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Research Article

How regulating and cultural services of ecosystems have changed over time in Italy

Alessio Capriolo[‡], Riccardo Giuseppe Boschetto[‡], Rosa Anna Mascolo[‡], Alessio Bulckaen[§], Stefano Balbi[§], Ferdinando Villa[§]

‡ ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale, Rome, Italy
§ BC3 - Basque Centre for Climate Change, IKERBASQUE, Basque Foundation for Science, Leioa, Spain

Corresponding author: Alessio Capriolo (alessio.capriolo@isprambiente.it)

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Abstract

In this experimental study, different components are computed for three different ecosystem services (ES). Specifically, supply, demand and use are estimated for pollination service, flood risk regulation service and nature-based tourism. These are analysed and assessed in 2012 and 2018 for the Italian context, in order to estimate the evolution over this period and to allow a significant comparison of results. The same methodology and models are applied for the selected accounting years and accounting tables and tend to reflect as closely as possible the System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA EA), which is the international standard endorsed by the United Nations to compile Natural Capital Accounting in 2021. Both biophysical and monetary assessments are performed using the ARIES technology, an integrated modelling platform providing automatic and flexible integration of data and models, via its semantic modelling nature. Models have been run adjusting the components of the global modelling approach to the Italian context and, whenever available, prioritising the use of local data to carry out the study. This approach is particularly useful to analyse trends over time, as potentially biased components of models and data are substantially mitigated when the same biases is constant over time. This study finds an increase in benefits over the period analysed for the ES examined. The main contribution of this pioneering work is to support the idea that ES accounting or

Natural Capital Accounting can provide a very useful tool to improve economic and environmental information at national and regional level. This can support processes to provide the necessary incentives to steer policy-making towards preventative rather than corrective actions, which are usually much less effective and more costly, both at environmental and economic levels. Nevertheless, particular attention must be paid to the meaning of the estimates and the drivers of these values to derive a direct or indirect relationship between the benefits observable and the actual Italian ecosystems condition.

Keywords

ecosystem services; biophysical and monetary assessment; natural capital accounting; ecosystem services accounting tables; ARIES

Introduction

Ecosystem services (ES) are defined as the contribution of nature to human well-being (de Groot et al. 2002,TEEB 2010)*[1]. This implies that humanity is strongly dependent on well-functioning ecosystems and natural capital that are the basis for a constant flow of ES from nature to society (Burkhard and Maes 2017). In this context, ES accounting (mainly physical and monetary use tables)*[1] provide an operational approach and a highly valuable tool for systematic integrative assessments of the multiple ecological, social-cultural and economic values that nature offers (La Notte et al. 2021). ES accounting offers an articulated framework and a valid methodological guidance to quantify such values, thus providing a sound base to align the domain of information pertaining to natural capital to the System of National Accounting (SNA), for a better integration of sustainability policies (UN 2020). This alignment occurs by means of accounts which expand the analytical capacity of national accounting for selected areas of specific concern (UN 2012). The System of Environmental-Economic Accounting (SEEA), proposed and supported by the United Nations since 1993, provides methodological guidelines for setting up satellite accounts concerning natural capital (UN 2014a, UN 2014b, UN 2017). In particular, the UN SEEA EA (the System of Environmental Economic Accounting - Ecosystem Accounting) does it for the ecosystem accounts and has recently become an international statistical standard (UN 2021a, UN 2021b). The European Commission, one of the major sponsors and leading player of the SEEA EEA revision, responded deciding to include a "module" on ecosystem accounts in the proposed extension of Reg. 691/2011 on European Environmental Accounts. In particular, Eurostat has created an ad hoc Task Force to prepare a legal proposal and the methodological documents for the implementation of the system. The text is currently still subject to internal consultations within the Commission (in and between the various Directorates General). The main technical reference at European level, relevant to designing and implementing an integrated accounting system for ecosystems and their services, is the “Knowledge and Innovation Project on an Integrated System for Natural Capital and ES Accounting (KIP INCA)”, set up by the European Commission (JRC) and other European institutions, such as the European Environment Agency and Eurostat and following the technical recommendations provided by the UN

SEEA EA and JRC (European Commission 2016, La Notte et al. 2017). The practice of ES accounting is undergoing rapid expansion and uptake by national governments and it is increasingly providing information for policy development worldwide. From a zero base in 2013, over 40 countries have been moving forward with Natural Capital Accounting (NCA) programmes (UN 2019, Hein et al. 2020). In April 2021, the Statistics Division of the UN Department of Economic and Social Affairs (UNDESA) and the UN Environment Programme (UNEP) launched ARIES for SEEA, which is able to produce SEEA accounts globally and enable NSOs to more rapidly produce accounts, as well as to customize them using their own data. Research on NCA has expanded its scope to the national scale in Italy following the issue of the National Law 221/2015, by means of which the National Committee on Natural Capital (NCNC) in Italy has been established and mandated to publish the annual Natural Capital Reports*[2]. Additionally, this marks an important stage of development on NCA in Italy due to the increased formal standing of this area of studies (CCN 2021). The Third Report on Natural Capital in Italy (CCN 2019, Capriolo et al. 2020) provides a first ES assessment and accounting tables attempting to expand the geographical scope of NCA applications, from merely local applications to a comprehensive national scale. In addition, the Third Report introduces ES models and spatial resolutions that are more country-specific if compared to other recent European studies, based on a continental scale (Vallecillo et al. 2018, Vallecillo et al. 2019, La Notte et al. 2021). Priorities indicated by the NCNC and local data availability have been the major drivers for selecting the ES of focus:

1. pollination service,
2. flood risk regulation service,
3. nature-based tourism.

Within this context, the main goals of this work are to generate national scale ES estimates that may significantly describe changes over time, but also to respond to the emerging EU legislation process of revision that will soon introduce Ecosystem Accounts at national level and more, in general, to pay attention to policy interest in these three ES that were measured.

In this article, we first describe the biophysical model and the applied monetary valuation methodology to estimate exchange values consistent with the SEEA EA*[3] and then we present the modelling results in extent accounts, supply and use tables, for the two years considered, 2012 and 2018, in line with the principles, definition and accounting structures described in the SEEA-EA framework (UN 2014a, UN 2014b, UN 2017, UN 2021a, UN 2021b). The outputs highlight the change over time of the biophycal and monetary dimensions of these ES which is rather relevant information for policy- and decision-making processes. The first ecosystem service taken into consideration is the pollination service, that is to say the ecosystem contribution by wild pollinators to the fertilisation of crops. In order to quantify physical supply and use for crop pollination, we relied on a biophysical model able to identify areas where it is most likely to occur. Within the wide variety of pollinable crops in Italy, the six crops examined here - excluding watermelon and melon, listed as horticultural crops in the Italian Agricultural Yearbook - represent over 50% of the physical production in tonnes of fruit-bearing crops in Italy (INEA 2013, CREA 2020).

The second ES described is the flood risk regulation service. The definition of this ES is different from the one catalogued in SEEA-EA (UN 2021c): although the biophysical model presents some similarity with the landslide mitigation service (related to the service supply), it does not imply a mass movement, but only a water one due to precipitation. On the other hand, it cannot even be associated with the ES river flood mitigation service because it considers areas that are not exclusively riparian. The biophysical model estimates the ability of vegetation and soil to retain excess run-off from precipitation. Thus, the reduction in the speed and volumes of water flow, due to the presence of ecosystem characteristics, mitigates or prevents damage to the human environment. The service should be present in areas currently able to naturally (totally or partially) mitigate this risk to people and property through water retention (SCS 1985, Zeng et al. 2017, Capriolo et al. 2020). Nature-based tourism is the third ecosystem service assessed in this article: it is a cultural ES that includes all physical and intellectual interactions with ecosystems, landscapes and sea-scapes (Vallecillo et al. 2018). It is a specific service within the broader recreation-related service of the SEEA-EA (UN 2021c) and considers only a component of tourism (the foreign one) based on nature enjoyment. We provide estimates of recreational tourism linked to the enjoyment of nature using data on in-bound tourism obtained through a preliminary econometric analysis. Lastly, we discuss advantages and disadvantages of the spatial modelling approach to building accounts for ES, also highlighting key challenges identified in the development of ES accounts in Italy. The importance of ES modelling is widely recognised in the scientific and policy push to understand ecosystem services and using information about them in environmental policy (Burkhard et al. 2012). As a matter of fact, whilst economic valuation methods for ES and biophysical models of natural processes have existed for decades, the rise of dedicated modelling platforms is a more recent development (Neugarten et al. 2018). This notably followed the release of the Millennium Ecosystem Assessment in 2005 (MA 2005) and, shortly after, the launch of systematic and sustained ES modelling approaches, such as the Integrated Valuation of Ecosystem Services and Tradeoffs (Sharp et al. 2014) and ARtificial Intelligence for Environment & Sustainability (ARIES) (Villa et al. 2014). Estimates in this paper have been carried out at the national level using ARIES technology and have been included in the Fourth National Report on the state of Natural Capital in Italy (CCN 2021).

Material and Methods

Starting from the framework adopted from the INCA project*[4] for ES accounts we have followed three main steps:

1. biophysical assessment of the ecosystem service
2. quantifying into monetary terms; and
3. compilation of supply and use tables consistent with the accounting structure of the SEEA EA.

This research has been conducted by customising ARIES models and data sources (Villa et al. 2014). Artificial Intelligence, in particular semantics, is used to optimise model selection and promoting the transparent reuse of data and models according to Findability, Accessibility, Interoperability and Reusability (FAIR) principles (Wilkinson et al. 2016). ARIES provides a suite of pre-formed ES models that can be run at any geographical scale. It automates model selection based on user specifications, such as spatio-temporal resolution and other specific queries (e.g. an ecosystem service or condition). Based upon its syntax and a large number of organised and semantically annotated global, national and local data layers, the tool generates the most appropriate model workflow (i.e. data sources and underlying algorithms). Model and data customization are important for capturing local knowledge, improving credibility and reducing the inherent inaccuracies of global or large-scale data. Our application has customized models with national data: in particular, we have used data from official national statistics, LULC maps 2012 updated to 2019 with high resolution layers on soil consumption (ISPRA 2018), higher resolution spatial layers on Italian protected areas, 20 metres resolution DEM, higher resolution rainfall and temperatures maps (ISPRA 2017). The choice of the two years (2012 and 2018) for the models' run is linked to the corresponding availability of CORINE land-cover maps (CLC). Generally speaking, the definition of actual and potential flow varies case by case, depending on the way ES are perceived, how they are modelled or on what proxies are used to assess them. This can mostly affect the result of ES accounts (Burkhard and Maes 2017). For this reason, in the following sections the definition of flow is provided for each ES with the purpose to set clear limits for what is explicitly considered in biophysical assessment. In this paper, by 'supply' we mean potential flow or capacity, so that it differs from the meaning of supply in the SEEA EA table, corresponding to actual flow. Lastly, the biophysical outputs have then been coupled with the monetary values to carry out the economic evaluation.

Pollination service

Pollination by wild insects and other animals is an intermediate regulation ecosystem service (ES), which is to say a service rendered by the ecosystem to itself, necessary for the provision of final ES, those from which the anthropogenic system directly benefits. In this case, the ecosystem performs functions of intermediate ecological regulation in support of the final service of crop biomass provision, on which fertilisation and agricultural productivity depend eventually (Cory et al. 2016). It is known that pollination can increase yields, quality and stability of fruit and seed crops (Bommarco et al. 2012). In fact, it was found that 87 out of 115 crops of global importance (~ 70%) benefit from animal pollination (Klein et al. 2007). The Italian bee fauna is one of the richest in the world in relation to the surface of our country. The latest official list includes 944 species (Pagliano 1995) belonging to six of the seven worldwide known families. In 2018, the IUCN Italian Committee, on behalf of the Ministry of the Environment, drew up the Red List for Apoidea. In total, there are 151 species of native bees in Italy for which there are sufficient data and indications of decline: out of 151 species assessed according to the rigorous criteria of the IUCN, 34 are those with different levels of threat. Nevertheless, there is a need for better spatial assessments of pollination as few studies are based on Species Distribution Models (SDMs) and these are at relatively coarse spatial resolution. Especially in highly fragmented landscapes like the ones in Italy, this resolution may fail to cover important habitats, such as hedgerows, small pastures and forests, with the risk to obtain biased pollinator distribution maps. Three most important elements are needed for pollinators to live in a habitat: suitable places to nest, sufficient food (provided by flowers) and availability of water near their nesting sites (Vallecillo et al. 2018). For this reason, the pollination model focuses on resource needs, flight behaviour of wild bees (the most relevant pollinator group for most crops (Free 1993) and, finally, on pollination service associated with certain crops (Capriolo et al. 2020). We rely on biophysical modelling to identify the areas in which pollination is most likely to occur, based on the overlapping presence of pollination-dependent crops (Klein et al. 2007) and areas with high pollinator habitat suitability (Martínez-López et al. 2019). The model quantifies the supply of the pollination service, on the basis of a relationship between the suitability of the habitat and the activity of pollinating insects. Habitat suitability expresses in synthesis key characteristics of the ecosystem: its ecological suitability for nesting, floral availability (representative parameter of the insect's foraging function) and its proximity to water sources such as rivers, lakes and waterways in general (CCN 2019). The notion of habitat suitability can be represented with an index with values ranging from 0 (habitat with no suitability) to 1 (very high habitat suitability). The activity of pollinators is simulated as a black spherical model representing a function of the average annual temperature (°C) and the average annual solar irradiation (W× m-2), as they can greatly affect insects foraging and, in turn, the number of active individuals (Martínez-López et al. 2019 for complete equations). For this reason, we use the black spherical model as a proxy of the abundance of pollinators. Modelling the relationship between active number of pollinators and habitat suitability describes the activity/microclimate relationship, from which we obtain a representation of the ES supply which refers to a potential flow (Capriolo et al. 2020). In order to represent the demand side of the ES, the model considers the production in metric tonnes of pollination dependent crops, multiplied by the pollination dependency rate (Klein et al. 2007). Additionally, only crops with a dependency rate greater than 0.2 have been considered for the modelling exercise. As a result, when ES supply (occurrence of insect activity and habitat suitability) and demand (production of pollinated-dependent crops according to the crop-specific dependency rate) are overlapped, we identify first the met demand and then the ES use. Due to a lack of national maps on agricultural production spatially distributed, we used the most recent and accessible spatialised data on crops extent and yield (Monfreda et al. 2008) which include 173 types of crops, but only six crops were taken into account: almond, apple, apricot, melon, pear and watermelon. Production data of the six crops for the years 2012 and 2018 were obtained from the Italian agricultural yearbooks and are illustrated in Table 1 (INEA 2013, CREA 2020). The economic valuation was carried out by applying a market-based method using the “farm gate”*[5] price at the producer site. The increase in agricultural production can be measured as a share of agricultural production attributable to pollination flow and, in monetary terms, by multiplying the output of the use of the service with the ‘farm gate’ basic price, for each of the different crops (CREA 2020, INEA 2013) and for both years. This component of production would not exist in the absence of ecosystem service and, therefore, represents as a whole the additional value deriving from the presence of pollinators (Vallecillo et al. 2018). These quantifications converge in the construction of the SEEA-EA accounts and can be collected in dedicated tables, both in biophysical and monetary terms (UN 2017, UN 2014a, UN 2014b, UN 2021a, UN 2021b).

Table 1.

Crops production in metric ton for the two years considered 2012 and 2018.

Crops	**Production (t) 2012**	**Production (t) 2018**
Almond	92,900	79,700
Apple	2,118,900	2,415,800
Apricot	253,600	229,300
Melon	587,800	607,300
Pear	651,700	718,700
Watermelon	420,400	581,700

Table 2.

Extent of crop pollination supply.

Pollination Supply	**Year 2012 (km^2)**	**Year 2018 (km^2)**	**Supply variation**	**Variation (%)**
Inland marsh	9.50	9.50	0	0
Saline	10.75	10.75	0	0
Vineyard	3,781.80	3,809.29	27.49	0.73
Olive grove	10,842.60	10,928.06	85.47	0.79
Fruit and berry plantation	2,930.88	2,994.60	63.73	2.17
Agricultural land with natural vegetation	23,418.28	23,482.01	63.73	0.27
Agro forestry land	1,801.56	1,799.31	-2.25	-0.12
Transitional woodland scrub	11,178.97	11,146.48	-32.49	-0.29
Moor and heathland	1,895.77	1,895.77	0	0
Sclerophyllous vegetation	10,101.63	9,982.18	-119.45	-1.18
Grassland	8,490.75	8,427.77	-62.97	-0.74
Coniferous forest	2,190.66	2,205.16	14.49	0.66
Mixed forest	10,944.56	10,944.56	0	0
Broadleaf forest	62,866.42	62,794.45	-71.97	-0.11
Sparse vegetation	2,951.87	3,037.59	85.72	2.90
Total	153,462.96	153,515.44	52.48	0.03

Table 3.

Crop pollination biophysical use for 2012 and 2018.

Pollination Biophysical Use (t)	Almond	Apple	Apricot	Melon	Pear	Watermelon	Total (t)
Year 2012	5,968.65	135,615.55	16,291.32	52,132.26	41,728.31	12.27	251,748.36
Year 2018	5,163.61	155,792.29	14,854.09	54,270.81	46,367.82	14.12	276,462.73
Use variation	-805.04	20,176.74	-1,437.23	2,138.55	4,639.51	1.84	24,714.37
Use variation (%)	-13.49	14.88	-8.82	4.10	11.12	15.08	9.82

Table 4.

Crop pollination contribution in percentage for the two years considered 2012 and 2018.

Pollinated Crops	Almond	Apple	Apricot	Melon	Pear	Watermelon	Total
Contribution % -2012	6.42%	6.40%	6.42%	8.87%	6.40%	0.003%	6.10%
Contribution % - 2018	6.48%	6.45%	6.48%	8.94%	6.45%	0.002%	5.97%

Table 5.

Monetary use table of the crop pollination between in 2012 and 2018.

Monetary Use (€)	Almond	Apple	Apricot	Melon	Pear	Watermelon	Total
Year 2012	4,409,339.13	57,708,485.61	8,723,349.66	19,226,899.08	30,790,900.58	1,801.11	120,860,775.17
Year 2018	6,335,701.30	67,733,811.46	8,591,752.91	25,167,543.20	30,576,793.81	2,229.81	138,407,832.49
Benefit variation	1,926,362.17	10,025,325.85	-131,596.75	5,940,644.11	-214,106.77	428.70	+17,547,057.31
Benefit variation (%)	43.69	17.37	-1.51	30.90	-0.70	23.80	14.52

Flood Risk Regulation Service

The flood risk regulation model maps and evaluates the service by identifying areas at risk of flooding (FHP: flood hazard probability) through an index consisting of a first climatic-weather parameter (CCN 2019) which gives an indication of presence, intensity and volume of precipitation, a second parameter that contains a topographical humidity index (Kirby and Beven 1979, Manfreda et al. 2011) which combines precipitation with the flow of water accumulation descending along the slope obtained from digital elevation model (DEM) and, lastly, a temperature parameter of the wettest quarter for the years (Trenberth et al. 2003, Hijmans et al. 2005, Utsumi et al. 2011). A further parameter needed to determine the supply component of the model is the Curve Number (CN), an indicator of potential run-off, which estimates the ability of vegetation and soils to retain excess run-off from precipitation. CN is a function of land cover, soil hydrological groups and slopes in some contexts (SCS 1985, Zeng et al. 2017) and is formed by combining each CN soil groups value with Corine Land Cover (CLC) classes for both 2012 and 2018 years (Suppl. material 1). CN scores range from 0 to 100, with higher scores indicating higher run-off. In order to evaluate the potential run-off over the six years, we consider the variation between the CN values associated with the actual CLC soil groups and CN values associated with the bare soil (or bare areas), where the run-off is greater, in line with a hypothetical scenario of substantial loss of service. This change is then multiplied by the FHP to obtain the biophysical indicator of the Flood Regulation Supply (FRS), which identifies the areas subject to flooding (equation 1). This relation allows us to compare the current probability of flood hazard (FHP) with that of a possible loss of service (bare areas) and to obtain an estimate of the actual flow of the service.

$$\mathrm{FRS} = \mathrm{FHP} \times (CN_{bareareas} - CN_{soilsgroup}) \quad \text{(eq. 1)}$$

Eq.1 represents the supply (potential flow/capacity) of the ecosystem service and is then spatially described (Fig. 1) by the areas on which the ES has an impact. Overlapping these areas on the land-cover and use data, which instead constitute the service demand and identify the assets and values benefiting from the service (or potentially at risk in case of service loss), it is then possible to estimate the use of the service. This model is the result of a simplification of those already published on a global or continental scale (Stürck et al. 2014, Ward et al. 2015), but has the advantage of being easily replicable even in contexts with little data available. The methodology adopted for the economic evaluation uses different monetary damage functions estimated for different land-cover and use classes (Huizinga et al. 2017). Damage values were initially elaborated from existing studies across some EU countries and the average damage value per land-cover and use class was applied to other EU Member States scaled to GDP per capita. The damage functions are built on observations from nine countries and, being nationally homogenous, they do not account for regional differences. The direct economic impacts (equation 2) are derived from depth-damage functions that express the damage cost in EUR/m^2 as a function of the flood water depth (in metres) for different classes of land-cover and use. Specifically, it is a function of the land-use type (damage value per each land use), the level of the damage (damage factor, based on water depth) and the extension of the flooded area by land-use type.

$$\sum_{i=1}^{n} \text{damage value}_i \times \text{damage factor}_i \times \text{extension of flooded area}_i \quad \text{(eq. 2)}$$

where i = land use type.

Monetary damage values (Suppl. material 2) are available for almost each class (few classes in Suppl. material 2 are missing with respect to Table 6) as they have been adjusted to the CLC classes identified as economic assets currently protected by the service. The economic values derived from this direct economic impact analysis represent the potential avoided damage arising from the presence of the ecosystem service.

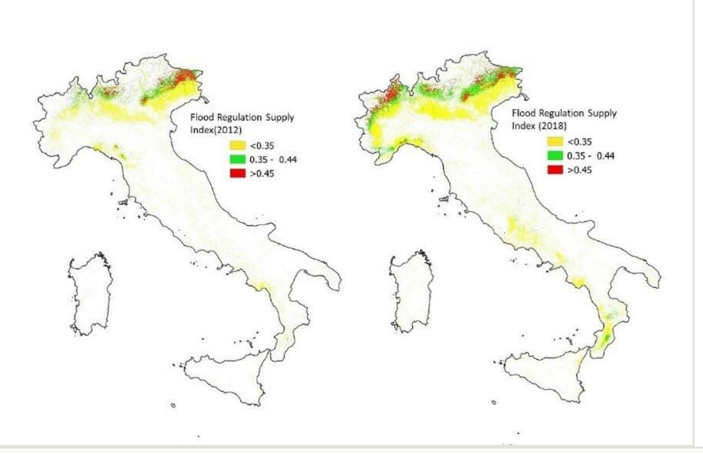

Figure 1.
Maps of flood regulation supply in 2012 and 2018.

Table 6.
Physical use of flood regulation service.

Flood Regulation Service Biophysical Use	**Area 2012 (km^2)**	**Area 2018 (km^2)**	**Variation**	**%**
Construction	17.24	21.24	4	23.20
Dump	10.5	18.49	8	76.10
Mineral extraction	191.18	250.65	59	31.11
Sport leisure facility	125.45	175.68	50	40.04
Green urban areas	56.73	75.47	19	33.03
Airport	84.72	133.95	49	58.11
Road rail network	102.46	148.44	46	44.88
Port	21.24	28.99	8	36.49
Industrial commercial units	1,841.05	2,298.87	458	24.87
High density urban	417.59	667.74	250	59.90
Medium density urban	5,656.33	7,239.73	1,583	27.99
Still water body	1,612.63	1,807.31	195	12.07

Flood Regulation Service Biophysical Use	**Area 2012 (km^2)**	**Area 2018 (km^2)**	**Variation**	**%**
Watercourse	470.32	495.06	25	5.26
Estuary	0.25	0.5	0	100.00
Coastal lagoon	180.68	283.64	103	56.98
Peat bog	4	4	0	0
Inland marsh	119.7	147.19	27	22.97
Salt marsh	75.47	153.19	78	102.98
Saline	26.99	34.99	8	29.64
Permanently irrigated arable land	265.4	463.07	198	74.48
Not irrigated arable land	28,674.02	40,241.59	11,568	40.34
Rice field	1,603.89	2,030.47	427	26.60
Vineyard	1,551.16	2,402.08	851	54.86
Olive grove	1,552.41	3,577.88	2,025	130.47
Fruit and berry plantation	1,484.18	2,199.91	716	48.22
Agricultural land with natural vegetation	5,380.94	8,951.57	3,571	66.36
Complex cultivation patterned land	6,784.65	10,356.78	3,572	52.65
Agro forestry land	32.49	127.2	95	291.51
Annual cropland associated with permanent	266.4	564.53	298	111.91
Pastureland	1,575.65	2,150.93	575	36.51
Transitional woodland scrub	1,814.56	4,196.14	2,382	131.25
Moor and heathland	486.31	922.15	436	89.62
Sclerophyllous vegetation	293.39	832.93	540	183.90
Grassland	932.39	1,877.53	945	101.37
Coniferous forest	3,636.11	5,629.84	1,994	54.83
Mixed forest	3,764.81	5,678.08	1,913	50.82
Broadleaf forest	12,746.12	22,237.73	9,492	74.47
Burned land	12.25	45.73	33	273.31
Beach dune and sand	633.51	713.98	80	12.70
Bare rock	206.42	338.62	132	64.04
Sparse vegetation	846.18	2,273.63	1,427	168.69
Total	85,596.71	131,888.73	46,292	54.08

Nature-Based Tourism

Nature-based tourism-related services are defined as the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. Nature-based tourism-related services are a part of the recreation-related services. According to the SEEA EA (UN 2021c), recreation-related services include services to both locals and non-locals (i.e. visitors, including tourists)

The model is inspired by previous works mapping outdoor recreational activities in Europe (Paracchini 2014) and is aimed to identify nature-based tourism in areas with a high naturalistic value. Data available on this kind of tourism are very scarce, both globally and nationally: in this purpose, one of the most useful sources of information for this process has been identified in a previous work (Paracchini et al. 2014), which has the merit of having involved an in-depth survey on visits to protected areas in more than 50 countries.

The model presents four fundamental assumptions:

1. only foreign tourism is considered (i.e. incoming or inbound) (Balmford et al. 2015) and, as a consequence, the role of domestic tourism is ignored in this specific study, although already addressed for Italy in a previous and recent work (Capriolo et al. 2020);
2. all the “naturalist” tourists go initially to protected areas as represented in the Balmford dataset (Balmford et al. 2015), while other tourist destinations, based on nature, are not considered – this, in particular, is probably a strong assumption considered that most of nature-related attractive spots are not covered by PA in the Italian context;
3. this approach disregards other country-specific touristic attractive elements, such as the weight of cultural tourism in the Italian context;
4. an incomplete dataset is used and, therefore, results should be interpreted with a high level of caution.

Since Italy was not significantly represented in the Balmford's dataset and, therefore, there was no chance to carry out a regression analysis that could include data for our country, it was decided to use the dataset only to run the econometric analysis and estimate the portion of nature-based tourists and then proceed with a distribution of nature-based visitors over all areas of potential naturalistic interest, going beyond the perimeter of the formally-protected areas. This has been done considering the conformation of our territory which, unlike other countries, where fewer large naturalistic areas coincide with protected areas, often shows landscape and naturalistic value even in non-protected areas or in areas that do not belong to the Natura 2000 network. However, it is desirable to proceed towards an improvement of this estimate as soon as more accurate local data on the number of visits to protected areas become available.

The model assigns an indexed and normalised value to each grid cell on the basis of specific features in order to obtain the supply:

- the naturalness of different land cover types – every landcover type is associated with a level of hemeroby*[6] to assess the degree of human influence in that area;
- presence of protected areas;
- distance from mountains and water bodies - to identify attractive areas for outdoor recreation;
- indicator of fauna richness linked to the presence of vertebrate species.

Potential supply is then weighted considering accessibility, intended as the distance from cities and road infrastructures, which means that the most accessible hot-spots for outdoor recreation are also the most likely to be visited by "naturalist" tourists. The result is a map of areas identified by weighing the attractive nature of each cell within the grid with its accessibility and this can be used to spatially spread the number of tourists at national level over the attractive areas (Fig. 2).

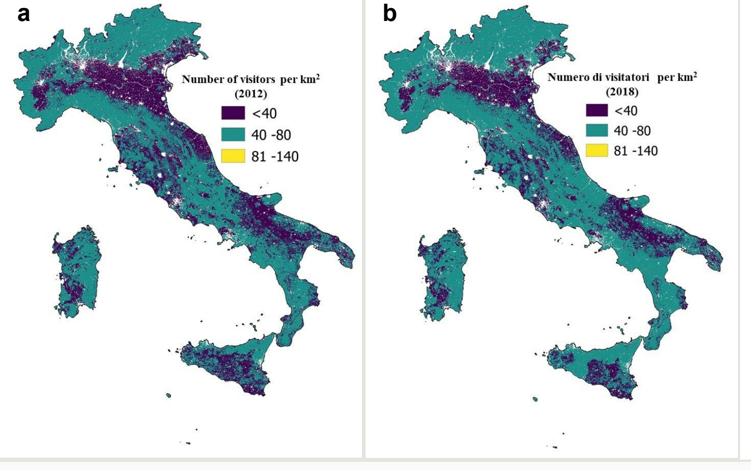

Figure 2.

Number of visitors for nature-based tourism in the two years 2012 and 2018.

We have built a simple univariate regression model to quantify the relationship between visits to protected areas and natural parks (dependent variable) with data on tourists arriving for leisure and recreational purposes from the United Nations World Tourism Organization*[7] (World Tourism Organization 2019). The univariate regression model, which intends to provide a starting analysis tool capable of estimating annual visits to protected areas as a function of incoming tourists associated with leisure activities, indicates that about 50% (precisely 50.05%) of inbound tourism is involved in nature-based tourism. The estimate obtained has a coefficient of determination R^2 equal to 0.835, which is an index of excellent confidence for regression diagnostics. The addition of further variables in a multivariate model was explored, including the percentage of land area covered by protected areas within each country and the percentage of the country economy represented by tourism, but these additional variables did not add predictive value nor were they statistically significant. Further details on the regression results and the test run on the econometric model are summarised in Suppl. material 3.

We use the proportion obtained from the regression analysis described above to predict the number of tourists at national level attracted by naturalistic elements and then to calibrate the relative attractiveness map. Once the number of inbound visitors for Italy, linked to the enjoyment of nature has been estimated, this has been spatially distributed on the basis of the characteristics of the landscape and of the operating dynamics of the model described above for the supply.

In order to obtain the share of expenditure relevant for nature-based tourism, the total expenditures for tourism in the economy is multiplied first by the percentage of travelling for holidays, leisure and recreation purposes and then by the percentage of this group of travellers engaging in nature-based tourism. The monetary value associated with nature-based tourism (MVNT) for the year 2018 is presented here below (equation 3):

$$\mathrm{MVNT} = \mathrm{Total\ expenditure\ on\ inbound\ tourism} = \frac{\mathrm{Leisure\ tourism\ and\ leisure\ time}}{\mathrm{Tourism\ made\ for\ personal\ reasons}} \times 50.05$$

(eq. 3)

We have considered data on total inbound foreign tourism expenditure, available from the United Nations tourism database (World Tourism Organization 2019). We have extracted the share attributable to leisure tourism and leisure time by applying the rate of visits with this specific destination preference to the total of visits made for personal reasons (i.e. those inclusive of both holiday tourism or linked to weddings funerals, etc., but net of travel for business). Then, the share of recreational tourism associated with experiences of enjoyment of nature is computed using the percentage estimated in the regression analysis (50.05%).

For the year 2012, in light of the absence of WTO data on tourism for Italy, the monetary value associated with the nature-based tourism (MVNT) is calculated as follows:

$\mathrm{MVNT} = \mathrm{TE} \times \mathrm{HT} \times \mathrm{VNT}$ (eq. 4)

Where,

TE = total expenditure for inbound foreign tourism;

HT = percentage of holiday tourism expenditure: 62% (CISET 2014);

VNT = percentage of visitors for nature-based tourism: 24.3% (CISET 2014).

Results

Pollination service

The pollination service supply table for the selected six crops (Table 1) describes the spatial extension of land-cover areas that provide the service for the two years considered jointly to the supply variation over this period (Table 2). The map in Fig. 3 reports, as an example, the use value spatialised for the "apple" crop, while Table 3 reports the biophysical use values expressed in metric tonnes for the six crops considered. Observing the production of pollinated crops and comparing it to the total production for the respective years, we have an indication, in percentage, of the contribution of pollination to these fruit crops production that remains substantially unchanged (6.10% in 2012 and 5.97% in 2018) (Table 4). Table 5 highlights the monetary use value that estimates the economic benefits (prices 2018) which arise from the pollination service. Fig. 4 provides, again as an example, the monetary use value of the apple pollination service. The monetary values are placed in the areas where the service is present with different intensity: pollination use index values range from 0 to 1 and are marked with different colours.

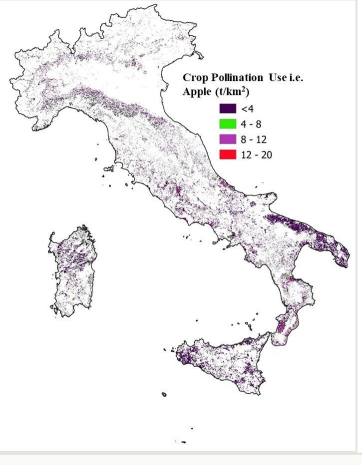

Figure 3.

Map of pollination service use for apple in 2018.

Flood risk regulation service

The use table represents the accounting format of ES and can be constructed in physical or monetary terms (UN 2014a, UN 2014b, UN 2017, UN 2021a, UN 2021b). In particular the first column of Table 6 shows the assets that were considered. Then the next columns show the area of each asset that potentially benefits from the flood risk regulation service, other than the change over time in absolute and percentage terms. The economic sectors that benefit from the ecosystem service are considered in Table 7. Table 6 and Table 7 show the change over time between 2012 and 2018. The monetary value index in Fig. 5 highlights areas of greatest potential economic risk in case of service loss.

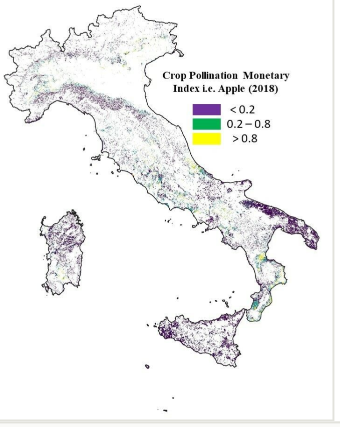

Figure 4.
Map of the monetary index of the pollination service use for apple in 2018.

Table 7.
Monetary use of flood regulation service.

	Economic sector				
Flood Regulation Monetary value (Milion €)	**Primary sector**	**Secondary sector**	**Tertiary Sector**	**Households**	**Total**
2018	2,201	13,559	648	90,532	106,940
2012	1,661	12,349	466	78,217	92,693
Benefit variation	540	1,210	182	12,315	14,247

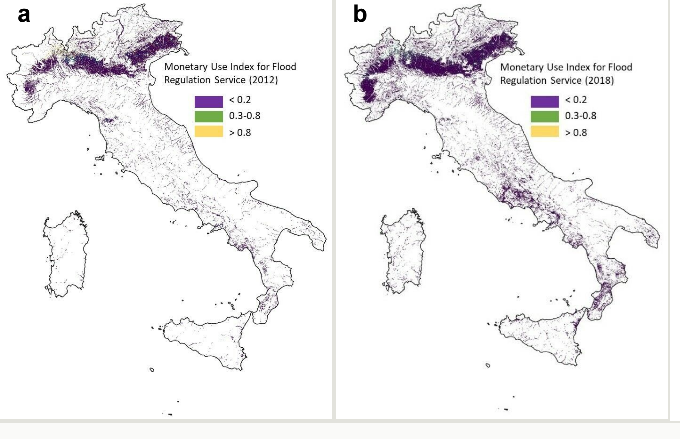

Figure 5.
Maps of monetary use index for the flood regulation service.

Nature-based tourism

Table 8 represents the use table of ES and reports the tourism rate in percentage for the two years, in the first column and data in monetary terms, in the other two columns, related respectively to the total value of inbound tourism expenditure and the total value of inbound tourism, based on nature. Fig. 6 shows the spatial distribution of the monetary value index for nature-based recreational tourism service (price 2018) for the two years taken into consideration.

Table 8.

Monetary use table for nature-based tourism in Italy.

Year	Nature-based holiday tourism rate (%)	Total value of inbound tourism expenditure (TE) (Million €)	Total value of inbound tourism, based on nature (MVNT)(Million €)
2018	25.51%	36,023.40	9,189.57
2012	15.07%	32,180.12	4,849.54
Benefit variation	10.44 %	3,843.28	4,340.03

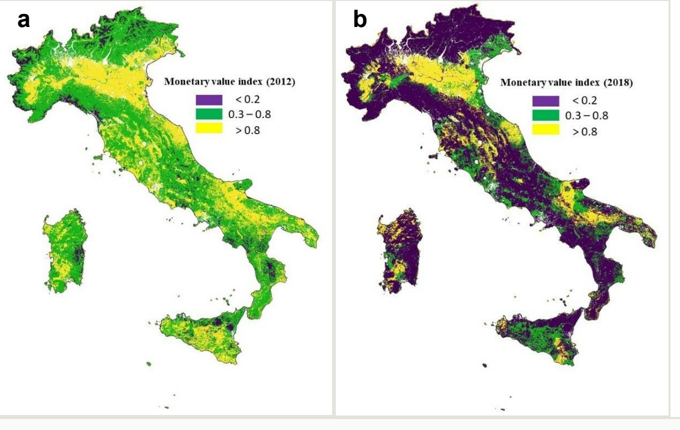

Figure 6.

Monetary value index for nature-based recreational tourism service.

Discussion and conclusions

A first generation of studies on ES carried out in Italy has mainly focused on single ecosystems typology (Alberini et al. 2007, Bonometto et al. 2015,Gatto 1988, Alberini et al. 2007, Goio et al. 2008, Notaro and Paletto 2012, Morri et al. 2014, Bonometto et al. 2015, Häyhä et al. 2015, Da Re et al. 2015, Franzese et al. 2015, Manes et al. 2016, ISPRA 2016, Franzese et al. 2017, ISPRA 2017, ISPRA 2018, Munafò 2019, Munafò 2020, Munafò 2021), protected areas (Schirpke et al. 2015,Sallustio et al. 2017, Masiero et al.

2018) or regional areas (La Notte et al. 2020, Di Pirro et al. 2021). However, such first-generation studies are often highly localised or scarcely up-scalable for the purpose of integrating into national accounts. This paper tries to present an original and experimental ecosystem service accounting that quantifies the actual flow of three ES at national level, using the newly-developed web-based ARIES technology. By customising three ES models to three contexts application with diverse ecological and socio-economic characteristics and data availability, we have taken a further step compared to a first attempt previously processed (Capriolo et al. 2020), where ES accounts were produced for Italy just for a single year. Since these kinds of accounts are definitely more useful when reporting changes over time, we tried to cover a short, but representative period of time. The estimates reported in our study indicate an evident increase in benefits over the six-year variation at least for two of the three ES examined. The pollination service recorded even a slight decrease if compared to the total production (Table 4) contextually to a slight increase in absolute terms of the overall service use, reflecting the increase of three crops out of five (Table 3), in particular due to apple and pear production. The analysis of the results shows that the variations in the pollination contribution are positive for the majority of the crops over the two years considered. However, in two cases - almond and apricot - this marginal increase of service occurs at the same time as a decrease in the total production of the two crops. This can be partly attributed to a change in the service supply (potential presence of pollinators), but above all, to a decrease in production in agricultural areas where the demand for the service is not satisfied (unmet demand). On the other hand, for the remaining crops (apple, melon, pear, watermelon), there is a trend of the same kind, between 2012 and 2018, which sees both total production and the pollination contribution increase, albeit in different percentages. In this case, the more consistent increase in production compared to the pollination service is explained, other things being equal, mostly with an increase in yield of agricultural areas where the demand for the service is not satisfied (unmet demand). It is important to bear in mind that this analysis does not consider changes in the quality or in the ecological conditions of ecosystems, so the calculated service flow is a potential one and not able to confirm empirical evidence relating to a higher mortality of bees and wild insects which is caused by the massive use of chemicals in agriculture (Sánchez-Bayo and Wyckhuys 2019). As far as the flood regulation service, the increase in benefits that matches the increase of the economic value for protected assets, is mainly due to the increase in biophysical and monetary terms on the demand side (12 billion EUR over the period 2012 - 2018). These changes are mainly attributable to the two main drivers of the model: the increase in supply (FRS) that can be seen from the maps in Fig. 1, where there is a net increase of the areas with an index greater than 0.45 (FRS) and the increase in demand which substantially represents changes in land consumption in the considered years. As an increase in soil consumption of about 150% from 1950s to date (ISPRA 2016, ISPRA 2017, ISPRA 2018) has led to a contraction of all the natural surfaces and the landscapes in Italy, this can generate a contradiction in terms of sustainability because the demand, which is expressed as land cover and land use, increases where protected assets increase and, therefore, where there is an increase in soil sealing and land consumption. Flood risk management depends on human presence in areas at risk of flooding and its increase is not necessarily good news. We can make the same conclusion with regard to nature-based recreation as the increase in monetary value over the period (4 billion EUR) of nature-based recreation is partly explained by the increase in ES supply, but mainly by the increased demand from inbound visitors. From Table 8 as well as from Figure 6, we can see that, in the face of a 10% increase in the share of tourists who choose to visit our natural areas, there is a 100% increase in the value of the expenses incurred for recreational activities, in line with the increasing trend of total visitors and holiday spending (World Tourism Organization 2019). However, this does not provide indications on its own relative to the sustainability of the recreational activity in preserving the ecological status of the highly natural areas visited. The expenses for nature-based tourism depend on the income and preferences for it and on the landscape and naturalistic value (ability to provide valuable recreational activities) as well as on the general conditions in the input markets of the tourism activity - travel, accommodation ... - , determined by external factors. Their variation in value can, therefore, reflect changes in any of the markets involved, without univocal meaning in terms of environmental pressures and benefits, nor of benefits specifically attributable to the quality of ecosystems. Even in cases where an apparent increase in natural resources has been detected, interpretation of data requires caution and more in-depth analysis on environmental conditions to detect whether the ES use is effectively sustainable or not. Beyond these caveats, it is also important to highlight that the accounts developed at the Italian level still leave some challenges to address, mainly related to data availability: in some cases a time misalignment is due to available datasets that do not exactly match the years assessed or they are not available at the required spatial resolution. This mainly hampers the development of consistent accounts for a representative time series. Further developments should focus on generating better data, for instance, in the field of spatial distribution and production of pollinator-dependent crops over time for crop pollination or in terms of actual and periodically-monitored nature-based tourists. However, this research has introduced a new workflow for ES accounts at the national level and it has focused on different ways of evaluating the use of ES. In addition, this work has presented a solid methodology to model ES that is going to contribute to the global research and experimental development of the ES assessment. Finally, the results of this work have been included as an integral part of the Report on the State of Natural Capital in Italy (CCN 2021), that has the aim to provide policy-makers with recommendations on how to draw up priority actions in a better way for the recovery and protection of national ecosystems.

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Supplementary materials

Suppl. material 1: ANNEX A doi

Authors: Alessio Capriolo
Data type: pedological
Brief description: Curve Number values attributed to soil groups for each class of CLC.
Download file (36.97 kb)

Suppl. material 2: ANNEX B doi

Authors: Alessio Capriolo
Data type: value of damage
Brief description: Values of damage functions per unit area for each of the CLC classes used.
Download file (13.80 kb)

Suppl. material 3: ANNEX C doi

Authors: Alessio Capriolo
Data type: statistical value
Brief description: Regression and tests for the NBT implementation.
Download file (19.00 kb)

Endnotes

*1 Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity

*2 In 2015, Italian lawmakers established a Natural Capital Committee (Law n. 221/2015). The Committee submits an annual report on the state of natural capital to the Prime Minister and the Parliament to support annual planning within established social, environmental and financial goals.

*3 Each time the monetary value has a specific and different meaning depending on the methodology used.

*4 https://ecosystem-accounts.jrc.ec.europa.eu/

*5 https://www.imf.org/external/pubs/ft/ppi/2010/manual/ppi.pdf

*6 The degree of naturalness is modelled through the hemeroby index, which is an index that measures the human influence on landscapes and flora. The hemeroby scale ranges from 1 (natural) to 7 (artificial) (Paracchini et al. 2014).

*7 WTO database element 1.16 was used, representing arrivals related to holidays, leisure and recreational tourism. The UN WTO is in the midst of a review of the website and the statistics it hosts, so the data received is not currently available to the public.