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Pablo Campos
Alejandro Caparrós
José L. Oviedo
Paola Ovando
Begoña Álvarez-Farizo
Luis Díaz-Balteiro
Juan Carranza
Santiago Beguería
Mario Díaz
A. Casimiro Herruzo
Fernando Martínez-Peña
Mario Soliño
Alejandro Álvarez
María Martínez-Jáuregui
María Pasalodos-Tato
Pablo de Frutos
Jorge Aldea
Eloy Almazán
Elena D. Concepción
Bruno Mesa
Carlos Romero
Roberto Serrano-Notivoli
Cristina Fernández
Jerónimo Torres-Porras
&
Gregorio Montero

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Instituto de Políticas y Bienes Públicos

INSTITUTO DE POLÍTICAS Y BIENES PÚBLICOS – CSIC

Instituto de Políticas y Bienes Públicos
Consejo Superior de Investigaciones Científicas
C/ Albasanz, 26-28
28037 Madrid (España)

Tel: +34 91 6022300
Fax: +34 91 3045710

http://www.ipp.csic.es

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Bridging the gap between national and ecosystem accounting

Pablo Campos*[1†], Alejandro Caparrós[1†], José L. Oviedo[1†], Paola Ovando[1], Begoña Álvarez-Farizo[1], Luis Díaz-Balteiro[2], Juan Carranza[3], Santiago Beguería[4], Mario Díaz[5], A. Casimiro Herruzo[2], Fernando Martínez-Peña[6], Mario Soliño[7], Alejandro Álvarez[1], María Martínez-Jáuregui[7], María Pasalodos-Tato[7], Pablo de Frutos[8], Jorge Aldea[9], Eloy Almazán[1], Elena D. Concepción[5], Bruno Mesa[1], Carlos Romero[2], Roberto Serrano-Notivoli[4], Cristina Fernández[1], Jerónimo Torres-Porras[3] and Gregorio Montero[7]

[1]Spanish National Research Council (CSIC), Instituto de Políticas y Bienes Públicos (IPP), C/ Albasanz, 26-28. E-28037 Madrid, [2]Technical University of Madrid (UPM), ETS Ingenieros de Montes, Ciudad Universitaria s/n. E-28040 Madrid, [3]Universidad de Córdoba, Cátedra de Recursos Cinegéticos y Piscícolas, Campus de Rabanales, Colonia San José, Ctra. Nacional IV-a, km 396. 14071 Córdoba, [4]Estación Experimental de Aula Dei (CSIC-EEAD), Av. Montañana 1.005, E-50059 Zaragoza, [5]Museo Nacional de Ciencias Naturales (CSIC-MNCN), Departamento de Biogeografía y Cambio Global (BGC-MNCN), C/ Serrano 115 bis, E-28006 Madrid, [6]Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Unidad de Recursos Forestales, Avda. Montañana 930. E-50059 Zaragoza, [7]National Institute for Agriculture and Food Research and Technology (INIA), Departamento de Selvicultura y Gestión Forestal (INIA - CIFOR), Ctra. A Coruña, km 7.5. 28040 Madrid, [8]Universidad de Valladolid (UVA), Facultad de Ciencias Empresariales y del Trabajo, C/ Chancillería 6. E-47003 Valladolid [9]Universidad de Valladolid (UVA), Instituto Universitario de Gestión Forestal Sostenible, Avda. de Madrid 44, Edificio E. E-34004 Palencia.

*Corresponding author. Email: pablo.campos@csic.es

[†] P.C., A.C. and J.L.O. share the first authorship.

Abstract

National accounting either ignores or fails to give due values to a country´s ecosystem services, products, total income and environmental asset variations. To overcome these shortcomings, we develop a spatially-explicit extended ecosystem accounting framework, which we test in the Mediterranean forests of Andalusia (Spain). This framework goes beyond the production boundary of standard national accounting by considering four private activities (forestry, hunting, residential and private amenity) and six public activities (mushroom, carbon, water, recreation, landscape and threatened biodiversity). To keep valuation consistent with standard accounts, we simulate exchange values for non-market goods and services. Manufactured capital and environmental assets are also integrated. Upon comparing extended to standard accounts, our results are 3.7 and 2.9 higher for gross value added and total income, respectively. These differences are explained primarily by the undervaluation of recreation, landscape and threatened biodiversity, and the omission of private amenity, carbon and water activities in standard accounts. Extended accounts, with their implementation of simulated exchange values, demonstrate that standard accounts measures only 17% of Andalusian forest ecosystem services.

Introduction

Ecosystem gross value added (GVA), also known as gross domestic product (GDP), as measured by the Standard System of National Accounts (SNA) (*1*), is generally regarded as sketchy at best when it comes to valuing the individual ecosystem services, products and total income of a country or region. This has spurred governments, consumers and private investors to seek an extended accounting framework for ecosystems to address the shortcomings of the SNA and its satellite system of Economic Accounts for Forestry (EAF) (*2*). As stated in the Rio +20 summit organized by the United Nations: "We recognize the need for broader measures of progress to complement the GDP in order to better inform policy decisions, and […] request the UN Statistical Commission […] to launch a program of work in this area" (*3*).

In this context, the System of Environmental-Economic Accounting 2012-Central Framework (SEEA-CF) was developed as a satellite of the SNA (hereinafter called "standard accounts") to improve the treatment of market environmental assets. However, just as with standard accounts, the SEEA-CF is limited to products traded in markets (*4*-*7*), and ignores individual ecosystem services embedded in products that are not subject to market transactions (e.g. threatened biodiversity). The System of Environmental Economic Accounting 2012-Experimental Ecosystem Accounting (SEEA-EEA) (*8-10*) aims to address this omission by proposing to measure all types of ecosystem service consumption (hereinafter called "ecosystem services") and environmental assets, but the SEEA-EEA is not yet a satellite standard accounting system. In fact, two of the most controversial components of SEEA-EEA methodology are, first, defining extended private and public economic activities, and, second, integrating market and non-market products into a single accounting framework. Several international initiatives are pilot-testing the SEEA-EEA, including the Wealth Accounting and Valuation of Ecosystem Services (WAVES) of the World Bank Ecosystem program (*11*), and other accounting applications have also been conducted for forest ecosystems at different scales, some using alternative approaches (*12-19*).

Our study constitutes the first attempt to measure at a regional scale forest ecosystem services, products, total income and environmental assets using a novel ecosystem accounting methodology, the "Agroforestry Accounting System" (AAS) (*20*) (hereinafter called "extended accounts"), which is consistent with the valuation criteria of standard accounts (*9, 21*). The contribution of our proposal (Supplementary text S1-S15) is twofold. First, extended accounts improve upon standard accounts and the SEEA-CF in that they consider environmental asset variations and natural resource growth and use, and treat manufactured capital and environmental assets in an integrated way. This entails: (i) explicitly considering as cost the intermediate consumption of own work-in-progress used up (e.g. standing timber or cork harvested) in the current period but grown in previous periods, which avoids attributing to the current period the product from a previous period as income; (ii) measuring as production function factors both environmental fixed assets services (e.g. land and standing biological resources) (*22*), and the intermediate consumption of own environmental services (e.g. carbon emission), allowing for a consistent integration of these values into the ecosystem extended accounts; and (iii) calculating total income by estimating capital gains and adding these to the net value added (NVA), thus making this estimate consistent with the concept of Hicksian income (*2, 21, 23-26*).

Second, we apply on a regional scale the simulated exchange value (SEV) (*12, 27*), a method that proposes to simulate market values for non-market ecosystem products for which no similar market exists (e.g., public recreation, landscape and threatened biodiversity). Despite the existence of a well-developed literature on non-market valuation methods and an increasing interest in extending the production boundary of standard accounts to non-market products (*28-30*), most non-market valuation studies tend to focus on the demand for non-market products and the associated consumer surplus (*31*). This approach does not produce values that can be consistently aggregated to the exchange values observed in markets and incorporated into standard accounts. To overcome this difficulty, the SEV method simulates the entire market, using non-market valuation methods to estimate demand and market data to estimate supply. Thus, assuming an appropriate market structure, we can determine the marginal price and quantity of the final product as if this had been traded in the market; that is, we determine the part of the consumer surplus that would be internalized in a potential market. This allows us to consistently integrate and compare in an extended accounts framework values from market products, such as timber, with values from non-market products, such as public recreation, both values estimated based on consumer preferences (*12*, *21*). This is new in the literature and is not only of theoretical interest but also has significant practical implications. This improves upon the government production cost base valuation criterion applied to public non-market products in standard accounts. It is also more consistent than previous approaches that have aggregated consumer surplus estimates and market values, such as the pioneering valuation of Earth ecosystem services by Costanza et al. (*32-34*) and the UK National Ecosystem Assessment (UK NEA) (*35, 36*).

In the next section, we develop the spatially-explicit results of extended accounts, focusing particularly on the following accounting figures: forest ecosystems extended gross value added (GVA) and net value added (NVA), ecosystem services (ES), environmental income (EI), total income (TI), environmental asset and total capital (C). We compare extended accounts results with the ES, GVA and NVA figures estimated with standard accounts. Ecosystem services (the value provided by nature to ecosystem product consumption) and environmental income (the income supplied by the ecosystem without paid labor, manufactured intermediate consumption and the user cost of manufactured capital) offer relevant information for all agents interested in the interaction between ecosystem assets and services and a country's economy (*5*). These individual values cannot be measured by standard accounts because the latter do not provide income estimates for individual products.

We test our extended accounts for 2010 in 43,864 km^2 of Mediterranean forests in the Andalusian region of Spain (Supplementary text S2). Our research presents all the conceptual challenges and practical difficulties of applying extended accounts to forests on a national or regional scale. Andalusia boasts a surface area of 87,268 km^2 and a population of 8.4 million people, figures resembling those of other countries in Europe (e.g. Austria), and exhibits a great variety of coniferous and hardwood forests, plants and animal species (*37*). We consider four private activities (forestry, hunting, residential and private amenity) and six public activities (mushroom picking, carbon, water, public recreation, landscape and threatened biodiversity). We conduct various surveys: a contingent valuation survey of 765 private forest landowners, a contingent valuation survey of 4,030 public visitors to forest recreation areas, a choice experiment survey of 3,214 households in Andalusia and of 836 households in the rest of Spain, a contingent valuation survey of 267 mushrooms pickers and a survey of 740 holders of Andalusian forest hunting reserves. We also improve natural growth function models for woody vegetation with our own measurements, create distribution maps for threatened biodiversity, run hydrological models, obtain microeconomic data from 58 agroforestry farm case studies and analyze the regional government's public forest expenditures. All this information is combined with data provided by the tiles of the Forest Map of Spain and the Third National Forest Inventory of Andalusia and is explained in detail in Supplementary Materials (text S3-S15, tables S1-S19 and figs. S1-S21).

Results

The most relevant result is the confirmation that extended accounts can indeed be applied at a large scale, and that spatially-explicit ecosystem accounting that is consistent with the standard accounts principle of exchange values is feasible. The detailed results that we present in the rest of this section are empirically relevant for one particular region, but they are equally, if not more, relevant as an illustration of the type of results that could be obtained for different ecosystems around the world.

Extended accounts estimate different economic figures based on the residual values offered by capital (Tables 1 and 2) and production (Table 3) accounts, the residual values being capital revaluation and net operating margin, respectively. At the beginning of 2010, Andalusian total forest capital comprised 94% environmental assets and 6% manufactured capital (e.g. forest plantations, buildings, equipment and other infrastructures) (Tables 1 and 2). Total capital was evenly distributed between private landowners and the government, but the latter held a much lower share (18%) of manufactured capital (Table 2).

Table 1. Social capital balance account of Andalusian forests

Class	1. Opening capital	2. Capital entries				3. Capital withdrawals					4. Revaluation	5. Closing capital
		2.1 Bought	2.2 Own	2.3 Other	2.4 Total	3.1 Used	3.2 Destructions	3.3. Reclasification	3.4 Other	3.5 Total		
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Capital (C) (2 + 3)	43,678,671	1,862	85,361	224,578	311,801	30,482		254,885	65,830	351,197	-401,847	43,237,428
2. Work in progress (WP)	1,103,754		37,953		37,953	30,476		36,848		67,324	107,776	1,182,160
3. Fixed capital (FC)	42,574,917	1,862	47,407	224,578	273,848	6		218,037	65,830	283,872	-509,623	42,055,268
3.1 Land (FCl)	38,990,247			224,578	224,578			218,037	65,830	283,867	-441,502	38,489,457
3.2 Biological resources (FCbr)	1,103,176										64,431	1,167,607
3.3 Manufactured fixed capital (FCm)	2,481,494	1,862	47,407		49,269				6	6	-132,553	2,398,205

Table 2. Landowner and government extended accounts social opening capital of Andalusian forests.

Activities	Environmental asset			Manufactured capital			Opening capital		
	Landowner (€·10^6)	Government (€·10^6)	Total (€·10^6)	Landowner (€·10^6)	Government (€·10^6)	Total (€·10^6)	Landowner (€·10^6)	Government (€·10^6)	Total (€·10^6)
Private	19,934		19,934	2,024	200	2,224	21,958	200	22,158
Forestry	4,812		4,812	424	196	620	5,236	196	5,432
Timber	1,387		1,387	226		226	1,613		1,613
Cork	1,023		1,023	12		12	1,035		1,035
Firewood	322		322	0		0	322		322
Nuts	23		23	0		0	23		23
Grazing	2,058		2,058	58		58	2,116		2,116
Conservation forestry				127		127	127		127
Government forestry					196	196		196	196
Hunting	767		767		4	4	767	4	771
Residential				1,600		1,600	1,600		1,600
Amenity	14,355		14,355				14,355		14,355
Public		21,263	21,263		258	258		21,521	21,521
Recreation		5,941	5,941		218	218		6,159	6,159
Mushrooms		1,414	1,414		5	5		1,419	1,419
Carbon		3,172	3,172					3,172	3,172
Landscape		4,928	4,928		9	9		4,937	4,937
Biodiversity		1,676	1,676		26	26		1,702	1,702
Water		4,132	4,132					4,132	4,132
Total	19,934	21,263	41,197	2,024	458	2,481	21,958	21,720	43,679

Table 3. Extended production account of Andalusian forests.

Class	Forestry 1 (€·10^3)	Hunting 2 (€·10^3)	Resi-dential 3 (€·10^3)	Private amenity 4 (€·10^3)	Recrea-tion 5 (€·10^3)	Mush-rooms 6 (€·10^3)	Carbon 7 (€·10^3)	Land-scape 8 (€·10^3)	Bio-diversity 9 (€·10^3)	Water 10 (€·10^3)	Forest ecosystems 11= ∑1 to 10 (€·10^3)
1. Total product (TP) (1.1 + 1.2)	419,182	32,485	51,508	1,134,735	207,696	43,238	224,578	381,747	79,519	277,649	2,852,338
1.1 Intermediate product (IP)	299,961	5,535	51,508								357,004
1.2 Final product (FP) (1.2.1 + 1.2.2)	119,221	26,950		1,134,735	207,696	43,238	224,578	381,747	79,519	277,649	2,495,334
1.2.1 Final product consumption (FPc)	46,100	5,535		1,134,735	202,713	43,093	224,578	379,384	75,303	277,649	2,389,090
1.2.2 Gross capital formation (GCF)	73,121	21,416			4,983	145		2,363	4,216		106,244
Environmental natural growth (ENG)	*37,953*	*20,883*									*58,837*
Manufactured gross fixed capital formation (MGFCF)	*35,168*	*532*			*4,983*	*145*		*2,363*	*4,216*		*47,407*
2. Total cost (TC) (2.1 + 2.2 + 2.3)	481,085	11,400	33,535	51,508	44,159	646	65,830	225,049	28,241		941,452
2.1 Intermediate consumption (IC)	157,678	6,609	2,732	51,508	16,021	166	65,830	206,082	7,956		514,581
2.1.1 Raw materials (RM)	32,764	5,627	609		281	6		123	110		39,521
2.1.2 Services (SS)	94,437	981	2,123	51,508	15,740	159	65,830	205,960	7,845		444,584
2.1.3 Work in progress used (WPu)	30,476										30,476
2.2 Labor cost (LC)	301,391	4,511	11,023		20,870	366		15,924	17,352		371,437
2.3 Consumption of fixed capital (CFC)	22,017	280	19,779		7,268	114		3,043	2,934		55,434
3. Net operating margin (NOM) (1 – 2)	-61,904	21,086	17,974	1,083,227	163,538	42,592	158,748	156,698	51,279	277,649	1,910,886
4. Gross valued added (GVA) (1 – 2.1)	261,503	25,876	48,776	1,083,227	191,676	43,072	158,748	175,665	71,564	277,649	2,337,757
5. Net valued added (NVA) (3 + 2.2)	239,487	25,597	28,997	1,083,227	184,408	42,958	158,748	172,622	68,630	277,649	2,282,323

The ecosystem service is estimated as the residual value of total product consumption minus total ordinary manufactured cost and normal return of ordinary manufactured capital within the accounting period (Table 4). In Andalusian forests, the value of ecosystem services represents 72% of total product consumption in 2010, of which 58% is contributed by private products (with commercial products constituting 4% and private amenity 54%) and 42% by public products (water 14%, carbon 11%, landscape 8%, recreation 5%, threatened biodiversity 2% and mushroom picking 2%) (Table 4). Following the standard classification of ecosystem services (*5*), the estimated values break down into 20% for provisioning services, 21% for regulating services and 59% for cultural services (Table 4). Fig. 1 shows a map of spatially-explicit values of forest ecosystem services in Andalusia in 2010.

Table 4. Extended accounts ecosystem services in Andalusian forests by individual product.

Class	Total product consumption	Ordinary intermediate consumption			Ordinary labor cost	Ordinary manufactured immobilized capital user cost	Ecosystem services	
		Raw materials	Services	Manufactured work in progress used				
	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(%)
1. Provisioning	493,153	37,756	21,705		152,965	-121,946	402,672	20.2
Timber	19,509	7,383	17,179		117,628	-130,313	7,632	0.4
Cork	49,146	23,276	649		4,836	-2,112	22,496	1.1
Firewood	2,325	227	91		486	162	1,359	0.1
Nuts	2,868	352	2,183		16,059	-15,726	0	0.0
Grazing	66,608	883	797		9,411	22,183	33,334	1.7
Hunting	31,953	5,627	711		4,257	2,092	19,266	1.0
Mushrooms	43,093	6	94		288	1,768	40,936	2.1
Water	277,649						277,649	13.9
2. Regulating	884,868	875	272,467		159,932	35,910	415,683	20.8
Carbon	224,578						224,578	11.3
Landscape	379,384	123	204,798		14,636	8,913	150,914	7.6
Biodiversity	75,303	110	6,490		14,553	13,958	40,192	2.0
Conservation forestry	34,673	163	11,976		21,479	1,054	0	0.0
Government forestry	170,930	479	49,202		109,264	11,985	0	0.0
3. Cultural	1,388,957	890	67,313		29,042	113,979	1,177,733	59.0
Private amenity	1,134,735		51,508				1,083,227	54.3
Public recreation	202,713	281	13,681		18,019	76,226	94,506	4.7
Residential	51,508	609	2,123		11,023	37,753	0	0.0
Total	2,766,978	39,521	361,486		341,939	27,943	1,996,088	100.0

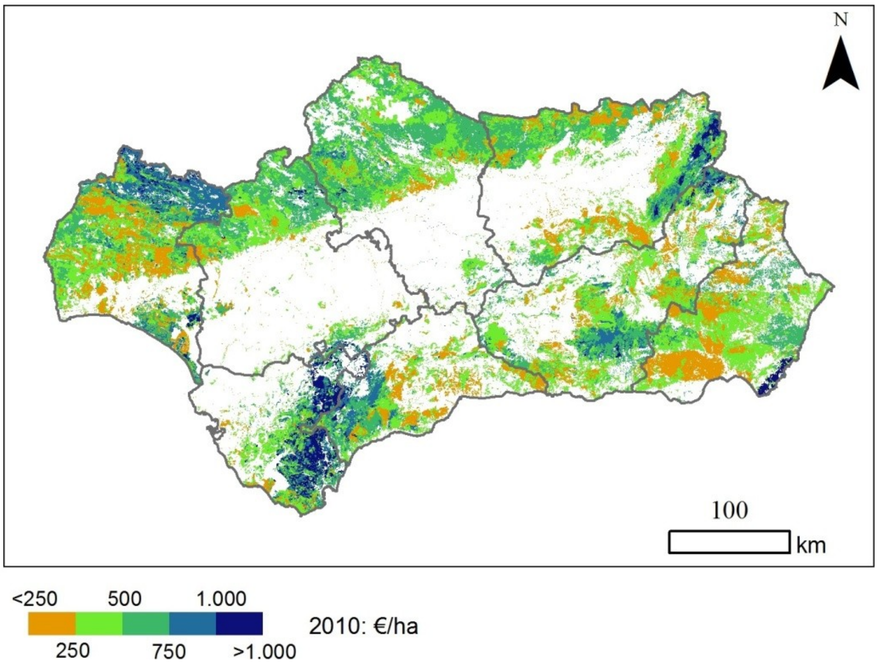

Fig. 1. Value of ecosystem services in Andalusian forests.

Gross value added and net value added represent the forest gross and net operating income estimated from the production account (Table 3). These figures differ dramatically between extended and standard accounts: the gross value added is 3.7 times higher when estimated by extended accounts (Table 5), a difference explained mostly by the omission in standard accounts of private amenity and carbon uptake, and by the partial incorporation of public recreation and landscape. The standard EAF (*2*), which also excludes from the SNA government forest expenditures and products, estimates a gross value added (*38*) that is 11.1 times lower than that estimated by extended accounts. Capital gains, measured as capital revaluation (Table 2) minus unexpected capital destruction and accounting capital adjustments (Table 5), also diverge between standard and extended accounts. In practice, standard accounts do not measure forest capital gains while extended accounts estimate capital losses (negative capital gains) of -602 million euro (Table 5), mainly due to the depreciation of land environmental assets that occurred in Andalusian forests in 2010. Net capital formation is -8 million euro in standard accounts and 30 million euro in extended accounts (Table 5). This difference is explained by the natural growth of timber and cork registered in forestry activity in extended accounts but omitted in standard accounts. Thus, forest total income, which adds capital gains to the net value added, can only be measured by extended accounts and is 2.9 times higher than the net value added of standard accounts (Table 5).

Table 5. Production, cost and income indicators of Andalusian forests from extended and standard accounts.

Class	Forestry 1 ($€·10^3$)	Hunting 2 ($€·10^3$)	Resi-dential 3 ($€·10^3$)	Private amenity 4 ($€·10^3$)	Public recreation 5 ($€·10^3$)	Mush-rooms 6 ($€·10^3$)	Carbon 7 ($€·10^3$)	Land-scape 8 ($€·10^3$)	Bio-diversity 9 ($€·10^3$)	Water 10 ($€·10^3$)	Forest ecosystems 11= ∑ 1 to 10 ($€·10^3$)
Extended accounts (AAS)											
1. Total product (TP) (1a + 1b)	419,182	32,485	51,508	1,134,735	207,696	43,238	224,578	381,747	79,519	277,649	2,852,338
1a. Total product consumption (TPc)	346,060	31,953	51,508	1,134,735	202,713	43,093	224,578	379,384	75,303	277,649	2,766,978
1b. Gross capital formation (GCF)	73,121	532	0		4,983	145		2,363	4,216		85,361
2. Total cost (TC) (2a + 2b + 2c)	481,085	11,400	33,535	51,508	44,159	646	65,830	225,049	28,241		941,452
2a. Intermediate consumption (IC)	157,678	6,609	2,732	51,508	16,021	166	65,830	206,082	7,956		514,581
2b. Consumption of fixed capital (CFC)	22,017	280	19,779		7,268	114		3,043	2,934		55,434
2c. Labor cost (LC)	301,391	4,511	11,023		20,870	366		15,924	17,352		371,437
3. Net operating margin (NOM) (1 – 2)	-61,904	21,086	17,974	1,083,227	163,538	42,592	158,748	156,698	51,279	277,649	1,910,886
4. Gross value added (GVA) (1 – 2a)	261,503	25,876	48,776	1,083,227	191,676	43,072	158,748	175,665	71,564	277,649	2,337,757
5. Net Value Added (NVA) (4 – 2b)	239,487	25,597	28,997	1,083,227	184,408	42,958	158,748	172,622	68,630	277,649	2,282,323
6. Net capital formation (NCF) (1b – 2b)	51,105	253	-19,779		-2,285	31		-680	1,283		29,927
7. Capital gains (CG)	146,215	509	-74,538	-686,140	930	-112	9,861	1,069	369		-601,838
8. Change of net worth (CNW) (6 + 7)	197,320	762	-94,318	-686,140	-1,355	-81	9,861	389	1,652		-571,911
9. Capital income (CI) (3 + 7)	84,311	21,594	-56,565	397,087	164,467	42,480	168,609	157,766	51,648	277,649	1,309,048
9a. Environmental income (EI)	243,691	23,013	0	397,087	178,235	42,424	168,609	147,849	50,266	277,649	1,528,824
9b. Manufactured income (MCI)	-159,380	-1,419	-56,565		-13,768	56		9,917	1,382		-219,776
10. Total income (TI) (5 + 7)	385,702	26,106	-45,542	397,087	185,337	42,846	168,609	173,691	69,000	277,649	1,680,485
11. Ecosystem services (ES)	64,821	19,266	0	1,083,227	94,506	40,936	224,578	150,914	40,192	277,649	1,996,088
Standard accounts (SNA)											
1. Total product (TP) (1a + 1b)	353,479	32,485	51,508		43,561	43,238		35,935	29,181	236,002	825,388
1a. Total product consumption (TPc)	318,311	31,953	51,508		38,577	43,093		33,572	24,964	236,002	777,981
1b. Gross capital formation (GCF)	35,168	532	0		4,983	145		2,363	4,216		47,407
2. Total cost (TC) (2a + 2b + 2c)	422,860	11,400	33,535	51,508	36,591	646		27,086	28,169		611,794
2a. Intermediate consumption (IC)	99,453	6,609	2,732	51,508	8,453	166		8,119	7,883		184,923
2b. Consumption of fixed capital (CFC)	22,017	280	19,779		7,268	114		3,043	2,934		55,434
2c. Labor cost (LC)	301,391	4,511	11,023		20,870	366		15,924	17,352		371,437
3. Net operating margin (NOM) (1 – 2)	-69,381	21,086	17,974	-51,508	6,969	42,592		8,849	1,012	236,002	213,594
4. Gross value added (GVA) (1 – 2a)	254,026	25,876	48,776	-51,508	35,108	43,072		27,816	21,298	236,002	640,465
5. Net value added (NVA) (4 – 2b)	232,010	25,597	28,997	-51,508	27,840	42,958		24,773	18,364	236,002	585,031
6. Net capital formation (NCF) (1b – 2b)	13,151	253	-19,779		-2,285	31		-680	1,283		-8,027
7. Ecosystem services (ES)	50,598	19,266	0		0	40,936		0	0	236,002	346,802
Economic accounts for forestry (EAF)											
1. Final product (FP)	428,938										428,938
2. Intermediate consumption (IC)	217,928										217,928
3. Gross value added (GVA) (1 – 2)	211,010										211,010
4. Labor cost (LC)	186,380										186,380
5. Mix gross operating margin (MGOM) (3 – 4)	24,630										24,630
Accounting systems comparison											
GVA_{AAS}/GVA_{SNA}	1	1	1	-21	5.5	1		6.3	3.4	1.2	3.7
NVA_{AAS}/NVA_{SNA}	1	1	1	-21	6.6	1		7	3.7	1.2	3.9
GVA_{AAS}/GVA_{EAF}	1.2										11.1
TI/NVA_{SNA}	1.7	1	-1.6	-7.7	6.7	1		7	3.8	1.2	2.9
ES_{AAS}/ES_{SNA}	1.3	1				1				1.2	5.8

Environmental income, estimated as the environmental net operating margin plus environmental capital gains (*20*) of products with a total or partial natural regeneration process, accounts for 91% of this total income (Table 5). The largest share of this environmental income comes from private amenity (26%), followed by water (18%), forestry (16%), public recreation (12%), carbon (11%), landscape (10%), threatened biodiversity (3%), mushroom picking (3%) and hunting (2%) (Table 5). Fig. 2 presents a group of maps showing spatially-explicit estimates of this environmental income by individual product. Additional maps with detailed spatially-explicit results are available at http://vicaf.cchs.csic.es (provisional access user name: guest1, and password: Hal024Euc61Pi23f).

Our results show that if we do not overcome the gaps of standard accounts and its satellite systems when applied to ecosystems, we risk making a substantial undervaluation of forest ecosystem services, total income and environmental assets. In our application, this is particularly true for non-market ecosystem environmental assets and their services. Landowner non-market private amenity stand out with respect to other forest products, with a total product value 2.25 times greater than that of sold products (i.e., forestry, hunting and residential) (Table 5). This orientation of Andalusian forest management toward the consumption of non-market amenity products by non-industrial private landowners is explained partly by a dominance of private ownership in these forests (73% private versus 27% public) and partly by private landowners' preferences towards recreation, lifestyle and leisure-related motivations for owning a forest property (*39*). Although the contribution of most public non-market products is not particularly noteworthy, when considered individually, when considered in unison (e.g. public recreation, landscape and threatened biodiversity) it slightly exceeds the contribution of private amenity to total income (Table 5).

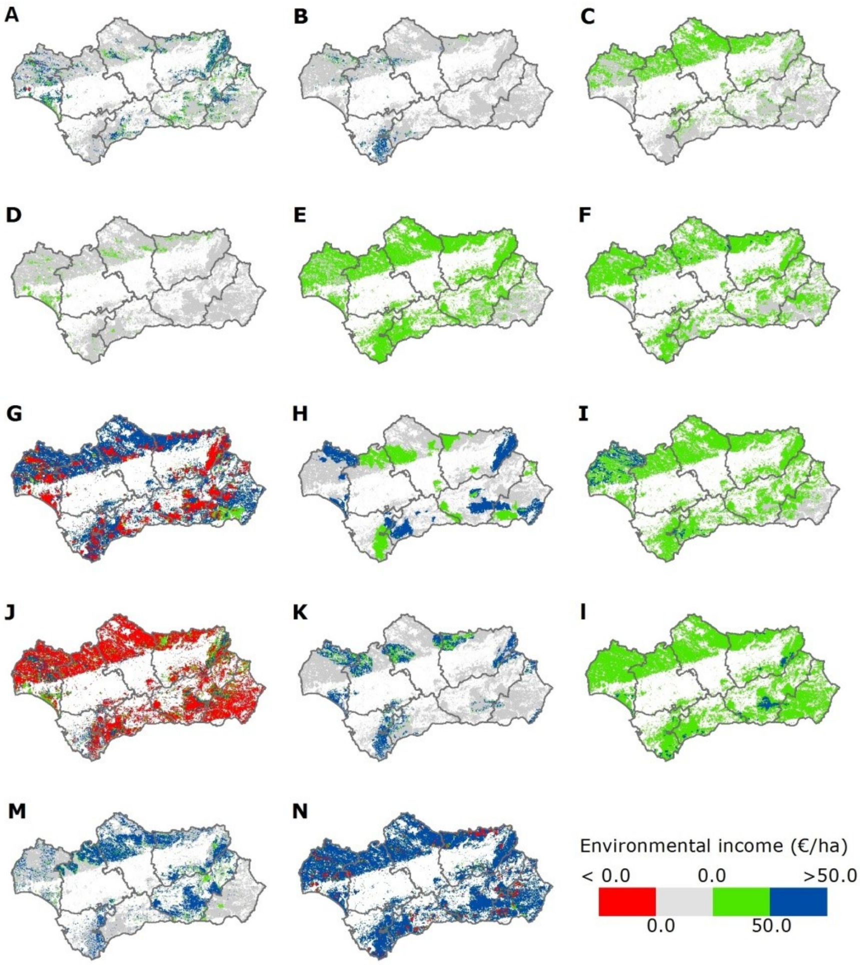

Fig. 2. Maps of environmental incomes by individual products and for all products aggregately in Andalusian forests (2010: €/ha). (**A**) timber, (**B**) cork, (**C**) firewood, (**D**) nuts, (**E**) grazing, (**F**) hunting, (**G**) private amenity, (**H**) public recreation, (**I**) mushrooms, (**J**) carbon, (**K**) landscape, (**L**) biodiversity, (**M**) water, (**N**) all products.

Policy remarks and discussion

The extended accounts framework proposed here is a fine-scale spatially-explicit ecosystem accounting method that registers the complexities and values generated by diverse forests in the economy of a region or a country. A generalized application of the total income concept and the simulated exchange value method would allow us to compare in a consistent way environmental asset changes, ecosystem services, income and capital consistently among ecosystems, regions, and countries, while maintaining the exchange value principle of standard accounts.

Although governments spend significant sums of money on managing and protecting forest ecosystem assets and their services, decisions are generally made without considering the appropriate economic statistics.

Standard accounts show that forestry represents 0.14% of Andalusian gross value added and 3.2% of the primary sector (*2*, *38*). When applying extended accounts, these contributions rise to 0.51% of the regional and to 35.45% of the primary sector, respectively (see Table 5 and Ref. (*38*)). As can be seen, the implications for the primary sector are immense.

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

Estimating simulated exchange values for non-market products would also allow us to make consistent comparisons of forest ecosystem services and income among countries, regardless of the ways that people access consumption. For example, although recreational visits to national parks in one country are charged while in another country they are open-access, the income generated could be consistently measured through extended accounts, with the only variation being who receives the income in each case. By contrast, standard accounts would record the market price in the first case, but only production costs in the second case, thus disrupting consistency in measuring income with this standard accounts, as production costs do not reflect consumer preferences.

A shortcoming of both extended and standard accounts is that total forest income does not include the environmental income embedded in all national industries. One example is the case of environmental income obtained by the tourism industry in surrounding natural areas (*13*) when these areas increase the value of the marketed services of local hostelry. In addition, several assumptions have influenced our results. The effect of the discount rate on asset values (*40*) is the clearest example but, as detailed in Supplementary Materials, there many more. That being said, measuring income entails valuating known economic facts as well as unknown expected future economic facts, and standard accounts are not free either of these needed assumptions.

There is still a long way to go before standard accounts can incorporate all the improvements tested in this novel extended accounts application. We do, however, believe that the application's scale and the relevance of the figures obtained show that we can generate spatially-explicit national income figures for forest ecosystems beyond strict market transactions. Although the changes required to implement these accounting improvements in current satellite standard accounts and statistical offices are substantial, the methods and data collection protocols from our extended accounts are well-developed and could be put into practice straight away by statistical offices if resources were made available. This is a path worth pursuing if we want to develop extended accounts that effectively reflect stock variation, ecosystem services, and natural resource use in economic activities.

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Additional author notes

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

Supplementary Materials for

Bridging the gap between national and ecosystem accounting

Pablo Campos,* Alejandro Caparrós, José L. Oviedo, Paola Ovando, Begoña Álvarez-Farizo, Luis Díaz-Balteiro, Juan Carranza, Santiago Beguería, Mario Díaz, A. Casimiro Herruzo, Fernando Martínez-Peña, Mario Soliño, Alejandro Álvarez, María Martínez-Jáuregui, María Pasalodos-Tato, Pablo de Frutos, Jorge Aldea, Eloy Almazán, Elena D. Concepción, Bruno Mesa, Carlos Romero, Roberto Serrano-Notivoli, Cristina Fernández, Jerónimo Torres-Porras and Gregorio Montero

*Corresponding author. E-mail: pablo.campos@cchs.csic.es

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Supplementary text for

Bridging the gap between national and ecosystem accounting

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Supplementary text

S1. Methods summary

Extended accounting aims to estimate total income, defined as the maximum net consumption of forest products that can be used up without diminishing net worth (*24-26*) in a given period (Supplementary text S3). This definition of total income means that income is calculated by adding any change in net worth to net consumption (*16, 24, 25*). Economic activities are differentiated between private and public (fig. S5), and they distinguish activities that are the responsibility of the landowner (private accounts) from those that are the responsibility of the government (public accounts) (*12, 16, 18*). Measuring total income requires registering economic data in production and capital accounts in an infinite time horizon (fig. S6).

Standard accounting resorts to using prices imputed from real markets of identical or similar substitute products when there are no observed prices for non-market products (Supplementary text S4). Standard accounts also equate the values of government-funded forest ecosystem products to the production cost of final products used by consumers free of charge and gross fixed capital formation. This valuation criterion does not provide results on the potential simulated exchange value of public products.

For non-market ecosystem products, an alternative is to apply non-market environmental valuation methods (Supplementary text S6 and fig. S7). These methods are usually applied to obtain the consumer surplus. However, this measure is not compatible with the standard and extended accounts principle of valuating products according to their real or simulated market prices. Simulated Exchange Value uses non-market valuation methods to simulate demand and market data to estimate product supply (Supplementary text S7). We apply this method in order to simulate the entire market (demand and supply) and so obtain marginal exchange prices for final products for which there are no observed market prices, or for which we do not have prices in similar markets elsewhere.

Using the supply and demand functions, and given an appropriate market structure, we can determine, within a context of a partial equilibrium analysis, what the marginal price and quantity of the final product would be if this had been traded in the market. That is, while non-market valuation alone estimates demand and usually focuses on consumer surplus, simulated exchange value determines which part of this consumer surplus would be internalized in a potentially implemented market. This difference is new in the literature and is not only of interest theoretically but also has significant practical implications.

S2. Regional application of forest ecosystem accounting

S2.1 Andalusia forests

We selected the Mediterranean forest ecosystems of the Andalusia region for the implementation of the extended accounts of the Agroforestry Accounting System (AAS). Andalusia is located in southern Spain, covers a surface area of 87,597 km2 with rich biodiversity, and has 8.4 million inhabitants. Its territory begins at sea level and rises to over 3,400 meters, and contains one of Spain's maximum rainfall points in the Sierra de Grazalema (Cádiz province) and one of the nation's lowest precipitation areas in the Tabernas desert (Almería province). The Mediterranean forests of Andalusia cover 43,864 km2 and are one of the 25 identified biodiversity hotspots in the world (*37*). They are covered by native hardwood forests consisting of the genus Quercus and others (43%), coniferous forests (20%), eucalyptus plantations (4%), shrublands (28%), natural grassland (3%) (41) and other forest land (2%) (table S3 and fig. S8).

These forests were shaped by human intervention to create the current cultural landscape (*42*), which takes the form of vegetation mosaics. There is a general consensus that over the centuries this process has increased the biodiversity and productivity of natural palatable plants that are available for animal consumption (*43, 44*). Extensive stockbreeding and the government's historic forest plantations in marginal forest areas have decisively shaped the pristine forest into cultural landscape mosaics, although they are in decline because of diminishing silvicultural works and livestock grazing in some areas.

For a long time, Andalusian forests have been used by the local population to obtain a variety of raw materials and food. In modern times, the improving household incomes of the Spanish population have created new demands for forest products, which are consumed by landowners, public users, and the society as a whole, primarily on local and national scales. These demands have led landowners to manage forests in favour of the production of amenities, which are privately consumed in most of the region's forests. These new demands have also influenced Andalusia's policy of promoting forest ecosystem services and products. This impacts the regional government's forest policy, which is increasingly oriented towards supplying public services to society.

S2.2 Data sources

We have used data from a wide variety of sources, at different spatial scales, although the minimum scale at which all estimations have been georeferenced is the vegetation type tiles of the Forest Map of Spain. The data sources are: (i) a survey of 765 private forest landowners, a survey of 4,030 public visitors in different forest recreation areas, a survey of 3,214 adults (> 18 years old) from households in Andalusia and a survey of 836 adults from households in the rest of Spain (Supplementary text S6), (ii) natural growth function models of biophysical measurements for woody vegetation provided by the literature and own estimates (Supplementary text S8), (iii) the tiles in the Forest Map of Spain (MFE), which are integrated with the information from the parcels of the Third National Forest Inventory (IFN3) of Andalusia (Supplementary text S9), (iv) the list of threatened wild species and their distribution maps in Andalusia (Supplementary text S10), (v) hydrological data from the Andalusia government (Supplementary text S11), (vi) a phone survey of 4,219 Andalusia households (Supplementary text S12), (vii) microeconomic data from 58 agroforestry farm case studies with bookkeeping data and an aggregated surface of 1,081 km^2, (viii) a survey of 740 holders of Andalusia forest hunting reserves (Supplementary text S14), and (ix) public forest expenditures of the regional government.

The period during which we collected data started in April 2008 and ended in June 2012, although all estimates are presented in 2010 euros (*45*).

S3. Extended accounts for forest ecosystems: the Agroforestry Accounting System

The Agroforestry Accounting System (hereinafter called extended accounts) extends the forest production function beyond the boundary of the standard System of National Accounts (hereinafter named standard accounts) based on the following criteria: (i) it presents georeferenced estimates by forest vegetation types (in our application this comprises the Andalusia forest area delimited by the Spanish forest law (*46*)), (ii) it works with three independent decision-makers: the landowner, the government and free access consumers, (iii) consumption of non-market final products is measured using the Simulated Exchange Value method, (iv) landowner and government have independent responsibilities assigned according to single economic activities/sub-activities, (v) government expenditures on forests are classified according to standard national accounting cost and production criteria and ascribed to the main economic activity (tables S4 and S5), (vi) government economic property rights are assumed for carbon sequestration, (vii) the criteria used for classifying economic activities is the main product that they produce, and (viii) the social production account distinguishes between private and public economic costs and products for each specific private and public activity (fig. S5).

The standard accounts (SNA) include the satellite Economic Account for Forestry activity (EAF). The EAF registers only the landowners' commercial products from the forest ecosystem, and omits some forest products that appear in the government and household standard accounts. The extended accounts regroup all forest ecosystem activities in an extended production account, which registers the extended landowner and government production accounts. The total individual product from extended accounts permits single measurements of total capital and the classification of this capital as either an environmental asset or manufactured capital. Extended accounts aim to measure both total income and environmental assets.

S3.1 Economic activity

From an accounting perspective, an economic activity is the relevant classification unit of a production process generating economic products. A natural production process is characterised by the absence of paid labour, manufactured input (intermediate consumption) and manufactured fixed capital during the generation of the products. However, the natural process generally requires the use of unpaid gatherers, and/or the appropriation of the forest environmental asset. By contrast, a manufactured production process requires investments in paid labour, manufactured intermediate consumption and manufactured fixed capital to obtain the products. Forest products are usually generated by the simultaneous confluence of both production processes (natural and manufactured) in the different economic activities.

Thus, an economic activity is defined by one or more products for which full production and capital accounts are implemented. An activity originating only from a natural production process may lead to a situation in which the production account only registers the value of the forest products on the production side and the work in progress used on the cost side. Standard accounts do not recognise an economic activity with a production process solely originating from a natural production function. Thus, if the product is traded the ecosystem service value is embedded in the final product consumption of the single economic activity and in the forest environmental asset value embedded in the forest market price.

Extended accounts classify forest economic activities based on the criterion of ownership. They distinguish between private and public activities according to the character of its primary product.

Private activities

The primary product of a private activity is usually intended for sale in formal markets, where the activity has observable commercial prices. These products are managed by a private or public independent economic unit that has acquired the exclusive right to their use and to the transfer of their capital value to third parties. In our application, we distinguish four private activities: forestry, hunting, residential and private amenity.

Forestry is composed of timber, cork, nuts, grazing, forestry conservation and government forestry sub-activities. *Timber*, *cork*, *nuts* and *grazing* sub-activities represent the production for which they are named. Forestry conservation and government forestry are incorporated into standard accounts as financed by government expenditures but their intermediate products are not recognised by standard accounts as producing silvicultural products. *Forestry conservation* includes government interventions to compensate landowner silvicultural works that generate intermediate products with the primary purpose of being used up as inputs to maintain and/or enhance public activities. In this case, we assume that the landowner bears the risks associated with the implementation of silvicultural works, and we simulate that the government "buys" from the landowner the intermediate products generated by forestry conservation, which are used up as own intermediate consumption (input) by the public activities of landscape conservation and threatened biodiversity preservation (table S4 and Supplementary text S6). *Government forestry* represents the direct government expenditures on forest fire-fighting works (excluding fire prevention) and the maintenance of historical public livestock paths (*cañadas*) and visitors' free access walking trails. The intermediate product generated by this sub-activity is used up as input by public recreation and landscape conservation activities.

Hunting activity includes game captures, as a substitute of the rental price for wild game species grazing, and government costs devoted to hunting management.

Residential activity includes intermediate and final production accruing from commercial and recreational dwellings in forest properties (with their auxiliary buildings and installations). Landowner's residential houses provide intermediate services that are used up by the private amenity activity.

Private amenity activity stems from the exclusive enjoyment by landowners of different environmental products and other amenities enjoyed in non-market final product consumption (*47*). This is the only private activity that does not meet the criteria that the final product be traded in a formal market; only the asset value associated with this amenity consumption is marketed as part of the land price.

Public activities

An activity is classified as public if its primary product is consumed and/or is appropriated without any commercial or equivalent transaction. Forests provide public products that, although not subject to market transactions, are economic because they are scarce and their provision usually involves a government manufactured production cost (tables S6 and S7 and fig. S9, S10 and S11). These public products are valued either by using market prices from similar markets (after being harvested they could become market products, e.g., mushrooms gathered by visitors with primary recreation motivation and open access to the forest) or by modelling the exchange value from a simulated market using the Simulated Exchange Value method (Supplementary text S7). Public activities are ascribed to forest ecosystem management performed by the government. In our application, we consider six forest public activities: mushroom picking, carbon, water, public recreation, landscape conservation and threatened biodiversity preservation.

Mushroom picking involves the collection of mycological species by open-access gatherers either for recreational or commercial purposes.

C*arbon* represents the sequestration of carbon resulting from the management and natural growth of woody vegetation in the forest.

Surface *water* includes the run-off water produced by forests and stored in government watershed dams.

Public recreation is the consumption of recreation services such as open-access forest recreational areas and trails managed by the government and open to the general public.

Landscape conservation are the services associated with conserving current vegetation and related scenic values in order to prevent the potential future loss of the current forest landscape.

Threatened *biodiversity preservation* involves preserving current levels of endangered wildlife and flora species in order to avoid future potential loss of these unique species.

S3.2 Production function

The forest production function (F) in our accounting framework is similar to the production function of model B in the Experimental Ecosystem Accounting (SEEA-EEA) (*8, 10, 20, 45*) guidelines that classifies the ecosystem environmental asset as nature´s production factor (*48*). We have refined it by extending the forest total products and production factors:

$$TP \equiv F(IC, LC, EFA, MFC), \qquad \text{[SM. Eq. 3.1]}$$

where IC stands for intermediate consumption, LC for labour costs, EFA for environmental fixed assets and MFC for manufactured fixed capital.

Total product (TP) [SE. Eq.1.1] is supplied as intermediate product (IP), which is used up in the same period by other forest activities, and as final product (FP), which could be final product consumption (FPc) or gross capital formation (GFC) [SE. Eq.1.2]. Total product consumption (TPc) is therefore the sum of intermediate product and final product consumption [SE. Eq.1.3].

Total cost [SE. Eq.1.4] includes intermediate consumption, labour cost and the consumption of manufactured fixed capital at replacement prices (table S4). Intermediate consumption [SE. Eq.1.5] stems from the forest intermediate product used up by the forest activities (own intermediate consumption of raw materials and services), the use of bought manufactured raw materials and services, carbon dioxide withdrawals, and environmental work-in-progress used that contribute to the forest total product for the accounting period. Labour costs [SE. Eq.1.6] comprise employees' paid salaries as well as the imputed residual value estimated for paid self-employed labour. Open-access forest product gatherers with a recreational motivation are not assigned any production costs

(*49*). Total capital is the sum of the environmental work in progress and fixed capital [SE. Eq.1.7] and [SE. Eq.1.8].

S3.3 Total products

Total products are valued *ad hoc* based on the institutional arrangement of product individual consumption and own investment. We value products using market prices (at producer prices), production costs increased by a normal margin, hedonic pricing, simulated exchange values and residual prices.

Private total products

We have identified ten single private products. *Forestry* products include *timber*, *cork*, *firewood, nuts, grazing, forestry conservation* and *government forestry*. The remaining products are *hunting*, *residential* and *private amenity*.

Timber, *cork* and *firewood* products are classified into intermediate product, sales, natural growth (environmental gross work in progress formation) and self-consumption (commercial products and private amenity) (table S4). Their valuation criteria are described in Supplementary text S7. *Nuts* products include pine-nuts and chestnut harvested. Although pine-nuts mature in a three-year period, we consider them to be produced within the year.

Grazing products are acorn and grass (including browse and other fruits) (table S2), which are intermediate products used up as input (own intermediate consumption) by livestock. We have not included livestock products in our extended accounts (where livestock is considered for a sample of Andalusian forests case studies (*47, 50*)). However, grazing implicitly includes the livestock effect on forest natural resource consumption. The evaluation criteria of these grazing intermediate products are described in Supplementary text S11.

Forestry conservation and *government forestry* total products are formed by intermediate products and own investment (manufactured gross fixed capital formation).

We value the total product from *hunting* by multiplying the annual captures from an ideal steady state of the animal population times the private environmental price (*51*) (or rental price (*52*)). We value the government manufactured fixed capital formation in *hunting* at production cost with an additional margin (Supplementary text S12).

Residential products are intermediate products that are considered as an input (own intermediate consumption) for private amenity.

The product from *private amenity* is a final consumption of private amenity services valued using the contingent valuation method (Supplementary text S6.1).

Public total products

We consider six public products: mushroom picking, carbon sequestration, water, recreation, landscape conservation and threatened biodiversity preservation. In this case, each product corresponds to a single activity.

Mushroom picking total product is the aggregated value of mushroom-picking consumption by public gatherers and government gross fixed capital formation on this activity (Supplementary text S10 and table S4).

Carbon total product is the natural growth of trees and shrubs during the period valued at the carbon market price (Supplementary text S5 and table 4).

Water total product is a residual value; that is, it is an unobservable final environmental product because it is embedded in the products from irrigated agriculture. We estimate this product by modeling water yield and the environmental price embedded in the irrigated land price. We have not identified government costs for forest water (Supplementary text S9 and table 4).

For the *recreation* public product, we estimate the marginal accounting equilibrium price and the corresponding quantity by simulating a market (Supplementary text S6 and S7). The final product includes final consumption estimated from the simulated recreation market using a contingent valuation survey of visitors to estimate the price, a survey of households to estimate the quantity (demand), governmental costs from this activity (supply) (Supplementary text S6.2 and S7.1), and manufactured gross fixed capital formation from construction and equipment deriving from the management of the recreation areas and public trails (table S4).

For *landscape conservation* we follow a similar approach as we did for recreation. We simulate public demand against the net return of the government cost used up for supplying the actual landscape conservation final product consumed without direct payment by the general public (Supplementary text S6.3 and S7.2). The simulated market for landscape conservation is derived from a choice experiment survey to Andalusian households (demand) and from governmental costs on this activity (supply). We estimate the landscape final product as the aggregated value of government final consumption (valued at ordinary total cost plus a normal manufactured margin), the simulated exchange value for the conservation of landscape services and the manufactured gross fixed capital formation from constructions and equipment originating in the public management domain (Supplementary text S6.2 and table S4).

We also followed this approach for threatened biodiversity preservation. Final product consumption was estimated using a choice experiment survey to households. As for landscape conservation, the simulated exchange value obtained from this survey is assumed to be additional to the government ordinary total cost to obtain the final product consumption for these services. Thus, *threatened biodiversity preservation* final product is integrated by final product consumption and government manufactured gross fixed capital formation. The final product consumption is valued by the total ordinary cost of manufactured production executed by the government in the current period plus the simulated exchange value for preserving these services, which is obtained from households' stated marginal willingness to pay estimated from the mentioned choice experiment. The government ordinary cost includes the cost of the historical depreciation of buildings and existing equipment at the beginning of the exercise that are used in the public management of threatened wild species (Supplementary text S6.3 and S7.2 and table S4).

S3.4 Total income

We define forest *total income* as the maximum forest potential consumption during the accounting period that does not reduce the real value of the forest capital (*2, 21, 23, 25, 26, 53*). This is equivalent, in extended accounts, to saying that total income [SE. Eq.1.9] is forest *net consumption* [SE. Eq.1.10] plus the *change in net worth* (*24,54*) [SE. Eq.1.11]. The latter is estimated as net capital formation (NCF) plus real capital gains (CG) (*25*).

Extended accounts allow us to estimate *total income* as the following three items: (i) net value added plus capital gains [SE. Eq.1.12], (ii) labour cost plus capital income [SE. Eq.1.13] and (iii) environmental income, labour cost and manufactured capital income [SE. Eq.1.14].

Net value added estimates operating income from the production accounts [SE. Eq.1.15] and represents compensations to labour and capital services, the later named here as net operating margin [SE. Eq.1.16] and [SE. Eq.1.17]. More precisely from the production account, environmental asset services are compensated by the environmental net operating margin and immobilised manufactured capital services are compensated by the manufactured net operating margin [SE. Eq.1.18]). The manufactured net operating margin [SE. Eq.1.19] is estimated as a normal return rate to the immobilised manufactured capital or directly as a residual value if the environmental net operating margin is null.

Net capital formation [SE. Eq.1.20] is gross capital formation minus consumption of fixed capital. *Gross capital formation* [SE. Eq.1.21] includes environmental work in progress formation and gross fixed capital formation. Other classification of gross capital formation [SE. Eq.1.22] is the natural growth standing at closing period (NG) and the manufactured gross fixed capital formation (MGFCF). We measure natural growth standing at closing period as gross capital formation and environmental work in progress used as intermediate cost (*25*).

Capital revaluation is the balance of capital entries and withdrawals reflected in the capital account [SE. Eq.1.23] (table S5). During the accounting period there are (i) capital entries from bought capital, gross capital formation and other capital entries, and (ii) capital withdrawals classified in work in progress used up, unexpected capital destructions, capital withdrawal reclassification of natural growth of woody opening work in progress, capital in the period and other capital withdrawals.

Capital gains [SE. Eq.1.24] are composed of capital revaluation and capital adjustment (table S5). *Capital adjustment* [SE. Eq.1.25] includes previously unexpected events and consumption of fixed capital at inventory prices in order to avoid double counting (*26*). The capital gains [SE. Eq.1.26] can be also defined as environmental capital gains plus manufactured capital gains.

Capital income is the total net return to capital from net operating margin and capital gains [SE. Eq.1.27]. Capital income can also be estimated as environmental income plus manufactured capital income [SE. Eq.1.28].

Forest ecosystem *profitability* represents the net return to immobilised capital against their economic services during the accounting period. *Immobilised manufactured capital* [SE. Eq.1.29] is made up of the working capital used up from manufactured bought intermediate consumption and manufactured opening fixed capital (MFCo). To estimate immobilised manufactured capital [SE. Eq.1.30] at producer and purchase prices we consider bought intermediate consumption, employee labour costs, final product sales, opening manufactured capital, bought manufactured capital entry and manufactured capital sales. The parameter c_i in Eq. 1.39 weighs the working capital employed and sales in an average annual figure for the respective items, being $0 < c_i < 1$.

The definition of total income discussed above shapes the Agroforestry Accounting System. Thus, products are separated into those consumed and those that continue to be in process (gross work in progress capital formation) that, when finished, are incorporated as fixed capital (gross fixed capital formation) to the forest total capital.

S3.5 Environmental income

Environmental income results from the service provided by an environmental asset. It is estimated by subtracting labour costs and normal returns of manufactured capital from total income [SE. Eq.1.31]. Environmental income from extended accounts is the sum of the environmental net operating margin and environmental capital gains [SE. Eq.1.32]. It can be calculated for each single product by using the residual value method, direct market rental prices or the hedonic pricing method. In extended accounts production and capital accounts provide all the data to estimate environmental income.

The challenge involved in making this estimate is measuring the normal manufactured capital income for each individual product [SE. Eq.1.27] and [SE. Eq.1.28]. The environmental net operating margin [SE. Eq.1.33] is estimated as the residual value which is obtained by subtracting the 'normal' manufactured margin from the total margin. We assume that the environmental net operating margin is either nil or positive (it cannot be negative) [SE. Eq.1.34], except for carbon product. Thus, we usually give zero value to the environmental net operating margin if the equation [SE. Eq.1.33] shows a negative value or a positive value that is lower than the imputed normal manufactured net operating margin [SE. Eq.1.19]. Manufactured capital income (MCI) is the aggregated value of manufactured net operating margin and manufactured capital gains [SE. Eq.1.35].

The environmental income from *timber* [SE. Eq.1.36] is measured directly by its natural growth (gross work in progress formation) [SE. Eq.1.37] plus its environmental capital gains [SE. Eq.1.38], both at stumpage prices. We assume positive expected natural growth. Environmental revaluation is purged out of the natural growth value at the opening period to avoid double counting. Timber environmental revaluation comes from work in progress, land and biological resource capital. *Cork* and *firewood* environmental income estimates use the same measurement criteria as those used for timber.

We have applied the residual value method to estimate the environmental income of nuts (pine-nuts and chestnuts), grazing, hunting (*20*), recreation, landscape, and biodiversity products. For these products, environmental income is estimated as the residual item of the total income figure [SE. Eq.1.31], which is measured from formal market values and non-market simulated exchange values.

Environmental income from *nuts* is estimated from net operating margin and capital revaluation residual values [SE. Eq.1.39]. The latter value comes from land and biological resources.

Environmental income from *grazing* contains the same items as nuts and is estimated from acorn and other grazing products (grass, browse and other palatable fruits) (Supplementary text S13 and tables S4 and S5).

Environmental income from *hunting* [SE. Eq.1.40] is the average final product of annual hunting captures minus government total costs on this activity and a residual manufactured net operating margin. We simulate normal hunting recreational captures, and estimate its rental price (*52*) or private environmental price (*55*). As we assume this activity to remain steady, environmental capital gains are due to the discounting effect. The latter revaluation is included in the final product of natural growth, with environmental capital gains being nil (Supplementary text S14 and tables S4 and S5).

For *recreation* we estimate environmental income by applying the residual value method to obtain the marginal price of visits and eligible total visits. After simulating the normal government manufactured margin and labour costs, we estimate recreation total income and then calculate as the residual value the recreation environmental income. We use the same methods to estimate *landscape* and *threatened biodiversity* services.

The environmental price of *water* is estimated using the hedonic pricing method applied to irrigated land. Specifically, we use the Guadalquivir basin average water environmental price for economic water yield runoff to the other basins´ dam systems in Andalusian rivers. As we did not identify manufactured costs at forest site for water activity, water final product [SE. Eq.1.41] equals water environmental income [SE. Eq.1.42].

For *mushroom picking* environmental income [SE. Eq.1.43] equals its environmental net operating margin, as this activity has only a government management manufactured cost and we assume that mushroom gatherers have free access to these resources and that therefore the opportunity cost for labour market compensation is zero. Further, we assume a steady escenario for mushroom management, making environmental capital gains nil. There is a local mushroom market price and the estate gate price times harvest gives mushroom picking final product consumption [SE. Eq.1.44]. In this management framework the latter consumption plus the government manufactured gross fixed capital formation is the value of the mushroom picking final product [SE. Eq.1.45].

Private amenity environmental income [SE. Eq.1.46] is measured by adding the residual environmental net operating margin and land revaluation associated to these private amenities.

Carbon environmental income [SE. Eq.1.47] is the residual environmental net operating margin [SE. Eq.1.48] plus carbon environmental capital gains. *Carbon* uptake is a joint tree woody final consumption product [SE. Eq.1.49] linked to woody vegetation natural growth and intermediate consumption related to woody harvested. Both items are valued at carbon market trading price.

Forestry conservation, *government forestry* and *residential* activities do not generate environmental income in extended accounts.

S3.6 Ecosystems services consumption

Academic researchers, national accountants and environmental public agencies seek to measure, on the one hand, the value of ecosystem products provided by labour force and manufactured immobilized capital and, on the other hand, the remaining component of ecosystem product value that originates in the service provided by the environmental asset. Here we measure the consumption of forest ecosystem services in order to answer the question: what is the contribution of the individual environmental assets of Andalusia forest ecosystems to total individual product consumption? We calculate these values from the individual total product consumption estimates in the regional aggregated sub-activities and activities registered in the production account.

Forest ecosystem service consumption refers to the contribution of forest environmental assets to individual total product consumption in the accounting period. We estimate this contribution by adding the values at regional scale of environmental work in progress used up (*48*) in the accounting period to the environmental net operating margin consumption (*8*) [SE. Eq.1.50] valued at environmental price, also known as "rental price"(*52*). Environmental net operating margin consumption is measured [SE. Eq.1.51] from ecosystem total product consumption minus ordinary intermediate consumption of raw materials, services and inventoried environmental work in progress used up, ordinary labour cost, and user cost of manufactured immobilized capital (consumption of fixed capital and normal return from manufactured immobilized capital) [SE. Eq.1.52]. Thus, we are able to measure the values of individual ecosystem services [SE. Eq.1.53] (*54*).

Accounting for the factorial distribution of the total net operating margin from the consumption of forest ecosystem individual products depends on the criteria used to separate the environmental and manufactured net operating margins on a regional scale. This factorial distribution of the total net operating margin prioritizes the imputed remuneration of manufactured immobilized capital at a profitability rate considered normal. We assume then that the residual value of the environmental margin is always non-negative. In the case of estimating a negative residual environmental margin value, we assume that the total net operating margin of individual product consumption is all manufactured net operating margin.

The individual values of all components of total product consumption are known, except for environmental net operating margin consumption, which is the balance in accounting identity of the production function of forest ecosystem consumption of total individual products.

S3.7 Capital values

Environmental assets [SE. Eq.1.54] comprise the inventories of environmental work-in-progress (produced and expected [SE. Eq.1.55]) and environmental fixed capital [SE. Eq.1.56] (table S5), the latter being made up of land and fixed biological resources. The manufactured fixed capital is composed of plantations, buildings, equipment and other fixed capital [SE. Eq.1.57].

The value of the environmental asset depends on the inventories at the closing of the accounting period (stocks of environmental works in progress) and the future environmental income from the asset. This environmental asset represents the present value of future expected resource rents, which is embedded in total forest product [SE Eq.1.58]. Resource rent is composed of the environmental work in progress used up net of environmental natural growth in the period and expected future environmental income. Forest ecosystem environmental assets are measured discounting the resource rent by a normal market or government interest rate.

In our application, the manufactured capital is estimated at market prices, except for gross fixed capital formation that is valued at production cost plus a normal manufactured capital margin. For valuing the environmental assets associated to private and public consumption, which is the main feature behind the forest ecosystem environmental asset services, we apply a private discount rate of 3%. An exception is the private amenity environmental asset, for which we use a discount rate based on the information from the survey of non-industrial forest landowners described in Supplementary text S6.1.

In this survey we included two questions to estimate the private amenity environmental asset (*47*). First, we asked landowners what they thought the current sale price of their forest property would be if it were sold. Then, we asked landowners to allocate (in %) how the land price that they stated derives from the commercial and amenity benefits from their land. Thus, we estimate the private amenity environmental asset value for each surveyed landowner (FClpa) by multiplying the percentage of land price explained by private amenity benefits by the total land market price stated in the survey. Then, we calculate a rate of private environmental discount (r_{pai}) for each landowner *i* from the survey sample as the ratio between the private amenity environmental income (EIpa) and the private amenity environmental land asset (FClpa) for the landowner.

Private amenity environmental income [SE. Eq.1.59] is estimated as the willingness to pay for the private amenity final product (Supplementary text S6.1) net of own intermediate consumption from the residential dwellings of private owners, adding the expectation of the real land revaluation (FClrpa) at the closing of the year 2010 [SE. Eq.1.60] and [SE. Eq.1.61]. This revaluation is calculated by considering the factor (1+ |), where | is the expected actual annual land revaluation rate. It is estimated as the average actual cumulative variation rate of the price of dry grasslands in Spain during the 1994-2010 periods, which is 3.41%. Thus, the estimated ex post private amenity environmental income (EIpa) is the net operating margin of this activity plus actual land revaluation [SE. Eq.1.62].

The private environmental discount rate we use in our application is the mean value of the private environmental discount rate from our sample of landowners (the total valid observations are 567 landowners). The capital value of the private amenity environmental land at the opening of the period is estimated by discounting the future income stream of private amenity environmental product by using this average private environmental discount rate (*47, 56*).

S4. Building standard accounts for forest ecosystems from the System of National Accounts

The System of National Accounts (SNA) estimates the nation's net value added at producer and purchaser prices, which exclude government subsidies and taxes on production. We follow this criterion to estimate the forest net value added for the standard accounts in our application [SE. Eq.2.1].

We build the forest ecosystem standard social production account with concepts and data from the SNA, which are recorded in the standard accounts of forestry and government. Omitting forest intermediate product in the standard accounts of silviculture does not prevent its implicit incorporation into the final products of economic activities that consume it. Here we reclassify the intermediate product into intra-consumption product so that we adapt to the SNA criterion of considering only final products.

The standard accounts offer the net value added from the forest private provisioning products based mainly on transactions. On the production side, the standard accounts record sales, own gross investment in manufactured capital, intra-consumption, and several forms of consumption without market transactions (auto-consumption, donations and in-kind payments). On the cost side, standard accounts take into account intermediate consumption (raw materials and services bought, and own intra-consumption), and consumption of manufactured fixed capital (e.g., buildings, plantations and machinery) during the year (*2*).

S4.1 Final product

The convention in standard accounts is naming as final product intra-consumption the intermediate products harvested that are usually for final sales (e.g., hay). Here, we extend the intra-consumption concept from standard accounts to include the intermediate products from extended accounts into final products in standard accounts.

The forest standard final product consumption [SE. Eq.2.2] integrates intra-consumption, sales, commercial auto-consumption, public environmental product consumption valued at government ordinary total cost, and other commercial final product consumption valued at imputed market prices or at ordinary private total cost. Standard net consumption [SE. Eq.2.3] is measured as the residual value from final consumption minus own and bought manufactured intermediate consumption [SE. Eq.2.4]. The standard manufactured net fixed capital formation [SE. Eq.2.5] is the manufactured gross fixed capital formation at production cost minus consumption of fixed capital at replacement cost (*57*).

Final product consumption from *timber* [SE. Eq.2.6] is valued at market producer prices times harvested quantities. Timber standard final product [SE. Eq.2.7] adds own manufactured gross fixed investment to final product consumption. *Cork*, *firewood* and *nuts* have the same valuation criteria in standard accounts as timber. Livestock *grazing* consumption is considered a forest final intra-consumption product in standard accounts [SE. Eq.2.8] and [SE. Eq.2.9], and is embedded in the standard livestock final product (*2*). Standard grazing final product [SE. Eq.2.10] is final consumption valued at market lease price (producer price) plus private manufactured gross fixed capital formation on the livestock grazing activity.

Forestry conservation is considered a forest final intra-consumption product [SE. Eq.2.11]. The intermediate product of this activity is valued at government ordinary production cost [SE. Eq.2.12]. The final product is valued at government total cost [SE. Eq.2.13], and it incorporates [SE. Eq.2.14] final consumption to the manufactured gross fixed capital formation [SE. Eq.2.15] valued at government investment production cost. *Forestry government* final product and total cost follows the same accounting criteria as the forestry conservation sub-activity in standard accounts.

Hunting (substitute value of game grazing) generates a final intra-consumption product [SE. Eq.2.16], [SE. Eq.2.17] and [SE. Eq.2.18] valued at private environmental price times quantity of captures. The intra-consumption product is a private environmental income embedded in the standard final product of the hunting activity (*7*). The hunting final product [SE. Eq.2.19] adds to final consumption the government manufactured gross fixed capital formation on hunting [SE. Eq.2.20].

Residential activity generates a final intra-consumption [SE. Eq.2.21] and [SE. Eq.2.22] that is valued at imputed market prices. This intra-consumption is used up by the *private amenity* activity as a standard own intermediate consumption [SE. Eq.2.23]. Total final product [SE. Eq.2.24] incorporates to final consumption the residential manufactured gross fixed capital formation [SE. Eq.2.25] valued at investment cost.

For public *recreation*, we consider as final product consumption [SE. Eq.2.26] the government ordinary total cost plus a normal manufactured ordinary net operating margin [SE. Eq.2.27]. The latter is estimated by applying a normal return rate to the ordinary manufactured immobilized capital on government public recreation [SE. Eq.2.28]. The standard final product from public recreation [SE. Eq.2.29] is final consumption and the associated manufactured gross fixed capital formation [SE. Eq.2.30]. The latter is valued at government investment total cost plus a normal manufactured net operating margin from the investment [SE. Eq.2.31], which is estimated applying a normal return rate (r) to the manufactured immobilized capital on government public recreation [SE. Eq.2.32]. *Landscape conservation* and *threatened biodiversity* activities have the same accounting criteria as public recreation in standard accounts.

The standard final product consumption from *mushroom picking* [SE. Eq.2.33] is valued at the market price at farm gate times quantity gathered. Mushroom picking final product [SE. Eq.2.34] adds to final consumption the government manufactured gross fixed capital formation [SE. Eq.2.35]. We estimated the latter using the same criteria as for public recreation.

85% of Andalusia forest *water* yield runoff regulated by dams was on average used up by agricultural irrigated crops in the period 2001-2010. The exchange value of water final product consumption [SE. Eq.2.36] is embedded in the consumption of irrigated crop products. This water final product consumption is valued by its environmental price times quantity used up by irrigated crops. There is no observed government forest water cost. The remaining 15% of water consumption corresponds to other activities in the Andalusian economy. The government water agency cannot charge more than the manufactured costs and a normal return to the manufactured immobilized capital involved.

S4.2 Net value added

There is consensus among economists and accountant experts on national income in attributing the major causes of the limitations of standard SNA (*1, 57*) and the Economic Account for Forestry (EAF) (*2*) to the narrowness of the concept of gross value added and the classification of economic activities. Another important cause of the shortcomings of these standard accounting systems is the omission of private non-woody environmental income (*4, 8, 10, 48*).

In our application we measure the net value added of standard accounts from the consumption of forest final commercial products and from the manufactured gross fixed capital formation net of own and bought intermediate consumption and consumption of fixed capital.

The above standard net value added concept omits the measurement of natural growth as final product and of work in progress used up as intermediate consumption in the sub-activities of *timber*, *cork* and *firewood*. These omissions cause an income temporization measurement problem in the standard net value added of these products (*25*).

In contrast with the above woody products, Table 5 and table S2 shows that the *nuts*, *grazing*, *forestry conservation*, *government forestry*, *hunting*, *residential* and *mushroom picking* products measure the real period net value added in standard accounts.

The net value added from standard accounts also omits the measurement of the non-commercial product from *private amenity*, although we simulate for this activity an own intermediate consumption that is a final intra-consumption of the *residential* activity.

For *public recreation*, *landscape conservation* and *threatened biodiversity preservation* products the net value added of standard accounts is based on the production cost plus a normal margin (table S4).

The standard net value added from *water* (which equals its environmental income) is embedded in the irrigated crops and other regulated water commercial uses. *Carbon* uptake product is not considered in standard accounts.

Finally, the Andalusian government measures a forestry activity gross value added at producer and purchaser prices by applying the satellite EAF (*58*). Here, the forestry activity gross value added estimated from standard accounts differs from that of EAF applied by the Andalusian government. The latter does not include the labour costs of the services provided by forestry enterprise.

S5. Woody products and carbon uptake income and capital

The AAS extends the SNA estimations of timber, cork and firewood by including: (i) natural growth, (ii) standing tree products that are harvested over the year, (iii) tree private provisioning and public regulating services, and (iv) tree asset accounts.

S5.1 Timber, cork and firewood growths and harvesting

The product associated with the natural growth (NG) of timber, cork and firewood is given by (*12, 59*): $NG=p_p^{'}g_s$; where $p_p^{'}$ is a vector of prices and is a vector of physical growth, measured in cubic meters (m^3) or metric ton (t), of these tree products over the accounting year. The price vector $p_p^{'}$ (per diametric class) shows the price at which the right to use these products in the future would be sold. To estimate this price vector we consider the probabilities (according to the tree species, tree management plan and the site index) of pruning/thinning, wildfire and natural mortality in each diametric class that remains to be achieved. Formally, the price vector is given by:

$$p_p^{'}=(p_p^1, p_p^2,\ldots, p_p^d,\ldots p_p^m).\qquad \text{[SM. Eq.5.1]}$$

$$\text{with}\quad p_p^d=\sum_{j=d}^{m}\frac{(p_g^j-p_k^j)\cdot\theta_h^d\cdot\pi_{jd}}{(1+r)^{(t_j-t_d)}}\ \text{for each } d=(1,2,\ldots,m\},\qquad \text{[SM. Eq.5.2]}$$

where p_g^j are forest prices at farm gate, p_k^j are felling costs, r is the discount rate, t_j and t_d are the age (in years) of a tree belonging to the diametric classes' j and d, respectively, and π_{jd} is the probability that a tree that is alive in a diametric class d is logged at each one of the j diametric classes that are to be reached ($\pi_{jd} = \Pr(j/d)$, j≥d). Thus, the price vector is defined based on the probability that a tree of a diametric class d is felled, burns or dies at each one of the subsequent diametric classes j.

The variable θ_h^d takes a value of 1 in case of ordinary timber species and has, therefore, no impact on the estimations. In the case of multi-harvest products such as cork, firewood or coppice crops, the variable θ_h^d is the harvest probability at each diametric class d and it takes a value between 0 and 1. The harvest probability at each diametric class depends upon the central age of the diametric class (y_d), the average number of years that a tree belongs to a certain diametric class (in year) (s_d) and the rotation length for final harvesting (t_h). Harvest of cork occurs every 9 years (after the first cork harvesting) and harvest of firewood every 25 years. The only species that delivers firewood of economic interest is *Quercus ilex*. Eucalyptus harvest occurs every 12 to 16 years, when managed as a coppice system. Natural growth accounts only for growth in the on-going cycle. Therefore, for coppice systems, natural growth disregards the expected growth for the next rotations that follow the ongoing one:

$$\theta_h^d=\left(y_d+s_d/2\right)/t_h.\qquad \text{[SM. Eq.5.3]}$$

$$\text{s.a: } 0\leq\theta_h^d\leq 1.\qquad \text{[SM. Eq.5.4]}$$

When θ_h^d attains a value lower than 1 for a diametric class d, the difference between 1 and θ_h^d is assigned to the next diametric class: $\theta_h^{j>d} = (1-\theta_h^d)$, which indicates that with a probability θ_h^d the harvest period will take place in diametric class d, and with a probability $\theta_h^{j>d}$ this harvest will take place in higher diametric classes, until:

$$\sum_{j=d}^{J} \theta_h^j = 1. \quad \text{[SM. Eq.5.5]}$$

Finally, the standing value of tree products that are harvested in the accounting year is recorded as an intermediate consumption in the form of work-in-progress used up (WPu). The latter is valued at the beginning of the accounting period as: $\delta(p_g-p_h)'q_h$, where p_h is a vector of the harvest cost for each diametric class; δ is the discount factor [$\delta=1/(1+r)$]; and q_h is the quantity of the harvested product.

The approach described in this sub-section is applied to vectors of prices and natural growth for 14 different diametric classes (m) (from 10 cm to 75 cm, within intervals of 5 cm) (tables S8 and S9).

S5.2 Tree woody products capital

Capital values (C) associated to tree products are estimated using the Net Present Value (NPV) approach. The C represents the discounted flow of landowner net revenues (NR) that are expected to be earned in the future (*8*) through products harvests at stumpage prices.

Total capital (C) includes tree environmental asset (EA) plus manufactured capital (MC). The environmental asset of tree products includes: (i) the expected flow of net revenues from those products in the ongoing harvesting turn, tree inventory of environmental work in progress (EWP); for multi-harvest products, this includes the expected flow in the remaining harvesting turns of the current cycle; (ii) annual nuts (pine-nuts or chestnuts) in the current tree rotation (FCbr); and (iii) the value of land without current tree cycles (FCl). As we know that the total value of the land plus the trees in any moment in time is given by all the future flow of net revenues, we estimate the value of the bare land as residual (taking out the value of the MC, as we detail below). That is, the following identities are true for capital:

$$C = \sum_{t=s}^{\infty} NR(t)\delta^{t-s}. \quad \text{[SM. Eq.5.6]}$$

$$C = EA + MC. \quad \text{[SM. Eq.5.7]}$$

$$EA = EWP + FCbr + FCl. \quad \text{[SM. Eq.5.8]}$$

S5.3 Tree private work in progress products

The existing and expected stocks of forest work in progress (EWP) products are generically termed as "produced work-in-progress" (EWPp) and "expected work-in-progress" (WPe), respectively. The latter represents the expectation of forest product growth in future rotations in the production cycle. Those are estimated as residual values between total expected forest products yields minus the existing (or standing) stocks (table S5).

Total EWP represents the value of the specific product that is expected to be harvested in the future. The EWP for ongoing timber, cork and firewood rotations is estimated according to:

$$EWP = p_s^{'} \cdot q_s. \quad \text{[SM. Eq.5.9]}$$

$$p_s^{'} = \sum_{j=d}^{m} \frac{(p_g^j - p_k^j) \cdot Y_{jd} \cdot \theta_h^d \cdot \pi_{jd}}{(1+r)^{(t_j - t_d)}}. \quad \text{[SM. Eq.5.10]}$$

$$Y_{jd} = \left(\frac{v_j}{v_d}\right). \quad \text{[SM. Eq.5.11]}$$

$$EWP = WPp + WPe. \quad \text{[SM. Eq.5.12]}$$

$$EWPp = p_p^{'}q_s.$$

$$EWPe = p_s^{'}q_s - p_p^{'}q_s. \quad \text{[SM. Eq.5.13]}$$

where q_s is a vector of m rows that records the existing timber, firewood or cork stocks (in m^3 or t) in the accounting period, and Y_{jd} is an expansion factor for tree product stocks that relates their unitary volume (or cork weight) of a tree of a diametric class d (V_d) and the volume/weight of that same tree in the following diametric classes j (V_j) to be reached. As before, θ_h^d takes a 1 value for ordinary timber species. For multi-harvest products (coppice timber, cork and firewood) the variables Y_{jd} and θ_h^d are only estimated for the ongoing rotation. In this case, the expansion factor Y_{jd} estimation is restricted to those diametric classes for which the aggregated length is lower than the rotation of the product: $\sum_{j=d}^{J} s_j \leq t_h$.

S5.4 Biological resources from expected cork, firewood and coppice crops rotations

The fixed capital of biological resources (FCbr) accounts for the standing value of trees yielding repeated products (i.e. multi-harvest products, such as firewood and coppice timber harvest). Biological resources account for the expected yields once ongoing rotations are accomplished. These biological resources are estimated using similar equations to [SM. Eq.5.9] and [SM. Eq.5.10], but taking into account all the rotations (except the ongoing one) that are expected to occur in the future. This would affect the expansion factor Y_{jd} estimation, since it has to be estimated for all diametric classes ($j \geq d$).

S5.5 Biological resources from expected nuts

Pine nuts and chestnuts are annual products that are harvested every year. We assume that harvesting only takes place when the product has commercial interest; that is, if a minimum annual threshold of production is achieved (for pine-nuts, 50 kg/ha). The economic value associated with harvesting nuts over the tree rotation ($FCbr_c$) is estimated as:

$$FCbr_c = p_c^{'} \cdot q_c. \qquad \text{[SM. Eq.5.14]}$$

$$p_c^{'} = \sum_{j=d}^{m} \frac{(p_g^j - p_k^j) \cdot \kappa_{jd} \cdot \theta_h^d \cdot \pi_{jd}}{(1+r)^{(t_j - t_d)}}. \qquad \text{[SM. Eq.5.15]}$$

$$\kappa_{jd} = \left((Y_j/Y_d) \ \ (x_j/x_d)\right). \qquad \text{[SM. Eq.5.16]}$$

Where q_c is a vector of nuts with commercial interest (kg/year) for each one of the d diametric classes, and is a vector of the standing prices of these nuts. The equation for estimating $p_c^{'}$ is similar to [SM. Eq.5.9], although it is adapted to consider that nuts are an annual product by including a corrected expansion factor (κ_{jd}). This factor relates the nuts yield of a tree of diametric class d (Y_d) with the nuts yield of that same tree at a diametric class j (Y_j) to be reached; and (x_j/x_d) addresses the correction due to differences in the time length (years) that a nut tree belongs to a diametric class d (x_d) and to the successive diametric classes j (x_j) (table S10).

S5.6 Land capital value from timber, cork and nuts production

The total land value (FCl) reflects the net present value (NPV) of the expected infinite stream of net revenues (NR) of tree products, including the expected edible fruits provided by the trees beyond the existing biota cycles. Part of this value is accounted as expected work-in-progress (EWP) and part as biological resource (FCbr) assets. The land fixed capital value (FCl) reflects the environmental income estimated as a residual value from [SM. Eq.5.8]. As indicated before, EWP and FCbr are not purely environmental asset values, since woody product and nut asset prices include the return to manufactured assets. To correct this we deduct manufactured capital (MC) to measure land environmental asset:

$$FCl = C - FCbr_c - EWPt - MC\,. \qquad \text{[SM. Eq.5.17]}$$

Manufactured capital (MC) refers to the asset value of plantations, infrastructure and equipment used in the production of tree products and edible fruits. The environmental income identities of tree products could be negative for certain periods, but if the NPV of the stream of these incomes is negative, the EA value is assumed to be zero (*8*). The negative incomes are then re-allocated as returns to manufactured investment.

S5.7 Carbon environmental asset value

Carbon uptake is entered in the accounts by using the carbon flux method. Carbon fluxes and stocks are valued by considering the carbon dioxide (CO_2) prices in the European Union Emission Trading System (this being reduced by 4% percent to take into account the impact that including forestry in this market would have by 2010 (*60*)). The valuation of carbon in trees and shrubs is considered both fixed environmental capital and intermediate consumption of emissions caused by felling, wildfires and natural death. The value of the public environmental asset of carbon is estimated by discounting planned future quantities of net fixed carbon. Depending on the expected variation in biomass, carbon-related values may be negative or positive over the years. The carbon asset value (EAc) is estimated as:

$$EAc = \sum_{d=1}^{m} Vc_d = \sum_{d=1}^{m} \left(\alpha \cdot V_d \cdot t_d \cdot \emptyset_d \cdot p_c^d \cdot\right), \qquad \text{[SM. Eq.5.18]}$$

where α is a constant parameter that relates timber volume (in m^3) to carbon stock (in t CO_2); V is the timber stock (in m^3) for the trees belonging to each one of the d diametric classes; $\emptyset$ defines the relation between annual carbon increase (ΔC) and carbon stock (S) for a single tree belonging to the diametric class d ($\emptyset_d = \Delta C_d / S_d$); and p_c^d is the carbon price. This carbon price considers the conditional probability of a tree of diametric class d to be alive at each one of the subsequent j diametric classes to be reached, and an expansion factor f_{si} that relates carbon stock of a tree of diametric class d to each one of the diametric classes j≥d to be reached.

$$p_c^d = \sum_{j=d}^{m} \frac{p \cdot \pi_{jd} \cdot f_{si}}{(1+r)^{(t_d - E_j)}}, \qquad \text{[SM. Eq.5.19]}$$

where E_j is the lifespan (in years) of diametric class j, and p is the price per t CO_2 considered (fig. S12).

S6. Discrete choice methods for environmental valuation

We use stated preferences and discrete choice methods to estimate the demand function for non-market landowner amenity consumption, public (open-access) recreation, landscape conservation and threatened biodiversity preservation. All these are products for which the demand curve is not directly observable in a market. Discrete choice methods for environmental valuation use surveys to simulate markets whereby respondents have to choose among several alternatives for the provision of a good. One of the alternatives usually implies not consuming an environmental product, while the other alternatives imply a specific provision of an environmental product at a given price. These scenarios make it possible to link product and price changes in the context of current consumption patterns.

Based on McFadden's Random Utility Theory (*61*), these models assume that respondents maximize their utility by choosing the alternative j that yields the highest utility (U_{ij}) to individual i. To model this, we work with an additively-separable linear utility function with a systematic (V_{ij}) and a random component (ε_{ij}) for individual i and alternative j:

$$U_{ij}= V_{ij}+ \varepsilon_{ij}= \alpha_j+ \beta_p A_{ij}+\hat{\beta}' X_{ij}+\varepsilon_{ij}, \quad \text{[SM. Eq.6.1]}$$

where αj is a constant specific to alternative j; A_{ij} is the price offered in alternative j to individual i and β_p is the parameter for the price; X_{ij} is a vector of attribute values of alternative j for individual i, and $\hat{\beta}$ is a vector of parameters for the attributes. If random errors (ε_{ij}) are independently and identically distributed with an extreme value distribution, the probability that individual i chooses alternative j out of K alternatives gives the conditional logit model:

$$P_{ij}= \frac{\exp{(V_{ij})}}{\sum_{k=1}^{K} \exp{(V_{ik})}}. \quad \text{[SM. Eq.6.2]}$$

This model assumes the independence of irrelevant alternatives (IIA) hypothesis, which does not generally hold (*62*). Alternatively, we work with the mixed logit model (*62*), which is a more appropriate approach in experiments with more than two alternatives and using attribute-based valuation. The mixed logit model is used to examine unobservable heterogeneous preferences, and allows for correlated error terms and unrestricted substitution patterns. In this model, parameters vary in the population according to a specified distribution (θ). The probabilities that individual i chooses alternative j is the integral of the conditional logit probabilities in [SM. Eq.6.2] over a density of parameters according to θ. These probabilities can be approximated through simulation for any value of θ. R being the number of draws from θ (we use R=500), the unbiased estimator of P_{ij} is defined as (*62*):

$$\check{P}_{ij}=\frac{1}{R}\sum_{r=1}^{R} \frac{\exp{(V_{ij})}}{\sum_{k=1}^{K} \exp{(V_{ik})}}. \quad \text{[SM. Eq.6.3]}$$

S6.1 Landowner private amenities

The landowner demand (willingness to pay) for private amenities was estimated through a survey of a random sample of 765 private forest land owners in Andalusia in 2010. Questionnaires were conducted face-to-face and were carried out by a team of trained personnel from the *Agencia de Medio Ambiente y Agua* (AMAYA) belonging to the Government of Andalusia. Prior to the survey, we conducted two focus-groups comprising three landowners and two experts and we pre-tested 52 landowners from the sample to validate the survey and to obtain the required information to design the final version.

We used a single-bounded contingent valuation question. This is a discrete choice question that presents two alternatives: (i) the current situation, where landowners own the land, obtain commercial operating income from their land investment and enjoy land amenities; and (ii) a situation where landowners renounce land ownership, and therefore land amenities, in order to make an alternative non-agroforestry investment that increases their commercial income by a specific amount of money annually. The single-bounded contingent valuation question asked landowners to state whether they would pay (give up) or would not pay a specific annual amount of money in order to keep their property and therefore their land amenities in the scenario described above. The wording was as follows:

"Imagine that you were offered the possibility of an alternative non-agroforestry investment that would increase your YEARLY monetary income by € [bid offered]. Would you sell your property in order to make this investment and obtain this increase of YEARLY monetary income?

 Yes No

 Don´t know/no answer"

The amount offered (bid) in euros was randomly taken from a vector of values that was expressed in euros per hectare. The survey software automatically multiplied this euro per hectare amount by the total hectares of the property as stated by the landowner in a previous question of the questionnaire. The bid vector values were [€75 per hectare, €140 per hectare, €240 per hectare, €450 per hectare]. These values were established in accordance with the answers to a single-bounded question in the pre-test in which the bid vector values were taken from a previous study (*63*). We took the quintiles of the willingness to pay (WTP) distribution obtained from this pre-test question and adjusted them to maintain the log of the distance between bids relatively constant. Alberini (*64*) shows that this is a good compromise between efficiency and information about the shape of the willingness to pay distribution.

The analysis of this question is performed using a log-logit model based on the conditional logit model in [SM. Eq.6.2] using maximum likelihood estimate procedures in the software NLOGIT 5.0. This model estimates the probability that a landowner would be willing to pay a specific bid to enjoy their land amenities. The results of this log-logit model are shown in table S11.

For the purposes of the survey, we conducted the sampling of private landowners by using a GIS layer of forest land area in Andalusia. A total of 11,500 random points were drawn from this GIS layer. We considered those points belonging to publicly-owned properties and points located in grids with less than 10% of forest area as invalid for the goals of the study. Similarly, we discarded points that corresponded to the same property and landowner. After removing these invalid points, we were left with 3,618 valid points. Each point was associated to the landowner information. Landowners were then randomly contacted by the survey team until 843 questionnaires were completed. However, 78 of these questionnaires were discarded as we considered that the property of the surveyed landowner was oriented predominantly towards agricultural production despite containing some forest land vegetation (always under 30% of the total area of the property). Therefore, our final sample included 765 private forest owners with an average property size of 464 hectares. As sampling was random over the forest map of Andalusia, we assume that the area covered is representative of the forest land area in Andalusia.

S6.2 Public recreation

To estimate the site-specific demand functions for public recreation in the natural areas of forest that receive public visits in Andalusia, we used a survey of public visitors and a survey of the Spanish population during 2010.

The first survey was performed with a random sample of 4,030 public visitors (≥ 18 years old) in nine different natural areas of Andalusia. The nine areas are *Alcornocales, Cazorla, Aracena, Cabo de Gata-Níjar, Sierra Nevada, Sierra de Grazalema-Las Nieves, Pinares de Doñana, Sierra María-Los Vélez and Andujar-Hornachuelos-Despeñaperros*. The latter includes three areas that are relatively close to each other and have similar vegetation. Questionnaires were conducted face-to-face and in situ, and were carried out by a trained survey team from the *Instituto de Estudios Sociales Avanzados* (IESA-CSIC). A series of focus group meetings were held prior to the survey and a pre-test of 96 questionnaires was carried out.

We used a single-bounded contingent valuation question. This is a discrete choice question that presents respondents with two alternatives: (i) a situation where respondents pay an additional amount (the bid offered in the single-bounded question) for their current recreational visit to the forest land; and (ii) a situation where they do not pay but have to renounce the recreational visit.

In Andalusia, public visitors to forest land areas have *a priori* no legal right to access privately- or even publicly-owned forest properties. Both the private and the public owner can prohibit access, and visitors only have the right to use public roads and some livestock driveways (*vias pecuarias*). However, there are some publicly-owned properties that are allocated by the regional and local governments to provide free-access to the general public. These recreational properties are usually endowed with public funds which supply infrastructure facilities to open-access visitors. Therefore, a scenario in which visitors would need to pay to access recreational areas is credible. There are also a few exceptions where access is limited for environmental reasons. For example, in Doñana National Park, only guided visits are allowed, and visitors must pay for this service. In this monopolist market, recreational resource rent may accrue to operators. By contrast, in the open-access context resource rent is captured by visitors as part of their consumer surplus.

The single-bounded contingent valuation question asked visitors to state whether they would pay or not pay a specific bid for the exact same visit that they were currently making, on that same day and in that particular area. To offer the bid, we used two payment vehicles: the payment of an entrance fee and the payment of increased trip-expenditures as a consequence of increased fuel prices (*65*). The wording of the contingent valuation question with each payment vehicle was as follows:

Entrance-fee question:

"Some natural areas (exceptionally in Spain and frequently in other countries) require an entrance fee for the purpose of contributing to the management expenses of these areas. Suppose that in this forest they were to establish an entrance fee for adults (children under age 16 free).

We are now asking you to assume that the total expenses of your visit would have been increased by the payment of an entrance fee to visit this area, doing exactly the same activity and with the same people.

If the expenses of your visit were increased by the payment of an entrance fee of € [bid offered] per adult, or a total increase of € [total bid offered] for all the people for which you have paid, would you still have come today? Please take into account that we are asking you to imagine a real payment and that you could not spend the money on alternative uses.

☐ Yes ☐ No

☐ Don´t know/no answer"

Trip-expenditure question:

"As you know trip costs have varied in recent years (e.g, gas prices have gone up and down regardless of the generalized increase in prices). Now we are going to ask you to imagine that the total expenditure of your visit increases for this reason, doing exactly the same activity (same transport, same food...) and with the same people.

We are now asking you to assume that the total expenses of your visit would have been increased by an increase in the price of gasoline, doing exactly the same activity and with the same people.

If the expenses of your visit had gone up by an increase in the price of gasoline of € per day [bid offered], would you still have come today? Please take into account that we are asking you to imagine a real payment and that you could not spend the money in alternative uses.

□ Yes □ No

□ Don´t know/no answer"

The bid per visit per person offered was randomly chosen from among the following values [€3, €6, €9, €12]. These values were established so that the difference between potential bids was always the same. We randomly assigned both the payment vehicle and the bid offered to each respondent so that they were evenly distributed in the sample. In the entrance-fee question the respondent was shown both the bid per person and the total bid to be paid according to the number of people that the respondent paid for during the visit. The focus group meetings concluded that in the case of the entrance fee, the payment information should be presented both ways (per person and total). In the increased trip expenditure question we only showed the total bid to be paid as the focus group meetings concluded that the usual behavior would be to pay the total amount covering all people paid for by the respondent.

This question is analyzed using a log-logit model based on the conditional logit model in [SM. Eq.6.2] using maximum likelihood estimates procedures in the software NLOGIT 5.0. This model estimates the probability that a visitor would pay a specific bid to enjoy a recreational visit to a specific open-access natural area in Andalusia. The results of this log-logit model are shown in table S12.

The proportion of visits received by each natural area considered was taken into account in the visitor sampling. As there were no official statistics on these visits, we used a preliminary analysis (a third of the sample) of the visits estimated from the survey of Spanish population. The sampling goal was to ensure in each area a maximum margin of error of 12% (±6%) for the proportion (with a confidence level of 95%) assuming a t-distribution. Thus, the minimum sample size at each forest land area was established at 288 questionnaires. The rest of the sample (up to 4,000 questionnaires in total) was allocated based on the proportion of visits to each area according to the preliminary results of the household survey. table S13 shows the sampling goal for each natural area based on the above-mentioned goals and criteria.

The questionnaires were allocated over 12 months (from July to June) in proportion to the visits per month received by the visitors' centers in each area. The different points for conducting the interviews were located at the start of hiking trails, in visitor centers and in recreational areas. These interview points were selected according to opinions of experts and rangers in each area. Visitors to be interviewed were randomly selected.

The survey of the Spanish population comprised a random sample of 3,214 adults (ε 18 years old) from Andalusia households and 836 adults from households in the rest of Spain (sharing the 96 pre-test questionnaires with the visitors' survey). Questionnaires were conducted face-to-face at the home of the respondent by a trained surveyor. From this survey we identified all the Andalusia forest land areas that received public visits in 2010 and estimated the total number of visits received in that year. The questionnaires included a set of questions that asked respondents the number of day-visits that they had made to different Andalusia open-access forests in the 12 months previous to the interview. The visit and visitor estimation results are shown in table S14. This survey is described in more detail in the next section as it included the choice experiment for the valuation of landscape conservation and threatened biodiversity preservation.

S6.3 Landscape conservation and biodiversity preservation products

We estimate a single demand function for landscape conservation and threatened biodiversity preservation products from a choice experiment included in the survey to 3,214 Andalusia households (see Supplementary text S6.2). The choice experiment used is a discrete choice case with four alternatives, where respondents were presented with three alternatives of an environmental program plus a *status quo* alternative. Both landscape conservation and threatened biodiversity preservation were included as part of this hypothetical environmental program. In choice experiments, the good being valued is described through attributes, which adopt different levels according to an experimental design. Thus, the alternatives in the experiment describe a program aimed at maintaining or increasing vegetation types in different Andalusia forest sites along with the number of threatened animal and plant species present in them. Each alternative was described by the attributes presented in table S15.

The environmental program alternatives were characterized by different levels of these attributes. Thus, to implement a program and achieve a specific outcome in terms of vegetation and threatened species in the specific area indicated in the alternative, the respondent would have to make a payment in the form of an annual tax over the next 30 years. We used an annual tax-fee because it is a coercive payment mechanism, which increases consequentiality in the scenario, and because it is a credible mechanism for this type of environmental program. The *status quo* alternative implied no payment and, as a consequence of not carrying out any environmental program, the areas presented in the choice set would reach the attribute levels described in the *status quo* level column in table S15.

As can be seen in table S15, the area and the vegetation form a single attribute because they are linked. We selected ten forest land areas to hypothetically apply this program: *Alcornocales, Andujar-Despeñaperros, Aracena, Cabo de Gata, Cazorla, Doñana, Grazalema, Hornachuelos, Sierra María-Los Vélez and Sierra Nevada.* As it was impractical to present the alternatives considered for the ten forest land areas selected in each choice set, the sample was stratified so that each respondent was only presented with the alternatives for three areas. To do this, the target population (Andalusia adults) was distributed into 12 strata based on the proximity of the respondent's municipality to the centroid of each area in the strata, selecting the closest three. Thus, the choice sets for each stratum correspond to a single combination of three areas as follows:

Stratum 1: *Aracena, Grazalema, Doñana*

Stratum 2: *Alcornocales, Grazalema, Doñana*

Stratum 3: *Doñana, Grazalema, Hornachuelos*

Stratum 4: *Aracena, Doñana, Hornachuelos*

Stratum 5: *Andujar-Despeñaperros, Hornachuelos, Grazalema*

Stratum 6: *Andujar-Despeñaperros, Cazorla, Hornachuelos*

Stratum 7: *Andujar-Despeñaperros, Cazorla, Sierra María-Los Vélez*

Stratum 8: Andujar-Despeñaperros, Cazorla, Sierra Nevada

Stratum 9: *Alcornocales, Grazalema, Hornachuelos*

Stratum 10: *Alcornocales, Grazalema, Sierra Nevada*

Stratum 11: *Cabo de Gata, Sierra Nevada, Sierra María-Los Vélez*

Stratum 12: *Cazorla, Cabo de Gata, Sierra Nevada*

In accordance with these strata, we used an experimental design to combine the different attribute levels (4 attributes with 4 levels each), creating 24 alternatives that were combined to create 8 choice sets presented in blocks of 2 cards. In each alternative, attributes such as the size of forested area and the kind of vegetation referred to each of the three specific areas while the biodiversity attribute referred to all forest lands in Andalusia. The tax-fee referred to the environmental program made up of the attribute levels of the alternative. The bid values for this attribute were established based on the comments and recommendations of experts and participants in the focus groups and were tested in the pilot survey mentioned above.

The choice experiment scenario asked respondents to state which of the four alternatives presented in the choice set they would choose. Respondents were told that in each choice situation the alternatives presented were the only ones available and that they should consider each choice situation as independent from the others. As the scenario presented was relatively complex, the survey team was trained to explain to respondents the implications of the different potential programs. For example, a decrease or increase in percentage of the forested area can be difficult to envisage so these changes were represented on colored maps. Respondents were shown a booklet with these maps and other information about the programs; interviewers were also given a manual for answering questions. The valuation scenario presented in the survey (in this case for stratum 1) is shown in Additional Data S1.

The analysis of these choice sets was performed using the mixed logit model [SM. Eq.6.3] with simulated maximum likelihood estimation procedures in the software NLOGIT 5.0. This model estimates the probability that a respondent would pay a specific bid for the implementation of an environmental program aimed at landscape conservation in specific forest land areas of Andalusia and the preservation of threatened species in all forest lands of Andalusia. The results of this mixed logit model are shown in table S16.

Once each combination of three areas (stratum) had been assigned to a municipality and with the objective of conducting 3,200 questionnaires, we carried out the sampling, taking into consideration the following criteria: (i) that each area was presented in at least 400 questionnaires, which offers a maximum margin of error of 10% (±5%) for the proportion (with a confidence level of 95%) assuming a normal distribution; and (ii) that each stratum was presented in at least 50 questionnaires in order to avoid a given stratum being presented in too few questionnaires.

To assign a stratum to a municipality, we first calculated the centroids of the natural park located within the limits of each area. Then, we calculated the distance between the municipalities and the centroid of each natural park corresponding to an area. At this point we had 10 distances calculated for each municipality, one for each park. In the case of *Andujar-Despeñaperros* this distance was double, using the closest one to the municipality. The next step was to calculate an initial combination of areas for each municipality. Twelve of the resulting combinations, which fulfilled the above criteria, were kept; thus ensuring a manageable number of combinations. All geographical calculations were performed using ARCGIS 9.3, taking the geographical boundaries for natural parks and municipalities from the *Instituto de Estadística y Cartografía de Andalucía* (*58*).

S7. Simulated exchange value method

The simulated exchange value method (*12, 27*) (SEV) method was used to value the products of public recreation, threatened biodiversity preservation and landscape conservation. In all cases, demand functions were estimated using stated preferences and discrete choice methods (Supplementary text S6).

S7.1 Public recreation

A conditional logit function with two alternatives (see equation [SM. Eq.6.2]) was estimated based on a contingent valuation survey conducted among visitors to 9 selected natural areas (Supplementary text S6.1). For each natural area, the function estimates the probability that a visitor will accept a surcharge for accessing the area. Knowing this probability and the number of visitors during the initial non-payment situation (estimated from the survey to households discussed in Supplementary text S6.1), the following Marshallian demand function was obtained (assuming that the income effect is negligible):

$$p_i(q_i)= \frac{\ln\left(q_i/(Q_i-q_i)\right)}{\beta_p} - \frac{\hat{\beta}'}{\beta_p}\bar{x}_i \qquad i \in [1,9]\ , \qquad \text{[SM. Eq.7.1]}$$

where p_i is the price of access, q_i is the number of visitors at each price, Q_i is the number of visits in the initial situation, in the absence of price, $\hat{\beta}$ is a coefficient vector associated with the explanatory variables, β_p is the coefficient of the price of access and $\bar{x}_i$ are the average values of the explanatory variables for natural area i.

With respect to market structure, in the short run, the natural areas are considered to be in monopolistic competition (because they are similar, but sufficiently differentiated goods). Based on this assumption, defining $R_{FA}(q_i)= p_i(q_i)q_i$ and assuming that the supply function would be determined exclusively by the fixed cost (C_{FA}) of opening the area to the public, the equilibrium values (p_i^*, q_i^*) are obtained for each natural area with the following maximization program:

$$\max_{q_i} R_{FA}(q_i) - C_{FA}. \qquad \text{[SM. Eq.7.2]}$$

As we obtained that q_i^* was close to $Q_i/2$ for all natural areas, we used the median, $\tilde{p}_i$, as a proxy of p_i^*, as this strategy simplifies the computation efforts and can be seen as an adequate approximation, especially considering that we are ultimately interested in the multiplication of the price times the quantity, and we have that $p_i^* q_i^* \approx \tilde{p}_i Q_i/2$ (see fig. S1, and Ref.(*27*) for a comparison of this approach with alternatives measures).

S7.2 Landscape conservation and threatened biodiversity preservation products

The value of landscape conservation and threatened biodiversity preservation was estimated using a single probability function based on a mixed logit model (see equation [SM. Eq.6.3]). Both non-market products were included as part of a hypothetical environmental programme (see Supplementary text S6.3).

To estimate this function, Andalusia was divided into 12 population strata. In all strata individuals were presented with cards that included the attribute "endangered biodiversity", whereas for each of the strata, variations in tree-lined surfaces refer to a different set of three species of trees (investigating 10 tree species altogether corresponding to the 10 natural areas described in S5.3). This structure implies that although the probability function had ten forest species as explanatory variables (attributes of the programme), estimates of payments that might actually be implemented had to be generated by simulating the decisions of the members of 12 strata. To this end, three alternatives for future changes were defined for each stratum (a, b and c), along with the actual situation (the *status quo* (s)). Alternatives a, b and c were intended to ensure the maintenance of the current number of hectares of a different tree species for each alternative. In addition, the three alternatives involved maintaining the current number of threatened species in all forest ecosystems of Andalusia. Thus, we estimated the probability (for each stratum) that each of the alternatives proposed is selected as a function of the (unique) price associated with alternatives a, b and c. This calculation is done using the optimal betas β^* estimated based on equation [SM. Eq.6.3] and the associated average amounts of the attributes for each of the three alternatives a, b and c.

In other words, conducting m_2 random draws for the random parameters, the following is calculated for each strata j:

$$Pr_n^*(j,p)= \frac{\sum_{r=1}^{m_2} Pr_{ni}^{*r}(p)}{m_2}, \quad n=a,b,c \quad m_2=5000 \qquad \text{[SM. Eq.7.3]}$$

where $Pr_{ni}^{*r}(p)$ has the form shown in equation [SM. Eq.6.3], but for the specific case of the alternatives a, b and c in strata j. Using this information, the revenue function, R_{BL}, for the set of 12 strata is written as follows:

$$R_{BL}(p)=\sum_{j=1}^{12} N_j\left(Pr_a^*(j,p)p+Pr_b^*(j,p)p+ Pr_c^*(j,p)p\right) . \qquad \text{[SM. Eq.7.4]}$$

where N_j is the number of adults of the Andalusia population corresponding to strata j. Finally, assuming for simplification purposes that the programme costs are fixed, C_{BL}, and that the market structure is a monopoly (or monopolistic competition in the short run), the price p* is determined by maximizing the following function:

$$\max_p R_{BL}(p) - C_{BL}. \qquad \text{[SM. Eq.7.5]}$$

However, as equation [SM. Eq.7.3], and hence [SM. Eq.7.4], are stochastic functions, one needs to make a large number of random draws to find a non-parametric revenue function to solve the maximization problem numerically. To do this, we set $\hat{x}_{ni}=\bar{x}$, and simulate $R_{BL}(p)$ for a large number of values within $p = [0, \bar{p}]$, by drawing for each price considered 500 draws and averaging the results. The non-parametric function obtained can be found in fig. S13.

The result is that revenue was maximized for a price (tax fee) equal to 122 euros per person and year. Note that, although the analysis uses the term “price” for joint payment for biodiversity and landscape, the payment vehicle actually used was a tax fee. This payment method was used exclusively to make the scenario more credible and to estimate the demand function, so it was not assumed during the analysis that everyone would have to pay the tax fee.

Finally, given that the simulated payment corresponds to landscape conservation and biodiversity preservation together, it is necessary to separate these two components. This separation was made according to the relative weight of the parameters associated with landscape and biodiversity in the estimated mixed logit model.

The spatial distribution of the product associated to biodiversity preservation is done assuming that all 224 species considered (Supplementary text S10) have the same value, and distributing the total value of the species among all of the hectares where they are present. For the tree species (landscape conservation), the total value that would be collected for each species at price p* is distributed among all of the hectares currently covered by that species.

S8. Modeling tree species management, natural growth functions and yields

S8.1 Tree species management models

The models developed represent forestry itineraries for a large group of tree species in Andalusian forestlands. Those itineraries account for the age at which each silvicultural operation is performed, its intensity, the criteria according to which different operations are executed, and their main objectives. For each silvicultural operation, we reckon the amount of extracted products (timber, cork, firewood and edible fruits), indicating whether it is intended to improve the stand productivity or obtain a final product. The estimated costs of the intervention, along with the assessment of the products, allow us to estimate the economic balance of each silvicultural operation throughout the entire rotation of the relevant species (*56*).

This is the first time that this forest modeling technique has been applied to slow-growing and long-rotation Mediterranean tree species, which are characterised by low rate timber growth and primary production of non-wood provisioning, regulating and cultural products. There is no similar work on multifunctional forestry with a quantitative assessment of several prioritized roles for each species, both ecologically and experimentally based, that can be applied on a real regional scale to an important set of typical Mediterranean species. Difficulties in developing and validating these new models of multifunctional management increase because of the need to compromise amongst several products types simultaneously (e.g., woods, edible fruits, cork, carbon sequestration, biodiversity preservation, water yield, landscape, recreation and mushroom). This methodology helped in the evaluation of some or all of the aforementioned products, while prioritizing those considered the most interesting and appropriate in each case. When one or more products are not a priority, then the forestry model guarantees their minimum and reversible threshold.

Foresters should ideally account for the needs and demands of society in order to predict the likely consequences of treatments they prescribe to an accurate extent. Nonetheless, the information on the likely economic, ecological and social benefits of Mediterranean forest ecosystems was, until now, scant as opposed to the implementation costs of silvicultural treatments (*66-68*). Within this context, we have developed silvicultural growth and yield models for the main forest species in Andalusia (*69*): *Quercus ilex ballota*, *Quercus suber*, *Quercus pyrenaica*, *Quercus faginea*, *Quercus canariensis*, *Castanea sativa*, *Populus* x *euramericana*, *Eucalyptus globulus*, *Olea europea*, *Abies pinsapo*, *Pinus halepensis*, *Pinus pinaster*, *Pinus pinea*, *Pinus nigra* and *Pinus sylvestris*. These models include either two productivity classes (medium-low and medium-high) or a site index. We developed various silvicultural models for the same species according to the structure of the forest stands (even-aged or uneven-aged) and whether the stands require high forest or coppice management. Furthermore, we provide silvicultural guidelines and product estimations for eight additional species which, due to the small area they occupy in Andalusia, are considered of lesser interest. These are *Pinus radiata*, *Salix spp.*, *Fraxinus spp.*, *Populus spp.*, *Juniperus spp.*, *Prunus spp.*and *Arbutus unedo*.

Our protocol for developing silvicultural models for the entire cycle for different forest species, consist of four work phases (fig. S14) (*69*).

1. Review of qualitative silvicultural literature on each species

This included a review of available information regarding the forestry treatments (including thinning, pruning, clearing and plantation systems or induced natural regeneration methods) that can and ought to be performed on different forest species and how to achieve them under different management systems (even-aged stand, uneven-aged stand, coppice).

2. Consultation of quantitative silvicultural literature on the species

This included data gathering and revision regarding timber and non-timber yielding production, carbon dioxide (CO_2) period fluxes and stocks; quantifying thinning programs (age at initial thinning, weight of each thinning and rotation), stand density over the course of the rotation (number of trees, basal area and volume per diameter class), regeneration system indicating the number of cuttings to be carried out and the intensity of the different cuttings depending on the purpose (preparation, dissemination, thinning and final harvesting), paying particular attention to the number of trees and volume to be extracted at each cutting.

3. Estimation of site quality or site index using habitat parameters

We identify the site quality and site index, as well as potential areas of expansion for each forest species considering the characteristics of the habitat of the species. This characterisation accounts for physiographic and climatic data and the National Forestry Inventory Data (NFI3) plots in Andalusia with presence of the tree species considered in this study. Once we determined the habitats for each species, we defined the marginal intervals and the central or optimal one. Those intervals are then mapped, yielding two classes that approximate the quality of the site based on the suitability of the territory for the species.

4. Redrafting of the information to define the full-rotation silviculture

The sources of information used to define the full-rotation silviculture comprise the literature related to qualitative and quantitative silviculture (steps 1 and 2 above), the database of the CIFOR-INIA network of permanent experimental plots, Andalusian forest management plans, inventories from the collaborating RECAMAN estates, NFI3 (Third National Forest Inventory) and unpublished internal documents from provincial forestry products in Andalusia. We gave priority to the information concerning directly the Andalusian forestlands, and the literature or data sources from Mediterranean forests in Spain are only used when the information on Andalusia is considered insufficient.

Fig. S15, S16, S17 and Additional Data S2 tables 1 to 8 (*69*) are examples of the suitability maps of the territory and of the complete cycle silvicultures, respectively. Those examples include the three most characteristic Mediterranean forest species in Andalusia, in terms of their area and commercial and environmental products: *Q. ilex*, *Q. suber*, and *P. pinea*.

S8.2 Tree natural growth and yield functions

Montero *et al*. (*69*) describe in detail the growth dynamics and the equations that show the evolution of the analysed forest stands. Management approaches to these stands include silvicultural operations (thinning, pruning…) that are defined by evolution of the density functions based on the Reineke theory (*70*) (i.e., the density-diameter relationship). We describe below the natural growth and yields models for key tree species and quality sites.

Holm oak (Quercus ilex.)

Holm Oaks have varying stand typologies in the Andalusian territory. For this species we consider the following models (Additional Data S2 tables 1 to 3) (*69*):

Silviculture in holm-oak even-aged forest for two different site indexes: Medium-high quality and low-medium quality.

Silviculture for holm-oak coppice.

Silviculture for uneven-aged stands of holm-oak.

Model relating holm-oak age with diameter at breast height

In general, for most forest species, the dominant height is the dasometric variable used as a reference to estimate the site index. However, in the case of the holm-oak, this variable is not the most indicative of site index, the diameter at breast height (dbh) being the far more significant variable in the development of this species. We have tested different models for fitting the age-dbh relationship. The best results correspond to the Richard-Chapman (*71*) model. We used age-diameter curves with this model to describe the two different site indexes. The method we employed was the “guide curve method” (*72*), 100 years being the reference age set.

Medium-low quality [SE. Eq.3.1].

Medium-high quality [SE. Eq.3.2].

Coppice [SE. Eq.3.3].

Uneven-aged stands [SE. Eq.3.4].

Where *dbh* is the diameter at breast height (cm) and *t* the age of the stand (years).

Holm oak acorn production model

The acorn production model allows annual production to be predicted based on the *dbh* of the tree. To develop the model, we used data provided by Fernández *et al*. (*73*). We tested different models, after which we selected a modified Hossfeld (*74*) function [SE. Eq.3.5], where $Prod_{acorn}$ is the annual acorn production expressed in kilogram per tree.

Evolution of stand density model

Based on literature relating to the different densities that have traditionally been used in the management of holm-oak forest (*75, 76*) as well as field data, Reineke's (*70*) equation was fitted to predict the evolution of the density in holm oak stands.

Even-aged forest [SE. Eq.3.6].

Uneven-aged forest.

Uneven-aged stand structure.

Coppice [SE. Eq.3.7].

Where *N* is the number of stems and *dbh* is the diameter at breast height.

Stone pine (Pinus pinea)

Together with the holm oak and the cork oak (*Quercus suber*), the stone pine is one of the most representative species of forestland in Andalusia. The stone pine is found in practically all Andalusia forest areas, although it presents differing characteristics depending on the area. The first differentiation that can be made with regard to this species in Andalusia is the distinction between open low land (*campiña*) and the mountain area. The term *campiña* embraces those areas with an altitude up to 150 meters and that mainly correspond to coastal areas of the province of Huelva. Furthermore, within each of these areas, we differentiate two site qualities (Additional Data S2 tables 4 to 7):

Low land:

Medium-high quality [SE. Eq.3.8], [SE. Eq.3.9], [SE. Eq.3.10] and [SE. Eq.3.11].

Where $Prod_{conepine}$ is the annual pine cone production expressed in kilograms per tree.

Medium-low quality [SE. Eq.3.12], [SE. Eq.3.13], [SE. Eq.3.14] and [SE. Eq.3.15].

Mountain areas:

Medium-high quality [SE. Eq.3.16], [SE. Eq.7.17], [SE. Eq.3.18] and [SE. Eq.3.19].
Medium-low quality [SE. Eq.3.20], [SE. Eq.3.21], [SE. Eq.3.22] and [SE. Eq.3.23].

Additionally, we have developed a model for uneven-aged stand silviculture (69).

Cork oak (Quercus suber)

We consider two different types of silvicultural models for cork oak stands, one for even-aged stands and another for uneven-aged stands. The Andalusian territory was divided into five cork production areas (*77, 78*), with Cadiz and Malaga considered as dense cork oak stands and the rest of the provinces as open cork oak woodlands. In these open cork oak areas, we chose data from two different sources: plots in Sierra of Sevilla were applied to the provinces of Seville, Córdoba and Jaén, and intermediate weighted data was applied to the provinces of Almeria and Granada.

Even-aged silviculture (Additional Data S2 table 8) [SE. Eq.3.24] and [SE. Eq.3.25]:

We use a cork weight prediction equation for individual trees (*78*) in order to calculate cork production. This cork weight function considers the debarking height (DH) along with the circumference either under or over cork (Additional Data S2 table 9). The DH is estimated according to the following expression [SE. Eq.3.26], where parameters a and b are characteristics of each of the zones (Additional Data S2 table 9). Pruning cork-oaks, provides firewood which is a main provisioning product of this species. The weight of the pruned wood per individual tree is estimated as:

Production of firewood without virgin cork bark [SE. Eq.3.27].
Production of virgin cork bark eq.11.28 [SE. Eq.3.28].
Production of twig bundles eq.11.29 [SE. Eq.3.29].

We assume that cork oaks are pruned every 27 years, 4 years after debarking or three years before the next one. We estimate the acorn production for this species using a simple model that was fitted using data from unpublished research studies from other CIFOR-INIA experimental plots [SE. Eq.3.30]. When applying the above equation it is important to bear in mind that this model refers to the mean experimental production for a 5-year period.

Uneven-aged silviculture [SE. Eq.3.31].

Equations to estimate cork oak production are the same as for even-aged silviculture.

S9. Modeling spatially-explicit timber and cork extractions and carbon uptake

S9.1 Timber

We use as base cartography the Spanish Forest Map (MFE), except for timber extraction estimations which are based on the Third National Forest Inventory (NFI3), as primary information from measured plots in the IFN3 was used. These plots and information about them have already been spatially referenced and are available on the MFE. In particular, data (volumes, growth, diameters, number of tree, etc.) corresponding to the 11,603 plots have been processed. As for the MFE, this mapping base is used in its most disaggregated form (tiles) and on the strata scale. These strata are defined on the provincial scale according to the main species, occupation, status of stand and fraction of canopy cover; for Andalusia as a whole, there are 140 strata. The number of tiles increases to 113,756 with sizes ranging from 2.5 hectares for wooded surfaces to 6.25 hectares for treeless areas. We should stress that there is a direct connection between the IFN and the MFE. This circumstance not only facilitates different tests but also results in considerable cost savings with respect to data processing.

Modelling the extraction of timber is based on data provided by public agencies, which provide information not only on fellings that have occurred in the publicly-owned forests of the study area, but also on the price of timber. This information is basic, enabling an allocation of a percentage of existing timber volume that can be cut in 2010 in areas that do not have this data. However, some disaggregated information at a forest property scale has been used, primarily based on information related to forest management plans. Accordingly, certain information was extracted at the parcel forest scale of cuttings produced in recent years, the method of benefit, etc.; not only to improve and complete planned allocations but also to assess possible errors.

Regarding timber and cork extractions, we follow a similar procedure: for each target species (the species that represents each stratum for timber harvesting), we calculate the ratio between the extractions and the existing volume growth in each grid and stratum. Because most grids do not contain MFE plots, we defined a grid model (as presented below) for each target species, considering the aggregation of the plots in each stratum. For each grid, growth is allocated to each type of age class in the diameter distribution that results from the data of all the plots. Furthermore, we weighted the extractions according to the surfaces on which they were actually carried out.

We follow a similar procedure for cork extraction, using in that case cork debarking data provided by the Andalusia Regional Government. Besides, for the cork extraction, public agencies also have information concerning the average index quality of cork and the stripping carried out in 2010.

We estimate the extractions that occurred during the reference year (2010) in each tile of the MFE. Thus, for each species that has a commercial use and for each stratum, the ratio between what is cut annually and current annual growth can be obtained. The estimation is based on only a portion of the stands' annual growth. Thus, when examining the growth of a species at the tile scale, information collected is based at the plot scale, and the aforementioned growth is associated with the tile that contains the plot, whenever the MFE confirms that the species is to be found in this tile. A limitation of this approach is that a high percentage (approximately 90%) of MFE tiles does not contain IFN plots, forcing search procedures that assign values to each of the tiles where there is no information directly from the IFN plots. To overcome this problem, the procedure consists in defining a tile type for each species objective (representative species from each stratum that have a timber use and/or non-forest products considered in this study) and stratum. This tile type is characterized by a diametric distribution, which is obtained from data for all same-stratum parcels that contain the target species. Finally, the target value, growth in this case, is assigned to the diametric classes that compose the stratum's tile type.

Nonetheless, it is necessary to take into account where the final cutting occurred, defining the strata at which the target species are found in a significant percentage of the tiles (i.e., where the species has a presence in more than 20% of the existing number of trees). Calculating the harvesting areas is not direct because it is necessary to assign the cubic meters resulting from extractions to the forest stands where it actually occurs. In general, on the harvesting area, all of the tiles that belong to the strata in which the exploited species exists are considered as representative. The next step in this procedure is to identify the tiles where these harvests will be distributed. To do this, we consider two criteria. The first is that the number of trees of the target species needs to be greater than 20% compared to the total number of trees in the tile. In contrast, the second criterion affects those tiles that lack information about the IFN3 plots. In such a case, to include these tiles it must be verified that this species is present based on the information provided by the MFE. At the intersection of the MFE with the publicly-owned forest ecosystems layer where the exploitation data for the target species are available, there are a large number of tiles within the same public forest ecosystem. All are chosen except those in which the plot of the target species is not present and those tiles that contain plots in which the number of trees of the target species is less than 20%. With this procedure, it is possible to calculate the area of the forest ecosystem that can be associated with the exploitation data associated with it.

The next step is weighting the extractions data to obtain a value (m^3/ha) for the strata present in each forest ecosystem. We assign to each of the strata a value of use-per-hectare according to the volume of use at each forest ecosystem. Next, we analyze both the tiles that cover the areas that are publicly-owned and those that are located in private areas. When working on the tile scale, we reckon the weighted use/growth ratio for the public and private forest ecosystems at each tile, by dividing the area of the tile belonging to public forest ecosystems by the total area of the tile. Conversely, and as verification, when the strata corresponding to a species for a particular province are completed, it is verified that this condition is fulfilled in all of the forest ecosystems where land use data are available. Otherwise, the above steps are recalculated. Finally, it is important to note that this entire methodology was developed in those tiles (from the plots of the IFN3) in which the final felling actually occurs. We exclude those protected areas where commercial exploitation is banned (i.e. National Parks).

S9.2 Cork

The information used to estimate the spatial distribution of cork production was provided by the Government of Andalusia and includes cork harvesting by cork category: virgin cork and reproduction cork (obtained from debarking cork oak trunk) and warblers (branches bark). Cork harvest data are given in metric tons while growth and volume data in cubic meters. To distribute the extraction of cork inside an area where there are tiles of cork from different strata, we consider a strata-weighted distribution. We define a weighting factor, which is obtained by multiplying the number of trees in each diametric class by the amount of cork per tree that corresponds to the corresponding diameter class. With the weighting factor of each stratum, we calculated the stripping of cork for each forest ecosystem. In this manner, we allocate the stripping to each strata of the forest ecosystem, according to the surface that the stratum occupies and its weight compared to the remaining strata that produce cork. Once the cork that is harvested in the period (work-in-progress used) is distributed between the tiles of the forest ecosystem we distribute this production amongst cork oak belonging to different diametric classes that are to be found at each tile. This distribution is weighted both by the number of harvested oaks in each diameter class and by the production of cork in the trees of each diametric class.

S9.3 Carbon uptake in trees and shrubs

The application of these models to the bush strata of Andalusia, along with the implementation of existing models of biomass estimation for tree species, allowed us to quantify the total biomass of bush and tree strata and the amount of carbon that is captured by both in the region. We use models that estimate the total accumulated biomass and average annual growth for the primary scrubland formations across Andalusia (see Supplementary text S8.1).

We base our tree carbon sequestration estimates on the volume increase data at the plot scale, considering the specific carbon content by tree species (in CO_2 metric tons by cubic meter) and an expansion factor that relates the total tree volume (roots included) to the timber volume (*79*). For the carbon contained in the shrub biomass our quantification is based on specific functions (*69*) that relate the fraction of shrub canopy cover (FCC) and height at each plot to total biomass stock and growth, and hence carbon stock and sequestration.

We further quantify net carbon sequestration in tree and shrub stratum by considering carbon dioxide releases. In the case of shrubs those releases are due to shrub clearing and forest fires during the accounting period. The average percentage of the shrubland surface that was annually cleared is based on own private landowners´ survey data analysis at the provincial and Andalusian scales. Tree mortality estimates come from Montero *et al*. (*69*).

The equations (*79*) used to estimate aboveground biomass are:

Tree growth and stock: *Quercus ilex* [SE. Eq.4.1], *Quercus* canariensis [SE. Eq.4.2], *Quercus faginea* eq. [SE. Eq.4.3], *Pinus sylvestris* eq. [SE. Eq.4.4], *Pinus pinea* [SE. Eq.4.5], *Pinus halepensis* [SE. Eq.4.6], *Pinus nigra* [SE. Eq.4.7], *Pinus pinaster* [SE. Eq.4.8], *Quercus suber* eq. [SE. Eq.4.9], *Castanea sativa* [SE. Eq.4.10], *Olea europea* [SE. Eq.4.11], *Abies pinsapo* eq. [SE. Eq.4.12], *Quercus pyrenaica* eq. [SE. Eq.4.13], *Populus* eq. [SE. Eq.4.14] and *Eucalyptus* [SE. Eq.4.15], with *C* being the Mg of carbon contained in each ton of dry matter and *dbh* the diameter at breast height in cm.

Shrub growth and stock. In the case of shrub biomass, we estimate models to predict the amount of biomass stock and growth for the shrub layer. We aimed for models that can be used by the managers and include variables that are easy to obtain using traditional forest inventories. The independent variables chosen were the fraction of the strata canopy covered with shrub (FCC_s) and the average height of the stratum shrubland (H_s), along with different transformations and combinations of them. It should be noted that these shrub variables are also collected in the grids of the Third National Forest Inventory (IFN3).

As baseline data to fit these models, an inventory of the shrubby formations of Andalusia was performed. The methodology used for data collection involved direct sampling methods based on the layout of grids of a specific surface in which green shrub is cut and weighed, and then referred to as dry matter after drying and weighing a representative sample. Although this methodology is expensive, it achieves very precise biomass estimates (*80-82*). In each rectangular 4 x 5 meter grid (834), the fraction of space covered with shrub and the average height was estimated. All the shrub was then brushed using a manual trimmer to the ground, and the total biomass of the freshly-cut grid was weighed. Once the biomass was weighed, a representative sample between 1.5 and 2.5 kg was collected, labeled with the data from the grid and sent to the laboratory for drying in a stove at 102±2ºC to determine their weight in dry matter (MS). Once the coefficients of transformation of green to dry matter for each grid was known, the weight of dry matter per hectare was determined for each of them. For each grid, a minimum of three trunks of the shrub species most representative of shrublands were collected to determine growth. By counting the growth rings at the base of the three selected plants, the average age of the grid was calculated (*69, 83*). Overall, 834 grids throughout the Andalusia territory were inventoried (*69*).

Once the database was obtained, various analyses were conducted using different fit techniques (linear and non-linear regression), with the following being the model that had the best properties, offering a 95% significance level in all parameters:

$$\ln(W) = -2.560 + 1.006 \cdot \ln(H_s) + 0.672 \cdot \ln(FCC_s), \qquad \text{[SM. Eq.9.1]}$$

where W is the amount of biomass expressed in tones of dry matter per hectare (Mg dry matter/ha), H_s the average height of the shrub expressed in decimeters (dm) and FCC_s the fraction of canopy covered with shrub expressed in %. This model has an adjusted R^2 of 0.64 and a standard estimation error of 0.7416

For the management and use of a resource, quantifying the growth or annual accumulation rate is just as important as knowing the accumulated stock. Knowing the average annual growth in t/ha·year in 694 of 834 biomass grids, we fitted different mathematical models, with the following being the most indicative:

$$\ln(Y) = -4.771 + 0.814 \cdot \ln(H_s) + 0.676 \cdot \ln(FCC_s), \qquad \text{[SM. Eq.9.2]}$$

with *Y* being the average biomass growth expressed in tons of dry matter per hectare per year (Mg of dry matter/ha·year), H_s the average height of the shrub expressed in decimeters (dm) and FCC_s the fraction covered by canopy of the shrub expressed in %. This model has an adjusted R^2 of 0.60 and a standard estimation error of 0.72657.

We would like to stress the novelty of this type of model, as there is no previous information to compute the biomass of Mediterranean shrubs at the aggregate scale.

S10. Threatened biodiversity preservation

Forest ecosystems tend to maintain high levels of biodiversity, including species which are rare and threatened (*84*). The economic value of environmental products derived from threatened biodiversity is nevertheless one of the most difficult to quantify both in physical and monetary units (*85*). It is expected that the weight of preserving this scarce public good will increase in future political agendas (*86, 87*). Development of tools and indicators to help assess the way in which programmes and policies will affect this biodiversity are thus important and timely.

The valuation of threatened biodiversity involves the estimation of societal preferences in the context of simulated markets, whose design requires relevant and accurate indicators of this biodiversity. These indicators must be based on the physical measurement of the distribution over space and time of unique biological entities (usually species) whose persistence is threatened. The physical measurement of these indicators must be subject to an economic assessment, in this case as passive consumption within a coherent evaluation system able to integrate the existence value of threatened species. Indicators of the risk of biodiversity loss must therefore be based on measurements of the distribution of threatened species in a given geographical area at a given time, and they must be capable of capturing its variation over space and time.

The threatened biodiversity indicators usually used have been based on locally and regionally well-known groups or organisms, mostly birds, plants and some groups of insects such as butterflies, by explicitly or implicitly assuming that they will be representative of all threatened biodiversity (*88, 89*). However, this assumption is questionable, because different groups of organisms tend to respond differently to the pressures that cause their decline or extinction (*90, 91*). Here, we develop a new process of selection of indicators, which was based on the concepts of the threat level of all species found in the territory, and on the regional responsibilities for species preservation. These indicator selection criteria are also based on the broadest-scale legislation, i.e., the European Birds and Habitats Directives in this case, to provide the list of protected species on a continental scale. This list was regionally expanded to include the most threatened species not covered by European legislation but which are endemic to the region, so that the responsibility for their preservation is exclusively regional.

The selection process started with the lists of threatened species included in the Annexes of the European Birds and Habitats Directives. First, we eliminated species whose distribution areas do not reach Andalusia, as well as species linked to non-forest habitats (urban, agricultural, freshwater and marine) on the basis of the information provided by the most recent national Red Books (*92-98*). We then completed this reduced regional list with the species native to Andalusia that are either 'Critically Endangered' or 'Endangered' and are not covered by the Directives, according to regional Red Books (*99-101*). The final list included 224 species: 81 plants, 76 birds, 31 mammals, 22 arthropods, six reptiles, five amphibians, and three molluscs (see Additional Data S3 table 1). We established regional threat level according to the technical IUCN guidelines (*102*) recently published in the corresponding Andalusia Red Books. Species protected by European Directives but not explicitly listed in Andalusia due to its low regional threat level were considered as Near Threatened (NT) if rare at the European scale or of Least

Concern (LC) if abundant or increasing (see Additional Data S3 table 1). Most species were included in the Endangered (EN; 67 species) and Vulnerable (VU; 55 species) categories. The list of indicators also included 10 species Critically Endangered (CR), two Extinct in the Wild (EW), and eight Data Deficient (DD).

We derived distribution maps of the species listed at the scale required for economic valuation from the available cartography: regional distribution maps of threatened species provided by the regional Administration, the Vertebrates Database of Spain (*103*), the Red Books of Andalusia invertebrates (*101*) and plants (*99*), the databases of the Anthos project (*104*) for vascular plants not included in the Red Books, the national butterfly Atlas for diurnal Lepidoptera (*105*), and the Atlas of wintering birds (*98*) as well as recent references on specific species (Additional Data S3 table 1; details in Ref. (*106*)).

We used directly official maps available from the regional government at the 1 km x 1 km UTM grid or at finer scales (131 species; 58.6%). The remaining maps were published at the 10 km x 10 km UTM grid scale. In these cases, we used the information available on the habitat requirements of these species (preferred vegetation types) and their altitudinal ranges to estimate what areas of the 10 km x 10 km squares were most likely actually occupied by each species. These methods, although less precise than those based on direct censuses, would, however, produce more realistic estimates than wide-scale presence-absence maps (*107*). Maps were downscaled by overlapping distribution maps with the types of habitats occupied by each species through a Geographic Information Systems (GIS). We updated species distribution maps from the most recent Atlas and from similar projects. We obtained the types of forest land occupied by each species in Andalusia from a comprehensive literature review on species requirements (see Additional Data S3 table 2, and Ref.(*106*)), after grouping the forest land types defined in the digital maps available (Andalusia vegetation map) into a smaller number of categories. Thus, we grouped the 72 forest land types (plus five additional categories of land uses) that were recognized in the vegetation map into 16 types according to dominant species (e.g., pines Pinus spp., deciduous or evergreen Quercus spp. oaks etc.) and woodland structure (closed forest or open woodland). We made no distinction among species of pines, junipers or evergreen or deciduous oaks on the basis of the habitat requirements of species, (see Additional Data S3 table 2, and Ref.(*106*)). Downscaling by overlapping distribution and vegetation maps was done separately for each species and Andalusia province; we then merged the eight provincial maps into a single regional map per species. We excluded agricultural, unproductive and wetland areas.

We used distribution maps at the 1 km x 1 km UTM grid scale to ascertain the presence-absence of each of the 224 indicator species in each of the 113,764 forest patches of differing size recognized in the Andalusia Forest Map by GIS overlapping. These presence-absence patterns, together with estimates of the size of the distribution area of each species obtained by summing the size of all suitable and likely occupied patches, were the physical bases for the estimation of the economic value of threatened biodiversity in the forest lands of Andalusia. The sizes of the distribution areas varied between zero (11 species currently absent from Andalusia) and more than four million hectares (the Sardinian warbler S. melanocephala and the Blackcap Sylvia atricapilla), with an average of approximately 450,000 hectares. Georeferenced distribution maps are available upon request.

The method developed here generated a list of manageable size including all species of conservation concern for a European territory of sizeable extension and biodiversity. The selection method met the requirements established by several authors and international agencies for use in rigorous assessments of threatened biodiversity (*106*), and can be used for the economic valuation of biodiversity through non-market valuation techniques as species can be ordered by threat level (*108, 109*). Finally, the procedure can be applied to any region of the European Union if the process starts with the lists of species of the Birds and Habitat Directives, or to any other region of the world, starting with the most appropriate legislation on threatened species and habitats (for example, the US Endangered Species Act). Species mapping methods can also be applied to any region, although their accuracy may vary according to the degree of detail of regional knowledge on the geographic distribution, threat status and habitat requirements of the selected species. In any case, the procedure provides objective methods based on two relevant concepts for analysing the existence value of threatened biodiversity, i.e. threat level and responsibility for preservation, thus obviating subjective choices of indicators for threatened biodiversity based on the degree of local or regional knowledge.

S11. Surface water yields

We applied a hydrologic model that estimates the annual flow of water in forest ecosystems and the surface water regulated by reservoirs, taking into account the surface occupied by the types of uses and vegetation in the forest ecosystems of Andalusia.

Water regulated by the public system of reservoirs is an environmental asset in the public domain. Surface water from precipitation, which is stored in reservoirs and intended for consumption in crop irrigation, industry and households, is valued as an environmental service of the forest ecosystems. The quantity of water stored that is to be released as ecological flow is not considered economic. In this research, the environmental price of regulated water is estimated using the hedonic price incorporated into the price of the land with water concessions for irrigated crops in the basin of the Guadalquivir River (*110*) (fig. S18).

Forest vegetation contributes to the regulation of water resources through its influence on relevant land water cycle processes that determine the conversion of precipitation water (P) into several land water flows: evapotranspiration (E), runoff (Q), deep aquifer recharge (R) and variation of the temporary internal water storages (ΔI). These flows constitute the fundamental land water mass balance: $P - E - Q - R - \Delta I = 0$. (fig. S19). The regulation of the land water balance by vegetation is especially relevant in climates with a structural hydric deficit, as is the case of Andalusia. On these regions, a large share of the total water resources is typically generated on the headwater areas, located in forest ecosystem regions, which feed the low lands located downstream in the catchment. In order to determine the annual water balance of the forest areas of Andalusia we used a hidro-ecological simulation model, the Soil and Water Assessment Tool (SWAT) (*111*). SWAT considers several geographic parameters, such as topography and soil characteristics, vegetation parameters and observed climatic data, in order to determine the physical quantities P, E, Q, R and ΔI. We applied this simulation model to all the forest patches in the Spanish Third National Forest Inventory in Andalusia.

The SEEA-EEA (*8*) considers natural water as the only non-biological natural resource rent recognized as an individual ecosystem service. The SEEA-EEA and the AAS forest ecosystem public natural water provisioning services originate the same individual water public environmental asset.

The SEEA-Water (*112*) refers to water in the river. This water could be dammed for economic uses and left to run in the natural channel to maintain the normal operation of the natural environment. We have not considered forest water activity as an independent water ecosystem, as the SEEA-Water does. We consider forest natural water activity as an individual forest environmental provisioning service exported to the water reservoirs and with its subsequent economic uses. Meanwhile, SEEA-Water recognizes a payment to the landowner by the water agency company, this landowner forest natural water revenue would affect the SEEA-Water by losing the current free natural water flow condition and the ownership of the forest natural water would become private environmental income both for AAS and SEEA-Water methodologies.

The hedonic pricing method was used to calculate the price of regulated surface water (reservoirs) from its use as irrigation water (marginal use). The income and environmental assets of regulated surface water was calculated based on this price in the forest ecosystems of Andalusia both in 2010 and in the period 2000-2009, which is considered representative of a stationary situation. The application of this methodology (hydro-ecologic and economic model) to the 18,060 km^2 of Andalusia forest ecosystems with regulated surface waters (waters that drain into a reservoir) enables the estimation of the 2010 income and environmental assets of forest surface water (*113*).

The environmental water asset price (p_k) is estimated because the marginal willingness of owners to actually pay for the irrigated land is estimated by the hedonic pricing method. This method is applied to market prices comparing land with alternative irrigation uses to rain-fed land in the same class. As the average volume of water consumed in a permanent form per unit area of irrigated surface in estates is known (*110*),

assuming a normal rate of return, the environmental income is directly calculated. In this case, by not having estimated manufactured costs of public administration that influence the natural capital of the forest ecosystem reservoir water, the environmental income coincides with the total income and the final product. The lower bound price of the public environmental asset of water flow stored in reservoir is implicit in the market price of land for irrigation.

When estimating the stationary environmental income, we assume that future prices of the environmental assets of forest water with economic uses will not vary and that the past decade's contributions to the reservoirs are taken into account. This stationary environmental income is taken into account to estimate the value of the environmental asset of the forest surface reservoir water. Because of the current regulation of property rights, the public administration determines that any surface rainwater that reaches the reservoir is a public environmental product. The transformation of a rainfed land into irrigated land, the public administration ceding the use of the reservoir water to the owner of the irrigated land through the payment of a management fee (does not include the environmental income of the water), implies transferring the environmental income of the surface water stored in the dams to the owner of the irrigated land. The use of this water for irrigation has been granted to private beneficiaries by the public administration over long periods. Accordingly, water becomes a private environmental asset embedded in the irrigated land price.

We only attribute environmental economic value to natural reservoir water from the surface runoff of rainwater that has an economic use. It is assumed that higher prices are generated not only by the reduced environmental price of irrigation water but also by the existence of other water users (industries, households and public administrations) that are regulated by the water public agency. Here, the environmental price of water considered is that for irrigation in the Guadalquivir River basin (*110, 113, 114*).

Both the public agency that manages regulated water (AMAYA) and the public administration directly incur costs of "forest hydrology" restoration that improves the quality of the reservoir water and reduce annual deposits of materials into the reservoirs. These costs are attributed in the public agency's water account by assuming that they are imposed in the public domain of the river channels offsite of forest land, which are not subject to economic quantification in this study (*112*). The hedonic price method that is applied to market prices (compared from the same land class) versus alternative irrigation uses (compared to dry land) yields the market environmental asset price of the natural regulated water consumed by irrigation products. Because there are no estimated manufactured costs from the public administration to influence the capital of natural forest land ecosystems reservoir water, environmental income is estimated by its hedonic price. Thus, the values of final product (FP), total income (TI) and environmental income (EI) coincide.

S12. Mushroom picking

We consider wild mushroom picking by public (open-access) visitors in Andalusia forest ecosystems as a public environmental good. This is supported by two facts: (i) land market prices do not incorporate the capital value of the income generated by this activity; and (ii) landowners generally do not prevent access to mushroom pickers.

Mushroom yields are generally missing in forest management plans. National official statistics are also limited when it comes to this forest activity, ignoring harvested quantities that are not marketed. To obtain the necessary information to estimate the income from this activity, we conducted a telephone survey to the Andalusia population (>18 years) in 2010 to gather information on the harvested quantities and market prices of the different mushroom species picked in these forest lands. We designed a stratified sampling over Andalusia households based on the province population and on the forest cover area, with a random sampling within each stratum. This design resulted in 17,242 potential observations, from which we obtained 8,076 responses to phone calls (47% of total attempts). Out of these 8,076 successful calls, 4,219 respondents agreed to participate in the interview (51% of answered calls), from which we identified 267 mushroom pickers (6.3% of survey participants) that represent our sample of respondents (table S17). All these respondents stated in the survey that they pick mushrooms mainly for their own consumption, although some also sold them.

Thus, the survey results offer information on market prices and yields (quantities) for different mushroom species from our sample of mushroom pickers. These data allowed us to estimate the final product of the mushroom-picking activity (FO_{mu}) in the

Andalusia forest lands in 2010. FO_{mu} is obtained as the summation of the price (weighted by the production quality) times harvested quantities for each mushroom species:

$$FO_{mu}= \sum_{i=1}^{n} q_i \cdot p_i. \qquad \text{[SM. Eq.12.1]}$$

where q_i is the harvested quantity of species i in the year, p_i is the market price of species i and n is the number of mushroom species. To estimate annual quantities of harvested mushroom by species, we used the following questions:

> "Could you indicate what species of edible wild mushrooms you picked in 2010?"
> "How many days did you spend picking this edible mushroom of that specific species in 2010?"
> "How many kilograms of this mushroom species did you pick by field visit on average during 2010?"

Thus, the harvested annual quantity for each species (q_i) is calculated as the product of number of pickers of species i estimated in Andalusia (pk_i), the average quantity of harvested mushroom of species i per visit (qv_i) and the average number of visits by pickers of species i (pkv_i):

$$q_i=pk_i \cdot qv_i \cdot pkv_i. \qquad \text{[SM. Eq.12.2]}$$

We obtained estimates for qv_i and pkv_i directly from questions 2 and 3 above. We calculated pk_i as the product of the population of adults in Andalusia (6,721,293), the percentage of mushroom pickers obtained from our phone survey (6.3%) and the percentage of pickers of species i, which we obtained from question 1 above (fig. S20). We estimate the total quantity of mushrooms picked in Andalusia in 2010 (Q_i; see table S17) as the sum of the partial quantities (q_i) of all mushroom species picked in Andalusia in 2010:

$$Q_i=\sum_{i=1}^{n} q_i. \qquad \text{[SM. Eq.12.3]}$$

To estimate market prices of different mushroom species we asked the following question when respondents stated that they sold part of their picked mushrooms:

> "Do you remember the price you were paid for selling a kilogram of this mushroom species when they were top quality?" "And for the rest of mushroom picked?"

In order to use a single price for each mushroom species, we weighted the average price of each species i (p_i) considering two mushroom qualities. The top quality is usually related to reduced cap sizes and in good organoleptic conditions, which makes it nice-looking for sale. Other qualities reach lower prices due to the mushroom appearance and size features, being less attractive for sale. Thereby, the market price assigned to mushroom species i (p_i) is calculated as follows:

$$p_i=f_{i1}\cdot p_{i1}\cdot f_{i2}\cdot p_{i2}, \qquad \text{[SM. Eq.12.4]}$$

where f_{i1} is the weighting factor for the top quality price of species i, p_{i1} is the mean top quality price of species i, f_{i2} is the weighting factor for the other quality price of species i and p_{i2} is the mean price for other quality species i. We calculated mean prices for each quality and species (p_{i1} and p_{i2}) from question 4 above. We obtained the weighting factors (f_{i1} and f_{i2}) from the survey based on the ratio of quantities marketed for each quality type:

$$f_{ij} = q_{ij}/q_i, \qquad \text{[SM. Eq.12.5]}$$

where f_{ij} is the weighting factor for species i and quality j, q_{ij} is the harvested annual quantity of species i and quality j and q_i is the harvested annual quantity of species i.

When prices for specific species i were not available from the survey, we used in order of priority the prices from the following data sources: (i) the average price of the species paid in the *Jimena de la Frontera* regional mushroom market in the 2008/09 campaign (*115*); (ii) the price of the species paid to mushroom pickers in sale sites as reported in the 2001 National Lactarius Project (*116*); (iii) the price of the species paid in sale sites according to the MICODATA Project (*117*); and (iv) a symbolic price of €1 per kg for species with no information on prices but that are usually consumed by mushroom pickers (table S18).

The estimation of total income from public mushroom picking in the Andalusia forest lands must incorporate the management costs devoted by the regional government to this activity. Environmental income from mushrooms is valued by the residual valuation method based on the harvested mushrooms market price in the forest land gate. The amount of mushrooms collected by the public does not have a private total cost because it is assumed that collectors have no opportunity costs (do not give up any gainful employment) and therefore, the values of the harvested mushrooms and private environmental income coincide. However, there is a government total cost attributable to public administration management, which could also lead to a final product of manufactured gross fixed capital formation. Total final product is composed of harvested mushrooms plus manufactured gross fixed capital formation. The total government manufactured cost and manufactured capital gains are known. We estimate the government manufactured net operating margin by imputing the normal rate (r) of return to government manufactured immobilized capital.

S13. Livestock grazing

The data for grazing were collected in 2010 (*47*) using a face to face survey to 765 private landowners randomly distributed in Andalusia; and getting bookkeeping data from 43 silvopastoral estates case studies (27 privately-owned and 16 publicly-owned) in Andalusia (*56*).

S13.1 Forage consumption

The measurement of the consumption of forage units by livestock grazing depends on (i) the size of livestock herds grazing at the silvopastoral estate (forest estate hereinafter), (ii) the energy requirement by species and breed, (iii) the age structure and distribution of the herds, and (iv) the supplementary forage. Each one of those variables has been estimated for a sample of 359 forest estates across Andalusia that covers the main forest vegetations in this region. Those forest estates are a sub-sample of the aforesaid 765 forest estates; and provide detailed information on the size and type of livestock herds by species and livestock breed, the time those animals stay in the forest estates and on the supplementary forage supplied. In the case of cattle, sheep and goats, the number of breeding females present on the farm was considered as of 1 January 2009. For bulls, Montanera pigs, non-Montanera pigs and horses, information was collected regarding the total number of livestock on the farm as of the same date.

The information collected by this survey was related to detailed information regarding annual energy requirements (measured in forage units (*118*) of metabolic energy, equivalent to 1 kg of barley with 14% of water content, 2,723 kcal) of females by livestock breed (for cattle, sheep and goats) and the average effective number of livestock (for fighting-bulls, horses and pigs) from 43 forest estates bookkeeping case studies (*56*). These 43 case studies correspond to forest estates with different livestock species using the grazing of the estates in 2010 for more than six months, except pigs, for which all movements were studied during the *montanera* season (not exceeding four months), during fall and winter times, when free-range pigs that roam oak woodlands (called dehesa) eat basically acorns.

The sample of 43 forest estates provides census information, the live-weight of the breeding females and the supplementary feeding for each livestock species by breed, gender and age throughout the study period. This information enabled us to estimate the parameters (by breeding female or an average animal) to estimate the total energy requirements of the livestock herds that owners have declared on their forest estates (*7*).

The grazing forage units consumption by species i and breed j was estimated using the residual valuation method for each species of livestock on the forest estates as total minus supplementary consumptions. The total energy requirements for cattle, sheep, goat and horse herds are estimated for a 161 sub-sample of forest estates (*56*) where those livestock species have been raised in 2010. This estimate is based on the annual energy needs of typical females measured in forage units and on an expansion factor that relates the energy requirements of a typical female to the total requirements of livestock herd (*7*). In the latter case, the additional energy requirements of the pregnancy and lactation of breeding females and the energy needs of calves and breeding males are included (table S19).

For the fighting-bull breed, it was estimated that the annual average requirements per animal regardless of age or sex reaches 3,888 Mcal per year (1,428 FU per year), which was multiplied by the number of animals of these species present on the forest estates. The latter value was drawn from the data on two fighting-bull cattle forest estates included in the sample of 43 forest estates for the case studies (*56*).

In the case of pigs, the total energy requirement estimate is based on information collected on nine forest estates among the 43 forest estates case studies. In these forest estates, two systems for fattening grazing pigs were identified: (i) the *montanera* season, which is based on the grazing of acorns and grass between October and February, and (ii) annual grazing, which is based on the use of pastures (including acorns) throughout the year.

The energy requirements of pigs that are *montanera*-fattened were estimated considering the kilograms of acorns required to obtain an *arroba* of weight (11.5 kg/*arroba*) during the *montanera* season. It is estimated that to replace one kilogram of live-weight, 8.5 kg of fresh acorns is required (97.75 kg of acorns/*arroba* of weight) (*119*). The requirements of pigs that consume other grasses were gauged based on procedures and methods described in the literature (*7*).

The energy consumed through supplementary forage is measured taking into account the amount of supplementary products consumed by livestock herds, as stated by the sub-sample of 161 landowners surveyed that raised different livestock species in 2010, and the metabolic energy content of supplementary foods according to the specialised literature (*7*).

S13.2 Intermediate product

Forests provide forage mainly by grazing as intermediate product. Final forage products are forage cut as natural hay and forage perennials leaves and stems final natural growth that remains standing for future forage consumption (final gross work in progress capital formation). The intermediate product and forage cut could embed the consumption of forage work in progress used up. We lack data on forage cut, final natural growth and work in progress used. In addition, grazing management usually requires durable investments, such as plantations, fence, building and equipment (manufactured gross fixed capital formation). As this investment is negligible in 2010 (*7*), grazing total product coincides with grazing intermediate product.

Grazing intermediate product is estimated based on prices observed in the competitive market of grazing lease in Andalusia. We measure the physical grazing forage units consumed (*7*) by predominant single forest estate vegetation (*7*). Grazed acorns are measured from an *ad hoc* holm oaks production function (Supplementary text S8). Grazing intermediate product includes grazed acorns and grass (including browse and other fruits). We measure grazing intermediate product multiplying the grazing forage units consumed by its lease price. Grazed grass is measured as residual value of total grazing less grazed acorns.

S13.3 Total cost

The grazing total cost components are those of standard accounts, with the addition of self-employed labor cost. The latter cost estimate allows estimating grazing net operating margin as pure capital return. The valuation criteria for the self-employed labor wage rate are conditioned by the assumption of a maximum marginal productivity of 80% of employee labor. When self-employed labor is presents, we estimate the mixed manufactured net operating margin as the net value added minus employee labor cost. If the mixed margin is negative, we assume all the value is a manufactured margin loss (*47, 120*).

S13.4 Net operating margin

The net operating margin is obtained subtracting total costs from the grazing intermediate product. We distinguish environmental and manufactured net operating margins. The latter is estimated imputing a normal return rate to the manufactured immobilized capital. Manufactured immobilized capital represents the landowner annual average investment in the livestock grazing activity. Manufactured immobilized capital is the sum of working capital and fixed capital in the accounting period. Manufactured immobilized working capital is estimated as half of grazing working capital (intermediate consumption bought plus labor cost) (Supplementary text S3.4).

The environmental net operating margin is estimated as a residual value from total margin less imputed manufactured margin. If the total margin is negative, then it is assumed that total margin is the manufactured margin, and that the environmental margin is null.

Grazing capital gains are classified as grazing acorn capital gains and consumable manufactured capital gains. Grazing capital gains are the residual value of capital revaluation minus unexpected capital destruction, and plus manufactured consumption of fixed capital. The latter is an accounting adjustment to avoid double counting.

S13.5 Total and environmental incomes

The Hicksian grazing total income is measured following the criteria showed in Supplementary text S3.6. The grazing environmental income is estimated by the residual value method. We assume that the manufactured net operating margin upper bound is the normal return rate times the manufactured immobilized capital. We further assume that manufactured capital gains are not taken into account by the landowners when they expect to obtain the normal return from the consumable manufactured immobilized capital.

Grazing environmental income corresponds to the landowner potential land rent (excluding any landowner grazing manufactured investment) for leasing the estate for livestock grazing. The landowner could not receive any request for leasing the estate and in this situation the environmental net operating margin is zero. We assume, as commented above, environmental margin is a non-negative value. On the contrary, environmental capital gains can be a negative value.

The environmental income includes the environmental net operating margin and the environmental capital gains; the later originates from grazing acorn environmental asset revaluation.

S13.6 Steady state environmental asset

To estimate the environmental asset value of grazing we discount the grazing environmental resource rent by a normative discounted rate (*4*). The grazing environmental price is measured deducting from the market grazing lease price the unitary cost prices of labor, intermediate consumption and the manufactured user cost of fixed capital (*51, 121*). Grazing resource rent includes opening period forage work in progress used and grazing environmental income. Assuming a steady state (physical forage natural growth equals forage consumption), the forage work in progress used has the value of the gross work in progress capital formation plus acorn capital gains (given the steady state assumption, manufactured capital gains are null and acorn environmental capital gains positive). Taking the grazing intermediate product as a reference point, we measured the future expected environmental income as a residual value.

Valuation of the grazing environmental asset depends on the future environmental income competitive market where the landowner acts as price taker. The steady state assumption (ignoring low positive acorn capital gains) permits the direct calculation of grazing environmental asset by discounting the expected environmental income by the normative normal rate (r) of return.

For the grazing environmental valuation we use a 3% real discount rate with the intention of representing the normal rate of return of Spanish Treasury bills and bond markets for a time horizon of 30 years. This is the criterion applied by the Spanish Treasury to compensate the landowner for land expropriation by the Government (*40*).

S14. Hunting forest accounts

Standard accounts exclude animal activity from forestry activity products. However, this criterion does not apply when animal products do not come from a manufactured production process. In this case, we do not value the hunting manufactured investment service, but the forest game grazed fodder consumption. Thus, by valuing the hunting recreational captures environmental income, we measure the forest game gazing stumpage value.

S14.1 Hunting forest standard and extended production accounts

The European Charter on Hunting (*122*) states that hunting activity includes meat, hides, furs and trophies provisioning products, game population sustainable management regulating services and recreational capture cultural services. We value hunting captures at their private rental price, total income, environmental income and environmental asset measured in 2010. We do not take into account the landowner private labor cost, manufactured capital income and manufactured capital. This is the same criterion adopted for the livestock grazing activity. The livestock activity is indirectly taken into account as the grazing fodder consumption embedded in final livestock products. By contrast, forest game grazing environmental income is measure by taking into account the substitute game captures private rental price (private environmental income).

We consider that it is not feasible to move settled wild game species to another site at a tolerable cost for the landowner. Thus, a formal market for leasing the wild game grazing landowner rights is not feasible (animals are inseparable from the land when they reproduce in the wild). The hunting captures rental price is the substitute value which indicates the value of the unobserved wild game grazing private rental price. Hence, as we do for forest livestock grazing, we measure wild game grazing environmental income through the substitute hunting captures private rental price and the government game expenditures.

The standard national forestry account (*2*) includes the private rental price for the hunting activity. The agriculture account records the market value of captures as private final product consumption, the private manufactured gross fixed capital formation and the private total cost. The household account estimates the public free hunting captures as final product consumption without incurring in any cost. The government account records the government manufactured gross fixed capital formation and the manufactured total cost.

We extend the standard EAF criteria by adding the government game manufactured gross capital formation and costs. We also incorporate the game capital revaluation into the hunting income measurement. To estimate the latter income we apply the same criteria followed for livestock grazing (*45, 123*).

Forest hunting extended accounts total product is the aggregated value of intermediate product, gross capital formation and other final product. The hunting intermediate product refers to the rental price of hunting captures for 2010 with population dynamics unknown (migrant species and other settled species) (*45*). The intermediate product is recorded twice as other final product. Hunting final product consumption comes from game species with known and unknown population dynamic. We assume a hunting steady state management, which implies that for species with known population dynamic their final consumption has the same value as their natural growth.

For settled game species with known population dynamics, natural growth is composed of environmental gross work in progress formation and gross fixed capital formation. The former integrates the births and revaluation of animals which do not have a primary economic reproductive function and the latter comprises the births and revaluation of females with economic primary reproductive function. The revaluation of animals represents the variation in the value at the closing of the period with respect to the value of the same animals at the opening of the period.

Natural growth is valued discounting future captures at their rental price (this corresponds to the private environmental price). We simulated the population dynamics of the main game settled species (red deer, fallow deer, mouflon, Spanish ibex, wild boar, rabbit and partridge) in forest estates reserves in Andalusia. Our findings indicated a near steady state situation for the three year period 2008-2010 (*124*). Hunting captures other final products are valued using direct market prices at estate gate under the assumption that the landowner does not incur in any manufactured cost. That is, rental price and market prices are the same prices (fig. S21).

The hunting final product includes final product consumption and government manufactured gross fixed capital formation. The government manufactured gross fixed capital formation is valued at production cost.

The government total cost includes the own intermediate consumption, bought intermediate consumption, labor cost and consumption of fixed capital. The intermediate product and own intermediate consumption are taken into account in this case to offset the double accounting of these hunting captures in the total product.

The measurement of other final product could over/under value their respective natural growth, which is unknown to us, thus we acknowledge the uncertain assumption of the steady state situation regarding captures of these species with unknown population dynamics. Due to a lack of data, we follow the criterion of the standard account for forestry of equating the market final product consumption value of recreational hunting with the private environmental income, since these captures of animals do not have production costs, apart from those of the landowner's own intermediate consumption (*2*).

We estimate the hunting total product consumption rental price (*52*) by using the residual valuation method. We multiply the individual head rental price (*55, 125*) by the heads captures i of each species j. The rental price is usually not observable, as it is embedded in the hunting lease price for the right to hunt (*125*). The lease price incorporates manufactured costs incurred in the breeding of game animals. From the lease price the rental price is obtained by deducting the landowner hunting own and bought intermediate consumptions, labor cost, consumption of fixed capital and an imputed normal manufactured capital income (*55, 125*).

Hunting total income is the aggregated value of the government labor costs plus the net operating margin and the government manufactured capital gains. We assume that government manufactured capital gains do not influence environmental income. Thus, the environmental net operating margin corresponds to the environmental income. This is the consequence of incorporating environmental revaluation in natural growth and other final products. Taking into account that government fixed capital formation is valued at its government investment cost; environmental income depends on the rental price (private environmental income) and the government ordinary cost.

S14.2 Environmental asset

The hunting environmental asset value is derived by applying a normal rate of discounting to the future infinite expected social environmental income. We expect that transactions in the leasing market for hunting recreational captures are based on the captures of an average year. In this study, we assume that the average captures are those for the period 2008-2010. We assume that the price of hunting lease estimated in 2010 based on our survey to 740 landowners of forest reserves in Andalusia corresponds to the future expected grazing lease price. The future total cost of private game management is also expected to be the same as in 2010. We assume that the governmental cost in 2010 will remain the same indefinitely. Hence, based on 2010 prices and assuming that captures for the period 2008-2010 and governmental costs for 2010 are constant, the expected future environmental income corresponds to the expected rental price minus ordinary governmental cost. We use a 3% real discount rate to estimate the hunting environmental asset (*40*).

S15. Supplementary equations

1. Forest extended accounting identities

Total products	TP = IP + FP	[SE. Eq 1.1]
Final product	FP = FPc + GCF	[SE. Eq.1.2]
Total product consumption	TPc = IP + FPc	[SE. Eq.1.3]
Total cost	TC = IC + LC + CFC	[SE. Eq.1.4]
Intermediate consumption	IC = ICo + ICb + ICc + EWPu	[SE. Eq.1.5]
Labor costs	LC = ELC + SLC	[SE. Eq.1.6]
Total capital	C = EWP + FC	[SE. Eq.1.7]
Total capital	C = EA + MFC	[SE. Eq.1.8]
Total income	TI = NC + CNW	[SE. Eq.1.9]
Net consumption	NC = TPc– IC	[SE. Eq.1.10]
Change of net worth	CNW = NCF + CG	[SE. Eq.1.11]
Total income	TI = NVA + CG	[SE. Eq.1.12]
Total income	TI = LC + CI	[SE. Eq.1.13]
Total income	TI = LC + EI + MCI	[SE.Eq.1.14]
Net value added	NVA = TP – IC – CFC	[SE. Eq.1.15]
Net value added	NVA = LC+ NOM	[SE. Eq.1.16]
Net operating margin	NOM = TP – TC	[SE. Eq.1.17]
Net operating margin	NOM = ENOM + MNOM	[SE. Eq.1.18]
Manufactured net operating margin	MNOM = r·MIC	[SE. Eq.1.19]
Net capital formation	NCF = GCF – CFC	[SE. Eq.1.20]
Gross capital formation	GCF = GWPF + GFCF	[SE. Eq.1.21]
Gross capital formation	GCF = NG + MGFCF	[SE. Eq.1.22]
Capital revaluation	Cr = Cc + Cw – Co – Ce	[SE. Eq.1.23]
Capital gains	CG = Cr + Cad	[SE. Eq.1.24]

Capital adjustment	$Cad = Ced - Cwd - NGw_{Oe} + Cea - Cwa + CFC_{IP}$	[SE. Eq.1.25]
Capital gains	$CG = ECG + MCG$	[SE. Eq.1.26]
Capital income	$CI = NOM + CG$	[SE. Eq.1.27]
Capital income	$CI = EI + MCI$	[SE. Eq.1.28]
Manufactured immobilized capital	$MIC = WC + MFCo$	[SE. Eq.1.29]
Manufactured immobilized capital	$MIC = MCo + c_1\ ICb + c_2 \cdot ELC + c_3 \cdot MCeb - c_4 \cdot FPs - c_5 \cdot MCwos$	[SE. Eq.1.30]
Environmental income	$EI = TI - LC - MCI$	[SE. Eq.1.31]
Environmental income	$EI = ENOM + ECG$	[SE. Eq.1.32]
Environmental net operating margin	$ENOM = NOM - MNOM$	[SE. Eq.1.33]
Environmental net operating margin (excluded carbon)	$ENOM \geq 0$	[SE. Eq.1.34]
Manufactured capital income	$MCI = MNOM + MCG$	[SE. Eq.1.35]
Timber environmental income	$EIt = NGt + ECGt$	[SE. Eq.1.36]
Timber gross work in progress formation	$GWPFt = NGt$	[SE. Eq.1.37]
Timber environmental capital gains	$ECGt = Crt - Cwrct$	[SE. Eq.1.38]
Nuts environmental income	$EIn = ENOMn + Crn$	[SE. Eq.1.39]
Hunting environmental income	$EIh = FPh - TCh_G - MNOMh$	[SE. Eq.1.40]
Water final product	$FPw = q_w \cdot p_w$	[SE. Eq.1.41]
Water environmental income	$EIw = FPw$	[SE. Eq.1.42]
Mushroom social environmental income	$EImu = FPmu - TCmu - MNOMmu$	[SE. Eq.1.43]
Mushroom final product consumption	$FPcmu = q_{mu} \cdot p_{mu}$	[SE. Eq.1.44]
Mushroom final product	$FPmu = FPcmu + MNOMmu$	[SE. Eq.1.45]

Private amenity environmental income	$EIpa = ENOMpa + FClrpa$	[SE. Eq.1.46]
Carbon environmental income	$EIc = ENOMc + FClrc$	[SE. Eq.1.47]
Carbon environmental net operating margin	$ENOMc = FPc – ICc$	[SE. Eq.1.48]
Carbon final product	$FPc = q_c \cdot p_c$	[SE. Eq.1.49]
Ecosystem services consumption	$ESc = EWPu + ENOM_O$	[SE. Eq.1.50]
Ordinary environmental net operating margin consumption	$ENOMc = TPc – RM_O – SS_O – EWPu – LC_O – CFC_O – MCI_O$	[SE. Eq.1.51]
Ordinary manufactured immobilized capital user cost	$MICuc_O = CFC_O + MCI_O$	[SE. Eq.1.52]
Ecosystem services consumption	$ESc = TPc – RM_O – SS_O – LC_O – MICuc_O$	[SE. Eq.1.53]
Environmental asset	$EA = EWP + EFA$	[SE. Eq.1.54]
Environmental work in progress	$EWP = EWPp + EWPe$	[SE.Eq.1.55]
Environmental fixed asset	$EFA = FCl + FCbr$	[SE.Eq.1.56]
Manufactured fixed capital	$MFC = FCp + FCb + FCe + FCo$	[SE. Eq.1.57]
Resource rent	$RR = EWPu – ENG + EI$	[SE. Eq.1.58]
Private amenity environmental income	$EIpa = ENOMpa + CGpa$	[SE. Eq.1.59]
Private amenity environmental net operating margin	$NOMpa = FPpa – ICopa$	[SE. Eq.1.60]
Private amenity capital gains	$CGpa = FClrpa$	[SE. Eq.1.61]
Ex post actual environmental income	$EIpa = NOMpa \cdot (1+\tau)$	[SE. Eq.1.62]

2. Standard net value added accounting identities

Standard forest net value added	$NVA = FPc + MGFCF - IC - CFC$	[SE. Eq.2.1]
Standard final commercial product consumption	$FPc = FPic + FPs + FPca + FPce_{PU} + FPco$	[SE. Eq.2.2]
Standard net consumption	$NC = FPc - IC$	[SE. Eq.2.3]
Standard manufactured intermediate consumption	$IC = ICb + ICo$	[SE. Eq.2.4]
Manufactured net fixed capital formation	$MNFCF = MGFCF - CFC$	[SE. Eq.2.5]
Trees timber products consumption	$FPct = p \cdot q$	[SE. Eq.2.6]
Timber final commercial product	$FPt = FPct + MGFCFt$	[SE. Eq.2.7]
Grazing product intra-consumption	$FPicg = p \cdot q$	[SE. Eq.2.8]
Livestock grazing final intra-consumption intermediate product	$FPicg = IPg$	[SE. Eq.2.9]
Livestock grazing final product	$FPg = FPicg + MGFCFg$	[SE. Eq.2.10]
Forestry conservation final intra-consumption product	$FPicfc = IPfc$	[SE. Eq.2.11]
Forestry conservation intermediate product	$IPfc = TCfc_{OPU}$	[SE. Eq.2.12]
Forestry conservation final product	$FPfc = TCfc_{G}$	[SE. Eq.2.13]
Forestry conservation final product	$FPfc = FPcfc + MGFCFfc$	[SE. Eq.2.14]
Forestry conservation gross fixed capital formation	$MGFCFfc = TCfc_{IPU}$	[SE. Eq.2.15]
Hunting final intra-consumption product	$FPich = IPh$	[SE. Eq.2.16]
Hunting intermediate product	$IPh = p \cdot q$	[SE. Eq.2.17]
Hunting final product intra-consumption	$FPch = IPh$	[SE. Eq.2.18]
Hunting final product	$FPh = FPch + MGFCFh$	[SE. Eq.2.19]

Government hunting manufactured gross fixed capital formation	$MGFCFh = TCh_{IPU}$	[SE. Eq.2.20]
Residential activity intermediate product	$IPr = p \cdot q$	[SE. Eq.2.21]
Residential activity final intra-consumption	$FPicr = IPr$	[SE. Eq.2.22]
Own private amenity intermediate consumption	$ICopa = FPcr$	[SE. Eq.2.23]
Residential activity final product	$FPr = FPcr + GFCFr$	[SE. Eq.2.24]
Residential activity manufactured gross fixed capital formation	$MGFCFr = TCr_{IPU}$	SE. Eq.2.25]
Government public recreation final product consumption	$FPcre = TCre_{OPU} + MNOMre_{O}$	[SE. Eq.2.26]
Government public recreation normal manufactured ordinary net operating margin	$MNOMre_{O} = r*IMCre_{O}$	[SE. Eq.2.27]
Government public recreation manufactured ordinary immobilized capital	$MICre_{O} = WCre_{O}+ FCo_{O}$	[SE. Eq.2.28]
Public recreation final product	$FPre_{G} = FPcre_{G} + GFCFre_{G}$	[SE. Eq.2.29]
Government public recreation manufactured gross fixed capital formation	$MGFCFre = TCre_{IPU} + MNOMre_{I}$	[SE. Eq.2.30]
Public recreation normal manufactured investment net operating margin	$MNOMre_{I} = r*IMCre_{I}$	[SE. Eq.2.31]
Government public recreation manufactured investment immobilized capital	$MICre_{I} = WCre_{I}+ MFCo_{I}$	[SE. Eq.2.32]
Mushroom final product consumption	$FOcm = p \cdot q$	[SE. Eq.2.33]
Mushroom final product	$FOm = FOcm + MGFCFm$	[SE. Eq.2.34]

Government mushroom manufactured gross fixed capital formation	$MGFCFm = TCm_{IPU} + MNOMm_{I}$	[SE. Eq.2.35]
Water final product consumption	$FPcw = p \cdot q$	[SE. Eq.2.36]

3. Modeling tree species management, natural growth functions and yields identities

Diameter at breast height for holm oak in medium low quality sites	$dbh=79.81\cdot(1-e^{-0.011\cdot t})\cdot\frac{1}{0.659}$	[SE. Eq.3.1]
Diameter at breast height for holm oak in medium high quality sites	$dbh=89.04\cdot(1-e^{-0.011\cdot t})\cdot\frac{1}{0.659}$	[SE. Eq.3.2]
Diameter at breast height for holm oak in coppice	$dbh=95\cdot e^{-42\cdot\frac{1}{t}}$	[SE. Eq.3.3]
Diameter at breast height for holm oak in uneven-aged stands	$dbh=0.0248\cdot t^2+1.63\cdot t+9.2395$	[SE. Eq.3.4]
Holm oak acorn production in kilogram per tree	$Prod=0.80\cdot e^{\frac{dbh^2}{(6.818+0.458)^2}}-1$	[SE. Eq.3.5]
Evolution of the density in holm oak in even-aged stand	$Ln(N)= -1.4666\cdot \ln(dbh) + 9.2395$	[SE. Eq.3.6]
Evolution of the density in holm oak in coppice	$Ln(N)= -1.286\cdot \ln(dbh) + 9.7104$	[SE. Eq.3.7]
Number of stems for stone pine in low land and medium-high quality sites	$N=0.7\cdot 10^{4.42-1.33\cdot \log_{10}(dbh)}$	[SE. Eq.3.8]
Diameter at breast height for stone pine in low land and medium-high quality sites	$dbh=0.3068\cdot t - 12.453$	[SE. Eq.3.9]
Volume for *Pinus pinea* in low land and medium-high quality sites	$vol_{unit=}0.001\cdot dbh^2 - 0.0181\cdot dbh + 0.1132$	[SE.Eq.3.10]
Cone pine production for *Pinus pinea* in low land and medium-high quality sites	$Prod_{conepine}=5\cdot 10^{-7}\cdot dbh^{3.9552}$	[SE.Eq.3.11]

Number of stems for *Pinus pinea* in low land and medium-low quality sites	$N=0.7\cdot10^{4.42-1.33\cdot\log_{10}(dbh)}$	[SE Eq.3.12]
Diameter at breast height for *Pinus pinea* in low land and medium-low quality sites	$dbh=0.2209\cdot t + 12.435$	[SE. q.3.13]
Volumen for *Pinus pinea* in low land and medium-low quality sites	$vol_{unit}=0.0005\cdot dbh^2 - 0.003\cdot dbh + 0.0224$	[SE. q.3.14]
Cone pine production for *Pinus pinea* in low land and medium-low quality sites	$prod_{conepine}=7\cdot10^{-8}\cdot dbh^{4.7112}$	[SE. q.3.15]
Number of stems for stone pine in mountain areas and medium-high quality sites	$N=0.7\cdot10^{4.42-1.33\cdot\log_{10}(dbh)}$	[SE. q.3.16]
Diameter at breast height for stone pine in mountain areas and medium-high quality sites	$dbh=-0.0015\cdot age^2 + 0.6104\cdot age - 1.4936$	[SE. q.3.17]
Volume for stone pine in mountain areas and medium-high quality sites	$Vol_{unit}=4\cdot10^{-5}\cdot dbh^{2.7648}$	[SE. q.3.18]
Cone pine production for stone pine in mountain areas and medium-high quality sites	$prod_{conepine}=0.0033\cdot dbh^{1.6212}$	[SE. q.3.19]
Number of stems for stone pine in mountain areas and medium-low quality sites	$N=0.7\cdot10^{4.42-1.33\cdot\log_{10}(dbh)}$	[SE. q.3.20]
Diameter at breast height for stone pine in mountain areas and medium-low quality sites	$dbh = -0.0004\cdot t^2 + 0.2618\cdot t - 1.4936$	[SE. q.3.21]
Volume for stone pine in mountain areas and medium-low quality sites	$vol_{unit}=2\cdot10^{-5}\cdot dbh^{3.0487}$	[SE. q.3.22]
Cone pine production for stone pine in mountain areas and medium-low	$prod_{conepine}=0.0055\cdot dbh^{1.4475}$	[SE. q.3.23]

quality sites		
Number of stems of cork oak in Cork oak even-aged	$N=617.64 \cdot e^{-0.036 \cdot d_n}$	[SE. q.3.24]
Diameter of cork oak in even-aged	$d_n=-0.0021 \cdot t^2 + 0.8266 \cdot t - 2.481$	[SE. q.3.25]
Debarking height production	$DH(m)= a + b \cdot dbh$	[SE. q.3.26]
Production of firewood without virgin cork bark	$P_{firewood}=-65.8531 + 4.5128 \cdot dbh$	[SE. q.3.27]
Virgin cork oak production	$P_{virgincork}= - 15.0909 + 1.2277 \cdot dbh$	[SE. q.3.28]
Twig bundles production of cork oak	$P_{twig}= -36.9871 + 3.0135 \cdot dbh$	[SE. q.3.29]
Acorn production of cork oak	$P_{acorn}=-0.0003 \cdot dbh^2 + 0.1349 \cdot dbh - 1.699$	[SE. q.3.30]
Number of stems of cork oak in Uneven-aged silviculture	$N=90.158 \cdot e^{-0.06 \cdot dbh}$	[SE. q.3.31]

4. Modeling geo-referenced timber and cork extractions and carbon uptake identities

Quercus ilex biomass	$C=\frac{0.475 \cdot e^{-2.31596+2.47745 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.1]
Quercus canariensis biomass	$C=\frac{0.486 \cdot e^{-1.40683+2.1111 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.2]
Quercus faginea biomass	$C=\frac{0.480 \cdot e^{-2.89305+2.52426 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.3]
Pinus sylvestris biomass	$C=\frac{0.509 \cdot e^{-2.50275+2.41194 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.4]
Pinus pinea biomass	$C=\frac{0.508 \cdot e^{-2.18177+2.42414 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.5]
Pinus halepensis biomass	$C=\frac{0.499 \cdot e^{-2.0939+2.20988 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.6]
Pinus nigra biomass	$C=\frac{0.509 \cdot e^{-2.7773+2.51564 \cdot \ln(dbh)}}{1000}$	[SE. Eq.4.7]

Pinus pinaster biomass $$C=\frac{0.511\cdot e^{-3.00347+2.49641\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.8]

Quercus suber biomass $$C=\frac{0.472\cdot e^{-3.36627+2.60685\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.9]

Castanea sativa biomass $$C=\frac{0.484\cdot e^{-1.70831+2.21544\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.10]

Olea europaea biomass $$C=\frac{0.473\cdot e^{-0.943709+1.94124\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.11]

Abies pinsapo biomass $$C=\frac{0.500\cdot e^{-2.52726+2.31499\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.12]

Quercus pyrenaica biomass $$C=\frac{0.475\cdot e^{-2.59695+2.53453\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.13]

Populus biomass $$C=\frac{0.483\cdot e^{-2.94077+2.56677\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.14]

Eucalyptus biomass $$C=\frac{0.475\cdot e^{-1.33002+2.19404\cdot \ln(dbh)}}{1000}$$ [SE. Eq.4.15]

Supplementary figures for

Bridging the gap between national and ecosystem accounting

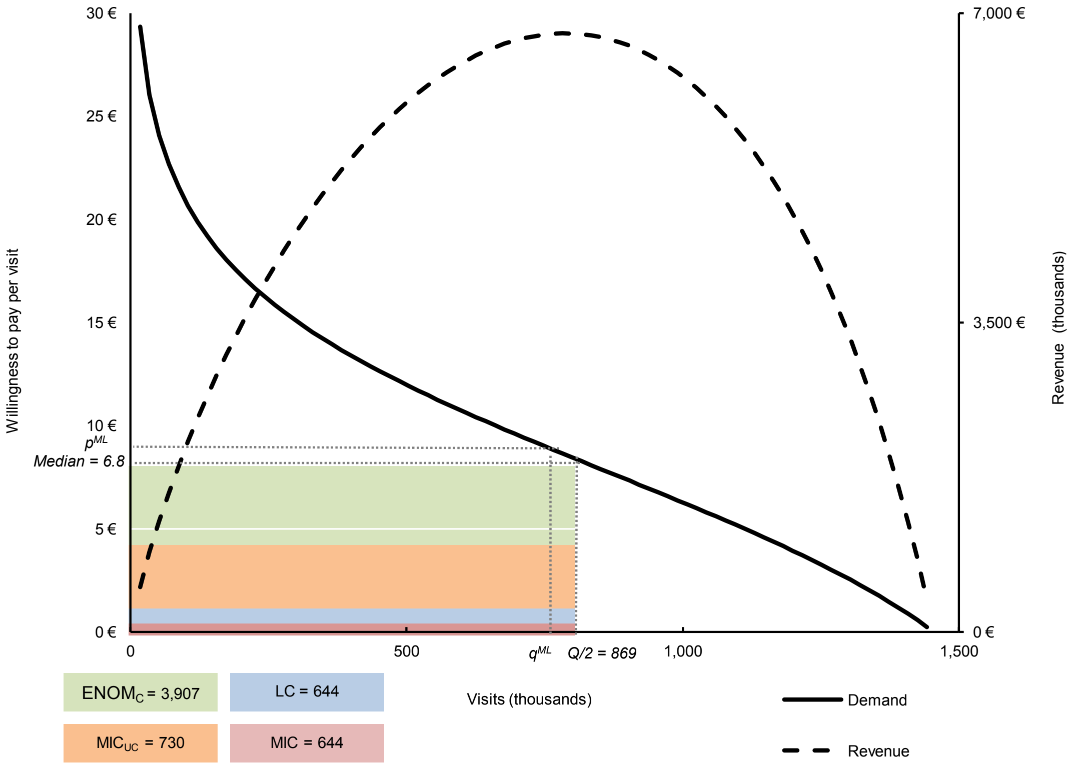


Fig. S1.

Public recreation final product consumption in the case of Alcornocales Natural Park (2010). Abbrevations: ENOMc: environmental net operating margin; MICuc: manufactured immobilized capital user cost; LCc: labor cost; MIC: manufactured intermediate consumption; qML: quantity monopolistic competition conditional logit; pML: price monopolistic competition conditional logit.

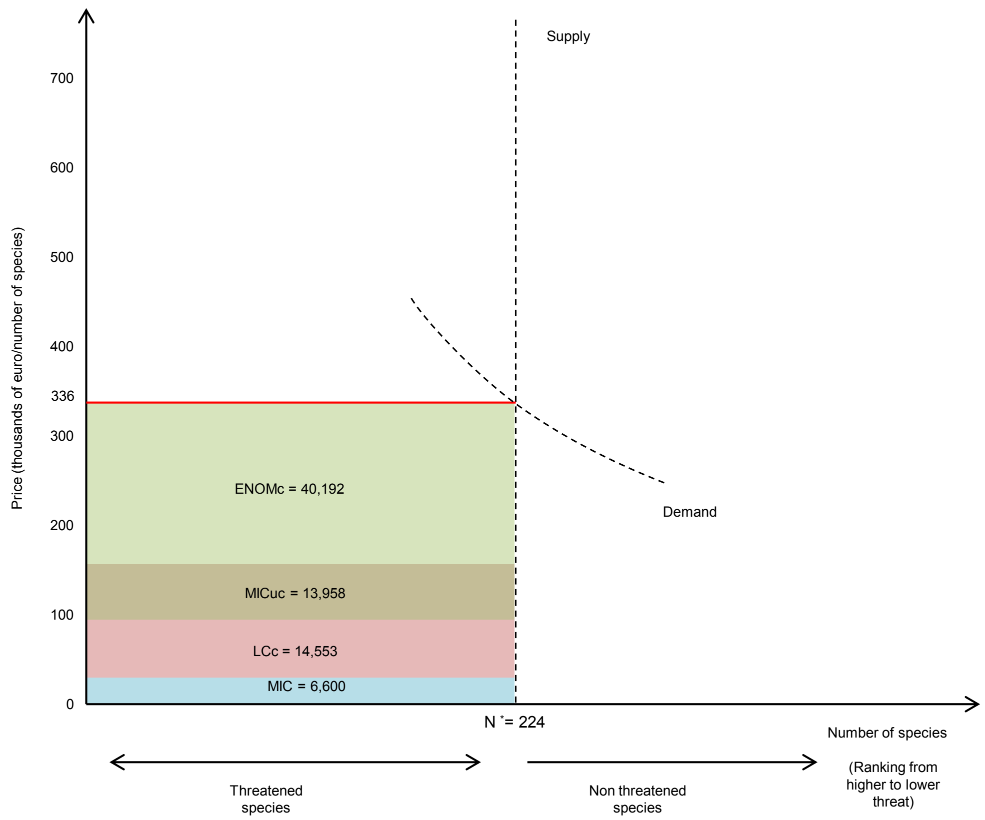


Fig. S2.

Threatened biodiversity final product consumption of Andalusia forest ecosystems (2010). Abbreviations: ENOMc: environmental net operating margin; MICuc: manufactured immobilized capital user cost; LCc: labor cost; MIC: manufactured intermediate consumption; N*: number of threatened species.

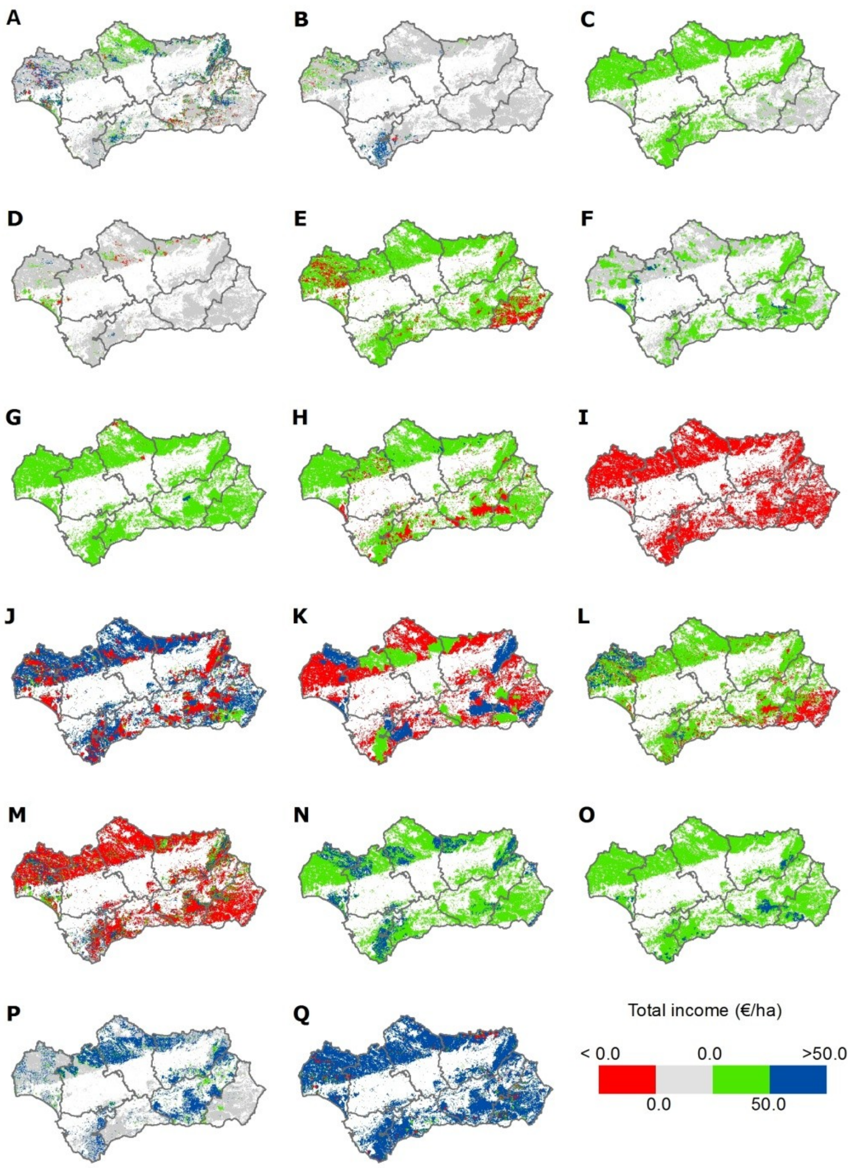


Fig. S3.

Mapped individual products total incomes of Andalusia forest ecosystems (2010: €/ha). (A) Timber. (B) Cork. (C) Firewood. (D) Nuts. (E) Grazing. (F) Conservation forestry. (G) Government forestry. (H) Hunting. (I) Residential. (J) Private amenity. (K) Public recreation. (L) Mushrooms. (M) Carbon. (N) Landscape. (O) Biodiversity. (P) Water. (Q) Total income of forest ecosystems.

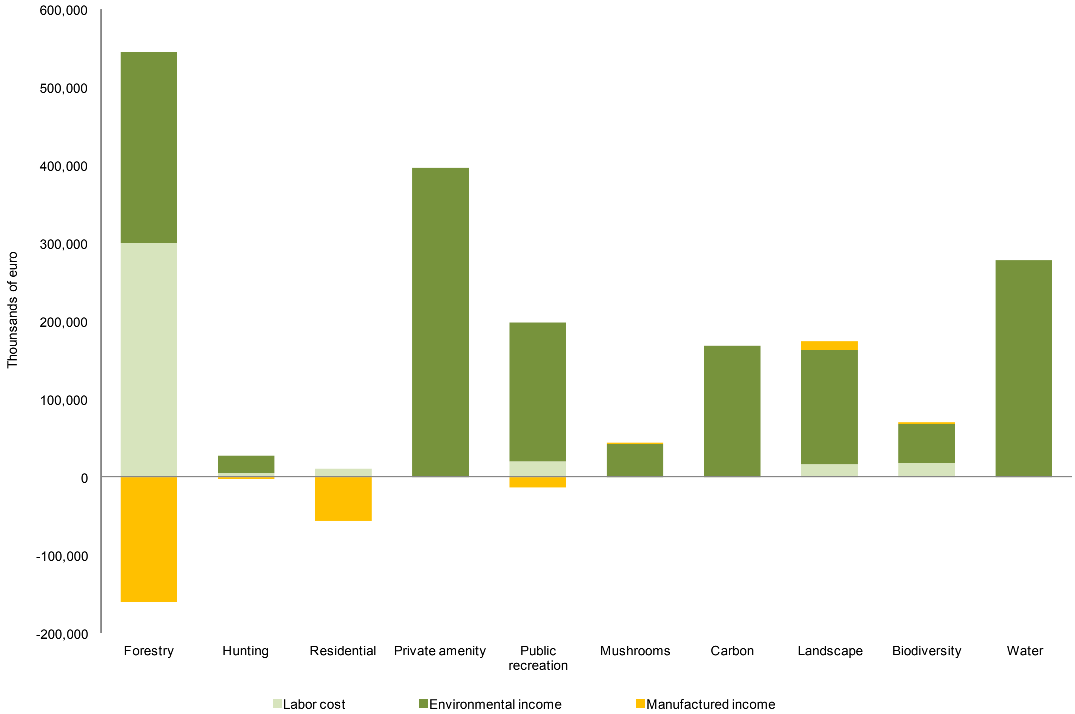


Fig. S4.

Total income factorial distribution by activities in Andalusia forest ecosystems (2010: in thousands of euro)

Class	Private activities				Public activities						Total
	Forestry	Hunting	Residential	Private amenity	Mushrooms	Public recreation	Biodiversity	Landscape	Water	Carbon	
PRODUCTION ACCOUNT	PRIVATE TOTAL PRODUCT (TP_{PR})				TOTAL PRODUCT (TP_{PU})						TP
	PRIVATE TOTAL COST (TC_{PR})				TOTAL COST (TC_{PU})						TC
LANDOWNER ACCOUNT	LADOWNER TOTAL PRODUCT ($TP_{PR,LO}$)				NOT APPLICABLE						TP_{LO}
	LANDOWNER TOTAL COST ($TC_{PR,LO}$)										TC_{LO}
GOVERNMENT ACCOUNT	GOVERNMENT PRIVATE TOTAL PRODUCT ($TP_{PR,GO}$)		NOT APPLICABLE		PUBLIC TOTAL PRODUCT ($TP_{PU,GO}$)						TP_{GO}
	GOVERNMENT PRIVATE TOTAL COST ($TC_{PR,GO}$)				PUBLIC TOTAL COST ($TC_{PU,GO}$)						TC_{GO}

Fig. S5.

Landowner, government and total production accounts by private and public activities of Andalusia forest ecosystems

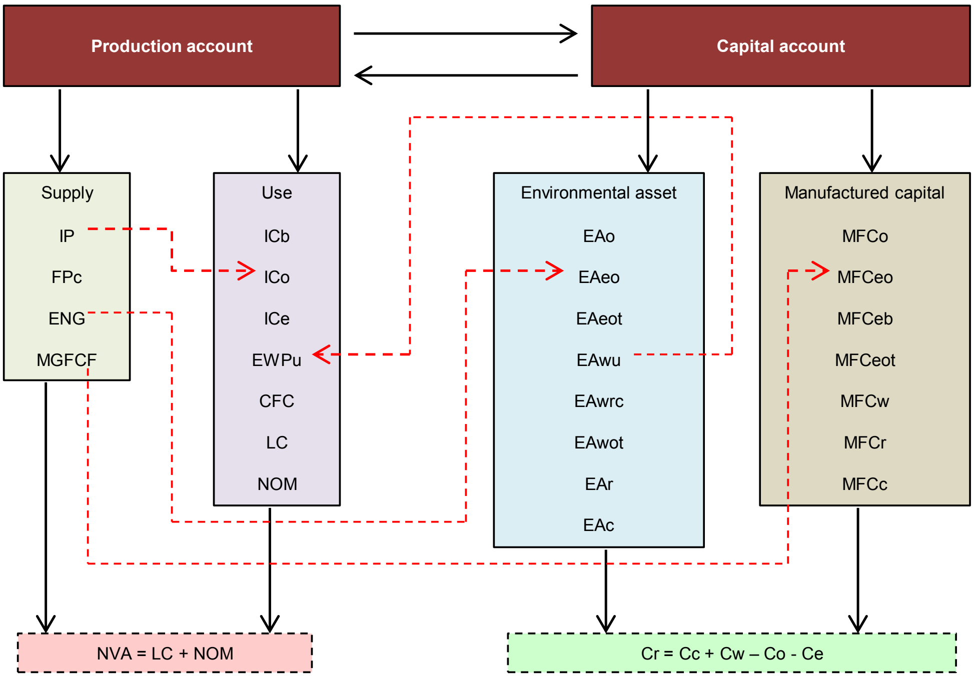


Fig. S6.

Stylized extended production and capital accounts. Abbreviations: IP: intermediate product; FPc: final product consumption; ENG: environmental natural growth; MGFCF: manufactured gross fixed capital formation; ICb: bought intermediate consumption; ICo: own intermediate consumption ; ICe; environmental intermediate consumption; EWPu: environmental work in progress used; CFC: consumption of fixed capital. LC: labor cost; NOM: net operating margin; EAo: opening environmental asset; EAeo: own environmental asset entries; EAeot: environmental asset other entries; EAwu: environmental asset used withdrawals; EAwrc: environmental asset reclassifications withdrawals; EAwot: environmental asset other withdrawals; EAr: environmental asset revaluation; EAc: closing environmental asset; MFCo: opening manufactured fixed capital; MFCeo: own manufactured fixed capital entries; MFCeb: bought manufactured fixed capital entries; MFCeot: manufactured fixed capital others entries; MFCw: manufactured fixed capital withdrawals; MFCr: manufactured fixed capital revaluation; MFCc: closing manufactured fixed capital; NVA: net valued added; Cr: capital revaluation; Cc: closing capital; Cw: capital withdrawals; Co: opening capital; Ce: capital entries.

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

Fig. S7.

Valuation methods apply to selected individual products of Andalusia forest ecosystems products and environmental assets. Abbreviations: AMAYA: Environment and water Agency of Andalusia; he: game animal head; ha: hectare; CMAYOT: department of environment and territory planning of Andalusia; CEM: Choice experiment method; S: ad hoc survey; PF: production function; IFN3: Third national forestry inventory; kg: kilogram; M: market; m3: cubic meter; HPM: hedonic price method; N: number of threatened biological species; t: metric ton; vi: visit; CVM: contingent valuation method; NPV: net present value; and SEV: simulated exchange value.. For details see Supplementary text.

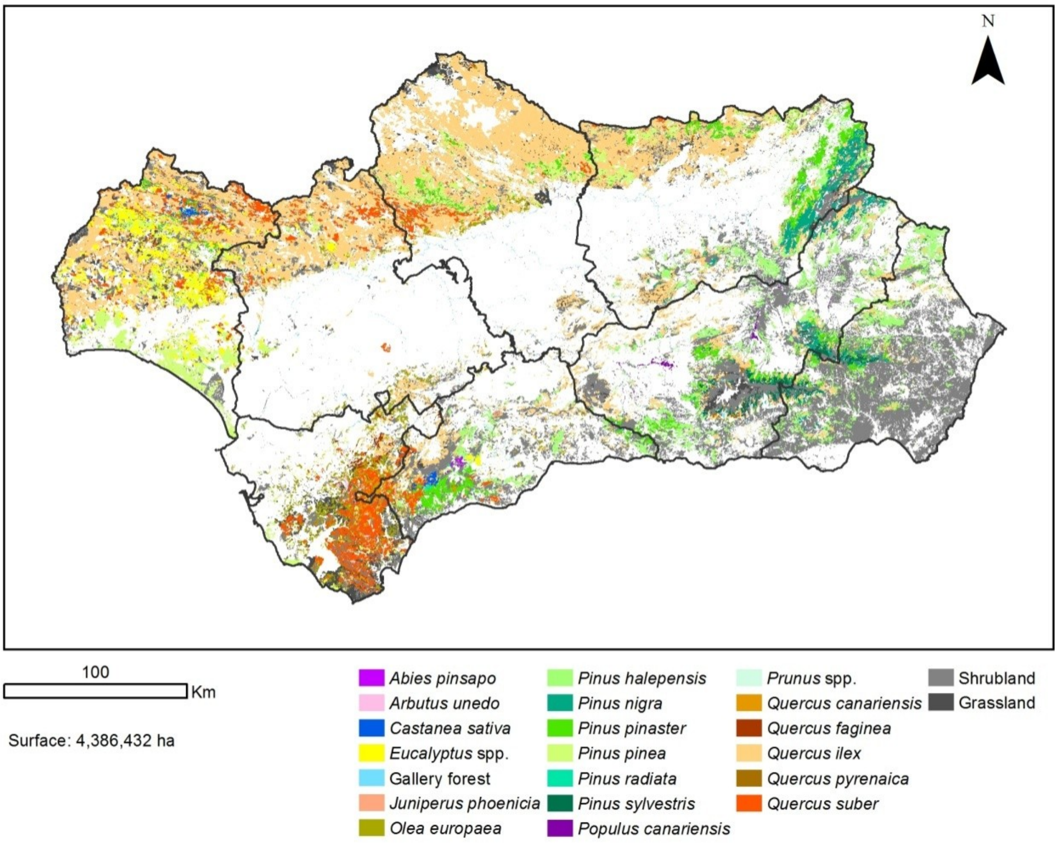


Fig. S8.

Andalusia *forest* ecosystems vegetations types

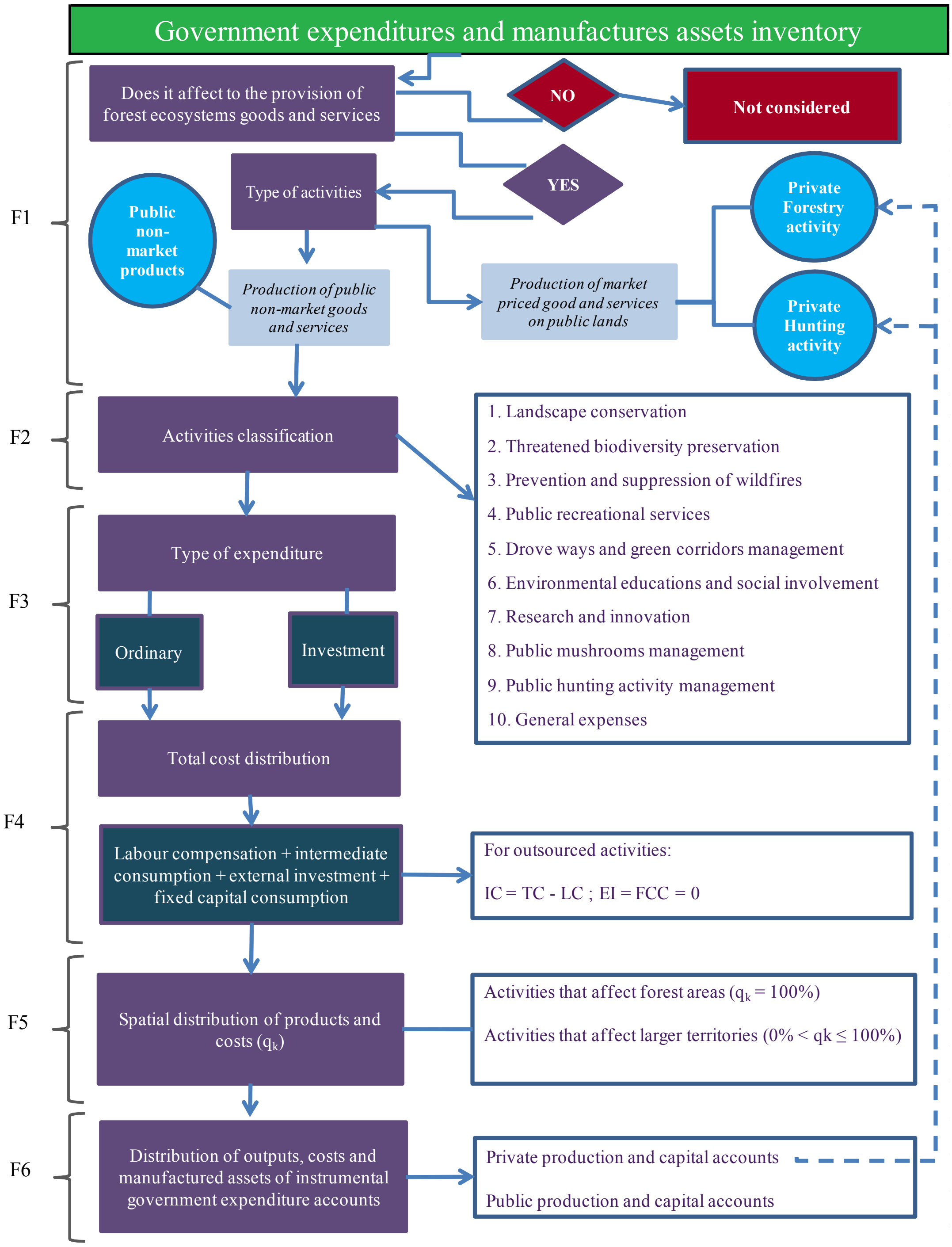


Fig. S9.

Functional classification of government expenditures and manufactured assets in Andalusian *forest* ecosystem

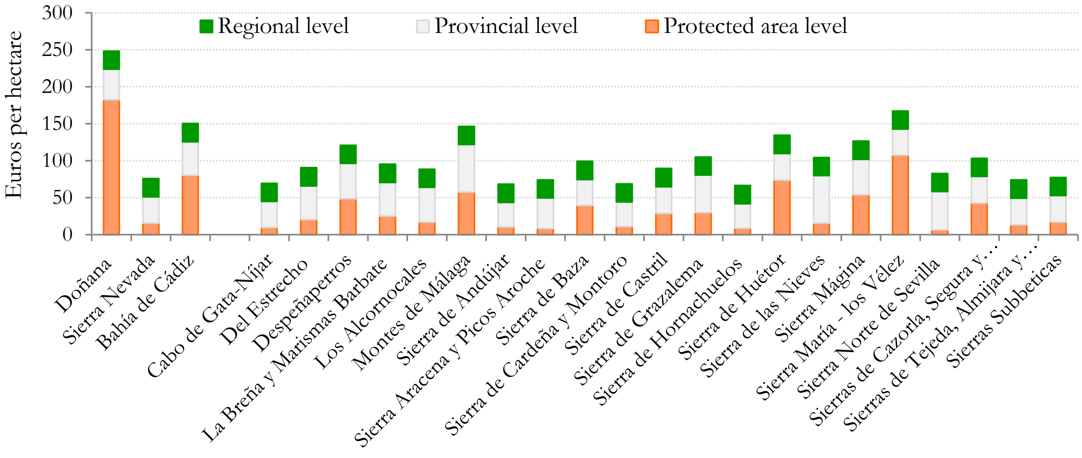


Fig. S10.

Distribution of government expenditures in protected natural areas of Andalusia (2010: €/ha)

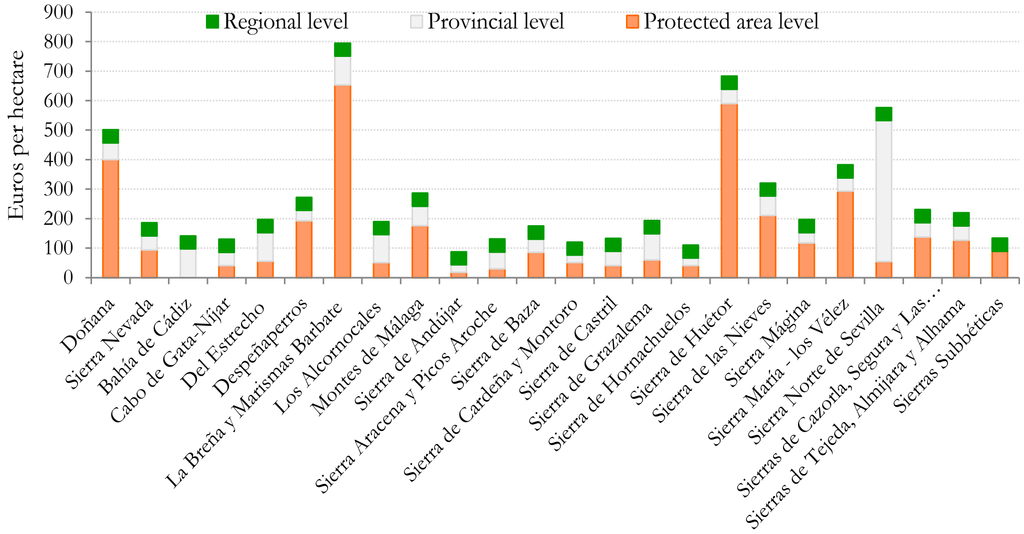


Fig. S11.

Distribution of government manufactured assets in protected natural areas of Andalusia (2010: €/ha)

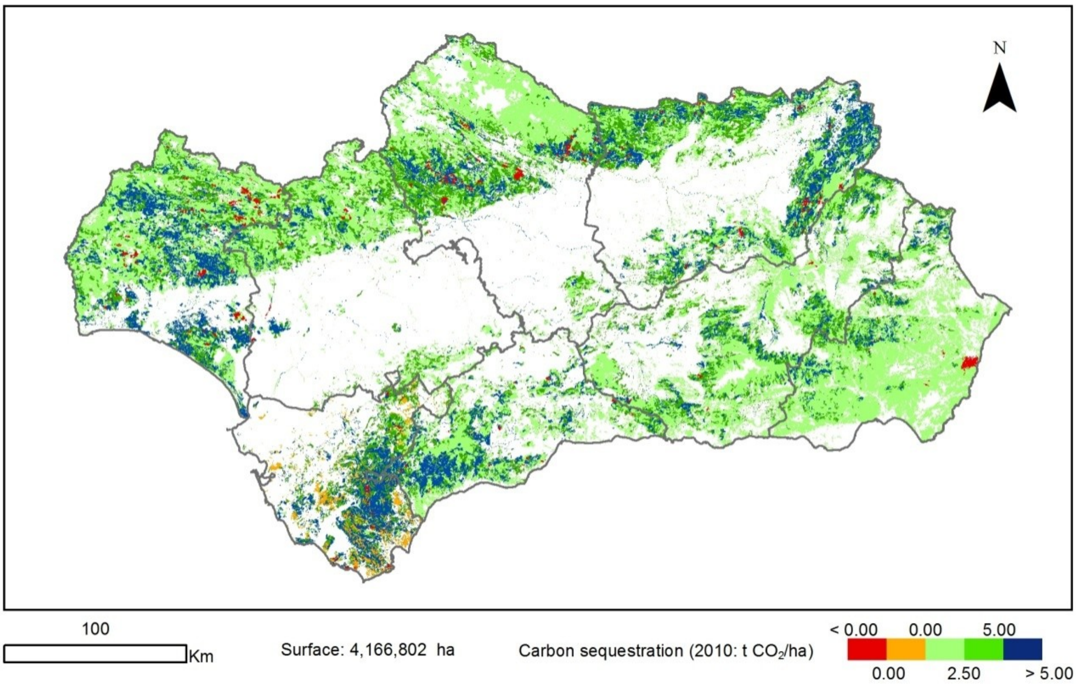


Fig. S12.
Andalusia forest ecosystems carbon uptake (2010: t CO2/ha)

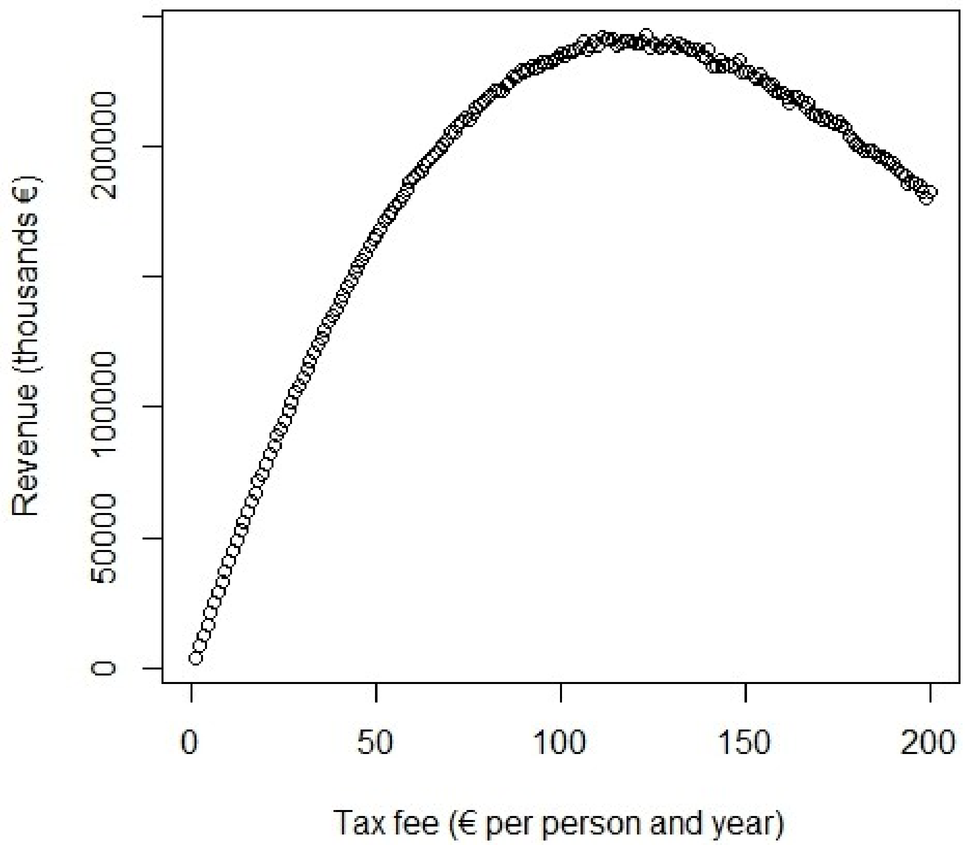


Fig. S13.
Non-parametric function for revenue from landscape conservation and threatened biodiversity preservation

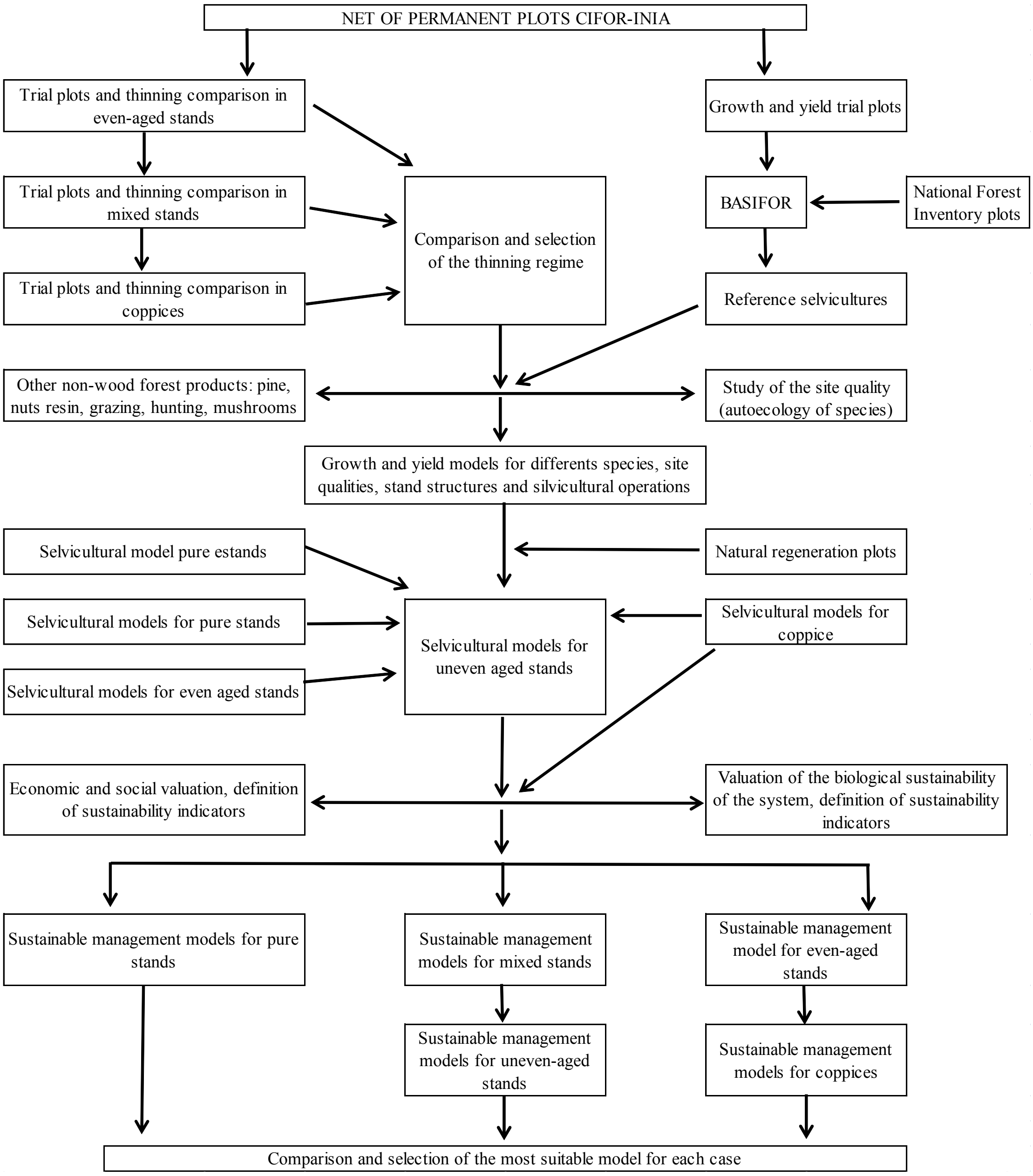


Fig. S14.

General scheme for the development of selvicultural models

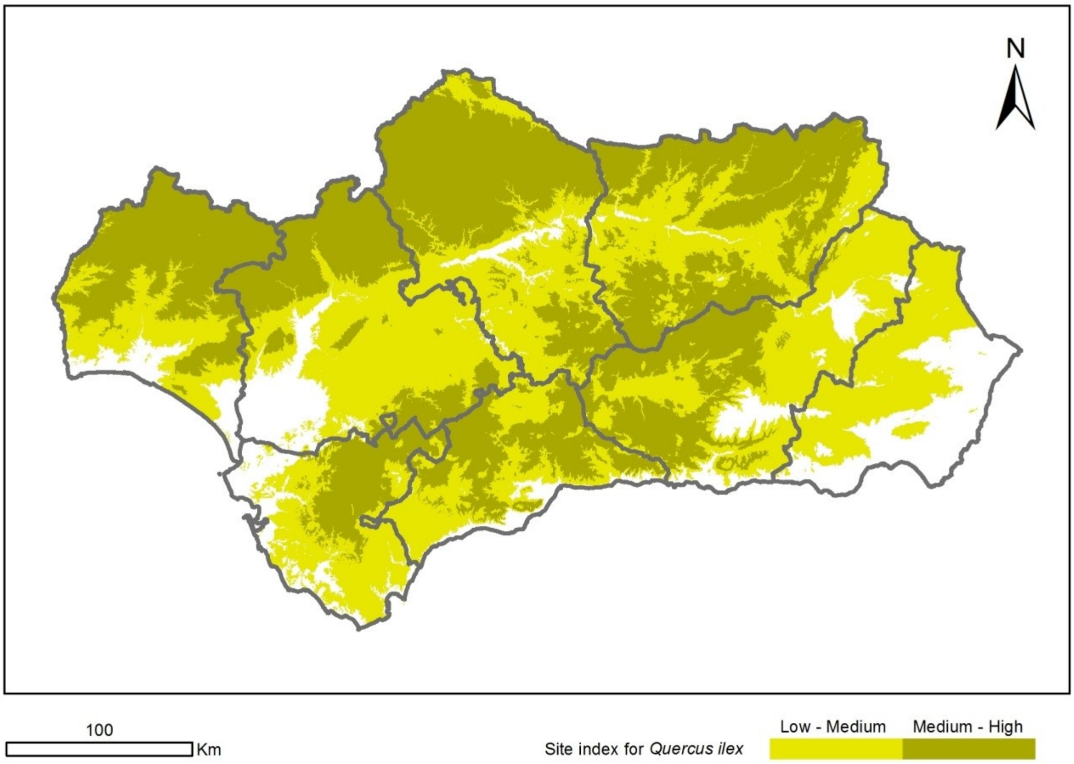


Fig. S15.
Suitability map of the territory for Quercus ilex in Andalusia

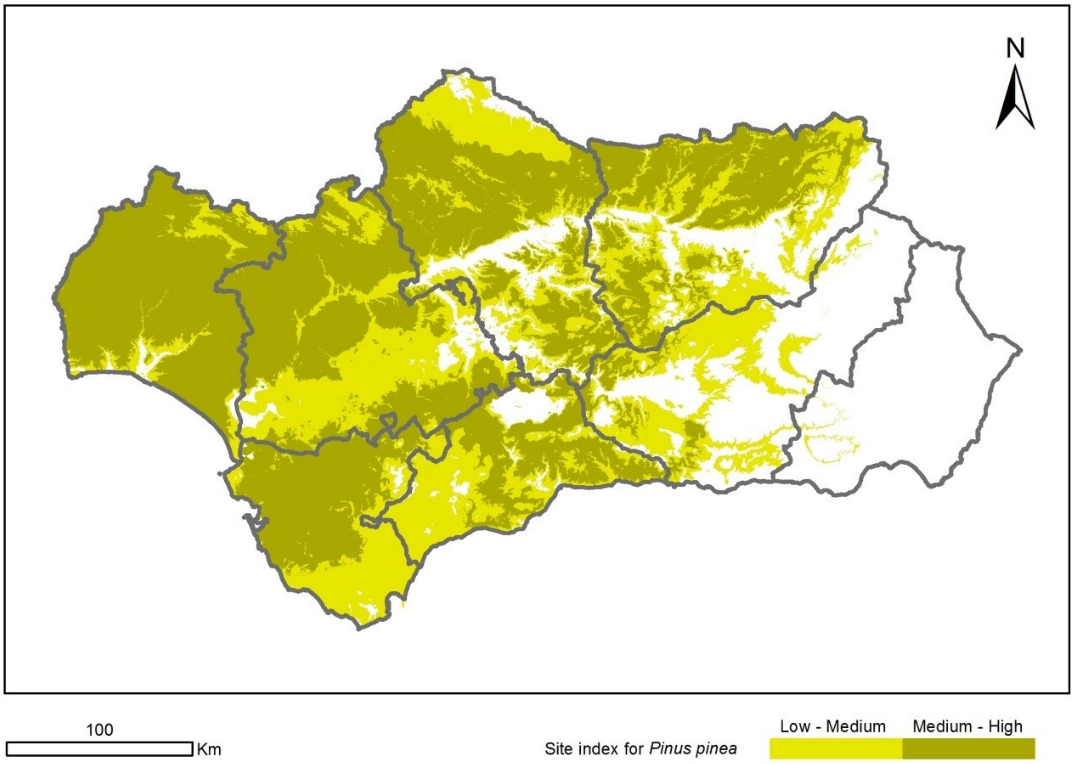


Fig. S16.
Suitability map of the territory for *Pinus pinea* in Andalusia

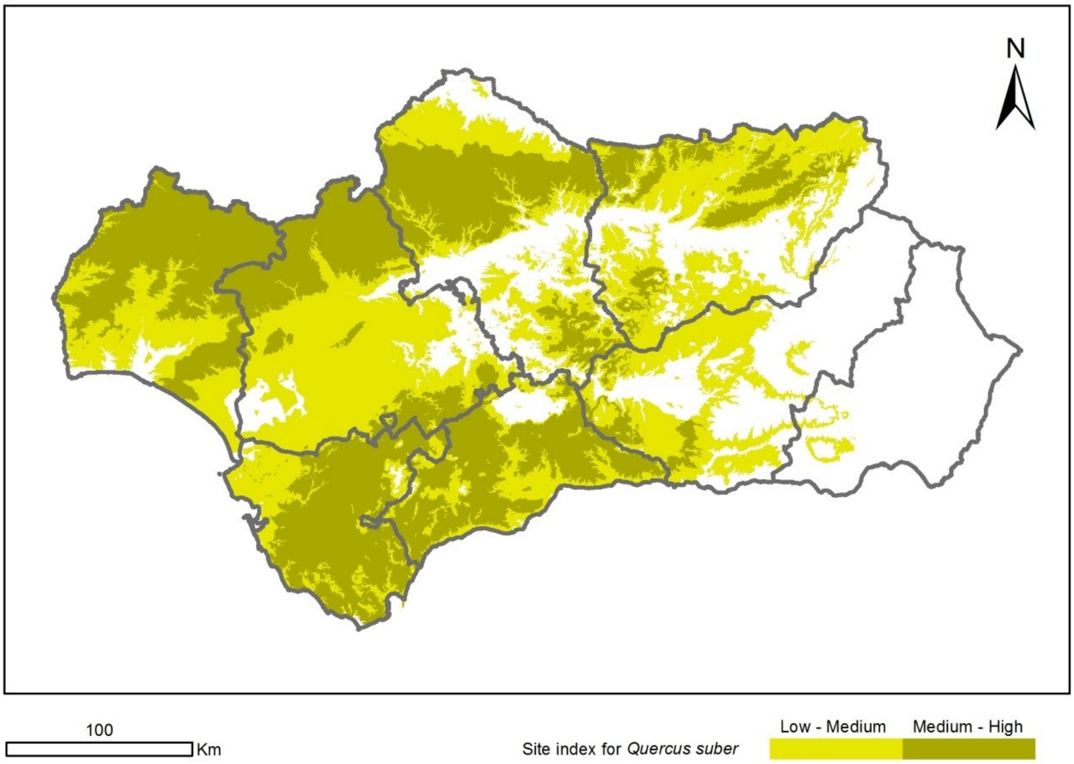


Fig. S17.
Suitability map of the territory for Quercus suber in Andalusia

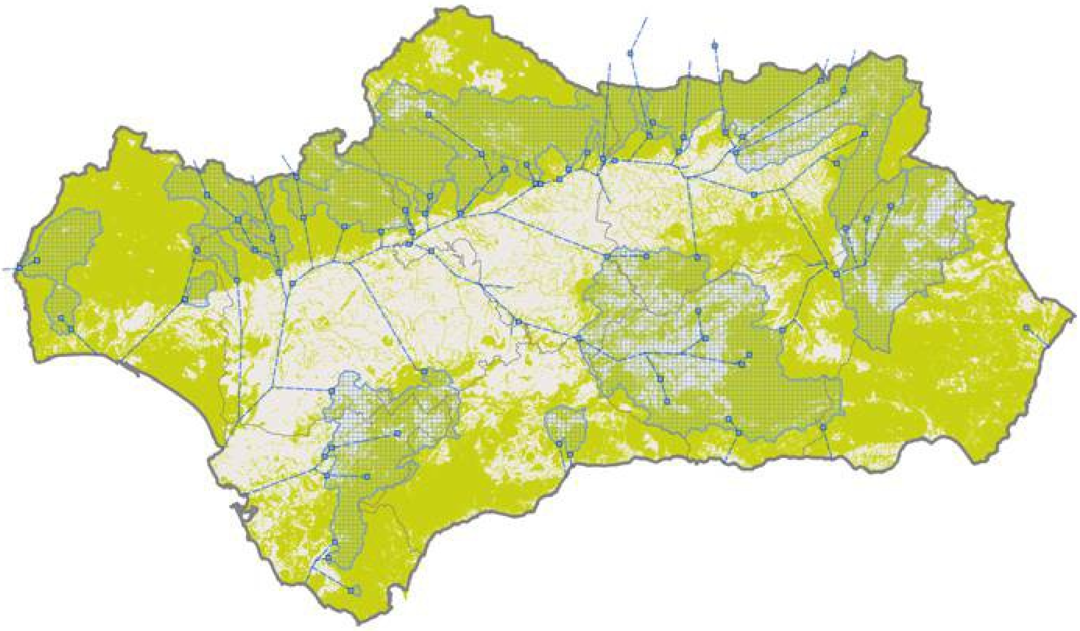


Fig. S18.

Map of Andalusian forest ecosystem regulated water reservoir systems. Andalusian forest lands (green), and surface water regulation system (blue dots: reservoirs; blue mesh: reservoir catchments; blue lines: river network). Most of the reservoir catchments support forest land uses.

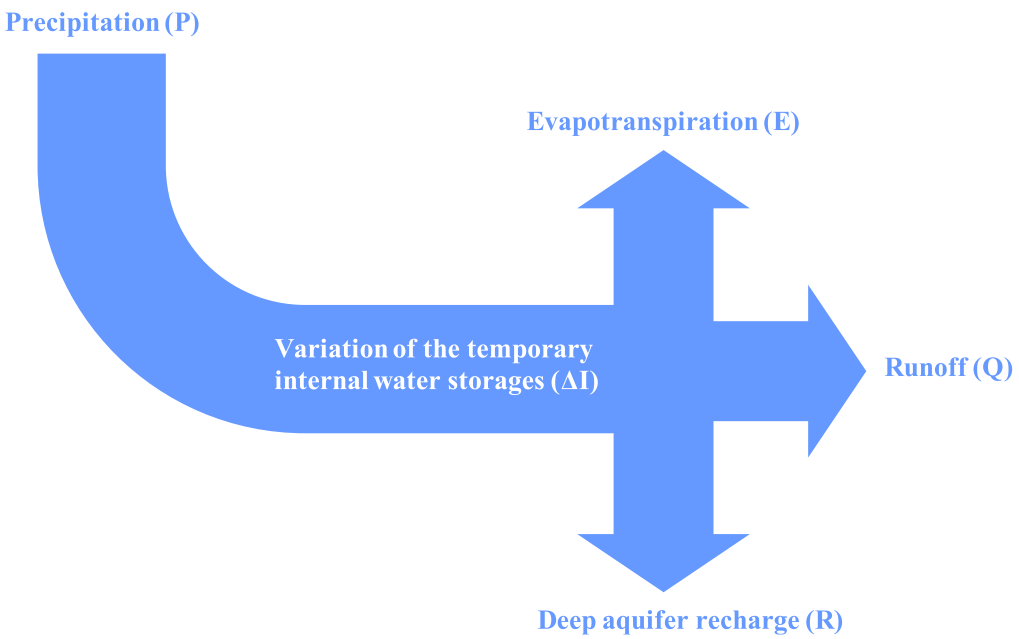


Fig. S19.
Hidrologic balance

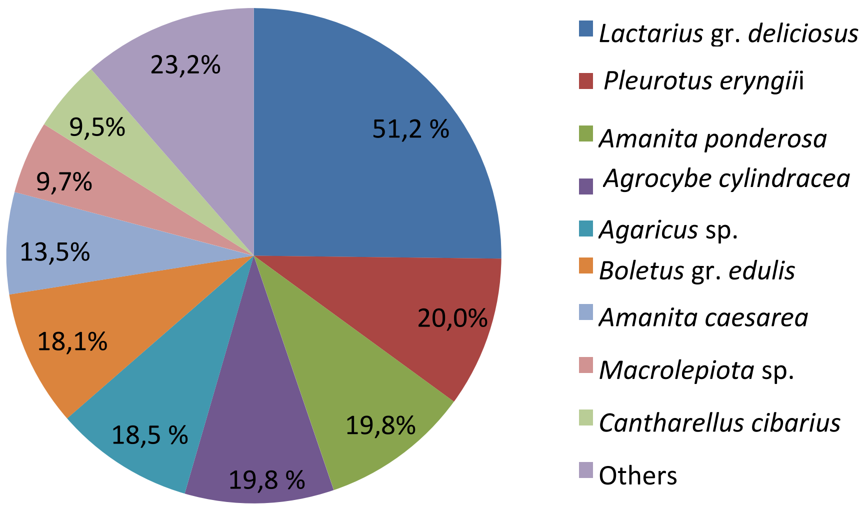


Fig. S20.
Mushroom harvester percentage respect to the total harvesters by fungal species (pri) in the region of Andalusia

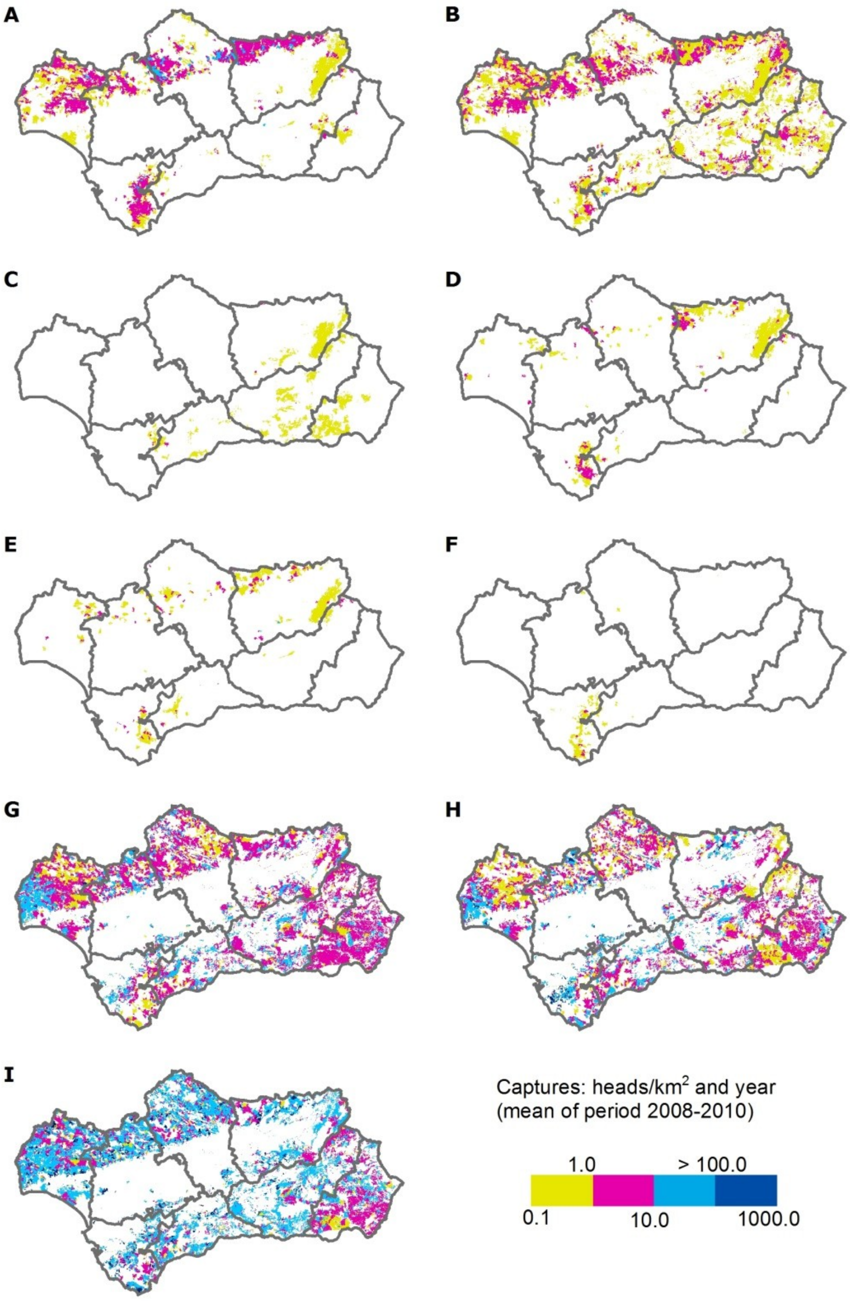


Fig. S21.

Captures: heads/km^2 and year (mean of period 2008-2010). (A) Red deer. (B) Wild board. (C) Spanish ibex. (D) Fallow deer. (E) Mouflon. (F) Roe deer. (G) Red patridge. (H) Rabbit. (I) Others.

Supplementary tables for

Bridging the gap between national and ecosystem accounting

Table S1.

Total production account of forestry in Andalusia forest ecosystems

Class	Timber	Cork	Firewood	Nuts	Grazing	Conservation forestry	Government forestry	Forestry
	1	2	3	4	5	6	7	8 = ∑ 1 a 7
	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Total product (TP) (1.1 + 1.2)	34,174	71,937	2,824	2,868	66,608	53,936	186,834	419,182
1.1 Intermediate product (IP)	4,663	23,086			66,608	34,673	170,930	299,961
1.2 Final product (FP) (1.2.1 + 1.2.2)	29,511	48,850	2,824	2,868		19,264	15,904	119,221
1.2.1 Final product consumption (FPc)	14,846	26,060	2,325	2,868		0	0	46,100
1.2.2 Gross capital formation (GCF)	14,665	22,790	499			19,264	15,904	73,121
Environmental natural growth (ENG)	*14,665*	*22,790*	*499*					*37,953*
Manufactured gross fixed capital formation (MGFCF)						*19,264*	*15,904*	*35,168*
2. Total cost (TC) (2.1 + 2.2 + 2.3)	155,124	51,258	1,160	18,941	14,258	53,745	186,599	481,085
2.1 Intermediate consumption (IC)	32,194	46,422	667	2,535	1,681	18,456	55,724	157,678
2.1.1 Raw materials (RM)	7,383	23,276	227	352	883	163	479	32,764
2.1.2 Services (SS)	17,179	649	91	2,183	797	18,292	55,245	94,437
2.1.3 Work in progress used (WPu)	7,632	22,496	348					30,476
2.2 Labor cost (LC)	117,628	4,836	486	16,059	9,411	34,080	118,890	301,391
2.3 Consumption of fixed capital (CFC)	5,302		7	347	3,166	1,210	11,985	22,017
3. Net operating margin (NOM) (1 – 2)	-120,950	20,679	1,664	-16,073	52,351	191	235	-61,904
4. Gross valued added (GVA) (1 – 2.1)	1,979	25,514	2,157	334	64,928	35,481	131,110	261,503
5. Net valued added (NVA) (3 + 2.2)	-3,322	25,514	2,150	-13	61,762	34,271	119,125	239,487

Table S2.

Total production account of forestry in Andalusia forest ecosystems

Class	Timber 1.1 ($€ \cdot 10^3$)	Cork 1.2 ($€ \cdot 10^3$)	Firewood 1.3 ($€ \cdot 10^3$)	Nuts 1.4 ($€ \cdot 10^3$)	Grazing 1.5 ($€ \cdot 10^3$)	Conservation forestry 1.6 ($€ \cdot 10^3$)	Goverment forestry 1.7 ($€ \cdot 10^3$)	Forestry 1 = ∑ 1.1 to 1.7 ($€ \cdot 10^3$)
Extended accounts (AAS)								
1. Total product consumption (TPc)	19,509	49,146	2,325	2,868	66,608	34,673	170,930	346,060
2. Intermediate consumption (IC)	32,194	46,422	667	2,535	1,681	18,456	55,724	157,678
3. Net consumption (NC) (1 – 2)	-12,685	2,724	1,658	334	64,928	16,217	115,206	188,382
4. Gross capital formation (GCF)	14,665	22,790	499	0	0	19,264	15,904	73,121
5. Total product (TP) (1 + 4)	34,174	71,937	2,824	2,868	66,608	53,936	186,834	419,182
6. Consumption of fixed capital (CFC)	5,302	0	7	347	3,166	1,210	11,985	22,017
7. Net capital formation (NCF) (4 – 6)	9,363	22,790	491	-347	-3,166	18,054	3,919	51,105
8. Labor cost (LC)	117,628	4,836	486	16,059	9,411	34,080	118,890	301,391
9. Total cost (TC) (2 + 6 + 8)	155,124	51,258	1,160	18,941	14,258	53,745	186,599	481,085
10. Gross value added (GVA) (5 – 2)	1,979	25,514	2,157	334	64,928	35,481	131,110	261,503
11. Net value added (NVA) (3 + 7)	-3,322	25,514	2,150	-13	61,762	34,271	119,125	239,487
12. Net operating margin (NOM) (5 – 9)	-120,950	20,679	1,664	-16,073	52,351	191	235	-61,904
13. Capital gains (CG)	77,676	57,318	13,845	1,010	4,167	1,101	-8,901	146,215
14. Change of net worth (CNW) (7 + 13)	87,039	80,108	14,336	663	1,000	19,155	-4,982	197,320
15. Capital income (CI)	-43,274	77,997	15,509	-15,062	56,517	1,292	-8,666	84,311
16. Environmental (EI)	91,428	80,518	14,336	791	56,619	0	0	243,691
17. Manufactured (MCI)	-134,702	-2,521	1,173	-15,853	-101	1,292	-8,666	-159,380
18. Total income (TI) (11 + 13 = 3 + 14 = 8 + 15)	74,354	82,833	15,994	997	65,928	35,372	110,224	385,702
Standard accounts (SNA)								
1. Total product consumption (TPc)	14,846	26,060	2,325	2,868	66,608	34,673	170,930	318,311
2. Intermediate consumption (IC)	19,900	840	319	2,535	1,681	18,456	55,724	99,453
3. Net consumption (NC) (1 – 2)	-5,054	25,221	2,007	334	64,928	16,217	115,206	218,859
4. Gross capital formation (GCF)	0	0	0	0	0	19,264	15,904	35,168
5. Total product (TP) (1 + 4)	14,846	26,060	2,325	2,868	66,608	53,936	186,834	353,479
6. Consumption of fixed capital (CFC)	5,302	0	7	347	3,166	1,210	11,985	22,017
7. Net capital formation (NCF) (4 – 6)	-5,302	0	-7	-347	-3,166	18,054	3,919	13,151
8. Labor cost (LC)	117,628	4,836	486	16,059	9,411	34,080	118,890	301,391
9. Total cost (TC) (2 + 6 + 8)	142,829	5,676	812	18,941	14,258	53,745	186,599	422,860
10. Gross value added (GVA) (5 – 2)	-5,054	25,221	2,007	334	64,928	35,481	131,110	254,026
11. Net value added (NVA) (3 + 7)	-10,355	25,221	1,999	-13	61,762	34,271	119,125	232,010
12. Net operating margin (NOM) (5 – 9)	-127,983	20,385	1,514	-16,073	52,351	191	235	-69,381
Economic accounts for forestry (EAF)								
1. Final product consumption (FPc)								428,938
2. Intermediate consumption (IC)								217,928
3. Gross value added (GVA) (1 – 2)								211,010
4. Labor cost (LC)								186,380
5. Mix gross operating margin (MGOM) (3 – 4)								24,630
Accounting systems comparison								
GVA_{AAS}/GVA_{SNA}	-0.4	1.0	1.1	1.0	1.0	1.0	1.0	1.0
NVA_{AAS}/NVA_{SNA}	0.3	1.0	1.1	1.0	1.0	1.0	1.0	1.0
GVA_{AAS}/GVA_{EAF}								1.2
LC_{AAS}/LC_{EAF}								1.6
TI/NVA_{SNA}	-7.2	3.3	8.0	-75.8	1.1	1.0	0.9	1.7
ES_{AAS}/ES_{SNA}		1.4	1.0		1.0			1.3

Table S3.

Total forest surface in Andalusia by predominant vegetation

Class	Surface	
	(ha)	(%)
1. Native hardwoods	1,900,348	43.3
1.1 Quercus species	1,691,054	38.6
Quercus ilex ssp. Ballota	1,408,170	32.1
Quercus suber	248,015	5.7
Quercus pyrenaica	5,726	0.1
Quercus faginea	18,307	0.4
Quercus canariensis	10,686	0.2
Others	150	0
1.2 Other hardwoods	209,294	4.8
Alnus glutinosa	1,094	0
Arbutus unedo	8,335	0.2
Castanea sativa	9,844	0.2
Olea europaea	127,454	2.9
Populus x canadensis	7,440	0.2
Others	55,127	1.3
2. Coniferous	890,101	20.3
2.1 Pine trees	862,264	19.7
Pinus halepensis	299,482	6.8
Pinus nigra	121,654	2.8
Pinus pinaster	164,628	3.8
Pinus pinea	243,559	5.6
Pinus radiata	1,694	0.1
Pinus sylvestris	31,247	0.7
2.2 Others coniferous	27,837	0.6
3. Eucalyptus spp.	173,694	4
4. Shrublands	1,202,659	27.4
5. Grasslands	145,709	3.3
6. Others	73,921	1.7
Total	4,386,432	100

Table S4.

Total production account of forest ecosystems in Andalusia

Class	Timber	Cork	Fire-wood	Nuts	Gra-zing	Conser-vation forestry	Govern-ment forestry	Fores-try	Hun-ting	Resi-dential	Private amenity	Public recreation	Mush-rooms	Carbon	Land-scape	Bio-diversity	Water	Forest ecosystem
	(€·10^3)	(€·10^3	(€·10^3	(€·10^3)	(€·10^3	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3	(€·10^3	(€·10^3)	(€·10^3)	(€·10^3	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)	(€·10^3)
1. Total product (TP)	34,174	71,937	2,824	2,868	66,608	53,936	186,834	419,182	32,485	51,508	1,134,735	207,696	43,238	224,578	381,747	79,519	277,649	2,852,338
1.1 Intermediate product (IP)	4,663	23,086			66,608	34,673	170,930	299,961	5,535	51,508								357,004
1.1.1 Woody standing harvested (IPng)	4,663	23,086						27,749										27,749
1.1.2 Grazing others (IPg)					56,080			56,080										56,080
1.1.3 Grazing acorn (IPa)					10,528			10,528										10,528
1.1.4 Recreational standing game hunted (IPh)									5,535									5,535
1.1.5 Intermediate production services (IPSS)						34,673	170,930	205,603		51,508								257,111
1.2 Final product (FP)	29,511	48,850	2,824	2,868		19,264	15,904	119,221	26,950		1,134,735	207,696	43,238	224,578	381,747	79,519	277,649	2,495,334
1.2.1 Sales (FPs)	14,846	26,060	1,860	2,868				45,635										45,635
1.2.2 Gross fixed capital formation (GFCF)						19,264	15,904	35,168	2,748			4,983	145		2,363	4,216		49,623
1.2.2.1 Plantations (GFCFp)						19,264	71	19,334										19,334
1.2.2.2 Own construction (GFCFc)							13,367	13,367	122			4,120	137		160	2,731		20,637
1.2.2.3 Born female game breeders (GFCFh)									2,215									2,215
1.2.2.4 Others (GFCFo)							2,467	2,467	410			864	7		2,202	1,486		7,436
1.2.3 Gross work in progress formation (GWPF)	14,665	22,790	499					37,953	18,668									56,621
1.2.3.1 Gross natural growth (GWPFng)	14,665	22,790	499					37,953										37,953
1.2.3.2 Born non-breeding game (GWPFh)									18,668									18,668
1.2.4 Autoconsumption (FPa)			465					465			1,134,735							1,135,200
1.2.5 Public environmental goods and services (FPeg)												202,713	43,093	224,578	379,384	75,303	277,649	1,202,720
1.2.9 Other final product (FPo)									5,535									5,535
2. Total cost (TC)	155,124	51,258	1,160	18,941	14,258	53,745	186,599	481,085	11,400	33,535	51,508	44,159	646	65,830	225,049	28,241		941,452
2.1 Intermediate consumption (IC)	32,194	46,422	667	2,535	1,681	18,456	55,724	157,678	6,609	2,732	51,508	16,021	166	65,830	206,082	7,956		514,581
2.1.1 Raw materials (RM)	7,383	23,276	227	352	883	163	479	32,764	5,627	609		281	6		123	110		39,521
2.1.1.1 Bought raw materials (RMb)	2,720	190	227	352	883	163	479	5,015	93	609		281	6		123	110		6,237
2.1.1.2 Own raw materials (RMo)	4,663	23,086						27,749	5,535									33,284
2.1.2 Services (SS)	17,179	649	91	2,183	797	18,292	55,245	94,437	981	2,123	51,508	15,740	159	65,830	205,960	7,845		444,584
2.1.2.1 Bought services (SSb)	17,179	649	91	2,183	797	18,292	55,245	94,437	981	2,123		8,172	159		7,996	7,773		121,643
2.1.2.2 Own services (SSis)											51,508	7,568			197,963	72		257,111
2.1.2.3 Environmental services (SSe)														65,830				65,830
2.1.3 Work in progress used (WPU)	7,632	22,496	348					30,476										30,476
2.1.3.1 Timber harvested (WPUt)	7,632							7,632										7,632
2.1.3.2 Cork stripping (WPUc)		22,496						22,496										22,496
2.1.3.3 Firewood prunning (WPUf)			348					348										348
2.2 Labor cost (LC)	117,628	4,836	486	16,059	9,411	34,080	118,890	301,391	4,511	11,023		20,870	366		15,924	17,352		371,437
2.3 Consumption of fixed capital (CFC)	5,302		7	347	3,166	1,210	11,985	22,017	280	19,779		7,268	114		3,043	2,934		55,434
2.3.1 Plantations (CFCp)	1,746					1,210		2,955										2,955
2.3.2 Buildings (CFCb)	232						5,876	6,108	90	19,739		6,056	96		745	1,161		33,995
2.3.3 Equipments (CFCe)	3,324		7	88	2,996		1,186	7,601	114	40		146	7		138	102		8,147
2.3.9 Others (CFCo)				259	171		4,923	5,352	76			1,066	11		2,159	1,672		10,336
3. Net operating margin (NOM)	-120,950	20,679	1,664	-16,073	52,351	191	235	-61,904	21,086	17,974	1,083,227	163,538	42,592	158,748	156,698	51,279	277,649	1,910,886
4. Net value added (NVA)	-3,322	25,514	2,150	-13	61,762	34,271	119,125	239,487	25,597	28,997	1,083,227	184,408	42,958	158,748	172,622	68,630	277,649	2,282,323

Surface: 4,386,432 hectares

Table S5.

Total capital account of forest ecosystems in Andalusia

Class	1. Opening capital (Co)	2. Capital entries: 2.1 Bought (Ceb)	2.2 Own (Ceo)	2.3 Other (Ceot)	2.4 Total (Ce)	3. Capital withdrawals: 3.1 Used (Cwu)	3.2 Destructions (Cwd)	3.3. Recla-sifications (Cwrc)	3.4 Other (Cwo)	3.5 Total (Cw)	4. Revaluation, (Cr)	5. Closing capital (Cc)
	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)	(€·10³)
1. Capital (C=WP+FC)	43,678,671	1,862	85,361	224,578	311,801	30,482		254,885	65,830	351,197	-401,847	43,237,428
2. Work in progress (WP)	1,103,754		37,953		37,953	30,476		36,848		67,324	107,776	1,182,160
2.0.1 Timber (WPt)	930,616		14,665		14,665	7,632		14,238		21,869	76,672	1,000,084
2.0.2 Cork (WPc)	133,482		22,790		22,790	22,496		22,126		44,623	28,804	140,453
2.0.3 Firewood (WPf)	39,656		499		499	348		484		833	2,301	41,623
2.1 Produced (WPp)	466,107		37,953		37,953	30,476				30,476	19,119	492,703
2.1.1. Timber (WPpt)	374,583		14,665		14,665	7,632				7,632	15,174	396,789
2.1.2 Cork (WPpc)	61,052		22,790		22,790	22,496				22,496	2,700	64,046
2.1.3 Firewood (WPpf)	30,473		499		499	348				348	1,245	31,868
2.2 Expected (WPe)	637,647							36,848		36,848	88,658	689,457
2.2.1 Timber (WPet)	556,034							14,238		14,238	61,498	603,294
2.2.2 Cork (WPec)	72,430							22,126		22,126	26,104	76,407
2.2.3 Firewood (WPef)	9,183							484		484	1,056	9,755
3. Fixed captial (FC)	42,574,917	1,862	47,407	224,578	273,848			218,037	65,836	283,872	-509,623	42,055,268
3.1 Land (FCl)	38,990,247			224,578	224,578			218,037	65,830	283,867	-441,502	38,489,457
3.1.1 Timber (FClt)	*422,670*										*9,390*	*432,060*
3.1.2 Cork (FClc)	*35,175*										*1,148*	*36,323*
3.1.3 Firewood (FClf)	*131,988*										*3,960*	*135,947*
3.1.4 Nuts (FClin)	*9,924*										*420*	*10,344*
3.1.5 Grazing others (FClg)	*1,944,843*											*1,944,843*
3.1.6 Grazing acorn (FCla)	*60,794*										*1,824*	*62,618*
3.1.7 Hunting (FClh)	*767,102*											*767,102*
3.1.8 Private ameneties (FCla)	*14,355,058*										*-686,140*	*13,668,917*
3.1.9 Public recreation(FClpr)	*5,941,174*											*5,941,174*
3.1.10 Mushrooms (FClm)	*1,414,138*											*1,414,138*
3.1.11 Carbon (FClca)	*3,171,608*			*224,578*	*224,578*			*218,037*	*65,830*	*283,867*	*227,898*	*3,340,217*
3.1.12 Landscape (FCll)	*4,928,297*											*4,928,297*
3.1.13 Biodiversity (FClb)	*1,675,544*											*1,675,544*
3.1.14 Forest water (FClfw)	*4,131,933*											*4,131,933*
3.2 Biological resources (FCbr)	1,103,176										64,431	1,167,607
3.2.1 Timber (FCbrt)	33,407										4,940	38,347
3.2.2 Cork (FCbrc)	854,458										49,902	904,360
3.2.3 Firewood (FCbrf)	149,906										8,060	157,967
3.2.4 Nuts (FCbrin)	12,844										371	13,215
3.2.5 Grazing acorns (FCbra)	52,561										1,158	53,719
3.3 Manufactured (FCm)	2,481,494	1,862	47,407		49,269				6	6	-132,553	2,398,205
3.3.1 Plantations (FCp)	224,453		19,334		19,334						524	244,312
3.3.2 Buildings (FCb)	2,179,950		20,637		20,637						-125,618	2,074,969
3.3.3 Equipments (FCe)	14,111	1,862			1,862				6	6	-677	15,290
3.3.4 Others (FCo)	62,979		7,436		7,436						-6,782	63,633

Surface: 4,386,432 hectares

Table S6.

List of activities and specific actions considered in the study of government expenditures in Andalusian forest ecosystems

Activity	Example of interventions
1. Landscape conservation	• Conservationist forestry applied to non-threatened habitats or species, • Hydrological - forestry restoration, • Supplementary works for landscape conservation.
2. Threatened species preservation	• Conservationist forestry applied to threatened habitats or species, • Management of wildlife rehabilitation and nursery centers.
3. Wildfires prevention and suppression	• Forestry applied to prevent wildfires, • Investment in buildings and infrastructure to prevent and suppress wildfires, • Surveillance and suppression of wildfires.
4. Public recreational services.	• Management visitors center in natural areas, • Management and maintenance of public recreational infrastructure.
5. Drove ways and Green corridors management	• Maintenance of drove ways and green corridors management, • Demarcation and improvement of drove ways and green corridors management.
6. Environmental educations and social involvement	• Outreaching activities related to government interventions in montery ecosystems, • Management of volunteers activities.
7. Environmental research and innovation	• Research and innovation in forest ecosystems, • Mapping, classification and inventories in forest ecosystems.
8. Public mushroom management	• Mycological garden management, • Specific mycology research.
9. Public hunting activity management	• Surveillance and control of hunting activity and hunters. • Management of Game health evaluation centers
10. General expenses	• Development of natural areas management plans and projects, • Natural areas and public forest demarcation, • Surveillance of natural areas, • General administrative costs.

Table S7.

Distribution of government expenditures by single product and activity of the Agroforestry Accounting System (AAS)

Activity	Products and activities of the AAS										
	Forestry				Hunting	Other market activities	Private amenity	Public recreation	Mush-rooms	Land-scape	Threatened biodiversity
	Timber, cork, firewood, nuts	Grazing	Conservation forestry	Others							
1. Threatened biodiversity											
1.1 Biodiversity oriented forestry			Y								Y
1.2 Other expenses											X
2. Landscape conservation											
2.1 Landscape oriented forestry			Y							Y	
2.2 Other expenses										X	
3. Wildfires services											
3.1 Wildfire oriented forestry			Y							Y	
3.2 Other expenses				Y						Y	
4. Public recreational services											X
5. Drove ways management..				Y				Y			
6. Environmental education..								X			
7. Environmental research…				X	X			X	X	X	X
8. Public mycological management									X		
9. Public hunting management					X						
10. General expenses											
10.1 Public forests demarcations				X	X			X	X	X	X
10.2 Other expenses				X	X			X	X	X	X

Table S8.

Average stumpage prices by species and range of diameter classes

Species	Period 2010		
	[0-15] (€/m^3)	[15.1-25] (€/m^3)	[25.1- ∞) (€/m^3)
Pinus sylvestris	7	12	-
Pinus pinea	4.04	10.34	29.12
Pinus halepensis	3.65	11.64	25.25
Pinus nigra	3.58	9.11	30
Pinus pinaster	2.44	11.35	26.33
Pinus canariensis	1	8	10
Pinus radiata	3	12	-
Eucalyptus globulus	4.33	11	26.99
Eucalyptus camaldulensis	4.88	11.08	-

Table S9.

Physical indicators for timber, cork and firewood in Andalusia (2010)

Class	Timber (m^3)	Cork (t)	Firewood (m^3)
Opening capital	77,864,552	234,613	75,501,194
Annual growth	2,673,053	96,971	1,384,158
Annual extraction	458,854	18,989	39,876

Table S10.

Total production, commercial and free for pinecone, chestnut and acorn in Andalusia

Class	Total production (tons)	Commercial (tons)	Free (tons)
Pinenuts	25,992	6,559	19,434
Chestnut	24,301	2,213	22,088
Acorn	619,109	183,156	435,953

Table S11.

Log-logit model from the single bounded question for the valuation of landowner private amenities

Explanatory variables	Log-logit model	
	Coefficient	*p-value*
Intercept (INT)	2.7975**	0.0162
Log of the bid (LBID)	-0.7242***	<0.0001
Property size in hectares (HA)	-0.0003*	0.0918
Eucalyptus (= 1 if there is eucalyptus vegetation in the property) (EUC)	-1.1926*	0.065
Aleppo pine (= 1 if there is Aleppo pine vegetation in the property) (PCA)	-0.9695***	0.0027
Log of the distance to the capital of the province (LPRO)	0.3832**	0.0457
McFadden Pseudo-R^2	0.0629	
Akaike Information Criterion	1.29	
n	455	

Asterisks (e.g.,*,**,***) denote significance at the 10%, 5%, and 1% levels, respectively.

Table S12.

Log-logit model from the single bounded question for the valuation of public recreation in nine forest areas in Andalusia

Explanatory variables	Log-logit model	
	Coefficient	*p-value*
Intercept	2.3325***	<0.0001
Log of bid	-1.4662***	<0.0001
Alcornocales area	-1.0695***	<0.0001
Andújar-Despeñaperros-Hornachuelos area	-0.2872*	0.0531
Aracena area	0.3912**	0.0118
Cabo de Gata area	0.2670*	0.0755
Cazorla area	0.3758***	0.0056
Grazalema area	0.1907	0.1702
Sierra María-Los Vélez area	0.2643	0.1408
Sierra Nevada area	-0.1323	0.276
Payment vehicle (= 1 if increased trip-expenditures)	1.5517***	<0.0001
Respondet's age (years)	0.0090**	0.0358
Total expenses in the visit	0.0055***	<0.0001
Dummy = 1 if the respondent belongs to a nature conservation association	0.5234**	0.041
Dummy = 1 if the respondent would come back to the area	-1.8059**	0.0177
McFadden's pseudo-R^2	0.18	
Akaike Information Criterion	2,317.60	
n	2,370	

Table S13.

Sampling goal of visitors for each natural area

Area	Sample (N)
Alcornocales	288
Andújar-Despeñaperros-Hornachuelos	576
Aracena	416
Cabo de Gata-Níjar	384
Cazorla	576
Pinares de Doñana	288
Sierra de Grazalema-Las Nieves	480
Sierra María-Los Vélez	288
Sierra Nevada	704
Total	4,000

Table S14.

Estimations of visitors (persons) and visits (days) to 27 forest areas in Andalucía

Area	Visitors			Visits		
	Andalucía	Rest of Spain	Total	Andalucía	Rest of Spain	Total
	(persons)	(persons)	(persons)	(days)	(days)	(days)
Alcornocales	192,395	346,903	539,299	907,605	830,090	1,737,695
Andújar-Despeñaperros-Hornachuelos	250,951	652,464	903,414	658,745	805,985	1,464,730
Aracena	284,411	497,812	782,223	1,641,635	1,569,687	3,211,322
Cabo de Gata-Níjar	257,224	575,703	832,928	1,332,129	1,304,927	2,637,057
Cazorla	386,882	614,083	1,000,966	1,811,027	1,650,349	3,461,376
Pinares de Doñana	209,125	366,039	575,164	708,935	677,865	1,386,800
Sierra de Grazalema-Las Nieves	403,612	727,743	1,131,355	1,913,498	1,741,384	3,654,883
Sierra María-Los Vélez	31,369	54,906	86,275	48,099	45,991	94,090
Sierra Nevada	646,198	1,131,059	1,777,257	2,846,198	2,721,457	5,567,654
Parque Natural del Estrecho	4,183	7,321	11,503	4,183	3,999	8,182
Desfiladero de los Gaitanes	20,913	36,604	57,516	48,099	45,991	94,090
La Breña y Marismas de Barbate	6,274	10,981	17,255	12,548	11,998	24,545
Los Reales de Sierra Bermeja	23,004	40,264	63,268	380,608	363,927	744,536
Montes de Málaga	37,643	65,887	103,530	85,741	81,984	167,725
Río Tinto	8,365	14,642	23,007	106,654	101,980	208,634
Sierra Alhamilla	6,274	10,981	17,255	10,456	9,998	20,454
Sierra de Baza	10,456	18,302	28,758	35,551	33,993	69,545
Sierra de Cardeña y Montoro	20,913	36,604	57,516	50,190	47,990	98,181
Sierra de Castril	4,183	7,321	11,503	6,274	5,999	12,273
Sierra de Filabres	10,456	18,302	28,758	12,548	11,998	24,545
Sierra de Gádor	6,274	10,981	17,255	50,190	47,990	98,181
Sierra de Huétor	27,186	47,585	74,771	161,027	153,969	314,996
Sierra Mágina	16,730	29,283	46,013	43,916	41,992	85,908
Sierra Norte de Sevilla	79,468	139,095	218,562	531,179	507,899	1,039,077
Sierras de Tejeda, Almijara y Alhama	71,103	124,453	195,556	161,027	153,969	314,996
Sierras Subbéticas	25,095	43,925	69,020	98,289	93,981	192,270
Torcal de Antequera	23,004	40,264	63,268	25,095	23,995	49,090
Total	2,246,008	3,931,254	6,177,261	13,691,445	13,091,386	26,782,831

Table S15.

Sampling goal of visitors for each natural area

Attribute	Levels	Status quo levels
Forest area and main vegetation	– Alcornocales – Cork oak – Andujar-Despeñaperros – Holm Oak – Aracena – Holm Oak – Cabo de Gata – European fan palm – Cazorla – Pine – Doñana – Pine – Grazalema – Holm Oak – Hornachuelos – Holm Oak – Sierra María-Los Vélez – Pine – Sierra Nevada – Pine	No forest area and vegetation targeted
Forested areas	– 10% decrease – Same area – 10% increase – 20% increase	10% decrease in the area of the three species in the three forest sites presented
Endangered species	– 5% increase (12 endangered species more) – same number of endangered species – 5% decrease (12 endangered species less) – 10% decrease(12 endangered species less)	5% increase (12 endangered species more)
Annual tax-fee during 30 years	– 10 euros – 20 euros – 30 euros – 40 euros	0 euros

Table S16.

Mixed logit model from the choice experiment derived for the valuation of landscape conservation and endangered biodiversity preservation in Andalusian forests

Atributtes	Mixed logit model			
	Coefficient	p-value	St. Deviation coefficient	p-value
Constant[1]	-1.2585	<0.0001		
Endangered species	0.0609	<0.0001	0.1563	<0.0001
Endangered species (quadratic)	-0.0028	<0.0001		
Forested area for cork oak	0.1067	<0.0001		
Forested area for cork oak (quadratic)	-3.7357E-06	<0.0001	3.7712E-06	<0.0001
Forested area for holm oak	0.030	0.0032	0.1081	<0.0001
Forested area for holm oak (quadratic)	-1.6695E-06	<0.0001	1.0545E-05	0.0168
Forested area for pines	0.1396	<0.0001	0.227	<0.0001
Forested area for pines (quadratic)	-1.5539E-05	<0.0001	1.1985E-05	<0.0001
Forested area for European fan palm	0.7976	0.0026	0.5820	0.0011
Forested area for European fan palm (quadratic)	-1.1970E-04	0.1933		
Bid	-0.0200	<0.0001		
McFadden Pseudo-R^2	0.1155			
Akaike Information Criterion	2.24			
n	6,197			

Asterisks (e.g.,*,**,***) denote significance at the 10%, 5%, and 1% levels, respectively.

[1] This is an alternative specific constant taking value 1 for environmental program alternatives and value 0 for the status quo alternative.

Table S17.

Mushroom harvester population (ph) and total amount harvested (Qi) in each Andalusia province

Province	Total population[*] (n)	Surveys answered (n)	Harvesters surveys (n)	Harvesters (p_h) (%)	Harvester population (n)	Total amount harvested Qi (ton)	Std. error (α=0,05)[**] (%)
Almería	556,239	591	26	4.41	24,543	249	1.66
Cádiz	987,046	695	32	4.64	45,829	1,084	1.56
Córdoba	650,643	674	47	6.94	45,126	973	1.92
Granada	743,326	678	37	5.5	40,920	830	1.72
Huelva	418,465	413	79	19.19	80,315	3,214	3.8
Jaén	539,165	403	30	7.54	40,663	1,134	2.58
Málaga	1,299,142	540	9	1.71	22,178	725	1.09
Sevilla	1,527,267	225	6	2.55	38,901	582	2.06
Total	6,721,293	4,219	267	6.33	425,399	8,790	0.73

Table S18.

Final price assigned to each mushroom species (pi), standard error and criteria followed

Species	Price (€ kg-1)	Std. Error α=0,05	Criteria
Agaricus sp.	1	-	5
Agrocybe cylindracea	1	-	5
Amanita caesarea	4.81	0	3
Amanita ponderosa	18	6.04	1
Boletus gr. edulis	4.64	1.2	3
Cantharellus cibarius	11.39	0.09	2
Chroogomphus rutilus	1	-	5
Craterellus cornucopioides	6.76	0.07	2
Craterellus tubaeformis	4.73	0.66	2
Helvella sp.	1	-	5
Hydnum repandum	2.91	0.06	2
Hygrophorus sp.	1	-	5
Lactarius gr. deliciosus	2.67	0.86	1
Leccinum spp.	4.81	1.67	3
Lepista nuda, L. personata	3.8	0.73	2
Macrolepiota sp.	1	-	5
Marasmius oreades	1	-	5
Morchella spp.	1	-	5
Pleurotus eryngii	4.85	1	4
Pleurotus eryngii var. ferulae	1	-	5
Ramaria flava	1	-	5
Russula cyanoxantha	1	-	5
Terfezia spp.	1	-	5
Tricholoma atrosquamosum	1	-	5
Tricholoma terreum	1	-	5

Table S19.

Average forage units consumption of the livestock and lease and environmental prices by predominant vegetation in Andalusia (2010)

Class	Farms (N)	Land (ha)	Grazing (FU/ha)	Lease price (€ 100/FU)	Environmental price (€ 100/FU)
Eucalyptus sp.	1	18	149	1	0
Native hardwoods	132	68,681	485	7	6
Olea europaea	*2*	*1,331*	*195*	*8*	*6*
Quercus suber	*17*	*6,498*	*351*	*10*	*9*
Quercus ilex	*113*	*60,852*	*505*	*7*	*6*
Pine trees	6	2,841	268	7	6
Pinus halepensis	*4*	*489*	*548*	*3*	*3*
Pinus pinea	*1*	*952*	*86*	*22*	*18*
Pinus sylvestris	*1*	*1,400*	*295*	*6*	*5*
Treelesslands	22	12,238	465	6	5
Shrubsland	*17*	*8,558*	*397*	*5*	*5*
Grassland	*5*	*3,680*	*623*	*7*	*6*
Total	161	83,777	474	7	6

Additional Data for

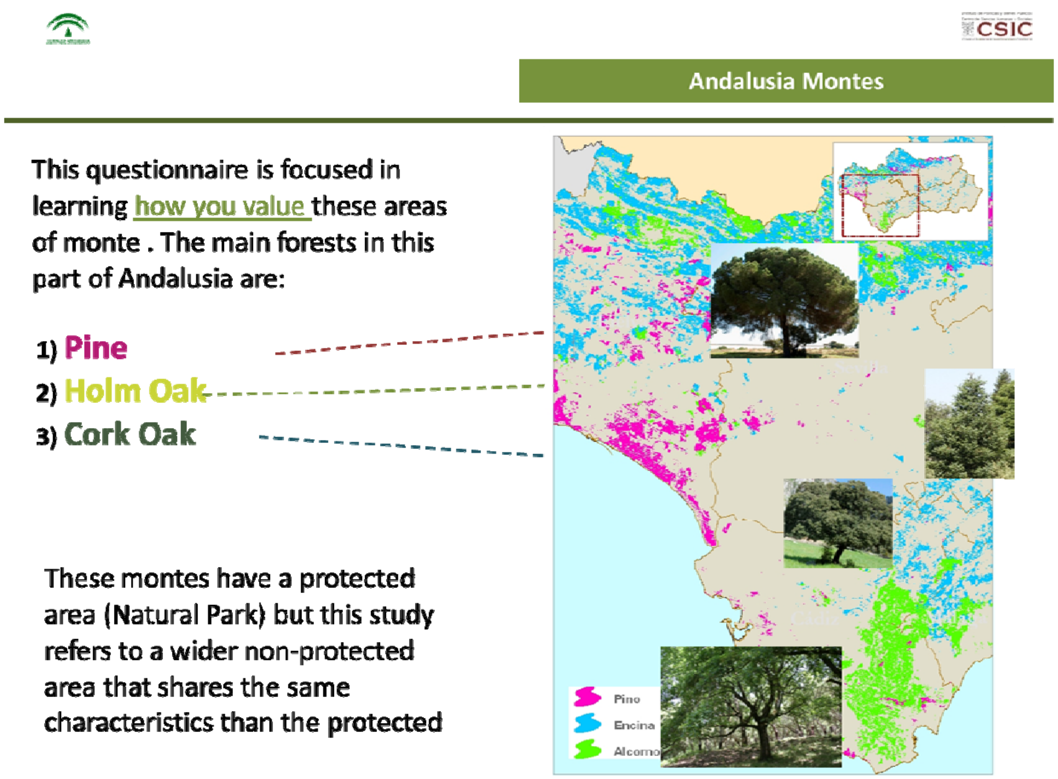
Bridging the gap between national and ecosystem accounting

Additional Data S1. Valuation scenario in the choice experiment. Example for stratum 1 (Alcornocales-Grazalema-Doñana)

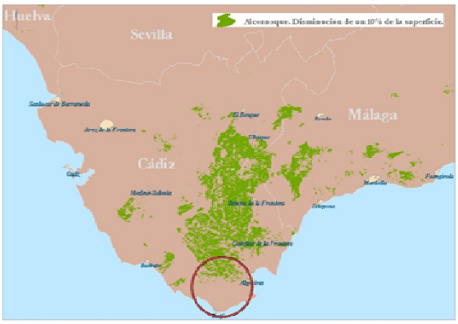
The material for the survey comprises several documents: the questionnaire, the manual for interviewers, and the booklet with the description of attributes and the possible and selected levels for the analysis. Individuals were informed about where the areas were and the main characteristics of the sites showing them cards such as the following. This information was completed with maps like the set shown in next picture. These maps were always referred to the sites being valued, thus, for each stratum there were three sets of maps. An extract with the main information presented follows.

“Next, you will be asked a series of questions to know your view in respect to future management of Andalusian Montes. Please, read thoroughly. Experts foresee potential changes depending on the decisions of management for these montes. The possible actions considered in this scenario are then as follows:

1) Keep the current level of service. This means less trees, less grass and pastures and extended scrubland in few years.
2) Increase resources to keep the situation as today.
3) Increase resources to increase the tree covered area with native species, wild animals and better habitats.

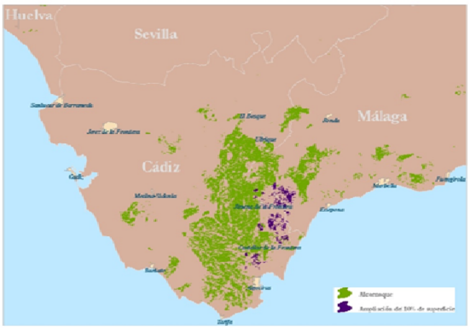


The following pages show the potential outcome derived from the possible actions explained before. Look carefully the series of maps where the effects are shown in colors (respondents were shown three sets of maps, one for each site in valuation).

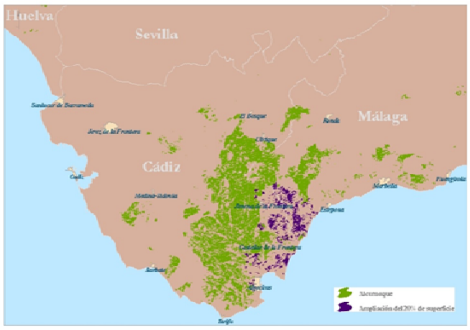


10% Decrease in Cork Oak

No variation: same area of Cork Oak



10% Increase in Cork Oak

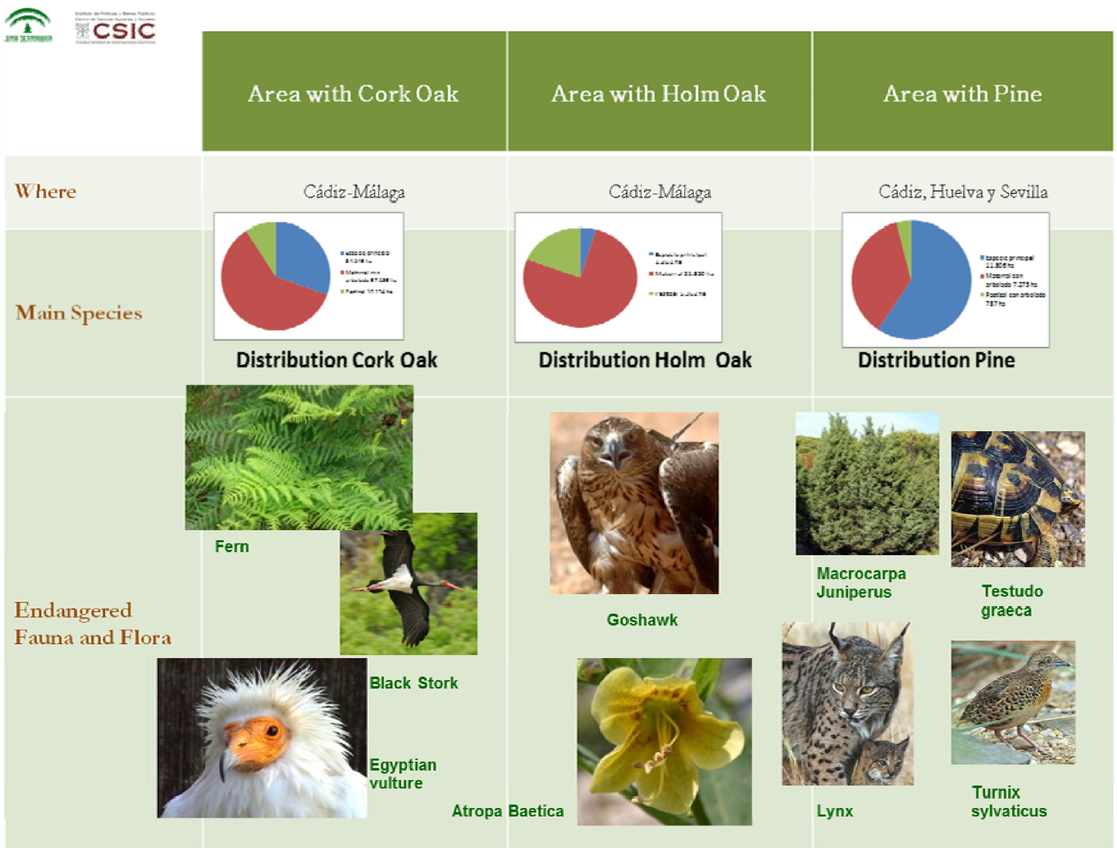


20% Increase in Cork Oak

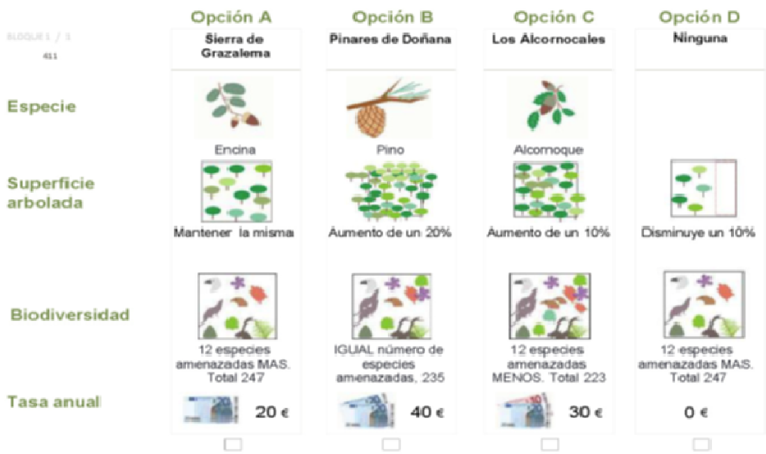
1

The availability of resources affects endangered species too.

Now you will see set of possible actions in the montes. These are options designed for experts for intervening in the management and the consequences in the environment in 30 years. To get these conservation objectives it is necessary an economic effort as shown at the bottom of each option with a varying annual tax. Actions can be combined to get the objectives in different proportions.



Choose one of the four options shown in cards. It is very important to complete all choices, otherwise we will not be able to consider your opinion properly. Please indicate your preferred option.”



Additional Data S2. Silviculture schedules datasets

This additional data contains 9 datasets with the silviculture schedules under different scenarios for the following tree species: *Quercus ilex*, *Pinus pinea* and *Quercus suber*.

Additional Data 2 table 1. Silviculture schedule for Quercus ilex: medium – high quality, highly populated regular stands.

Additional Data 2 table 2. Silviculture schedule for Quercus ilex: medium – low quality.

Additional Data 2 table 3. Silviculture schedule for Quercus ilex: uneven-aged stands.

Additional Data 2 table 4. Silviculture schedule for Pinus pinea in open countryside (campiña): Medium-high quality.

Additional Data 2 table 5. Silviculture schedule for Pinus pinea in open countryside (campiña): Medium-low quality.

Additional Data 2 table 6. Silviculture schedule for Pinus pinea in Sierra Morena: Medium-high quality.

Additional Data 2 table 7. Silviculture schedule for Pinus pinea in Sierra Morena: Medium-low quality.

Additional Data 2 table 8. Silviculture schedule for Quercus suber: Massif of El Aljibe. evolution of the structure and density of even-aged stand from assisted natural regeneration (first cycle).

Additional Data 2 table 9. Parameters for the estimation of the debarkimg height in different zones of Andalusia.

Additional Data 2 table 1. Silviculture schedule for *Quercus ilex* : meidum - high quelity, highly populated regular stands

Year	Dg (cm)	N/ha before thinning	N/ha to be extracted	N/ha after thinning	Total Biomass (T/ha)	Biomass extracted (T/ha)	C extracted (TC/ha)	Annual acorn production (kg/ha)	Crown diameter (m)	FCC (%)	Intervention	Criteria to be applied	Objective pursued
0 T1	0	625	0	625	0	0	0	0	-	-	Site preparation. Plantation	Plough with disc plough and open furrows to a depth of 60-80cm and 4 meters apart using a ripper furrower. Plantation spacing 4x4 (625 trees ha^{-1}). If there is a large amount of scrub, this will be cleared prior to land preparation. Mechanized plantation where the terrain allows, using year-old plants at a density of 500 plants ha^{-1}.	Prepare the land not only so that the plants can easily develop deep roots, establish themselves and develop but also to avoid weed competition. Establish the new forest stand such that it can develop without difficulty.
1 T1	0	625	0	625	0	0	0	0	-	-	Hoeing and replacement of failed plants	Use a cultivator or disc harrow before the weeds go to seed to avoid seed dispersion. Remove manually or with a brushcutter between the plants. Residual herbicides can be effective to eliminate herbaceous weeds. Replace failed plants if these account for more than 10%.	Reduce or eliminate the competition to the holm-oak plants from herbaceous vegetation or scrub.
3 T1	0,5	580	0	580	-	0	0	0	-	-	Hoeing	Use a cultivator or disc harrow before the weeds go to seed to avoid seed dispersion. Remove manually or with a brushcutter between the plants. Residual herbicides can be effective to eliminate herbaceous weeds. Replace failed plants if these account for more than 10%.	Reduce or eliminate the competition to the holm-oak plants from herbaceous vegetation or scrub.
25 T1	10,2	450	0	450	13,5	0	0	431,7	2,4	20,7	Open to grazing	Cattle grazing. Restricted sheep and pig grazing in the 5th -6th year.	Start to utilize the pasture and the few acorns produced by the young trees.
30 T1	13	440	132	308	26,4	7,9	3,76	447,9	3	21,5	Formation pruning and first thinning	The first formation pruning involves removing up to 1/3 - 2/3 of the total height of the holm-oak. First thinning: Around 300 trees per hectare are left after the first thinning and the rest are removed.	Formation of the stand and elimination of competition so that the selected trees can grow and develop better.
60 T1	29,5	298	149	149	128,1	64,1	30,4	859,8	6,3	46,5	Maintenance pruning and thinning	Pruning is performed so that no more than 30% of the crown is eliminated. Do not cut branches thicker than 15-18 cm in diameter to avoid injuries which are difficult to heal. Remove the least productive or defective trees.	Extract firewood and browse for the cattle. Decrease the tree density to reduce competition and favor both the production of grass and crown growth which in turn will lead to greater acorn production.
100 T1	48,2	136	48	88	198,6	70,1	33	1.067,60	10,1	70	Improvement and conservation cuttings. Maintenance pruning	Remove defective trees and those with the lowest acorn production. Prune the least vigorous branches up to a 1/3 of the volume of the crown.	Favor crown growth and increase acorn and grass production. Obtain firewood and browse.
130 T1	58,8	80	16	64	191,2	38,24	18,2	1.014,50	12,2	74,8	Improvement and conservation cuttings. Maintenance pruning	Remove weaker trees and those with lower acorn production.	Favor crown growth and increase acorn and pasture production.
160 T1	66,9	58	10	48	190,8	32,9	15,6	894	13,8	72	Improvement and conservation cuttings. Maintenance pruning.	Remove weaker trees and those with lower acorn production	Favor crown growth and increase acorn and pasture production.
170 T1	70,1	44	26	18	162,4	95,94	45,6	354,5	14,5	29,6	Regeneration cuttings	About 60% of the trees are cut and we are left with around 18 trees per hectare. Soil preparation is performed and the gaps between the trees are sown.	Commence renovation so that the young trees begin to take over from the old ones in their biological and productive functions. Achieve >2000 plants per hectare.
185 T1	72	16	0	16	63	-	0	325,2	14,85	27,7	Thinning	Adult trees are kept for acorn production and enhancement of biological and scenic biodiversity. Only very weak trees are extracted. The best of the young trees are selected taking into consideration the spatial distribution which should be as homogeneous as possible	Adult trees continue to produce acorns. Select around 750 young trees to promote diameter growth. Prune from below.
15 T2	5,1	2000	1250	750	20	12,5	5,9		1,4	11,4		Scrub clearance if there is an abundance of it.	
200 T1	74	13	0	13	54,9	-	0	272,7	15,2	23,8	Thinning and pruning		
30 T2	13	675	338	337	40,5	20,3	9,6	490,1	3	23,5		Selection of the best trees and prune up to half the height.	Promote diameter growth of the young stand as well as acorn and pasture production.
230 T1	75	10	0	10	43,6	-	0	213,05	15,5	18,8	Thinning and pruning		
60 T2	29,5	326	163	163	140,2	70,1	33,3	940,6	6,3	50,8		Selection of the best trees and prune up to half the height.	Promote diameter growth of the young stand as well as acorn and pasture production.
100 T2	48	136	48	88	128,1	129,1	61,3	1061,4	10	69,4	Improvement and conservation cuttings. Maintenance pruning	Remove defective trees and those with the lowest acorn production. Prune the least vigorous branches up to a 1/3 of the volume of the crown.	Favor crown growth and increase acorn and grass production. Obtain firewood and browse.

Additional Data 2 table 2. Silviculture schedule for *Quercus ilex* : medium - low quality

Year	Dg (cm)	N/ha before thinning	N/ha to be extracted	N/ha after thinning	Total Biomass (T/ha)	Biomass extracted (T/ha)	C extracted (TC/ha)	Annual acorn production (kg/ha)	Crown diameter (m)	FCC (%)	Intervention	Criteria to be applied	Objective pursued
0 T1	0	625	0	625	0	0	0	0	0,4	0,7	Site preparation.	Plough with disc plough and open furrows to a depth of 60-80cm and 4 meters apart using a ripper furrower. Plantation spacing 4x4 (625 trees ha^{-1}). If there is a large amount of scrub, this will be cleared prior to land preparation.	Prepare the land not only so that the plants can easily develop deep roots, establish themselves and develop but also to avoid weed competition.
											Plantation	Mechanized plantation where the terrain allows, using year-old plants at a density of 500 plants ha^{-1}.	Establish the new forest stand such that it can develop without difficulty.
1 T1	0	625	0	625	0	0	0	0	0,4	0,7	Hoeing and replacement of failed plants	Use a cultivator or disc harrow before the weeds go to seed to avoid seed dispersion. Remove manually or with a brushcutter between the plants. Residual herbicides can be effective to eliminate herbaceous weeds. Replace failed plants if these account for more than 10%.	Reduce or eliminate the competition to the holm-oak plants from herbaceous vegetation or scrub.
3 T1	0,4	580	0	580	-	0	0	0	0,4	0,9	Hoeing	Use a cultivator or disc harrow before the weeds go to seed to avoid seed dispersion. Remove manually or with a brushcutter between the plants.. Residual herbicides can be effective to eliminate herbaceous weeds. Replace failed plants if these account for more than 10%.	Reduce or eliminate the competition to the holm-oak plants from herbaceous vegetation or scrub.
25 T1	9,2	497	0	497	4,97	0	0	399,5	2,2	19,2	Open to grazing	Cattle grazing. Restricted sheep and pig grazing in the 5th -6th year.	Start to utilize the pasture and the few acorns produced by the young trees.
30 T1	11,5	470	141	329	9,4	2,8	1,3	387,8	2,7	18, 5	Formation pruning and first thinning	The first formation pruning involves removing up to 1/3 - 2/3 of the total height of the holm-oak. First thinning: Around 300 trees per hectare are left after the first thinning and the rest are removed.	Formation of the stand and elimination of competition so that the selected trees can grow and develop better.
60 T1	26,5	306	153	153	30,6	15,3	7,3	741,8	5,7	39	Maintenance pruning and thinning	Pruning is performed so that no more than 30% of the crown is eliminated. Do not cut branches thicker than 15-18 cm in diameter to avoid injuries which are difficult to heal. Remove the least productive or defective trees.	Extract firewood and browse for the cattle. Decrease the tree density to reduce competition and favor both the production of grass and crown growth which in turn will lead to greater acorn production.
100 T1	43	147	88	59	39,69	23,8	11	608	9	37,7	Improvement and conservation cuttings. Maintenance pruning	Remove defective trees and those with the lowest acorn production. Prune the least vigorous branches up to a 1/3 of the volume of the crown.	Favor crown growth and increase acorn and grass production. Obtain firewood and browse.
130 T1	52,7	55	15	40	22	6	2,85	548,7	11	37,8	Improvement and conservation cuttings. Maintenance pruning	Remove weaker trees and those with lower acorn production.	Favor crown growth and increase acorn and pasture production.
160 T1	60	38	10	28	20,14	5,3	2,5	455,5	12,4	34	Improvement and conservation cuttings. Maintenance pruning.	Remove weaker trees and those with lower acorn production	Favor crown growth and increase acorn and pasture production.
170 T1	62	26	11	15	14,56	6,2	2,9	254,4	12,8	19,4	Regeneration cuttings	About 60% of the trees are cut and we are left with around 18 trees per hectare. Soil preparation is performed and the gaps between the trees are sown.	Commence renovation so that the young trees begin to take over from the old ones in their biological and productive functions. Achieve >2000 plants per hectare.
185 T1	65	14	0	14	8,68	0	0	251,76	13,4	19,9		Adult trees are kept for acorn production and enhancement of biological and scenic biodiversity. Only very weak trees are extracted. The best of the young trees are selected taking into consideration the spatial distribution which should be as homogeneous as possible	Adult trees continue to produce acorns. Select around 750 young trees to promote diameter growth. Prune from below.
15 T2	4,5	2000	1250	750	-	-	0		1,3	9,5	Thinning	Scrub clearance if there is an abundance of it.	
200 T1	67	13	0	13	8,58	0	0	242,6	13,8	19,6			
30 T2	11,6	575	173	402	11,5	3,5	1,6	480,9	2,7	23	Thinning and pruning	Selection of the best trees and prune up to half the height.	Promote diameter growth of the young stand as well as acorn and pasture production.
230 T1	70	10	0	10	7,2	-	0	196,64	14,45	16,4			
60 T2	26,5	346	173	173	34,6	17,3	8,22	838,8	5,7	44,11	Thinning and pruning	Selection of the best trees and prune up to half the height.	Promote diameter growth of the young stand as well as acorn and pasture production.
100 T2	43,2	136	82	54	36,72	22,14	10,52	560,27	9,06	34,8	Improvement and conservation cuttings. Maintenance pruning	Remove defective trees and those with the lowest acorn production. Prune the least vigorous branches up to a 1/3 of the volume of the crown.	Favor crown growth and increase acorn and grass production. Obtain firewood and browse.

Additional Data 2 table 3. silviculture schedule for *Quercus ilex:* uneven-aged stands

DC (cm)	Age	Time step	N before	N dead	N burned	N extracted	N after	kg stem firewood (kg/tree)	kg firewood in branches bigger than 7cm (kg/tree)	kg firewood in branches between 2 y 7 cm (kg/tree)	kg firewood in branches smaller than 2 cm (kg/tree)	C extracted T/tree	kg acorn/tree
0			56				46						
5	23	10	46	5	-	3	38	3	0,6	2	1,7	0	
10	34	10	38	4	-	2	32	14	5,3	8,1	6,6	0,01	
15	46	12	32	1	-	4	27	32	18,1	18,1	14,6	0,04	1,66
20	60	13	27	1	-	4	22	57	43,4	32,3	25,9	0,08	2,83
25	74	14	22	1	-	4	17	90	85,6	50,5	40,2	0,14	4,21
30	90	15	17	1	-	1	15	130	149,2	72,7	57,6	0,21	5,73
35	106	16	15	1	-	1	13	177	238,5	99	78,1	0,31	7,36
40	124	18	13	1	-	1	11	232	358	129,4	101,6	0,44	9,06
45	144	19	11	1	-	1	9	294	512,4	163,9	128,3	0,58	10,81
50	164	20	9	1	-	2	6	364	706,1	202,4	157,9	0,76	12,57
55	186	22	6	-	-	2	4	441	943,7	244,9	190,6	0,96	14,32
60	0	0	4	-	-	1	3	526	1.229,90	291,6	226,4	1,19	16,07
65	0	0	3	-	-	1	2	618	1.569,20	342,3	265,1	1,45	17,78
70	0	0	2	-	-	1	1	717	1.966,20	397	306,9	1,75	19,46
75	0	0	1	1	-		0	824	2.425,60	455,9	351,7	2,07	21,11

Additional Data 2 table 4. Silvicultural schedule for *Pinus pinea* in open countryside (campiña): Medium-high quality

Year	H (m)	Dg (cm)	N/ha before thinning	N/ha Stems to be extracted	N/ha after thinning	V before thinning (m^3/ha)	Vol. ext. (m^3/ha)	V after thinning (m^3/ha)	Biomass MS extracted (T/ha)	C extracted (T C/ha)	Pine cone production (kg/ha)	Intervention	Criteria to be applied	Objective pursued
0 T1	-	-	830-1500	0	830-1500	0	0	0	0	0	0	Site preparation	Mechanized clearance, straight-line or spot tillage depending on the soil type and topography	Eliminate spontaneous vegetation and prepare the soil so that plants are able to establish themselves and thrive, free from competition during the first years
8 T1	-	-	1300	0	1300	0	0	0	0	0	-	First pruning	Enhancement pruning, always leaving three or more whorls	Improve the straightness of the stem and apical dominance of the plants
15 T1	5	15,5	1225	612	613	89,3	44,6	44,7	53,1	27	15,6	First thinning Second pruning	Systematic thinning affecting 50% of the trees Affects lower whorls between a 1/3 and ½ the total height of the tree	Increase spacing between trees to stimulate Ø growth and pine cone production by reducing competition Increase the proportion of clean stem and stimulate the branches in the upper half to the crown, which is where pine cone production is concentrated.
25 T1	7,5	20,5	600	240	360	97,4	39	58,5	41	20,8	27,8	Second thinning	Systematic thinning affecting 40% of the trees	Decrease competition for water, nutrients and light. Promote diameter growth and pine cone production per tree.
40 T1	10,7	27	356	107	249	125,8	37,8	88	35,6	18,1	57,1	Third thinning Third pruning	Systematic thinning affecting 30% of the least vigorous trees and attempting to achieve a balanced distribution. Elimination of lower whorls up to a height of 6.5 to 7 meters.	Decrease competition for water, nutrients and light. Promote diameter growth and pine cone production per tree. Achieve the highest possible wood quality from the lower 6 to 7 meters of the stem and stimulate the upper part of the crown to increase quantity and quality of pine cone production
70 T1	14,6	35	234	105	129	164,9	74	90,9	65,6	33,3	82,5	Brush removal- superficial harrowing (optional))		
100 T1 0 T2	16,7	40	120	60	60	118,7	59,3	59,3	51,8	26,3	65,1	First regeneration cutting Seed input	Cut 50% of the least vigorous trees. 2 to 3 kg of pine kernels per ha	Open gaps to allow regeneration to establish itself Assure natural regeneration in the cleared gaps.
120 T1	17	42	58	46	12	64,8	51,4	13,4	44,7	22,7	15,8	Second regeneration cutting	80% of the remaining trees are harvested	Promote the development of the regeneration so that in turn the young trees will replace the old ones
20 T2	6,5	18	>2000	1350	650	222,8	150,4	72,4	168,3	85,5	30	Seed input	Place seeds under the crown area of removed trees and in gaps where regeneration has not established itself successfully both in terms of quantity and quality	Complete the regeneration process and start the next production cycle
130T1 30 T2	17,5 9,5	45 25	6 625	250	375	178, 6	71,4	107,1	69,1	35,1	63,4	Cleaning, thinning and pruning	Selection and pruning of the best trees after the first and second regeneration cuttings and thinning of defective stems in thick clumps	Prepare the young stand to start pine cone production and to develop over the course of the next rotation.
140T1 40 T2	18 10,7	46 27	370	111	259	47	14,1	32,9	37	18,8	59,4	Cleaning, thinning and pruning	Selection and pruning of the best trees after the first and second regeneration cuttings and thinning of defective stems in thick clumps	Prepare the young stand to start pine cone production and to develop over the course of the next rotation.

Additional Data 2 table 5. Silvicultural schedule for *Pinus pinea* in open countryside (campiña): Medium-low quality

Year	Dg (cm)	N/ha before thinning	N/ha Stems to be extracted	N/ha after thinning	V before thinning (m^3/ha)	Vol. ext. (m^3/ha)	V after thinning (m^3/ha)	Biomass MS extracted (T/ha)	C extracted (T C/ha)	Pine cone production (kg/ha)	Intervention	Criteria to be applied	Objective pursued
0 T1		1500		1500	0	0	0	0	0	0	Site preparation	Mechanized clearance, straight-line or spot tillage depending on the soil type and topography	Eliminate spontaneous vegetation and prepare the soil so that plants are able to establish themselves and thrive, free from competition during the first years
3 T1		1425		1425	0		0	0	0	0	First superficial harrowing	Harrowing between platation lines Manual hoeing	Eliminate competition for water and nutrients. Encourage the development of plants
5 T1		1350		1350	0		0	0	0	0	Second superficial harrowing	It applies in similar conditions to the first harrowing	Eliminate competition for water and nutrients. Encourage the development of plants
8 T1		1300		1300	0		0	0	0	0	First pruning	Enhancement pruning, always leaving three or more whorls	Improve the straightness of the stem and apical dominance of the plants
15 T1	15	1225	613	612	110,1	55,1	55	49,1	24,9	14,9	First thinning	Systematic thinning affecting 50% of the trees	Increase spacing between trees to stimulate Ø growth and pine cone production by reducing competition
15 T1	15	612		612	55	0	55	0	0	14,9	Second pruning	Affects lower whorls between a 1/3 and ½ the total height of the tree	Increase the proportion of clean stem and stimulate the branches in the upper half to the crown, which is where pine cone production is concentrated.
15 T1	15	612		612	55	0	55	0	0	14,9	Brush removal- superficial harrowing	Brush removal and subsequent harrowing or only harrowing if the is not very powerful	Eliminate competition with spontaneous vegetation
25 T1	18	600	240	360	78,2	31,3	46,9	29,9	15,2	20,7	Second thinning	Systematic thinning affecting 40% of the trees	Decrease competition for water, nutrients and light. Promote diameter growth and pine cone production per tree.
35 T1	20	348	104	244	56,5	16,9	39,6	16,7	8,5	23	Third thinning	Systematic thinning affecting 30% of the least vigorous trees and attempting to achieve a balanced distribution.	Decrease competition for water, nutrients and light. Promote diameter growth and pine cone production per tree.
35 T1	20	244		244	39,6	0	39,6	0	0	23	Third pruning	Elimination of lower whorls up to a height of 6.5 to 7 meters.	Achieve the highest possible wood quality from the lower 6 to 7 meters of the stem and stimulate the upper part of the crown to increase quantity and quality of pine cone production
35 T1	20	244		244	39,6	0	39,6	0	0	23	Brush removal- superficial harrowing	Brush removal and subsequent harrowing or only harrowing if the is not very powerful	Eliminate competition with spontaneous vegetation and favoring pine cone production
50 T1	23,5	236		236	53,8	0	53,8	0	0	47,6	Brush removal- superficial harrowing	Brush removal and subsequent harrowing or only harrowing if the is not very powerful	Eliminate competition with spontaneous vegetation and favoring pine cone production
65 T1	27	230		230	70,4	0	70,4	0	0	89,2	Brush removal- superficial harrowing (optional))		
85 T1	31	224		224	91,8	0	91,8	0	0	166,5	Brush removal- superficial harrowing (optional))		
105 T1	35,5	220		220	120,1	0	120,1	0	0	309,7	Brush removal- superficial harrowing (optional))		
120 T1 0 T2	39	205	103	102	136,5	68,6	67,9	83,7	42,5	223,6	First regeneration cutting	Cut 50% of the least vigorous trees.	Open gaps to allow regeneration to establish itself
120 T1 0 T2	39	102		102	67,9	0	67,9	0	0	223,6	Brush removal- superficial harrowing (optional))	Brush removal- superficial harrowing (optional))	Promote the installation and development of regeneration
120 T1 0 T2	39	102		102	67,9	0	67,9	0	0	223,6	Seed input	2 to 3 kg of pine kernels per ha	Assure natural regeneration in the cleared gaps.
125 T1 5 T2	40	96 2000	77	19	67,4	54,1	13,3	66,5	33,8	46,9	Second regeneration cutting	80% of the remaining trees are harvested	Promote the development of the regeneration so that in turn the young trees will replace the old ones
130 T1 10 T2	41,2	19 2000	10	9	14,2	7,5	6,7	9,3	4,7	25,5	Final cutting	Cutting of all mature trees except a reserve of 5 to 10 trees ha^{-1} to promote landscape diversity and birdlife	
130 T1 10 T2	41,2	8 2000		8	6	0	6	0	0	22,7	Seed input	Seed contribution under the canopy of trees felled and areas or stands where regeneration has not been successfully installed in quantity and quality	Complete the regeneration process and start the next production cycle
135 T1 15T2	42,3 15	6 1500			4,74	0	4,74	0	0	0	Cleaning, thinning and pruning	Selection and pruning of the best trees after the first and second regeneration cuttings and thinning of defective stems in thick clumps	Prepare the young stand to start pine cone production and to develop over the course of the next rotation.

Additional Data 2 table 6. Silvicultural schedule for *Pinus pinea* in Sierra Morena: Medium-high quality

Year	H (m)	Dg (cm)	N/ha before thinning	N/ha Stems to be extracted	N/ha after thinning	V before thinning (m^3/ha)	Vol. ext. (m^3/ha)	V after thinning (m^3/ha)	Biomass MS extracted (T/ha)	C extracted (T C/ha)	Pine cone production (kg/ha)	Intervention	Criteria to be applied	Objective pursued
0 T1	-		>1000	0	>1000	0	0	0	0	-	0	Site preparation	Mechanized clearance, straight-line or spot tillage depending on the soil type and topography	Prepare the soil so that plants are able to establish themselves and thrive, free from competition during the first years
10 T1	6	7,5	>1000	0	700	0	0	0	0	-	60,6	Pre-commercial thinning and pruning	Cut defective trees and enhancement pruning of the rest	
20 T1	8	19,8	700	250	450	107,7	38,5	69,2	39,3	19,9	187,9	First thinning. Enhancement prunning until	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor big crowns.
40 T1	13,1	33,5	450	200	250	296,3	131,7	164,6	112,4	57,1	244,8	Second thinning. Enhancement prunning until 4-5 meters height.	Low thinnig and and surface distribution of selected trees	Reduce competition. Encourage fruit production. Favor quercus species development. Disminishing fire risk.
70 T1	17,8	42,4	250	140	110	315,7	176,8	138,9	139,3	70,7	157,8	Third thinning	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor quercus species
120 T1 0 T2	22,7	54,5	110	55	55	278,1	139,1	139,1	100,5	51,1	118, 6	First regeneration cutting		
130 T1 10 T2	23	55	55	35	20	142,6	90,8	51,9	65,4	33,2	43,7	Final cutting	Cutting of all mature trees except a reserve of 20 trees ha^{-1} to promote landscape diversity and birdlife	
	6	7	>1000	0	1000	-	-	-	0	-	77,4	Pre-commercial thinning and clearing if needed	Brush clearing, precommercial thinning and enhancement pruning in the remaining trees	Promote the growth of the best trees. Reduce the risk and impact of fires.
20 T2	8	18	1000	450	550	118,2	53,2	65	56,1	28,5	196,7	First thinning. Enhancement prunning until 3,0 meters	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk.
40 T2	13,5	33,1	550	250	300	350,3	159,2	191,1	136,4	69,3	288,1	Second thinning. Enhancement prunning until 4-5 meters height.	Low thinnig and and surface distribution of selected trees	Reduce competition. Encourage fruit production. Favor quercus species development. Disminishing fire risk.
70 T2	18	42,5	300	175	125	381,4	222,5	158,9	175,1	88,9	180	Third thinning	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor quercus species development. Disminishing fire risk. Leave the stand with the definitive density.
120 T2 0 T3	23	60	125	50	75	412,3	164,9	247,4	115,4	58,6	188,9	First regeneration cutting		
130 T2 10 T3	23,0 6,0	61	75	55	20	17,5	12,8	4,7	132,1	67,1	51,75	Final cutting	Cutting of all mature trees except a reserve of 20 trees ha^{-1} to promote landscape diversity and birdlife	

Additional Data 2 table 7. Silvicultural schedule for *Pinus pinea* in Sierra Morena: Medium-low quality

Year	H (m)	Dg (cm)	N/ha before thinning	N/ha Stems to be extracted	N/ha after thinning	V before thinning (m^3/ha)	Vol. ext. (m^3/ha)	V after thinning (m^3/ha)	Biomass MS extracted (T/ha)	C extracted (T C/ha)	Pine cone production (kg/ha)	Intervention	Criteria to be applied	Objective pursued
0 T1	-		>1000	0	>1000	0	0	0	0	-	0	Site preparation	Mechanized clearance, straight-line or spot tillage depending on the soil type and topography	Prepare the soil so that plants are able to establish themselves and thrive, free from competition during the first years
20 T1	5.5	16	>1000	450	550	93.76	42.19	51.57	42.16	21.42	167.37	First thinning. Enhancement prunning until ½ height meters	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk.
40 T1	9.5	25.7	550	200	350	218.70	79.53	139.17	59.11	30.03	211.50	Second thinning. Enhancement prunning until 3-4 meters height.	Low thinning. Prunning in the remaing trees until 3-4 meters height.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk
70 T1	12.6	30.2	350	175	175	227.61	113.81	113.81	76.47	38.85	133.57	Third thinning	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor quercus species development. Disminishing fire risk. Leave the stand with the definitive density.
120 T1	15.2	39.6	175	87	88	259.99	129.25	130.74	73.33	37.25	99.43	First regeneration cutting of 50% of the trees	Open holes to favor the regeneration, taking care of the surface distribution.	Encourage the installation and development of regeneration. Releasing quercus and shrubs of interest.
130 T1	15.4	40	88	68	20	134.81	104.17	30.64	58.73	29.83	22.93	Final cutting	Cutting of all mature trees except a reserve of 20 trees ha^{-1} to promote landscape diversity and birdlife	
140 T1	15.5	42	20	0	20	35.55	-	35.55	0	-	24.61	Leave the old trees that have survived.		
20 T2	5.5	16	>2000	1350	650	187.53	126.58	60.95	126.48	64.25	197.81	First thinning. Enhancement prunning until ½ height meters	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk.
40 T2	9.5	25.7	650	275	375	258.47	109.35	149.12	81.27	41.29	226.61	Second thinning. Enhancement prunning until 3-4 meters height.	Low thinning. Prunning in the remaing trees until 3-4 meters height.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk
70 T2	12.6	30.2	375	175	200	243.87	113.81	130.06	76.47	38.85	152.65	Third thinning	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor quercus species development. Disminishing fire risk. Leave the stand with the definitive density.
120 T2	15.2	39.6	200	100	100	297.13	148.57	148.57	84.29	42.82	112.99	First regeneration cutting of 50% of the trees	Open holes to favor the regeneration, taking care of the surface distribution.	Encourage the installation and development of regeneration. Releasing quercus and shrubs of interest.
130 T2	15.4	40	100	80	20	153.19	122.55	30.64	69.09	35.10	22.93	Final cutting	Cutting of all mature trees except a reserve of 20 trees ha^{-1} to promote landscape diversity and birdlife	
140 T2	15.5	42	20	0	20	24.61	0	24.61	0	-	24.61	Leave the old trees that have survived.		
20 T3	5.5	16	>2000	1350	650	-	-	-	126.48	64.25	197.81	First thinning. Enhancement prunning until ½ height meters	Low thinnig and and surface distribution of selected trees.	Reduce competition. Encourage fruit production. Favor big crowns. Disminishing fire risk.

Additional Data 2 table 8. Silvicultural schedule for *Quercus suber*: Massif of El Aljibe. Evolution of the structure and density of even-aged stand from assisted natural regeneration (first cycle)

Year	D over cork (cm)	H (m)	DH (m)	N/ha before thinning	N/ha Stems to be extracted	N/ha after thinning	Prunning N/ha	Production trees N/ha	First debarking N/ha	Debarked trees N/ha	Low quality cork kg/ha	High quality cork kg/ha	Tot cork kg/ha	Intervention	Criteria to be applied	Objective pursued
0 T1				1500	0	1500								Assisted regeneration Hoeing	Achieve a minimum of 1.500 trees ha-1 Prepare the implantation	Achieve the regeneration of the stand Reduce or eliminate the competition
5 T1		0,53		1350	0	1350								Open to grazing	After years of boundedness it is opened to take advantage of the open range	Allow the utilization by pigs
14 T1	4,18	2,13		1200	0	1200								Open to goats	Above 1,5-2,0 m height	Allow the utilization by goats
18 T1	7,9	2,9		1.043	313	730	730							Thinning First formation prunning	Reduce stand density in 30% Until ½ of the total height	Regulación de la densidad y 1ª selección de árboles más prometedores. Formation of straight and clean stems
21 T1	10,45	3,52		715	0	715								Open to cattle	Above 10 cm of diameter	Allow the utilization by cows
27 T1	15,1	4,7		698	198	500	500							Thinning Second formation prunning Scrub clearing	Reduce stand density until 450-550 trees ha^{-1}. Height ≤ 2 m. Manual clearing with brushcutter	Density control. Promote selected trees. Formation of straight and clean stems. Reduce competition. Diminish fire risk.
36 T1	21,5	6,4	1,35	497	222	275	275	249	249		2.317		2.317	Des-bornizamiento Poda (los árboles que lo necesiten) Thinning Clearing	Trees with CSB ≥ 60 cm. Prunning fuste height from 2,5 to 3,0 m. Cutting until density 250-300 trees ha^{-1} Manual clearing with brushcutter	Commence of the cork production Formation of straight and clean stems Density control. Promote selected trees. Reduce competition. Diminish fire risk.
45 T1	27	7,9	1,7	273	0	273	273	273	25	248	898	2.894	3.791	Prunning of those trees in need 2º debarking Debarking for first time of the remaining trees Clearing	Prunning fuste height from 2,5 to 3,0 m. Manual clearing with brushcutter	Formation of straight and clean stems Commence of the cork production Reduce competition. Diminish fire risk.
54 T1	31	9,2	1,95	270	85	185		270		270	413	4.563	4.976	3º debarking Thinning Clearing	 Cutting until density 175-200 trees ha^{-1} Manual clearing with brushcutter	 Density control. Promote selected trees. Reduce competition. Diminish fire risk.
63 T1	34,9	10,3	2,2	183	0	183		183		183	280	3.981	4.260	4º debarking Clearing	 Manual clearing with brushcutter	 Reduce competition. Diminish fire risk.
72 T1	38,5	11,3	2,4	181	41	140		181		181	221	4.897	5.118	Thinning in years 72, 90 and 117 in order to para regulate stand density		
81 T1	42	12,1	2,6	138	0	138		138		138	169	4.457	4.626			
90 T1	45,3	12,8	2,8	135	40	95		135		135	165	5.092	5.257			
99 T1	48,5	13,4	3	92	0	92		92		92		3.995	3.995			
108 T1	51,6	13,9	3	89	0	89		89		89		4.425	4.425	Scrub clearing in winter-auttum when debarking		
117 T1	54,7	14,3	3	86	11	75		86		86		4.496	4.496			
126 T1	57,6	14,6	3	71	0	71		71		71		3.926	3.926			
135 T1	60,4	14,9	3	68	0	68		68		68		3.946	3.946			
144	63,2	15,1	3	63	31	32		63		63		3.824	3.824	Start of the regenaration leaving 50% of the mass		
0 T2																
153 T1	65,9	15,3	3	26	0	26		26		26		1.645	1.645	Debarking		
9 T2		1,2														
162 T1	68,5	15,5	3	21	0	21		21		21		1.382	1.382	Debarking		
18 T2	7,9	2,9														
171 T1	71,1	15,6	3	17	0	17		17		17		1.161	1.161	Debarking		
27 T2	15,1	4,7														
180 T1	73,6	15,8	3	12	12	0		12		12		848	848	Debarking and cutting of the ramaining trees		
36 T2	21,5	6,4														

Additional Data 2 table 9. Parameters for the estimation of the debarking height in different zones of Andalusia

Zone	A	B
Almería	0,237	0,075
Cádiz	-1,222	0,108
Córdoba	0,279	0,075
Granada	0,237	0,075
Huelva	0,754	0,062
Jaén	0,279	0,075
Málaga	-1,222	0,108
Seville	0,279	0,075

Additional Data S3. Biodiversity datasets

This additional data contains two datasets related with biodiversity. (Additional Data 3 table 1) List of species selected as indicators of the endangered biodiversity and concern. (Additional Data 3 table 2) Sources of data used to map the distribution of indicator species of conservation concern.

Additional Data 3 table 1. List of species selected as indicators of the endangered biodiveristy maintained by Andalusian forests in 2010. Groups: P, plants; B, birds; MM, mammals; AR, arthropods; R, reptiles; AM, amphibians; ML, mollusks; Annex in Directives: Bird Directive for birds and Habitats Directive otherwise; and regional threat status: EW, Extinct in the Wild; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; DD, Data Deficient; and LC, Least Concern.

Additional Data 3 table 2. Sources of data used to map the distribution of indicator species of conservation concern, as well as of the information on habitat requirements and altitudinal ranges used to downscale maps available at the 10 km x 10 km UTM scale to finer scales63. Maps based on source (1) were not needed to downscale since they were constructed at the 1 km x 1 km UTM scale. Habitat types referred to categories of the regional vegetation map62. Sources: 1: Regional authorities; 2: Barea-Azcón, J. M., et al. (coords.). Libro Rojo de los Invertebrados de Andalucía. 4 Tomos. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla (2008); 3: Bosch, J., et al. (eds). Seguimiento de Alytes dickhilleni. Informe final. Monografías SARE, Asociación Herpetológica Española, Ministerio de Agricultura, Alimentación y Medio Ambiente. Madrid (2012); 4: Carretero, M.A., et al. Seguimiento de Algyroides marchi. Informe final. Monografías SARE. Asociación Herpetológica Española – Ministerio de Medio Ambiente y Medio Rural y Marino. Madrid (2010); 5: García-Barros, E., et al. Atlas de las mariposas diurnas de la Península Ibérica e Islas Baleares (Lepidoptera: Papilionoidea & Hesperioidea). Monografías S.E.A., 11. Zaragoza (2004); 6: Ibáñez, S. & Gil, F. First records of the endemic Polyommatus golgus (Hübner, 1913) and Agriades zullichi (Hemming, 1933) in Almería province (E. Sierra

Nevada, S. Spain). Atalanta 40: 191-192 (2009); 7: Martí, R. & del Moral, J.C. (eds.). Atlas de las Aves Reproductoras de España. Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología, Madrid (2003); 8: Palomo, L.J., et al. (eds.). Atlas y Libro Rojo de los mamíferos terrestres de España. Ministerio de Medio Ambiente, Madrid (2008); 9: Pleguezuelos J.M., et al. (eds.). Atlas y libro rojo de los anfibios y reptiles de España. Ministerio de Medioambiente. Madrid (2004); 10: Prieta, J. & del Moral, J.C. La grulla común invernante en España. Población en 2007 y método de censo. SEO/BirdLife, Madrid (2008); 11: Proyecto Anthos: www.anthos.es; 12: Palomino, D., et al. Atlas de las aves en invierno en España 2007-2010. Ministerio de Agricultura, Alimentación y Medio Ambiente-SEO/BirdLife, Madrid (2012); 13: Verdú, J.R. & Galante, E. (eds.). Libro Rojo de los invertebrados de España. Ministerio de Medio Ambiente, Madrid (2008).

Additional Data 3 table 1 (part 1)

Group	Species	Annex in Directives	Threat status
P	*Abies pinsapo* Boiss.		EN
B	*Aegypius monachus*	I	EN
AR	*Agriades zullichi*		EN
AR	*Agrodiaetus violetae*		CR
B	*Alectoris rufa*	II	LC
R	*Algyroides marchi*	IV	VU
P	*Allium rouyi* Gaut.		EN
AR	*Alphasida (Betasida) espanoli*		EN
AR	*Alphasida (Betasida) ferreri*		EN
AM	*Alytes dickhilleni*	II - IV	NT
B	*Anthus campestris*	I	DD
P	*Antirrhinum charidemi* Lange.	II - IV	EN
AR	*Apteromantis aptera*	II - IV	VU
B	*Apus caffer*	I	VU
B	*Aquila adalberti*	I	CR
B	*Aquila chrysaetos*	I	VU
P	*Aquilegia pyrenaica* subsp. *cazorlensis* (Heywood) Galiano & Rivas Mart.	II - IV	EN
P	*Arenaria nevadensis* Boiss. & Reut.	IV	EN
P	*Armeria velutina* Weilw. ex Boiss. & Reut.	II - IV	VU
P	*Artemisia granatensis* Boiss.	II - IV	EN
B	*Asio flammeus*	I	NT
P	*Astragalus algarbiensis* Coss. ex Bunge	II - IV	NT
P	*Astragalus tremolsianus* Pau.	II - IV	VU
P	*Atropa baetica* Willk.	II - IV	EN
AR	*Baetica ustulata*	II - IV	VU
MM	*Barbastella barbastellus*	II - IV	VU
P	*Biscutella sempervirens* subsp. *vicentina* (Samp.) Malagarriga	II - IV	NT
AR	*Bombus (Megabombus) reinigiellus*		EN
B	*Bubo bubo*	I	NT
B	*Bucanetes githagineus*	I	NT
AM	*Bufo calamita*	II - IV	LC
AR	*Buprestis splendens*	II - IV	NT
B	*Burhinus oedicnemus*	I	VU
B	*Calandrella brachydactyla*	I	NT
MM	*Canis lupus*	II - IV	CR
MM	*Capra pyrenaica*	V	VU
MM	*Capreolus capreolus*	V	VU
B	*Caprimulgus europaeus*	I	VU
P	*Carduus myriacanthus* Salzm. ex DC	II - IV	VU
P	*Centaurea citricolor* Font Quer	II - IV	EN
P	*Centaurea gadorensis* Blanca	II - IV	VU
P	*Centaurea pulvinata* (Blanca) Blanca	II - IV	VU
AR	*Cerambyx cerdo*	II - IV	LC
R	*Chalcides bedriagai*	IV	NT
B	*Charadrius morinellus*	I	LC
B	*Chersophilus duponti*	I	EN
ML	*Chondrina maginensis*		EN
B	*Ciconia ciconia*	I	LC
B	*Ciconia nigra*	I	EN
B	*Circaetus gallicus*	I	NT
B	*Circus aeruginosus*	I	EN
B	*Circus cyaneus*	I	NT
B	*Circus pygargus*	I	VU
R	*Coluber hippocrepis*	IV	NT
B	*Columba livia*	II	LC
B	*Columba oenas*	II	EN
B	*Columba palumbus*	II	LC
B	*Coracias garrulus*	I	NT
R	*Coronella austriaca*	IV	EN
P	*Coronopus navasii* Pau	II - IV	EN
B	*Corvus corone*	II	LC
B	*Corvus monedula*	II	LC
B	*Coturnix coturnix*	II	NT
P	*Crepis granatensis* (Willk.) Blanca & Cueto	II - IV	VU
B	*Crex crex*	I	DD
P	*Culcita macrocarpa* C. Presl.	II - IV	EN
P	*Cytisus malacitanus* subsp. *moleroi* (Fern. Casas.) A. Lora		EN
AM	*Discoglossus galganoi*	II - IV	NT
AM	*Discoglossus jeanneae*	II - IV	NT
B	*Egretta garzetta*	I	LC
B	*Elanus caeruleus*	I	VU
B	*Emberiza hortulana*	I	NT
MM	*Eptesicus serotinus*	IV	NT
P	*Erica andevalensis* Cabezudo & J. Rivera		EN
P	*Erigeron frigidus* DC	II - IV	VU
AR	*Eriogaster catax*	II - IV	NT
P	*Erodium astragaloides* Boiss. & Reut.	II - IV	EN

Additional Data 3 table 1 (part 2)

Group	Species	Annex in Directives	Threat status
P	*Erodium cazorlanum* Heywood		EN
P	*Erodium rupicola* Boiss.	II - IV	EN
P	*Euphorbia nevadensis* Boiss. & Reut. subsp. *nevadensis*	IV	VU
AR	*Euphydryas aurinia*	II	LC
P	*Euxomodendron bourgaeanum* Coss.	II - IV	EN
B	*Falco columbarius*	I	DD
B	*Falco naumanni*	I	NT
B	*Falco peregrinus*	I	VU
MM	*Felis silvestris*	IV	NT
P	*Festuca elegans* Boiss. subsp. *elegans*	II - IV	NT
B	*Galerida theklae*	I	NT
P	*Galium viridiflorum* Boiss. & Reut.	II - IV	VU
B	*Gallinago gallinago*	II	NT
P	*Gaudinia hispanica* Stace & Tutin	II - IV	VU
MM	*Genetta genetta*	IV	NT
P	*Geranium cazorlense* Heywood		EN
B	*Glareola pratincola*	I	EN
AR	*Goniomma compressisquama*		EN
B	*Grus grus*	I	NT
B	*Gypaetus barbatus*	I	EW
B	*Gyps fulvus*	I	LC
P	*Helianthemum alypoides* Losa & Rivas Goday	II - IV	VU
P	*Helianthemum caput-felis* Boiss.	II - IV	NT
ML	*Helicella stiparum*		EN
MM	*Herpestes ichneumon*	V	LC
B	*Hieraaetus fasciatus*	I	VU
B	*Hieraaetus pennatus*	I	LC
P	*Hieracium texedense* Pau		EN
AR	*Hybalus ameliae*		EN
P	*Hymenostemma pseudoanthemis* (Kunze) Willk.	II - IV	VU
MM	*Hypsugo savii*	IV	NT
ML	*Iberus gualtieranus*		EN
P	*Jurinea fontqueri* Cuatrec.	II - IV	EN
R	*Lacerta schreiberi*	II - IV	CR
P	*Laserpitium longiradium* Boiss.	II - IV	EN
P	*Leontodon boryi* Boiss ex DC	II - IV	VU
P	*Leontodon microcephalus* (Boiss ex DC.) Boiss.	II - IV	VU
P	*Limonium estevei* Fern. Casas		EN
P	*Limonium malacitanum* Díez Garretas		EN
P	*Linaria tursica* Valdés & Cabezudo	II - IV	EN
P	*Lithodora nitida* (Ern) R. Fern.	II - IV	EN
AR	*Lucanus cervus*	II	NT
B	*Lullula arborea*	I	LC
B	*Luscinia svecica*	I	NT
MM	*Lynx pardinus*	II - IV	EN
AR	*Macrothele calpeiana*	II	VU
AR	*Maculinea nausithous*	II - IV	NT
B	*Melanocorypha calandra*	I	NT
P	*Micropyropsis tuberosa* Romero Zarco & Cabezudo	II - IV	EN
MM	*Microtus cabrerae*	II - IV	CR
B	*Milvus migrans*	I	NT
B	*Milvus milvus*	I	CR
MM	*Miniopterus schreibersii*	II - IV	VU
P	*Moehringia fontqueri* Pau	IV	VU
MM	*Mustela putorius*	IV	NT
MM	*Myotis bechsteinii*	II - IV	EN
MM	*Myotis blythii*	II - IV	VU
MM	*Myotis capaccinii*	II - IV	CR
MM	*Myotis daubentonii*	IV	DD
MM	*Myotis emarginata*	II - IV	VU
MM	*Myotis escalerai*	II - IV	VU
MM	*Myotis myotis*	IV	VU
P	*Narcissus bugei* (Fern. Casas) Fern. Casas		EN
P	*Narcissus fernandesii* G. Pedro	II - IV	VU
P	*Narcissus humilis* (Cav.) Traub	II - IV	LC
P	*Narcissus longispathus* Pugsley	IV	EN
P	*Narcissus nevadensis* Pugsley	II - IV	EN
P	*Narcissus tortifolius* Fern. Casas		EN
P	*Narcissus triandrus* L. subsp. *pallidulus* (Graells) Rivas Goday	IV	LC
P	*Narcissus viridiflorus* Schousboe	II - IV	VU

Additional Data 3 table 1 (part 3)

Group	Species	Annex in Directives	Threat status
B	*Neophron percnopterus*	I	CR
MM	*Nyctalus lasiopterus*	IV	VU
MM	*Nyctalus leisleri*	IV	VU
MM	*Nyctalus noctula*	IV	EW
P	*Odontites granatensis* Boiss.	II - IV	EN
B	*Oenanthe leucura*	I	NT
P	*Ornithogalum reverchonii* Lange	IV	VU
P	*Orobanche densiflora* Salzmann ex Reuter in DC.	II - IV	LC
B	*Otis tarda*	I	CR
B	*Pandion haliaetus*	I	VU
P	*Papaver rupifragum* Boiss. & Reut.		EN
AR	*Parachtes deminutus*		EN
AM	*Pelobates cultripes*	II - IV	NT
B	*Phasianus colchicus*	II	LC
B	*Pica pica*	II	LC
P	*Picris willlkommi* (Schultz Bip.) Nyman	IV	VU
P	*Pinguicula nevadensis* (H. Lindb.) Casper	II - IV	VU
MM	*Pipistrellus kuhlii*	IV	NT
MM	*Pipistrellus pygmaeus*	IV	DD
P	*Plantago algarbiensis* Sampaio	II - IV	NT
AR	*Plebicula golgus*	II - IV	EN
MM	*Plecotus austriacus*	IV	NT
B	*Pluvialis apricaria*	I	NT
AR	*Proserpinus proserpina*	II	LC
AR	*Psiloderes zariquieyi*		EN
B	*Pterocles alchata*	I	VU
B	*Pterocles orientalis*	I	EN
B	*Pyrrhocorax pyrrhocorax*	I	DD
P	*Quercus alpestris* Boiss.		EN
MM	*Rhinolophus euryale*	II - IV	VU
MM	*Rhinolophus ferrumequinum*	II - IV	VU
MM	*Rhinolophus hipposideros*	II - IV	VU
MM	*Rhinolophus mehelyi*	II - IV	EN
P	*Rosmarinus tomentosus* Huber-Morat & Maire	IV	EN
AR	*Rossomyrmex minuchae*		EN
P	*Rothmaeleria granatensis* (Boiss, ex DC.) Font Quer		EN
AR	*Saga pedo*	II	NT
P	*Salix hastata* L. subsp. *sierrae-nevadae* Rech. fil.		EN
P	*Salix salviifolia* Brot. subsp. *australis* Franco	II - IV	NT
P	*Santolina elegans* Boiss.	IV	VU
P	*Sarcocapnos baetica* (Boiss. & Reut.) Nyman subsp. *integrifolia* (Boiss.) Nyman		EN
P	*Scilla odorata* Link	IV	NT
B	*Scolopax rusticola*	II	LC
P	*Senecio elodes* Boiss.	II - IV	EN
P	*Senecio nevadensis* Boiss. & Reut.	II - IV	VU
P	*Seseli intricatum* Boiss.	II - IV	EN
P	*Silene mariana* Pau	II - IV	VU
P	*Silene stockenii* A.O. Chater		EN
P	*Sisymbrium cavanillesianum* Valdés-Bermejo & Castroviejo	II - IV	NT
P	*Solenanthus reverchonii* Degen		EN
P	*Spiranthes aestivalis* (Poiret) L.C.M. Richard	IV	NT
B	*Streptopelia turtur*	II	VU
B	*Sturnus vulgaris*	II	LC
B	*Sylvia atricapilla*	II	LC
B	*Sylvia borin*	II	EN
B	*Sylvia cantillans*	II	LC
B	*Sylvia communis*	II	NT
B	*Sylvia conspicillata*	II	DD
B	*Sylvia hortensis*	II	DD
B	*Sylvia melanocephala*	II	LC
B	*Sylvia undata*	I	NT
MM	*Tadarida teniotis*	IV	NT
R	*Testudo graeca*	II - IV	EN
B	*Tetrax tetrax*	I	VU
P	*Teucrium charidemi* Sandwith	IV	VU
P	*Teucrium turredanum* Losa & Rivas Goday	II - IV	VU
P	*Thymelaea broteriana* Cout.	IV	NT
P	*Thymus carnosus* Boiss.	II - IV	VU
B	*Turdus iliacus*	II	LC
B	*Turdus philomelos*	II	LC
B	*Turdus pilaris*	II	LC
B	*Turdus torquatus*	II	LC
B	*Turdus viscivorus*	II	LC
B	*Turnix sylvatica*	I	CR
B	*Vanellus vanellus*	II	NT
P	*Veronica micrantha Hoffmanss. & Link*	II - IV	NT
P	*Viola cazorlensis* Gand.	IV	EN

Additional Data 3 table 2 (part 1)

Species	Data source	Habitat types	Elevation range
Abies pinsapo Boiss.	1	-	-
Aegypius monachus	1	-	-
Agriades zullichi	6	Shurbland-grassland	2000-3300 m a.s.l.
Agrodiaetus violetae	2	Shurbland-grassland	800-1800 m a.s.l.
Alectoris rufa	7, 12	Shurbland-grassland	-
Algyroides marchi	4	Riparian forest/Srhubland-grassland	-
Allium rouyi Gaut.	1	-	-
Alphasida (Betasida) espanoli	2	*Quercus faginea* open woodland	1200-2000 m a.s.l.
Alphasida (Betasida) ferreri	2	*Abies pinsapo* forest	-
Alytes dickhilleni	3	Aquatic/Riparian forest	-
Anthus campestris	7	Shurbland-grassland	-
Antirrhinum charidemi Lange.	1	-	-
Apteromantis aptera	13	Shurbland-grassland	-
Apus caffer	7	Open woodland	-
Aquila adalberti	1	-	-
Aquila chrysaetos	1	-	-
Aquilegia pyrenaica subsp. *cazorlensis* (Heywood) Galiano & Rivas Mart.	1	-	-
Arenaria nevadensis Boiss. & Reut.	1	-	-
Armeria velutina Weilw. ex Boiss. & Reut.	1	-	-
Artemisia granatensis Boiss.	1	-	-
Asio flammeus	7, 12	Shurbland-grassland	-
Astragalus algarbiensis Coss. ex Bunge	11	Shurbland-grassland	-
Astragalus tremolsianus Pau.	1	-	-
Atropa baetica Willk.	1	-	-
Baetica ustulata	1	-	-
Barbastella barbastellus	8	Closed forests, except *Eucalyptus* spp. plantations	-
Biscutella sempervirens subsp. *vicentina* (Samp.) Malagarriga	11	Cliffs	-
Bombus (Megabombus) reinigiellus	2	Shurbland-grassland	1600-3500 m a.s.l.
Bubo bubo	7, 12	Open woodland/Shrubland-grassland/Cliffs	-
Bucanetes githagineus	7, 12	Shurbland-grassland	-
Bufo calamita	9	Agricultural/Open woodland/Shrubland-grassland	-
Buprestis splendens	2	*Pinus* spp. forests	-
Burhinus oedicnemus	7, 12	Open woodland/Shrubland-grassland	-
Calandrella brachydactyla	7, 12	Shurbland-grassland	-
Canis lupus	1	-	-
Capra pyrenaica	8	Shrubland-grassland/Cliffs	-
Capreolus capreolus	8	All habitats, except aquatic, unproductive, wetlands and agricultural	-
Caprimulgus europaeus	7	Open woodland	-
Carduus myriacanthus Salzm. ex DC	1	-	-
Centaurea citricolor Font Quer	1	-	-
Centaurea gadorensis Blanca	1	-	-
Centaurea pulvinata (Blanca) Blanca	1	-	-
Cerambyx cerdo	13	*Quercus* spp. woodland and forests	-
Chalcides bedriagai	9	Open woodland/Shrubland-grassland	-
Charadrius morinellus	7, 12	Shurbland-grassland	-
Chersophilus duponti	1	-	-
Chondrina maginensis	2	Shurbland-grassland	200-1000 m a.s.l.
Ciconia ciconia	7, 12	Shurbland-grassland	-
Ciconia nigra	1	-	-
Circaetus gallicus	7	Open woodland/Shrubland-grassland	-
Circus aeruginosus	1	-	-
Circus cyaneus	7, 12	Shurbland-grassland	-
Circus pygargus	1	-	-
Coluber hippocrepis	9	Evergreen *Quercus* spp. open woodland/Riparian forest/Shrubland-grassland	-
Columba livia	7, 12	Shrubland-grassland/Cliffs	-
Columba oenas	7, 12	Riparian forest/Open *Quercus* spp. woodland	-
Columba palumbus	7, 12	Open woodland/Closed forest	-
Coracias garrulus	7	Open woodland/Shrubland-grassland	-
Coronella austriaca	9	Open woodland/Shrubland-grassland	-
Coronopus navasii Pau	1	-	-
Corvus corone	7, 12	Open woodland/Riparian forest	-
Corvus monedula	7, 12	Open woodland/Riparian forest	-
Coturnix coturnix	7	Shurbland-grassland	-
Crepis granatensis (Willk.) Blanca & Cueto	1	-	-
Crex crex	7, 12	Shurbland-grassland	-
Culcita macrocarpa C. Presl.	1	-	-
Cytisus malacitanus subsp. *moleroi* (Fern. Casas.) A. Lora	1	-	-
Discoglossus galganoi	9	Open woodland/Riparian forest	
Discoglossus jeanneae	9	Open woodland/Riparian forest	
Egretta garzetta	1	-	-
Elanus caeruleus	7, 12	Open woodland	-
Emberiza hortulana	7	Open woodland/Shrubland-grassland	-
Eptesicus serotinus	8	Open woodland/Riparian forest	-
Erica andevalensis Cabezudo & J. Rivera	1	-	-
Erigeron frigidus DC	1	-	-
Eriogaster catax	5	Deciduous *Quercus* spp. forests and woodland	-
Erodium astragaloides Boiss. & Reut.	1	-	-
Erodium cazorlanum Heywood	1	-	-
Erodium rupicola Boiss.	1	-	-
Euphorbia nevadensis Boiss. & Reut. subsp. *nevadensis*	1	-	-
Euphydryas aurinia	5	Open woodland/Shrubland-grassland	-
Euxomodendron bourgaeanum Coss.	1	-	-
Falco columbarius	12	Shurbland-grassland	-
Falco naumanni	1	-	-
Falco peregrinus	7, 12	Cliffs	-
Felis silvestris	8	All habitats, except aquatic, cliffs, unproductive, wetlands, agricultural and closed forests	-
Festuca elegans Boiss. subsp. *elegans*	11	-	-
Galerida theklae	7, 12	Open woodland/Shrubland-grassland	-
Galium viridiflorum Boiss. & Reut.	1	-	-
Gallinago gallinago	7, 12	Shurbland-grassland	-
Gaudinia hispanica Stace & Tutin	1	-	-

Additional Data 3 table 2 (part 2)

Species	Data source	Habitat types	Elevation range
Genetta genetta	8	All habitats, except aquatic, cliffs, unproductive, wetlands and agricultural	-
Geranium cazorlense Heywood	1	-	-
Glareola pratincola	7	Shurbland-grassland	-
Goniomma compressisquama	2	Shurbland-grassland	-
Grus grus	10	Open woodland/Shrubland-grassland	-
Gypaetus barbatus	1	-	-
Gyps fulvus	1	-	-
Helianthemum alypoides Losa & Rivas Goday	1	-	-
Helianthemum caput-felis Boiss.	11	Shurbland-grassland	-
Helicella stiparum	2	Shurbland-grassland	-
Herpestes ichneumon	8	Open woodland/Riparian forest/Shrubland-grassland	-
Hieraaetus fasciatus	1	-	-
Hieraaetus pennatus	7	Open woodland/Closed forest/Riparian forest	-
Hieracium texedense Pau	1	-	-
Hybalus ameliae	2	*Olea europaea* forest/Shrubland-grassland	-
Hymenostemma pseudoanthemis (Kunze) Willk.	1	-	-
Hypsugo savii	8	All habitats, except unproductive, wetlands and agricultural	-
Iberus gualtieranus	2	Shurbland-grassland	-
Jurinea fontqueri Cuatrec.	1	-	-
Lacerta schreiberi	2	Riparian forest	-
Laserpitium longiradium Boiss.	1	-	-
Leontodon boryi Boiss ex DC	1	-	-
Leontodon microcephalus (Boiss ex DC.) Boiss.	1	-	-
Limonium estevei Fern. Casas	1	-	-
Limonium malacitanum Díez Garretas	1	-	-
Linaria tursica Valdés & Cabezudo	1	-	-
Lithodora nitida (Ern) R. Fern.	1	-	-
Lucanus cervus	2	Deciduous forests	-
Lullula arborea	7, 12	Open woodland	-
Luscinia svecica	7, 12	Open woodland/Shrubland-grassland	-
Lynx pardinus	1	-	-
Macrothele calpeiana	13	Open woodland and olive groves	-
Maculinea nausithous	5	Shurbland-grassland	-
Melanocorypha calandra	7, 12	Shurbland-grassland	-
Micropyropsis tuberosa Romero Zarco & Cabezudo	1	-	-
Microtus cabrerae	1	-	-
Milvus migrans	7	Open woodland/Riparian forest	-
Milvus milvus	1	-	-
Miniopterus schreibersii	1	-	-
Moehringia fontqueri Pau	1	-	-
Mustela putorius	8	All habitats, except aquatic, cliffs, unproductive, wetlands and agricultural	-
Myotis bechsteinii	1	-	-
Myotis blythii	1	-	-
Myotis capaccinii	1	-	-
Myotis daubentonii	8	Riparian forest	-
Myotis emarginata	1	-	-
Myotis escalerai	8	Closed forests/Riparian forests	-
Myotis myotis	1	-	-
Narcissus bugei (Fern. Casas) Fern. Casas	1	-	-
Narcissus fernandesii G. Pedro	1	-	-
Narcissus humilis (Cav.) Traub	11	-	-
Narcissus longispathus Pugsley	1	-	-
Narcissus nevadensis Pugsley	1	-	-
Narcissus tortifolius Fern. Casas	1	-	-
Narcissus triandrus L. subsp. *pallidulus* (Graells) Rivas Goday	11	-	-
Narcissus viridiflorus Schousboe	1	-	-
Neophron percnopterus	1	-	-
Nyctalus lasiopterus	8	Closed forest	-
Nyctalus leisleri	8	Closed forest	-
Nyctalus noctula	8	Closed forest	-
Odontites granatensis Boiss.	1	-	-
Oenanthe leucura	7, 12	Shurbland-grassland	-
Ornithogalum reverchonii Lange	1	-	-
Orobanche densiflora Salzmann ex Reuter in DC.	11	-	-
Otis tarda	1	-	-
Pandion haliaetus	1	-	-
Papaver rupifragum Boiss. & Reut.	1	-	-
Parachtes deminutus	2	Shurbland-grassland	-
Pelobates cultripes	9	Open woodland/Shrubland-grassland	-
Phasianus colchicus	7, 12	Shurbland-grassland	-
Pica pica	7, 12	Open woodland/Riparian forest/Shrubland-grassland	-
Picris willlkommi (Schultz Bip.) Nyman	1	-	-
Pinguicula nevadensis (H. Lindb.) Casper	1	-	-
Pipistrellus kuhlii	8	Open woodland/Riparian forest	-
Pipistrellus pygmaeus	8	Closed forests/Riparian forests	-
Plantago algarbiensis Sampaio	1	-	-
Plebicula golgus	1	-	-
Plecotus austriacus	8	Closed forests/Riparian forests	-
Pluvialis apricaria	7	Shurbland-grassland	-
Proserpinus proserpina	5	Riparian forest	-
Psiloderes zariquieyi	2	Shurbland-grassland	-
Pterocles alchata	7, 12	Shurbland-grassland	-
Pterocles orientalis	7, 12	Shurbland-grassland	-
Pyrrhocorax pyrrhocorax	7, 12	Shrubland-grassland/Cliffs	-
Quercus alpestris Boiss.	1	-	-
Rhinolophus euryale	1	-	-
Rhinolophus ferrumequinum	1	-	-
Rhinolophus hipposideros	1	-	-
Rhinolophus mehelyi	1	-	-
Rosmarinus tomentosus Huber-Morat & Maire	1	-	-
Rossomyrmex minuchae	2	Shurbland-grassland	1800-2100 m a.s.l.

Additional Data 3 table 2 (part 3)

Species	Data source	Habitat types	Elevation range
Rothmaeleria granatensis (Boiss, ex DC.) Font Quer	1	-	-
Saga pedo	2	Shurbland-grassland	-
Salix hastata L. subsp. *sierrae-nevadae* Rech. fil.	1	-	-
Salix salviifolia Brot. subsp. *australis* Franco	11	-	-
Santolina elegans Boiss.	1	-	-
Sarcocapnos baetica (Boiss. & Reut.) Nyman subsp. *integrifolia* (Boiss.) Nyman	1	-	-
Scilla odorata Link	11	-	-
Scolopax rusticola	12	Open woodland/Shrubland-grassland	-
Senecio elodes Boiss.	1	-	-
Senecio nevadensis Boiss. & Reut.	1	-	-
Seseli intricatum Boiss.	1	-	-
Silene mariana Pau	1	-	-
Silene stockenii A.O. Chater	1	-	-
Sisymbrium cavanillesianum Valdés-Bermejo & Castroviejo	11	Agricultural	-
Solenanthus reverchonii Degen	1	-	-
Spiranthes aestivalis (Poiret) L.C.M. Richard	11	-	-
Streptopelia turtur	7	Open woodland/Riparian forest	-
Sturnus vulgaris	7, 12	Shurbland-grassland/Open woodland/Riparian forest	-
Sylvia atricapilla	7, 12	Riparian forests/Deciduous forests (spring)/All forests and shurblands (winter)	-
Sylvia borin	7	Riparian forest/Deciduous *Quercus* spp. closed forests	-
Sylvia cantillans	7	Evergreen *Quercus* spp. open woodland and closed forest/Shrubland-grassland	-
Sylvia communis	7	Open woodland/Shrubland-grassland	-
Sylvia conspicillata	7	Shurbland-grassland	-
Sylvia hortensis	7	Evergreen *Quercus* spp. open woodland	-
Sylvia melanocephala	7, 12	Open woodland/Closed forest/Shrubland-grassland	-
Sylvia undata	7, 12	Shurbland-grassland	-
Tadarida teniotis	8	Cliffs	-
Testudo graeca	1	-	-
Tetrax tetrax	7, 12	Shurbland-grassland	-
Teucrium charidemi Sandwith	1	-	-
Teucrium turredanum Losa & Rivas Goday	1	-	-
Thymelaea broteriana Cout.	11	Shurbland-grassland	-
Thymus carnosus Boiss.	1	-	-
Turdus iliacus	12	Open woodland/Shrubland-grassland	-
Turdus philomelos	7, 12	Open woodland/Riparian forest	-
Turdus pilaris	12	*Juniperus* spp. forests/Shrubland-grassland	-
Turdus torquatus	12	*Juniperus* spp. and *Pinus* spp. forests/Shurbland-grassland	-
Turdus viscivorus	7, 12	Open woodland/Closed forest	-
Turnix sylvatica	1	-	-
Vanellus vanellus	7, 12	Shurbland-grassland	-
Veronica micrantha Hoffmanss. & Link	11	Deciduous forests	-
Viola cazorlensis Gand.	1	-	-

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