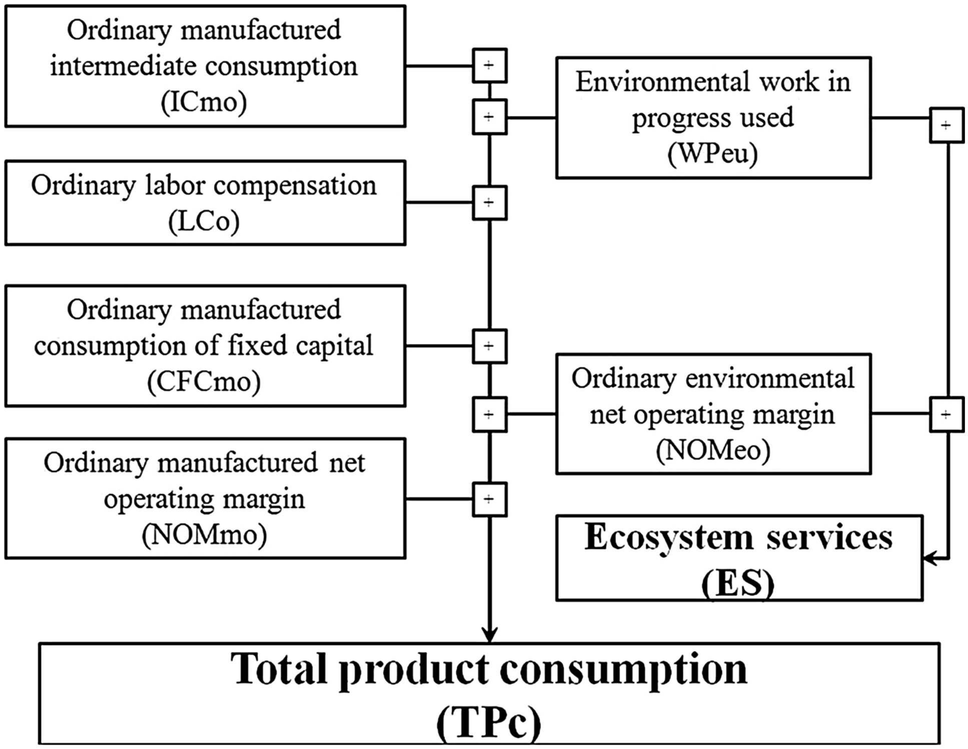

Fig. 5. Holm oak *dehesa* total product consumption under the Agroforestry Accounting System.

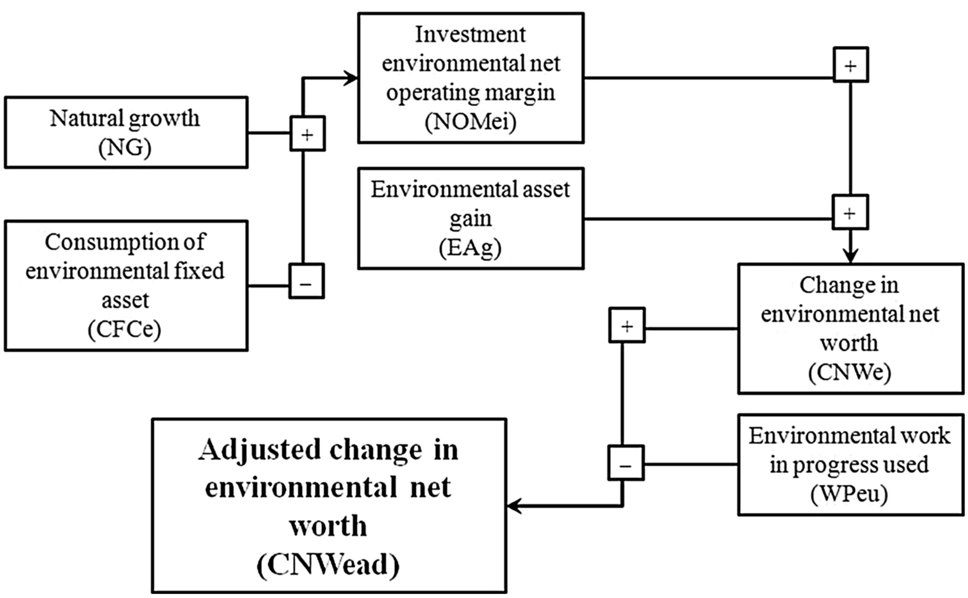

Fig. 6. Holm oak *dehesa* adjusted change in environmental net worth under the Agroforestry Accounting System.

(Campos et al., 2019a, 2019b, 2020).

We estimate the environmental income directly by aggregating the values of the environmental net operating margin and the environmental asset gain embedded in the net value added and the capital gain, respectively. After re-arranging the components of this first equation for the *dehesa* environmental income (Eq. 3), the components of a second environmental income equation (Eq. 4) are estimated, displaying the link between the ecosystem service and the adjusted change in environmental net worth. Thus, the environmental income is defined as the maximum possible ecosystem services without causing negative adjusted change of environmental net worth in the accounting period (Campos et al., 2019a, 2019b, 2020). Given Eq. 4, environmental income can be defined as the maximum possible sustainable total product consumption in the accounting period while still maintaining the adjusted change in environmental net worth equal to zero (for details see Supplementary text S1-S2):

$$EI = NOMe + Eag \quad (3)$$

$$EI = ES + CNWead \quad (4)$$

3.4. Accounting framework income integration

Comparisons of ecosystem services and incomes estimated by the refined System of National Accounts (rSNA) and AAS methodologies are important in order to understand the contributions of *dehesas* to private and public economies and their generation through human and natural production factors. We develop the comparisons of the rSNA and AAS income and ecosystem service sustainability indexes for individual activity, farmer, government and *dehesa*

The results for the AAS and rSNA methodologies applied in the *dehesa* reveal the differences in the definitions of economic activity, the valuations of the final products without market price consumed and the inclusion in the AAS of the farmer voluntary opportunity cost. These changes modify the net value added at basic price estimated by the rSNA in the *dehesa*. As we had the data for the farms, by applying the rSNA we were able to reveal the values of the ecosystem services and the net value added embedded in the rSNA total product. Furthermore, the rSNA provides the values for the changes in the environmental assets hidden in the commercial activities valued by the standard SNA.

As such, the intermediate services on an aggregate scale for the 19 *dehesa* activities values coincide at social price and producer price (market price), but this is not so for the individual activities, as their margins, environmental incomes and ecosystem services are affected.

The AAS methodology applied in this *dehesa* study values the consumption of the total product at observed or simulated social price, thus avoiding bias in the estimates of ecosystem services and incomes. By contrast, the rSNA valuation is biased because it omits the social price and the final product consumption without market price is valued at production cost, thus theoretically weakening it in comparison to the consistency of the AAS.

3.4.1. Farmer SNA_F and AAS_F income integration

The AAS and SNA have a direct link that consists of adjusting the corresponding variables estimated by both systems of accounts applied in the *dehesa* study. The farmer Agroforestry Accounting System (AAS_D) and standard System of National Accounts (SNA_F) applied to the *dehesa* study differ in the (i) periodization (timing) of the measurement of the net operating margin and (ii) the incorporation of the ordinary environmental net operating margin of the amenity activity (NOMeoa). The periodization bias is due to the moment at which the margin (benefit) is measured. The AAS_F methodology measures the net operating margins in the period in which the total products are generated, while the SNA_F estimates them at the moment they are harvested.

The concepts and valuations of the farmers' capital in the AAS_F and SNA_F are identical. The production accounts of both accounting methodologies present notable changes. The SNA_F does not measure the total capital income of the *dehesa*, as it omits the valuations of the ordinary environmental net operating margin of the amenity activity (NOMeoa) and the capital gain.

The omissions in the SNA_F of variables that are explicitly accounted for by the AAS_F are: (i) the natural growth of woody product work in progress (timber, cork and firewood) valued at the closing of the current period and existing inventoried game animals that are expected to be harvested in the future, (ii) the ordinary environmental net operating margin of the amenity activity NOMeoa, and (iii) the work in progress used (WPeu) of woody products and settled game species inventoried.

The integration of SNA farmer net value added ($NVA_{bp,SNA,F}$) in the AAS farmer net value added ($NVA_{sp,AAS,F}$) is shown in Fig. 7. Whereas $NVA_{sp,AAS,F}$ is the net value added at social prices for the farmer in the AAS, ISSncc is the non-commercial intermediate product of services compensated by government. $NVA_{bp,SNA,F}$ is the net value added for the farmer in the standard SNA at basic prices.

The farmer AAS net operating margin at social price is measured by adjusting the farmer standard SNA net operating surplus at basic prices, which entails: (i) adding the net operating surplus at basic prices of net mixed income, the non-commercial intermediate products of the service of amenity auto-consumption (ISSnca), natural growth, the change in the value of the final product of amenity auto-consumption (by substituting the production cost for landowner marginal willingness to pay), the gross capital formation of livestock capital, and (ii) subtracting the woody products of environmental work in progress used, the livestock product of manufactured work-in-progress used, the own ordinary non-commercial intermediate consumption of the service of amenity auto-consumption (SSncooa) and the adjusted change in livestock capital according to the livestock purchases in the current period (Fig. 8):

3.4.2. Integration of SNA and AAS dehesa incomes

The integration of the *dehesa* Agroforestry Accounting System (AAS_D) and standard System of National Accounts (SNA_D) methodologies implies the incorporation of government economic activities.

The integration of the *dehesa* SNA net value added at basic prices ($NVA_{bp,SNA,D}$) into the AAS net value added at social prices ($NVA_{sp,AAS,D}$) is obtained by: (i) adding to the $NVA_{bp,SNA,D}$ the net operating surplus at basic prices of net mixed income, the non-commercial intermediate products of the service of amenity auto-consumption (ISSnca), natural growth, the change in the value by substituting the production cost for landowner marginal willingness to pay in the private amenity final product consumption, the change in the value by substituting the production cost for revealed or stated consumer marginal willingness to pay in the government public final goods and services consumption (ΔPGS) (mushrooms, water supply, recreation, landscape and wild threatened biodiversity), the gross capital formation of livestock capital, the carbon final product consumption (FPcca); and (ii) subtracting the woody products of environmental work in progress used, the livestock product of manufactured work-in-progress used, the own ordinary non-commercial intermediate consumption of the service of amenity auto-consumption (SSncooa), the carbon consumption of environmental fixed asset (CFCe) and the adjusted change in livestock capital according to the livestock purchases in the current period (Fig. 9).

The *dehesa* AAS_D net operating margin at social prices ($NOM_{sp,AAS,D}$) with respect to the net operation surplus at basic prices of the SNA ($NOS_{bp,SNA,D}$) are differentiated by the same components as those for the net value added, except labor compensation, which is not a component of $NOM_{sp,AAS,D}$ (Fig. 10).

3.5. Ecosystem service sustainability index

This *dehesa* study introduces the economic ecosystem service sustainability index (ESSI). We propose that total product consumption (TPc) economic sustainability can be measured by the economic ecosystem service sustainability index (ESSI). The ESSI is the coefficient between environmental income and ecosystem service. Departing from the environmental income and ecosystem service definitions, the TPc economic sustainability requires an ESSI figure of one or higher value. We understand that the value of TPc is ecologically sustainable when the closing environmental asset corresponds to a programmed management that conserves the natural resources of the habitat above the safe minimum standard (SMS) in the infinite future. In other words, while economic sustainability is defined by ESSI figures that indicate the over/under-consumption threshold, ecological sustainability is defined by a biophysical environmental (ecosystem) asset endowment threshold that avoids irreversible (non-man-made reproducible) natural variety losses (Norton, 1987).

The conservation forestry and fire service activities do not contain biological production factors; therefore, the ESSI is not applicable. By definition, the rSNA does not estimate the ecosystem services of the nature based non-commercial products of amenities, public recreation, landscape, wild biodiversity and carbon. However, the rSNA does recognize the private amenity environmental income derived from change in environmental asset in the current period.

In this *dehesa* study, we estimate the ESSI of rSNA and AAS that indicate the economic sustainability of the individual activity product consumption in the current period. In addition, we assume that the

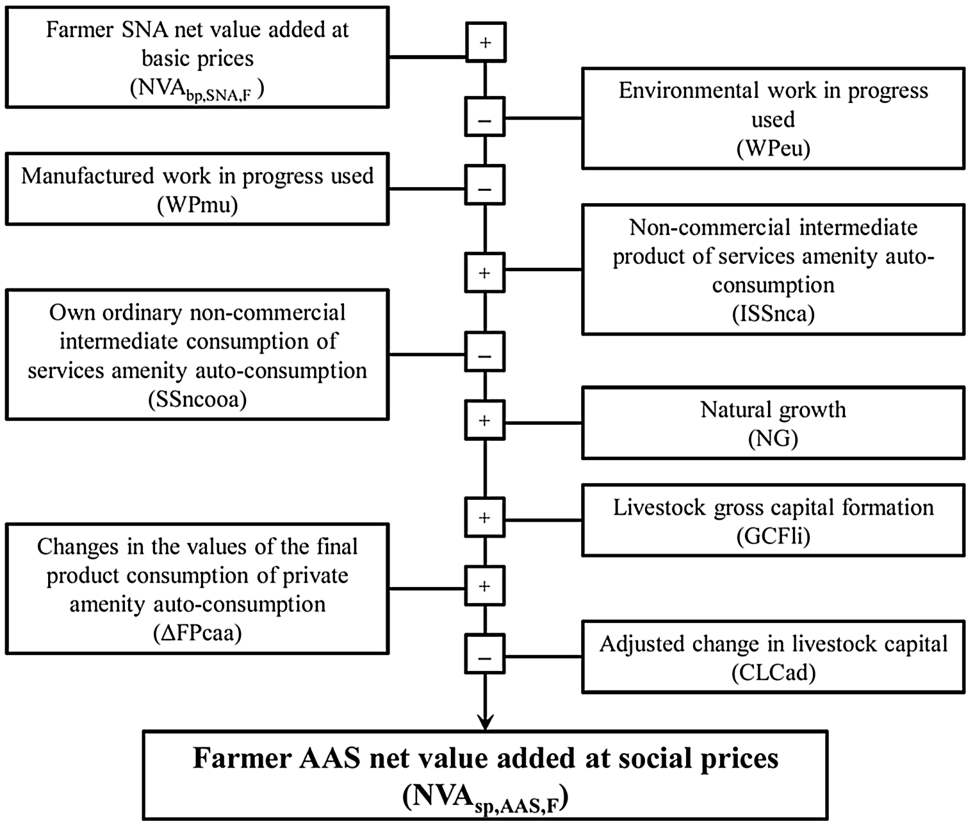

Fig. 7. Integration of standard System of National Accounts farmer net value added in the Agroforestry Accounting System.
Abbreviations: SNA standard is System of National Accounts; bp is basic prices; F is farmer; sp is social prices; AAS is Agroforestry Accounting System.

current period ESSI is conditioned to the requirement that the programmed future management avoids the environmental asset falling below the ecological safe minimum standard over the complete cycle of reproduction of the biological species. ESSI figures lower than one indicate unsustainable product consumption in the current period. An ESSI ≥ 1 indicates that the total product consumption does not reduce the value of the environmental assets at the closing of the period, thus showing the sustainability of the total product consumption. As such, an ESSI ≥ 1 indicates that the amount of ecosystem services embedded in the product consumption during the period is compatible with the conservation of the type of environmental asset valued. Where an ESSI < 1 is estimated, this indicates that total product consumption exceeds the rates of natural or assisted generation that would allow the perpetual continuity of the environmental asset in the future, *ceteris paribus*.

There are two possible reasons why an individual activity would have an ESSI value of zero there. On the one hand, an ESSI value of zero may indicate that there is no product consumption in the current period. In this situation the ecosystem service measurement is not applicable. On the other hand, an ESSI value of zero may be due to a zero value for the ecosystem service (resource rent) of the individual total product consumption. A negative ESSI indicates a negative environmental income, which is only possible if the negative value of the adjusted change in environmental net worth is greater than the zero or positive value of the ecosystem service.

4. Physical and economic results for the holm oak *dehesa* case study

The results from the sixteen *dehesas* are relevant as an experimental case study application, but the *dehesa* sample cannot be statistically representative of the Spanish *dehesas*. Even so, the physical and economic results reveal the general trends in Spanish *dehesas*. In this Andalusian *dehesa* study, we describe the average physical and economic results. We contrast the economic results for the 2010 period (year), comparing the application of the AAS and the rSNA as regards capitals, incomes, ecosystem services and ecosystem service sustainability indexes. The economic results are presented for individual farmer and government activities and for *dehesa* farmer and government *activities.* We also show the incomes and ecosystem services for the sixteen individual *dehesas* studied (see Supplementary materials: text S3-S4, Figs. ST1-ST6 and Tables ST1-ST3, for detailed results).

4.1. Data sources

There is no official economic information on the *dehesas*, therefore we have had to produce this private *dehesa* economic data through formal voluntary agreements in which the land and livestock owners agreed to provide the data in the format required by this *dehesa* study. As compensation, the owner receives a summary report of the results for their *dehesa* from the research institution. The primary data for an individual *dehesa* provides the starting point for gathering the physical and economic data we used (Campos et al., 2017, 2019b; Ovando et al., 2015, 2016). The biophysical and economic data used for estimating direct and indirect production cost, sales and own-consumption of forestry, livestock, game and crops as well as other single products are derived from a two-year (2009–2010) fieldwork study carried out in the sixteen *dehesa* sites. This *dehesa* study is also the source of primary data on gross capital formation and change in environmental net worth (Campos et al., 2017, 2019b).

Along with data gathered at the *dehesa* scale, additional information includes macro geo-referenced data on government spending and questionnaires gauging consumer willingness-to-pay for the public non-market final product consumptions (Campos et al., 2019a). The AAS application to the *dehesa* study required statistics from the third National Forestry Inventory (NFI) in Andalusia. We used modeled NFI data

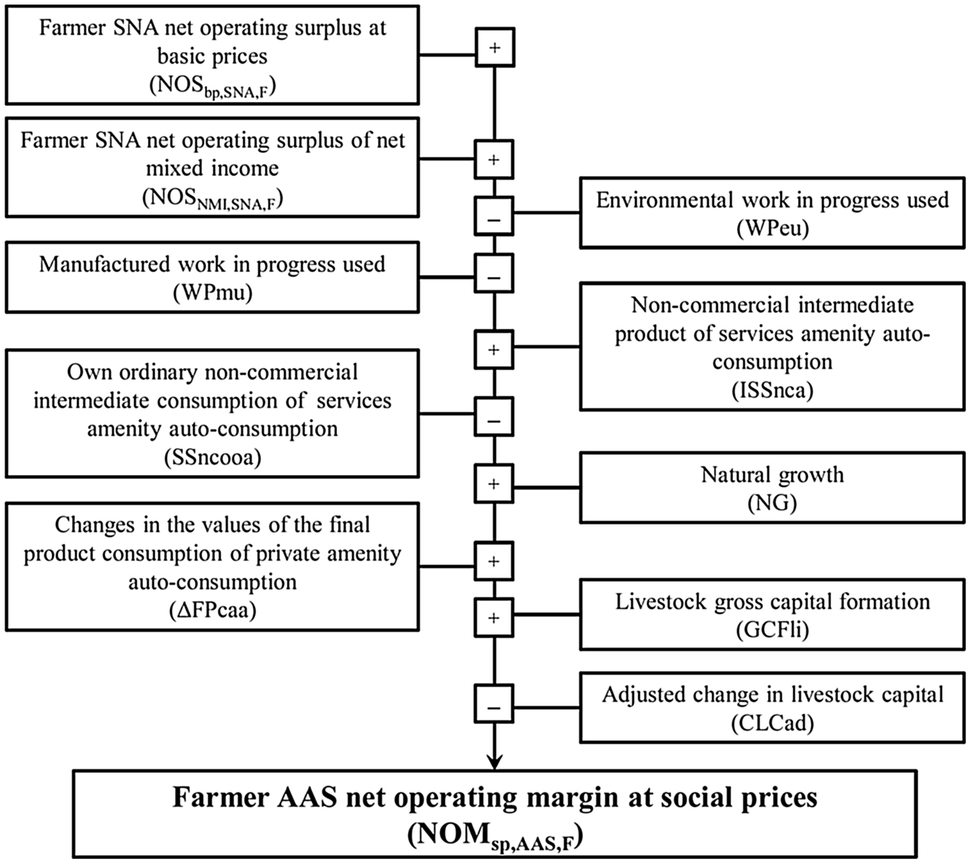

Fig. 8. Integration of standard System of National Accounts farmer net operating surplus in the net operating margin of the Agroforestry Accounting System. Abbreviations: SNA standard is System of National Accounts; bp is basic prices; F is farmer; sp is social prices; AAS is Agroforestry Accounting System.

for tree diameters and our own data for hunting species at the *dehesa* sites in the form of biological growth functions for woody plant (trees and shrubs) work-in-progress products and hunting species net birth, intermediate product and own intermediate consumption for the period along with market cost data per individual activity and its products.

The above information is complemented by tree growth, yield and silviculture models for different forest species in the *dehesa* study (Ovando et al., 2015, 2016, 2017). Data on forest structure (species and age class distribution) comes from our own tree inventory data for the *dehesa*. Where we did not have our own inventory data we used the data for the nearest land use tiles from the third NFI (Montero et al., 2015). The dynamic models and environmental prices for game species populations in Andalusia were taken from Carranza et al. (2015), and Martínez-Jauregui et al. (2016). These data sources are used to model tree and hunting species biological growth functions, which are in turn reflected in tree and animal natural growth (NG) and in the opening and closing values of tree and animal environmental assets. Woody forest products and game species inventoried and harvested over the accounting period are categorized as environmental work in progress used (WPeu). Work in progress used, natural growth and environmental asset values for tree and game species are valued according to environmental prices. This environmental value is the discounted unitary resource rent times the physical quantity at the time of the future harvest.

4.2. Spanish and Andalusian dehesa areas and ownership

The land use tiles of the third National Forest Inventory in which Mediterranean open woodlands dominate in five regions of the west, center and southwest of Spain, occupy 6,722,133 ha. Holm oak open woodlands represent more than 72 % of the Mediterranean open woodland area in the west and southwest of Spain. In Andalusia, the holm oak open woodlands account for 1,408,170 ha of the total area of Mediterranean open woodlands of 1,812,654 ha (see details in Campos et al., 2020: Supplementary text S1.1, Table ST1, p. 3). Although holm and cork oak woodlands are grazed by game species and livestock, the main economic intermediate raw material product of holm and cork oaks woodlands is the grazing of its final cork product (stripped). In Spain, the holm oak open woodlands occupy an area 11 times larger than that of the cork oak woodlands. In Andalusia, the holm oak woodlands are 6 times larger. These holm oak woodland landscapes are part of silvo-pastoral and agroforestry farms known in Spain as *dehesas*.

The Spanish *dehesa* and Portuguese *montado* are agroforestry farms that dominate the western and southwestern landscapes of the Iberian Peninsula. The *dehesa* is an economic unit in which the landowner (henceforth farmer) and the government manage those activities that fall within their domain, within which, each makes independent decisions. In the five regions in which they have the largest presence, the Spanish *dehesas* (farms) occupy a total area 3.6 million hectares. 56 % of this total area is comprised of wooded vegetation, and the remaining 44 % is occupied by shrublands, grasslands and agricultural crops. Most of the 4575 *dehesas* of a size equal to or greater than 200 ha belong to private owners (non-industrial). These represent 4% of the *dehesa* owners, 64 % of the total *dehesa* area and 62 % of the *dehesa* wooded area (see details in Campos et al., 2020: Supplementary text S1.2, Table ST2, p. 7).

The predominance of the holm oak woodlands among Mediterranean open woodlands is reflected in its majority presence in the Spanish *dehesas*. Andalusia has 1099 *dehesas* that are 200 ha or more in size. These *dehesas* have a total area of 505,105 ha and an average size of 500 ha, which represents 68 % of the total area occupied by *dehesas* in Andalusia (MAPA, 2008, Table 18, p. 44).

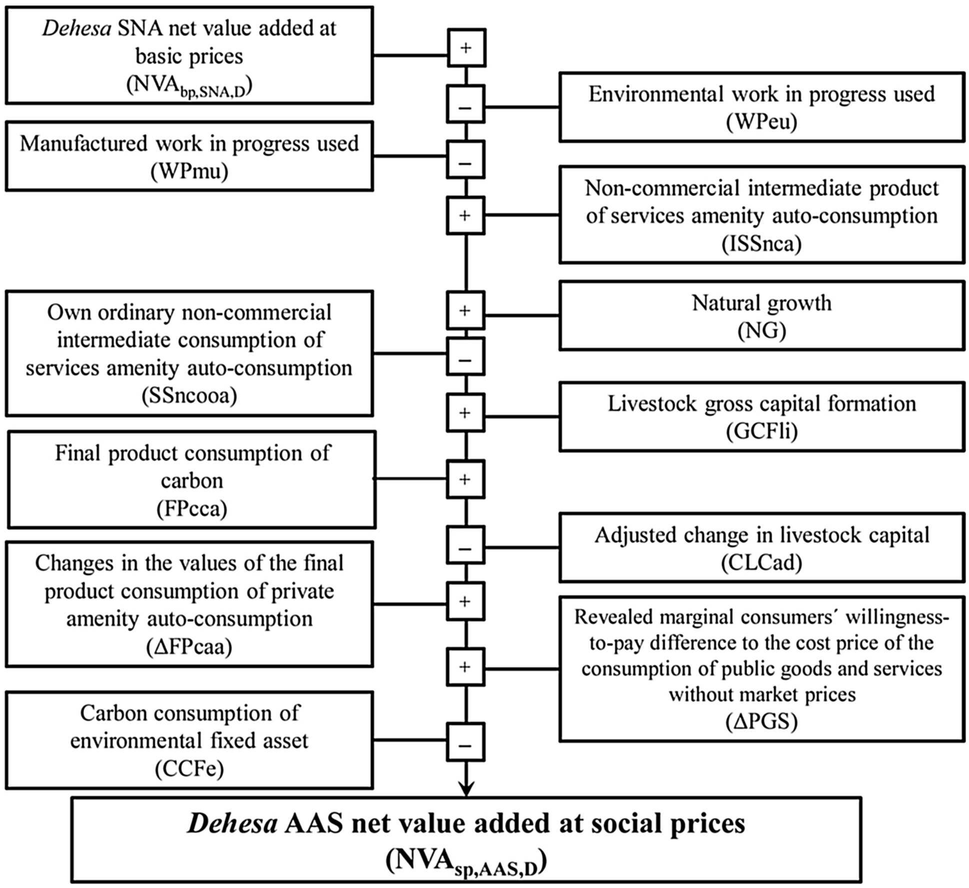

Fig. 9. Integration of *dehesa* standard System of National Accounts net value added in the Agroforestry Accounting System net value added.
Abbreviations: SNA standard is System of National Accounts; bp is basic prices; D is *dehesa;* sp is social prices; AAS is Agroforestry Accounting System.

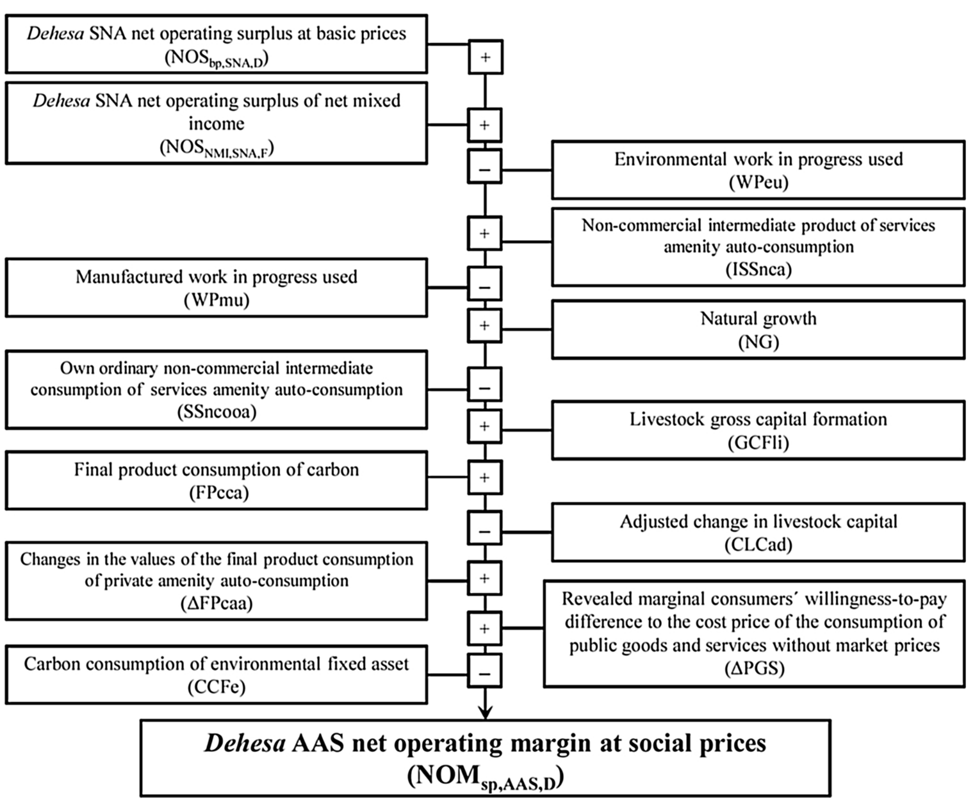

Fig. 10. Integration of *dehesa* standard System of National Accounts net operating surplus in the net operating margin of the Agroforestry Accounting System.
Abbreviations: SNA standard is System of National Accounts; bp is basic prices; D is *dehesa*; sp is social prices; AAS is Agroforestry Accounting System.

This *dehesa* study reveals the diversity of natural environments in which holm oaks are present and in which they dominate the landscape in Andalusia (Fig.1). This micro scale application to the holm oak *dehesa* case study (sixteen *dehesas* occupying a total of 9032 ha) only covers a small portion of the *dehesas* of the Andalusian region *s* (743,775 ha). The average property size of these *dehesas* is 565 ha (Table A1), which is 1.2 times the average Andalusian *dehesa* property size of around 200 ha (MAPA, 2008, Table 18, p. 44). In these holm oak *dehesa* case study, *open woodlands* account for 78 % of the total area, while coniferous forests make up 8% (Table A1). Holm oaks comprise 90 % of the open woodland area and the fractional canopy cover of these holm oak open woodlands is 34 % (Table A2).

In this *dehesa* study, we have valued 19 single activities grouped into the institutional sectors of the farmer (landowner) and the government, which together provide the results for each of the sixteen *dehesas* from which the average data per hectare is gathered and presented in the tables and figures. The tables and figures show the data classified into individual activity, farmer, government and *dehesa* (mean figure for the sixteen *dehesas* studied). There are 13 activities in this *dehesa* study that produced environmental incomes, and 11 activities that generated ecosystem services in 2010.

4.3. Physical yield and input indicators

We briefly define the main biophysical *yield and input* indicators that aid in understanding the economic outcomes and describe indicators of natural growth and extraction of woody natural resources of the forest in the indefinite future. This reinforces our normative assumption that future management of biological resources is expected to be sustainable from an ecological perspective.

The *dehesa* generates one annual work unit (AWU)[4] per 122 ha, with 89 % of labor hours being demanded by the farmer and 11 % by the government. Self-employed labor is only provided by the farmer and accounts for 23 % of the *dehesa* man-hours (Table A3). We estimate that 17 % of the self-employed labor receives no monetary compensation, 77 % of which is concerned with livestock activity, 18 % with hunting activities and the rest with other activities (Table A3, Fig. A1). Livestock activity accounts for 45 % and hunting activity represents 17 % of the annual labor demand (hours of work).

Physical natural growth and harvest indicators refer to the self-production area (Table A4). In this *dehesa* study, where holm oaks predominate, there is a small area of timber tree species with an average natural growth of 2.2 m^3/ha where no timber is harvested in the accounting period. Cork trees make up a small area, growing 0.8 t/ha and stripping 0.3 t/ha. Holm oak firewood growth is 1.0 m^3/ha and pruning is 0.2 m^3/ha. Natural fodder grazing (grass, browse, acorns and other non-industrial fruits) by livestock, as well as by hunting species account for 13.8 % and 86.2 % of the total grazing forage unit consumption of 520.2 FU/ha, respectively. This grazed natural fodder is shared by both livestock (57.7 %) and hunting species (42.3 %). The largest proportions of hunting species are red deer and wild boar, with capture rates of 7.4 and 1.8 units per he/km^2, respectively. The opening inventory of female livestock is 15 he/km^2, while the cow equivalent stocking rate[5] is 73 % cows and 27 % sheep and goats. In this *dehesa* study, the *dehesas* also provided excellent nutrition for Iberian pigs (and other hybrid pig breeds), which partially occurred in *montanera* grazing season (October -January). In this *dehesa* study, *montanera* grazing of fattened Iberian pigs accounts for 14 % of total fodder grazing by livestock and game species (Tables A4-A5). Mushrooms are gathered at a rate of 2.4 kg/ha by public open access recreational visitors. The rate of recreational visits is 1.6 visit/ha. Carbon net fixation by trees and shrubs occurs at a rate of 2.3 tCO_2/ha. There is one threatened species per square kilometer. Economic final water runoff is collected at a volume of 680 m^3/ha. Farmer residential housing accounts for 47.7 m^2/ha.

4.4. Agroforestry Accounting System capitals, incomes and ecosystem services

In this subsection we present a summary of the AAS economic results in tables and figures. Further details can be found in the economic tables in the Appendix. For a more a in-depth description of the results readers can consult the Supplementary material related to this *dehesa* study.

4.4.1. Total capital

The environmental assets of the pasture account for 84 % of its total capital estimated by the AAS methodology. The contribution of the government environmental assets to its total capital is greater than that of the farmer, although there is a very large environmental asset contribution in both institutional sectors at 97 % and 78 %, respectively (Table 1).

In the case of holm oak pasture, the private owner (non-industrial) auto-consumption of amenities entails the greatest contribution of an individual environmental asset, at 34 % of the total environmental asset. It is followed in importance by the consumption of the final product of surface water stored in government reservoirs and destined to irrigate agricultural products at 16 % of total environmental assets. In the case of pasture, the environmental asset of the water used to irrigate crops is considered to be appropriated by the government because no market value is derived by the owner of the pasture. The paradox here is that the government, in the first concession of the right to the annual quota of reservoir water for irrigation of agricultural crops, donates the value of the environmental asset of the water to the owner of the irrigated land.

The grass consumed by livestock and hunting species (considering that the environmental value of the average hunting captures over the last three years corresponds to the value of the grass consumed at the environmental price) adds up to a combined value of € 1,353.4 / ha.

In this *dehesa* study, the AAS opening environmental asset of the farmer accounts for 78 % of total farmer opening capital (Tables 1-A6). There are notable contrasts among the environmental assets of the farmer for individual activities. Grass and acorn, respectively, contribute 35 % and 3% to farmer commercial product environmental assets (all farmer except self-contained private amenity). The environmental asset of the private amenity activity is 1.25 times greater than that of the farmer commercial products. Manufactured residential houses and livestock fixed investment, respectively, represent 31 % and 46 % of famer manufactured total fixed investment. As might be expected, the aggregate opening manufactured fixed capital of the farmer is 12.5 times greater than that of the government (Tables 1-A6).

The AAS environmental assets of the farmer are 1.6 times larger than those of the government (Tables 1-A6). The AAS environmental assets of the government are divided among water yield (representing 41 % of such assets), public recreation (18 %) and landscape environmental assets (13 %) (Tables 1-A6).

4.4.2. Total income

4.4.2.1. Net value added. In the *dehesa* study, the labor demands generated by hunting and livestock activities account for 47 % of employment demand, the fire service activity accounts for 16 %, and the remaining 15 activities only make up 37 % of the employment demanded (Tables 2-A7).

The farmer net value added at social price accounts for 62 % of the total net value added of the *dehesa* case study (Tables 2-A7). This result highlights the economic character of the private-public mixed natural

[4] The annual work unit (AWU) is equivalent to a person employed full-time in the *dehesa* who provides services for 1,826 hours per year (MAPA, 2010).

[5] Based on the daily maintenance requirement (kcal/day) of a non-pregnant reproductive female for cattle, sheep and goats (Martín et al., 1987).

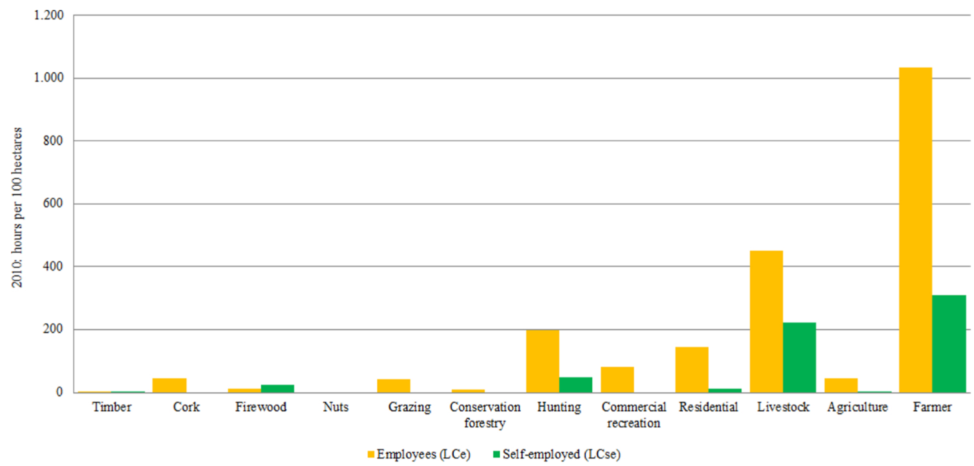

Fig. A1. Farmer labor demand in Andalusian holm oak *dehesa* case study (2010: hours per 100 hectares).

Table 1
Agroforestry Accounting System opening capital in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Opening environmental asset			Opening manufactured capital			Opening capital		
	Farmer	Government	Total	Farmer	Government	Total	Farmer	Government	*Dehesa*
Timber	35.5		35.5	0.7		0.7	36.2		36.2
Cork	880.9		880.9	2.0		2.0	882.9		882.9
Firewood	165.4		165.4	1.8		1.8	167.2		167.2
Nuts	0.5		0.5				0.5		0.5
Grazing	923.7		923.7	64.3		64.3	988.0		988.0
Grass	*857.7*		*857.7*	*64.3*		*64.3*	*921.9*		*921.9*
Acorn	*66.0*		*66.0*				*66.0*		*66.0*
Conservation forestry				10.1		10.1	10.1		10.1
Hunting	429.7		429.7	117.8		117.8	547.5		547.5
Commercial recreation				87.0		87.0	87.0		87.0
Residential				488.2		488.2	488.2		488.2
Livestock				716.0		716.0	716.0		716.0
Agriculture				69.9		69.9	69.9		69.9
Amenity	3,051.7		3,051.7				3,051.7		3,051.7
Fire services					48.5	48.5		48.5	48.5
Recreation		638.2	638.2		31.9	31.9		670.0	670.0
Mushrooms		442.9	442.9		17.9	17.9		460.8	460.8
Carbon		356.0	356.0					356.0	356.0
Landscape		438.1	438.1		2.3	2.3		440.4	440.4
Biodiversity		169.3	169.3		24.4	24.4		193.8	193.8
Water		1,443.2	1,443.2					1,443.2	1,443.2
Total	5,487.3	3,487.7	8,975.0	1,557.7	125.0	1,682.7	7,045.0	3,612.7	10,657.7

heritage of the *dehesas*, which are privately owned by family farmers (privately owned non-industrial).

In the *dehesa* case study, the AAS net value added of the farmer was 1.6 times greater than that of the government (Tables 2-A7).

The environmental net operating margin (NOMe) shows large contrasts in its composition between farmers and the government in *dehesas* (Tables 2-A7).

4.4.2.2. Ecosystem services. In the *dehesa* study, own ordinary non-commercial intermediate consumption of the service of private amenity auto-consumption (SSncooa) has the same value as the ISSnca from the voluntary opportunity costs of farmer activities. We have estimated values of zero in the period for the ecosystem services of timber, nuts, commercial recreation, residential and agricultural products.

The AAS economic ecosystem services of the farmer are 1.1 times higher than those of the government (Table 2). The ecosystem services of cork, firewood, livestock grazing and hunting make up 34 % of farmer ecosystem services. The private amenity ecosystem service represents 66 % of total ecosystem services of the farmer (Table 2). Water and carbon account for 46 % and 28.0 % of government ecosystem services, respectively. Farmer and government ecosystem services are 2.9 and 1.4 times higher than their respective environmental incomes (Table 2).

In this *dehesa* study, the AAS economic ecosystem services at social prices make up 45 % of the value of the final product consumption in the *dehesa* study (Table 2). The three types of provisioning, regulatory and cultural ecosystem services contribute 43 %, 18 % and 39 % to total ecosystem services, respectively (Table 3).

4.4.2.3. Environmental income. The environmental income in the *dehesa* study comes from the positive contribution of the ecosystem services and the negative adjusted change in the environmental net worth (CNWead) (Table 2, Fig. 11). This result for the latter is not due to excess physical consumption of resources over their natural growths in 2010, but rather, stems mainly from the decrease in the private amenity environmental asset price in 2010 (Table A6). The carbon service also presents a notable negative flow of the CNWead. However, grazing and game activities present negligible negative CNWead (Table 2).

In this *dehesa* study, the environmental income represents 67 % of the total income (Table 2). The government manages activities that produce 1.9 times more environmental income than those of the farmer (Table 2, Fig. 11). The environmental income of the famer differs

Table 2
Agroforestry Accounting System total income factorial allocation measured at social prices in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Tim-ber 1	Cork 2	Fire-wood 3	Nuts 4	Gra-zing 5	Con. forestry 6	Hun-ting 7	Comm. recreation 8	Residen-tial 9	Live-stock 10	Agri-culture 11
1. Total product (TP)	0.6	27.6	11.9		40.9	2.1	116.9	10.1	20.4	459.8	4.9
1.1 Intermediate product (IP)	0.4	4.4	1.6		40.3	2.1	75.6		14.0	111.7	1.1
1.1.1 Raw materials (RM)					26.4		18.0				0.3
1.1.2 Services (ISS)	0.4	4.4	1.6		14.0	2.1	57.5		14.0	111.7	0.8
1.2 Final product (FP)	0.2	23.2	10.2		0.6		41.3	10.1	6.3	348.0	3.8
1.2.1 Final product consumption (FPc)		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Gross capital formation (GCF)	0.2	9.7	0.4				11.6		2.3	168.3	0.7
1.2.2.1 Manufactured (GCFm)							0.3		2.3	168.3	0.7
1.2.2.2 Natural growth (NG)	0.2	9.7	0.4				11.3				
2. Intermediate consumption (IC)	0.1	8.8	3.1		5.9	0.4	55.8	7.1	1.9	369.2	3.4
2.1 Raw materials	0.0	0.3	0.7		1.9	0.2	30.6	3.2	0.6	146.6	1.4
2.1.1 Bought (RMb)	0.0	0.3	0.7		1.9	0.2	7.7	3.2	0.6	124.9	1.4
2.1.2 Own (RMo)							22.9			21.8	
2.2 Services (SS)	0.1	0.4	0.3		4.0	0.3	13.5	3.9	1.4	21.7	1.3
2.2.1 Bought (SSb)	0.1	0.4	0.3		4.0	0.3	13.5	3.9	1.4	21.7	1.3
2.2.2 Own (SSoo)											
2.2.2.1 Commercial (SScoo)											
2.2.2.2 Non-commercial (SSncoo)											
2.3 Work in progress used (WPu)		8.1	2.1				11.6			200.9	0.7
2.3.1 Manufactured (WPmu)										200.9	0.7
2.3.2 Environmental (WPeu)		8.1	2.1				11.6				
3. Consumption of fixed capital (CFC)	0.1	0.5	0.2		2.6	0.1	7.7	4.2	13.8	14.8	2.6
4. Net value added (NVA)	0.4	18.2	8.5		32.4	1.6	53.4	−1.2	4.6	75.8	−1.0
4.1 Labour compensation (LC)	0.2	8.1	3.2		5.1	1.2	19.9	5.6	10.1	44.0	3.9
4.2 Net operating margin (NOM)	0.2	10.2	5.3		27.3	0.4	33.5	−6.8	−5.5	31.8	−4.9
4.2.1 Manufactured (NOMm)	0.0	0.5	4.9		2.1	0.4	4.1	−6.8	−5.5	31.8	−4.9
4.2.2 Environmental (NOMe)	0.2	9.7	0.4		25.2		29.4				
4.2.2.1 Ordinary environmental net operating margin (NOMeo)					25.2		18.0				
4.2.2.2 Investment environmental net operating margin (NOMei)	0.2	9.7	0.4				11.3				
5. Ecosystem services (ES)	0.0	8.1	2.1	0.0	25.2		29.7				
6. Capital gain (CG)	1.3	55.6	8.5	0.0	−5.4	−0.2	−10.4	−3.8	−26.0	−28.5	−3.3
6.1 Manufactured (CGm)	−0.1	−0.5	−0.2		−2.4	−0.2	−10.4	−3.8	−26.0	−28.5	−3.3
6.2 Environmental (EAg)	1.4	56.1	8.7	0.0	−3.0		0.0				
7. Adjusted change in environmental net worth (CNWead)	1.6	57.7	6.9	0.0	−3.0		−0.3				
8. Environmental income (EI)	1.6	65.8	9.1	0.0	22.2		29.4				
9. Total income (TI)	1.7	73.9	17.0	0.0	27.0	1.4	43.0	−5.0	−21.4	47.2	−4.3

Class	Amenity 12	Farmer Σ1 − 12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13 − 19	*Dehesa* Σ1 − 19
1. Total product (TP)	295.2	990.3	34.1	24.3	13.4	49.5	91.1	11.0	81.9	305.3	1,295.6
1.1 Intermediate product (IP)		251.4	31.5							31.5	282.8
1.1.1 Raw materials (RM)		44.7									44.7
1.1.2 Services (ISS)		206.7	31.5							31.5	238.2
1.2 Final product (FP)	295.2	738.9	2.7	24.3	13.4	49.5	91.1	11.0	81.9	273.8	1,012.8
1.2.1 Final product consumption (FPc)	295.2	545.8		23.7	13.3	49.5	90.2	9.9	81.9	268.6	814.4
1.2.2 Gross capital formation (GCF)		193.1	2.7	0.6	0.1		0.8	1.1		5.2	198.3
1.2.2.1 Manufactured (GCFm)		171.5	2.7	0.6	0.1		0.8	1.1		5.2	176.8
1.2.2.2 Natural growth (NG)		21.6									21.6

(*continued on next page*)

Table 2 (*continued*)

Class	Amenity 12	Farmer Σ1 − 12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13 − 19	*Dehesa* Σ1 − 19
2. Intermediate consumption (IC)	169.1	624.8	11.1	2.5	0.1		70.1	1.8		85.6	710.5
2.1 Raw materials		185.5	0.0	0.1	0.0		0.1	0.0		0.2	185.7
2.1.1 Bought (RMb)		140.8	0.0	0.1	0.0		0.1	0.0		0.2	141.0
2.1.2 Own (RMo)		44.7									44.7
2.2 Services (SS)	169.1	216.0	11.1	2.5	0.1		70.1	1.8		85.4	301.4
2.2.1 Bought (SSb)		46.9	11.1	1.5	0.1		1.9	1.8		16.3	63.2
2.2.2 Own (SSoo)	169.1	169.1		1.0			68.1			69.1	238.2
2.2.2.1 Commercial (SScoo)	14.0	14.0		1.0			32.1			33.1	47.1
2.2.2.2 Non-commercial (SSncoo)	155.0	155.0					36.0			36.0	191.1
2.3 Work in progress used (WPu)		223.4									223.4
2.3.1 Manufactured (WPmu)		201.5									201.5
2.3.2 Environmental (WPeu)		21.8									21.8
3. Consumption of fixed capital (CFC)		46.6	1.0	1.2	0.0	19.0	2.1	0.4		23.8	70.4
4. Net value added (NVA)	126.1	318.9	22.0	20.6	13.3	30.5	18.8	8.7	81.9	195.8	514.7
4.1 Labour compensation (LC)		101.4	22.0	4.0	0.1		5.7	3.6		35.4	136.7
4.2 Net operating margin (NOM)	126.1	217.5	0.0	16.7	13.1	30.5	13.1	5.1	81.9	160.5	378.0
4.2.1 Manufactured (NOMm)		26.6	0.0	1.0	0.5		0.2	0.8		2.5	29.2
4.2.2 Environmental (NOMe)	126.1	190.9		15.6	12.6	30.5	13.0	4.3	81.9	157.9	348.8
4.2.2.1 Ordinary environmental net operating margin (NOMeo)	126.1	169.3		15.6	12.6	49.5	13.0	4.3	81.9	176.9	346.2
4.2.2.2 Investment environmental net operating margin (NOMei)		21.6				−19.0				−19.0	2.6
5. Ecosystem services (ES)	126.1	191.1		15.6	12.6	49.5	13.0	4.3	81.9	176.9	368.1
6. Capital gain (CG)	−187.7	−199.9	−1.0	1.3	0.4	−33.7	0.9	2.0		−30.0	−229.8
6.1 Manufactured (CGm)		−75.5	−1.0	1.3	0.4		0.9	2.0		3.7	−71.8
6.2 Environmental (EAg)	−187.7	−124.4				−33.7				−33.7	−158.1
7. Adjusted change in environmental net worth (CNWead)	−187.7	−124.6				−52.7				−52.7	−177.3
8. Environmental income (EI)	−61.6	66.5		15.6	12.6	−3.2	13.0	4.3	81.9	124.2	190.8
9. Total income (TI)	−61.6	119.0	21.0	21.9	13.7	−3.2	19.7	10.8	81.9	165.9	284.8

Accounting identities: *Net value added:* NVA = TP – IC – CFC = NVA = LC + NOM; *Ecosystem services*: ES = NOMeo + WPeu; *Change in adjusted environmental net worth*: CNWead = NOMei + EAg – WPeu; *Environmental income*: EI = NOMe + EAg = EI = ES + CNWead and *Total income*: TI = NVA + CG = TI = LC + EI + NOMm + CGm.

Table 3
Agroforestry Accounting System ecosystem services at social prices in the Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Farmer	Government	*Dehesa*
1. Provisioning services	65.0	94.5	159.5
Timber	0.0		0.0
Cork	8.1		8.1
Firewood	2.1		2.1
Nuts	0.0		0.0
Grazing	25.2		25.2
Grass and browse	*11.4*		*11.4*
Acorns	*13.7*		*13.7*
Hunting	29.7		29.7
Mushrooms		12.6	12.6
Water		81.9	81.9
Livestock	0.0		0.0
Agriculture	0.0		0.0
2. Regulating services		66.8	66.8
Carbon		49.5	49.5
Landscape		13.0	13.0
Biodiversity		4.3	4.3
Conservation forestry	*n.a*(*)		*n.a*(*)
Fire services	*n.a*(*)		*n.a*(*)
3. Cultural services	126.1	15.6	141.7
Private amenity	126.1		126.1
Public recreation		15.6	15.6
Commercial recreation	0.0		0.0
Residential	0.0		0.0
Total	191.1	176.9	368.1

n.a(*): not apply.

considerably from that of the government, mainly as a result of the land depreciation and the economic water runoff stored in the watershed public dams during the accounting period (Table 2, Fig. 11).

The main positive environmental incomes from the individual farmer activities come from cork, grazing and hunting. Private amenities result in a negative environmental income in the current period (Table 2, Fig. 11). For government individual activities, water generates a notable positive environmental income, while carbon contributes a slightly negative environmental income (Table 2, Fig. 11).

4.4.2.4. Individual dehesa versus sample average dehesa incomes. There are notable differences between individual *dehesa* study in terms of the quantity and composition of the respective incomes and ecosystem services of the *dehesas* at social prices (Table A8), although our *dehesa* samples are not intended to be representative of all the *dehesas* in Spain. The statistics shown in Table A8 provide an idea of the dispersion of the different estimates. Net value added shows the closest proximity between the mean, median and lower coefficient of variation, thus indicating that this indicator presents the most stable values in the sample. The largest difference between mean and median is found for surface areas due to three extreme values in the upper tail of the distribution. However, the coefficient of variation for this variable is not as high as for capital income and environmental income. In the case of ecosystem services, although they show a wide range of values, the median and mean are very close, and the coefficient of variation is also low compared to the other indicators, excluding the aforementioned net value added. In summary, it seems that the indicators that incorporate some form of capital gain show higher variability of values (Table A8).

4.5. Comparison of economic results of the Accounting frameworks

4.5.1. Total capital

The total opening capital of the pasture, measured by the AAS methodology, is 1.2 times higher than that measured by the rSNA (Tables 1, A6 and A9). This sub-estimation of capital is due to the fact that the RSNA does not value the environmental assets of carbon, public recreation, landscape and endangered wild biodiversity activities (see Campos et al., 2019a for detailed connection of balance entries and withdrawals). The rSNA and AAS estimates of farmer total capital equate, as do those for government manufactured capital and environmental assets with market prices. The total opening capital of the AAS is 18 % greater than that of the rSNA (Tables 1, A6 and A9). The AAS environmental assets are 22 % higher than those of the rSNA. The government environmental assets estimated by the AAS are 85 % higher than those measured by the rSNA. These differences are due to the fact that the rSNA values the private amenity auto-consumption, the public products of recreation, landscape and biodiversity, as well as the water supply (though only partially), at production cost (Tables 1, A6 and A9).

4.5.2. Products, incomes and ecosystem services

Tables A10-A11 present the measurements of total product, total income, ecosystem services, net value added and environmental income of the refined System of National Accounts (rSNA). Tables A10-A11 reveal the lack of carbon activity records by comparison with the Agroforestry Accounting System (AAS), as the carbon activity is not recognized as an rSNA activity in the *dehesa* study. The limited contributions of the harvested wood products and their natural growth result in the practical absence of bias associated with the temporization in the rSNA measurement of woody products in the case of the holm oak *dehesa* study. The farmer intermediate product in the AAS is 2.2 times the respective value in the rSNA (Tables 2, A7, A10 and A11).

The total cost in the AAS is 1.7 times higher than the corresponding cost in the rSNA (Tables 2, A7, A10 and A11). This variation is due to the incorporation of the intermediate consumption of amenities and the environmental product in progress used.

The AAS and rSNA results for intermediate amenity services reveal

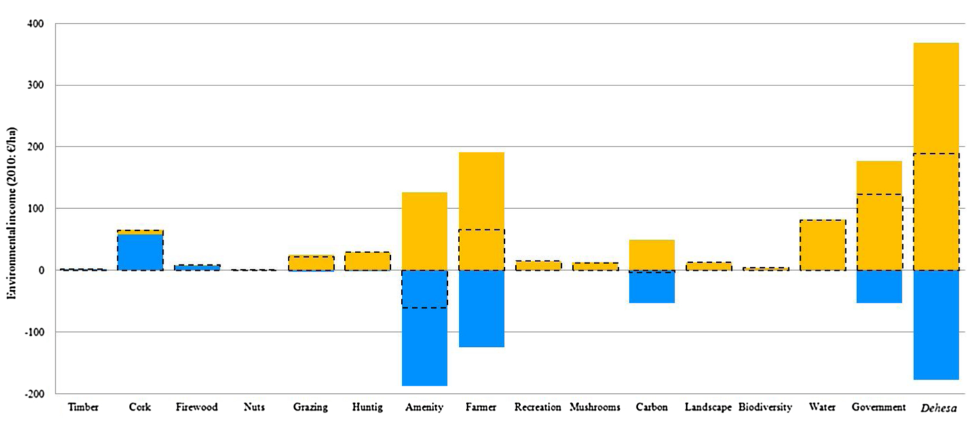

Fig. 11. Agroforestry Accounting System environmental income at social prices in the Andalusian holm oak *dehesa* case study (2010: €/ha).

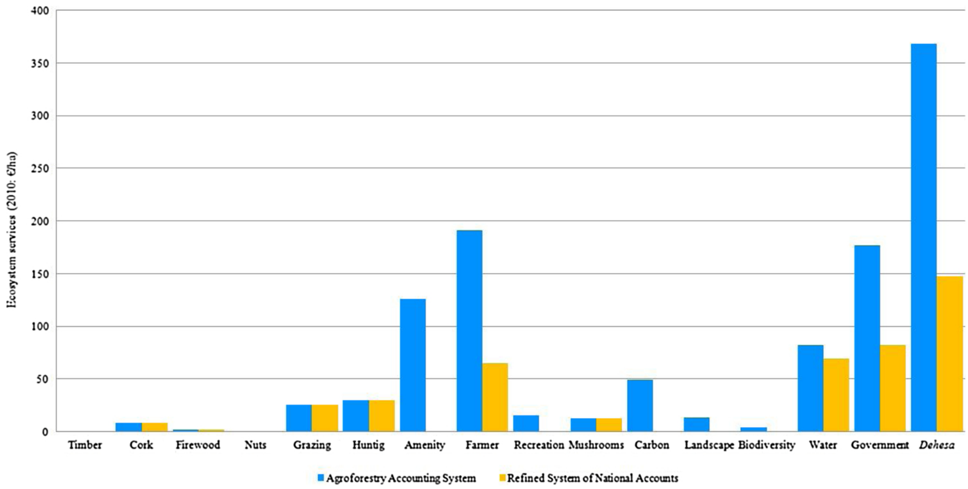

Fig. 12. Agroforestry Accounting System and refined System of National Accounts ecosystem services at social and basic prices in the Andalusian holm oak *dehesa* case study (2010: €/ha).

that the management of the livestock and hunting activities in the *dehesa* study is orientated towards private landowner amenity auto-consumption.

The rSNA applied to the *dehesa* study shows measurements at basic prices of the ecosystem services and gross value added that are 0.4 and 0.3 times those of their respective AAS values at social prices (Tables 2, A7, A10 and A11, Fig. 12).

The rSNA estimates environmental incomes from 9 activities, and the AAS estimates 13 activities from the total of 19 activities valued. The rSNA does not estimate the ecosystem service of the final product consumed of an amenity, although it does recognize the environmental income from the variation in the environmental asset of the land based on the auto consumption of amenities.

The environmental income of the *dehesa* under the AAS at social prices is 190.8 €/ha and under the rSNA at basic prices it is 22.6 €/ha (Table 4, Fig. 13). The same comparison with reference to the environmental income of the farmer under the respective accounting methodologies reveals 66.5 €/ha and -59.6 €/ha.

Comparisons of rSNA and AAS show that under the rSNA the farmer gross value added for both commercial and non-commercial products is undervalued (Table 4). The rSNA overvalues the commercial net operating surplus and undervalues non-commercial products, with the net value added for the *dehesa* being similar in value to that of the AAS (Table 4).

The rSNA and AAS show the same ecosystem service values for commercial products. However, the ecosystem services are notably undervalued for non-commercial products by the rSNA. The ecosystem service result for the *dehesa* under the rSNA is only 40 % that of the AAS.

The environmental incomes of the commercial products measured by the rSNA and AAS show the same values. The rSNA and AAS environmental incomes of the non-commercial products, however, differ even more than in the case of ecosystem services. When compared to the absolute value for the environmental income of the *dehesa* measured by the AAS, the main reason for the negative undervaluation of the environmental income (12 %) by rSNA is that the rSNA does not estimate the amenity ecosystem service.

4.6. Economic ecosystem service sustainability index

The ecosystem service sustainability index (ESSI) for most activities according to the AAS results point to sustainability, except for grazing, amenity and carbon activities (Table 5). In the amenity and carbon activities, negative values indicate negative results for environmental income. In the case of amenity, an index lower than zero lacks a clear biological meaning, since it will depend on whether the demand for amenity consumption by the owner is maintained in the future without affecting the programmed sustainable biophysical silvo-pastoral management (Table 5).

The rSNA presents a zero value ESSI for the estimated activities, as well as for some others, due to the lack of omission of final product consumption in the accounting period. The ESSI for ecosystem services omitted from the measurements of environmental incomes in the rSNA are those related to government public recreation, landscape, biodiversity and carbon activities.

The ESSI for the *dehesa* study as a whole measured by the rSNA indicate a greater degree of unsustainable use of resources than those measured by the AAS. This is due to the effect of the greater number of environmental incomes estimated by the AAS compared to those valued by the rSNA. The AAS presents an ESSI of 0.5, indicating unsustainable use of resources for the aggregate products consumed in the current period.

5. Discussion of dehesa results and policy implications

5.1. Andalusian holm oak dehesa results, findings and further challenges

5.1.1. Comparison of accounting framework results for Andalusian holm oak dehesas

Given the marginality of the quantities and the net operating margins for woody products in the holm oak *dehesa*, the notable differences in the ecosystem services and environmental income estimated by the AAS and rSNA methodologies are due to the different valuation criteria for the consumption of final products without market prices as well as the inclusion of the carbon activity in the AAS and its exclusion in the rSNA. The differences in the valuations of the net operating margins by the AAS and the rSNA, respectively, are mainly explained by the different valuation criteria for the final product of private amenity auto-consumption. Another important reason for the discrepancy in the net operating margins of the hunting and livestock activity is the fact that the AAS valuations are at social prices whereas the rSNA valuations are at basic prices.

In our application of the AAS we value the consumption of final products without market prices of the public recreation, landscape conservation and threatened biodiversity conservation services at social prices. While the AAS values these three services included in the government activities according to the simulated transaction price stated by the public consumer willingness to pay, the rSNA values them at production price. These differences in the types of transaction price applied give rise to large discrepancies among the valuations of the

Table 4
Agroforestry Accounting System and refined System of National Accounts ecosystem services and incomes at social and basic prices in the Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Commercial			Non-commercial				*Dehesa*
	Woody product *	Non-woody product**	Sub-total	Amenity	Land-scape	Others***	Sub-total	
1. Net valued added (NVA)								
rSNA	20.7	21.5	42.2	0.0	5.7	90.4	96.1	138.4
AAS	27.2	187.6	214.7	126.1	18.8	155.0	300.0	514.7
2. Net operating margin (NOM)								
rSNA	9.2	−90.3	−81.1	0.0	0.0	82.7	82.7	1.6
AAS	15.7	75.7	91.4	126.1	13.1	147.3	286.6	378.0
3. Ecosystem services (ES)								
rSNA	10.2	54.8	65.0	0.0	0.0	82.2	82.2	147.2
AAS	10.2	54.8	65.0	126.1	13.0	164.0	303.0	368.1
4. Changes in manufactured capital (CCm)								
rSNA	−0.9	−166.4	−167.3		1.8	5.5	7.2	−160.0
AAS	−0.9	−166.4	−167.3		1.8	5.5	7.2	−160.0
5. Adjusted changes in environmental net worth (CNWead)								
rSNA	66.3	−3.2	63.1	−187.7	0.0		−187.7	−124.6
AAS	66.3	−3.2	63.1	−187.7	0.0	−52.7	−240.4	−177.3
6. Environmental income (EI)								
rSNA	76.5	51.6	128.1	−187.7	0.0	82.2	−105.5	22.6
AAS	76.5	51.6	128.1	−61.6	13.0	111.3	62.6	190.8
7. Total income (TI)								
rSNA	86.1	−57.0	29.1	−187.7	6.6	94.2	−86.9	−57.8
AAS	92.6	109.0	201.6	−66.1	19.7	125.1	83.2	284.8

* *Commercial woody product activities* are timber, cork and firewood.
** *Commercial non-woody product activities* are nuts, grazing, conservation forestry, hunting, commercial recreation, residential, livestock, agriculture and fire services.
*** *Non-commercial others activities* are recreation, mushrooms, carbon, biodiversity and water.

ecosystem services and incomes estimated by the AAS and rSNA methodologies for government activities in the studied *dehesa*.

The valuations of total capital of the *dehesa* according to the AAS and rSNA approaches coincide for the farmer activities but not for the government activities because the rSNA valuation of non-commercial government activities omits the ecosystem service (resource rent) of the consumption of final products without market prices.

Academic as well as government environmental communities have expressed concern with regard to the hidden "monetary" contribution of nature-based non-economic free goods and services to the final product consumptions of landscape type economic activities, which results from the rejection of the transaction price valuation criterion applied in rSNA and AAS. The invisibility of the non-economic biophysical ecosystem contribution to the net value added of economic activities under the rSNA and AAS frameworks is the necessary condition to generate labor income and cultural landscape environmental assets (e.g., the holm oak *dehesa*).

Among the economic activities for which the ecosystem service and environmental asset contributions are not made visible is the government fire service activity. The commercial intermediate product status of the fire services in this *dehesa* study is based on the fact that the government considers the holm oak woodland vegetation type present in the *dehesa* to be an inter-generational public legacy that must be conserved for future generations, in a context where the landowner is not required to incur investment costs for their natural or artificial regeneration. In this circumstance, the cost of the government fire service activity is not reflected in the intermediate consumption of grazing activity, so we create the fire services activity, which gives the non-commercial intermediate product of services used as own ordinary intermediate consumption of services by the landscape activity. This fire service activity implicitly provides hidden free services that have the effect of reducing the cost of forage, which is grazed by farmer controlled animals, both game species and livestock. Thus, the value added of game species and extensive livestock rearing is higher than it would

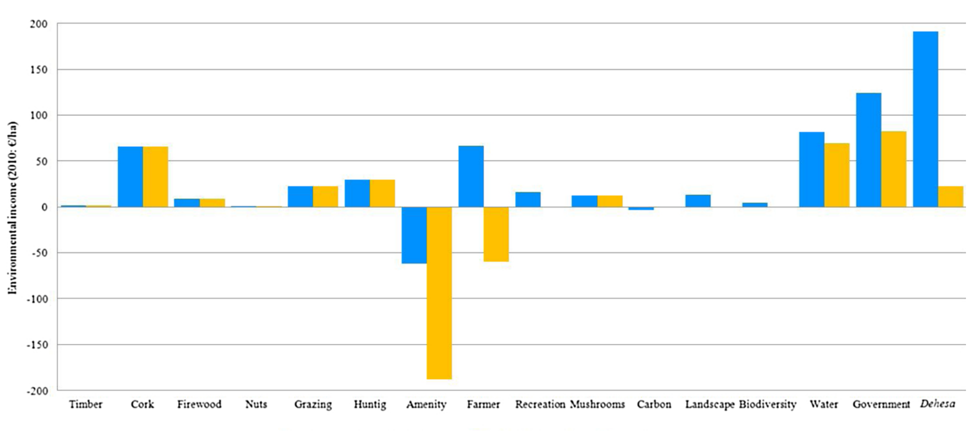

Fig. 13. Agroforestry Accounting System and refined System of National Accounts environmental incomes at social and basic prices in the Andalusian holm oak *dehesa* case study (2010: €/ha).

Table 5
Agroforestry Accounting System and refined System of National Accounts ecosystem service sustainability indexes at social and basic prices in the Andalusian holm oak *dehesa* case study (2010).

Class	Refined System National Accounts			Agroforestry Accounting System		
	Environmental income (EI) €/ha	Ecosystem services (ES) €/ha	ESSI (Index) EI/ES	Environmental income (EI) €/ha	Ecosystem services (ES) €/ha	ESSI (Index) EI/ES
1. Farmer	−59.6	65.0	−0.9	66.5	191.1	0.3
Timber	1.6	0.0	0.0	1.6	0.0	0.0
Cork	65.8	8.1	8.1	65.8	8.1	8.1
Firewood	9.1	2.1	4.2	9.1	2.1	4.2
Nuts	0.0	0.0	0.0	0.0	0.0	0.0
Grazing	22.2	25.2	0.9	22.2	25.2	0.9
Hunting	29.4	29.7	1.0	29.4	29.7	1.0
Amenity	−187.7	*	*	−61.6	126.1	−0.5
2. Government	82.2	82.2	1.0	124.2	176.9	0.7
Recreation	0.0	0.0	0.0	15.6	15.6	1.0
Mushrooms	12.6	12.6	1.0	12.6	12.6	1.0
Carbon	0.0	0.0	0.0	−3.2	49.5	−0.1
Landscape	0.0	0.0	0.0	13.0	13.0	1.0
Biodiversity	0.0	0.0	0.0	4.3	4.3	1.0
Water	69.6	69.6	1.0	81.9	81.9	1.0
Dehesa	22.6	147.2	0.2	190.8	368.1	0.5

Abbreviation: EI is environmental income; ES is ecosystem services; ESSI is economic ecosystem services sustainable index.
* It is non-applicable.

be if the same herds were to graze the same *dehesas* without human-induced improvement to grazing productivity. A cost for the government fire service could not be attributed to the controlled animal grazing activities because we would expect the government costs to be the same or even higher to maintain the value of the landscape conservation services of the *dehesa* woodlands.

The captures of migratory game species are considered *res nullius* or free goods that become economic goods due to the landowner's right of exclusion of third parties from open access to game captures. The migratory game species captures are recorded according to their environmental price at the opening of the accounting period, which is attached to the net present value of the captures of infinite future periods in the environmental fixed asset of the land and which we have not recorded as environmental work in progress used (in contrast to the way in which this latter recording criterion is adopted in the case of settled game species captures). The consequence in accounting terms is that it is first recorded as an intermediate raw material, valued at environmental price (in our case this is also the market price of the final product consumed). Thus, in the case of this *dehesa* study we know that the migratory hunting species originate in the main from breeding areas in European and African countries. Thus, the ‘free goods’ of migratory hunting captures contribute to a greater net value added of the *dehesas* and to increasing the value of the game species environmental fixed assets of the land.

In summary, the economic valuation of the environmental income may be depleted as a condition for the generation of income from labor and manufactured investment. Thus, the valuations of ecosystem services and environmental incomes in the studied *dehesa* could be considered third-order residual values in the economic transactions. This subsidiarity arises because the environmental prices of the wild natural resources have a residual economic value which only emerges after the payment of labor and manufactured investment services. The paradox is that the depletion (dissipation) of the ecosystem environmental income may be a necessary condition for the existence of income from labor and manufactured investment. Thus, thanks to the fact that the natural resource rent may be depleted (it is zero), the farmer can receive income from labor and manufactured investment. The public consumer benefits from the consumption of free goods and services of nature, shaped by the economic activities of the farmer and the government in the studied *dehesa*.

The circumstance of economic ownership is sufficient to consider if a good or service is legally "private," even if it is in fact an open access public economic good collected by recreational public visitors in the *dehesas*. Among this type of open access private good we include mushrooms harvested by open access recreational public visitors to the *dehesa*. The legal status of mushrooms is one in which landowners have private ownership. However, most landowners do not prevent access to free mushroom collection by recreational visitors in Andalusian *dehesas*. The consequence of this is that the value of the mushrooms gathered is a government activity, those who benefit from it being the public gatherers who usually consume it. In this example, the landowner is not affected by the net value added of the product of mushrooms, though it does affect that of the government, and therefore the total value added of the *dehesas*.

In the *dehesas*, the conservation of the landscape is of social interest due to its value as a cultural legacy as well as its ecosystem services, favoring the continuation of the commercial hunting and livestock activities. The government activity of fire services entails a significant demand for labor, thus fixing the population in the unpopulated rural areas where the *dehesas* are usually located. Thus, maintaining the quality of the holm oak *dehesa* cultural landscape public service is justified by the employment generated through the animal and fire activities intermediate product of services without direct environmental income generation.

Our objective in uncovering the diversity of free natural goods and services that affect the landowner and government activities is to make visible in the AAS net value added the biophysical quantities of free goods used. Whether they are intermediate, environmental, work in progress used or final products, all point to the economic importance of the free natural resource services embedded in the final product consumptions of the *dehesas*.

It should be noted that the measurement of net value added must take into account the effects of actions taken by the owner and the government in the past. The important question here is whether these actions would have been the same if the farmers had known earlier that the compensation and opportunity costs would be different. In other words, voluntary compensation and opportunity costs will condition the management options preferred by landowners in the future and consequently, the net value added of the *dehesas* could vary without having been anticipated in the valuation of the environmental assets at the closing of the accounting period. Beyond the environmental income, the questions of sustainable total income and ecological sustainability are important to us.

5.1.2. Accounting challenges of carbon and private amenity environmental asset gains

Through this *dehesa* study, the main challenges addressed in this area of accounting are the environmental asset revaluations of carbon and private amenity activities in the current period. The long-term time scale that we took into account for the closing environmental asset valuations in 2010, all else being equal, leads to an unknown degree of uncertainty related to subjective environmental asset gain estimates. The result for the studied *dehesa* as a whole, pointing to the unsustainability of the economic ecosystem services in 2010 contrasts with the biophysical sustainability result forecasted at the same time for an infinite horizon (Table A4). The unsustainable ecosystem service results obtained in this *dehesa* study are due to the change in the adjusted environmental net worth of carbon and amenity in the accounting period.

It must be taken into account that the changes in the future net carbon flows (fixation less emission) of the holm oaks embrace the complete life cycle, which exceeds two hundred years. Consequently, the discount of the carbon resource rent at a rate of 3%, suggests that future flows, distant in time from the current period (year), do not significantly influence the estimate of the environmental asset revaluation of the carbon in the current period. In contrast, the current cycles of the aging holm oaks give greater weight to the higher emissions that are produced in periods closer to the current period. Shrublands, however, have a cutting cycle of circa 25 years on average, and this shorter rotation period has a significant influence on the environmental income result for carbon.

Amenity environmental asset revaluation may be affected by high year-to-year volatility of land prices both increases and decreases. We have estimated that in the Spanish *dehesa* over the period 1994–2010 there was an annual cumulative rate change of 3.4 % in real land prices (Ovando et al., 2016). This land price volatility undermines the short time horizon meaning of the amenity sustainability but does not influence the long term sustainability of the *dehesa* private amenity final product auto-consumption sustainability.

5.2. Dehesa ecosystem accounting policy implications

The aim of the Agroforestry Accounting System (AAS) is to provide information to the target groups (beneficiaries) and particularly to governments, which are responsable for developing the standardized regulations of the future Economic Ecosystem Accounting methodology (EEA) to be applied by national and sub-national offices for statistics.

The expectation that an agreement will be reached in the near future on the United Nations Statistic Division (UNSD) manual of ecosystem accounting has led to increased government interest in the results of experimental ecosystem accounting applications. This is the case for the types of accounts developed in this study of the *dehesa*. Our application of the rSNA and AAS accounting methodologies are examples of how to develop estimates for ecosystem services and environmental assets of SNA commercial products, based on a standard agroforestry accounts approach, like the EAA/EAF methodology applied in the European Union, extending it to create others like the rSNA and AAS methodologies. These approaches are applicable at any unit area scale for the ecosystem, their possible use having been more developed at farm scale. Farm scale is the indispensable initial starting point for estimating, in a consistent manner, the social prices of farmer and government agroforestry activities affected by intermediate products of services and their counterpart of intermediate consumption of services which give rise to the voluntary opportunity costs incurred by the owners of the land and livestock. Thus, it is at farm scale that we have applied our rSNA and AAS approaches, and where the greatest difficulties exist for applying ecosystem environmental accounting. Our study applied to the *dehesa* may serve as an example to the national statistics offices as well as to other public administrations at subnational level that require agroforestry accounts in order to draw up policies and take decisions on the management of the multiple agroforestry land uses and controlled animals. Our rSNA and AAS methodologies for ecosystems may help to guide the standardization of accounts and they represent an initial example of the implementation of new economic-environmental concepts and variables which could be incorporated in the future provision of standardized economic-environmental statistics by governments.

As regards the drawing up of policies, in order to identify and value the products and incomes from which the people of the *dehesas* benefit, it is useful to determine the contributions of their public and private products. For example, according to Spanish law, mushrooms are private products from which the landowner, in practice, derives no benefit in the form of income from the resource. In the rSNA, we give priority to the economic owner and therefore mushrooms have been incorporated as a product owned by the government (as a collective owner of free economic consumption). The government, we assume, in effect donates the mushrooms gathered to recreational mushroom pickers. They acquire ownership of the mushrooms once harvested, and these harvested mushrooms have a market price and therefore a public environmental asset value (public natural capital), managed by the government. The failure to internalize the environmental asset in the market price of the land is due to the fact that the law penalizes illegal harvesting to the value of the mushrooms harvested, and this compensation does not cover the cost to the private owner of excluding the free access to mushroom pickers. In this case, the policy of internalization of the possible income from the resource of the mushrooms to favor the owner could be achieved in the same way as occurs for the public farmers. By law, the public owner can impose a sanction on illegal harvesting of an amount exceeding the value of the harvested mushrooms, thereby compensating the owner with an amount superior to the cost of restricting access to mushroom pickers.

This study has assessed the voluntary opportunity costs incurred by private non-industrial farmers. However, when designing policies, the government could propose concerted actions with landowners that would increase public products and/or mitigate the expected loss of net value added and/or ecosystem services in the future. The additional non-voluntary opportunity cost that could result from the concerted action can be estimated at the simulated normal manufactured profit obtained after the implementation of the concerted action, minus the ordinary manufactured margin (NOMmo) and the non-commercial intermediate services (ISSnc) prior to the concerted action. This calculation requires a system of AAS-type accounts at activity and *dehesa* scale.

There are also policy matters to be addressed on the measurement of net value added in situations where ecosystem services have zero economic values. Data regarding harvested physical natural products can provide valuable information on the free contribution of these products to maintaining economic activities in the spatial unit. Moreover, free physical ecosystem services could be made possible to satisfy the basic needs of the poorest rural families in many areas of the world (Sjaastad et al., 2005).

In this study of the *dehesa,* the results for the rSNA and AAS methodologies applied show that the total incomes generated by the agroforestry activities depend on the biophysical quantities and on the environmental assets of the farms and other territories at any scale. We draw attention the fact that based on the results of the application of different valuation methods for goods and services without market price; it is technically possible to reach standardization at any scale for economic-environmental accounts of agroforestry landscapes. However, there are still certain challenges pending, such as the measurement of the biophysical productivity of work in progress products which require multiple periods (maturation of the product in cycles of several years) until their future harvesting. The results for the government activities reveal that there are productive links with the activities of the farmer, and therefore it is the government that must address the challenge of approving the public spending budget which is an inevitable element of the implementation in the near future of the public offer for standardized national and subnational ecosystem accounting, in accordance with the expected UNSD manual, which is due to be agreed in the spring of 2021. The implementation of the environmental accounts will continue to require improvements in the procedures used to obtain the economic-environmental statistics according to the objectives pursued with the standardized environmental account statistics at each moment in time in a context of progressive future improvements. However, the initial agreement on the UNSD standard economic ecosystem accounting may be closer to the rSNA type approach than to that of the AAS. At least that seems to be the most likely direction of the ongoing proposal of the SEEA-EEA under discussion. Therefore, considering the ecosystem as an institutional sector, the SEEA-EEA could estimate inconsistent measurements of ecosystem services and adjusted net value added with respect to the concept of total income (European Communities, 2000: pp. 87–88) and the institutional sectors of the SNA (European Commission, 2009).

6. Concluding remarks

The AAS methodology incorporating a set of economic indicators aimed at measuring total income can be replicated for any spatial unit (both terrestrial and marine areas). The AAS production and balance accounts are conceptual economic tools that are able to uncover the factorial allocation of total income into human capital income, manufactured capital income and environmental income. The latter is broken down into ecosystem services and change in adjusted environmental net worth, thus allowing us to estimate the ecosystem service sustainability index.

This study advocates that the environmental income is a variable which expresses the maximum sustainable economic natural resource extraction, as long as no single environmental asset is on the verge of extinction. Where this condition is fulfilled, meaning that a critical threshold of environmental assets does not apply, the environmental income represents a maximum possible ecosystem service contribution to sustainable product consumption in the *dehesa* (spatial unit).

In this AAS application to the *dehesa* study, the *dehesa* ecosystem service value is higher than that of the environmental income; therefore, the ecosystem service of the period is not sustainable. However, even if the environmental income is higher than the ecosystem service, the former may not reflect sustainable physical ecosystem service consumption. This possible discrepancy between the economic and physical sustainability of environmental income is due to the fact that the environmental income of the period represents a social relationship of reciprocal exchange while the physical sustainability involves a biotic functional relationship independent of human transaction numerarie.

All economic valuation of renewable natural resources presents an insurmountable weakness in situations where critical thresholds of environmental asset preservation exist. This weakness is well documented in economic science and the only way to deal with it is by exercising precaution. When it is known that the future regeneration capacity of a given environmental asset places it in danger of extinction due to its extreme physical scarcity, then a loss of well-being for current generations associated with the preservation of this environmental asset may be imposed by the government on consumers, as long as current generations consider the inherent cost to be a tolerable social cost. In this study of the *dehesas*, the conservation of threatened biodiversity was guaranteed by consumer willingness-to-pay, thereby facilitating conservationist management of the *dehesa* by the government.

The *dehesa* results confirm the consistency of the AAS estimates based on total product and total income of individual *dehesa* activities, some of which are linked by the production of intermediate services and consumption of own services that exist across many of them. The results reveal that the productive functions of intermediate services link multiple activities for which farmer and government are responsible. These interactions take place simultaneously within the economic activities of the *dehesa* and they guide our development of the Agroforestry Accounting System (AAS) and System of National Accounts (rSNA) applications. The life cycles of hundreds of years of Mediterranean tree species of the *Quercus* genus and the subjective choice of discount rate mean that the estimates of present discounted value of the resource rents can be highly volatile. The difficulties are amplified by the need for information on government expenditures attributed to *dehesa* activities as well as the need to design bio-economic models, scheduled for the future, which will guarantee the economic and ecological sustainability of the *dehesa* environmental assets indefinitely. Nevertheless, this *dehesa* study shows that it is possible to measure physical and economic indicators in a consistent manner, while providing information on environmental and manufactured values for ecosystem services, environmental incomes, total income, change of net worth, environmental assets and total capital. The comparison of the AAS and rSNA ecosystem service measurements reveals substantial variations due to omissions and biases in the valuations of agroforestry farm products and costs by the rSNA.

The AAS results for the *dehesas* suggest that the data shortcomings of the rSNA can be overcome by creating and applying AAS agroforestry accounts, thus providing better information for the development of government policy and facilitating scheduled sustainable management of natural resource by landowners.

The information provided by AAS of this type, applicable to any agroforestry micro spatial economic unit, could allow policy makers to better mitigate failures through the design and implementation of government policies and landowner-scheduled sustainable management of the natural resources.

CRediT authorship contribution statement

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

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Appendix A

Tables A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11 and Fig. A1.

Table A1
Vegetation cover and other land uses in the non-industrial privately owned holm oak *dehesa* case study in Andalusia (2010).

Class	*Dehesa* 1	*Dehesa* 2	*Dehesa* 3	*Dehesa* 4	*Dehesa* 5	*Dehesa* 6	*Dehesa* 7	*Dehesa* 8	*Dehesa* 9	*Dehesa* 10	*Dehesa* 11	*Dehesa* 12	*Dehesa* 13	*Dehesa* 14	*Dehesa* 15	*Dehesa* 16	*Dehesa*	
	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	%
1. Useful agrarian land	178	738	2,009	1,258	186	286	464	207	302	356	286	313	1,312	708	76	297	8,974	99.4
Open woodland	178	660	1,821	568	63	102	301	191	294	286	256	245	1,159	632	64	249	7,066	78.2
Quercus ilex	*178*	*583*	*1,821*	*381*	*63*	*102*	*234*	*186*	*294*	*278*	*201*	*231*	*1,032*	*574*	*64*	*139*	*6,361*	*70.4*
Quercus suber		*12*		*47*			*54*	*0*		*8*			*126*	*58*		*35*	*341*	*3.8*
Others oaks		*65*		*116*			*9*					*13*					*204*	*2.3*
Wild olive				*23*			*3*	*5*			*55*					*75*	*160*	*1.8*
Coniferous	0	78	0	469	96	4	0	0	0	0	0	0	0	0	0	31	678	7.5
Pinus pinea		*78*		*331*			*0*										*409*	*4.5*
Pinus pinaster				*138*													*138*	*1.5*
Pinus nigra					*1*												*1*	*0.0*
Pinus halepensis					*90*	*1*											*92*	*1.0*
Others coniferous					*5*	*3*										*31*	*39*	*0.4*
Eucalyptus				55			55	2			0						112	1.2
Other forest [a]			1	34	0	29	37				2	39	30	12			185	2.0
Shrubland [b]		0	120	62	0	46	43		1	49	4	4	83	37	11	10	471	5.2
Grassland		0	58		3	88	5		7	19	1	9	40	27	1	7	266	2.9
Croplands			9	70	24	17	23	14		0	23	16			1		196	2.2
2. Others [c]	1	2	2	3	0	0	3	4	4	0	9	1	24	2	0	2	58	0.6
3. Total	179	740	2,010	1,260	186	286	468	211	306	356	296	314	1,336	710	77	298	9,032	100.0

Notes: [a] Includes riparian forests, other species and mixed oaks-conifers forests. [b] Includes shrubland and shrubland with grassland. [c] Infrastructure and unproductive surface.

Table A2
Canopy cover fraction in holm oak *dehesa* case study in Andalusia (2010).

Class	Surface (ha)	Canopy cover fraction (%)
1. Open woodland	7,066	34.0
2. Coniferous	678	11.9
3. Other forest[a]	297	5.9
4. Shrubland	471	
5. Grassland	266	
6. Croplands	196	
7. Others[b]	58	
Dehesa	9,032	

Notes: [a] Includes riparian forests, other species, mixed oaks-conifers forests and eucalyptus. [b] Infrastructure and unproductive surface.

Table A3
Labor demand in holm oak *dehesa* case study in Andalusia (2010).

Class	Employees			Self-employed			*Dehesa*		
	Quantity h/ha	Wage rate €/h	Labor cost €/ha	Quantity h/ha	Wage rate €/h	Labor cost €/ha	Quantity h/ha	Wage rate €/h	Labor cost €/ha
1. Landowner	10.3	9.5	98.2	3.1	1.0	3.1	13.4	7.5	101.4
Timber	0.0	6.5	0.2	0.0			0.0	4.4	0.2
Cork	0.5	17.6	8.1				0.5	17.6	8.1
Firewood	0.1	16.3	2.0	0.2	4.9	1.2	0.4	8.8	3.2
Nuts									
Grazing	0.4	12.5	5.1				0.4	12.5	5.1
Con. forestry	0.1	12.4	1.2				0.1	12.4	1.2
Hunting	2.0	9.9	19.6	0.5	0.7	0.3	2.5	8.0	19.9
Comm. recreation	0.8	6.9	5.6				0.8	6.9	5.6
Residential	1.5	6.8	10.0	0.1	1.3	0.1	1.6	6.5	10.1
Livestock	4.5	9.4	42.6	2.2	0.6	1.4	6.7	6.5	44.0
Agriculture	0.4	8.7	3.9	0.0			0.5	8.5	3.9
2. Government	1.7	21.2	35.4				1.7	21.2	35.4
Fire services	1.0	21.0	22.0				1.0	21.0	22.0
Recreation	0.2	22.9	4.0				0.2	22.9	4.0
Mushrooms	0.0	21.4	0.1				0.0	21.4	0.1
Landscape	0.3	21.0	5.7				0.3	21.0	5.7
Biodiversity	0.2	21.0	3.6				0.2	21.0	3.6
Total	12.0	11.1	133.6	3.1	1.0	3.1	15.1	9.1	136.7

Table A4
Productive physical indicators in holm oak *dehesa* case study in Andalusia (2010).

Class	Unity	Useful land (ha)	Quantity	Quantity/ha
1. Timber				
1.1 Natural growth	m^3	790	1,759	2.2
2. Cork				
2.1 Natural growth	t	341	260	0.8
2.2 Extraction	t	341	91	0.3
3. Firewood				
3.1 Natural growth	m^3	6,906	6,655	1.0
3.2 Extraction	m^3	6,906	1,605	0.2
4. Acorn	t	6,361	650,348	102.2
4.1 Commercial	FU	6,361	641,366	100.8
4.2 Free	FU	6,361	8,982	1.4
5. Forage unit	FU	9,032	8,515,546	942.8
5.1 Grazing	FU	9,032	4,698,210	520.2
Commercial	FU	9,032	2,729,836	302.2
Livestock	*FU*	*9,032*	*2,176,316*	*241.0*
Hunting	*FU*	*9,032*	*553,520*	*61.3*

(*continued on next page*)

Table A4 (*continued*)

Class	Unity	Useful land (ha)	Quantity	Quantity/ha
Free	FU	9,032	1,968,373	217.9
Livestock	*FU*	*9,032*	*279,463*	*30.9*
Hunting	*FU*	*9,032*	*1,688,910*	*187.0*
5.2 Supplements	FU	9,032	3,817,337	422.6
Livestock	FU	9,032	3,518,610	389.6
Hunting	FU	9,032	298,727	33.1
6. Hunting captures				
6.1 Red deer	he	9,032	672	7.4(*)
6.2 Wild boar	he	9,032	162	1.8(*)
7. Livestock stock				
7.1 Females				
Bovine	he	9,032	1,004	11.1(*)
Ovine	he	9,032	1,718	19.0(*)
Caprine	he	9,032	1,306	14.5(*)
7.2 Birth				
Bovine	he	9,032	501	5.5(*)
Ovine	he	9,032	1,359	15.0(*)
Caprine	he	9,032	1,077	11.9(*)
7.3 Sales				
Bovine	he	9,032	336	3.7(*)
Ovine	he	9,032	1,278	14.1(*)
Caprine	he	9,032	1,075	11.9(*)
Porcine	arrobas	9,032	13,273	1.5
7.4 Ageing (breeders)				
Bovine	he	9,032	145	1.6(*)
Ovine	he	9,032	200	2.2(*)
Caprine	he	9,032	253	2.8(*)
8. Residential	m^2	9,032	4,308	47.7(*)
9. Recreation	visits	9,032	14,026	1.6
10. Mushrooms	kg	9,032	21,443	2.4
11. Carbon				
11.1 Fixation	t CO_2	8,778	32,584	3.7
Wooded	t CO_2	8,041	19,472	2.4
Shrubland	t CO_2	737	13,112	17.8
11.2 Emissions	t CO_2	8,778	12,505	1.4
Wooded	t CO_2	8,041	9,145	1.1
Shrubland	t CO_2	737	3,361	4.6
11.3 Net fixation	t CO_2	8,778	20,079	2.3
Wooded	t CO_2	8,041	10,328	1.3
Shrubland	t CO_2	737	9,751	13.2
12. Threatened species	nº	9,032	89	1.0(*)
13. Water	m^3	8,974	72,941,762	8,128
13.1 Intermediate production	m^3	8,974	38,205,647	4,257
Evapotranspiration	m^3	8,974	38,263,025	4,264
Negative variation	m^3	8,974	57,377	6
13.2 Final product	m^3	8,974	34,736,115	3,871
Runoff	m^3	8,974	21,025,202	2,343
Ecological	*m^3*	*8,974*	*14,922,446*	*1,663*
Economic	*m^3*	*8,974*	*6,102,756*	*680*
Deep aquifer recharge	m^3	8,974	12,613,293	1,406
Positive variation	m^3	8,974	1,097,619	122

Abbreviations: m^3 is cubic meters; t is ton; FU is forage unit; he is head; m^2 is square meter; kg is kilograms; tCO_2 is equivalent carbon dioxide ton and u is unit of threatened wild species.

Table A5
Iberian pig grazing in Montanera season in holm oak *dehesa* case study in Andalusia-Spain Andalusia, Spain (2010).

Dehesa code	Surface	Weight of Iberian pigs in Montanera*		Forage unit consumption		Montanera duration	Average number of Iberian pigs in Montanera per year and *dehesa*
		Entries	Withdrawals				
	ha	Arrobas**	Arrobas	FU***	FU/ha	Months	Heads
Dehesa 1	179	10.1	14.6	19,039	106.5	4	62
Dehesa 2	740	7	15	120,629	163.1	5	292
Dehesa 3	2,010	9.5	14.2	375,219	186.7	4	1,172
Dehesa 8	211	9	14	45,442	215.5	4	132
Dehesa 9	306	9	14	33,393	109.1	5	97
Dehesa 10	356	10.2	14	37,414	105.2	4	143
Dehesa 14	710	7.2	9.3	26,357	37.1	3	182
Dehesa 16	298	8.5	14.3	4,699	15.8	5	13
Total	4,809			662,194	137.7		2,093
Mean value	601	8.8	13.7	82,774	117.4	4	262

* Montanera is the season that pig is fattened by grazing acorns.
** Arrobas is a Spanish weight unit of 11.5 kg.
*** Forage unit is a metabolic energy unit equivalent to a kilogram of barley.

Table A6
Agroforestry Accounting System capital balance of work in progress and fixed capital in holm oak *dehesa* case study in Andalusia (2010: €/ha).

Class	1. Opening capital	2. Capital entries				3. Capital withdrawals						4. Revaluation	5. Closing capital
		2.1 Bought	2.2 Own	2.3 Others	2.4 Total	3.1 Used	3.2 Sales	3.2 Destructions	3.3.Recla-ssifications	3.4 Others	3.5 Total		
	(Co)	(Ceb)	(Ceo)	(Ceot)	(Ce)	(Cwu)	(Cws)	(Cwd)	(Cwrc)	(Cwo)	(Cw)	(Cr)	(Cc)
1. Capital (C = WP + FC)	10,657.7	38.4	164.3	68.3	271.0	223.4	8.3	8.9	57.8	29.1	327.5	−175.2	10,426.1
2. Work in progress (WP)	418.8	24.3	119.3	14.9	158.5	223.4			9.7	3.1	236.2	21.3	362.4
Timber (WPt)	10.2		0.2		0.2				0.2		0.2	0.9	11.1
Cork (WPc)	132.9		9.7		9.7	8.1			9.1		17.2	16.7	142.1
Firewood (WPf)	38.4		0.4		0.4	2.1			0.4		2.5	3.7	40.0
Non breeding livestock (WPnbl)	200.9	23.8	96.1	13.0	132.8	200.9					200.9	0.0	132.8
Hunting (WPh)	35.7	0.5	12.3	1.9	14.7	11.6				3.1	14.7	0.0	35.7
Agriculture (WPa)	0.7		0.7		0.7	0.7					0.7		0.7
3. Fixed capital (FC)	10,239.0	14.1	45.0	53.4	112.5		8.3	8.9	48.1	26.0	91.3	−196.5	10,063.7
3.1 Land (FCl)	7,912.0			49.5	49.5				48.1	19.0	67.1	−171.7	7,722.7
Timber (FClt)	*25.3*											*0.8*	*26.1*
Cork (FClc)	*31.8*											*1.0*	*32.7*
Firewood (FClf)	*3.4*											*0.1*	*3.5*
Nuts (FCln)	*0.3*											*0.0*	*0.3*
Grass *and browse(FClg)*	*857.7*												*857.7*
Acorns (FCla)	*14.0*											*-0.2*	*13.8*
Hunting (FClh)	*385.1*												*385.1*
Agriculture(FClag)	*55.1*												*55.1*
Amenity (FClea)	*3,051.7*											*-187.7*	*2,864.0*
Recreation (FCler)	*638.2*												*638.2*
Mushrooms (FClem)	*442.9*												*442.9*
Carbon (FClec)	*356.0*			*49.5*	*49.5*				*48.1*	*19.0*	*67.1*	*14.4*	*352.8*
Landscape (FClel)	*438.1*												*438.1*
Biodiversity (FCleb)	*169.3*												*169.3*
Water (FClew)	*1,443.2*												*1,443.2*
3.2 Biological resources (FCbr)	1,087.6	5.0	37.2	3.9	46.1		8.3	8.1		6.6	23.0	50.2	1,160.8
Timber (FCbrt)	0.0												0.0
Cork (FCbrc)	716.2											47.6	763.8
Firewood (FCbrf)	123.6											5.2	128.9
Nuts (FCbrn)	0.2											0.0	0.2
Acorns (FCbra)	52.0											−2.6	49.4
Breeding livestock (FCbrb)	186.6	4.8	35.5	2.7	43.0		8.3	8.1		3.3	19.7	−0.2	209.7
Hunting (FCbrh)	8.9	0.2	1.7	1.2	3.1					3.3	3.3	0.2	8.9
3.3 Plantations (FCp)	6.1											−0.1	6.1
3.4 Infrastructure (FCco)	1,103.4		7.8		7.8							−56.8	1,054.4
3.5 Equipments (FCe)	126.0	9.1			9.1			0.9		0.4	1.3	−18.8	115.1
3.9 Others (FCo)	3.9											0.7	4.6

Table A7
Agroforestry Accounting System total product and net value added at social prices in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Timber 1	Cork 2	Fire-wood 3	Nuts 4	Gra-zing 5	Conserv. forestry 6	Hun-ting 7	Comm. recreation 8	Residen-tial 9	Live-stock 10	Agri-culture 11
1. Total product (TP_{sp})	0.6	27.6	11.9		40.9	2.1	116.9	10.1	20.4	459.8	4.9
1.1 Intermediate product (IP_{sp})	0.4	4.4	1.6		40.3	2.1	75.6		14.0	111.7	1.1
1.2 Final product (FP_{pp})	0.2	23.2	10.2		0.6		41.3	10.1	6.3	348.0	3.8
1.2.2 Final product consumption (FPc_{pp})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Gross capital formation (GCF)	0.2	9.7	0.4				11.6		2.3	168.3	0.7
1.2.2.1 Manufactured (GCFm)							0.3		2.3	168.3	0.7
1.2.2.2 Natural growth (NG)	0.2	9.7	0.4				11.3				
2. Intermediate consumption (IC_{sp})	0.1	8.8	3.1		5.9	0.4	55.8	7.1	1.9	369.2	3.4
2.1 Manufactured intermediate consumption (ICm)	0.1	0.7	1.0		5.9	0.4	44.1	7.1	1.9	369.2	3.4
2.1.1 Bought (ICmb)	0.1	0.7	1.0		5.9	0.4	21.2	7.1	1.9	146.6	2.7
2.1.2 Own ($ICmo_{sp}$)							22.9			21.8	
2.1.3 Manufactured work in progress used (WPmu)										200.9	0.7
2.2 Environmental intermediate consumption (ICe)		8.1	2.1				11.6				
2.2.1 Environmental work in progress used (WPeu)		8.1	2.1				11.6				
3. Consumption of fixed capital (CFC)	0.1	0.5	0.2		2.6	0.1	7.7	4.2	13.8	14.8	2.6
4. Net value added (NVA_{sp}) (TP_{sp}-IC_{sp}-CFC)	0.4	18.2	8.5		32.4	1.6	53.4	−1.2	4.6	75.8	−1.0
4.1. Labour compensation (LC)	0.2	8.1	3.2		5.1	1.2	19.9	5.6	10.1	44.0	3.9
4.2. Net operating margin (NOM_{sp})	0.2	10.2	5.3		27.3	0.4	33.5	−6.8	−5.5	31.8	−4.9
4.2.1 Manufactured net operating margin ($NOMm_{sp}$)	0.0	0.5	4.9		2.1	0.4	4.1	−6.8	−5.5	31.8	−4.9
4.2..2 Environmental net operating margin (NOMe)	0.2	9.7	0.4		25.2		29.4				

Class	Amenity 12	Farmer Σ1-12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13-19	*Dehesa* Σ1-19
1. Total product (TP_{sp})	295.2	990.3	34.1	24.3	13.4	49.5	91.1	11.0	81.9	305.3	1,295.6
1.1 Intermediate product (IP_{sp})		251.4	31.5							31.5	282.8
1.2 Final product (FP_{pp})	295.2	738.9	2.7	24.3	13.4	49.5	91.1	11.0	81.9	273.8	1,012.8
1.2.2 Final product consumption (FPc_{pp})	295.2	545.8		23.7	13.3	49.5	90.2	9.9	81.9	268.6	814.4
1.2.2 Gross capital formation (GCF)		193.1	2.7	0.6	0.1		0.8	1.1		5.2	198.3
1.2.2.1 Manufactured (GCFm)		171.5	2.7	0.6	0.1		0.8	1.1		5.2	176.8
1.2.2.2 Natural growth (NG)		21.6									21.6
2. Intermediate consumption (IC_{sp})	169.1	624.8	11.1	2.5	0.1		70.1	1.8		85.6	710.5
2.1 Manufactured intermediate consumption (ICm)	169.1	603.0	11.1	2.5	0.1		70.1	1.8		85.6	688.6
2.1.1 Bought (ICmb)		187.7	11.1	1.5	0.1		2.0	1.8		16.5	204.3
2.1.2 Own ($ICmo_{sp}$)	169.1	213.7		1.0			68.1			69.1	282.8
2.1.3 Manufactured work in progress used (WPmu)		201.5									201.5
2.2 Environmental intermediate consumption (ICe)		21.8									21.8
2.2.1 Environmental work in progress used (WPeu)		21.8									21.8

(*continued on next page*)

Table A7 (*continued*)

Class	Amenity 12	Farmer Σ1-12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13-19	*Dehesa* Σ1-19
3. Consumption of fixed capital (CFC)		46.6	1.0	1.2	0.0	19.0	2.1	0.4		23.8	70.4
4. Net value added (NVA_{sp}) (TP_{sp}-IC_{sp}-CFC)	126.1	318.9	22.0	20.6	13.3	30.5	18.8	8.7	81.9	195.8	514.7
4.1. Labour compensation (LC)		101.4	22.0	4.0	0.1		5.7	3.6		35.4	136.7
4.2. Net operating margin (NOM_{sp})	126.1	217.5	0.0	16.7	13.1	30.5	13.1	5.1	81.9	160.5	378.0
4.2.1 Manufactured net operating margin ($NOMm_{sp}$)		26.6	0.0	1.0	0.5		0.2	0.8		2.5	29.2
4.2..2 Environmental net operating margin (NOMe)	126.1	190.9		15.6	12.6	30.5	13.0	4.3	81.9	157.9	348.8

Table A8
Agroforestry Accounting System individual *dehesa* incomes and ecosystem services differences in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Surface (ha)	Total income (TI)	Capital income (CI)	Net valued added (NVA)	Environmental income (EI)	Ecosystem services (ES)	Labor cost (LC)
Dehesa 1	179	474.8	406.6	790.8	441.9	618.0	68.2
Dehesa 2	740	444.3	218.1	691.7	300.9	423.9	226.2
Dehesa 3	2,010	190.5	97.5	395.6	63.3	285.6	93.0
Dehesa 4	1,260	−7.9	−109.9	322.5	−102.3	204.0	102.0
Dehesa 5	186	124.7	101.8	318.6	124.1	212.9	23.0
Dehesa 6	286	532.4	507.6	546.9	594.8	534.6	24.8
Dehesa 7	468	228.9	180.2	598.4	240.5	493.8	48.8
Dehesa 8	211	19.2	−27.2	283.0	−69.6	367.9	46.4
Dehesa 9	306	401.7	351.3	617.8	402.1	569.4	50.4
Dehesa 10	356	1,287.9	1,237.9	897.3	1,441.7	671.1	50.1
Dehesa 11	296	317.5	246.0	516.9	315.2	438.8	71.5
Dehesa 12	314	169.6	20.5	320.6	149.0	343.9	149.1
Dehesa 13	1,336	467.0	83.7	818.5	190.0	473.7	383.3
Dehesa 14	710	33.3	−64.0	223.6	−40.6	110.2	97.2
Dehesa 15	77	431.5	386.1	577.7	447.9	455.5	45.4
Dehesa 16	298	304.2	270.1	604.6	324.2	574.2	34.1
Total	9,032	284.8	148.1	514.7	190.8	368.1	136.7
Minimal	76.8	−7.9	−109.9	223.6	−102.3	110.2	23.0
Maximum	2,010.2	1,287.9	1,237.9	897.3	1,441.7	671.1	383.3
Standard deviation	534.2	308.0	319.6	206.1	363.6	159.9	92.9

Table A9
Refined System of National Accounts System opening capital in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Opening environmental asset			Opening manufactured capital			Opening capital		
	Farmer	Government	Sub-total	Farmer	Government	Sub-total	Farmer	Government	*Dehesa*
Timber	35.5		35.5	0.7		0.7	36.2		36.2
Cork	880.9		880.9	2.0		2.0	882.9		882.9
Firewood	165.4		165.4	1.8		1.8	167.2		167.2
Nuts	0.5		0.5				0.5		0.5
Grazing	923.7		923.7	64.3		64.3	988.0		988.0
Grass	857.7		857.7	64.3		64.3	921.9		921.9
Acorn	66.0		66.0				66.0		66.0
Conservation forestry				10.1		10.1	10.1		10.1
Hunting	429.7		429.7	117.8		117.8	547.5		547.5
Commercial recreation				87.0		87.0	87.0		87.0
Residential				488.2		488.2	488.2		488.2
Livestock				716.0		716.0	716.0		716.0
Agriculture				69.9		69.9	69.9		69.9
Amenity	3,051.7		3,051.7				3,051.7		3,051.7
Fire services					48.5	48.5		48.5	48.5
Recreation					31.9	31.9		31.9	31.9
Mushrooms		442.9	442.9		17.9	17.9		460.8	460.8
Carbon									
Landscape					2.3	2.3		2.3	2.3
Biodiversity					24.4	24.4		24.4	24.4
Water		1,443.2	1,443.2					1,443.2	1,443.2
Total	5,487.3	1,886.1	7,373.5	1,557.7	125.0	1,682.7	7,045.0	2,011.1	9,056.2

Table A10
Refined System of National Accounts total product and net value added in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Timber 1	Cork 2	Fire-wood 3	Nuts 4	Gra-zing 5	Con. forestry 6	Hun-ting 7	Comm. recreation 8	Residen-tial 9	Live-stock 10	Agri-culture 11
1. Total product (TP_{bp})	0.2	23.2	10.2		28.2	1.6	59.4	10.1	20.4	163.9	4.6
1.1 Intermediate product (IP_{bp})					27.6	1.6	18.0		14.0	33.9	0.8
1.2 Final product (FP_{pp})	0.2	23.2	10.2		0.6		41.3	10.1	6.3	130.0	3.8
1.2.2 Final product consumption (FPc_{pp})		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Gross capital formation (GCF)	0.2	9.7	0.4				11.6		2.3	−49.8	0.7
1.2.2.1 Manufactured (GCFm)							0.3		2.3	−49.8	0.7
1.2.2.2 Natural growth (NG)	0.2	9.7	0.4				11.3				
2. Intermediate consumption (IC_{bp})	0.1	8.8	3.1		5.9	0.4	55.8	7.1	1.9	168.3	3.4
2.1 Manufactured intermediate consumption (ICm)	0.1	0.7	1.0		5.9	0.4	44.1	7.1	1.9	168.3	3.4
2.1.1 Bought (ICmb)	0.1	0.7	1.0		5.9	0.4	21.2	7.1	1.9	146.6	2.7
2.1.2 Own ($ICmo_{bp}$)							22.9			21.8	
2.1.3 Manufactured work in progress used (WPmu)											0.7
2.2 Environmental intermediate consumption (ICe)		8.1	2.1				11.6				
2.2.1 Environmental work in progress used (WPeu)		8.1	2.1				11.6				
3. Consumption of fixed capital (CFC)	0.1	0.5	0.2		2.6	0.1	7.7	4.2	13.8	14.8	2.6
4. Net value added (NVA_{bp}) (TP_{bp}-IC_{bp}-CFC)	0.0	13.8	6.9		19.7	1.1	−4.1	−1.2	4.6	−19.2	−1.3
4.1 Labour compensation (LC)	0.2	8.1	3.2		5.1	1.2	19.9	5.6	10.1	44.0	3.9
4.2 Net operating margin (NOM_{bp})	−0.2	5.8	3.6		14.6	−0.1	−24.0	−6.8	−5.5	−63.2	−5.2
4.2.1 Manufactured net operating margin ($NOMm_{bp}$)	−0.4	−3.9	3.2		−10.6	−0.1	−53.4	−6.8	−5.5	−63.2	−5.2
4.2.2 Environmental net operating margin (NOMe)	0.2	9.7	0.4		25.2		29.4				

Class	Amenity 12	Farmer Σ1-12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13-19	*Dehesa* Σ1-19
1. Total product (TP_{bp})	14.0	335.8	34.1	7.7	13.4		77.9	5.8	69.6	208.5	544.4
1.1 Intermediate product (IP_{bp})		96.1	31.5							31.5	127.5
1.2 Final product (FP_{pp})	14.0	239.8	2.7	7.7	13.4		77.9	5.8	69.6	177.1	416.8
1.2.2 Final product consumption (FPc_{pp})	14.0	264.7		7.1	13.3		77.1	4.8	69.6	171.8	436.5
1.2.2 Gross capital formation (GCF)		−24.9	2.7	0.6	0.1		0.8	1.1		5.2	−19.7
1.2.2.1 Manufactured (GCFm)		−46.5	2.7	0.6	0.1		0.8	1.1		5.2	−41.3
1.2.2.2 Natural growth (NG)		21.6									21.6
2. Intermediate consumption (IC_{bp})	14.0	268.9	11.1	2.5	0.1		70.1	1.8		85.6	354.6
2.1 Manufactured intermediate consumption (ICm)	14.0	247.1	11.1	2.5	0.1		70.1	1.8		85.6	332.8
2.1.1 Bought (ICmb)		187.7	11.1	1.5	0.1		2.0	1.8		16.5	204.3
2.1.2 Own ($ICmo_{bp}$)	14.0	58.7		1.0			68.1			69.1	127.8
2.1.3 Manufactured work in progress used (WPmu)		0.7									0.7
2.2 Environmental intermediate consumption (ICe)		21.8									21.8
2.2.1 Environmental work in progress used (WPeu)		21.8									21.8

(*continued on next page*)

Table A10 (*continued*)

Class	Amenity 12	Farmer Σ1-12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13-19	*Dehesa* Σ1-19
3. Consumption of fixed capital (CFC)		46.6	1.0	1.2	0.0		2.1	0.4		4.8	51.4
4. Net value added (NVA_{bp}) (TP_{bp}-IC_{bp}-CFC)		20.3	22.0	4.0	13.3		5.7	3.6	69.6	118.1	138.4
4.1 Labour compensation (LC)		101.4	22.0	4.0	0.1		5.7	3.6		35.4	136.7
4.2 Net operating margin (NOM_{bp})		−81.1	0.0	0.0	13.1		0.0	0.0	69.6	82.7	1.6
4.2.1 Manufactured net operating margin ($NOMm_{bp}$)		−145.9	0.0	0.0	0.5		0.0	0.0		0.5	−145.3
4.2.2 Environmental net operating margin (NOMe)		64.8			12.6				69.6	82.2	147.0

Table A11
Refined System of National Accounts total income factorial allocation at basic prices in Andalusian holm oak *dehesa* case study (2010: €/ha).

Class	Tim-ber 1	Cork 2	Fire-wood 3	Nuts 4	Gra-zing 5	Con. forestry 6	Hun-ting 7	Comm. recreation 8	Residen-tial 9	Live-stock 10	Agri-culture 11
1. Total product (TP)	0.2	23.2	10.2		28.2	1.6	59.4	10.1	20.4	163.9	4.6
1.1 Intermediate product (IP)					27.6	1.6	18.0		14.0	33.9	0.8
1.1.1 Raw materials (RM)					26.4		18.0				
1.1.2 Services (ISS)					1.3	1.6			14.0	33.9	0.8
1.2 Final product (FP)	0.2	23.2	10.2		0.6		41.3	10.1	6.3	130.0	3.8
1.2.1 Final product consumption (FPc)		13.5	9.8		0.6		29.7	10.1	4.0	179.8	3.2
1.2.2 Gross capital formation (GCF)	0.2	9.7	0.4				11.6		2.3	−49.8	0.7
1.2.2.1 Manufactured (GCFm)							0.3		2.3	−49.8	0.7
1.2.2.2 Natural growth (NG)	0.2	9.7	0.4				11.3				
2. Intermediate consumption (IC)	0.1	8.8	3.1		5.9	0.4	55.8	7.1	1.9	168.3	3.4
2.1 Raw materials	0.0	0.3	0.7		1.9	0.2	30.6	3.2	0.6	146.6	1.4
2.1.1 Bought (RMb)	0.0	0.3	0.7		1.9	0.2	7.7	3.2	0.6	124.9	1.4
2.1.2 Own (RMo)							22.9			21.8	
2.2 Services (SS)	0.1	0.4	0.3		4.0	0.3	13.5	3.9	1.4	21.7	1.3
2.2.1 Bought (SSb)	0.1	0.4	0.3		4.0	0.3	13.5	3.9	1.4	21.7	1.3
2.2.2 Own (SSoo)											
2.2.2.1 Commercial (SScoo)											
2.2.2.2 Non-commercial (SSncoo)											
2.3 Work in progress used (WPu)		8.1	2.1				11.6				0.7
2.3.1 Manufactured (WPmu)											0.7
2.3.2 Environmental (WPeu)		8.1	2.1				11.6				
3. Consumption of fixed capital (CFC)	0.1	0.5	0.2		2.6	0.1	7.7	4.2	13.8	14.8	2.6
4. Net value added (NVA)	0.0	13.8	6.9		19.7	1.1	−4.1	−1.2	4.6	−19.2	−1.3
4.1 Labour compensation (LC)	0.2	8.1	3.2		5.1	1.2	19.9	5.6	10.1	44.0	3.9
4.2 Net operating margin (NOM)	−0.2	5.8	3.6		14.6	−0.1	−24.0	−6.8	−5.5	−63.2	−5.2
4.2.1 Manufactured (NOMm)	−0.4	−3.9	3.2		−10.6	−0.1	−53.4	−6.8	−5.5	−63.2	−5.2
4.2.2 Environmental (NOMe)	0.2	9.7	0.4		25.2		29.4				
4.2.2.1 Ordinary environmental net operating margin (NOMeo)					25.2		18.0				
4.2.2.2 Investment environmental net operating margin (NOMei)	0.2	9.7	0.4				11.3				
5. Ecosystem services (ES)	0.0	8.1	2.1	0.0	25.2		29.7				
6. Capital gain (CG)	1.3	55.6	8.5	0.0	−5.4	−0.2	−10.4	−3.8	−26.0	−28.5	−3.3
6.1 Manufactured (CGm)	−0.1	−0.5	−0.2		−2.4	−0.2	−10.4	−3.8	−26.0	−28.5	−3.3
6.2 Environmental (EAg)	1.4	56.1	8.7	0.0	−3.0		0.0				
7. Adjusted change in environmental net worth (CNWead)	1.6	57.7	6.9	0.0	−3.0		−0.3				

(*continued on next page*)

Table A11 (*continued*)

Class	Tim-ber 1	Cork 2	Fire-wood 3	Nuts 4	Gra-zing 5	Con. forestry 6	Hun-ting 7	Comm. recreation 8	Residen-tial 9	Live-stock 10	Agri-culture 11
8. Environmental income (EI)	1.6	65.8	9.1	0.0	22.2		29.4				
9. Total income (TI)	1.3	69.5	15.3	0.0	14.3	0.9	−14.5	−5.0	−21.4	−47.7	−4.6

Class	Amenity 12	Farmer Σ1-12	Fire services 13	Recrea-tion 14	Mush-rooms 15	Carbon 16	Land-scape 17	Bio-diversity 18	Water 19	Govern-ment Σ13-19	*Dehesa* Σ1-19
1. Total product (TP)	14.0	335.8	34.1	7.7	13.4		77.9	5.8	69.6	208.5	544.4
1.1 Intermediate product (IP)		96.1	31.5							31.5	127.5
1.1.1 Raw materials (RM)		44.4									44.4
1.1.2 Services (ISS)		51.7	31.5							31.5	83.1
1.2 Final product (FP)	14.0	239.8	2.7	7.7	13.4		77.9	5.8	69.6	177.1	416.8
1.2.1 Final product consumption (FPc)	14.0	264.7		7.1	13.3		77.1	4.8	69.6	171.8	436.5
1.2.2 Gross capital formation (GCF)		−24.9	2.7	0.6	0.1		0.8	1.1		5.2	−19.7
1.2.2.1 Manufactured (GCFm)		−46.5	2.7	0.6	0.1		0.8	1.1		5.2	−41.3
1.2.2.2 Natural growth (NG)		21.6									21.6
2. Intermediate consumption (IC)	14.0	268.9	11.1	2.5	0.1		70.1	1.8		85.6	354.6
2.1 Raw materials		185.5	0.0	0.1	0.0		0.1	0.0		0.2	185.7
2.1.1 Bought (RMb)		140.8	0.0	0.1	0.0		0.1	0.0		0.2	141.0
2.1.2 Own (RMo)		44.7									44.7
2.2 Services (SS)	14.0	60.9	11.1	2.5	0.1		70.1	1.8		85.4	146.4
2.2.1 Bought (SSb)		46.9	11.1	1.5	0.1		1.9	1.8		16.3	63.2
2.2.2 Own (SSoo)	14.0	14.0		1.0			68.1			69.1	83.1
2.2.2.1 Commercial (SScoo)	14.0	14.0		1.0			32.1			33.1	47.1
2.2.2.2 Non-commercial (SSncoo)							36.0			36.0	36.0
2.3 Work in progress used (WPu)		22.5									22.5
2.3.1 Manufactured (WPmu)		0.7									0.7
2.3.2 Environmental (WPeu)		21.8									21.8
3. Consumption of fixed capital (CFC)		46.6	1.0	1.2	0.0		2.1	0.4		4.8	51.4
4. Net value added (NVA)		20.3	22.0	4.0	13.3		5.7	3.6	69.6	118.1	138.4
4.1 Labour compensation (LC)		101.4	22.0	4.0	0.1		5.7	3.6		35.4	136.7
4.2 Net operating margin (NOM)		−81.1	0.0	0.0	13.1		0.0	0.0	69.6	82.7	1.6
4.2.1 Manufactured (NOMm)		−145.9	0.0	0.0	0.5		0.0	0.0		0.5	−145.3
4.2.2 Environmental (NOMe)		64.8			12.6				69.6	82.2	147.0
4.2.2.1 Ordinary environmental net operating margin (NOMeo)		43.2			12.6				69.6	82.2	125.4
4.2.2.2 Investment environmental net operating margin (NOMei)		21.6									21.6
5. Ecosystem services (ES)		65.0			12.6				69.6	82.2	147.2
6. Capital gain (CG)	−187.7	−199.9	−1.0	1.3	0.4		0.9	2.0		3.7	−196.2
6.1 Manufactured (CGm)		−75.5	−1.0	1.3	0.4		0.9	2.0		3.7	−71.8
6.2 Environmental (EAg)	−187.7	−124.4									−124.4
7. Adjusted change in environmental net worth (CNWead)	−187.7	−124.6									−124.6
8. Environmental income (EI)	−187.7	−59.6			12.6				69.6	82.2	22.6
9. Total income (TI)	−187.7	−179.6	21.0	5.3	13.7		6.6	5.6	69.6	121.8	−57.8

Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104692.

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