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Research Article

Towards implementing Mapping and Assessment of Ecosystems and their Services in Cyprus: A first set of indicators for ecosystem management

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Abstract

Ecosystems deliver a range of services that are important for human well-being. Although Ecosystem Services (ES) assessments have been carried out worldwide in different geographical areas, islands are still under-represented. This research presents the first set of indicators developed for Mapping and Assessment of Ecosystems and their Services (MAES) provided by the ecosystems of Cyprus, as required by the EU Biodiversity Strategy, along with the rationale behind the selection criteria. In total, 269 potential indicators were assessed in terms of data availability at the national/subnational level and their suitability for MAES and were classified using a "traffic light" system on the basis of overall suitability (i.e. conceptually and in terms of datasets). The results showed that 89 indicators (Green indicators) can be directly used for assessing ES in Cyprus. Amongst these 89 Green indicators, 28 are considered to be new additions to the EU MAES list, since they were proposed solely for Cyprus ecosystems, as a result of consultation with local stakeholders. Provisioning and cultural services could be adequately mapped, but lack of data was observed for several regulating services (e.g. erosion, pollution, carbon sequestration). Not all Green indicators, identified herein, are relevant for assessing ES provided by ecosystems in Cyprus, whereas Green indicators which measure similar ES might be redundant. For a given geographical context, there might be relevant (and important) indicators which are not included in the MAES list and this is why consultation with stakeholders is advisable. Knowledge gaps and needs for further improving MAES on the island are also discussed.

Keywords

Ecosystem services, decision-making, Mediterranean islands, policy, planning, sustainability

Highlights

- The first set of indicators for MAES in Cyprus is proposed.
- There is a good representation of indicators for all main ecosystem services (ES) on the island.
- Coordinated effort is still required for mapping several regulating services indicators.
- Stakeholders are important for tailoring indicators developed at the EU level to the local geographical context.
- A parsimonious number of indicators can be employed as ES pressure and condition indicators.

Introduction

Ecosystems can deliver a range of services that are important for human well-being including food production, air and water purification and conservation of genetic diversity for future use (Jacobs et al. 2015). The Millennium Ecosystem Assessment (MA; Millennium Ecosystem Assessment (Program) 2005) was the first large scale ecosystem assessment approach implemented globally and it provided a framework for identification, classification and evaluation of services. MA has been adopted and further refined by later initiatives, such as The Economics of Ecosystems and Biodiversity (TEEB), initiated in 2007 and the Common International Classification of Ecosystem Services (CICES; https://cices.eu/), proposed in 2009. The three international classification systems available to classify ecosystem services (Maes et al. 2013) relate, to a large extent, to each other; all three include provisioning, regulating and cultural services. An important difference adopted by TEEB was the use of habitat services instead of supporting services in MA, to highlight the importance of ecosystems to provide good quality habitat, which should be safeguarded (Kumar 2012). CICES moves a step forward and focuses on the ecosystem service dimension. Accordingly, services are either provided by living organisms (biota) or by a combination of living organisms and abiotic processes (Maes et al. 2014).

Target 2 (Maintain and restore ecosystems and their services) of the EU Biodiversity Strategy and Action 5 therein, aim to improve the knowledge about Ecosystem Services (ES) in the EU territory. According to this action, Member States (MS) need to map and assess the state of the ecosystems and their services, to evaluate their economic value and promote the incorporation of such information in their reporting schemes, by 2020 (European Commission 2011). The implementation of MAES in Europe is guided by the framework presented in Maes et al. (2013), CICES (Potschin and Haines-Young 2012) and the proposed list of indicators and assessment approaches that are presented in Maes et al. (2013). The use of scientific evidence, such as that emanating from MAES and ecosystem assessments, is expected to highly improve policy and management responses, assisting the transition from the prevailing economic model to a sustainable economy as envisaged by the EU Horizon 2020 vision (Maes and Jacobs 2017).

Work for ES mapping and assessment has been undertaken in all EU countries, Switzerland and several Balkan countries (Maes et al. 2013, Dimopoulos et al. 2017). In the cases of Spain and the UK, it has been an initiative of the respective national governments. Although these case studies provided a useful body of material, frameworks, indicators and quantification methods differed widely and comparisons are therefore very difficult. In addition, in these first studies, the availability of data, time and material resources were the most important factors for developing the methodology underpinning MAES (Maes et al. 2014). The adoption of the hierarchical structure of the CICES classification for ecosystem services was hence adopted for MAES in Europe.

Mapping and Assessment of Ecosystems and their Services is an ongoing process in most of the countries at national, regional or case-study level (i.e. Albert et al. 2016, Maes and Jacobs 2017, Nikodinoska et al. 2018, Václavík et al. 2019, Kokkoris et al. 2018, Kokkoris et al. 2019). In most of the cases, the CICES classification, the CORINE Land Cover dataset and the reporting streams under the EU environmental directives are used (Maes et al. 2014, Grêt-Regamey et al. 2015). National assessments mostly cover forests, followed by agro-ecosystems, freshwater ecosystems and marine ecosystems (Maes et al. 2014). Considering ES supply, cultural services, such as tourism and recreation opportunities provided, are the most frequently assessed services, followed by provisioning (nutrition and materials, such as timber) and regulating (e.g. erosion control) (Maes et al. 2014, Wolff et al. 2015, Fish et al. 2016). Even though the guidance is available, the national implementation of this procedure requires the development of sets of indicators that are most relevant and sufficient to provide the state of ES (Albert et al. 2016). The discussion about the adoption of indicators for ES and their implementation in policies, planning and management (Wolff et al. 2015, Jacobs et al. 2015, Albert et al. 2016, Maes and Jacobs 2017), as well as their application at the national level, is ongoing (Hauck et al. 2013, Albert et al. 2016, Mononen et al. 2016, Tratalos et al. 2016).

The coastal, marine and inland ecosystems of islands provide valuable regulating, provisioning and cultural services to more than 500 million people (Millennium Ecosystem Assessment (Program) 2005). Although ES assessments have been carried out worldwide in different geographical areas (Egoh et al. 2008, Häyhä et al. 2015, Nikodinoska et al. 2018), islands are still under-represented (Aretano et al. 2013). This is also mirrored in the

Mediterranean region where few studies are island specific (Aretano et al. 2013, Ciftcioglu 2017, Manolaki and Vogiatzakis 2017). Islands are isolated pieces of land ("isola effect"), limited in resources and are more susceptible to externalities than the mainland (Balzan et al. 2018, Millennium Ecosystem Assessment (Program) 2005), therefore, insights on ES identification and provision are of utmost importance for resource management. The natural land cover of island systems has changed drastically under the pressure of growing human populations and consequent exploitation of the landmass (Millennium Ecosystem Assessment (Program) 2005, Vogiatzakis et al. 2016, Chiarucci et al. 2017). Watershed modification on islands has had a negative impact on water resources in terms of water quality and quantity, as well as flow regime (García-Nieto et al. 2018).

The development of a national ES assessment is an obligation for Cyprus, an island state, stemming from the country's obligation as a full EU member and due to the fact that the island is one of the ten Mediterranean Basin hotspots, based on plant endemism and richness (Medail and Quezel 1999). Biodiversity and ecosystem conservation in Cyprus face currently several challenges. Recent changes on the island, similar to other Mediterranean areas, such the abandonment of agrosilvopastoral practices, the intensification of agriculture and the increase in urban development (Zomeni et al. 2018), have been suggested to lead to the loss of biodiversity and lower ecosystem service supply (García-Nieto et al. 2018). Climate change is expected to impact the ecosystems of the eastern Mediterranean and their services as a result of increased temperatures and reduced precipitation (Sarris et al. 2011, Lelieveld et al. 2016, Vogiatzakis et al. 2016). Under this context, MAES is considered a useful framework for the sustainable management of ecosystems on the island.

The aim of this paper is to guide policy- and decision-makers in Cyprus through the process of MAES with a view to contextualise its application nationally. This is done by presenting and discussing the results of the first approach taken to define, assess and map indicators for the implementation of MAES in the country. Accordingly, the objectives were to:

1. Review the potential indicators that are provided at a European level for MAES;
2. Evaluate the data currently available for their determination at NUTS2 (Nomenclature of Territorial Units for Statistics; NUTS) level for Cyprus;
3. Propose the first set of indicators for MAES in Cyprus; and
4. Propose a mapping method for those indicators, including mapping examples (i.e. a sub-set of indicators for terrestrial and freshwater ecosystems).

Materials and methods

The methodological steps and rationale employed for ES indicators assessment are given in Fig. 1 and include:

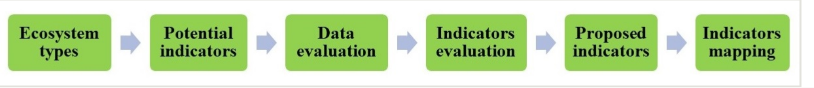

Figure 1.

Rationale for the 1st MAES implementation in Cyprus.

Step 1 - Ecosystem types: Following the guidance for large scale assessments (Maes et al. 2013, Maes et al. 2014), the broad terrestrial ecosystem types of the island were classified into the following categories, based on CLC 2012: a) agricultural land b) pastureland, c) forests, d) maquis/shrublands and e) freshwater ecosystems (Suppl. material 1; Fig. S1). CORINE level III was used to derive broad ecosystem types which correspond to Ecosystem types at level II.

Step 2 - Potential indicators: The potential indicators that could be useful for MAES in Cyprus were identified, for each broad ecosystem type and each category of services (provisioning, regulating and cultural) according to CICES (Potschin and Haines-Young 2012). Although the conceptual framework and indicators' lists, proposed by Maes et al. 2014, were followed, additional indicators (28) were introduced, based on the character of ecosystems in Cyprus and in consultation with Government Departments and NGOs who considered the additional indicators appropriate for the local context. The latter (Suppl. material 1; Tables S1-3) were identified following face-to-face meetings with 30 officials from the Departments of Forests, Environment, Agriculture, Water Development and Game and Fauna, as well as Birdlife Cyprus and Terra Cypria NGOs. The meetings took place during the period December 2017-June 2018.

Step 3 - Data evaluation: Two criteria were employed to evaluate suitability-validity of all available data sources as potential for ES indicators' mapping in Cyprus: a) *suitability* – based on the quality and characteristics of the data (e.g. spatial resolution, credibility, easily perceived by the users, age of the data, % of land covered), b) *availability and short term accessibility* – based on the availability and format of the data (e.g. ownership, non-spatial format). For example, the data (to determine a potential indicator) were considered suitable in the case that they cover the whole island (e.g. agricultural land, forest area), they were systematically monitored (e.g. water consumption for drinking or irrigation purpose), they had fine spatial resolution (e.g. less than or equal to 1 km) and they were recently monitored (e.g. for the distribution of the agricultural land, the most recent data available). If the criteria for the suitability were met, the availability and short-term accessibility were assessed (e.g. the public service/authority is capable of providing them for free in the short term). It should be mentioned that, due to the political situation on the island, consistent data are available and monitored and, therefore, submitted to the EU only for the Area effectively Controlled by the Government of the Republic of Cyprus (ACGRC), since the acquis communitaire is suspended in the northern part. Truly island-wide data exist only on EU related portals (ESDB, Eurostat), but these are usually of coarse spatial resolution, with the exception of Copernicus CLMS, which makes the implementation of MAES difficult at a local scale.

Moreover, data sources that could be used for MAES were also identified and include: 1. The Eratosthenes database (joint data from the public sector, maintained by the Department of Geological Survey) which is the main source for mapping biophysical data at a national level/sub national level; 2. The Statistical Service of Cyprus (http://www.mof.gov.cy) which is the source for relevant statistical non-spatial data; 3. Additional data from several government Departments (e.g. Environment, Geological Survey, Forests, Agriculture) which are now open and publicly available (www.data.gov.cy); 4. Cyprus Agricultural Payments Organization (CAPO): The CAPO dataset holds the land parcel information system (LPIS) for 2013 and provides information on the type of farm and type of crops cultivated on each plot, including grasslands; 5. European Datasets including European Soil Data Centre (ESDAC) - https://esdac.jrc.ec.europa.eu/; COPERNICUS (https://www.copernicus.eu/en) and Eurostat (https://ec.europa.eu/eurostat).

Based on the aforementioned criteria of data suitability, availability and short term accessibility, datasets were then assigned to three categories using a "traffic light" system, following Maes et al. 2014: a) data that fulfil the above-mentioned criteria and can be used in MAES for Cyprus (Green colour); b) data that partly meet the criteria (Orange colour) and c) data that do not meet the criteria and therefore cannot be used for MAES for Cyprus (Red colour; Fig. 2). For instance, if a dataset is suitable and readily available, then it is characterised as green in the proposed scheme. On the other hand, if it is suitable, but not readily available (e.g. significant time is required to obtain it), then it is categorised in the orange class, whereas an unsuitable dataset, which is also unavailable, is red in the scheme. Giving a specific example, agricultural land (e.g. area, crop types) is systematically monitored, the data have spatial resolution relevant to the size of the island and they are available for use (Green colour). Therefore, these data could be used in the next step, i.e. indicators evaluation.

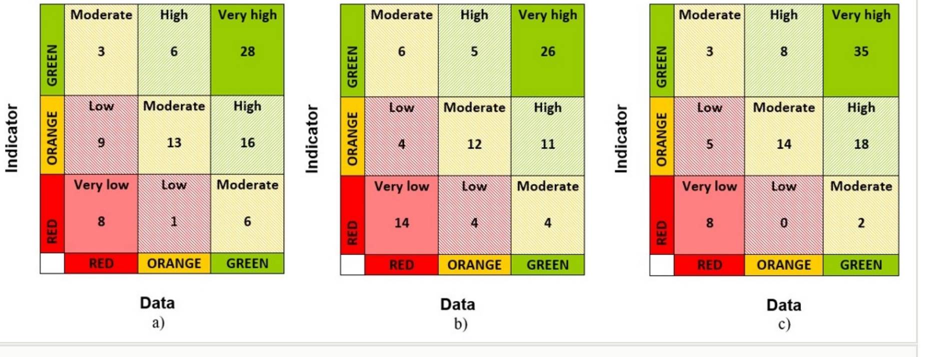

Figure 2.

Evaluation of ES indicators for a) forests and shrublands, b) agricultural and pasture and c) freshwater ecosystems (and numbers of potential indicators per category). The characterisation on a scale from very low to very high is a function of an indicator's conceptual suitability and existing data suitability for its mapping (traffic light system: green, orange, red).

Step 4 - Indicators evaluation: This step was a combined evaluation of indicators and the datasets available for mapping the indicators (e.g. an indicator might be appropriate conceptually for mapping a given ES, but the quality of respective data might be poor to map; see sections 2 and 3 above). For the indicators' assessment, we followed the classification that is provided in Fig. 2 , which is based on the availability/quality of spatial data for mapping and the potential to transfer the information to policymaking and implementation (Maes et al. 2014). Therefore, the potential indicators were accordingly classified in one of five categories (very low, low, moderate, high, very high; see Fig. 2), based on their potential use for the ES assessment at the national level.

Step 5 - Proposed indicators (at a sub-national level): Considering the above mapping methodologies and the indicator evaluation method (Fig. 2), a sub-set of indicators was selected (Table 1), belonging to the very high category (Fig. 2 ; see upper right green corner). Currently, the indicators that are placed in the green area (Fig. 2; Table 1; Suppl. material 1; Tables S1-3), which is defined by very high data suitability and indicators' suitability, were considered as appropriate for use in MAES in Cyprus. In addition, for ES mapping, using indicators classified in the green area (Fig. 2) and in order to guide future mapping efforts, a proposed methodology was provided out of five suitable alternatives (Andrew et al. 2015, Martínez-Harms and Balvanera 2012): A) direct mapping with survey and census that provides complete spatial information of the distribution of a service (data-intensive approach); B) empirical models of ESs developed from point-based measurements of services; C) if no ES data exist, a priori rule-based models; D) extrapolation; E) data integration.

Table 1.

Ecosystem service indicators of very high suitability per ecosystem type and the proposed method for their mapping [A,B,C,D,E]. Underlined are the indicators proposed by the stakeholders.

Agricultural & pasture land	**Forests & shrublands**	**Freshwater**
	Provisioning ecosystem services	
1. Agricultural area [**E**] 2. Hunting areas and seasons [**E**] 3. Areas important for groundwater abstraction in agro-ecosystems [**A**] 4. Areas with access to treated municipal wastewater for irrigation [**A**] 5. Agricultural areas equipped with irrigation facilities [E] 6. Groundwater bodies location in the island [**E**] 7. Yields of feed or food crops (tonnes/ha; tonnes dry matter/ha; MJ/ha) [**A**] 8. Area of energy crops (ha) [**A**] 9. Biofuel, biodiesel, bioethanol (kToe) [**A**]	1. Hunting areas and seasons [**A**] 2. Important areas for groundwater abstraction [**E**] 3. Forest biomass stock [**E**] 4. Forest biomass increment [**A**] 5. Forest for timber, pulp wood etc. production [**A**] 6. Commercial forest tree volume & harvesting rates [**A**] 7. Trees (presence): pines for resins [**A**] 8. Tree species (timber trees) [**A**] 9. Wood consumption (industrial roundwood, fuelwood) [**A**]	1. Number and area of the dams that fishing is allowed [**E**] 2. Number and production (per species) of fish farms [**E**] 3. Freshwater aquaculture production (e.g. trout production) [**A**] 4. Water consumption for drinking [**A**] 5. Number and capacity of dams [**E**] 6. Number of boreholes in watersheds [**E**] 7. Volume of water bodies [**A**] 8. Stream water discharge [**A**] 9. Extent of permanent flow section per stream [**E**]

Agricultural & pasture land	Forests & shrublands	Freshwater
Regulating and maintenance ecosystem services		
1. High Nature Value farmland (HNVf) [**E**] 2. Number of floods/year that cause problems in agricultural areas [**E**] 3. Traditional plantations/orchards area (ha) [**E**] 4. Area cultivated with legumes [**E**] 5. Humidity Index [**E**] 6. Land Use Change [**E**]	1. C storage in forest [**D**] 2. C sequestration by forest (NPP; NEP) [**D**] 3. Forest soil condition: chemical soil properties [**D**] 4. Areas where aquifers are located [**E**] 5. Forest area (ha) [**E**] 6. Area of peri-urban forests (ha) [**E**] 7. Forest species distribution [**E**] 8. Investments in forests maintenance/ management [**A**] 9. Protected Areas for nursery populations [**E**] 10. Forest area designated for habitat-landscape protection: Natura2000 etc. [**E**]	1. Nitrate Vulnerable Zones (NVZs) [**E**] 2. Area of riparian forests [**E**] 3. Number and efficiency of wastewater treatment plants [**A**] 4. Volume of treated wastewater (tonnes/year) [**A**] 5. Area of wetlands [**E**] 6. Floodplains areas (and record of annual floods) [**A**] 7. Floodplains area [**E**] 8. Area of wetlands located in flood risk zones [**E**] 9. Ecological status [**A**] 10. Morphological status [**E**] 11. Number of introduced vertebrates in rivers and riparian areas [**A**] 12. Chemical status [**A**] 13. Surface of flood-prone areas [**E**] 14. Percentage of wetlands covered by Natura 2000 areas [**E**]
Cultural ecosystem services		
1. Density and number of bicycle routes and trails into agricultural and forest land [**E**] 2. Number of environmental info centres into agricultural areas [**E**] 3. Number of agricultural/ traditional festivals [**E**] 4. Religious monuments, pilgrim paths in agro-ecosystems [**E**] 5. Number of traditional, PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication) products in an area [**E**] 6. Number of nature/agricultural landscape photos uploaded on web portals [**E**] 7. Number and capacity of agritourist hotels/ motels in an area [**E**] 8. Degree of hemeroby [**E**] 9. Agricultural landscape structure [**A**] 10. Symbolic species [**A**] 11. Percentage of agricultural land into protected areas [**E**]	1. Density and number of bicycle routes and (natural) trails into agricultural and forest land [**E**] 2. Number of environmental information/education centres [**E**] 3. Number of visitors [**E**] 4. Number and density of natural trails or nature study trails [**E**] 5. Number of nature/agricultural landscape photos uploaded on web portals [**E**] 6. Distribution of sites of emblematic plants/forest/species [**A**] 7. Religious monuments [**A**] 8. Number and capacity of hotels/ motels in forest areas [**A**] 9. Percentage of agricultural land into forest areas [**E**]	1. National Parks and Natura 2000 sites [**E**] 2. Waterfalls [**E**] 3. Fishing reserves [**E**] 4. Classified sites (world heritage, label European tourism) [**E**] 5. Number of Environmental Centres in wetlands areas [**E**] 6. Natural heritage and cultural sites [**E**] 7. Number of visitors (surface or number of wetlands located next to a bike path) [**E**] 8. Number or area of wetlands near nature study trails or natural trails for walking [**E**] 9. Number or area of wetlands that have birdwatching or facilities for educating/ informing citizens [**E**] 10. Contrasting landscapes (lakes close to mountains) [**E**] 11. Sacred/religious sites (catastrophic events, religious places) [**E**] 12. Proximity to urban areas of scenic rivers or lakes [**E**]

Based on the MAES methodology (Maes et al. 2014), the CORINE 2012 was employed to map broad ecosystem types - level 3 on the island, using the ESRI ArcGIS software (v. 10.5.1).

Step 6 - Indicators Mapping: Following the rationale above, we present in this paper four mapped indicators from different categories of ecosystem services, namely distribution of cultivated land (provisioning), distribution of HNVfs and ecological status of freshwater (regulating) and tourism potential (cultural). The selection of these indicator/maps was based on the importance of the service at a national level and their relevance at the planning level. All four services are directly linked to the main economic sectors of the island and therefore any threats to these and the resulting changes in their amount and spatial extent might upset the balance on this insular environment. The mapping method for each of the indicators presented was as follows:

1. Distribution of cultivated land: this was mapped by including all cropland and pasture lands as per the CAPO data for 2013.

2. Distribution of HNVfs: The potential HNV farmland was delimited by combining the three HNV farmland-groups described in the European HNV indicator study (Brunbjerg et al. 2016). We combined high resolution spatial data from the land parcel information system (LPIS) for 2013 (the latest available dataset), with datasets on farming typology rules, agro-chemical inputs, water use intensity, Natura2000 sites, water bodies and Important Bird Areas (IBAs) in a common spatial framework. The methodology is described in detail elsewhere (Zomeni et al. 2018).

3. Ecological status: the Green indicator for assessing important regulating services for freshwater, is available through the competent authority of the Water Development Department of Cyprus and it concerns the results from biomonitoring programmes from the implementation of the Water Framework Directive (WFD; 2000/60/EC). According to the WFD, ecological status is classified into 4 quality classes (High, Good, Moderate, Poor and Bad), through comparison of biological quality elements (BQEs; benthic invertebrate fauna, phytobethos, macrophytes and fish fauna) with reference conditions, i.e. the communities indicative of undisturbed or minimally disturbed sites.

4. Recreation/tourism potential: Recreation was mapped, based on spatial and temporal analysis of geocoded images uploaded on flickr (flickr.com®) content-sharing application for the period 2005- 2014. The analysis relied on the IVEST recreation model (Sessions et al. 2016), using monthly and yearly number of spatially defined images, uploaded to flickr from each unique visitor, thus simulating photo user day (PUD) with visitor-day.

Results

Indicators assessment/selection for MAES in Cyprus

In the supplementary materials (see Suppl. material 1; Tables S1-3), the indicators for the ESs after their assessment (according to indicators suitability x data suitability) are presented for agro-ecosystems, forest ecosystems and freshwater ecosystems, respectively. Out of the 269 indicators evaluated in this paper, 89 were characterised as Green indicators which can be used directly for ecosystem management in Cyprus. Green indicators are distributed amongst ecosystem types as follows: forest and maquis 28/90; agroecosystems 26/86; and freshwater 35/93 (see Figure 2; per broad ecosystem type see - Suppl. material 1; Tables S1-3). The assessment of indicators revealed that 27 indicators with very high suitability (top right corner in Figure 2) can be used for assessment of provisioning services in Cyprus, 30 indicators for regulating services and 32 for cultural ecosystem services (Table 1). Furthermore, amongst these indicators (Suppl. material 1), there were 28 additional indicators (distributed in the three categories) proposed by this study which were considered to be appropriate and can be used at the national/subnational level (Table 1 underlined). The evaluation of mapping methods, on the basis also of the existing datasets at national/subnational level, showed that most of the 269 indicators can be mapped either by direct mapping (Method A) or by data integration (Method E) (seeTable 1).

Mapping examples

The maps for four important/representative services, one per major ES category are shown in Figs. 3-6. The potential of agricultural land for food provision is presented, based on the major crop types on the island (Fig. 3). A large part of the island is used for agricultural purposes and the most important crops are fodder, cereals, vineyards, orchards and annual crops. In Fig. 4, the extent of potential HNVfs on the island is presented, which captures a composite indicator which can be used as a proxy for pollination and biological pest control (Zomeni et al. 2018). HNVfs include olive and carob orchards and vineyards, where typically low intensity management practices are applied. As is observed from Fig. 4, a large part of the island's agricultural area could be characterised as HNVfs. The ecological status of freshwater bodies is illustrated in Fig. 5, as a proxy for regulating services. The majority of freshwater bodies have moderate to good ecological status, while high values are observed mainly to the upper parts of watersheds, in the mountain Troodos. Finally, the ES of recreational opportunities is presented in Fig. 6 as the number/ density of photos uploaded in Flickr per ecosystem type. As could be observed, human activity is higher in the coastal areas of Paphos, Limassol, Larnaka, Ammochostos and Keryneia. In this map, photos from the main urban centres (e.g. Nicosia, Limassol) of the island are also visible, indicative of relevant activities there.

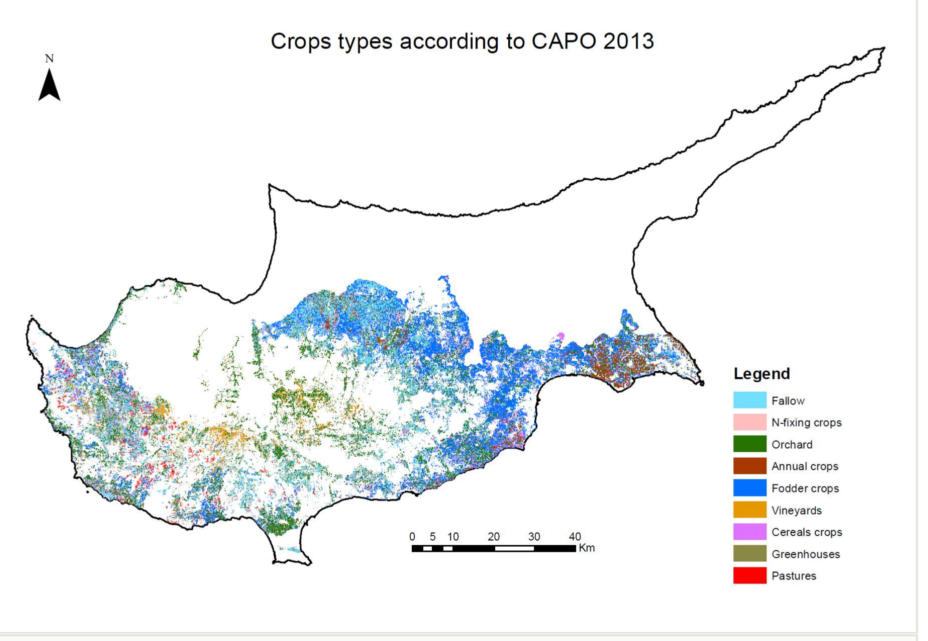

Figure 3.

Extent of cultivated land in Cyprus.

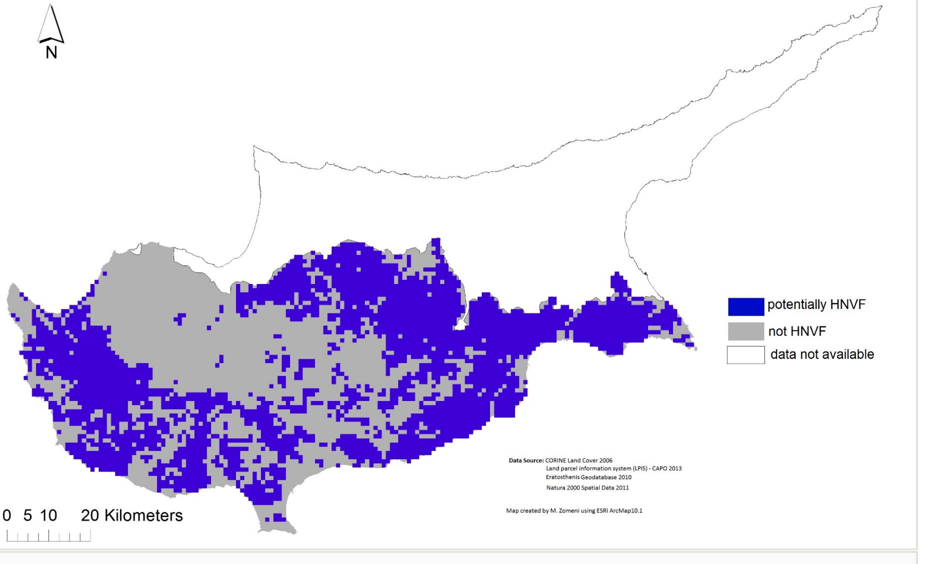

Figure 4.

Extent of HNVfs in the island (Zomeni et al. 2018).

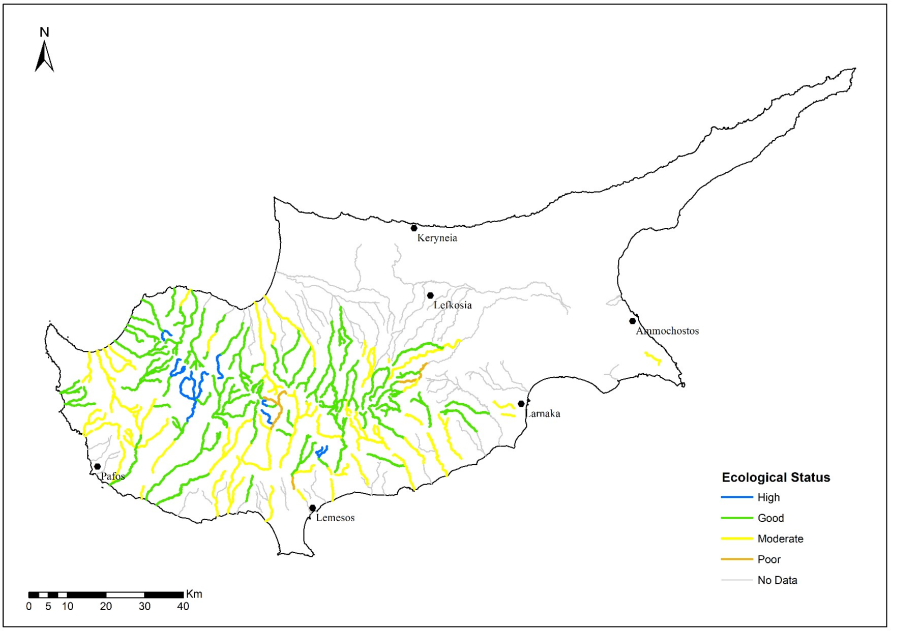

Figure 5.

Ecological status of freshwater bodies in Cyprus.

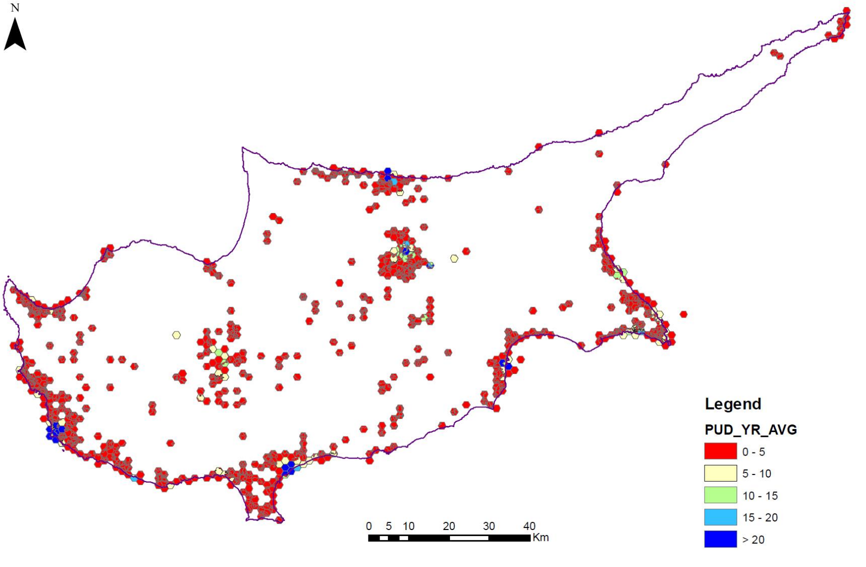

Figure 6.

Number of photos uploaded daily from various natural and urban sites.

Discussion

Integration of ecosystem services assessment in planning from municipal to country level is currently considered of utmost importance for achieving sustainability (Albert et al. 2016). The interconnection of ecosystem services and local communities in small islands and island states present a challenge and a special case for sustainable development identified in the United Nations (UN) Agenda 21 and the MA (Millennium Ecosystem Assessment (Program) 2005). These challenges arise from size, isolation and a fragile economy increasingly susceptible to externalities and result in difficulties for planning and management.

This is the first study in Cyprus which attempts the development of an ES assessment methodology on an island scale following similar studies at the European level. As such, it contributes directly to the implementation of MAES in Cyprus, thus fulfilling the EU biodiversity strategy's objective 2, Action 5. In addition, the study should be seen as a facilitation exercise to guide mainly government departments which are called to embrace relatively new terms and methodology and apply it at the local level. It highlights that the time is right for a national ecosystem assessment, since there are now at hand a plethora of well-tested methodologies, but also datasets readily available to contribute towards mapping and assessment of ES. A major benefit of MAES, beyond its contribution to the EU biodiversity strategy, is the establishment of a national reference system for planning and decision-making which could control whether local decisions meet national requirements.

The series of methodological papers produced by the European Commission and Joint Research Centre (Maes and Jacobs 2017, Maes et al. 2013) are of great help to member states' policy-makers, since they provide standard established procedures for ES mapping and assessment. However, these methodologies are not prescriptive and usually refinement is necessary at the national level (Dimopoulos et al. 2017), so that they can be of practical use for policy formulation and planning. In addition, they are usually conditioned by dependency on the local context and the availability and quality of datasets. In this view, the proposed indicators for MAES in Cyprus, although some are still coarsely defined, are useful in multi-level planning and for quantification and monitoring of the ES.

The Green indicators regarding the provisioning services in agro-ecosystems involve the production potential (agricultural land) and groundwater bodies presence/water exploitation in agricultural areas, which is an issue of major importance for the island. Energy crop production, although belonging to the green indicators, is not important presently for Cyprus. The respective indicators for the regulating services involve processes, such as carbon sequestration and proxy indicators for pollination (e.g. HNVfs) and N uptake from the atmosphere (e.g. legumes crops). Many additional indicators could be mapped (e.g. bicycle routes, Protected Designation of Origin products (PDOs), festivals for the cultural services provided by agroecosystems). Although this is a positive outcome of this exercise, there are still important MAES indicators, especially those linked to regulating services, that have been categorised as Red indicators, since their mapping is quite difficult at present, considering the methodology described herein and the MAES framework. These are available in the Table S1 (Suppl. material 1) and some examples include CH_4 production from manures, pollinator species distribution, N balance in agricultural land, pollution in agricultural soils and C sequestration in agricultural land.

In the case of forest ecosystems, there is better distribution of Green indicators across the three groups of services. Major provisioning services can be readily mapped, including forest biomass, wood consumption and hunting and groundwater abstraction areas (see Suppl. material 1; Table S2). Important regulating services can also be assessed, such as C storage and sequestration and forest soils conditions. In addition, further work is needed for erosion and flood risk mapping (currently in the orange category). There is a plethora of indicators for which data exist in order to map forest cultural services in Cyprus.

Regarding freshwater ecosystems, there is a slight variation in the number of Green indicators across the three groups of services with indicators for regulating and cultural services to be the most abundant (14 and 12, respectively), while the number of Green indicators for provisioning services is limited to nine (9). The most important provisioning services are related, as is expected in semi-arid regions worldwide, to the water resources supply i.e. volume of water bodies, number and capacity of dams etc. Important regulating services, provided by freshwater habitats in Cyprus, can be assessed using indicators mainly derived by the (bio)monitoring programmes i.e. ecological and chemical status or from the implementation of other European Directives like Floods Directive (2007/60/EC). Important Orange indicators might also be used to assess mainly regulating and cultural services (i.e. water volume and hydrological flow and nutrient load).

In addition to the indicators proposed by MAES, we have added a number of new indicators (Table 1) which were a result of consultation with government departments. These were considered appropriate and important at the local context and include water, hunting and tourism-related indicators, for which long term data at the national scale are available. Water scarcity is a major environmental problem on the island and this is expected to be exacerbated as a result of increased pressure due to climate change on this service (Vogiatzakis et al. 2016). Therefore, we have included groundwater abstractions areas, dams and groundwater bodies recharge. Microclimate regulation by forests also needs to be considered for an island where the heat island effect is already present (Theophilou and Serghides 2014) and is expected to intensify under climatic change. Thus, we added urban and sub-urban forest area as an indicator. Hunting has an important role in the rural society as it is not simply a recreational activity, but also an important revenue source for the state; this is why hunting areas as an indicator are proposed. The inclusion of additional cultural indicators linked mainly to tourism, such as density and number of bicycle routes and trails into agricultural and forest land and the number of visitor/environmental centres, reflect again the importance that the tourism sector has for the national economy. The island is an attractive destination to tourists due to numerous seaside resorts, but also due to its rich culture i.e. the presence of many historic and religious monuments which can be incorporated into cultural ES indicators (such as the number of religious monuments within forests).

According to the fifth MAES report (Maes et al. 2018), there are several key indicators proposed for pressures and condition at the EU level. Many of the Green indicators, proposed herein, can be used as pressure or condition indicators since data time series are available for their mapping. For example, land use change, water over-exploitation and agricultural land in Natura 2000 areas could be used for agroecosystems. In the case of forest ecosystems, these indicators are forest cover change, number of fires and forest area. For freshwaters ecosystems, such indicators include land take (conversion from natural to artificial), water exploitation index and ecological status (Fig. 5). However, identification of pressure and condition indicators for Cyprus was beyond the scope of this study.

The available data and the indicators, as assessed in detail in this work, show that the ES supply in Cyprus could be estimated, mapped and monitored. Although, taking into account the demand, in addition to the ES supply, is also a fundamental step in ES assessment (Albert et al. 2016), currently there is a lack of data in Cyprus to quantify it. One main issue is the lack of a database that will contain all the respective information for MAES. A good first step towards this is the creation of the national open data portal (https://www.data.gov.cy/). In addition, important for MAES in Cyprus, is the modernisation of the public services data collection methods, in order to include data georeferencing during monitoring and recording.

Due to their importance for island communities, agricultural land, pollination, tourism and water provision are often some of the key ecosystem services assessed in island-related studies (see review in Balzan et al. 2018). Therefore, we have also mapped indicatively these four services. The development of the methodology for the mapping and quantification of ES is promising and moving rapidly (Crossman et al. 2013, Jacobs et al. 2015, Albert et al. 2016). In this case as a provisioning service indicator, the data that were available for the types of crops, at a field level, allowed the mapping of the food-providing potential from fields. The mapping detail in the CAPO dataset allows for a relatively easy mapping of food-provisioning services. However, data for the yields for each crop would have been preferable, since they could provide a more accurate picture of food provisioning through the years. For providing fodder from grasslands and fodder crops, the distribution of the fields cultivated with feed crops was selected. This could be a proxy for determining the capability of the agricultural land to provide feed for the animal production in the island. However, a lot of animal feed is imported in Cyprus. In this case, the use of a demand indicator as well (e.g. livestock units) would be useful for assessing the potential of the ecosystem to support the total of animal production in the island. Since the aim of this research was to explore and establish the supply indicators for MAES, demand indicators were not elaborated at this stage.

The distribution of HNVfs on the island is a useful indicator for pollination and pest control, as shown in several studies regarding HNVf (Öckinger and Smith 2007, Doxa et al. 2010, Carvalheiro et al. 2011, Zulian et al. 2013). HNVfs in Cyprus are mainly characterised by low intensity cropping systems, small scale agriculture and a high diversity of crop types (Zomeni et al. 2018). The generally low use of agrochemicals, especially pesticides, in HNVfs, as well as the high diversity of crop types, alternative habitats and uncultivated flowering margins provide resources that could potentially enhance pollinator and natural enemy abundance.

Freshwater ecosystems in the island provide goods and services of critical importance, yet they are amongst the most heavily altered ecosystems, due to alterations of natural flow regimes by man-made dams, land-use changes and water abstraction which has profound impacts on lotic communities. As presented in Fig. 5, the majority of the systems have moderate to good ecological status and this is an important indicator for water provisioning. Major threats for freshwater bodies include over-exploitation, due to the water scarcity, water pollution, fragmentation, destruction or degradation of habitat and the introduction of alien species.

Regarding the cultural service "providing opportunities for recreation", we used the number of photos uploaded in webpages/apps (e.g. Flickr) per area. This was used as a proxy for the popularity of each area. In this case, higher photo upload from a location, means higher popularity for an area and higher number of visitors. Urban areas were not excluded, as cultural services could also be provided there and keeping it is a useful comparison between urban and rural areas popularity.

The accuracy of our mapping results, regardless of method, is a function of the assumptions and the quality of the data. Biophysical data (e.g. land cover variables) are mostly used for MAES (Maes and Jacobs 2017). The sub-set of the ES indicators that can be readily mapped in Cyprus, as presented in the current study, were selected, based on the data availability for mapping and their suitability to capture the ES provided. Mapping for those indicators can be done either directly using existing survey and census data or using products of simple data integration exercises (Martínez-Harms and Balvanera 2012). The current study showed that there is neither lack of indicators and methods, nor lack of data (in terms of reliability, availability, access, spatial and thematic analysis) which may be an obstacle to the mapping/evaluation of ES. Obviously, some gaps have been recorded for some indicators, but not to the extent that it hinders the estimation of many of the provided ES by ecosystem type. Even for the northern part of the island, where data might not be available and empirical models have been developed from point-based measurements of services, a priori rule-based models could be used for a fairly reliable assessment of many of the indicators proposed herein.

Conclusions and future steps

The information that is provided in this first attempt for Cyprus could offer new insights to consider synergies and trade-offs between ES and landscape planning, in order to safeguard and enhance, where possible, the long-term supply of ES. The key messages stemming from this work are summarised below:

- There is a good representation of indicators for all main ecosystem services and broad ecosystem types on the island;

- These indicators can be already mapped since data and methods are already available;
- Not all Green indicators, identified herein, are relevant to Cyprus, whereas Green indicators which measure similar ES might be redundant;
- Although there is a good number of Green indicators identified, there are many more Orange indicators of equal importance which can be used (with coordinated effort);
- Some relevant (and important) indicators for a given geographical context might be outside the list proposed by Maes et al. (2014), that is why consultation with stakeholders is advisable.
- There is a parsimonious number of Green indicators for all Ecosystem types and ES which can be employed as pressure and condition indicators;

For further research, the following issues are regarded as crucial for the implementation of the MAES methodology in Cyprus:

1. Determine demand indicators, for a more accurate assessment of the MAES in the island, to further support ecosystems management and decision-making;
2. Mapping of all Green indicators presented in this work for MAES in Cyprus;
3. Define pressure and condition indicators, based on the recent work by Maes et al. (2018)
4. Research on the relation of the ES with the ecosystem state (e.g. pollution) and characteristics (e.g. size, habitat type);
5. Increase consultations on the data needed for mapping with the competent authorities through targeted thematic workshops, bringing together all the groups involved (Government Departments, Universities and NGOs).

Amongst the issues that should be further considered, are what kind of information could be useful for the decision-makers, for which type of decisions and by whom. In order to achieve this, there is a need for elaborating on a roadmap for implementation of the framework for ES evaluation which will include the development of a national database for MAES, establishment of working groups for MAES (e.g. involving scientists and stakeholders) and active participation in international networks, such as the Ecosystem Service Partnership.

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References

- Albert C, Bonn A, Burkhard B, Daube S, Dietrich K, Engels B, Frommer J, Götzl M, Grêt-Regamey A, Job-Hoben B, Koellner T, Marzelli S, Moning C, Müller F, Rabe S, Ring I, Schwaiger E, Schweppe-Kraft B, Wüstemann H (2016) Towards a national set of ecosystem service indicators: Insights from Germany. Ecological Indicators 61: 38-48. https://doi.org/10.1016/j.ecolind.2015.08.050
- Andrew M, Wulder M, Nelson T, Coops N (2015) Spatial data, analysis approaches, and information needs for spatial ecosystem service assessments: a review. GIScience & Remote Sensing 52 (3): 344-373. https://doi.org/10.1080/15481603.2015.1033809
- Aretano R, Petrosillo I, Zaccarelli N, Semeraro T, Zurlini G (2013) People perception of landscape change effects on ecosystem services in small Mediterranean islands: A combination of subjective and objective assessments. Landscape and Urban Planning 112: 63-73. https://doi.org/10.1016/j.landurbplan.2012.12.010
- Balzan MV, Caruana J, Zammit A (2018) Assessing the capacity and flow of ecosystem services in multifunctional landscapes: Evidence of a rural-urban gradient in a Mediterranean small island state. Land Use Policy 75: 711-725. https://doi.org/10.1016/j.landusepol.2017.08.025
- Brunbjerg AK, Bladt J, Brink M, Fredshavn J, Mikkelsen P, Moeslund J, Nygaard B, Skov F, Ejrnæs R (2016) Development and implementation of a high nature value (HNV) farming indicator for Denmark. Ecological Indicators 61: 274-281. https://doi.org/10.1016/j.ecolind.2015.09.027
- Carvalheiro LG, Veldtman R, Shenkute AG, Tesfay GB, Pirk CWW, Donaldson JS, Nicolson SW (2011) Natural and within-farmland biodiversity enhances crop productivity. Ecology Letters 14 (3): 251-259. https://doi.org/10.1111/j.1461-0248.2010.01579.x
- Chiarucci A, Fattorini S, Foggi B, Landi S, Lazzaro L, Podani J, Simberloff D (2017) Plant recording across two centuries reveals dramatic changes in species diversity of a Mediterranean archipelago. Scientific Reports 7 (1): 5415. https://doi.org/10.1038/s41598-017-05114-5
- Ciftcioglu GC (2017) Assessment of the relationship between ecosystem services and human wellbeing in the social-ecological landscapes of Lefke Region in North Cyprus. Landscape Ecology 32 (4): 897-913. https://doi.org/10.1007/s10980-017-0494-y
- Crossman N, Burkhard B, Nedkov S, Willemen L, Petz K, Palomo I, Drakou E, Martín-Lopez B, McPhearson T, Boyanova K, Alkemade R, Egoh B, Dunbar M, Maes J (2013) A blueprint for mapping and modelling ecosystem services. Ecosystem Services 4: 4-14. https://doi.org/10.1016/j.ecoser.2013.02.001
- Dimopoulos P, Drakou E, Kokkoris I, Katsanevakis S, Kallimanis A, Tsiafouli M, Bormpoudakis D, Kormas K, Arends J (2017) The need for the implementation of an Ecosystem Services assessment in Greece: drafting the national agenda. One Ecosystem 2 https://doi.org/10.3897/oneeco.2.e13714
- Doxa A, Bas Y, Paracchini ML, Pointereau P, Terres J, Jiguet F (2010) Low-intensity agriculture increases farmland bird abundances in France: High nature value farmland birds. Journal of Applied Ecology 47 (6): 1348-1356. https://doi.org/10.1111/j.1365-2664.2010.01869.x

- Egoh B, Reyers B, Rouget M, Richardson D, Le Maitre D, van Jaarsveld A (2008) Mapping ecosystem services for planning and management. Agriculture, Ecosystems & Environment 127 (1): 135-140. https://doi.org/10.1016/j.agee.2008.03.013
- European Commission (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Europen Union.
- Fish R, Church A, Winter M (2016) Conceptualising cultural ecosystem services: A novel framework for research and critical engagement. Ecosystem Services 21: 208-217. https://doi.org/10.1016/j.ecoser.2016.09.002
- García-Nieto AP, Geijzendorffer I, Baró F, Roche P, Bondeau A, Cramer W (2018) Impacts of urbanization around Mediterranean cities: Changes in ecosystem service supply. Ecological Indicators 91: 589-606. https://doi.org/10.1016/j.ecolind.2018.03.082
- Grêt-Regamey A, Weibel B, Kienast F, Rabe S, Zulian G (2015) A tiered approach for mapping ecosystem services. Ecosystem Services 13: 16-27. https://doi.org/10.1016/j.ecoser.2014.10.008
- Hauck J, Schweppe-Kraft B, Albert C, Görg C, Jax K, Jensen R, Fürst C, Maes J, Ring I, Hönigová I, Burkhard B, Mehring M, Tiefenbach M, Grunewald K, Schwarzer M, Meurer J, Sommerhäuser M, Priess J, Schmidt J, Grêt-Regamey A (2013) The promise of the ecosystem services concept for planning and decision-making. GAIA - Ecological Perspectives for Science and Society 22 (4): 232-236. https://doi.org/10.14512/gaia.22.4.6
- Häyhä T, Franzese PP, Paletto A, Fath B (2015) Assessing, valuing, and mapping ecosystem services in Alpine forests. Ecosystem Services 14: 12-23. https://doi.org/10.1016/j.ecoser.2015.03.001
- Jacobs S, Burkhard B, Van Daele T, Staes J, Schneiders A (2015) 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services. Ecological Modelling 295: 21-30. https://doi.org/10.1016/j.ecolmodel.2014.08.024
- Kokkoris I, Dimopoulos P, Xystrakis F, Tsiripidis I (2018) National scale ecosystem condition assessment with emphasis on forest types in Greece. One Ecosystem 3 https://doi.org/10.3897/oneeco.3.e25434
- Kokkoris I, Bekri E, Skuras D, Vlami V, Zogaris S, Maroulis G, Dimopoulos D, Dimopoulos P (2019) Integrating MAES implementation into protected area management under climate change: A fine-scale application in Greece. Science of The Total Environment 695 https://doi.org/10.1016/j.scitotenv.2019.07.336
- Kumar P (Ed.) (2012) TEEB. The economics of ecosystems and biodiversity: Ecological and economic foundations. Paperback. Routledge, London. https://doi.org/10.4324/9781849775489
- Lelieveld J, Proestos Y, Hadjinicolaou P, Tanarhte M, Tyrlis E, Zittis G (2016) Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. Climatic Change 137: 245-260. https://doi.org/10.1007/s10584-016-1665-6
- Maes J, Teller A, Erhard M, et al. (2013) An analytical framework for ecosystem assessments under action 5 of the EU Biodiversity Strategy to 2020 discussion paper, final, April 2013. European Union
- Maes J, Teller A, Erhard M, et al. (2014) Indicators for ecosystem assessments under action 5 of the EU Biodiversity Strategy to 2020. European Commission
- Maes J, Jacobs S (2017) Nature-Based Solutions for Europe's Sustainable Development. Conservation Letters 10 (1): 121-124. https://doi.org/10.1111/conl.12216

- Maes J, Teller A, Erhard M, et al. (2018) An analytical framework for mapping and assessment of ecosystem condition in EU. European Union
- Manolaki P, Vogiatzakis I (2017) Ecosystem services in a peri-urban protected area in Cyprus: a rapid appraisal. Nature Conservation 22: 129-146. https://doi.org/10.3897/natureconservation.22.13840
- Martínez-Harms MJ, Balvanera P (2012) Methods for mapping ecosystem service supply: a review. International Journal of Biodiversity Science, Ecosystem Services & Management 8 (1-2): 17-25. https://doi.org/10.1080/21513732.2012.663792
- Medail F, Quezel P (1999) Biodiversity Hotspots in the Mediterranean Basin: Setting Global Conservation Priorities. Conservation Biology 13 (6): 1510-1513. https://doi.org/10.1046/j.1523-1739.1999.98467.x
- Millennium Ecosystem Assessment (Program) (2005) Our human planet: summary for decision-makers. Island Press, Washington, [D.C.].
- Mononen L, Auvinen A-P, Ahokumpu A-L, Rönkä M, Aarras N, Tolvanen H, Kamppinen M, Viirret E, Kumpula T, Vihervaara P (2016) National ecosystem service indicators: Measures of social–ecological sustainability. Ecological Indicators 61: 27-37. https://doi.org/10.1016/j.ecolind.2015.03.041
- Nikodinoska N, Paletto A, Pastorella F, Granvik M, Franzese PP (2018) Assessing, valuing and mapping ecosystem services at city level: The case of Uppsala (Sweden). Ecological Modelling 368: 411-424. https://doi.org/10.1016/j.ecolmodel.2017.10.013
- Öckinger E, Smith H (2007) Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. Journal of Applied Ecology 44 (1): 50-59. https://doi.org/10.1111/j.1365-2664.2006.01250.x
- Potschin M, Haines-Young R (2012) Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecology 28 (6): 1053-1065. https://doi.org/10.1007/s10980-012-9756-x
- Sarris D, Christodoulakis D, Körner C (2011) Impact of recent climatic change on growth of low elevation eastern Mediterranean forest trees. Climatic Change 106 (2): 203-223. https://doi.org/10.1007/s10584-010-9901-y
- Sessions C, Wood S, Rabotyagov S, Fisher D (2016) Measuring recreational visitation at U.S. National Parks with crowd-sourced photographs. Journal of Environmental Management 183: 703-711. https://doi.org/10.1016/j.jenvman.2016.09.018
- Theophilou MK, Serghides D (2014) Heat island effect for Nicosia, Cyprus. Advances in Building Energy Research 8 (1): 63-73. https://doi.org/10.1080/17512549.2014.890538
- Tratalos JA, Haines-Young R, Potschin M, Fish R, Church A (2016) Cultural ecosystem services in the UK: Lessons on designing indicators to inform management and policy. Ecological Indicators 61: 63-73. https://doi.org/10.1016/j.ecolind.2015.03.040
- Václavík T, Lautenbach S, Kuemmerle T, Seppelt R (2019) Mapping land system archetypes to understand drivers of ecosystem service risks. Atlas of ecosystem services: Drivers, risks, and societal responses. [ISBN 978-3-319-96229-0]. https://doi.org/10.1007/978-3-319-96229-0_12
- Vogiatzakis IN, Mannion AM, Sarris D (2016) Mediterranean island biodiversity and climate change: the last 10,000 years and the future. Biodiversity and Conservation 25 (13): 2597-2627. https://doi.org/10.1007/s10531-016-1204-9
- Wolff S, Schulp CJE, Verburg PH (2015) Mapping ecosystem services demand: A review of current research and future perspectives. Ecological Indicators 55: 159-171. https://doi.org/10.1016/j.ecolind.2015.03.016

- Zomeni M, Martinou A, Stavrinides M, Vogiatzakis I (2018) High nature value farmlands: challenges in identification and interpretation using Cyprus as a case study. Nature Conservation 31: 53-70. https://doi.org/10.3897/natureconservation.31.28397
- Zulian G, Maes J, Paracchini ML (2013) Linking land cover data and crop yields for mapping and assessment of pollination services in Europe. Land 2 (3): 472-492. https://doi.org/10.3390/land2030472

Supplementary material

Suppl. material 1: Suplementary file doi

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