Global Ecology and Conservation 32 (2021) e01907

Contents lists available at ScienceDirect

Global Ecology and Conservation

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

Systematic Conservation Planning in a Mediterranean island context: The example of Cyprus

C.S. Christodoulou[a,*], G.H. Griffiths[b], I.N. Vogiatzakis[c,d]

[a] Department of Forests, Ministry of Agriculture, Rural Development and Environment, 26 Louki Akrita, 1414 Nicosia, Cyprus
[b] Department of Geography and Environmental Sciences, University of Reading, Whiteknights, PO Box 227, Reading RG6 6AB, UK
[c] Faculty of Pure and Applied Sciences, Open University of Cyprus, Cyprus
[d] Department of Environmental and Earth Sciences, University of Milano-Bicocca, Italy

ARTICLE INFO

Keywords:
Effectiveness
Endangered species
Irreplaceability
Marxan
Natura 2000

ABSTRACT

Cyprus' biodiversity is under increasing pressure due to anthropogenic activities. TheNatura 2000 (N2K) sites under the Habitats Directive cover 10.4% of its island's land surface while designation has been hindered by a complex political situation. We used a comprehensive dataset of Red Data Book (RDB) plants for the island and applied systematic conservation planning (SCP) to, (i) assess whether plant conservation features are adequately represented in the current Sites of Community Importance (SCIs) of the N2K, (ii) evaluate the effectiveness of the protected areas designated for plants by assessing the solutions of SCP against five widely used criteria and iii) suggest alternative protected areas configurations following basic principles of SCP. We run two scenarios in Marxan, using different cost surface and Boundary Length Modifier (BLM) parameters, one for all Annex II plant species and one for RDB plants. Targets were set for all conservation features (CFs) on the basis of their endangered status and endemism. The *total area* required to satisfy the targets ranged from 2.23% to 5.46% of the island's area. Solutions with *uniform cost* achieve targets for the lowest cost but have the smallest overlap with the existing N2K (52.5–60.3%). Solutions with *variable cost* achieve significantly higher overlap with N2K (72.9–75.9%). The use of BLM reduces fragmentation and increases the number of irreplaceable PUs in both scenarios. The overlap of irreplaceable PUs with Critically Endangered species is high. Results corroborate that state-owned land provide protection to most threatened species, but there is a need for additional protected areas. Our findings provide a basis for improving the N2K network design in Cyprus to achieve biodiversity targets set for 2030, such as the increase of the land area providing legal protection to threatened plant species by considering our priority list of species and sites for future designation.

1. Introduction

The establishment of the ecological network *Natura 2000* (N2K), across all member states of the European Union (EU), is a major milestone and a turning point in the history of nature conservation in Europe (Jones-Walters and Čivić, 2013). The N2K network was the main EU response to the Convention on Biological Diversity (Trochet and Schmeller, 2013); in particular, the Habitats Directive was the response to the large-scale destruction of natural habitat and the increasing numbers of threatened species (Coffey and

* Corresponding author.
E-mail address: cyflora@outlook.com (C.S. Christodoulou).

https://doi.org/10.1016/j.gecco.2021.e01907
Received 18 June 2021; Received in revised form 21 October 2021; Accepted 2 November 2021
Available online 18 November 2021
2351-9894/

Richartz, 2003). The N2K network is considered as the most important conservation policy in the EU, which has the best prospect of success due to the development of specific policies and financial mechanisms (Maiorano et al., 2007).

The European N2K network was established as a complementary measure to existing nationally protected areas, for the protection of threatened species and habitats in the long term (Araújo, 2009). However, the effectiveness of the N2K network in adequately representing biodiversity features is questionable. The design of the N2K network and selection of sites has been chiefly based on a number of habitats and species of community importance, listed in the Annexes of the Habitats Directive. The selection process has primarily been expert driven (Maiorano et al., 2007), without employing any decision support tools to facilitate the design of optimal reserve networks (Evans, 2012). Moreover, the selection of sites has been influenced by political, economic, cultural and social factors (Trochet and Schmeller, 2013). As a result, several studies have highlighted inadequacies in the representation for both the terrestrial (Dimitrakopoulos et al., 2004; Maiorano et al., 2007) and the marine realm (Giakoumi et al., 2011, 2012).

In Cyprus, great effort has been made to select representative sites, according to the provisions of the Habitats and Birds Directives, for the establishment of the N2K network (Christodoulou et al., 2018). As with other EU Member States, in Cyprus the selection of Sites of Community Importance (SCIs) under the Habitats Directive was based on thorough knowledge of the distribution of habitats and species included in the Annexes of the Habitats Directive (expert-driven). Therefore, the prioritisation and selection of sites was not done in a systematic manner (sensu Pressey, 1999; Margules and Pressey, 2000). In addition, the process of selection of the N2K sites was constrained by the political situation due to the suspension of *acquis communautaire* in the Turkish occupied area (TOA) and the exclusion of the UK Sovereign Base Areas (SBAs) from the Accession Treaty of Cyprus. Moreover, socio-economic parameters such as development areas (i.e. for housing and tourism) and the strong legal right of private ownership, were also considered in order to avoid conflicts and facilitate implementation. Currently the area of the designated N2K sites under the Habitats Directive (terrestrial part of SCIs and Special Areas of Conservation, SACs, Fig. 1) is 961 km^2 accounting for 17.9% of the area under the effective control of Cyprus Government (CYGCA).

In addition to the designation of the N2K sites, an important milestone for biodiversity conservation on the island was the publication of the *Red Data Book of the Flora of Cyprus* (Tsintides et al., 2007). This was published though after the main designation of the N2K sites on the island. The inclusion of the RDB species, which were recently increased from 238 to 252 (Christodoulou et al., 2018), in the initial reserve selection process would have maximised conservation efforts, in a complementary manner (Pressey et al., 1993; Pressey, 1996; Margules and Pressey, 2000; Justus and Sarkar, 2002) within the N2K network by utilising the same area and resources. Red Lists apply to all species of a particular taxonomic group, in this case vascular plants, and thus could be used to expand the scope of the Habitats Directive beyond the plant species included in Annex II of the Directive (D'Amen et al., 2013). Therefore, despite the fact

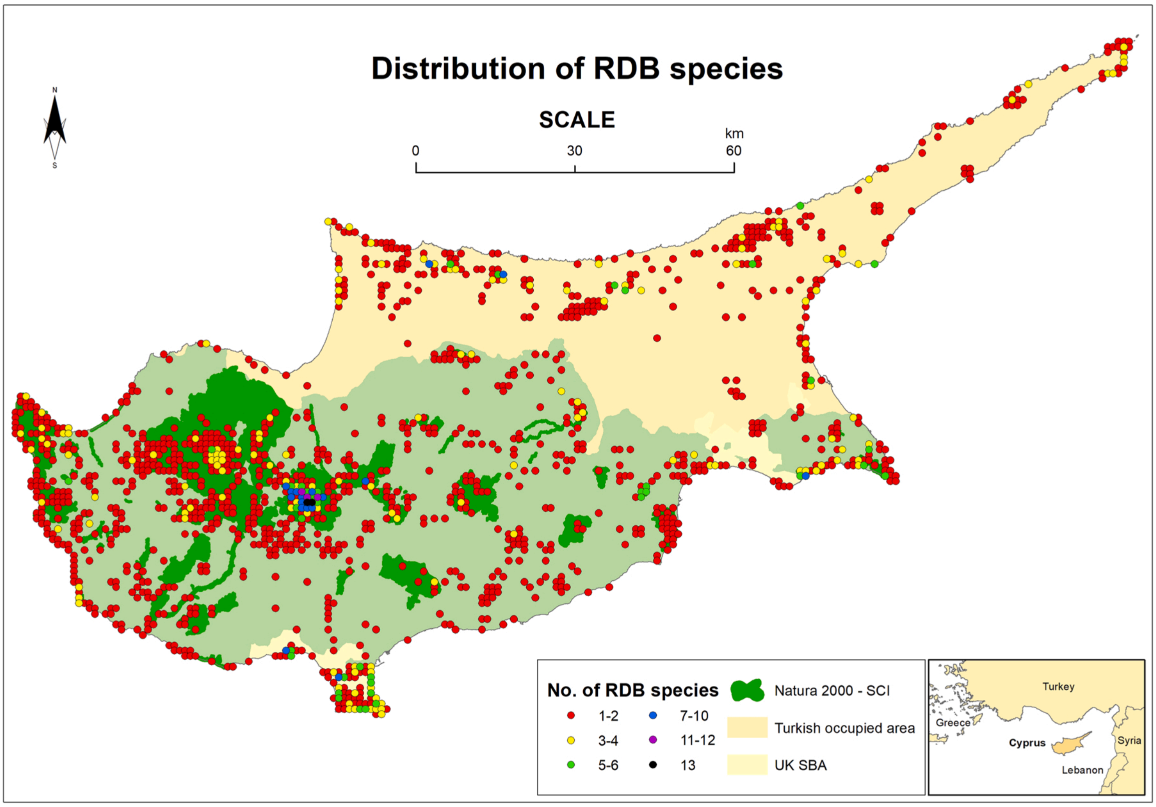


Fig. 1. Location map of Cyprus and distribution map of RDB plants in grid cells of 1 × 1 km *(To the south: area under Cyprus government control; to the north: Turkish Occupied Area; in yellow: UK Sovereign Base Areas).*

that this is not a primary objective, the N2K network could significantly contribute towards the protection of all threatened species (Trochet and Schmeller, 2013), including those that are not listed in Annex II, thus fulfilling one of the objectives of the Habitats Directive in providing protection to endangered species. It is noteworthy that only 19 out of the 252 threatened plant *taxa* (Christodoulou et al., 2018) are included in the Annexes II and IV of the EU Habitats Directive (Appendix 1). Consequently, the remaining 233 threatened species were not directly considered during the prioritisation and selection of N2K sites. Furthermore, not all 19 Annex II plant *taxa* are among the most threatened, i.e. Critically Endangered (CR) and Endangered (EN). There are other CR and EN species, which are also endemic to the island but not included in Annex II of the Habitats Directive.

Hitherto, no evaluation of the effectiveness of the N2K network (in terms of design efficiency) in protecting the threatened plants of the island has been undertaken. Both Cyprus and Luxembourg, due to absence of data, were excluded from an evaluation across twenty-five EU member states of the effectiveness of the N2K network in covering threatened species included in the IUCN Red List (Trochet and Schmeller, 2013). This type of assessment is essential to determine whether the N2K network in each country provides adequate protection for habitats and species. However, the evaluation was undertaken as a simple map overlay of threatened species in a GIS without the added benefits of Systematic Conservation Planning.

Systematic Conservation Planning (SCP) is an emerging science (Margules and Pressey, 2000; Possingham et al., 2006) that can be employed in reserve design (Pressey et al., 2007; Rondinini and Pressey, 2007), focusing on the selection of a minimum set of representative sites (network) which *complement* each other and achieve defined, quantitative conservation objectives (Pressey et al., 1993). The principles which underpin SCP are useful for achieving conservation objectives in any geographical context (Margules and Pressey, 2000; Pressey et al., 2007). In the case of Mediterranean islands however, SCP application is paramount given that space is limited and many islands are biodiversity hotspots often with a high rate of endemism (Médail, 2017; Vogiatzakis et al., 2016). Conservation therefore, has to compete with other conflicting land uses in landscapes characterised by high plant diversity. Consequently, we need tools to address conservation priorities effectively so that designation of Protected Areas has a higher probability of successful implementation.

This paper is the first attempt to evaluate the effectiveness of the N2K network in Cyprus to provide adequate protection for threatened plants, which represent 15.3% of the indigenous flora. Furthermore, this is the first application of a Systematic Conservation Planning approach (Margules and Pressey, 2000), considering key concepts and principles (Possingham et al., 2006; Kukkala and Moilanen, 2013), for reserve network design in the particular geographic context of an island state. Therefore, the objectives of the paper are to, (i) assess whether conservation features (namely RDB species and Annex II species) are adequately represented in the current N2K SCIs, (ii) evaluate the effectiveness of the existing protected areas designated for terrestrial vascular plants in Cyprus by assessing the solutions of SCP analysis against five criteria (Pressey et al., 2002), and (iii) suggest alternative configurations for these sites following basic principles of Systematic Conservation Planning.

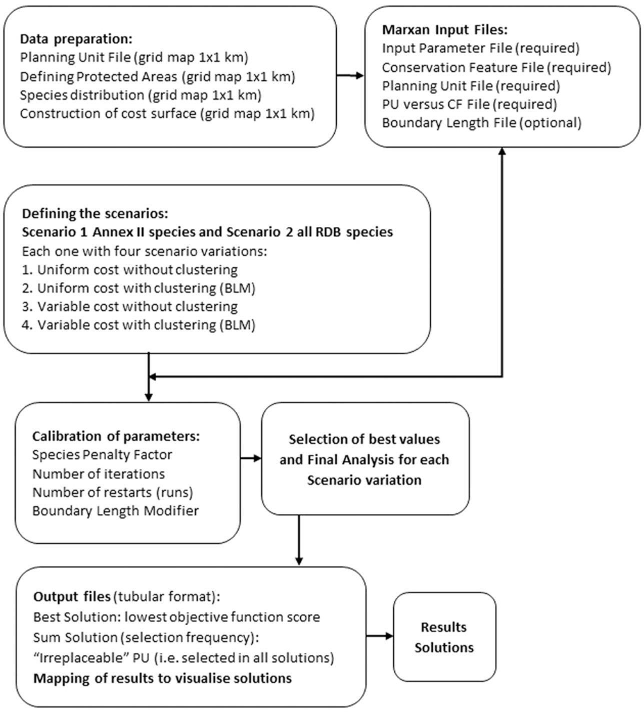


Fig. 2. Steps in data preprocessing and analysis in Marxan.

2. Materials and methods

2.1. Study area

Cyprus, with an area of 9251 km^2 (Fig. 1), is the third largest island in the Mediterranean (Edwards et al., 2010). The flora of Cyprus consists of 1649 indigenous taxa of Spermatophytes and Pteridophytes and 254 introduced naturalised and casual taxa (Hand et al., 2011). This plant richness is comparable to the rest of the large Mediterranean islands where the overall range of flora is between 1550 and 3250 taxa (Medail and Quezel, 1997; Médail, 2021). The Red Data Book of the Flora of Cyprus (RDB) has identified 238 threatened taxa (Critically Endangered, Endangered and Vulnerable) (Tsintides et al., 2007), which have been recently updated to 252 (Christodoulou et al., 2018), representing 14.3% of the indigenous flora.

2.2. Data analysis

To select priority areas, we employed Marxan (Appendix 5), the most extensively used software employed for reserve design (Ball et al., 2009; Watts et al., 2009) as described in Fig. 2. The main outputs of a Marxan analysis are the summed and best solution files. Summed solution is the selection frequency of each planning unit (PU: usually equal-sized grid cells dividing a planning region), used as a surrogate for irreplaceability (Stewart and Possingham, 2005). Best solution is the run with the best objective value (smallest objective function score) from all the good solutions that have been produced (Game and Grantham, 2008; Ball et al., 2009; Ardron et al., 2010).

2.2.1. Planning Units

Typically, in Marxan the area of interest is divided into planning units (PUs) used as candidate conservation units to be selected or not in the analysis. For the preparation of the PU file, a 1 km^2 grid was overlaid on the map of Cyprus resulting in 9677 grid cells (PUs). The selection of PU size was based on a sensitivity analysis where in addition to 1 km x 1 km grid, five more PU sizes were tested (Appendix 2). For the test analysis the relevant input files were prepared for each scenario of different cell sizes. The analyses used the same variables for threatened species (i.e. targets and penalty) and Marxan parameters (i.e. restarts, iterations, PU cost and status and algorithm used). The results of best solutions were analysed to determine the most efficient PU size (Appendix 2). In this work, irreplaceable PUs were considered to be those having a selection frequency of 100%, i.e. those PUs which were selected in every solution (Fig. 2).

2.2.2. Conservation Features (CFs) and Protected Areas (PAs)

We used all threatened indigenous plant taxa included in RDB (Tsintides et al., 2007), as updated by Christodoulou et al. (2018), many of which are endemic, to provide the so-called conservation features (CFs). Following a regional assessment, the IUCN threat categories considered for the analysis were Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) whereas the categories Regionally Extinct (RE), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD) were excluded (see Jackson et al., 2009 and Drummond et al., 2010; Simaika and Samways, 2009). The preparation of the distribution maps (occurrence/presence only data) for the threatened plants (CR, EN and VU) was based on the GIS layers of Area of Occupancy (AOO), as derived from the mapping produced during the RDB island wide survey (Tsintides et al., 2007) and by the work of Christodoulou et al. (2018), which indicate confirmed occurrence of the plants.

The selection of targets for CFs was based on their occurrences within PUs, expressed as a percentage of the total number of occurrences for each CF island-wide. The targets were determined based on two parameters. First, by considering the IUCN threat category of each threatened species, and following the recommendation that higher targets should be allocated to threatened species to ensure their persistence within reserve areas (Pressey et al., 2007; Ardron et al., 2010) and to avoid any increase in their extinction risk (SANBI, 2010). Second, taking into account whether a species is endemic or indigenous, with endemic species receiving higher priority (Hoffmann et al., 2008). Table 1 shows the allocation of targets for each category of CFs. The target for each CF (number of occurrences) is given in Appendix 3. It should be noted that, for the Annex II species (92/43/EEC) the representation targets were adjusted accordingly in order to comply with the EU recommendation for having a proportion of 60% of their occurrences within N2K network so as to be considered as sufficiently represented (Nagy et al., 2007).

The selection of protected areas used for the analysis was primarily determined by the requirement to provide legal status for the protection of terrestrial vascular plants. Therefore, the protected areas network (PAN hereafter) in this study comprises all sites

Table 1
Representation targets for Conservation Features (RDB species) and type, set according to the IUCN threat categories and status.

IUCN category and status of CFs	Number of *taxa* (% of the total)	Target % of occurrences	Type of CF
CR, Endemic	6 (2.4)	100	1
CR, Indigenous	40 (15.9)	75	2
EN, Endemic	7 (2.8)	75	3
EN, Indigenous	56 (22.2)	50	4
VU, Endemic	35 (13.9)	50	5
VU, Indigenous	108 (42.8)	25	6
Total number of *taxa*:	252		

declared under the Habitats Directive as Sites of Conservation Importance (SCIs) and those SCIs nominated as Special Areas of Conservation (SACs). Also, all Nature Reserves (NR) declared under Forest Law (Fig. 1).

2.2.3. Cost surface

In order to generate solutions that achieve all specified targets for the minimum cost, we developed a variable cost surface considering different parameters (Ardron et al., 2010) using the most recent CORINE map (2018), the map of PAN and the map of State Forest Land (SFL) as follows: (a) the land-ownership such as State Forest Land (SFL) (low cost, 0.5) and private land (high cost, 1, 2, 3 or 4 units) given that state land is generally easier to designate as a protected area compared to private ownership (Kirkpatrick, 1983); (b) existing Protected Areas (PAs) (very low cost, 0.1); (c) the CORINE Land Cover classes up to level 3, with varying cost (1–3 units) for each land class (Appendix 4a); and, (d) the coastal zone which has a high potential for touristic development. CORINE, a pan-European project which provides consistent and comparable data on land cover, uses a three level hierarchical nomenclature for the following board land cover types: artificial surfaces, agricultural areas, forests/semi-natural areas, wetlands and waterbodies (Heymann et al., 1994). The various combinations of the PU cost are illustrated in Appendix 4b and 4c.

2.3. The scenarios

We run two scenarios with different datasets: (i) all plant species included in Annex II of the Habitats Directive and, (ii) all threatened plants included in the Red Data Book of the Flora of Cyprus (RDB), as updated by Christodoulou et al. (2018). The purpose of the analysis was to independently identify near optimal solutions using different constraints of cost variation and clustering and thus to provide a range of alternative, cost efficient reserve configurations for each scenario. Also, a key objective was to evaluate the effectiveness of the existing PA network in adequately representing Annex II and RDB species.

2.3.1. Scenario 1: Annex II species

The first Scenario was based on the plant species included in Annex II (Appendix 1 and 5) of the Habitats Directive (92/43/EEC). All taxa are included in the Red Data Book of the Flora of Cyprus (RDB), which was published after their inclusion in the Habitats Directive. These species, among others, were those considered for the selection and design of the N2K SCIs in Cyprus, for the Habitats Directive. Under this scenario, four sub-scenarios were analysed (Table 2): two with a uniform cost surface (area cost) and two with a varying cost surface. In both cases one was run with the Boundary Length Modifier (BLM) and the other without (Appendix 5).

2.3.2. Scenario 2: All RDB species

The second Scenario was based on the RDB species (252 taxa, Appendix 3), which hitherto have not been considered in any reserve selection exercise, apart from the 19 taxa included in Annex II of the Habitats Directive. As with the previous scenario, four sub-scenarios were also examined here; two with a uniform cost surface with and without BLM and two with a varying cost surface with and without BLM (Table 2).

2.3.3. Scenario variations

The two main Scenarios were analysed using two cost surfaces, a uniform cost (each PU=1, which is equal to the area of the PU 1 km^2) surface and a variable cost surface, each of them with and without the use of a Boundary Length Modifier (BLM), which is used to control the fragmentation and clustering of reserve solutions (Table 2).

2.3.4. Marxan calibration

Marxan software does not deliver a simple 'one-off' solution. The generation of good results requires that input parameters must first be calibrated (Game and Grantham, 2008) so as to ensure that Marxan generates sets of solutions which approach the optimum (lowest cost), while meeting the pre-defined targets of conservation features (CFs). The calibrated values of Species Penalty Factor (SPF), BLM, number of iterations and restarts (repeat runs), used to perform the final analyses for the two Scenarios are presented in Table 2. In addition, the status of all PUs was set to zero (unlocked) indicating that they are not locked into or out of the reserve solution.

Table 2
The two Scenarios and their abbreviation, with the main parameters used in relation to cost surface and use of Boundary Length Modifier (BLM) and the calibrated parameter used in the analyses.

Scenario name parameter variations	Abbreviation	Iterations	Restarts	BLM value	Specie Penalty Factor value
Scenario 1 Annex II species with Uniform Cost and no BLM	S1UCnoBLM	10^8	500	–	2
Scenario 1 Annex II species with Uniform Cost with BLM	S1UCwithBLM	10^8	500	0.5	2
Scenario 1 Annex II species with Variable Cost and no BLM	S1VCnoBLM	10^8	500	–	2 & 3
Scenario 1 Annex II species with Variable Cost with BLM	S1VCwithBLM	10^8	500	0.05	2 & 3
Scenario 2 RDB species with Uniform Cost and no BLM	S2UCnoBLM	10^8	500	–	2
Scenario 2 RDB species with Uniform Cost with BLM	S2UCwithBLM	10^8	500	0.5	2
Scenario 2 RDB species with Variable Cost and no BLM	S2VCnoBLM	10^8	500	–	2 & 3
Scenario 2 RDB species with Variable Cost with BLM	S2VCwithBLM	10^8	500	0.05	2 & 3

2.4. Identifying contiguous sites by clustering

The best solutions for Scenarios 1 and 2 were used to aggregate neighbouring planning units so as to identify and visualise the number and size of clustered sites for each Scenario variation. Thus, the proportion and size of large reserves, which are generally preferred over small ones, can be quantified.

2.5. Evaluating the effectiveness of N2K network

The final analytical step was the evaluation of the effectiveness of the existing PAN in Cyprus by comparing the solutions derived from Marxan analysis using five of the six measures proposed by Pressey et al. (2002) (Table 7). Effectiveness in this sense refers to the assessment of the network's design as a means to streamline resources' allocation and improve decision making. The analysis is confined only to the area under the effective control of the Cyprus Government (CYGCA), where N2K sites have been designated.

3. Results

3.1. Scenarios

The results of Scenarios 1 and 2 with uniform (area) cost and without a compactness objective (S1UCnoBLM and S2UCnoBLM) provide the most efficient (minimum cost) solutions in terms of area needed for achieving the specified targets (216 km^2 and 498 km^2 respectively). However, both solutions have the longest boundary length resulting in very scattered reserve solutions (Figs. 3a, 3b, 4 and 5). On the other hand, the variations with the application of BLM (S1UCwithBLM and S2UCwithBLM) improved the compactness of solutions (Figs. 3a, 3b, 4 and 5), by a decrease in the boundary length of − 28.9 and − 25.4% respectively; however, with a small increase in area of only 2.3% (221 km^2) and 4.8% (522 km^2) respectively.

Using a variable cost surface, the reserve solutions generated for Scenarios 1 and 2 achieved all the targets with a slightly larger area of 217 km^2 for S1VCnoBLM and 520 km^2 for S2VCnoBLM (Fig. 3a and 3b), accounting for an increase of 0.5% and 4.4% compared to the respective solutions with uniform cost (S1UCnoBLM and S2UCnoBLM). Moreover, the use of a variable cost encouraged clustering, thus the reserve solutions have a shorter boundary length by − 10.3 and − 2.2% (Fig. 3a, 3b, 4 & 5) as compared with the respective solutions with uniform cost. The application of a BLM promoted a further improvement in clustering, with a decrease of − 13.4% and − 11.13% in boundary length and a small increase of 0.9% and 1.7% in area for S1VCwithBLM and S2VCwithBLM respectively (Figs. 3a, 3b, 4 and 5), as compared with the scenario variation without BLM (S1VCnoBLM and S2VCnoBLM).

The results of both Scenarios with the use of a variable cost surface although requiring a slightly larger area (more PUs), provide more feasible solutions. Moreover, the inclusion of a variable cost surface gives the highest proportion of overlap with existing reserves of up to 75% (Table 3) and greatest proportion of selected PUs within State Forest Land, the second low-cost category, as well as in the

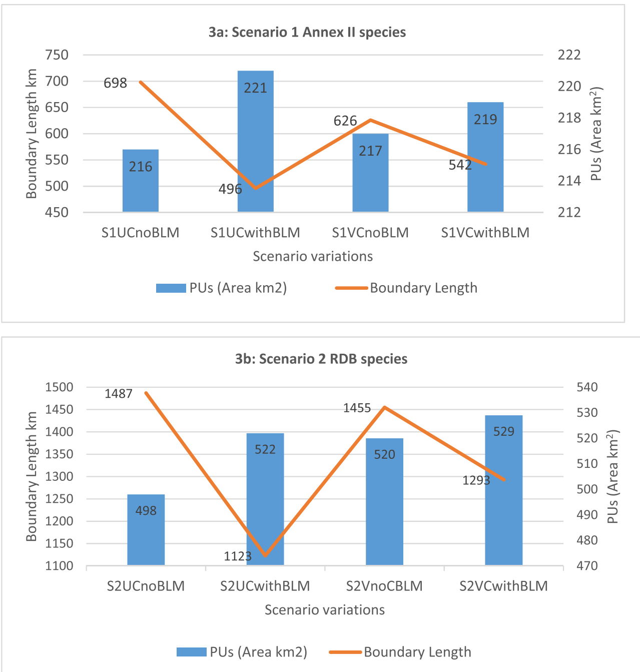


Fig. 3. a and b: Number of Planning Units (km2) selected and Boundary Length in km for the four Scenario 1 and 2 variations.

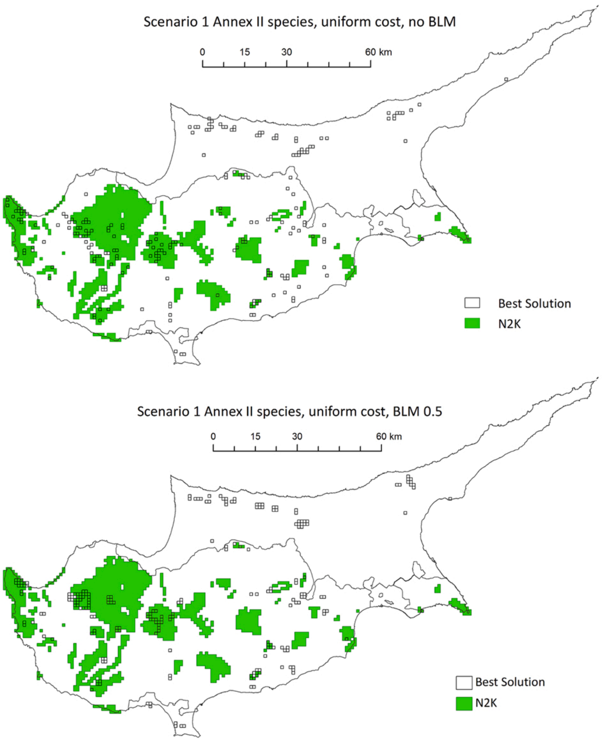


Fig. 4. Best solution for Scenario 1 Annex II species with uniform and variable cost, with and without BLM. N2K in the map is synonymous to the protected area network (PAN) as defined in this study.

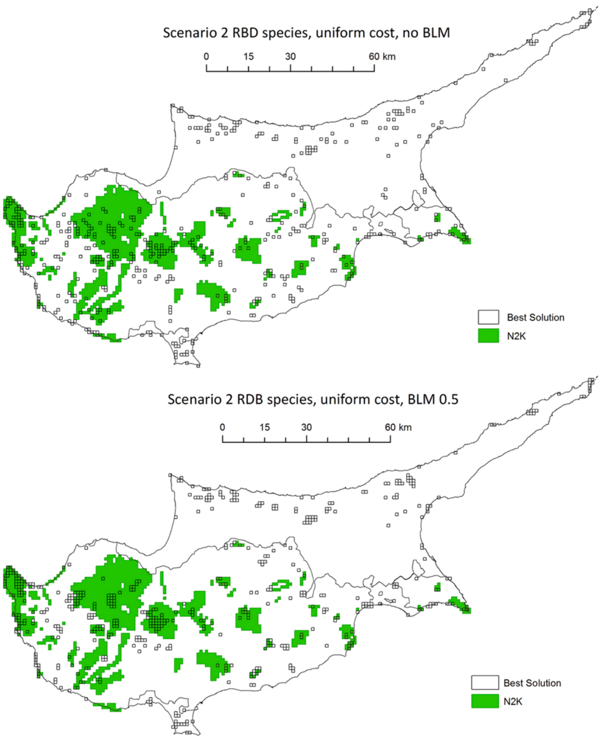


Fig. 5. Best solution for Scenario 2 RDB species with uniform and variable cost, with and without BLM. N2K in the map is synonymous to the protected area network (PAN) as defined in this study.

Table 3
Allocation of selected PUs of the Best Solutions (BS) of the two Scenarios in the Cyprus Government Controlled Area (CYGCA), the Turkish Occupied Area (TOA) and the Sovereign Base Areas (SBAs). Overlapping of BS with PAN.

Scenario	PUs in BS (area km^2)	PUs in CYGCA	PUs in TOA	PUs in SBAs	PUs Overlapping N2K[a]	Overlapping %[a]
S1UCnoBLM	216	161	50	5	95	59.01
S1UCwithBLM	221	162	52	7	96	59.26
S1VCnoBLM	217	162	51	4	121	74.69
S1VCwithBLM	219	162	52	5	123	75.93
Average	**218.25**	**161.75**	**51.25**	**5.25**		
S2UCnoBLM	498	358	113	27	188	52.51
S2UCwithBLM	522	378	116	28	228	60.32
S2VCnoBLM	520	369	126	25	269	72.90
S2VCwithBLM	529	379	127	23	281	74.14
Average	**517.25**	**371**	**120.5**	**25.75**		

[a] Calculated in relation to the proportion of PUs selected in the CYGCA.

other low cost categories in private land (Table 4). Therefore, the solutions with a variable cost surface are likely to have better opportunities for implementation.

Conversely, the results of Scenario 1 and 2 with uniform cost (with and without clustering) indicate that although the area needed to achieve the targets is relatively smaller, the proportion of overlap with existing PAN is substantially smaller (52.5–60.3%) as compared to the Scenario variations with variable cost, both with and without clustering (Table 3). Therefore, a larger number of additional reserves and area is required to meet the targets.

The analyses also identified the “irreplaceable” PUs in each Scenario variation; the irreplaceability of PUs is correlated with the distribution of CFs and is influenced by the use of uniform and variable costs surface as well as application of BLM. Generally, for both Scenario 1 and 2, when using uniform cost a smaller number of PUs were identified as irreplaceable. However, the number of irreplaceable PUs increased considerably with the use of a variable cost surface. In a similar way, the inclusion of a compactness objective (BLM) increased the number of irreplaceable PUs for both uniform and variable cost surfaces (Table 5). In addition, variable cost surface increased the proportion of overlap between the best solutions of both Scenario 1 and 2, with and without BLM (Table 5 and Fig. 6).

By using Marxan, the area required to achieve the specified targets of the 252 RDB species (Scenario 2), ranges from 498 to 529 km^2 for all four best solutions, accounting for 5.14–5.46% of the study area. The respective area for Scenario 1 Annex II species, is 216–221 km^2, representing 2.23–2.28% of the study area (Fig. 3a & 3b). Furthermore, the results of all Scenario 1 and 2 variations provide a range of additional solutions with similar scores and area and slightly different spatial arrangement thus allowing for more options which promote flexibility.

3.2. Identifying contiguous sites by clustering

Considering the results of clustering (Table 6), for both Scenarios, the solution providing the smallest number of clusters and the largest average cluster area (hence fewer and larger sites) are S1UCwithBLM and S2UCwithBLM (Fig. 7 & 8). Both of these results are not constrained by a variable cost and thus, the BLM has more effect. The second best options are S1VCwithBLM and S2VCwithBLM (Fig. 7 & 8), where compactness is constrained by the use of variable cost surface.

3.3. Evaluating effectiveness

Number of reserves: the number of existing PAN sites (36, see Fig. 1) designated is significantly smaller than the proposed sites for Scenarios 1 and 2 (selected for the whole island not only the CYGCA), which range from 66 to 138 and from 170 to 300 respectively,

Table 4
Allocation of selected PUs of the Best Solutions (BSs) of the two Scenarios in the different cost values of the variable cost surface (* for the scenario variations with uniform cost the BSs were overlaid with the variable cost layer so as their PUs to acquire the respective value to enable the comparison).

Scenario	PUs in BS (area km^2)	Cost value of PUs					
		0.1 (N2K)	0.5 (SFL)	1	2	3	4
S1UCnoBLM*	216	95	58	28	31	3	1
S1UCwithBLM*	221	96	64	30	27	3	1
S1VCnoBLM	217	121	65	18	13	0	0
S1VCwithBLM	219	123	65	18	13	0	0
S2UCnoBLM*	498	188	118	66	79	42	5
S2UCwithBLM*	522	228	111	54	75	49	5
S2VCnoBLM	520	269	139	52	48	9	3
S2VCwithBLM	529	281	135	52	48	11	2

Table 5
Area of Best Solutions (BSs), Irreplaceable PUs (based on Selection Frequency) and proportion of overlap in km^2 for both Scenarios.

Scenario name	PUs in BS (km^2)	Overlap of BS (km^2)	Irreplaceable PUs (km^2)	Overlap of irreplaceable PUs (km^2)
S1UCnoBLM	216	133	11	9
S1UCwithBLM	221		42	
S1VCnoBLM	217	181	86	77
S1VCwithBLM	219		101	
Total overlap		91		8
S2UCnoBLM	498	336	93	86
S2UCwithBLM	522		154	
S2VCnoBLM	520	443	257	226
S2VCwithBLM	529		278	
Total overlap		241		81

depending on the Scenario variation considered (Table 7 & 6, Fig. 7 & 8).

Total area: the total area of the existing terrestrial part of the PAN, currently 961 km^2 (equal to 17.9% of the CYGCA), is considerably larger than the proposed sites. In Scenario 1, the total area of sites ranges between 216 and 221 km^2, accounting for 2.23–2.28% of the study area (island). For Scenario 2, the total area ranges from 498 to 529 km^2 accounting for 5.14–5.46% of the study area.

Representativeness: Under the current status of the PAN 8 of the 19 CFs of Scenario 1 and 110 out of 252 CFs of Scenario 2 are represented to their specified target (see Appendix 3). In the proposed solutions all CFs of the two Scenarios achieve their targets.

Efficiency: In Scenario 1 there are 7 overrepresented and 11 underrepresented CFs (represented above and below the target level respectively), whereas for Scenario 2 there are 78 overrepresented and 142 underrepresented CFs. In the solution generated for Scenario 1 there are no over- or underrepresented CFs; for Scenario 2 there are no underrepresented CFs, while 48–60 CFS are overrepresented depending on which Scenario variation is considered (Table 7).

Land Ownership: 79% of the existing PAN sites is within SFL albeit with the above-mentioned deficiencies in efficiently representing the threatened species (over- and underrepresented). The proportion of proposed reserves selected in SFL ranges from 65.3% to 75.3% for Scenario 1 and from 55.2% to 66.5% for Scenario 2. This is an indication that not all threatened species can be protected within SFL as some of them are confined to other land ownership types.

4. Discussion

Our assessment shows that the current PAN sites, under the present political conditions (TOA and SBAs), do not represent adequately all Annex II and RDB plant species while a number of CFs are overrepresented (see Table 7). Following basic principles of SCP, the solutions for both scenarios provide a range of alternative reserve configurations, which achieve the predefined specified targets for both scenarios, in a much smaller area and with high overlap with the existing PAN sites, thus less additional area is required. However, there is some over-representation of CFs in scenario 2. As indicated in Table 3, for both Scenarios a considerable number of selected PUs is found in the TOA and the SBAs signifying their importance for a comprehensive network.

4.1. Solutions

The solutions generated, for both Scenarios, using a uniform cost were the most efficient at achieving all targets for the smallest possible area, albeit the sites were scattered and fragmented resulting in long boundaries. The application of a compactness objective (BLM) reduced fragmentation (clustering) with a small increase in area. However, both Scenarios achieved a relatively small overlap with the existing PAN sites ranging from 52.5% to 60.3% (Table 3) requiring larger additional area to be designated in PUs with higher cost (Table 4), thus less likely to be implemented. The main difficulties to implement solutions requiring proportionally large additional areas in private property are the expected reaction from land owners (Kirkpatrick, 1983) and the associated unwillingness of the authorities to promote such reserve solutions.

The reserve configurations produced using a variable cost surface met the targets with slightly larger area. However, overlap with the existing PAN sites increased significantly for both Scenarios, ranging from 72.9% to 75.9% (Table 3) and clustering of sites was promoted, without using a BLM. Significantly however, the overlap with low cost PUs is greater (Table 4). This means therefore that, a smaller additional area is needed for designation and in PUs with low cost value, hence improving the possibility for implementation. The use of a compactness objective (BLM) promoted a further improvement in clustering with a small area increase.

The solutions generated achieve all the predefined targets for the minimum area cost, 2.23–2.28% and 5.14–5.46% of the island (study area) for Scenario 1 and 2 respectively. Importantly, the method considers the limitations of available resources and the possible conflicts with competing land uses (Pressey et al., 2002; Possingham et al., 2006). The solutions incorporating the BLM, achieve a reasonable level of compactness whilst also keeping the selected area small. This has the advantage of reducing the need for significant expansion of the reserve network and a less fragmented network, an ecologically desirable objective (Possingham et al., 2000).

Furthermore, the solutions are efficient (Pressey et al., 2002) and represent adequately all CFs according to their targets, aiming at ensuring a favourable conservation status (Kukkala and Moilanen, 2013). The possible exception is the over-representation of a number of CFs in Scenario 2 owing to the large number of CFs in this Scenario and the coexistence of many CFs in common PUs. The

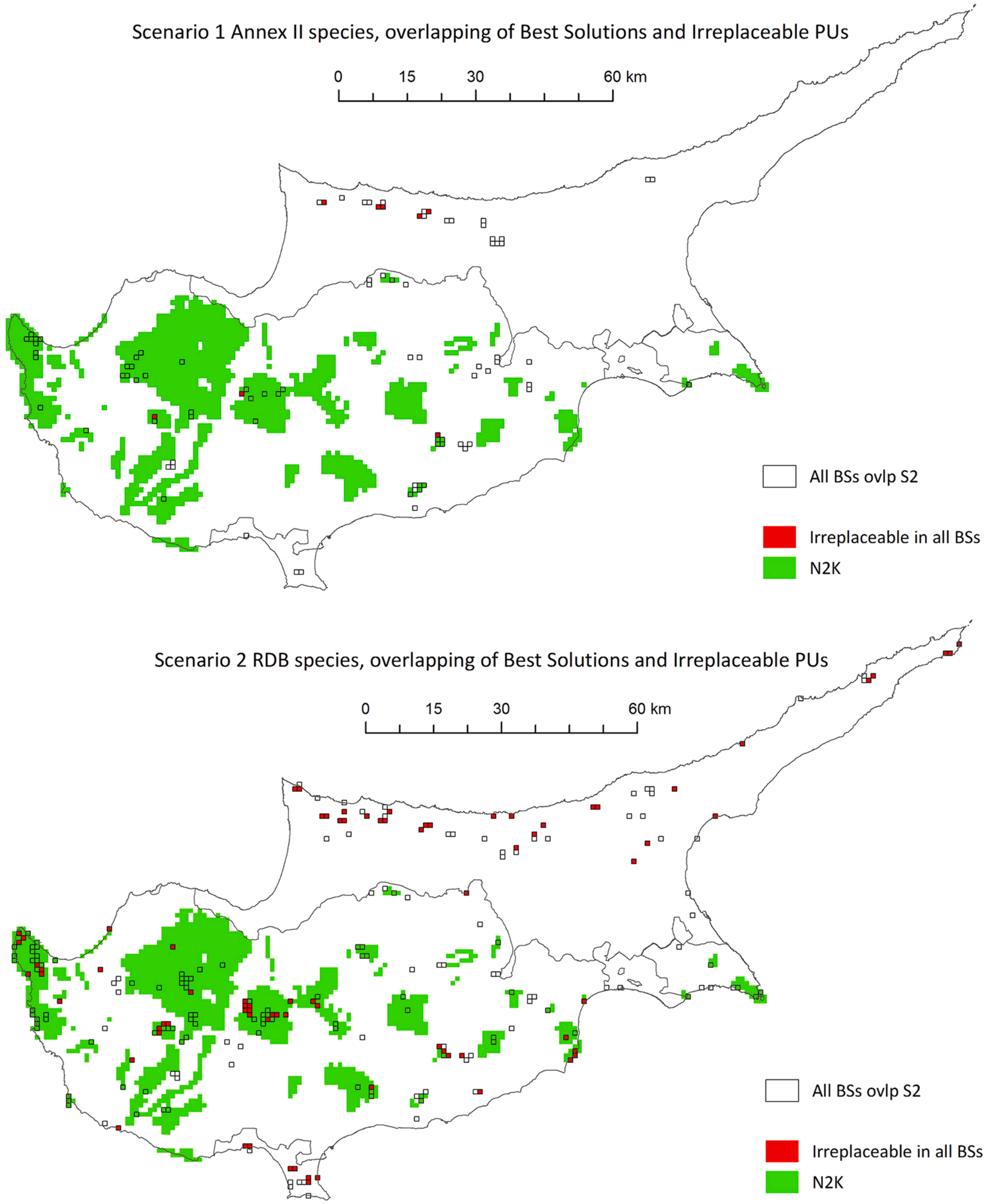


Fig. 6. Overlapping of PUs and irreplaceable PUs for all four BSs for Scenarios 1 & 2. N2K in the map is synonymous to the protected area network (PAN) as defined in this study.

solutions also provide flexibility (Pressey et al., 1993; Ball et al., 2009) by offering a range of near-optimal solutions with slightly different configurations thus allowing for negotiation with all stakeholders involved. The solutions generated with the variable cost achieve the highest possible overlap with the existing PAN sites and other low cost value PUs, thus increasing the feasibility of implementation. Also, the proposed additional reserves are complementary (Pressey et al., 1993; Margules and Pressey, 2000; Justus and Sarkar, 2002) to the existing PAN network as they add (contain) the unrepresented and under-represented CFs. Also, the analyses identified the irreplaceable PUs through selection frequency, key priority areas for conservation required in the reserve network to

Table 6
Area of best solution (BS), number and average area of clusters, proportion of small clusters (1–2 PUs) in relation to number of clusters and proportion of small clusters in relation to total solution area for each Scenario variation.

Scenario name	Area of BS km^2 (PUs)	Number of clusters	Average cluster area km^2 (mean)	Standard deviation	% of small clusters (1–2 PUs)	% of small clusters of total area
S1UCnoBLM	216	138	1.57	1.12	88.4	69.9
S1UCwithBLM	221	66	3.35	4.52	62.1	26.7
S1VCnoBLM	217	112	1.94	1.97	78.6	47.5
S1VCwithBLM	219	85	2.58	3.51	72.9	35.2
S2UCnoBLM	498	300	1.66	1.45	86.0	62.0
S2UCwithBLM	522	170	3.07	4.64	67.0	27.6
S2VCnoBLM	520	279	1.86	2.26	83.0	52.9
S2VCwithBLM	529	232	2.28	3.64	79.7	42.2

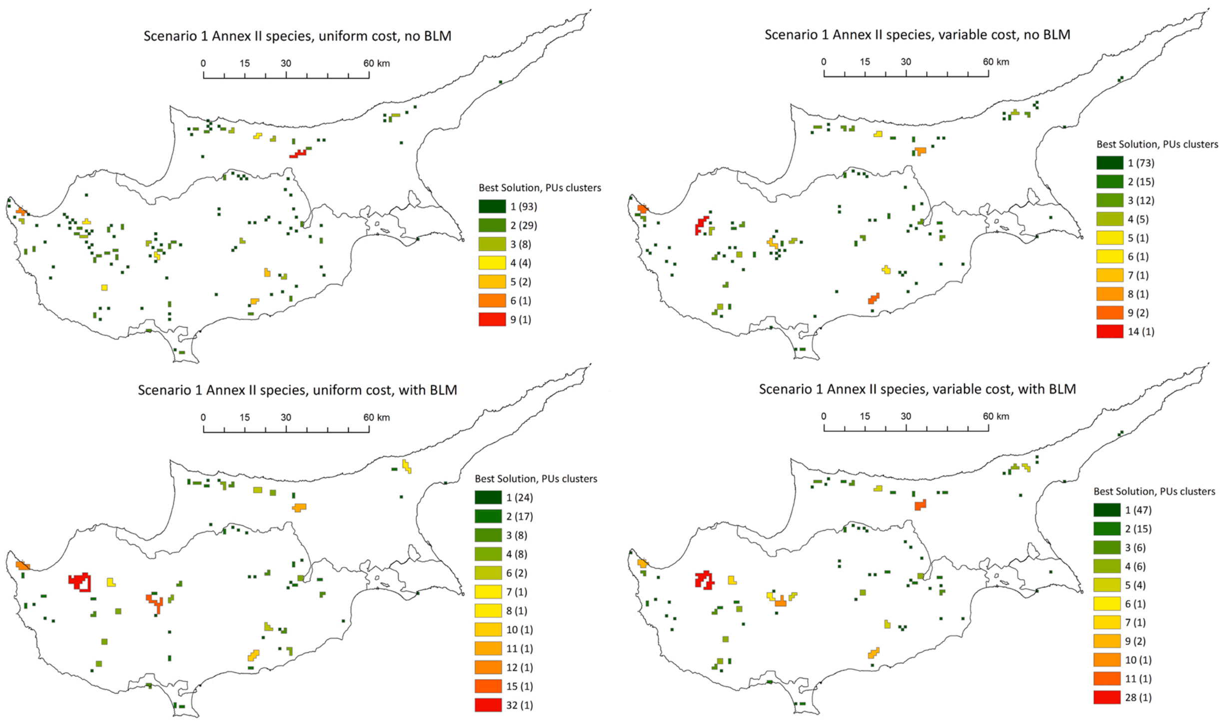


Fig. 7. Clustering of reserves for Scenario 1 Annex II species with uniform and variable cost, with and without BLM. The first number indicates the size of cluster (number of PUs) and the number in parenthesis the frequency of each cluster category.

meet all specified targets (Pressey et al., 1993; Ferrier et al., 2000; Kukkala and Moilanen, 2013).

The results of both Scenarios indicate that the application of the BLM increased the number of PUs identified as irreplaceable, for both Scenario variations with uniform and variable cost surfaces (Table 5); this trend has been also observed by Carwardine et al. (2007). Furthermore, the use of variable cost surface increased considerably the number of PUs identified as irreplaceable (i.e. selected in all solutions) as well as the overlap between the best solutions (Table 5). This is an indication of the influence of variable cost, and to a smaller extent of BLM, resulting in less flexible solutions, because there is not much flexibility to replace the irreplaceable PUs (Kukkala and Moilanen, 2013), therefore implementation might be affected. Also, as suggested by Delavenne et al. (2011) the use of real-world cost reduces flexibility.

The correlation of irreplaceable PUs with the hotspots of threatened species (i.e., PUs containing 5–13 CFs, sensu Christodoulou et al., 2018) is moderate because 26 out of the 60 hotspots were never identified as irreplaceable in any of the four best solutions of Scenario 2, whereas only 16 hotspots were identified as irreplaceable in all best solutions and the remaining 18 were identified as irreplaceable in at least one of the four BSs. Therefore, not all hotspots were required for achieving the targets and their inclusion may result in overrepresentation of CFs. On the other hand, 52 out of 81 irreplaceable PUs contain 50% of the occurrences of Critically Endangered CFs, signifying the correlation of rare features with irreplaceability (Carwardine et al., 2007; Cabeza and Moilanen, 2001). Conversely, CFs with a wide distribution, i.e. *Taraxacum aphrogenes*, *Phlomis cypria* subsp. *occidentalis*, *Phlomis brevibracteata* and *Ophrys kotschyi* can provide flexibility in reserve design (spatial configuration). However, despite the wide distribution, when the targets are high as in the case of *Ophrys kotschyi*, an Annex II priority species, then flexibility is reduced because most of the occurrences

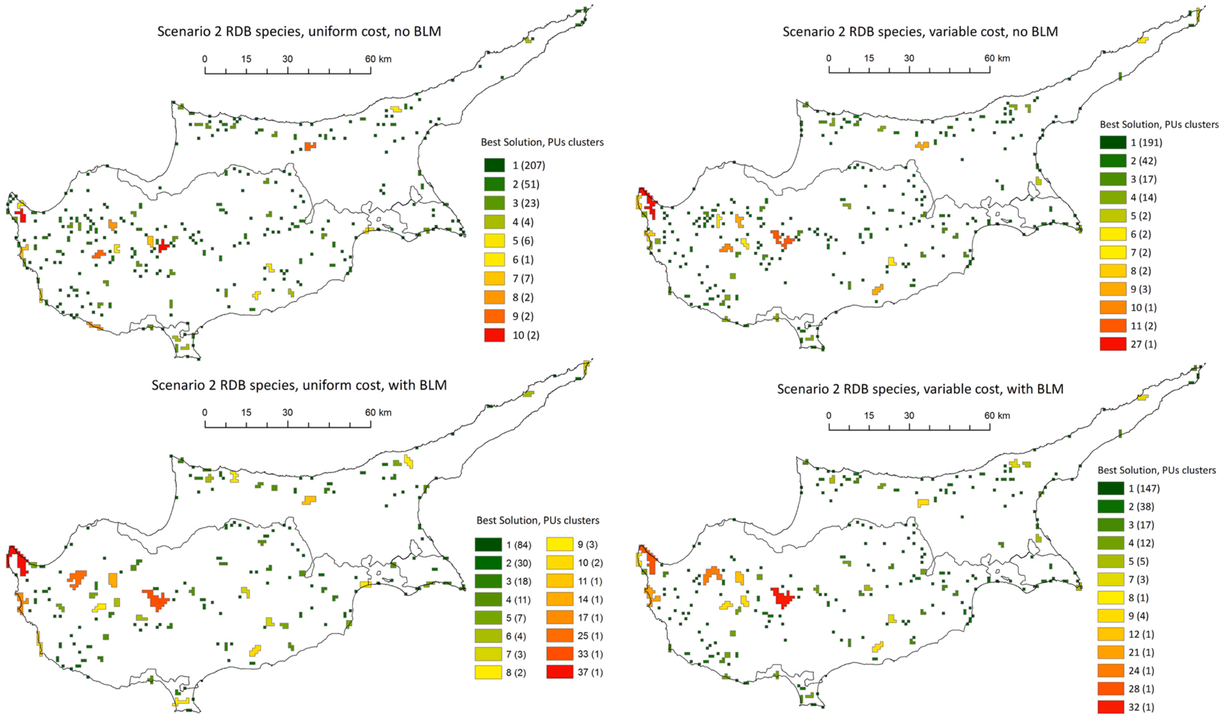


Fig. 8. Clustering of reserves for Scenario 2 RDB species with uniform and variable cost, with and without BLM. The first number indicates the size of cluster (number of PUs) and the number in parenthesis the frequency of each cluster category.

Table 7
Measures of effectiveness and values for existing N2K and proposed reserves for the two Scenarios wherever applicable (after Pressey et al., 2002).

Effectiveness measures	Protected Area Network (PAN)	Re-designed	
		Scenario 1 Annex II Species	Scenario 2 RDB species
1. Number of sites	36	66–138 (Clusters, Table 6)	170–300 (Clusters, Table 6)
2. Total area of km^2	961	216–221[a] (Table 5) Range of 4 scenario variations	498–529[a] (Table 5) Range of 4 scenario variations
3. Representativeness Number of CFs within PAN achieving their targets	S1[b]: 8 out of 19 achieve targets S2[c]: 110 out of 252 achieve target	19 (all)	252 (all)
4. Efficiency Number of under- and over-represented CFs	S1[b]: 7 out of 19 overrepresented, 11 underrepresented S2[c]: 78 out of 252 overrepresented, 142 underrepresented (of which 107 out of N2K)	All CFs achieved exactly the specified targets (no under- or over-representation)	No CF underrepresented 48–60 CFs overrepresented Range of 4 scenario variations
5. PAs within different ownerships (%) – or within SFL	79% in SFL and 21% in other ownership (Estimations only for CYGCA where N2K were designated using exact area of designated sites)	65.3–75.3% (141–165 PUs) in SFL the remaining in other ownership, mainly private. Range of 4 scenario variations (Estimations for the whole island, based on grid cells of best solutions and SFL grid layer)	55.2–66.5% (275–353 PUs) in SFL the remaining in other ownership, mainly private. Range of 4 scenario variations (Estimations for the whole island, based on grid cells of best solutions and SFL grid layer)

Explanatory notes: a: area calculated as grid-cells (1 km^2). b: 5 out of 19 CFs (Brassica hilarionis, Delphinium caseyi, Phlomis cypria subsp. cypria, Salvia veneris, Sideritis cypria) are restricted to the TOA. Also, the calculation of targets achievement for 6 more taxa (Astragalus macrocarpus subsp. lefkarensis, Crepis pusilla, Ophrys kotschyi, Phlomis brevibracteata, Scilla morrisii, Tulipa cypria) considered the whole range of their distribution, including the TOA and the SBAs where no N2K have been designated. The calculations of representativeness considered the PAN sites as mapped for the needs of the study. c: From the 142 CFs that have not achieved their targets 35 are confined to the CYGCA where N2K sites have been designated; 43 are confined to the TOA and 12 to SBAs where no N2K have been designated. Also, 31 CFs occur in the CYGCA and the TOA, 5 CFs occur in the CYGCA and the SBAs and 11 occur in CYGCA, TOA and SBAs.

are required to meet the targets.

4.2. Evaluation of methodology employed

All maps used in the analysis were based on the planning unit (PU), with the size of the grid based on a sensitivity analysis and which also considered the size of ownership and feasibility of reserve implementation. Regular grids are preferred over irregular while the smaller the size of the grid-cell the lower the area required to achieve the targets (Ardron et al., 2010; Nhancale and Smith, 2011) and the more possible options for spatial arrangement. For the preparation of the cost surface to be incorporated into the PU map for estimating the 'cost' of reserve selection, simple but meaningful parameters were employed that reflected, as far as possible, the current situation of human influence on the landscape and the potential threats to CFs. In order to incorporate an ecological aspect into the cost surface (Ardron et al., 2010), we used the recent CORINE land cover data (Heymann et al., 1994). This approach was decided due to the absence of detailed island habitat maps, a common practice in ecological studies (see Bunce et al., 2008), but also the lack of mapped land valuation data (Fois et al., 2019). Although this is an approximation it provides a useful basis and it is widely employed in SCP exercises (Ardron et al., 2010).

The conservation features (CFs) distribution map used for the analysis was based on presence only data, which may have resulted in omission errors (i.e. conservation features are considered to be absent from areas in which they have not been recorded but may be present). Consequently, it may lead to reduced efficiency by requiring more area to achieve the targets; which in turn might have a negative impact on feasibility of the conservation plan (Hermoso et al., 2015). However, when the objective is the conservation of threatened species overestimating areas of occurrence is more desirable than underestimating them, justifying thus the use of presence only data (Zaniewski et al., 2002). The availability of presence-absence (documented absence) or additionally accurate data on population size would have considerably increased the confidence of the results (Margules and Sarkar, 2007). However, such detailed data were not available and not feasible to collect for all species (252) within the timeframe of this research and on an island scale.

Nevertheless, the data used is considered as complete, up-to-date and of high quality because it covers all plant species evaluated as threatened all over the island. The data were collected for the same purpose, during the same time-period using the same methodology and have been continuously updated and improved until 2016. Another important point is that the presence only data concern rare, threatened species with generally restricted distribution, including species confined to particular geological substrate (i.e. gypsophilous and serpentinophilous) or specialised habitat (i.e. chasmophytes, hydrophilous) or restricted to the highest elevations, i.e. the top of Troodos National Forest Park, which is a centre of endemism and a hotspot of threatened species (Christodoulou et al., 2018). Thus, it is unlikely that these species will have a wider distribution than is currently documented.

Threatened species can be used as fine-filter conservation features that may not be sufficiently represented by coarse-filter approaches, such as habitats or vegetation classes (Ardron et al., 2010). The RDB species used in this study represent 15.3% of the flora of Cyprus and occur in all habitat types including synanthropic vegetation. Many of them are characteristic species of very important habitat types (Annex I, 92/43/EEC): *Cedrus brevifolia* represents the endemic cedar forest (habitat type 9590*), *Gypsophila lineariifolia* and *Teucrium salaminium* the gypsophilous vegetation (1520*), *Hirtellina lobelii* and *Onosma caespitosa* the chasmophytic vegetation (8210), *Alyssum akamasicum* and *Acinos troodi* the serpentinophilous communities (62B0*), *Crypsis hadjikyriakou* and *Poa pratensis* the peat grasslands of Troodos (6460*) and *Callitriche brutia* and *Crassula vaillantii* the vernal pools (3170*). Therefore, this approach can indirectly achieve conservation of important habitat types.

Of course it has to be pointed out that suggestions for the creation or reconfiguration of any PA network are subject to conservation features of interest. In our case such a network would have been significantly different if the analysis had included different taxa.

4.3. Cluster analysis of Marxan solution

Although the Marxan analysis used two cost surfaces with and without the use of a compactness objective (BLM) and for each scenario variation 500 solutions were generated, only a small number of these solutions were examined as potential reserves, i.e. the best solution and few more solutions having the smallest objective function score. However, the best solution or any other of the low score alternative solutions may not be the one that the stakeholders, such as land owners and other local authorities, would prefer, according to their criteria; thus, some of the solutions other than the best solution may have more chances to be accepted (Segan et al., 2011).

Cluster analysis of solutions can be more informative in relation to the spatial configuration of reserve networks, i.e. how similar spatially is one solution to another (Ardron et al., 2010). This analysis can identify representative configurations of solutions, which are statistically dissimilar thus the solution space to be examined more effectively (Segan et al., 2011; Linke et al., 2011). The identification of different solutions provides additional planning opportunities (flexibility) that can be exploited to facilitate implementation (Linke et al., 2011). Cluster analysis could provide additional reserve solutions which can have similar cost value but spatially different thus expanding the opportunities and improving flexibility to negotiate with stakeholders and find a feasible solution to implement. However, the spatial arrangement of solutions is limited when the conservation features are rare with restricted distribution (Cabeza and Moilanen, 2001).

4.4. Further research

Considering the space and resources limitations, the competing land uses (Pressey et al., 1993, 2002) and the rich biodiversity of Mediterranean islands (Médail, 2017; Vogiatzakis et al., 2016), the application of SCP approaches should be a priority. However, there are only few examples of the application of such methods, particularly in the marine realm (Giakoumi et al., 2011; Giakoumi et al., 2012). In the terrestrial part of Mediterranean islands research is limited to the evaluation of effectiveness of Protected Areas (N2K network) (Dimitrakopoulos et al., 2004; Fois et al., 2018) and the identification of conservation gaps (Fois et al., 2018; Christodoulou et al., 2018). The application of SCP approach, involving the determination of representation targets of the CFs and the use of reserve selection software is a significant improvement of previous work, which identified conservation gaps for the RDB species across the island (Christodoulou et al., 2018).There could have been alternatives ways to run the analysis by: i) using lower targets to provide more flexibility, because the restricted distribution and the relatively high targets may limit flexibility; ii) using as a representation target a percentage of the population instead of occurrences (although this data is not currently available for all RDB species). However, given the threatened status and number of conservation features involved (252 taxa representing 15.3% of the indigenous flora), as well as the geographical scale of the analysis that covered the whole island, the approach employed is considered satisfactory.

As the results demonstrated both in the TOA and the UK SBAs there are important locations with numerous threatened CFs, some of which confined locally (i.e. 43 to the TOA and 12 to the SBAs while 5 more species are restricted to SBAs and the TOA). Therefore, these areas contribute to a comprehensive reserve network (Table 3) and provide important conservation opportunities (Christodoulou et al., 2018) should a unified reserve network be put in place in the future.

A challenge for current and future reserve design is how to account for changes resulting from the impacts of climate change on species and habitats distribution (Parmesan and Yohe, 2003; Root et al., 2003; Parmesan, 2006; Schneider and Bayne, 2015). It is likely that many species, especially those with restricted range, will shift out of the existing reserves (Araújo et al., 2004; Hannah et al., 2007; Thomas and Gillingham, 2015). Consequently, existing reserves designed on the basis of current species distribution will probably be inadequate to guarantee long-term species persistence (Alagador et al., 2016; Schloss et al., 2011). Predicted climate change is expected to influence the distribution of threatened species either by possible migration into new areas with suitable climate or extinction in areas where the present climate conditions will cease to exist, such as the highest parts of the Troodos range. An assessment of the robustness of the existing and proposed reserve network under projected climate change would be useful but beyond the scope of this paper.

5. Conclusion

The design, selection and designation of the existing N2K network in Cyprus was based on a wide range of habitats (Annex I) and species (Annex II) of the Habitats Directive and not confined to protection of the threatened plants of the island. Nevertheless, by using systematic methods and decision-support tools the design could be complementary so as to include all threatened plant species along with the habitats and species of community importance. Therefore, by utilising the same resources to achieve high efficiency by the maximum representation for the minimum possible area and to increase the feasibility of implementation (Margules and Pressey, 2000; Possingham et al., 2006; Watson et al., 2011). In addition, it may provide the basis for improving the design of protected areas and thus contribute to EU's biodiversity targets set for 2030, which include the increase of land area to 30% by providing legal protection as demonstrated by this study. The analysis generated results that have both conservation planning and policy importance, and can facilitate the creation of a coherent network of protected areas. As such they strengthen the position of competent authorities to negotiate for the implementation of the additional reserves needed.

This is the first time that SCP is employed on the island of Cyprus and has demonstrated that Marxan can be applied to identify candidate sites for conservation areas island-wide. This method incorporates fundamental principles of Systematic Conservation Planning, uses quantitative, explicit objectives and it is transparent and repeatable (Ardron et al., 2010). Although Marxan cannot guarantee a single optimal solution, the usefulness of only one optimal result is limited in any case due to the feasibility of implementation for political and practical reasons. On the other hand, Marxan can handle significant conservation problems involving a large amount of data with huge number of possible solutions, producing a range of near optimal solutions thus allowing for flexibility in negotiations for the designation of new or the expansion of existing reserves (Ball et al., 2009).

The application of SCP approaches, as demonstrated in this work, can provide effective and efficient solutions, especially for Mediterranean islands, which have rich and threatened biodiversity but the opportunities for conservation are hindered by conflicting land uses and the limited availability of resources and land.

Declaration of Competing Interest

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

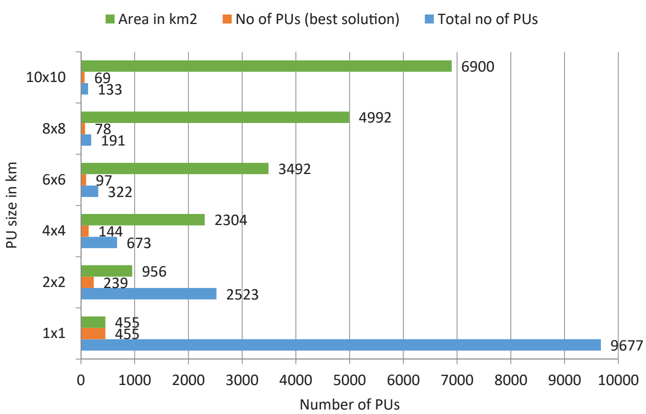
Acknowledgements

We would like to acknowledge the financial support of the A.G. Leventis Foundation, the Department of Forests for providing distributional data for the Red Data Book species and many colleagues who provided plant records.

Appendix 1. Cyprus plant taxa of Annexes II & IV of the Habitat Directive (92/43/EEC) and their IUCN threat category according to the RDB (*: priority species)

Latin name	IUCN Category	Status
*Arabis kennedyae**	EN	Endemic
Astragalus macrocarpus subsp. *lefkarensis**	VU	Endemic
Brassica hilarionis	EN	Endemic
*Centaurea akamantis**	EN	Endemic
*Chionodoxa lochiae** (=*Scilla lochiae*)	VU	Endemic
Crepis pussila	VU	Indigenous
Crocus cyprius	VU	Endemic
Crocus hartmannianus	VU	Endemic
*Delphinium caseyi**	CR	Endemic
*Ophrys kotschyi**	VU	Near-endemic
Phlomis brevibracteata	VU	Endemic
Phlomis cypria subsp. *cypria*	VU	Endemic
Phlomis cypria subsp. *occidentalis*	VU	Endemic
*Pinguicula crystallina**	VU	Indigenous
Ranunculus kykkoensis	VU	Endemic
Salvia veneris	VU	Endemic
*Scilla morrisii**	EN	Endemic
Sideritis cypria	EN	Endemic
Tulipa cypria	EN	Endemic

Appendix 2. Sensitivity analysis for the selection of PU size using the best solution output



.

Appendix 3. Species file with all 252 threatened CFs including their type, target and total number of occurrences (Type: 1: CR, Endemic; 2: CR, Indigenous; 3: EN, Endemic; 4: EN, Indigenous; 5: VU, Endemic; 6: VU, Indigenous. Target: number of occurrences, see also Table 1)

ID No.	Latin Name of conservation feature	IUCN category	Type	Target	No. of Occurrences
11	*Achillea cretica*	VU	6	4	14
1149	*Achillea maritima* subsp. *maritima*	VU	6	10	38
13	*Achillea santolinoides* subsp. *wilhelmsii*	CR	2	2	2
15	*Acinos troodi* subsp. *troodi*	VU	5	8	15
21	*Aegilops bicornis*	VU	6	6	22
1240	*Aethionema arabicum*	VU	6	6	23
1459	*Aethionema carneum*	EN	4	2	4
34	*Agrimonia eupatoria*	CR	2	2	2
45	*Aizoon hispanicum*	VU	6	3	10
1757	*Allium exaltatum*	VU	5	9	18
1971	*Allium guttatum*	VU	6	5	20
64	*Allium marathasicum*	CR	1	3	3

(continued on next page)

(*continued*)

ID No.	Latin Name of conservation feature	IUCN category	Type	Target	No. of Occurrences
70	*Allium roseum*	VU	6	1	5
78	*Alopecurus myosuroides*	VU	6	1	2
79	*Alopecurus utriculatus*	VU	6	3	10
82	*Alyssum akamasicum*	VU	5	14	27
90	*Alyssum umbellatum*	VU	6	3	10
102	*Ambrosia maritima*	CR	2	3	4
105	*Ammophila arenaria*	EN	4	1	2
2268	*Anacyclus clavatus*	VU	6	1	2
126	*Anthemis chia*	VU	6	2	6
129	*Anthemis parvifolia*	VU	6	1	2
2267	*Anthemis tomentosa*	EN	4	4	8
135	*Anthriscus caucalis*	VU	6	1	2
1602	*Apocynum venetum*	CR	2	2	3
144	*Arabis kennedyae*	EN	3	4	5
148	*Arbutus unedo*	CR	2	2	2
149	*Arctium lappa*	VU	6	4	15
153	*Argyrolobium uniflorum*	CR	2	2	3
5341	*Arum cylindraceum* subsp. *pitsyllianum*	EN	3	3	4
166	*Arum italicum* subsp. *italicum*	VU	6	2	9
168	*Arum rupicola*	VU	6	12	49
169	*Arum sintenisii*	VU	5	2	4
181	*Asphodeline lutea*	VU	6	1	1
184	*Asphodelus tenuifolius*	VU	6	2	9
1772	*Astragalus echinus* var. *chionistrae*	VU	5	6	11
1775	*Astragalus macrocarpus* subsp. *lefkarensis*	VU	5	13	17
204	*Astragalus suberosus*	EN	4	8	15
2252	*Bellium minutum*	EN	4	1	1
251	*Brachypodium glaucovirens*	VU	6	5	21
254	*Brassica hilarionis*	EN	3	14	18
293	*Bupleurum nodiflorum*	EN	4	3	5
301	*Cachrys scabra*	EN	4	10	19
304	*Calamagrostis epigejos*	VU	6	2	9
308	*Callitriche brutia*	EN	4	5	9
312	*Campanula delicatula*	CR	2	3	4
316	*Campanula podocarpa*	EN	4	1	1
333	*Carex illegitima*	VU	6	1	5
324	*Carthamus caeruleus (=Carduncellus caeruleus)*	CR	2	1	1
358	*Cedrus brevifolia*	VU	5	11	21
360	*Celtis tournefortii*	EN	4	10	19
362	*Centaurea akamantis*	EN	3	2	3
370	*Centaurium maritimum*	EN	4	3	6
2163	*Centropodia forskalii*	EN	4	2	3
379	*Cephalanthera rubra*	VU	6	1	2
390	*Ceratocapnos palaestina*	EN	4	2	3
394	*Chaenorhinum rubrifolium*	VU	6	5	20
422	*Cistanche phelypaea*	CR	2	1	1
428	*Cladium mariscus*	VU	6	1	4
450	*Convolvulus humilis*	CR	2	2	3
451	*Convolvulus lineatus*	VU	6	6	25
463	*Coronilla repanda* subsp. *repanda*	VU	6	9	36
473	*Crambe hispanica*	EN	4	2	4
475	*Crassula vaillantii*	VU	6	5	21
2239	*Crepis pusilla*	VU	6	6	11
489	*Crithopsis delileana*	VU	6	1	5
490	*Crocus cyprius*	VU	5	6	11
491	*Crocus hartmannianus*	VU	5	8	16
501	*Crypsis aculeata*	VU	6	3	13
503	*Crypsis factorovskyi*	VU	6	5	19
2259	*Crypsis hadjikyriakou*	CR	1	2	2
513	*Cyclamen graecum* subsp. *anatolicum*	CR	2	2	2
515	*Cymbalaria longipes*	CR	2	1	1
2131	*Cynanchum acutum*	EN	4	1	2
2320	*Cynara makrisii*	VU	5	1	2
523	*Cynoglossum troodi*	VU	5	6	12
528	*Cyperus cyprius*	VU	5	9	17
540	*Dactylorhiza iberica*	EN	4	3	6
543	*Datisca cannabina*	VU	6	6	24
550	*Daucus durieua*	CR	2	2	3
552	*Daucus guttatus*	VU	6	2	6
555	*Delphinium caseyi*	CR	1	4	4

(*continued on next page*)

(*continued*)

ID No.	Latin Name of conservation feature	IUCN category	Type	Target	No. of Occurrences
560	*Dianthus tripunctatus*	CR	2	2	2
2323	*Dichoropetalum kyriakae (=Peucedanum kyriakae)*	EN	3	2	2
571	*Echinaria capitata*	VU	6	1	2
578	*Echium glomeratum*	CR	2	2	3
1097	*Echium judaeum*	EN	4	3	5
588	*Enarthrocarpus arcuatus*	VU	6	2	8
592	*Ephedra nebrodensis*	VU	6	1	2
598	*Epipactis condensata*	CR	2	4	5
600	*Epipactis microphylla*	CR	2	3	4
606	*Erica manipuliflora*	VU	6	4	14
612	*Erodium crassifolium*	VU	6	9	35
2265	*Eryngium campestre*	VU	6	2	7
2133	*Erysimum kykkoticum*	VU	5	1	2
628	*Eupatorium cannabinum*	EN	4	1	1
629	*Euphorbia aleppica*	EN	4	2	3
648	*Euphorbia hirsuta (=E. pubescens)*	CR	2	1	1
642	*Euphorbia lemesiana*	VU	5	6	11
644	*Euphorbia paralias*	EN	4	12	24
652	*Euphorbia thompsonii*	VU	6	5	19
662	*Ferula cypria*	VU	6	2	8
664	*Ferulago syriaca*	VU	6	2	6
672	*Filago mareotica*	VU	6	1	1
674	*Fimbristylis ferruginea*	VU	6	1	4
679	*Fritillaria acmopetala*	CR	2	1	1
680	*Fritillaria persica*	EN	4	2	3
684	*Fumaria capreolata*	EN	4	1	2
686	*Fumaria gaillardotii*	EN	4	1	2
700	*Galium divaricatum*	VU	6	2	8
2032	*Galium humifusum* var. *lasiocarpum*	EN	4	1	1
706	*Galium pisiferum*	VU	6	4	16
1145	*Geum heterocarpum (=Orthurus heterocarpus)*	VU	6	1	5
725	*Geum urbanum*	VU	6	1	3
734	*Gundelia tournefortii*	EN	4	5	9
1117	*Gypsophila linearifolia*	EN	4	5	9
742	*Haplophyllum buxbaumii*	EN	4	3	6
1831	*Hedera helix* subsp. *poetarum*	EN	4	3	5
745	*Hedysarum cyprium*	VU	5	17	33
1832	*Helianthemum ledifolium* subsp. *lasiocarpum*	VU	6	4	16
752	*Helianthemum sanguineum (=Atlanthemum sanguineum)*	EN	4	1	2
2235	*Herniaria hemistemon*	VU	6	4	16
1808	*Hippocrepis emerus* subsp. *emeroides (=Coronilla emerus* subsp. *emeroides)*	EN	4	4	7
1532	*Hirtellina lobelii*	CR	2	2	2
1112	*Hyacinthus orientalis*	VU	6	1	1
790	*Hypecoum pendulum*	CR	2	3	4
795	*Hypericum hircinum*	VU	6	3	11
2040	*Hypericum lanuginosum* var. *lanuginosum*	VU	6	3	10
797	*Hypericum perfoliatum*	EN	4	3	5
804	*Ifloga spicata*	EN	4	2	4
813	*Ipomoea imperati*	EN	4	11	22
812	*Ipomoea sagittata*	CR	2	1	1
816	*Isolepis cernua*	VU	6	2	6
828	*Juncus littoralis*	VU	6	2	8
829	*Juncus maritimus*	VU	6	2	6
1421	*Lactuca tetrantha*	VU	5	6	12
858	*Lathyrus cassius*	EN	4	2	3
865	*Lathyrus setifolius*	EN	4	1	2
893	*Limonium aucheri*	EN	4	4	7
897	*Limonium mucronulatum*	CR	1	3	3
901	*Limosella aquatica*	VU	6	4	16
905	*Linaria pelisseriana*	VU	6	2	8
910	*Linum maritimum*	VU	6	2	6
1411	*Lomelosia argentea*	VU	6	3	12
1412	*Lomelosia brachiata*	VU	6	1	3
926	*Lotus angustissimus*	CR	2	2	2
2250	*Lotus conimbricensis*	VU	6	1	3
929	*Lotus cytisoides*	VU	6	5	21
954	*Malvella sherardiana*	EN	4	2	4
956	*Mantisalca salmantica*	CR	2	2	2
2048	*Maresia nana var. glabra (=Malcolmia nana var. glabra)*	CR	1	1	1
996	*Mentha aquatica*	CR	2	3	4

(*continued on next page*)

(*continued*)

ID No.	Latin Name of conservation feature	IUCN category	Type	Target	No. of Occurrences
1001	*Mesembryanthemum crystallinum*	VU	6	1	4
2325	*Micromeria cristata* subsp. *cristata*	EN	4	1	2
1025	*Monotropa hypopithys*	CR	2	2	3
1855	*Moricandia arvensis*	VU	6	1	2
1034	*Myosotis minutiflora*	VU	6	2	8
1050	*Neurada procumbens*	EN	4	2	4
1054	*Nigella ciliaris*	EN	4	1	1
396	*Notholaena marantae*	VU	6	2	8
1064	*Ochthodium aegyptiacum*	VU	6	3	11
1074	*Ononis diffusa*	EN	4	1	2
1087	*Onosma caespitosa*	VU	5	6	11
2071	*Onosma gigantea* var. *hispida*	CR	2	8	11
1091	*Onosma orientalis*	VU	6	1	5
1092	*Onosma troodi*	VU	5	12	23
1100	*Ophrys kotschyi*	VU	5	44	59
1119	*Orchis caspia*	CR	2	1	1
1118	*Orchis palustris*	CR	2	2	2
1125	*Origanum cordifolium*	VU	5	14	28
2324	*Ornithogalum neurostegium*	VU	6	1	2
1135	*Ornithogalum trichophyllum*	VU	6	5	20
1148	*Osyris alba*	VU	6	2	7
1880	*Papaver cyprium (=P. rhoeas subsp. cyprium)*	VU	5	11	21
2251	*Paronychia echinulata*	CR	2	2	3
1180	*Peganum harmala*	CR	2	1	1
1192	*Phillyrea latifolia*	VU	6	4	17
1193	*Phleum subulatum*	VU	6	1	5
1194	*Phlomis brevibracteata*	VU	5	34	67
2081	*Phlomis cypria* subsp. *cypria*	VU	5	4	8
2082	*Phlomis cypria* subsp. *occidentalis*	VU	5	43	86
1202	*Phyla nodiflora*	VU	6	4	14
2366	*Pinguicula crystallina*	VU	6	7	9
1247	*Poa compressa*	VU	6	1	3
1250	*Poa pratensis*	VU	6	1	3
1272	*Potentilla recta*	EN	4	2	3
1291	*Pteris vittata*	EN	4	1	2
1313	*Ranunculus constantinopolitanus*	EN	4	1	1
2215	*Ranunculus creticus*	VU	6	1	2
1318	*Ranunculus isthmicus*	VU	6	1	3
1319	*Ranunculus kykkoensis*	VU	5	5	9
1322	*Ranunculus millefolius* subsp. *millefolius*	EN	4	3	6
1324	*Ranunculus neapolitanus*	EN	4	1	1
1327	*Ranunculus repens*	VU	6	1	2
1328	*Ranunculus rumelicus*	VU	6	1	3
1334	*Reichardia picroides*	VU	6	3	10
1012	*Rhodalsine geniculata*	VU	6	1	2
1376	*Rumex vesicarius*	VU	6	1	5
1390	*Salsola soda*	VU	6	1	2
1392	*Salvia dominica*	VU	6	1	3
1394	*Salvia hierosolymitana*	CR	2	2	3
1396	*Salvia pinnata*	CR	2	1	1
1397	*Salvia sclarea*	CR	2	3	4
1398	*Salvia veneris*	VU	5	11	21
2240	*Saponaria mesogitana*	VU	6	2	6
1406	*Saponaria orientalis*	VU	6	2	6
1408	*Satureja thymbra*	EN	4	3	6
1418	*Scandix grandiflora*	EN	4	1	1
1420	*Scandix stellata*	VU	6	2	8
1917	*Schoenoplectus tabernaemontani (=Scirpus lacustris* subsp. *tabernaemontani)*	EN	4	1	2
407	*Scilla lochiae (=Chionodoxa lochiae)*	VU	5	7	9
1429	*Scilla morrisii*	VU	5	16	21
1432	*Sclerochloa dura*	VU	6	3	11
2306	*Securigera cretica*	EN	4	2	3
1448	*Sedum microstachyum*	VU	5	12	23
1457	*Serapias aphroditae*	VU	5	3	6
1458	*Serapias parviflora*	CR	2	2	2
1468	*Sideritis cypria*	VU	5	9	18
1924	*Silene dichotoma*	EN	4	1	2
1480	*Silene fuscata*	CR	2	1	1
1483	*Silene gemmata*	VU	5	10	20
2109	*Silene kotschyi* var. *maritima*	EN	4	4	8

(*continued on next page*)

(*continued*)

ID No.	Latin Name of conservation feature	IUCN category	Type	Target	No. of Occurrences
1503	*Sisymbrium polyceratium*	VU	6	2	9
2329	*Solenopsis antiphonitis*	EN	3	2	2
557	*Staphisagria macrosperma (= Delphinium staphisagria)*	EN	4	1	1
1543	*Stipagrostis lanata*	CR	2	3	4
1545	*Suaeda aegyptiaca*	VU	6	6	22
1553	*Tamarix hampeana*	EN	4	2	4
1560	*Taraxacum aphrogenes*	VU	5	43	85
1563	*Taraxacum holmboei*	VU	5	5	10
1565	*Teesdalia coronopifolia*	VU	6	1	5
2370	*Teucrium karpasiticum*	VU	5	9	18
5480	*Teucrium salaminium*	VU	5	4	8
1590	*Tordylium apulum*	VU	6	1	3
1618	*Trifolium globosum*	VU	6	1	1
1649	*Triplachne nitens*	VU	6	8	33
1658	*Tulipa akamasica*	CR	1	1	1
1657	*Tulipa cypria*	EN	3	11	15
1661	*Tussilago farfara*	VU	6	1	5
1665	*Umbilicus horizontalis*	VU	6	6	22
1670	*Urtica membranacea*	VU	6	2	8
1676	*Valantia muralis*	EN	4	2	3
1686	*Valerianella triceras*	VU	6	2	6
1689	*Verbascum blattaria*	CR	2	2	3
1691	*Verbascum orientale*	VU	6	1	5
1694	*Verbena supina*	VU	6	5	20
2331	*Viburnum tinus* subsp. *tinus*	VU	6	1	5
2266	*Vicia lutea*	VU	6	1	2
1726	*Vincetoxicum canescens*	EN	4	3	5
1731	*Viola parvula*	CR	2	2	3
1735	*Vulpia brevis*	CR	2	2	3
1738	*Vulpia muralis*	VU	6	1	3

Appendix 4a. Cost value of CORINE Land Cover classes present in Cyprus (H: high, M: medium, L: low)

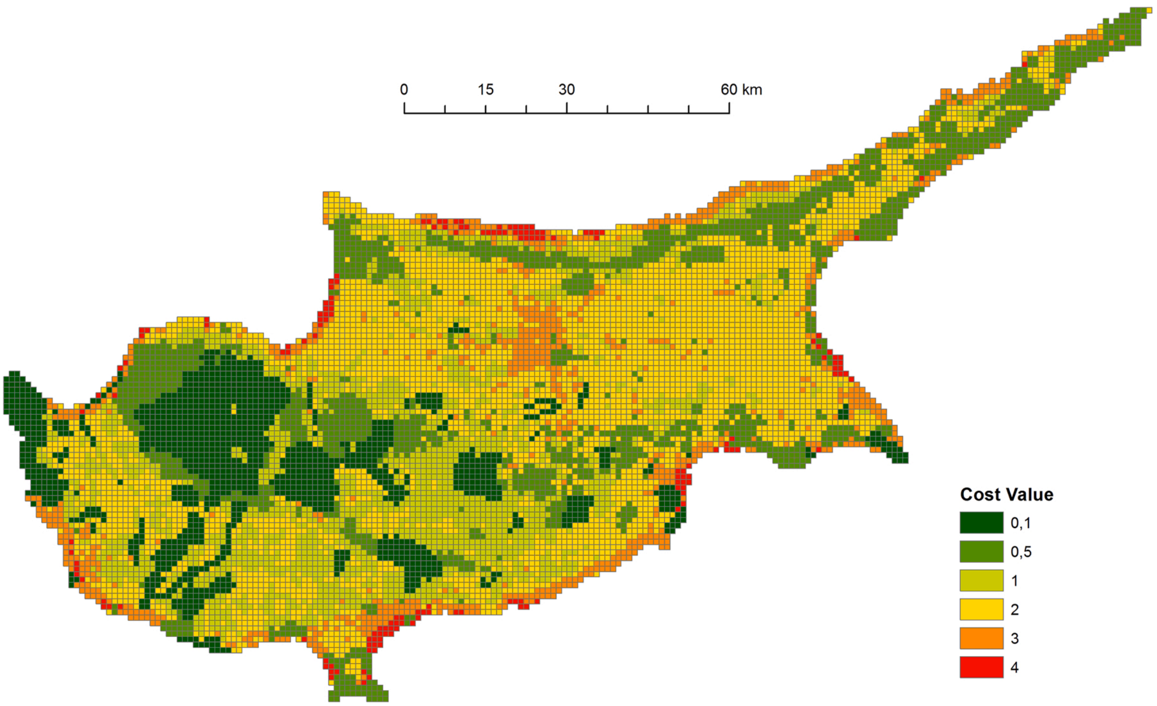
CLC code/name Level 3	Value	Cost Value
1.1.1 Continuous urban fabric	H	3
1.1.2 Discontinuous urban fabric	H	3
1.2.1 Industrial or commercial units	H	3
1.2.2 Road and rail networks and associated land	H	3
1.2.3 Port areas	H	3
1.2.4 Airports	H	3
1.3.1 Mineral extraction sites	H	3
1.3.2 Dump sites	H	3
1.3.3 Construction sites	H	3
1.4.1 Green urban areas	M	2
1.4.2 Sport and leisure facilities	M	2
2.1.1 Non-irrigated arable land	M	2
2.1.2 Permanently irrigated land	M	2
2.2.1 Vineyards	M	2
2.2.2 Fruit trees and berry plantations	M	2
2.2.3 Olive groves	M	2
2.3.1 Pastures	L	1
2.4.1 Annual crops associated with permanent crops	M	2
2.4.2 Complex cultivation patterns	M	2
2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation	L	1
3.1.1 Broad-leaved forest	L	1
3.1.2 Coniferous forest	L	1
3.1.3 Mixed forest	L	1
3.2.1 Natural grassland	L	1
3.2.3 Sclerophylous vegetation	L	1
3.2.4 Transitional woodland/shrub	L	1
3.3.1 Beaches, dunes, and sand plains	H	3
3.3.2 Bare rock	M	2
3.3.3 Sparsely vegetated areas	M	2
3.3.4 Burnt areas	M	2
4.1.1 Inland marshes	M	2
4.2.1 Salt marshes	M	2
5.1.1 Water courses	M	2
5.1.2 Water bodies	L	1

Appendix 4b. Matrix with the possible combinations of cost value (SFL: State Forest Land, N2K: protected areas Natura 2000 and Nature Reserves, CLC: Corine Land Cover, CB: Coastal Buffer)

Map 1 × 1 km		SFL	N2K	CLC	CLC	CLC	CB	CB	CB
	Cost Value	0.5	0.1	1	2	3	1	1	1
SFL	0.5	N/A	0.1	0.5	0.5	0.5	0.5	0.5	0.5
N2K	0.1	0.1	N/A	0.1	0.1	0.1	0.1	0.1	0.1
CLC	1/2/3	0.5	0.1	N/A 1*	N/A 2*	N/A 3*	2	3	4
CB	1	0.5	0.1	2	3	4	N/A	N/A	N/A

* In case when the only input spatial layer is CLC

Appendix 4c. Map of combined cost surface (derived from CORINE land classes, SFL and N2K)



.

Appendix 5. Glossary of technical terms employed in the manuscript

Annex II species: plant and animal species (excluding birds) of community importance whose conservation requires the designation of Sites of Community Importance which are eventually declared as Special Areas of Conservation (Natura 2000 sites).

Marxan: is a decision support software used for the design of a range of possible reserve configurations that meet the conservation objectives and consider all possible constraints such as cost, existing reserves or other land uses. The main outputs of a Marxan analysis are the summed and best solution files.

Summed solution is the selection frequency of each Planning Unit, used as a surrogate of irreplaceability.

Best solution is the run with the best objective value (smallest objective function score) from all the good solutions that have been produced.

Best solution: one of the main output files of Marxan, which is the run that comprises the selection of PUs with the best objective value (smallest objective function score) from all the good solutions that have been produced. However, every set of runs may result in a different best solution; therefore, the meaning of best should be carefully considered as this solution may be slightly different than other top listed solutions.

Planning Units (PUs): spatial units within the entire planning area (i.e. domain, or study area), which can be defined using regular gridded (e.g. hexagonal) or using landscape features-based (e.g. reefs, water catchments) as in Marxan.

Cost (uniform, variable): the cost of including each PU in the reserve, which can be either uniform for all PUs or variable (having a different value for each PU). This can be based either on monetary value, ecological value or suitability and desirability of PUs for conservation.

Objective function: the mathematical formulation of the minimum set problem, according to which Marxan analysis allocates a score (value) for every reserve configuration.

Boundary Length Modifier (BLM): an optional parameter used in Marxan analysis to control/improve the compactness of the reserve solutions.

References

Alagador, D., Cerdeira, J.O., Araújo, M.B., 2016. Climate change, species range shifts and dispersal corridors: an evaluation of spatial conservation models. Methods Ecol. Evol. 7, 853–866.

Araújo M.B., 2009. Protected Areas and Climate Change in Europe (Report). Strasbourg.

Araújo, M.B., Cabeza, M., Thuiller, W., Hannah, L., Williams, P.H., 2004. Would climate change drive species out of reserves? An assessment of existing reserve selection methods. Glob. Change Biol. 10, 1618–1626.

Ardron, J.A., Possingham, H.P., Klein, C.J. (Eds.), 2010. Marxan Good Practices Handbook, Version 2.. Pacific Marine Analysis and Research Association, Victoria, BC, Canada.

Ball, I.R., Possingham, H.P., Watts, M.E., 2009. Chapter 14: Marxan and relatives: software for spatial conservation prioritization. In: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds.), Spatial Conservation Prioritization: Quantitative Methods and Computational Tools. Oxford University Press, Oxford, pp. 185–195.

Bunce, R.G.H., Metzger, M.J., Jongman, R.H.G., Brandt, J., de Blust, G., Elena-Rossello, R., Groom, G.B., Halada, L., Hofer, G., Howard, D.C., Kovar, P., Mucher, C.A., Padoa-Schioppa, E., Paelinx, D., Palo, A., Perez-Soba, M., Ramos, I.L., Roche, P., Skanes, H., Wrbka, T., 2008. A standardized procedure for surveillance and monitoring European habitats and provision of spatial data. Landsc. Ecol. 23, 11–25.

Cabeza, M., Moilanen, A., 2001. Design of reserve networks and the persistence of biodiversity. Trends Ecol. Evol. 16, 242–248.

Carwardine, J., Rochester, W.A., Richardson, K.S., Williams, K.J., Pressey, R.L., Possingham, H.P., 2007. Conservation planning with irreplaceability: does the method matter? *Biodiversity*. Conservation 16, 245–258.

Christodoulou, C.S., Griffiths, G.H., Vogiatzakis, I.N., 2018. Using threatened plant species to identify conservation gaps and opportunities on the island of Cyprus. Biodivers. Conserv. 27, 2837–2858.

Coffey, C., Richartz, S., 2003. The EU Habitats Directive: Generating Strong Responses. No. D 17. Institute for European Environmental Policy, London.

D'Amen, M., Bombi, P., Campanaro, A., Zapponi, L., Bologna, M.A., Mason, F., 2013. Protected areas and insect conservation: questioning the effectiveness of Natura 2000 network for saproxylic beetles in Italy. Anim. Conserv. 16, 370–378.

Delavenne, J., Metcalfe, K., Smith, R.J., Vaz, S., Martin, C.S., Dupuis, L., Coppin, F., Carpentier, A., 2011. Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools. ICES J. Mar. Sci. 69, 75–83.

Dimitrakopoulos, P.G., Memtsas, D., Troumbis, A.Y., 2004. Questioning the effectiveness of the Natura 2000 Species Areas of Conservation strategy: the case of Crete. Glob. Ecol. Biogeogr. 13, 199–207.

Drummond, S.P., Wilson, K.A., Meijaard, E., Watts, M., Dennis, R., Christy, L., Possingham, H.P., 2010. Influence of a threatened-species focus on conservation planning. Conserv. Biol. 24, 441–449, 24 francesco.carimi.

Edwards, S., Hudson-Edwards, K., Cann, J., Malpas, J., Xenophontos, C., 2010. Classic Geology in Europe 7: Cyprus. Terra Publishing, Harpenden.

Evans, D., 2012. Building the European Union's Natura 2000 network. Nat. Conserv. 1, 11–26.

Ferrier, S., Pressey, R.L., Barrett, T.W., 2000. A new predictor of the irreplaceability of areas for achieving a conservation goal, its application to real-world planning, and a research agenda for further refinement. Biol. Conserv. 93, 303–325.

Fois, M., Bacchetta, G., Cogoni, D., Fenu, G., 2018. Current and future effectiveness of the Natura 2000 network for protecting plant species in Sardinia: a nice and complex strategy in its raw state? J. Environ. Plan. Manag. 61, 332–347.

Fois, M., Fenu, G., Bacchetta, G., 2019. Estimating land market values from real estate offers: a replicable method in support of biodiversity conservation strategies. Ambio 48 (3), 313–323.

Game, E.T., Grantham, H.S., 2008. Marxan User Manual: For Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada, p. 127.

Giakoumi, S., Grantham, H.S., Kokkoris, G.D., Possingham, H.P., 2011. Designing a network of marine reserves in the Mediterranean Sea with limited socio-economic data. Biol. Conserv. 144, 753–763.

Giakoumi, S., Katsanevakis, S., Vassilopoulou, V., Panayotidis, P., Kavadas, S., Issaris, Y., Kokkali, A., Frantzis, A., Panou, A., Mavrommati, G., 2012. Could European marine conservation policy benefit from systematic conservation planning? Aquat. Conserv.: Mar. Freshw. Ecosyst. 22, 762–775.

Hand R., Hadjikyriakou G.N. and Christodoulou C.S. (ed.) 2011– (continuously updated): Flora of Cyprus - a dynamic checklist. ⟨http://www.flora-of-cyprus.eu/⟩.

Hannah, L., Midgley, G., Andelman, S., Araújo, M., Hughes, G., Martinez-Meyer, E., Pearson, R., Williams, P., 2007. Protected area needs in a changing climate. Front. Ecol. Environ. 5, 131–138.

Hermoso, V., Kennard, M.J., Linke, S., 2015. Assessing the risks and opportunities of presence-only data for conservation planning. J. Biogeogr. 42, 218–228.

Heymann, Y., Steenmans, C., Croissille, G., Bossard, M., 1994. CORINE Land Cover. Technical Guide. Office for Official Publications of the European Communities, EUR12585 Luxembourg.

Hoffmann, M., Brooks, T.M., da Fonseca, G.A.B., Gascon, C., Hawkins, A.F.A., James, R.E., Langhammer, P., Mittermeier, R.A., Pilgrim, J.D., Rodrigues, A.S.L., Silva, J.M.C., 2008. Conservation planning and the IUCN Red List. Endanger. Species Res. 6, 113–125.

Jackson, S.F., Walker, K., Gaston, K.J., 2009. Relationship between distributions of threatened plants and protected areas in Britain. Biol. Conserv. 142, 1515–1522.

Jones-Walters, L., Čivić, K., 2013. European protected areas: past, present and future. J. Nat. Conserv. 21, 122–124.

Justus, J., Sarkar, S., 2002. The principle of complementarity in the design of reserve networks to conserve biodiversity: a preliminary history. J. Biosci. 27, 421–435.

Kirkpatrick, J.B., 1983. An iterative method for establishing priorities for the selection of nature reserves: an example from Tasmania. Biol. Conserv. 25, 127–134.

Kukkala, A.S., Moilanen, A., 2013. Core concepts of spatial prioritisation in systematic conservation planning. Biol. Rev. 88, 443–464.

Linke, S., Watts, M., Stewart, R., Possingham, H.P., 2011. Using multivariate analysis to deliver conservation planning products that align with practitioner needs. Ecography 34, 203–207.

Maiorano, L., Falcucci, A., Garton, E.O., Boitani, L., 2007. Contribution of the Natura 2000 Network to Biodiversity Conservation in Italy. Conserv. Biol. 21, 1433–1444.

Margules, C., Sarkar, S., 2007. Systematic Conservation Planning. Cambridge University Press, Cambridge.

Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243–253.

Médail, F., 2017. The specific vulnerability of plant biodiversity and vegetation on Mediterranean islands in the face of global change. Reg. Environ. Change 17, 1775–1790.

Médail, F., 2021. Plant biogeography and vegetation patterns of the Mediterranean Islands. Bot. Rev. https://doi.org/10.1007/s12229-021-09245-3.

Medail, F., Quezel, P., 1997. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Ann. Mo. Bot. Gard. 84, 112–127.

Nagy, D., Tripolszky, S., Schnell, A.A. (Eds.), 2007. Natura 2000 Site Designation Process with a special focus on the Biogeographic seminars, Second edition. CEEWEB, Budapest.
Nhancale, B.A., Smith, R.J., 2011. The influence of planning unit characteristics on the efficiency and spatial pattern of systematic conservation planning assessments. Biodivers. Conserv. 20, 1821–1835.
Parmesan, C., 2006. Ecological and evolutionary responses to recent climate change. Annu. Rev. Ecol. Evol. Syst. 37, 637–669.
Parmesan, C., Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421, 37–42.
Possingham, H.P., Ball, I.R., Andelman, S., 2000. Mathematical methods for identifying representative reserve networks. In: Ferson, S., Burgman, M. (Eds.), Quantitative Methods for Conservation Biology. Springer-Verlag, New York, pp. 291–305.
Possingham, H.P., Wilson, K.A., Andelman, S.J., Vynne, C.H., 2006. Protected areas: goals, limitations, and design. In: Groom, M.J., Meffe, G.K., Carroll, C.R. (Eds.), Principles of Conservation Biology, 3rd edition. Sinauer Associates, Sunderland, MA, pp. 509–533.
Pressey, R.L., Humphries, C.J., Margules, C.R., Vane-Wright, R.I., Williams, P.H., 1993. Beyond opportunism: key principles for systematic reserve selection. Trends Ecol. Evol. 8, 124–128.
Pressey, R.L., 1996. Protected areas: where should they be and why should they be there? In: Spellerberg, I.F. (Ed.), Conservation Biology. Longman Harlow, London, pp. 171–185.
Pressey, R.L., 1999. Editorial - systematic conservation planning for the real world. Parks 9, 1–6.
Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M., Wilson, K.A., 2007. Conservation planning in a changing World. Trends Ecol. Evol. 22, 583–592.
Pressey, R.L., Whish, G.L., Barrett, T.W., Watts, M.E., 2002. Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. Biol. Conserv. 106, 57–69.
Rondinini, C., Pressey, R.L., 2007. Systematic conservation planning in the European Landscape: conflicts, environmental changes, and the challenge of countdown 2010. Conserv. Biol. 21, 1404–1405.
Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweigk, C., Pounds, J.A., 2003. Fingerprints of global warming on wild animals and plants. Nature 421, 57–60.
SANBI, 2010. Threatened Species: A Guide to Red Lists and Their Use in Conservation. Threatened Species Programme,, Pretoria, South Africa, p. 28.
Schloss, C.A., Lawler, J.J., Larson, E.R., Papendick, H.L., Case, M.J., Evans, D.M., DeLap, J.H., Langdon, J.G.R., Hall, S.A., McRae, B.H., 2011. Systematic conservation planning in the face of climate change: bet-hedging on the Columbia Plateau. PLoS One 6 (e28788), 1–9.
Schneider, R.R., Bayne, E.M., 2015. Reserve design under climate change: from land facets back to ecosystem representation. PLoS One 10, e0126918.
Segan, D.B., Game, E.T., Watts, M.E., Stewart, R.R., Possingham, H.P., 2011. An interoperable decision support tool for conservation planning. Environ. Model. Softw. 26, 1434–1441.
Simaika, J.P., Samways, M.J., 2009. Reserve selection using Red Listed taxa in three global biodiversity hotspots: Dragonflies in South Africa. Biol. Conserv. 142, 638–651.
Stewart, R.R., Possingham, H.P., 2005. Efficiency, costs and trade-offs in marine reserve system design. Environ. Modeming Assess. 10, 2003–2213.
Thomas, C.D., Gillingham, P.K., 2015. The performance of protected areas for biodiversity under climate change. Biol. J. Linn. Soc. 115, 718–730.
Trochet, A., Schmeller, D.S., 2013. Effectiveness of the Natura 2000 network to cover threatened species. Nat. Conserv. 4, 35–53.
Tsintides, T., Christodoulou, C.S., Delipetrou, P., Georgiou, K. (Eds.), 2007. The Red Data Book of the Flora of Cyprus. Cyprus Forestry Association, Lefkosia.
Vogiatzakis, I.N., Mannion, A.M., Sarris, D., 2016. Mediterranean island biodiversity and climate change: the last 10,000 years and the future. Biodivers. Conserv. 25, 2597–2627.
Watson, J.E.M., Grantham, H.S., Wilson, K.A., Possingham, H.P., 2011. Systematic conservation planning: past, present and future. In: Ladle, R.J., Whittaker, R.J. (Eds.), Conservation Biogeography. Wiley-Blackwell, Oxford, pp. 136–160.
Watts, M.E., Ball, I.R., Stewart, R.S., Klein, C.J., Wilson, K., Steinback, C., Lourival, R., Kircher, L., Possingham, H.P., 2009. Marxan with Zones: software for optimal conservation based land- and sea-use zoning. Environ. Model. Softw. 24 (12), 1–9.
Zaniewski, A.E., Lehman, A., Overton, J., 2002. Predicting species spatial distributions using presence-only data: a case study of native New Zealand ferns. Ecol. Model. 157, 261–280.