One Ecosystem 2: e13718
doi: 10.3897/oneeco.2.e13718

Research Article

Ecosystem Service capacity is higher in areas of multiple designation types

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Academic editor: Bilyana Borisova

Received: 16 May 2017 | Accepted: 04 Sep 2017 | Published: 08 Sep 2017

Citation: Nikolaidou C, Votsi N, Sgardelis S, Halley J, Pantis J, Tsiafouli M (2017) Ecosystem Service capacity is higher in areas of multiple designation types. One Ecosystem 2: e13718.
https://doi.org/10.3897/oneeco.2.e13718

Abstract

The implementation of the Ecosystem Service (ES) concept into practice might be a challenging task as it has to take into account previous “traditional” policies and approaches that have evaluated nature and biodiversity differently. Among them the Habitat (92/43/EC) and Bird Directives (79/409/EC), the Water Framework Directive (2000/60/EC), and the Noise Directive (2002/49/EC) have led to the evaluation/designation of areas in Europe with different criteria. In this study our goal was to understand how the ES capacity of an area is related to its designation and if areas with multiple designations have higher capacity in providing ES.

We selected four catchments in Greece with a great variety of characteristics covering over 25% of the national territory. Inside the catchments we assessed the ES capacity (following the methodology of Burkhard et al. 2009) of areas designated as Natura 2000 sites, Quiet areas and Wetlands or Water bodies and found those areas that have multiple designations. Data were analyzed by GLM to reveal differences regarding the ES capacity among the different types of areas. We also investigated by PCA synergies and trade-offs among different kinds of ES and tested for correlations among landscape properties, such as elevation, aspect and slope and the ES potential.

Our results show that areas with different types or multiple designations have a different capacity in providing ES. Areas of one designation type (Protected or Quiet Areas) had in general intermediate scores in most ES but scores were higher compared to areas with no designation, which displayed stronger capacity in provisioning services. Among Protected Areas and Quiet Areas the latter scored better in general. Areas that combined both designation types (Protected and Quiet Areas) showed the highest capacity in 13 out of 29 ES, that were mostly linked with natural and forest ecosystems. We found significant synergies among most regulating, supporting and cultural ES which in turn display trade-offs with provisioning services. The different ES are spatially related and display strong correlation with landscape properties, such as elevation and slope.

We suggest that the designation status of an area can be used as an alternative tool for environmental policy, indicating the capacity for ES provision. Multiple designations of areas can be used as proxies for locating ES "hotspots". This integration of "traditional" evaluation and designation and the "newer" ES concept forms a time- and cost-effective way to be adopted by stakeholders and policy-makers in order to start complying with new standards and demands for nature conservation and environmental management.

Keywords

Ecosystem Services hotspots, Natura 2000, Quiet Protected Areas, Biodiversity, Agriculture, Elevation, Slope, Ecosystem Service trade-offs and synergies, cultural services, provisioning services, regulating services, supporting services

Introduction

In an attempt to halt biodiversity loss, the European Union (EU) has adopted a strategy recognizing the importance of ecosystem services (ES) (Maes et al. 2016). Under this framework many initiatives of mapping and assessing ES have been developed (Haines-Young et al. 2012, Kandziora et al. 2013, Brown and Fagerholm 2015). The incorporation of ES into an integrated environmental policy approach (deGroot et al. 2010) follows the new era of sustainable management (Maes et al. 2012b). The interactive and multidimensional relation between biodiversity and ES (Onaindia et al. 2013) reveals the need for a well-established integrated policy plan embracing various elements of the natural environment to result in a cost and time effective strategy for biodiversity conservation and human well-being (Lafferty and Hovden 2003, Bennett 2004, Chan et al. 2016).

Currently EU environmental policy is mainly based on Directives following specific recommendations, thus leading to a wide range of interpretations and accompanied implementations by member states (Alphandéry and Fortier 2001, Apostolopoulou and Pantis 2009). "Traditional" environmental policies are conducted at local or regional level, while the perspective of contemporary environmental policy initiatives lies on national or even coarser scale under the framework of EU legislation (Beunen et al. 2013).

Apart from Habitats (92/43/EEC) and Birds (79/409/EEC) Directives which indicate the designation of conservation networks -by means of the Natura 2000 network- to preserve biodiversity (Tsianou et al. 2013), there are also other environmental directives aiming at protecting nature but also ensuring human well-being. Among them, Environmental Noise Directive's (2002/49/EC) goal is to mitigate the detrimental for human health environmental problem of noise pollution by mapping and recognizing the main noise sources of each member state, as well as assessing Quiet Areas –meaning sites free of human induced noise (Votsi et al. 2012). Moreover the Water Framework Directive (2000/60/EC) as the basic regulatory framework of the EU regards the improvement of the quality of all water resource (Muxika et al. 2007, Demetropoulou et al. 2010). The existing environmental legislation so far promotes measures which, either directly or indirectly, use natural areas as a key criterion for assessing the quality of ecosystems (Paetzold et al. 2010). Thus it could be argued that areas that fulfill the prerequisites of the various environmental Directives are of high natural value. In such areas ES are expected to thrive, especially in cases where the prerequisites of more than one Directive are met. Hence, rather than focusing on each and every ES of the landscape (Haines-Young et al. 2012, VanOudenhoven et al. 2012, Geijzendorffer and Roche 2013), finding "hotspots" of ES could be more efficient (Chee 2004).

To approach this need we combined in our methodology information on the designation of an area and the ES potential of the area. Specifically we selected four catchments in Greece, with a broad variety of characteristics covering over 25% of the national territory. Inside the catchments we focused on areas with different type of designations, namely Natura 2000 (Habitat Directive 92/43/EC and Bird Directive 79/409/EC), Quiet Areas (Noise Directive 2002/49/EC), Wetlands/Water bodies (Water Framework Directive 2000/60/EC and other policy frameworks). Intersecting of the areas mentioned above resulted in the identification of areas with more than one designation (Natura 2000 site + Quiet Area, Natura 2000 site + Quiet Area + Wetland/Water body). We used Corine Land Cover and following the methodology of Burkhard et al. (2009), we assessed the potential of ES in the different categories of areas. As landscape features such as altitude, slope and aspect, have a great influence on land use, particularly when it comes to large spatial scales (Briassoulis 2009), we also tested relations among these properties and the potential of ES delivery within the study areas. Moreover, taking into account that ES interact with each other (Lee and Lautenbach 2016, Rodriguez et al. 2006) we investigated synergies or trade-offs among them.

Our goal was to understand how the ES potential of an area is related to its landscape features and its designation type (i.e. Natura 2000, Quiet Area, Wetland) and whether areas with multiple designations have higher capacity in providing ES. Interpreting land use and ES interaction could help in developing a general framework of management tools and an integrated environmental policy combining experience from "traditional" policies and new insights from the ES concept.

Material and methods

We selected four catchments in Greece (Geodata.gov 2015), with a broad variety of characteristics covering over 25% of the national territory 34655 Km^2 (Fig. 1). Necessary geographic data for the selected study areas were collected in GIS. Inside the catchment areas we identified land uses using the CORINE Land Cover 2000 database (EEA 2016). We evaluated the ES capacity of each land cover type following the assessment matrix of Burkhard et al. (2009). In this methodology several ES corresponding to four categories (supporting, provisioning, regulating and cultural services) are spatially designated according to land cover types of CORINE. Each land cover type corresponds to a certain ES score ranging from 0 when there is no relevant ES capacity, to 5 when there is high relevant capacity (for details see Matrix for the assessment of the different land cover types' capacities to provide selected ecosystem goods and services, Burkhard et al. 2009).

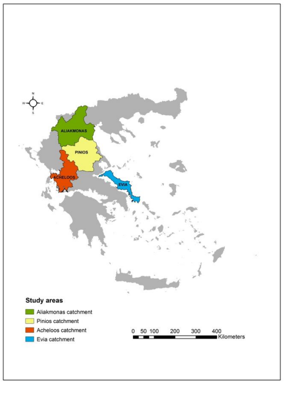

Figure 1.

Study catchment areas (Greece). ALIAKMONAS Catchment (12410 km$^{2)}$ is the largest river basin in Greece, characterized by mountainous and semi-mountainous areas. It includes the Aliakmonas river and Lake Kastoria. PINIOS Catchment (11062 km^2) includes Pinios river and is characterized by the largest lowland area of the country. ACHELOOS Catchment (7530 km^2) includes Achelloos river, Lake Trichonida (the largest natural lake in Greece), other numerous rivers, lakes and lagoons and remarkable mountainous regions. EVIA Catchment (3686 km^2) includes the homonymous island (the second largest of the country) and displays diverse and complex geological structure with both mountains and lowland areas.

Inside the catchments we identified the areas which fulfill the criteria for different types of designation namely Quiet Areas (EU Noise Directive 2002/49/EC), Natura 2000 sites (Habitat Directive 92/43/EC and Bird Directive 79/409/EC), Wetlands/Water bodies (EU Water Framework Directive 2000/60/EC and other policy frameworks) as following:

1. For “Quiet Areas” we followed the methodology of Votsi et al. (2012) [Quiet areas include sites with no human-induced noise sources constituting an index of naturalness/wilderness of the landscape. The identification of Quiet Areas is based on the identification of the main anthropogenic noise sources using several spatial datasets (i.e. Corine Land Cover, road network etc.) as well as the generated sound levels based on existing literature reviews (e.g. Ramis et al. 2003,Jackson et al. 2008).]
2. For “Protected Areas” we used the spatial data of Natura 2000 network (borders of sites) (EEA 2014), while
3. “Wetlands/Water bodies” were identified from the Corine Land Cover (code 4xx-5xx). Remaining areas in the catchments were those with no designation ability.

All shapefiles were converted to raster format (cell size 500m x 500m). We superimposed all the raster layers (Fig. 2) and intersected them for the identification of areas with more than one designation type. Thus in the examined catchments each cell (of known ES score) was categorized into the following designation types: ND= No Designation, PA= Protected Area (Natura 2000 site), QA= Quiet Area (meaning free of anthropogenic noise sources - for a detailed description see Votsi et al. 2012), PAQA= Protected Area & Quiet Area, PAQAW= Protected Area & Quiet Area & Wetland/Water body (Fig. 2). It has to be noted that Wetlands/Water bodies were not handled as a separate category as the majority are already included in the Natura 2000 network..

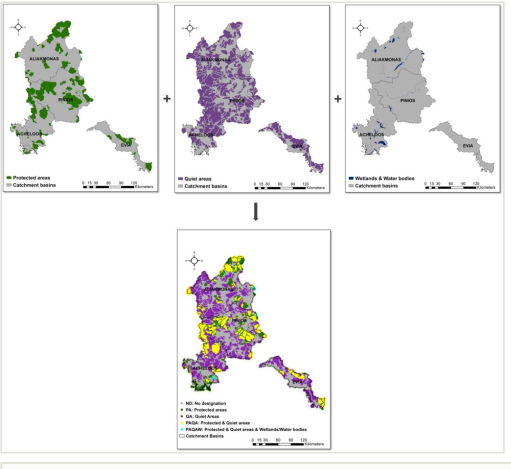

Figure 2.

Areas according to type and number of designations. Superimposing of Protected Areas (Natura 2000 Network) (left upper map), Quiet Areas (Environmental Noise Directive) (middle upper map), Wetlands/Water bodies (right upper map) lead after intersection to: the categorization of areas according to type and number of designation (lower map). [Codes: ND: No designation, PA: Protected Area, QA: Quiet area, PAQA: Protected Area + Quiet area, PAQAW: Protected Area + Quiet Area+Wetland/Waterbodies].

In our geodata set we also included landscape parameters such as elevation, slope and aspect. For elevation we used the 1 km Digital Elevation Model (EEA 2004) while slope and aspect were calculated by using spatial analyst toolbox. All analysis and production of maps was performed using ArcMap GIS 10.1 (ESRI 2010). The Projected Coordinate System used was GRS 1980 Transverse Mercator.

Statistical analysis

Data were analyzed by GLM to reveal differences among the different categories of areas regarding the ES capacity. Correlations among landscape properties (elevation, slope and aspect) and the ES capacity were also tested. A Principal Component Analysis (PCA) for 29 variables that correspond to the examined ES was carried out in order to group the variables and specify the synergies and trade-offs between ES as proposed by Raudsepp-Hearne et al. (2010) and tested by Depellegrin et al. (2016). All statistical analysis was performed using SPSS v. 21 (IBM Corp 2012).

Results

ES capacity in the studied catchments and in areas of various or multiple designations

In all studied catchments (data not shown) a great percentage of surfaces (over 50%) are occupied by forests and semi-natural areas, while agricultural areas cover also significant parts (22 to 47%). Hence supporting, regulating, provisioning and cultural services (capacity score >0) are provided respectively from the 99.9 %, 98.2%, 97.1% and 95.9% of total study areas surface. Aliakmonas and Acheloos have all the 29 ES while Pinios has 28 and Evia 26 ES, respectively. The missing ES are related mostly to absence of coastal lagoons and wetlands from the Evia catchment.

Fig. 2 shows the areas of different or multiple designation types. Areas with no designation (ND) have the highest amount of area in the four catchments (13266 km^2, 38% of the total surface) followed by Quiet Areas (QAs) (12467 Km^2, 36% of the total surface) and by areas that are both Quiet and Protected (PAQAs) (5455 Km^2, 16% of the total surface). The least amount belongs to the type Protected Areas only (PAs) (3335 Km^2, 9.6% of the total surface) and much less fulfill the criteria of all designation types (PAQAW) (132 Km^2, 0.4% of the total surface).

Table 1 shows the average score of each ES (the capacity based on land cover type) at each of the five categories of areas as well as results of ANOVA comparing differences among them. Scores of supporting services such as “Biodiversity” and “Reduction of Nutrient Loss” were significantly higher in PAQAs intermediate in PAs, and QAs and lowest in the ND areas . “Abiotic Heterogeneity” had a higher score in PAQAW while the reverse was observed for “Biotic Waterflow” and “Exergy capture”. Provisioning services (except those related to water, i.e “Capture Fisheries”, “Aquaculture” and “Freshwater” as well as

"Wild foods") were highest in ND intermediate in PAs, QAs, or PAQAs and lowest in PAQAW . Regulating services such as “Local” and “Global Climate Regulation”, “Air Quality” and “Erosion Regulation”, “Water purification” and “Pollination” had significantly higher scorers in PAQAs and lower in PAQAW. A similar pattern presented also the “Nutrient regulation” except that the score for this ES exhibited the lowest values in ND areas. “Flood protection” and “Groundwater Recharge” decreased significantly from PAQAW to ND. Cultural services had highest values in PAQAW intermediate in PAs and QAs and lowest values in ND.

Table 1.

Average capacity score of each ES in each of the five categories of areas as well as results of ANOVA comparing differences among them (*P: *<0.05, **<0.001, ***<0.0001*). [Codes: ND: No designation, PA: Protected Area, QA: Quiet Area, PAQA: Protected Area + Quiet Area, PAQAW: Protected Area + Quiet Area + Wetland/Waterbodies]

	F	*P*	ND	PA	QA	PAQA	PAQAW
Supporting services							
Abiotic Heterogeneity	288.40	**	3.01^{b}	3.04^{c}	3.01^{b}	2.99^{a}	3.56^{d}
Biodiversity	3046.30	***	3.04^{a}	3.45^{b}	3.58^{c}	3.79^{d}	3.61^{c}
Biotic Waterflow	439.96	**	3.22^{c}	3.15^{b}	3.29^{d}	3.30^{d}	1.09^{a}
Metabolic Efficiency	1362.98	***	2.69^{a}	3.12^{c}	3.09^{b}	3.35^{d}	3.80^{e}
Exergy Capture	3.50	*	3.93^{b}	3.94^{bc}	3.95^{c}	3.95^{bc}	3.80^{a}
Reduction of Nutrient Loss	3506.76	***	2.44^{a}	3.15^{c}	3.40^{d}	3.76^{e}	2.99^{b}
Storage Capacity	411.02	**	3.28^{a}	3.57^{c}	3.47^{b}	3.62^{d}	4.16^{e}
Provisioning services							
Crops	3024.28	***	2.48^{e}	1.49^{d}	1.35^{c}	0.91^{b}	0.00^{a}
Livestock	1185.89	***	2.62^{e}	1.88^{c}	2.05^{d}	1.82^{b}	0.54^{a}
Fodder	1372.92	***	1.91^{e}	1.41^{d}	1.28^{c}	1.06^{b}	0.57^{a}
Capture Fisheries	5986.20	***	0.02^{b}	0.16^{d}	0.03^{c}	0.00^{a}	2.19^{e}
Aquaculture	104.99	**	0.00^{a}	0.02^{b}	0.00^{a}	0.00^{a}	0.04^{c}
Wild Foods	1920.32	***	1.27^{a}	2.02^{b}	2.16^{c}	2.23^{d}	2.91^{e}
Timber	780.51	**	1.07^{b}	1.52^{c}	1.71^{d}	1.70^{d}	0.00^{a}
Wood Fuel	1806.26	***	1.44^{b}	1.94^{c}	2.30^{d}	2.37^{e}	0.00^{a}
Energy (Biomass)	1462.59	***	1.99^{d}	1.20^{c}	1.22^{c}	0.93^{b}	0.02^{a}
Biochemicals	884.40	**	1.53^{b}	1.96^{c}	2.09^{d}	2.13^{e}	0.00^{a}
Freshwater	6012.71	***	0.04^{b}	0.25^{d}	0.06^{c}	0.00^{a}	3.59^{e}
Regulating services							
Local Climate Regulation	701.84	**	2.39^{b}	2.67^{c}	2.78^{d}	2.81^{e}	1.80^{a}
Global Climate Regulation	892.15	**	1.50^{b}	1.85^{c}	1.90^{d}	2.04^{e}	0.91^{a}
Flood Protection	712.79	**	1.16^{a}	1.50^{d}	1.39^{b}	1.47^{c}	2.03^{e}

Groundwater Recharge	509.32	**	1.03^{a}	1.23^{d}	1.19^{b}	1.20^{c}	1.63^{e}
Air Quality Regulation	1132.90	***	0.76^{b}	1.34^{c}	1.45^{d}	1.58^{e}	0.00^{a}
Erosion Regulation	1060.23	***	1.36^{b}	1.91^{c}	2.08^{d}	2.28^{e}	0.00^{a}
Nutrient regulation	1423.65	***	0.99^{a}	1.78^{c}	1.74^{bc}	2.19^{d}	1.56^{b}
Water purification	1493.12	***	1.09^{b}	1.76^{c}	1.85^{d}	2.27^{e}	0.11^{a}
Pollination	1972.02	***	1.09^{b}	1.76^{c}	1.94^{d}	2.22^{e}	0.00^{a}
Cultural services							
Recreation & Aesthetic Values	1595.78	**	2.29^{a}	2.98^{c}	2.89^{b}	3.18^{d}	4.11^{e}
Intrinsic Value of Biodiversity	2780.42	**	1.76^{a}	2.59^{b}	2.83^{c}	3.04^{d}	2.94^{cd}

Overall, our results showed that areas with most designations (i.e PAQAW) presented the highest capacity in 10 out of 29 ES (most of them as expected were relevant to aquatic ecosystems). Areas that combined two designation types (i.e. PAQA) showed the highest capacity in 13 out of 29 ES. Those ES were mostly linked with natural and forest ecosystems. Areas with no designation (ND) displayed stronger capacity in provisioning services - ES that are linked to human activity. Areas with single designation (PA or QA) displayed highest capacity in few (<10) ES and among those two categories QAs scored in general better than PAs.

ES capacity in relation to landscape properties

Table 2 displays the correlation coefficients of ES capacity towards the landscape properties of aspect, slope and elevation. Strong positive correlations (cor. coef. >0.4) were found among the ES “Biodiversity”, “Reduction of nutrient loss” and “Intrinsic value of biodiversity” to slope as well as elevation, while the same holds among “Pollination” and slope. On the other hand the ES “Crops” displayed strong negative correlation to slope and elevation while the same holds among “Fodder” and “Energy” to slope.

Table 2.

Pearson correlation coefficient (N=138625) of ES capacity scores towards slope, aspect and elevation (all correlations except “Biotic water flow” to slope are significant at *P>0.001*).

		slope	aspect	elevation
Supporting services				
AH	Abiotic heterogeneity	-0.11	-0.07	-0.15
B	Biodiversity	0.48	0.24	0.44
BWF	Biotic waterflow	0.00	-0.06	0.05
ME	Metabolic efficiency	0.22	0.16	0.27
EC	Exergy capture	-0.12	-0.09	-0.04
RNL	Reduction of nutrient loss	0.51	0.25	0.46
SC	Storage capacity	0.06	0.02	0.16

Provisioning services				
C	Crops	-0.52	-0.26	-0.47
L	Livestock	-0.37	-0.16	-0.33
F	Fodder	-0.40	-0.17	-0.31
CFS	Capture fisheries	-0.11	-0.10	-0.08
A	Aquaculture	-0.02	-0.01	-0.02
WF	Wildfoods	0.37	0.17	0.38
T	Timber	0.26	0.11	0.27
WFU	Woodfuel	0.39	0.19	0.34
E	Energy (Biomass)	-0.42	-0.22	-0.34
BCH	Biochemicals (Medicine)	0.26	0.13	0.22
FRW	Freshwater	-0.11	-0.10	-0.08
Regulating services				
LCR	Local climate regulation	0.20	0.06	0.22
GCR	Global climate regulation	0.25	0.11	0.29
FP	Flood protection	0.18	0.05	0.22
GR	Groundwater recharge	0.16	0.10	0.20
AQ	Air quality	0.30	0.12	0.32
ER	Erosion regulation	0.30	0.15	0.33
NR	Nutrient regulation	0.32	0.14	0.37
WP	Water purification	0.33	0.15	0.39
PLL	Pollination	0.40	0.16	0.37
Cultural services				
REC	Recreation & aesthetic values	0.31	0.13	0.33
IVB	Intrinsic value of biodiversity	0.46	0.24	0.40

As regards aspect the correlation coefficients were in general lower, showing a less important influence of this landscape property on ES capacity. Highest positive correlations were observed for “Reduction of nutrient loss”, “Biodiversity” and “Intrinsic value of biodiversity” (cor. coef.: 0.24-0.26), and highest negative for “crops” and “energy” (cor. coef.: -0.26 and -0.22, respectively).

Trade-offs and synergies among ESs

Fig. 3 shows the results of the PCA analysis exploring synergies and trade-offs among ES. Four groups of ES were observed. Group 1 (displaying small distance between the variable points) had mostly regulating ES accompanied by some cultural, supporting and provisioning services related to natural production (Biochemicals, Timber, Wood fuel, Wild foods). Group 2 consisted of two supporting services (Reduction of nutrient loss, Biodiversity). Group 3 contained three provisioning services related to aquatic ecosystems

(Aquaculture, Capture fisheries, Freshwater) and Abiotic heterogeneity. Group 4 comprised of provisioning services related to agricultural activity (Fodder, Energy, Crops, and Livestock).

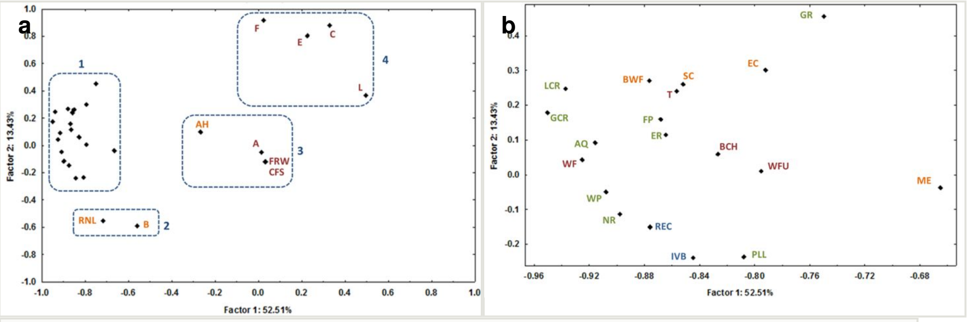

Figure 3.

Relationship between Factor 1 and Factor 2 loadings as derived from PCA. Factor 1 explains the 52.51% and Factor 2 the 13.4% of the total variance. Dotted lines and numbers indicate the four groups identified. Orange colour = supporting services, red colour = provisioning services, green colour = regulating services, blue colour = cultural services. For abbreviations of services see Table 1

a: All 4 groups of ES

b: Details of group 1

Factor 1 representing 52.51% of the total variance recognized synergetic interactions among ES of groups 1 and 2, which in turn showed antagonistic interactions with some of the ES of group 4, such as Livestock and Crops. Pronounced synergistic effects were observed between most ES of group 4 (Fodder, Crops, Energy). The low factor scores of group 3 (ES associated with the aquatic environment) might be explained by the fact that only a few land cover types have a high capacity (score = 5) to provide such services, while other types have no capacity at all.

Discussion

Our study revealed that the ES capacity varies between areas of different or multiple designation types. An area with multiple designation types most possibly has higher ES capacity, which should be taken into consideration for effective policy initiatives. The effect of landscape features and especially those of elevation and slope are important in shaping the distribution of land uses in the landscape and hence play a major role in ES delivery. Although the study areas showed in general a high potential of all types of services there are significant trade-offs among provisioning services and supporting, regulating and cultural services.

ES capacity in areas of various or multiple designations

As expected, areas with no designation (ND) were the most dominant and comprised the highest percentage (38%) of the studied areas. These areas were mostly dominated by more intensive land use and had in general a high score (capacity) in provisioning services. Surprisingly the next category, namely Quiet Areas (QAs) had an almost equal amount of surface (36%). Although human presence is taken for granted in our study areas, the fact that QAs occupy this great percentage of land surfaces, indicates that there are still many areas without noise pollution and low sound intensity anthropogenic activities, since their definition is based on the distance from multiple human activities producing noise (Votsi et al. 2012). QAs showed in general medium to high scores in ES capacity, with relatively higher scores for some supporting services but also for "Livestock" and some other forest related provisioning services.

Areas that had the single designation as Protected Areas (PAs) belonging to the Natura 2000 network (i.e not characterized as "quiet") covered a smaller percentage of land surfaces in the four catchments (9.6%). Many scientists have assessed the ES of Protected Areas and their capacity to maintain ecological integrity (e.g. Castro et al. 2015, Maes et al. 2012a). There is a distinguished dependency between certain species or habitat types and ES, especially regarding socio-cultural and regulating services (Bastian 2013). Our findings show that PAs have medium relevant capacity to provide all ES and relatively higher capacity to provide some that correspond to the provision of suitable habitats for different species such as "Abiotic heterogeneity". Moreover they have good capacity of some ecosystem services such as "Flood protection", "Groundwater recharge" and "Nutrient regulation". Surprisingly, PAs showed lower biodiversity than QAs, although their designation has as a major aim the protection of biodiversity. It has to be noted that many sites of Natura 2000 network are not "quiet" due to their fragmentation by a rapidly expanding transport network (Selva et al. 2011) and due to the fact that they comprise a significant amount of agricultural areas (Kallimanis et al. 2008, Tsiafouli et al. 2013, Vlami et al. 2017) in which also human-induced noise is produced.

Areas that have both designation types, i.e. are Protected & Quiet (PAQAs) were found to occupy greater land surface (16%) than the one occupied by PAs alone, indicating the predominance of "quiet protected areas" against "noisy protected areas" (Votsi et al. 2014) (such as the PA category). Sites of the Natura 2000 network which are located away of human activity are considered noise refuges (Votsi et al. 2014) that promote the conservation of certain species and their habitats (Wallace 2008). In our study we further found that they have a higher capacity in ES delivery. Specifically, PAQAs that could be characterized as "quiet protected areas" had the highest score in most supporting, regulating and cultural services compared to the other categories of areas investigated. Areas of the above category which in addition include wetlands/water bodies preserve also the quietness value. These areas (PAQAW) though have the smallest total area (covering less than 0.5% of the catchment surface) reflecting the rarity of landscapes that combine all these ecological features. Areas around wetlands and water bodies often suffer intense human activity, regardless their protection status, due to the surrounding fertile lands (Drakou et al. 2008). Despite their small expansion these areas have high capacity in providing many ES including of course provisioning services related to water, such as “Aquaculture”, “Freshwater” and “Capture fisheries”.

Relation of elevation, slope and aspect to ES

Among landscape properties investigated, aspect had the lowest influence on the capacity of ES. The most important correlations found (but with a relative low cor. coef.) showed that the potential of the ES “Reduction of nutrient loss”, “Biodiversity” and “Intrinsic value of biodiversity” tends to increase from East to West, while the opposite happens for “Crops” and “Energy”. This differentiation could be related to differences in solar radiation from East to West.

As regards elevation and slope we found that increasing elevation and/or slope leads to a decrease in provisioning services such as “Crops”, “Fodder” and “Energy”. On the contrary major supporting, regulating and cultural ES such as “Biodiversity”, “Reduction of nutrient loss” and “Intrinsic value of biodiversity” increase with increasing slope and elevation while the ES “Pollination” increases also with slope. These results were expected as the altitude gradient (elevation and slope) cause climatic differences affecting land cover and land use types (Shrestha and Zinck 2001) which are interdependent of the ES potential. Hence increased elevation poses difficulty in management and access of farming machinery and might involve unfavorable climate conditions for cultivation as well. The decrease of the ES “Crops” with increasing altitude leads in turn to the “Reduction of nutrient loss” due to the positive influence of natural vegetation cover and the decrease of those agricultural activities degrading surface water bodies and groundwater (Shukla et al. 2010).

On the other hand “Biodiversity” and its “Intrinsic value” were found to thrive in higher altitudinal zones that are more remote and lacking of human disturbance and are dominated by natural vegetation cover (mostly forests). It should be noted though that Greece has a tremendous shoreline - zero altitude, with a high touristic value. This value is not covered by the methodology of Burkhard et al. (2009), which apparently gives higher scores mostly for forest land uses which are usually at higher-elevation habitats. This finding should be taken into consideration in future assessment studies.

Synergies and or trade-offs among ES

Understanding interactions between ES is a critical step towards assessing the drivers of landscape change and how they influence the potential, flow and demand of ES (Depellegrin et al. 2016). Our results showed trade-offs between regulating and cultural services versus provisioning services such as “Crops”, “Livestock” and “Fodder”. So an area with increased ability to provide supporting services such as “Biodiversity” and “Reduction of nutrient loss” has less capacity to provide services such as “Crops”, “Livestock”, “Fodder”, “Energy” and vice versa. These results were similar irrespective of catchment area or type of area studied and this might be explained that in our study we analyzed the capacity of ES provision using data that derive from the type of land use only.

Regulating and cultural services provide intermediary benefits to mankind (Kumar and Wood 2010) including climate regulation, protection from extreme events (floodplains, erosion) (Braat and Groot 2012), spiritual enrichment and ecotourism development. Nevertheless enhancement of provisioning services may cause degradation of regulating and cultural services, with vital importance for sustaining ecological processes (Costanza et al. 2016). To ensure sustainability in the long-term there is need to focus on multiple services within a given area of land (Eastburn et al. 2017). In agricultural ecosystems, which comprise a large part of terrestrial ecosystems (22-47% in our study areas) the intensity of management plays a significant role from below-ground diversity (Tsiafouli et al. 2015) to landscape diversity (Tscharntke et al. 2005). A number of studies (e.g.Gardi et al. 2016, Marton et al. 2016, Sidhu and Joshi 2016, Winkler et al. 2017) show the way how to optimize the delivery of multiple ecosystem goods and services and reduce trade-offs (Tsiafouli et al. 2017).

Conclusions

Alternative environmental management to safeguard biodiversity requires integrated approaches including spatial and functional information of the landscape (Haddock et al. 2007). In the present study we found patters in ES capacity with reference to spatial information by combining landscape properties, land uses and “legislative” information, i.e. the type of designation. Based on our findings areas with multiple designations could serve as proxies for locating ES hotspots. In our case these were “Protected & Quiet Areas”. The type of ES delivered is related to the location of where it derives from in the landscape. Higher elevations most probably serve better for supporting and regulating services and lower elevations are better for provisioning services. Insight on geographical distribution of ES and their direct or indirect relation with the designation status of the landscape could assist in cost and time effective policy. Furthermore, management initiatives could be more easily implemented by stakeholders and other relevant authorities to confront with biodiversity threats, climate change but also to keep pace with current trends of nature conservation.

Acknowledgements

EU project SCALES No 226852 (Matching Funds via ELKE of Aristotle University of Thessaloniki).

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