Ecosystem Services 46 (2020) 101207

Contents lists available at ScienceDirect

Ecosystem Services

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

Biophysical and economic assessment of four ecosystem services for natural capital accounting in Italy

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ARTICLE INFO

Keywords:
Ecosystem Service
Natural Capital Account
Artificial Intelligence
Outdoor Recreation
Pollination
Flood Control
Water Provision
ARIES

ABSTRACT

We present methods and results of country-based natural capital assessments for four ecosystem services (ES) in Italy. The spatial mapping and the assessment have been carried out in both physical and monetary terms for (i) crop pollination, (ii) outdoor recreation, (iii) flood regulation (iv) and water provision, using the ARIES (Artificial Intelligence for Ecosystem Services) technology, which provides and integrates the necessary data and models. Extent, supply and use accounting tables have been developed for the same ecosystem services in line with the United Nations System of Environmental Economic Accounting (UN-SEEA) guidelines and Experimental Ecosystem Accounting (EEA) initiative. This work represents a first official and nationwide assessment of ecosystem services for the Italian Government in accomplishment of the Italian law n. 221/2015, applying a variety of different models and economic valuation methods to provide systematic and replicable information on natural capital through national accounting tables. We find that land management and maintenance of the countryside and forestland, which represent the typical Italian landscape, are fundamental. Our application also identifies several modelling challenges that need to be addressed before a methodological path for integrated ecosystem and economic accounting may be considered rigorous and reliable.

1. Introduction

Over the past two decades a growing body of science has debated the importance of natural capital and ecosystem services (ES) for human well-being and developed assessment methods on such issues (Bockstael et al., 2000; Balmford et al., 2002; de Groot et al., 2002; Howarth and Farber, 2002; Heal et al., 2005; Barbier, 2007; Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008; Fisher et al., 2008; Mäler et al., 2008; Tschirhart, 2009; Liu et al., 2010; Turner et al., 2010), laying the foundations for their incorporation into national accounting systems (Banzhaf and Boyd, 2012; Bartelmus, 2014, 2015; Dasgupta, 2009; Heal, 2007; Mäler et al., 2008; Obst et al., 2016; Remme et al., 2015; United Nations et al., 2014).

Adjusted and/or extended measures of national wealth have been proposed by Nordhaus and Tobin (1972), Weitzman (1976), Mäler and Wyzga (1976) who started the debate, which then progressed with Dasgupta and Heal (1979), Hartwick (1990), Dasgupta and Mäler (1991), and Mäler (1991) who proposed a complete system of national accounts inclusive of environmental natural resources. Lutz (1993), Hartwick (1994), and more recently Dasgupta and Mäler (2000), Hartwick (2000) provided ways to estimate shadow prices for green national accounts; Weitzman (2001), Arrow et al. (2004) and Dasgupta (2009) further expanded on the welfare theory of green national accounts.

In the European Union, key institutions such as the DG Environment in collaboration with the Joint Research Center (JRC), Eurostat and the European Environment Agency are piloting applications of ecosystem accounts (Vigerstol and Aukema, 2011; Nedkov and Burkhard, 2012; Zulian et al., 2013; Burkhard and Maes, 2017; La Notte et al., 2017; Vallecillo et al., 2018, 2019). Consortia aimed at exchanging experiences in this field have emerged, such as ESMERALDA which has built on previous ES projects and databases (e.g. OpenNESS, OPERAs, etc.).

While methods may differ among countries (Jäppinen and Heliölä, 2015; Santos-Martín et al., 2016; Parker et al., 2016; Crouzat et al., 2019) to match national ecosystem assessment standards to political contexts, resources and interests (Obst et al., 2016; Vardon et al., 2016; Schröter et al., 2016), a significant share of natural capital accounting (NCA) implementations (CBS & WUR, 2016, 2017; UN, 2019; Hein et al., 2020) have built on the SEEA-EEA framework (UN, 2014; 2017). The

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https://doi.org/10.1016/j.ecoser.2020.101207
Received 21 October 2019; Received in revised form 30 September 2020; Accepted 8 October 2020

latter represents a fundamental attempt to standardize NCA practices, by following a similar accounting structure as the System of National Accounts (SNA).

Only a small number of NCA studies have been carried out for Italy. They have mainly focused on wetlands (Alberini et al., 2007; La Notte, 2011; Bonometto et al., 2015), forests (Gatto, 1988; Goio et al., 2008; Notaro et al., 2012; Morri et al., 2014; Da Re et al., 2015; Häyhä et al., 2015), protected areas (Schirpke et al., 2015), marine ecosystems (Franzese et al., 2015, 2017; ISPRA, 2016a; Vassallo et al., 2017) and soils (ISPRA, 2016b, 2017a, 2018a), analysed as point cases. Such first-generation studies are often highly localized and scarcely replicable or up-scalable for the purpose of accounting. This article seeks to expand the geographical context of applications to the national level while improving model specificity and spatial resolution with respect to country estimates from relatively recent European-scale studies (La Notte et al., 2017; Vallecillo et al., 2018, 2019). The results significantly contribute to the ES national assessment presented in the official 'Report on the Natural Capital in Italy 2019′ and its national accounting tables.[1] In particular, our research customizes the ARIES (Artificial Intelligence for Ecosystem Services) globally customizable models and data sources (Martínez-López et al., 2019) for four different ES, by using the most appropriate model parameterizations and data officially available at the national level (see Annex I Dataset). Priorities indicated by the National Committee on Natural Capital in Italy and local data availability have been the major drivers for selecting the ES of focus: (i) crop pollination, (ii) outdoor recreation, (iii) flood regulation and (iv) water provision.

After describing the biophysical models and the monetary valuation methodologies applied, we present modelling outputs in a format that fits the extent, supply and use tables, in accordance with the accounting principles and frameworks described in the SEEA-EEA framework (UN, 2014, 2017). Finally, we discuss the limitations of the analysis and outline expected challenges for further progress of NCA in Italy.

2. Material and methods

This work has been carried out using the ARIES technology.[2] ARIES is a web-based modelling platform that identifies, customizes and connects data and model components according to the geographies and temporal contexts of interest, addressing scales from local to global (Villa et al., 2014). ARIES integrates diverse modelling techniques and types of knowledge, including quantitative and semi-quantitative data sources and expert opinion: applications of the ARIES technology are widely available in the literature (e.g. Bagstad et al., 2014; Balbi et al., 2015; Willcock et al., 2018). The unique feature of ARIES is the use of semantics and machine reasoning to connect distributed spatial data and ES modelling components. When new semantically annotated data or models, covering specific spatial and temporal extents or resolutions, are made available to the ARIES network, they can automatically substitute the more generic resources to obtain better results. Model and data customization are important for capturing local knowledge, improving credibility, and reducing the inherent inaccuracies of global or large-scale data.

This application has involved the provision of national data[3], regarded as more accurate compared to what already available in the ARIES network, as well as the customization of modelling components based on country- or region-specific knowledge. All models described in the following sections are spatially explicit and can run at different spatial resolutions (for more insights please refer to Martínez-López et al., 2019). Model outputs, which are expressed in form of dimensionless indexes, have been calibrated to absolute values using empirical observations. We also applied valuation methodologies and produced spatially explicit monetary outputs, further aggregated by geographical units to generate the accounting tables. The Extent, the Supply and the Use tables have been filled taking into account the recommendations of the SEEA-EEA guidelines (UN, 2014, 2017). These processes are described in detail in the flow charts in Figs. 1, 2, 3, and 5.

2.1. Outdoor recreation

Outdoor recreation is a cultural ES that includes all physical and intellectual interactions with ecosystems, land- and sea-scapes (Vallecillo et al., 2018). It covers the biophysical characteristics or qualities of ecosystems that are viewed, observed, experienced or enjoyed in a passive or active way by people. The recreation model aims to identify and assess areas with high naturalness potential for ecosystem-based recreation in Italy, also considering their accessibility.

2.1.1. Biophysical outdoor recreation model

The recreation supply component of the model represents areas of naturalistic value that can be enjoyed by potential beneficiaries (Annex II.1), computed through a multiplicative function of human influence and distance-driven accessibility of nature-based factors of attractiveness (elements of high environmental relevance such as protected areas,[4] mountain peaks and water bodies).

The biophysical model (Martínez-López et al., 2019) quantifies recreation demand as a weighted sum of two normalized indices, one related to a recreation-driven mobility function adapted from Paracchini et al. (2014), but originally based on Geurs and van Eck (2001), and the other related to population density, using a decay function that takes into consideration the greater or lesser inclination of the population to travel, according to the belonging demographic class.

The recreation demand component computes the likelihood that part of the population takes a day trip within a feasible maximum distance (assumed up to 80 Km one way and modifiable in the mobility function, see Martínez-López et al., 2019), using estimated travel time from targeted cities above 50.000 inhabitants (Uchida and Nelson, 2010). Therefore, the model does not capture touristic flows including overnight stays (although they can be incorporated by adjusting the mobility function). Unlike authoritative works produced in the European context (Vallecillo et al., 2018), the model does not simulate movements only within a restricted buffer around areas of high naturalistic value, but it considers the likelihood of moving from every populated area to any possible destination. A Cobb-Douglas multiplicative function (Fuleky, 2006), that relates recreation supply and demand, estimates their mutual spatial overlay, representing the outdoor recreational use. Physical use figures correspond to the number of visitors potentially reaching different sites. In order to convert the index values provided by the model into absolute values, we used a geo-database (Schägner et al., 2017) with spatial distribution of visitors counting throughout Europe and calibrated the index numbers with real data collected from the 55 available observations for Italy.

2.1.2. Economic valuation

We applied the so-called 'travel cost' method, as an alternative to other methods such as simulated exchange values (Caparrós et al., 2003,

[1] 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 to support annual planning within established social, environmental and financial goals.

[2] Official website https://aries.integratedmodelling.org

[3] In particular, we have used national LULC maps 2012 updated to 2017 with high resolution layers on soil consumption (ISPRA 2018a), higher resolution spatial layers on Italian protected areas, 20 meters resolution DEM, higher resolution rainfall and temperatures maps (ISPRA,2017b), hydrological data (Braca and Ducci, 2018), real estate values from the Italian Tax Revenue Agency Observatory for asset estimation.

[4] Official List of Protected Areas (EAUP) MATTM- National Geoportal http://www.pcn.minambiente.it/.

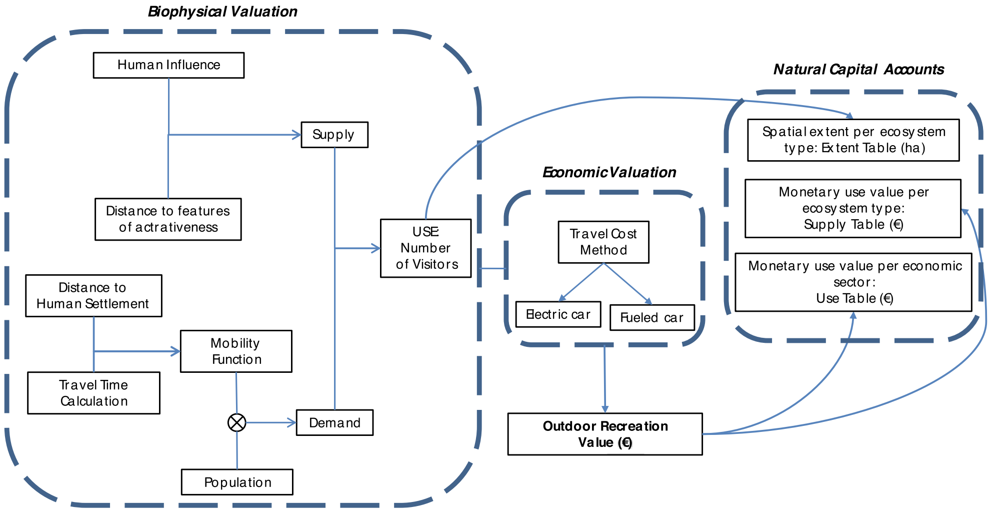

Fig. 1. Outdoor recreation service: from ecosystem service modelling to accounting tables.

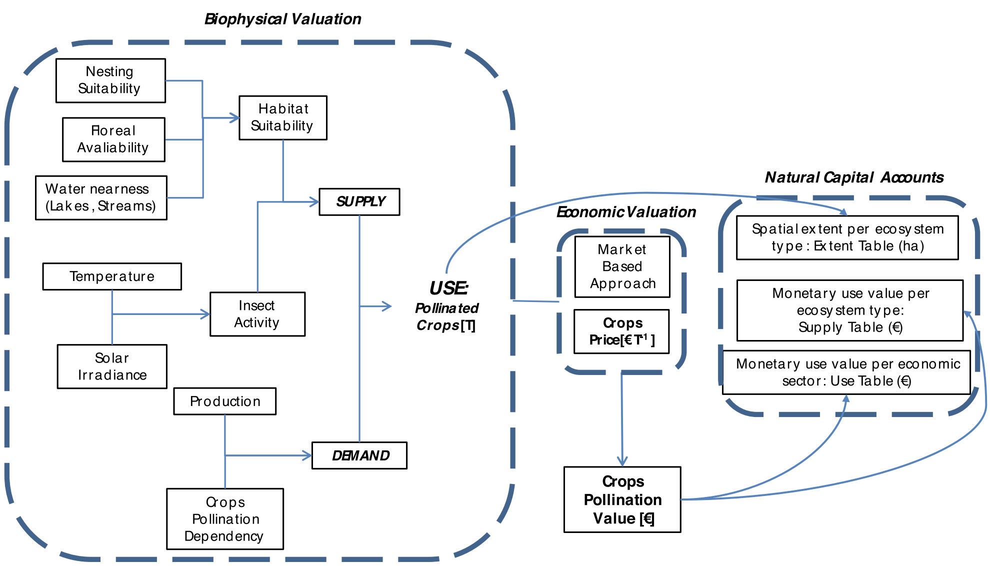

Fig. 2. Crop pollination service: from ecosystem service modelling to accounting tables.

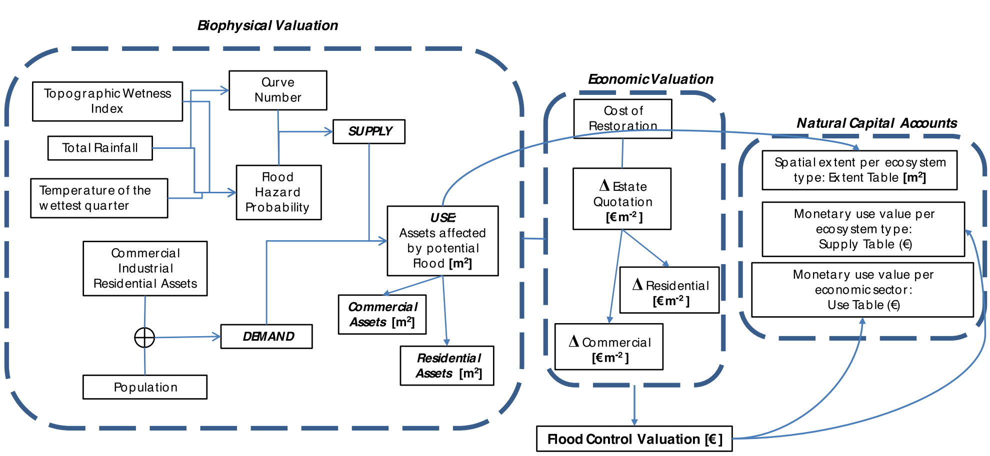

Fig. 3. Flood regulation service: from ecosystem service modelling to accounting tables.

2017) or resource rent (Remme et al., 2015). The ‘travel cost’ method has been extensively applied over the years. It was proposed by Hotelling (1949), and further developed in its operational aspects by other scholars (Clawson, 1959; Clawson and Knetsch, 1966). This approach has been used to estimate the overall financial expenses generated by recreational activities or only the fuel costs associated with visiting recreational sites (among others: Atkinson and Obst, 2016; Vallecillo et al., 2018), In this study we opted for this second option due to lack of data. Starting from the travel time used within the recreation model and considering an average speed of 60 km/h, under a combined urban and extra-urban route[5], with a fuel cost equal to 1.65 €/L[6] referred to a gasoline-fueled car, and a cost of about € 0.4/Kw h for an electric vehicle[7], we assumed the costs per km associated to a recreation experience reported in Table 1. We also assumed that a daily trip includes an average occupancy rate of two people per vehicle. The aggregate monetary value is shown in Table 3.

The flow chart in Fig. 1 describes the relationship between the biophysical and the economic valuation modules that contribute to the NCA tables for outdoor recreation.

2.2. Crop pollination

Crop pollination is an ES resulting from the fertilisation of crops by wild insects and other animals, helping to maintain or increase crop production.

Crop pollination by bees and other animals is a potentially valuable ES in many landscapes of mixed agricultural and natural habitats. Pollination can increase the yield, quality, and stability of fruit and seed crops. Indeed, Klein et al. (2007) have found that 87 of 115 globally important crops (around 70% of the total crop extent analyzed) benefit from animal pollination. Despite these numbers, it is important to realize that not all crops depend on animal pollination. Some crop plants are wind- (e.g., staple grains such as rice, corn, wheat) or self-pollinated (e.g., lentils and other beans), with no need of animal pollinators to successfully produce fruits or seeds. Klein et al. (2007) provides a list of crops and their pollination requirements that can help identify whether crops in a region of interest may benefit from wild animal pollinators.

2.2.1. Biophysical crop pollination model

A wide range of animals can be important pollinators (e.g. flies, birds, bats), but bees are the most important for most crops (Free, 1993). In order for bees to live in a habitat, they need two elements: suitable places to nest and sufficient food (provided by flowers) near their nesting sites (Vallecillo et al., 2018). Pollinators are then capable to fly to nearby crops and pollinate them as they collect nectar and pollen. As a result, this model focuses on the resource needs and flight behaviors of wild bees and the pollination service associated to some crops. Although honey bees are sometimes considered as an options to mitigate the lack of wild pollinators, the state-of-art literature suggests that wild pollinators are much more effective and thus not fully substitutable (Garibaldi et al., 2013; Winfree et al., 2018).

The biophysical model (Martínez-López et al., 2019) calculates pollination supply as pollinator occurrence, or the ability of the environment to support wild insect pollinators, as a function of the insect forage activity (Corbet et al., 1993) and the habitat suitability, which is in turn a function of nesting suitability, floral availability and proximity to water (rivers, lakes and streams).

Next, the model estimates pollination demand as the product of each pollination dependency rate (Klein et al., 2007) and the relative production for 30 crop types (see Annex II.2) requiring insect pollination for optimal yields (Monfreda et al., 2008). All pollination analyses are run at 1 km resolution, which is comparable to the maximum distance of most insect pollinator flights (Gathmann and Tscharntke, 2002; Danner et al., 2016). We used the agricultural areas mapped in Monfreda et al. (2008) to spatially distribute the actual national total production[8] of each pollination dependent crop over the corresponding surfaces and we then considered only the crops where pollination supply is present (defined as ‘met demand’). With respect to notable reports developed at EU level (Vallecillo et al., 2018), we have extended the analysis to a much wider variety of Italian crops (30) benefited from agricultural pollination.

2.2.2. Economic valuation

Among the available methods (Allsopp et al., 2008; Breeze et al., 2016; Hanley et al., 2015; Melathopoulos et al., 2015), we applied a market-based method taking into account crop market prices. In this way we ensured the alignment with the national accounting system, as the pollination service contributes to agricultural production volumes that are already included in the national accounts (UN, 2014). Due to a lack of data on the agricultural production of individual farms, data from the literature on the different agricultural yields at the national level were used to allocate the total national aggregates of crop production to the spatial extent of each individual crop. This constitutes a drastic approximation that highlights an urgent need for more granular farm data to improve the assessment.

The share of crop production attributable to pollination has been calculated by multiplying the outcome from the use values (the portion of ‘met demand’ identified by the dependency ratio) and the market price[9] for each of 30 different crops (Annex II.2). This component of production would not exist without the ES, and therefore it represents the additional value deriving from the presence of wild pollinators. This valuation method does not account neither for the partial substitutability of wild pollinators with honey bees or the potential re-allocation of labour and capital assets that would result from a reduced production. This may lead to a minimal overestimation of the contribution and value of the service.

Eventually, the model overlays supply and demand to produce grid-scale pollination use values. The flow chart in Fig. 2 describes the relationship between the biophysical and the economic valuation modules that contribute to the NCA tables for pollination.

2.3. Flood regulation

Flood regulation is an ES that results from the capacity of vegetation and soils to retain excess runoff from rainfall. The reduction in the speed and volumes of water flows attributable to ecosystem features (primarily vegetation) results in reduced damage to the human environment. The service is delivered where a lower risk of flooding is attributable to the natural mitigation of this risk through water retention. The analysis identifies the Italian population affected and focuses on the impact that potential floods have on residential and commercial assets.

Table 1
Energy consumption and costs for different sources of energy.

Energy consumption of electric vehicle (Kw/h)	*Cost (€/km)*
0,28	**0,11**
Fuel consumption of gasoline-fueled car (l/km)	*Cost (€/km)*
11,8	**0,14**

[5] Data processing from the Copert model, http://emisia.com/products/copert-4

[6] Data processing from https://dgsaie.mise.gov.it/prezzi_carburanti_mensili.php

[7] Data processing from https://www.arera.it/it/index.htm

[8] http://arearica.crea.gov.it/report_d.php.

[9] https://arearica.crea.gov.it/report_d.php.

2.3.1. Biophysical flood regulation model

The flood regulation ES is modeled according to Martínez-López et al. (2019). This model constitutes a simplification of previously published global or continental-scale ones (Stürck et al., 2014; Ward et al., 2015). The model uses the flood hazard probability index, which accounts for physical and bioclimatic parameters (Kirkby and Beven, 1979; Manfreda et al., 2011) characterizing the ecosystem capability to control a potential flood. Floods are mitigated by water retention from soil and vegetation, which regulate the excess runoff from rainfall (Zeng et al., 2017; Soil Conservation Service, 1985). Precipitation in each year of the analysis drives the computation of runoff from storm events, which is repeated twice: firstly using the actual land cover data and secondly by considering all vegetated sites in each watershed as impervious areas. The resulting runoffs are compared to establish the reduction in runoff due to vegetation. The reduced runoff is then intersected with assets to determine the service use.

The flood regulation demand is computed as an index on the basis of population or assets distribution within the area at risk of flooding. This provides an assessment of people and property exposure to potential flood risk. The model estimates the overall ES use value through a multiplicative function between the supply and the demand.

2.3.2. Economic valuation

Among the available methods (see for example Ricardo Energy & Environment, 2016; Brookhuis and Hein, 2016), we chose to apply an innovative cost-based method, which belongs to the avoided damage methodologies. Assuming that the ES no longer exists, the expected damage is assessed for some categories of assets (residential and commercial buildings) affected by a potential flooding in the areas identified by the use of the service. The potential restoration cost (ISPRA, 2013) is then applied as a proxy to estimate the ES avoided damage value.

The intensity of flooding is usually given by an indicator of the height level reached by the water above the road level, which is assumed to not exceed 3 meters from the ground floor. The potential damage is calculated by overlapping the potential floodable areas with the presence of buildings throughout the national territory,[10] and considering the corresponding restoration cost of the concerned buildings.

This methodology for the economic assessment, applied on an experimental basis, takes into consideration only potential damage to residential and commercial structures, leaving to future analysis the estimate of damage to people health, infrastructures (cost of restoration or cost of disruption in the infrastructures' network service), economic activities and crop fields (disruption in production activity):

$$V = \sum_{x_i=1}^{n} S_{x_i} \cdot (Q(R)_i - Q(NR)_i) \quad (1)$$

where the sum of the S_{x_i} represents the built surface affected by the potential flooding identified by the use indicator; $Q(R)_i$ is the real estate value[11] of *a renovated unit* expressed in €/m^2 in the area; $Q(NR)_i$ is the real estate value[12] of a *non-renovated unit* in the same area expressed in €/m^2. Following a flood event, we assumed that each property needs complete restoration. In this circumstance the difference between the market value of an apartment to be restored and one in perfect conditions may be considered as a proxy of the restoration cost for the damaged structures.

One main limitation of this approach derives from the approximation in quantifying both exposure and vulnerability of assets, which depends very strongly on the specific element considered. Depending on the type of building and the state of maintenance, the damage to the structure caused by a flood event theoretically can vary from small to complete destruction. The assessment of expected damage may be even more problematic in complex urban areas, with the presence of artistic and cultural heritage.

The flow chart in Fig. 3 describes the relationship between the biophysical and the economic valuation modules that contribute to the NCA tables.

2.4. Water provisioning

Water provisioning is an ES resulting from natural surface and ground water bodies that provide water for drinking and other human uses. The Hydrological Balance GIS Based (BIGBANG) model, developed by ISPRA at the national scale (Braca and Ducci, 2018), was used to produce estimates of the total hydrological balance including total precipitation, real evapotranspiration, recharge of the aquifers or infiltration and surface runoff, covering the entire national territory.

2.4.1. Biophysical water provisioning model

The BIGBANG model is based on the Thornthwaite and Mather approach (Thornthwaite and Mather, 1955), which simulates the hydrological components using precipitation and temperature data along with land use data and information on hydraulic and geological characteristics of the land. The BIGBANG water balance equation is illustrated in Fig. 4:

where P is the total precipitation, E is the real evapotranspiration, R is the superficial outflow, G is the recharge of the groundwater table and ΔV is the variation of the water content in the soil, whose (cumulated and balanced) contribution is considered to be approximately zero on an annual basis (Fig. 4). Starting from the evaluation of the amount of water that exceeds the storage capacity of the ground (Toth et al., 2013), it is possible to evaluate the surface runoff (R) and the groundwater recharge (G), based on the potential infiltration coefficient (Celico, 1988).

The hydrological balance is strongly affected by the value of the meteoric flow and by the assessment of evapotranspiration. Data are interpolated using geo-statistical techniques, therefore particular care must be given to the spatial interpolation procedure of the monthly rainfall data in the first case and temperature in the second case (ISPRA, 2017b).

The balance scheme works at a resolution of 1 km, which is quite coarse for local assessments, but acceptable for national ones. Recharge and runoff do not depend directly on soil qualities, but solely on potential infiltration coefficient parameterized on hydro-geological basis (Celico, 1988). This consists of only 15 possible values that cover all the diversity of the Italian territory. In addition, the storage of water in artificial lakes and water bodies or horizontal exchanges between cells is not modeled (Braca and Ducci, 2018). In any case, thanks to the capacity of the model to integrate data on land cover and use, it is possible to estimate the variation in the variables of the hydrological balance according to the soil consumption in different periods (ISPRA, 2016b, 2017a, 2018a). The increase in surface runoff is considered in this case a proxy of the water volume to be further managed.

2.4.2. Economic valuation

Among the available methods discussed in literature (see for example Kumar, 2005; Remme et al., 2015), we applied a market-based valuation known as "resource rent" (Badura et al., 2017). The resource rent value is defined as the difference between the benefit price and the unit costs of labour, produced assets and intermediate inputs.

No established resource rent value exists in Italy for water resources, which are broadly seen as a public good. However, it can be argued that the return on invested capital, applied by private water management companies, is in reality a vested rent deriving from the control of the

[10] Data processing on CLC 2012.

[11] Real Estate Observatory (Tax Revenue Agency).

[12] Real Estate Observatory (Tax Revenue Agency).

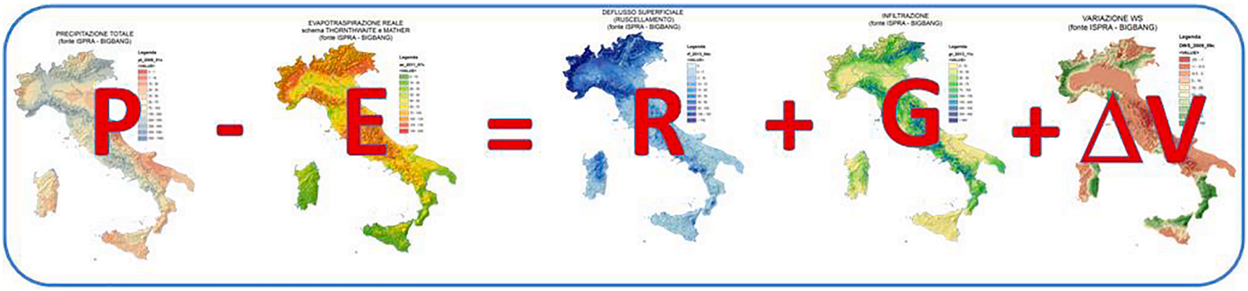

Fig. 4. Equation of the hydrological balance.

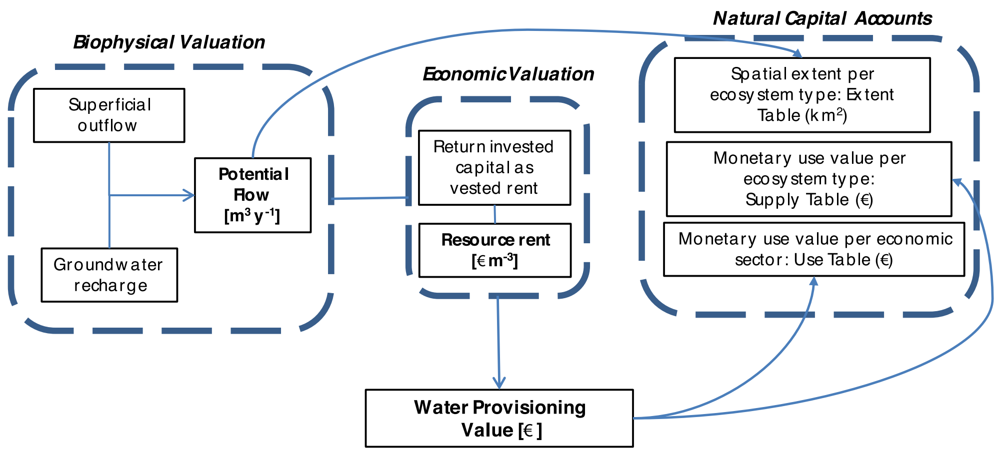

Fig. 5. Water provisioning service: from ecosystem service modelling to accounting tables.

resource. The rate of return on invested capital, which has been capped by the national legislation of 1996[13] at 7%, is still applied by companies all over the country. Thus, we used the current return on invested capital as reference (i.e. a proxy for the resource rent) for our estimate of the monetary value of the water provision service provided by the environment and already included in the national accounts. On average, this return on invested capital corresponds in Italy to the 10% of the whole tariff. We finally considered the volumes of water collected[14] and the percentages of consumption assigned to the different classes of users[15], with a water tariff of 1,29 €/m^3 [16]for potable use and an average value between 0.04 and 0.07 €/m^3 for irrigation use (Arcadis, 2012), to estimate the monetary value for the two different uses (Table 9). The flow chart in Fig. 5 describes the relationship between the biophysical and the economic valuation modules that contribute to the NCA tables:

3. Results

3.1. Outdoor recreation extent, supply and use tables

The extent of the outdoor recreation ES (Table 2) describes the spatial extent of the use calculated by the biophysical model, spatially distributed over the different types of ecosystem. The terrestrial ecosystem types considered (Maes et al., 2014) have been selected on the basis of the most updated high resolution layers available for Italy (ISPRA, 2018b).

The supply table (Table 3, right side) describes which type of ecosystem provides different quantities of the ES use (UN, 2014). As a result, it is possible to understand the origin of the service from the various types of ecosystem. The provision of the ES, expressed in monetary terms, is given by the number of visits (Annex II.1) associated to the travel cost of each visit (Badura et al., 2017). Two scenarios have been considered for the monetary calculation: the first one assumes households moving with gasoline-fueled cars while the second one uses electric cars as mean of transportation. The use table (Table 3, left side) indicates which economic sectors (including households) benefit from the ES use (La Notte et al., 2017). The same total use value, already distributed among ecosystems of origin in the supply table, is allocated to the economic sectors.

Spatial maps facilitate the identification of sites with high recreation supply and demand at the same time, where outdoor recreation daily trips are most likely to happen. Since the model simulates visits based on two main criteria: the naturalistic value and the proximity of the user population (whose behavior is modeled through a mobility function decaying with distance); the combination of these criteria rewards forest and woodland as destinations of the recreational experience. At the same time city parks are undervalued with a travel cost method, due to their proximity to users. Fig. 6 illustrates (left side) areas where a value of the use index is closer to one (red colored). Areas with low supply or demand receive values closer to zero (blue colored). The highest values of the monetized use in the outdoor recreation service (Fig. 6, right side) are represented by the red colored areas.

3.2. Crop pollination extent, supply and use tables

The extent of crop pollination ES describes the spatial extent of the

[13] Standardized method for defining cost components and determining the reference tariff of the integrated water service (GU General Series n.243 of 16–10-1996). However, the results of the referendum in Italy (June 2011) established to change the methodology for defining the tariff on water by eliminating the component "return on invested capital".

[14] Focus ISTAT 'World Water Day' 2018 (https://www.istat.it/it/files//2018/03/EN_Focus-acque-2018.pdf).

[15] Focus ISTAT 'World Water Day', 2017.

[16] Data processing from ARERA data on national average water tariff (www.arera.it).

Table 2
Outdoor recreation extent table.

Outdoor Recreation *Italy*	Type of ecosystem							
	Green urbanareas	Crop land	Grass land	Heathland and Shrubs	Wood land and forest	Wet land	Rivers and lakes	Others[20]	Total
				Extent table (ha)					
2018	7875	14,155,164	2,112,489	2,307,123	10,629,819	88,029	248,274	585,027	30,133,800

[20]The 'Others' category refers to a number of remaining terrestrial types that are less relevant when taken individually.

Table 3
Outdoor recreation supply and use tables.

	Type of economic sector				Type of ecosystem								
	Primary sector	Secondary sector	Tertiary sector	Households	Green urban areas	Crop land	Grass land	Heath land and Shrubs	Wood land and forest	Wet lands	Rivers and lakes	Others	Total
Outdoor Recreation *Italy, € million*													
		Use table				*Supply table*							
2018 (Gasoline vehicle)			8357	0,66	2486	658	745	4091	10	40	325	8357	
2018 (Electric vehicle)			6565	0,52	1953,22	516,98	585,34	3214,25	7,86	31,43	255,35	6565	

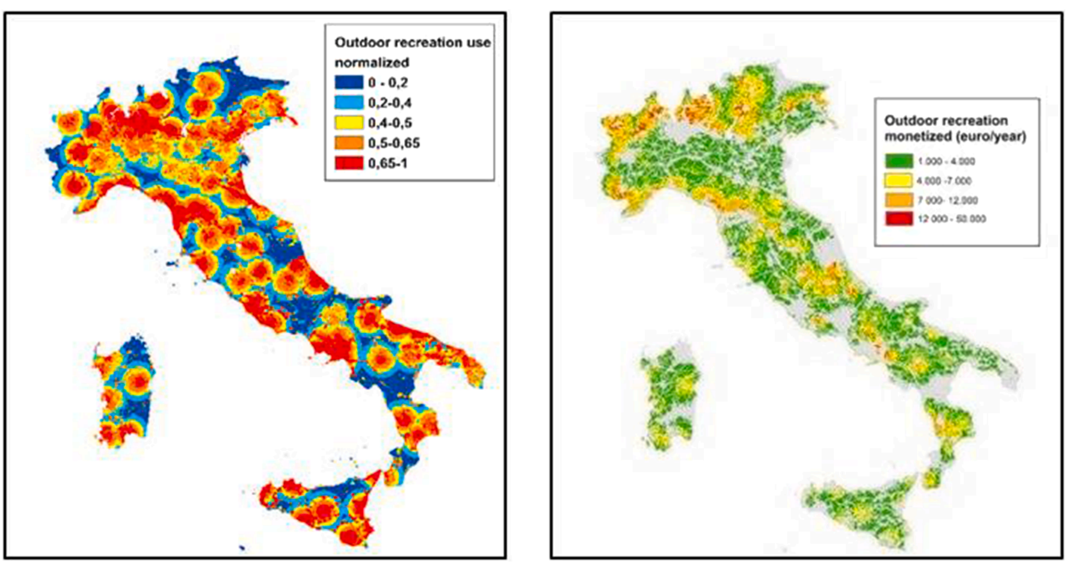

Fig. 6. Maps of normalized and monetized use value of the outdoor recreation service per year with a resolution at 300 m.

Table 4
Crop pollination extent table.

Crop Pollination *Italy*	Type of ecosystem								
	Green urban areas	Crop land	Grass land	Heath land and Shrubs	Wood land and forest	Wet land	Rivers and lakes	Others	Total
				Extent table (ha)					
2018		1,448,454							

ecosystem types providing the service (Table 4), as computed in the crop pollination model.

Considering the extent of the pollinated crops and the extension of the Italian agricultural area, around 12,9 Mha (ISTAT, 2010), it follows that pollination occurs in around 11% of all croplands. The supply table (Table 5, right side) shows from which ecosystem type the ES is produced while the use table (Table 5, left side) indicates which economic sectors benefit from the ES. The share of the "met demand" values,

Table 5
Crop pollination supply and use tables.

	Type of economic sector				Type of ecosystem							
	Primary sector	Secondary sector	Tertiary sector	House holds	Green urban areas	Crop land	Grass land	Heath land and Shrubs	Wood land and forest	Wet lands	Rivers and lakes	Others
Crop Pollination *Italy, € million*		*Use table*					*Supply table*					
2018		1939				1939						

which represents the contribution of the pollination service to crop production, is allocated to the agricultural (primary) sector (see also Annex II.2).

The pollination use index values range from 0 to 1 and are marked in different colors (Fig. 7, left side): the values are placed in the areas where the service is present with different intensity. Grey values represent *un-met* demand, while red areas represent “hot spots” where the use index value is higher (i.e. 0.4 to 1). The Fig. 7 (right side) quantifies the monetized crop pollination use values.

3.3. Flood regulation extent, supply and use tables

The extent of the flood control ES (Table 6) is represented by the areas and the population where the service use is present as output of the biophysical model.

The supply table (Table 7, right side) does not show from which ecosystem type the service is produced, as it was for the previous ES accounting applications, but the affected assets on which the service has an impact. The monetary values, either in the supply or use table, are computed in Eq. (1).

The use table (Table 7, left side) indicates which economic sectors benefit from ES. The same total use value attributed by the model to the flood control service in the supply table, is allocated to the economic sectors in this case households/tertiary sector and secondary sector.

The maps in Fig. 8 shows the use of the service, for type of affected assets, that is present where there is a lower o medium risk of flooding and ecosystems are currently able to mitigate it naturally through water retention.

Population and assets that mostly use the flood risk regulation service are located within the provinces of Turin in Piedmont, Milan, Como, Varese, Lecco in Lombardy, Padua, Vicenza, Treviso in Veneto, Udine and Pordenone in Friuli, the province of Rome in Lazio, Naples in Campania and Catania and Messina in Sicily.

3.4. Water provisioning extent, supply and use tables

The water provisioning accounts comply with SEEA-EEA guidelines only where feasible, due to considerable lack of spatial data on water withdrawals (especially the direct ones), storage in artificial basins and network losses.

The extent of the water provision ES is given in Table 8 by the areas where the potential flow, which represents the superficial outflow plus the net groundwater recharge, is present (Fig. 9). We do not consider in the computation neither the external inflow nor change in artificial reservoirs.

The supply table (Table 9 , right side) shows which ecosystem type generates the service flow. In this case, the flow of renewable water, including superficial outflow plus the net groundwater recharge, that is annually and naturally produced (m^3/year), represents the ‘potential flow’ spatially shown in Fig. 9.

The use table (Table 9, left side) indicates which economic sector benefits from the ES. The actual flow of water abstraction for a given period (m^3/year) is allocated to households and primary sector. Data availability is provided only for two sectors: for 15,975 mln$\cdot m^3$ (primary sector) and 9490 mln$\cdot$ m^3 (household)[17].

The map in Fig. 9 highlights that the areas with the greatest water provision flow are those in the northern regions, fed by alpine streams and characterized by a significant supply of surface and underground water. On the other hand, streams that have shorter and more irregular paths are located along the Apennines, the central ridge, and in the South where they correspond to lower supply values. Thus circulation of groundwater is still abundant in the central regions, while in the south

[17] Data processing on ‘Focus Giornata mondiale dell’acqua 2018′ (www.istat.it).

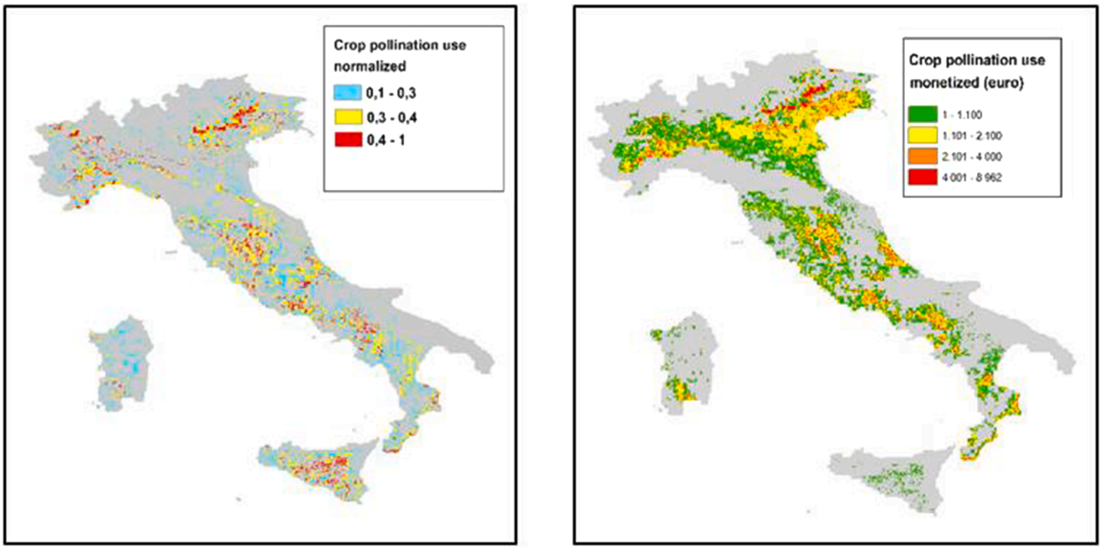

Fig. 7. Maps of normalized and monetized use value of the crop pollination service. On the left side is illustrated the variability of the Use normalized index and its range of dimensionless values, on the right side the range of variability of the monetized Use values in euro.

Table 6
Flood regulation extent table.

	Type of affected asset		
Flood Regulation *Italy*	Commercial/ Industrial uses *(m^2)*	Residential/ housing *(m^2)*	Population (number of inhabitants)
	Extent table		
2018	31,457,272	124,031,033	3,596,805

Table 7
Flood regulation supply and use tables.

Type of economic sector					Type of affected asset		
Flood Regulation *Italy, € million*	Primary sector	Secondary and tertiarysector	Households	Total	Commercial/ Industrial uses	Residential/ housing	Total
		Use table			*Supply table*		
2018		7770	39,070	46,840	7770	39,070	46,840

the usable groundwater is rather scarce and confined within short stretches of coastal plain (Campania and Calabria), where they often undergo phenomena of saltwater intrusion.

As a general overview, a summary monetary use values (Table 10) in absolute terms of the four ES in 2018 follows:

As far as beneficiaries are concerned, households represent the sector that most benefits from outdoor recreation, flood regulation and water provisioning, while agriculture is the only beneficiary from crop pollination.

4. Discussion and conclusion

Overconsumption of natural resources, unsustainable management practices, land degradation and the effects of climate change deeply affect ES supply. The loss of supply results in economic losses, which are still rarely taken into account by national economic policies. Thus national ES accounting is a useful tool for assessing the change of economic value by the socio-economic system as a whole. Considering the urgency of the environmental crisis and the legal mandate[18] to implement environmental accounting schemes in Italy, immediate actionability and replicability of the assessment methods are key necessities. We consider this study as part of an experimental process and a first significant attempt to establish a workable monitoring strategy for the future.

Although methodologies to define ES-related flows of biophysical and monetary values to human societies may vary depending on the service and its characteristics, maintaining internal coherency and comparability is one of the main challenges of NCA. Notwithstanding the guidelines included in the SEEA-EEA framework (UN, 2014), accurate ES accounting is still very challenging and demanding in terms of data: substantial work is needed to adapt and test methods that can be and remain consistent with national accounts. This is particularly true for monetary valuation. A long-running dispute in NCA concerns the adequacy and relevance of exchange values versus welfare values. The choice about the valuation approach depends mainly on the aim of the assessment (UN, 2017). When the purpose of accounting is to integrate ecosystem values with the SNA, then exchange value methods would appear to be the only one compatible. If the primary aim is, instead, to highlight the contribution of the ecosystems to well-being, welfare values, which are related to changes in consumer surplus, would become eligible (Obst et al., 2016). In this study, we embraced the first approach and avoided the use of shadow pricing methods, for a better alignment

[18] Law n. 221/2015.

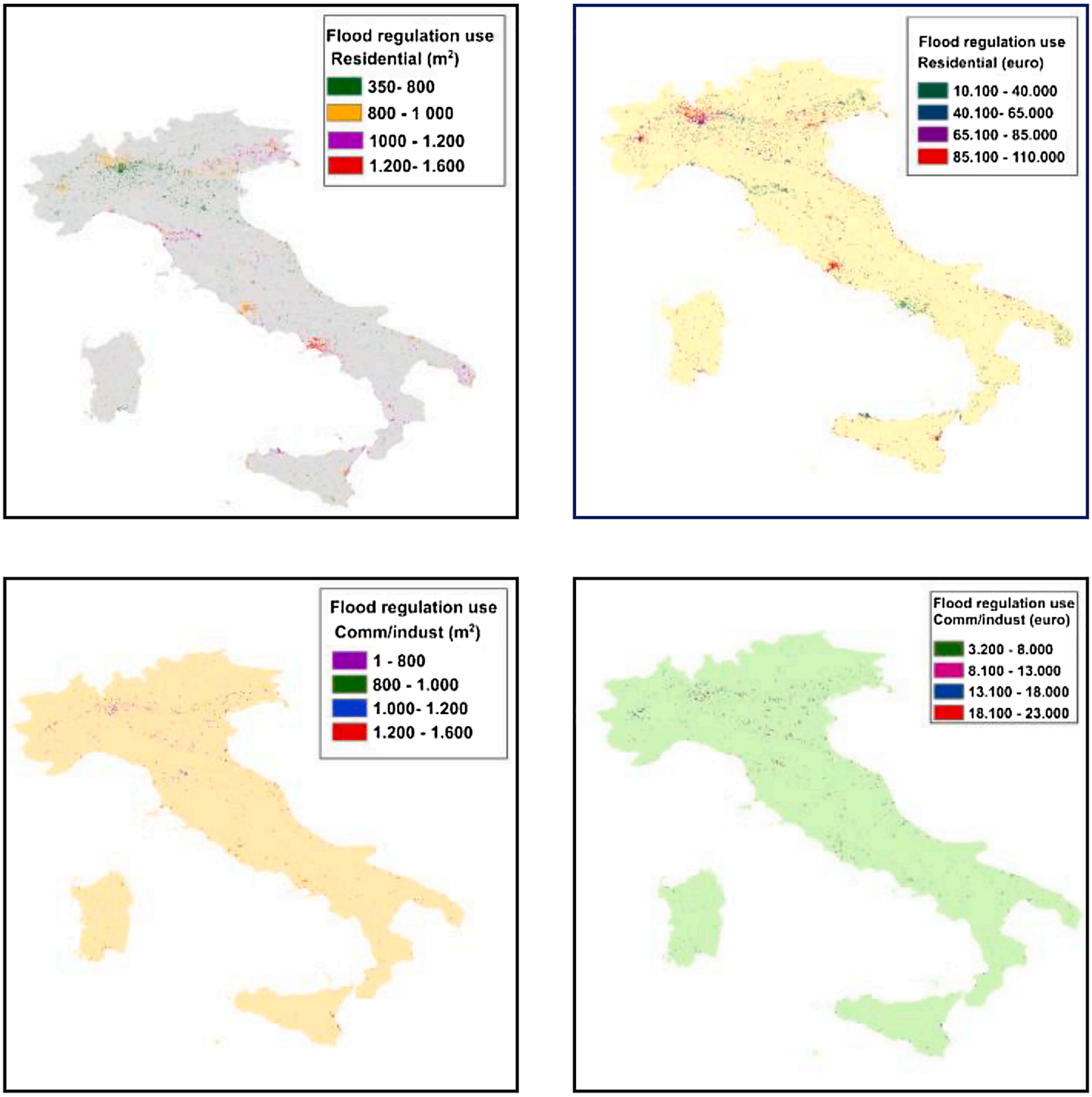

Fig. 8. Maps of physical and monetized use for the flood regulation service.

Table 8
Water provision extent table.

Water Provisioning *Italy*	Type of ecosystem							
	Green urban areas	Crop land	Grass land	Heath land and Shrubs	Wood land and forest	Wet land	Rivers and lakes	Total
				Extent table (km^2)				
2018	37,889	31,422,452	9,543,560	7,655,294	48466,32	101,617	974,48	98,202,021

with national accounts.

Our study addressed regional- and national-scale models for four different ES, showing how spatial models of ES flows can be used in the context of ecosystem accounting. The ES modelling provides the basis upon which the monetary valuation and the accounting tables are generated, in accordance, when feasible, with the guidelines described in the SEEA-EEA framework (UN, 2014, 2017). In this application ES are firstly assessed in physical terms, using indicator-driven equations or, when appropriate, process-based models, which represent the functions of the ecosystem and the interactions between ES demand and supply. Although the described application has been achieved in two separate steps, first by modelling ES within the ARIES platform and second by applying the monetary valuation methodology, we envision the possibility of integrating both phases in a single user-friendly platform which can take into account user-provided data and parameters and preferences on valuation methods. We argue that this vision should be pursued in parallel with the ongoing effort on standardization by SEEA-EEA for a widespread diffusion of NCA. Our application identifies several

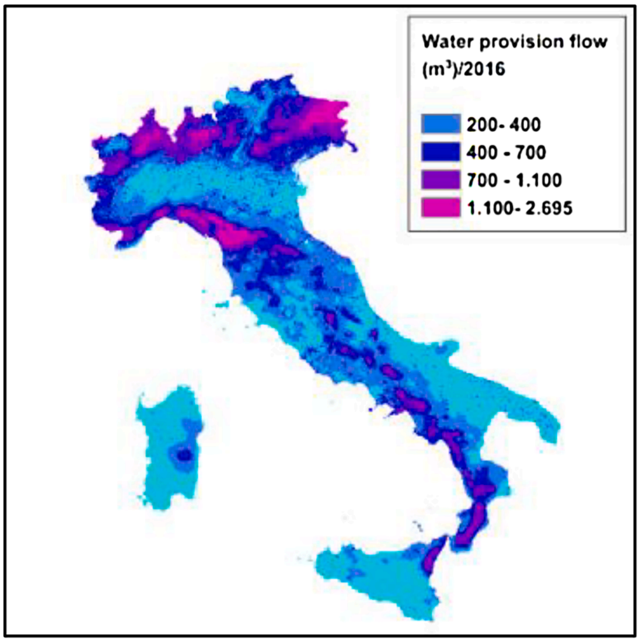

Fig. 9. Map on water provisioning flow values.

modelling challenges that need to be addressed before a methodological path for integrated ecosystem and economic accounting may be considered rigorous and reliable enough to provide a basis for standardization. Here we highlight some of the main challenges faced for each ES problem area.

Regarding outdoor recreation modelling, the calibration of the modelling output is currently hindered by the lack of monitored access data on visitors to recreational areas. As a consequence, our analysis had to rely on few calibration points. A larger survey on the number of visitors in more nature-based locations might greatly improve the overall estimates. Indeed, nature-based measures are an ideal strategy to combine conservation and local development (Vallecillo et al., 2018), and our estimates on the economic value of outdoor recreation may confirm the importance of supporting such policies.

Regarding crop pollination, the main limiting factor was related to the harvested area and locations of the potentially pollinated crops. In absence of spatially disaggregated national data we made use of a coarse resolution global layer by Monfreda et al. (2008), which is built using national statistics. Future applications might significantly improve with information provided by Earth Observation technologies as it's already happening for land cover types. However current projects in this field, are mostly focusing on non-pollinated crops, because of their global relevance as staple food.

Concerning the flood regulation service, an important innovation is related to the fact that we do not consider areas that are currently considered at risk in terms of hydraulic hazard; rather, we look at areas that might be at risk in the absence of service. The monetary value is limited only to the avoided damage on buildings, postponing assessments related to infrastructure, health and agriculture to future developments.

Modelling the water supply provision service was highly challenging because currently there is no overall accounting of water resources withdrawn and collected which, net of losses, would constitute the use of the service. Therefore, the model computes the ES flow using physically based equations. A further critical point is that there is no homogeneous pricing across the national territory; therefore, monetary values had to be estimated on the basis of average rates.

Other areas of improvement which apply to all four modelling strategies include more comprehensive consideration of ecosystem conditions and a higher temporal resolution to represent more precisely

Table 9
Water provisioning supply and use tables.

	Type of economic sector				Type of ecosystem								
	Primary sector	Secondary and Tertiary sector	Households	Total	Green urban areas	Cropland	Grassland	Heathland and Shrubs	Woodland and forest	Wetlands	Rivers and lakes	Others	Total
Water Provision *Italy*		*Use table (€ million)*						*Supply table (million m³/year)*					
2018	87,87		1224,21	1312,08	37,889	31422,45	9,543,560	7,655,249	48,466,732	101,617	974,447	10716,82	115218,84

Table 10
Summary table of monetary use values for four ecosystem services.

Ecosystem Services	*Use (Billion €)*	*Use (€/ha)*
Water provisioning	1,3	*N/A*
Flood Control	46,8	Residential areas: 3,150,000 Commercial areas: 2,470,000
Outdoor recreation	8,4	275
Crop pollination	1,9	1339

dynamic process over a certain accounting period. This is the case for hydrological processes, which can better capitalize on existing data from weather stations and river gauges.

Even though the employed ES models are still relatively coarse in spatial and temporal scale, compared to more fine-grained and realistic ecological models, we argue that they are appropriate for accounting purposes. On the one hand, they are accessible, avoiding the need for parameter- and data-hungry models and the associated complexity of use. On the other hand, thanks to the ARIES semantic-driven technology they can adapt to the user-selected spatio-temporal context to produce context-dependent results by using the most appropriate data and model parameterizations available in the ARIES network, enabling rapid assessment and largely automated operation without loss of transparency. This is crucial since in an age of rapidly growing data availability, the standard for "best available data" changes quickly. As new datasets for model inputs with greater accuracy, spatial and temporal resolution become available, ES assessments can be updated by re-running the models and aggregating the results over shorter periods that better fit the inherent temporal scaling of the processes underlying ES provision.

This article is based on a one-time assessment (2018) of the estimated value of four selected ES. Future NCA studies in Italy will build on this and focus on the change in value over time. Although valuing total stock of natural capital has been criticised on different grounds (Heal et al., 2005), a clearer picture of the economic relevance of ES in Italy can lead to highlight policy implications as well. In general, the same policy actions can have multiple benefits on several ES, thus identifying synergies among policies at different scales is key.

Land management and maintenance of the countryside and forestland, which are the main destinations for the outdoor recreation service and represent the typical Italian landscape, are essential. Such awareness should lead to devising national policy that can support local administrators in enhancing protection of natural areas and developing nature-based outdoor recreation facilities (e.g. bike and walking paths, green infrastructure). A well-devised national policy could push the income generated by this ES much beyond the potential 8.4 billion € estimated by our study.

Similar policies (e.g. planting wild flowers in green infrastructures, help farmers to reduce the use of pesticides) could act in synergy in rural areas to improve the suitability of the landscape for pollinator nesting and foraging, particularly in the vicinity of crop fields that depend on pollination. Crop pollination is likely to be contributing around 10% of the economic value to a sector with a national added value of around 29 billion €. Decision-makers can use in different ways information on pollinators, their abundance across a landscape, and the pollination services that are provided in several ways. Firstly, with maps of pollinator abundance and crops that need them, land planners could predict consequences of different policies on pollination services and income to farmers (Priess et al., 2007). Secondly, farmers could use these maps to locate crops efficiently, given their pollination requirements and predictions of pollinator availability. Third, institutions could use these outputs to optimize investments that benefit both biodiversity and farmers. Finally, governments or other organizations proposing payment schemes for ES could use the results to estimate who should pay whom, and how much.

Italy is already extremely concerned with hydro-geological risk, but the estimated potential flood damage (46.8 billion €) mitigated by natural vegetation can clarify its real magnitude, being much higher than the actual damage of 2019 flood events in the country (3.58 billion)[19]. Again, nature is providing a huge value in terms of protection from flood events thanks to its water retention capacity. This must be better taken into account by national land planning policies.

Finally, the magnitude of the figures estimated for water provision can give an idea of the importance of protecting natural areas in the mountain regions of Italy. Here it must be noted that we adopted a conservative approach for valuing water that takes into account only the direct use of the resource, likely leading to an underestimation of the total value we would have had by considering also the potential indirect impact on the primary and secondary sectors (consequences from unavailability of water).

Overall the described application has demonstrated the feasibility of moving towards a widespread application of SEEA-EEA compliant country-based accounts using globally available ES models and exchange value-based valuation methods. This is one of the first studies made available at such geographical scope (Italy) using the ARIES technology, which is poised to automate accounting routines for producers of natural capital accounts, capitalizing on both global and local data and parameters, while respecting the ownership and return on investment of user-provided information. As such, this study will pave the way to a new wave of country-based applications which will deliver an easy to use NCA technology for a more sustainable world.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research is supported by the Basque Government through the BERC 2018-2021 program and by the Ikertzaile Doktoreentzako Hobekuntzarako doktoretza-ondoko Programa and by Spanish Ministry of Economy and Competitiveness MINECO through BC3 María de Maeztu excellence accreditation MDM-2017-0714.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2020.101207.

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[19] Data processing from: Dipartimento Nazionale della Protezione Civile; Centri Funzionali Regionali di: Calabria, Toscana, Prov. Autonoma di Trento; LAMMA-Regione Toscana; OSMER-Friuli Venezia Giulia; ARPA Sardegna, ARPA Piemonte, ARPA Calabria, ARPA Veneto, ARPA Emilia Romagna, ARPA Toscana; MiPAAF; Atti e Decreti del Governo della Repubblica (pubblicati su G. U.); Atti e Decreti delle Giunte Regionali; http://www.protezionecivile.it; www.ilgiornaledellaprotezionecivile.it; http://polaris.irpi.cnr.it; www.nimbus.it; www.meteoweb.eu; www.ilfattoquotidiano.it

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