Ecosystem services supply in protected mountains of Greece: setting the baseline for conservation management

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ABSTRACT
The mapping and assessment of ecosystems and their services, an initiative under the EU Biodiversity Strategy to 2020, sets the basis for national ecosystem assessments in EU Member States, including Greece. The highly diverse and heterogeneous Greek landscape provides multiple ecosystem services (ES) and benefits to society. However, the rich knowledge base corresponds to limited research to support a national ecosystem assessment in Greece. In this paper, we apply a rapid method to map ecosystem types and quantify ES supply provided by mountainous protected areas. Using habitat type level data, we created a detailed ecosystem type map that was used as a baseline to assess the supply of provisioning and regulating and maintenance ES. We also applied a site-oriented approach to record and score the ES supply in each protected area. Summing up individual ES supply resulted in a total ES supply map which was used to identify ES hot spot areas within the Greek Natura 2000 mountainous sites. The results: (1) corroborate the hypothesis that protected areas should be treated as high value bio-physical and social-cultural complexes accounting for a significant part of the national capital; (2) highlight data gaps at the national level and limitations of ES mapping methods under such data restrictions; (3) are intended to provide to stakeholders and decision-makers, baseline information for future applied research and conservation management actions.

Introduction

With the adoption of the Habitats (92/43/EEC) and Birds (2009/147/EEC) Directives (Council of the European Communities 1992 and Council of the European Communities 2009, respectively) and the establishment of the Natura 2000 Network of Protected Areas (PA), all EU Member States are conducting surveillance and monitoring programs on the conservation of natural habitats and wild fauna and flora to maintain biodiversity. In the past 25 years, following the obligations of those Directives, a vast amount of ecological data and information has been collected and analyzed on habitat and species conservation status, the habitats’ spatial distribution and land cover, and pressures and threats in and around each protected area. Greece is a biodiversity hot spot in the EU within the Mediterranean biogeographical region (Georgiou and Delipetrou 2010; Dimopoulos et al. 2013) and hosts a network of 419 protected Natura 2000 sites (Special Areas for Conservation: SACs and Special Protection Areas: SPAs) covering about 27% of its national land territory. Out of those, 37% of SACs are mountainous PAs.

Mountain landscapes encompass high species diversity (e.g. by providing habitats for different types of species), a high diversity of ecosystem types – natural, semi-natural, and cultivated (e.g. forests, cliffs, grasslands, pastures, and traditional cultivations) – and a remarkable diversity of economic activities (e.g. stock raising, forestry, agriculture, hunting, year-round tourism), which provide a range of ES and benefits to society (Körner and Ohsawa 2005). Mountain ranges rank among the ecosystems supplying a vast variety of ES, globally (Grêt-Regamey et al. 2012) and in Europe (Maes et al. 2011). For instance, the provisioning of wildlife or cultivated products and biofuels are critical ES for human well-being provided by such ecosystems. Mountain landscapes are also critical for the regulation of global climate, soil erosion prevention and are also home to recreational activities, inherent in the culture of many countries (Grêt-Regamey et al. 2012; Egarter Vigl et al. 2016). They are also significant ‘science labs,’ since mountain ecosystems are highly sensitive to climate change (Beniston 2003; Löffler et al. 2011). For instance, melting glaciers at mountain areas provide strong evidence of climate change (Köhler and Maselli 2009), while rare plants and animals, adapted to specific high-altitude...
climate conditions, struggle to survive over ever diminishing areas (Bonasoni et al. 2009).

In Greece, mountainous areas have been a significant element of the culture of the Greek society with communities being shaped around them for centuries (Caftanzoglou 1994). They are also characterized by intensive agriculture and grazing (Zervas 1998; Tzanopoulos et al. 2011), especially in the past decades; they also host a range of recreational activities, such as mountain sport activities in the mountains of Epirus attracting local, national, and also international mountain admirers from around Europe (Papadimitriou and Gibson 2008) and regulating functions that safeguard society, e.g. from flooding (Maas and Macklin 2002). Mountains are also part of the economic and regional planning strategies (Matsouka and Adamakopoulos 2007) and have been also proposed as an alternative for renewable energy provision (Katsoulakos 2011), while already numerous renewable energy plants (e.g. wind parks, hydroelectric energy stations) are in operation, hereby using ecosystems as a substrate for infrastructure. Although their importance has been partly studied in either ecological (Zervas 1998; Maas and Macklin 2002; Range et al. 2005) or social-economic studies (Papadimitriou and Gibson 2008), a dedicated assessment of the dynamic social-ecological systems of Greek mountains and an assessment of their ES is missing (Dimopoulos et al. 2017).

So far, the ecosystem services (ES) supplied by these ecosystems, as well as the social, cultural, economic, and regional implications and planning requirements for each area have been ignored in the detailed biophysical evaluations of Natura 2000 sites. The present study allows for the inclusion of these dimensions that have so far been neglected by assessing provisioning, regulating, and maintenance, but also cultural ES. We selected and assessed the biodiversity rich (endemics, range-restricted taxa, numerous habitat types) mountain ranges of Greece (Strid 1986; Strid and Tan 1991; Georgiou and Delipetrou 2010; Dimopoulos et al. 2013) included in the delineated mountainous Natura 2000 sites – SACs, which serve a perfect field for this kind of scientific experimentation on ES.

Our objective is to identify and assess the ES supply provided by Natura 2000 protected mountain areas of Greece (with the term ‘supply’ we refer to the potential capacity of the various ecosystem types to provide services). In this paper, we: (1) make use of the available biodiversity data of the Natura 2000 sites, in combination with other spatial referenced data, to identify and map ecosystem types and associated ES supply; (2) identify areas of high ES supply at mountainous, Natura 2000 sites and analyze their spatial distribution throughout Greece; (3) document the main data gaps for mapping and assessing ES in these sites; (4) propose alternatives to integrated site management with the use of ES assessments as a supporting tool for the implementation of the PA’s management plans.

Our study is framed within Action 5 of the EU Biodiversity Strategy which encourages the Member States to map and assess ecosystems and their services (MAES). Action 5 creates a knowledge base on ecosystems and ES to underpin the achievement of the biodiversity targets, but also to inform decision-making of related policies on water, climate, agriculture, or regional planning. The specific focus on mapping and assessment of ES provided by the Natura 2000 network is highly relevant. Understanding how the network can provide a range of benefits to people through the supply of ES is crucially important to help deliver its full conservation and social-economic potential.

Materials and methods

We used the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin 2013) for the identification, mapping, and assessment of the ES provided by the ecosystems of the mountainous SACs of Greece and the development of a national-scale rapid assessment model (Figure 1). We based our mapping and assessment approaches on Burkhard et al. (2009), Maes et al. (2014), Jacobs et al. (2015), and Erhard et al. (2016), who used ES indicator scores assigned to specific areas in an assessment matrix. We use the term ES indicator to refer to a set of measures that provide quantitative or qualitative information on the provision of certain ES. The term primary indicator is used to refer to the targeted ES (e.g. supply of climate regulating service, food provision, aesthetic value), whereas secondary indicator is used to refer to a set of variables, proxies, or composite indicators that can be used to account for one or more primary ES indicators (Egoh et al. 2012).

The proposed methodology includes two mapping-assessment approaches: (1) the habitat-type-level approach and (2) the site-level approach, both based on evaluation matrices (Tables S1 and S2 of the supplement). The habitat-type-level approach was selected to assess ES potential supply using the available detailed spatial data (habitat types’ polygons) and thematically represent them within mountainous SACs. The site-level approach was selected to assess and present the total ES potential supply at each mountainous SAC and simultaneously provide information about the type and ES supply present at each site.
Evaluation and rating of the available data was made by using the expert elicitation. Due to the selection of this method, it was possible to extract information at the site level for all kinds of ES, but when it came to the habitat-type level it was not possible always to specifically allocate an ES to a specific habitat. This proved to be particularly true for the cultural ES. We therefore decided to include cultural services, only at the site-level analysis to estimate the total ES potential supply and have a brief estimate of their contribution to the total ES score. However, for the habitat-type-level analysis, the available information, did not allow for a detailed analysis and quantification of the cultural ES.

With ‘expert elicitation’ we refer to the scientific and professional background of the authors and local stakeholders’ perception and the synthesis of their opinion. The authors of this paper have conducted long-term management studies at Natura 2000 mountainous areas (Dimopoulos 1993; Dimopoulos and Georgiadis 1994; Dimopoulos et al. 2006, 2013; Zogaris et al. 2009; Kokkoris et al. 2014), including a consultation with local, regional, and national stakeholders (i.e. primary and secondary sector representatives, administrative staff of management bodies and state agencies, local, regional, and national decision makers) (Table S3). The outputs of these studies and the consultation were included also in legislative decisions and national legislation modifications. The most important example is the compilation of the National Biodiversity Strategy (Hellenic Ministry of the Environment and Climate Change, 2014), which has been adopted by the Greek Parliament and is now a State Law. However, expert elicitation always includes a systematic bias.

Each habitat type was rated for the capacity to supply each ES category under a ‘0 to 5’ rating scale, using the ‘pressure’ parameter information and expert’s judgment evaluation, resulting in the ES supply matrix for each habitat type (Table S1).

**Habitat-type-level approach**

**Ecosystem type map**

For the identification of the ecosystem types, we created a typology which allows the correspondence of all habitat types (including the habitats of Hellenic importance not listed in Annex I of the Dir. 92/43/EEC) (Dafis et al. 2001; Dimopoulos et al. 2006; European Commission 2013) to MAES ecosystem type classes based on the habitat types’ interpretation (Table 1; Table S1). Subsequently, by using spatial analysis techniques, we grouped spatially explicit habitat type data according to the ecosystem type classification and we represented them thematically, resulting in the ecosystem type map of the mountainous protected areas in Greece.

**Provisioning and regulating and maintenance ES maps**

Most of the Natura 2000 data attributes concern or are directly connected with ecological and land use spatial information. Most of these data provide accurate information at the national scale that can be used to assess provisioning and regulating and maintenance ES. Based on these data and by using the authors’ expert elicitation for the assessment of the habitat types’ supply, regarding provisioning and regulating and maintenance ES at the mountainous Natura 2000 sites in Greece, we created a rating matrix (Table S1) of ES supply for each habitat type.

Within this matrix, each ES-related cell is filled with a score and a color representing the quality of the data used (degree of certainty). This data quality assessment was made by applying expert judgment on the available information that refers to (1) area,

| Table 1. Typology of the correspondence of the habitat types present in the study area to the MAES categories (Level 1 and Level 2). The asterisk ‘*’ refers to habitat of conservation priority in Europe. In italics, the habitats of Hellenic importance (See Supplemental Table S1 for habitat types’ names). National working codes for unvegetated riverbeds and waterbodies without vegetation (UR and WB, respectively) are also included. |
|-----------------------------------------------|
| **MAES categories**                           | **Natura 2000 Habitat types’ codes** |
| **Level 1**                                   | **Level 2**                            |
| Terrestrial (Settlements)                     | 1050                                   |
| Urban                                          | 1020, 1021                             |
| Cropland                                       | 5150, 6170, 6220*, 6230*, 6420, 6430, 6510, 62A0, 651A |
| Grassland                                      | 1030, 1031, 9110, 9130, 9140, 9150, 9160, 9180*, 9250, 9260, 9270, 9280, 9290, 9310, 9340, 9350, 9370*, 9410, 9530*, 9540, 9560*, 9580*, 91CA, 9160, 91D0, 91E0*, 91NM, 9254, 92A0, 92C0, 92D0, 9340, 9344, 9518, 9540 |
| Heathland and shrub                            | 2250*, 2260, 4060, 4090, 5110, 5210, 5330, 5340, 5350, 5420, 5430 |
| Sparsely vegetated land                        | 1061, 1210, 1240, 1310, 2110, 2120, 21B0, 3280, 8140, 8210, 8220, 8260, 8310, 8250, UR |
| Wetlands                                       | 1410, 1420, 3130, 3170*, 7230, 72A0, 72B0 |
| Freshwater (Rivers and lakes)                  | 3150, 3240, 3260, 3280, 3290, WB |
| Marine                                         | 1120*                                  |
| Coastal                                        | 1130                                   |
| Marine inlets and transitional waters          | 1130                                   |


(2) habitat-type quality, (3) abiotic features, (4) biodiversity, (5) ecosystem functions, (6) bio-physical, and (7) social-economic data derived from the Natura 2000 monitoring and mapping field protocols’ datasets. In Table S4, the data quality evaluation and rating method is presented, which results in certainty designation. Using spatial analysis, this information was matched to the relevant habitat-type spatial data (vector polygons) and resulted in thematic maps representing the evaluation and the spatial distribution of the two focal ES categories (Provisioning and Regulating and Maintenance). The data quality rating was also exploited to create the ‘Degree of certainty map’ referring to the supplied ES. Degree of certainty maps were also created in order to provide the baseline information on the major ES data gaps, as well as on their spatial identification, through highlighting of data (cells in the matrix) or areas (on the map) with low degree of certainty.

**Site-level approach**

This approach was implemented for the ES mapping at the site level and includes a wider range of data, which were assigned to accurate, spatially referenced ES indicators for this level of analysis. In Greece, most studies in Natura 2000 areas are based on published data from previous reporting/monitoring assessments or on special environmental studies conducted by management bodies. For the identification of the delivered ES, three types of secondary indicators were used (Table 2): (1) indicators related to the protected area features corresponding to the ES potential supply (derived from the Natura 2000 datasets, e.g. forest area per site, priority habitats per site, flora species of Directive 92/43/EEC per site); (2) indicators describing social-ecological features of the area, corresponding to the potential societal demand for ES (e.g. sites of special natural beauty, controlled hunting areas); and (3) indicators describing infrastructure and cultural features, corresponding to the anthropogenic contribution to ES supply (e.g. number of archaeological areas per protected site, number of settlements designated as traditional per site). The exact definitions and units of measurement of those are presented in Table 2. The identification, selection, and quantification of appropriate indicators and data to quantify the broad range of ES are critical for robust ES assessments (Wallace 2007; Egoh et al. 2012; Seppelt et al. 2012; Burkhard et al. 2012a; Maes et al. 2014). To account for those issues in this study, the selection of indicators and their evaluation was based on accurate national-scale data (Natura 2000 Network habitat type mapping) (Dafis et al. 1996, 2001) and on a recent pool of more than 5200 field-monitoring protocols sampled in the Natura 2000 mountainous sites (Hellenic Ministry of Environment and Energy 2016a, 2016b). The non Natura-2000-based data are derived from officially designated, open access quantitative and spatial referenced information (geodata.gov.gr; odysseus.culture.gr; skiresort.info).

By combining the above attributes for each site, an assessment matrix was created (Table S2). This matrix provides the matching of each Natura 2000 site with the secondary indicators; the score of each secondary indicator was given by: (1) using the available numerical/quantitative data information; (2) expert judgment weighting for standardization among different data units; and (3) assigning the available data to a score of a ‘0 to 3’ rating scale. The score values in the matrix read as follows for each ES: 0 = not present, 1 = low, 2 = medium, 3 = high.

For each Natura 2000 site, a total ES value was also calculated by: (1) summing each site’s secondary indicator weighted scoring; and (2) creating a ranking among the studied sites based on their total ES score. We spatially represented the total ES score of each area, linked to the relevant Natura 2000 spatial data (protected areas’ vector polygons). Hence, the studied sites were differentiated in ES ‘hot’ (high total ES scores) and ES ‘cold’ (low total ES scores) areas.

**Results**

**Ecosystem types**

Using the cross-walk table between habitat type and ecosystem type, the ecosystem-type map of the mountainous Natura 2000 areas (SACs) has been compiled (Figure 2). The study area comprises 10 ecosystem types that consist of 87 habitat types (including settlements). The dominant ecosystem type is woodland and forest, followed by heathland and shrub, cropland, grasslands, sparsely vegetated land, and settlements representing 55, 24, 11, 6, 2, and 1% of the total cover, respectively; all other categories contribute to the remaining 1% of the area (Figure 3).

**Ecosystem services**

**Habitat-type and ecosystem-type-level approach**

From the resultant maps for Provisioning (Figure 4) and Regulating and Maintenance ES (Figure 5), it is evident that the studied sites are of major importance for the provision of Regulating and Maintenance services, with 67% of the total area being rated as of ‘Very high’ importance, 12% as of ‘High’ importance, and 10% as of ‘Medium’ importance. On the contrary, mountainous Natura 2000
Table 2. List of primary and secondary ES indicators used for the site-level ES assessment of the ES supply of mountain areas in Greece along with examples of ES measured (based on the CICES nomenclature). For each secondary indicator, we provide the reference unit of the assessment and its description. Indicator rating is based on expert judgment. The input data source is also given.

| Primary ES indicator (with list of potentially provided ecosystem services) | Secondary ES indicator | Provisioning | Cultural | Unit | Description of indicandum | References |
|---|---|---|---|---|---|---|
| **Regulating and maintenance** | **Forest area** | **Protected area features** | **Forest area at site (m²) per maximum recorded forest area at a site** | **Indicates the capacity of forest areas to provide various ecosystem services. E.g. forest ecosystems play a key role in the global carbon cycle, lifecycle maintenance depends to a large extent on integrity, health, and vitality of forested areas, forests provide a multitude of benefits in terms of climate regulation, human health, recreation, refuges, fresh water supply, and many others (e.g. flood protection, water purification, aesthetic value)** | Dafis et al. 1996, 2001 |
| **Lifecycle, maintenance, climate regulation** | **Timber, wild fruits and mushrooms, aromatic and pharmaceutical plants** | **Aesthetic value, outdoor activities, scientific** | **Forest area** | **Indicates the capacity of forest areas to provide various ecosystem services. E.g. forest ecosystems play a key role in the global carbon cycle, lifecycle maintenance depends to a large extent on integrity, health, and vitality of forested areas, forests provide a multitude of benefits in terms of climate regulation, human health, recreation, refuges, fresh water supply, and many others (e.g. flood protection, water purification, aesthetic value)** | Dafis et al. 1996, 2001 |
| **Lifecycle, maintenance, water flow maintenance, pollution** | **Biomass production for grazing, aromatic and pharmaceutical plants** | **Outdoor activities, scientific** | **Grazing land** | **Total area (m²) available for grazing at site per maximum recorded grazing area at a site** | **Grazing land in mountainous Natura 2000 areas has the highest species diversity, which contributes to the delivery of a range of provisioning services, e.g. quality and nutrition value of fodder, because of higher variety of micro-element, supply of honey, herbs for medicine and materials for cosmetics. Furthermore, the semi-natural grasslands have higher contribution to maintenance of habitats for engendered species and pollinators. Semi-natural grasslands can supply higher rates of cultural services, including the recreational, education, scientific, aesthetic, and cultural heritage value.** | Dafis et al. 1996, 2001; statistics.gr |
| **Pollination, lifecycle maintenance** | **Cultivated products** | **Agro-tourism, research** | **Cultivated area** | **Cultivated area (m²) at site per maximum cultivated area recorded at a site** | **Areas with cultivated land inside the Natura 2000 Network provide direct provisioning services. At the same time, they provide regulating and maintenance services, e.g. ‘pit-stops’ for migratory birds; ornamental and cultural services opportunities for agro-tourism, scientific research or provide an aesthetic value (e.g. via cultivation alternations and patterns)** | Dafis et al. 1996, 2001 |
| **Lifecycle maintenance, climate regulation, water flow maintenance** | **Cultivated products, genetic resources** | **Agro- and eco-tourism** | **Settlement area** | **Settlement area (m²) at site per maximum settlement area recorded at a site** | **Mountainous areas of the Natura 2000 Network are home to small villages, with a rural traditional characteristic. These areas are also used for ecosphere and agro-tourism initiatives. These areas help maintain a community cohesion and generate relational sociocultural values. In these areas, many unique and threatened services are present, e.g. production of products using traditional agricultural and farming techniques, maintenance of local varieties of fruit, vegetables and domestic animals, maintenance of local folklore and dialects.** | Dafis et al. 1996, 2001 |
| **Lifecycle maintenance, climate regulation** | **Water for drinking and irrigating** | **Research, aesthetic value, eco-tourism (e.g. bird watching, photography)** | **Lakes** | **Presence of inland lakes at the site** | **Inland lakes are rare in Greece and support a variety of unique ES (e.g. water provision during the summer months, nesting stations for migratory birds, fresh-water-related recreational activities)** | Dafis et al. 1996, 2001 |
| **Lifecycle maintenance, genetic resources** | **Genetic resources** | **Research, Eco-tourism (e.g. photography, botany tours and exploration)** | **Flora species (92/43 EEC)** | **Number of Annex II (92/43 EEC) flora species at site per maximum number of Annex II (92/43 EEC) flora species recorded at a site** | **The presence and number of flora species designated as protected at EU level is an important biodiversity maintenance service and valuable genetic resource; they provide unique research and recreational opportunities.** | Dafis et al. 1996, 2001 |
| **Lifecycle maintenance, genetic resources** | **Genetic resources** | **Research, Eco-tourism (e.g. bird watching, photography)** | **Fauna species (92/43 EEC)** | **Number of Annex II (92/43 EEC) fauna species at site per maximum number of Annex II (92/43 EEC) fauna species recorded at a site** | **The presence and number of fauna species designated as protected at EU level is an important biodiversity maintenance service and valuable genetic resource; they provide unique research and recreational opportunities.** | Dafis et al. 1996, 2001 |
| **Lifecycle maintenance, biomass production, genetic resources** | **Biomass production, traditional livestock farming, recreation** | **Eco-tourism, traditional livestock farming, recreation** | **Priority habitat types (92/43 EEC)** | **Number of priority habitat types at site per maximum number of priority habitat types recorded at a site** | **The presence and number of habitat types designated as of priority importance at EU level provide a unique added value to the hosting site; they provide important biodiversity maintenance services (e.g. unique species composition and ecological characteristics) and valuable genetic resource provision (pharmaceutical plants e.g. Crocus sp., endangered species) and biomas (e.g. biomass for traditional grazing techniques); simultaneously they provide unique research and recreational opportunities (e.g. eco- and agro-tourism)** | Dafis et al. 1996, 2001; Hellenic Ministry of Environment and Energy 2016a, 2016b |
| **Mediation of flows, lifecycle maintenance, climate regulation** | **Timber production, biomass production, food, genetic resources** | **Eco-tourism, hunting, recreation, research** | **Habitat types (92/43 EEC)** | **Number of Annex II (92/43 EEC) habitat types at site per maximum number of habitat types (92/43 EEC) recorded at a site** | **Presence and number of habitats designated as protected at EU level, provide important biodiversity maintenance (e.g. biodiversity reserves) and regulating services and provide a valuable genetic resource for pharmaceutical plants, wild fruits, timber, game, and biomass (e.g. biomass for grazing) simultaneously, they provide research and recreational opportunities (e.g. zoologists, botanists, ecologists, naturalists, hunters)** | Dafis et al. 1996, 2001; Hellenic Ministry of Environment and Energy 2016a, 2016b |
| Primary ES indicator | Provisioning | Cultural |
|----------------------|--------------|----------|
| Regulating and maintenance | Meat and dairy products | Livestock |
| Maintenance of traditional grazing techniques, agro-tourism, scientific research, eco-tourism, aesthetic, existence, request value | Livestock population size at site per maximum livestock population size estimation at a site | Livestock in mountainous Natura 2000 areas refers to animals raised using traditional, sustainable grazing techniques (e.g. semi-subistence farming); these animals (mostly goats, sheep and secondarily cows) are a great source of food and the patterns of grazing provide habitat and biodiversity maintenance |
| Lifecycle maintenance | Genetic resources | Wildlife refuges | Presence of wildlife refuges at the site | Areas designated as wildlife refuges in Greece are established for biodiversity maintenance, habitat quality improvement, and game population increase providing a series of direct and indirect ecosystem services |
| Game population maintenance | Food | Controlled hunting areas | Presence of controlled hunting areas at the site | Controlled hunting areas provide recreational opportunities for hunting under a specific framework, proposed for each area from the local authorities. Hunting is under payment, while the type and quantity of killed game is limited per hunter in each hunting period. These areas also provide excellent training field for hounds and junior hunters |
| Game population maintenance | Food | Game breeding stations | Presence of game breeding stations at the site | Game breeding stations include small, mainly outdoor, breeding infrastructure within a broader natural area. These areas are very important for game population and biodiversity maintenance. They also support scientific and educational actions related to hunting, game health and maintenance and hunting management. They are an indirect indicator for the presence of cultural services and maintenance sites of game population |
| Genetic material maintenance enhancement | Agricultural, livestock, and energy products | Eco-tourism, aesthetic value, research | Presence of eco-development areas at the site | Eco development areas are designated to promote biodiversity and maintain local genetic materials (e.g. by the reintroduction of local genetic material of wild fauna and wild flora), while at the same time promote green energy production, eco-tourism maintenance, repair and restoration of historical, religious, and cultural monuments and sites |
| Lifecycle maintenance | Wild fruits and game, aromatic and medicinal plants | Aesthetic value, inspiration (art), outdoor recreation, research | Sites of Special Nature Beauty (SSNB) | The designation of these sites is very important in Greece; they include not only areas with unique natural characteristics (e.g. forests, gorges, waterbodies), but also areas with important traditional infrastructure (e.g. an old, stone-build bridge, a traditional village, etc.) |
| Lifecycle maintenance | Biomass production, timber, wild fruits, aromatic and medicinal plants | Eco-tourism, agro-tourism, research, aesthetic value, educational value | National park | National parks usually host more than one Natura 2000 areas. The inclusion of an area in a National Park provides an added value, because it is better studied, protected, and communicated as important for various ecosystem services |
| - | - | Recreation, educational value, research | Ski centers | Indicates the location where cultural ecosystem services (e.g. winter sports, scientific research) are supplied by a mountainous landscape |
| Maintenance of rural biodiversity | Traditional products | Agro-tourism, aesthetic and historical value, research | Traditional settlements | The presence of traditional settlements indicates areas where natural features are used by local population to generate traditional products, while regulating the rural lifecycle. They also identify locations where eco-tourism activities take place, and places where nature has a high value for rural societal cohesion |
| - | - | Historical and aesthetic value, research | Archaeological sites | Presence and number of archaeological sites indirectly indicates the possibility for combined recreational activities in the protected area (e.g. trekking in a forest trail with ancient ruins) |
sites dominate medium and below medium scores of Provisioning services’ supply within their boundaries, with only ca. 24% of their total area having a score higher than ‘Medium’.

Degree of certainty matrix and map – identification of data gaps
We consider the maps depicting the degree of certainty (Figures 6 and 7) as a thematic representation of the data quality and data gaps regarding ES supply. The mapped ES are considered as definitely present at each site; however, this map represents the quality of the data or the knowledge which the evaluators used to rate each ES. The map highlights that the evaluation quality for the Regulating and Maintenance services is very high with almost 75% of the area rated as containing information of very high quality (green colored); none of the polygons/cells is marked as having bad data quality. On the other hand, data for Provisioning services are considered as inadequate, i.e. most of these data of medium or low quality (polygons/cells colored in yellow or orange, respectively). This confirms the lack of accurate, quantitative data needed for the evaluation of provisioning services at each site, even for a small-scale assessment (i.e. nationwide).

Site-level approach
Using the site-level assessment, we created an ‘Ecosystem Service Identity Card (ID)’ (e.g. Figure 8) for each
mountainous Natura 2000 site; this ID consists of the provided ES, accompanied by the evaluation of each ES and the total ES score per site at the relevant assessment matrix (Table S2). Based on the total ES score, a hierarchy of the sites was created. Thus, the ES ‘hot-’ and ‘cold-’ spot sites were identified and thematically presented on the total ES supply and hot spot map (Figure 9). Mountainous areas of Belles (including lake Kerkini) (GR1260001), Prespes (GR1340001), Lefka Ori (GR4340008), Pilio (GR1430001), Parnon (GR2520006), Dikti (GR4320002), and Olympos (GR1250001) are identified as the top ES supply hot spot areas, while the entire island of Crete could be characterized as an ES supply hot spot area.

Interpreting the matrix and the resultant thematic map, all highly rated sites are characterized by: (1) large area size that could supply multiple ES; (2) high biodiversity values; and (3) the supply of unique social-economic activities, such as officially characterized traditional settlements (Prespes, Lefka Ori, Parnon, Pilio, Olympos) and recreational services (e.g. ski centers in Pilio and Olympos).
Figure 5. Spatial distribution of regulating and maintenance services at 91 mountainous sites (SACs) in Greece. The proximity to major urban centers is also indicated in the map.

Figure 6. Thematic representation of the ‘degree of certainty’ of provisioning services at 91 mountainous sites (SACs) in Greece.
Discussion

The ES concept was designed to be included in the decision-makers’ agenda through various tools for environmental and natural resources management (e.g. Millennium Ecosystem Assessment 2005). Still more effort is needed for its actual inclusion in natural resource management and decision-making (Kienast et al. 2009). That lack of inclusion is strongly related to the presence of enabling conditions, institutional capacity, but also the credibility of generated information (Ruckelshaus et al. 2013). The latter is questioned in policy and decision-making mostly due to heterogeneous ES assessment methodologies, classification systems for ES, a multiplicity in accounting and valuation methods (Jacobs et al. 2015), and the degree of uncertainty in the assessment or the inability to account for it (Willemen et al. 2015). For accounting uncertainty, it is crucial to include ES into decision-making; to inform and support decision-making trust needs to be gained to scientific evidence (Rae et al. 2007; Willemen et al. 2015). The uncertainty (or certainty) threshold of each case is defined in different ways depending on the case studied (Hamel and Bryant 2017); either qualitatively (e.g. after consultation among scientists, stakeholders,
and decision-makers) or in a quantitative way (Hou et al. 2013; Schulp et al. 2014). In the present study, the calculation of uncertainty is limited to the quality of the available data, presenting it thematically on a qualitative scale ranging from ‘Very low’ to ‘Very high,’ which is considered as adequate for this first, national-level ES assessment in mountainous protected areas. The results of this study highlight the need for more detailed assessments for the Greek territory, including acquisition of more accurate data for ES. We argue that it is essential for the use of ES information in decision-making to define and set context-specific thresholds for the level of certainty above which the results are acceptable and adequate for informing decision-making.

Conservation management in Greece until now has mostly been targeting specific species or sites of biodiversity importance, excluding societal needs or relationships with the management approaches (Apostolopoulou et al. 2014). Several proposals have been made to view the country’s natural resources as part of an integrated social-ecological system (Apostolopoulou et al. 2012) in which society plays a crucial role. However, the implementation is still pending. A significant amount of work has been done in the country so far focusing either on the biophysical (Skapetas et al. 2004; Sidiropoulou et al. 2015) or the social-economic part (Latinopoulos 2014). In this study, we view Greek landscapes as social-ecological systems and quantify and spatialize the way humans interact with nature; this will provide robust scientific evidence that can prove to be useful for a more efficient conservation management.

We assessed ES supplied by mountain ecosystems that are of significant importance for the Greek social-ecological system (Grunewald et al. 2007; Katsoulakos 2011). Our focus on sites of biodiversity importance (Natura 2000) and ES was due to data availability and quality, but also because there are already policy and governance mechanisms in place for these areas (PA agencies). The matrix-based methodological framework we used to account for ES (Burkhard et al. 2012a) allows for a rapid national-scale assessment of the ES supply within the Natura 2000 mountain sites.

This approach enabled us to: (1) identify for the first time, the type and the quantity of the ES supplied by mountain Natura 2000 sites in Greece; (2) assess the spatial distribution of the ES supplied by these sites; (3) use this scientific information to offer a ‘fresh’ point of view for the mountain protected areas in Greece, highlighting their importance as an inherent part of the national natural capital. The identification of hot spots and areas of significance

Figure 9. Total scoring of the provided ecosystem services & hot spots at 91 mountainous Natura 2000 sites (SACs) in Greece. The island of Crete (box at the bottom of the map) is identified as an ES hot spot area. Numbers 1 to 7 indicate the sites with top total ES scores (1: Mt Belles & Lake Kerkini, 2: Prespes lakes area, 3: Mt Olympos, 4: Mt Pilio, 5: Mt Parnon, 6: Mt Lefka Ori, 7: Mt Dikti).
for the supply of ES could be a very useful tool for the PA managers of the mountain regions of Greece. The identified ‘hot spots’ of total ES supply could indicate locations where bundles of ES are generated and multiple ecological functions take place (Queiroz et al. 2015). The ‘richness’ of ES supplied by each PA could be a reflection of the variety of habitats and ecosystem types present in this PA, but also of the multiple ways that the Greek society is linked to nature in these areas. The identification of ES ‘hot spots’ could give additional information for PA managers who, at a time of economic and financial crisis and the resulting insufficiency of resources, might need to prioritize and choose specific places to take action. At a future stage, this work could be extended towards a more detailed analysis of the spatial trade-offs emerging among the different ES supplied, but also a targeted measurement of the ES flows to society and demand.

Assumptions and limitations of the study

An important issue that this study tries to overcome is the lack of cultural elements (e.g. traditional settlements, archaeological sites) from EU-wide assessments which vary per country and are an integral part of the environment, being shaped historically as part of the ecosystem (Vlami et al. 2017). For the Greek national-scale assessment, the cultural elements are particularly important; since these areas (1) are considered as an ideal expression of a generalized cultural service indicator, (2) provide, through their long-living and stable ecosystems with high cultural value, regulating and maintenance services, as well as provisioning and cultural services that support the relational values among people and nature (Chan et al. 2016).

The main methodological limitation of the present rapid assessment is related to the elaboration of data with various degrees of heterogeneity, certainty, and accuracy. The proposed matrix and the mapping models for the association of the habitat types with the major ES supplied are also flexible and updatable only by replacing the old values with the most recent ones; thus, an assessment module for a rapid overview of the contemporary provision and spatial distribution of the ES was created. Methods used in this study can be applied to rapidly evaluate the provided ES also outside the Natura 2000 Network sites, by using Corine Land Cover datasets and any other available spatial referenced information. Still at the national and local level, additional data need to be collected in order to improve the degree of certainty in scientific outputs (Kosoy and Corbera 2010), which will in turn improve the way they are included in decision-making.

Even though the resulting information is limited to the two main ES categories, when implementing the habitat-type-level approach, and to the identification of the three main ES and total ES value at each site (site level approach), it is the first fundamental step of guiding the national scaled ES research and ES concept activation in Greece. The present study provides adequate information to trigger the interest of researchers and decision-makers towards the exploration of the management potential of ES to ameliorate the national capital attributes and values. We believe and agree with Burkhard et al. (2012b) that there is no time to hesitate, waiting for more detailed data from the various fields and sub-fields of science, to prepare a national-scale strategy for sustainable management of ES in the protected areas. Simultaneously, current protection legislation for these areas may unintentionally block or prevent important ES supply (Jacobs et al. 2015) and should be urgently reconsidered on the basis of the ES concept.

Conclusion

This study: (1) documents the variation among the Natura 2000 mountain sites of Greece, in terms of ES supplied; (2) is a first quantitative evidence of the significance of the Natura 2000 sites as hosts to a variety of ES; and (3) gives a first ranking of the sites that supply the greatest amount of ES. This assessment also revealed that ES hot spot sites are of major environmental and conservation importance, but also of social-economic interest. Therefore, it provides a valuable tool for identifying priority areas for conservation assessments and detailed ES case-studies, where the compilation and implementation of management plans should consider all aspects of social-ecological systems. The results of this study are adequate for triggering nationwide interest on ES, set a clear target to urgently conduct more detailed case studies, and produce large-scale assessments at regional and local level. However, these results need to be further elaborated as key elements for the compilation and implementation of the site-oriented management plans for the Special Areas of Conservation within the Natura 2000 ecological network. The material produced (evaluation matrices and maps) is an important part of the reference data needed for the implementation of MAES for the Greek territory. ES assessments on different spatial scales (regional and local) require information from stakeholders, experts and policymakers, participatory mapping, and valuation of the ES supply, as well as of the potential demand and the possible future contrasting scenarios, in order to supply ES researchers and stakeholders with the most accurate and reliable data.
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No potential conflict of interest was reported by the authors.

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