Are protected areas covering important biodiversity sites? An assessment of the nature protection network in Sicily (Italy)

Abstract

GIS spatial analysis of three indicators (vegetation value, faunal richness and landscape heterogeneity) was used to detect and map High-Value Biodiversity Areas (HVBAs), estimate the coverage of biodiversity in the Sicilian protected areas network, and identify new priority areas that could improve long-term biodiversity conservation outcomes. Findings indicated that only 32% of HVBAs are currently covered by the protected areas network. Hotspot analysis revealed that a modest expansion (less than 1%) in the current extent of protected areas would include a disproportionate amount (56%) of biodiversity hotspots, and identified prioritized candidates HVBAs for designation of new protected areas.

Keywords: Protected areas**;** biodiversity value; conservation planning; GIS; spatial analysis; hot spots.

Highlights

- Data on 81 terrestrial habitats, 213 threatened plant species and 146 fauna species are used to map areas with high biodiversity value.
- Spatial analysis shows that only 32% of areas with high biodiversity value are currently protected.
- A small increment of the existing protected area network could include a disproportionate amount of biodiversity hot spots.

1. Introduction

Protected areas are the primary tool for conserving biodiversity, promoting long-term sustainability and raising public awareness of ecological and socio-economic benefits of natural capital and ecosystem services (Bastian, 2013; Geldmann *et al*. 2013; Kettunen and ten Brink, 2013; Millennium Ecosystem Assessment, 2013; Stolton *et al*., 2015).

Although protected areas, both in number and coverage, have been globally increasing significantly over the last few decades, the existing global network covers less than 20% of areas important for biodiversity and ecosystem services (UNEP-WCMC, 2014; Joppa *et al*., 2106; UNEP-WCMC and IUCN, 2016), and does not offer a sufficient contribution to the representativeness of areas important for biodiversity and ecosystem services (Skidmore, 2011; Rodrigues *et al*., 2004; Tantipisanuh *et al*., 2016).

To expand the current network, and prioritize systems of protected areas towards the internationally agreed AICHI Biodiversity Targets 11 (Harrison *et al*., 2010; Joppa *et al.* 2013; Pringle, 2017), policy makers and land use planners could benefit from science-based spatial biodiversity assessments, which generate metrics and maps tracking biodiversity values that would be understandable to a wide audience (SANBI & UNEP-WCMC, 2016; Van Vleet *et al*., 2016; Scott *et al*., 2018). However, assessing biodiversity values is a complex, and costly task, especially at large scale. If successful attempts have been made, aggregating these measurements into a single metric tracking full biodiversity value to humans still remains a challenge (Green *et al*., 2005; UNCED, 2007; Magurran, 2013; Gao *et al*., 2014; Willcock *et al*., 2018).

In this study, we develop and implement a simple approach to assess biodiversity values, and analyse spatial relations between existing protected areas and biodiversity distribution in Sicily. Our evaluation approach is consistent with current practice which use "surrogates such as sub-sets of species, species assemblages and habitat types" as measures of biodiversity (Margules and Pressey, 2000; Rodrigues and Brooks, 2007).

We assess and combine in a Geographical Information System (GIS) framework three biodiversity indicators: vegetation value, faunal richness, and landscape heterogeneity. The vegetation value and the faunal richness are composite indicators. For their assessment, we integrate available (surveyed) data on plants, animals, and habitat types with expert opinions. In the analysis of flora and fauna, we take into account only endangered, vulnerable and/or near threatened species included in the IUCN Global and Italian Red Lists, European Birds and Habitats Directives, and Bern Convention. Habitat types are examined in terms of: suitability, that represents the capacity of a given habitat to support selected species (U.S. Fish and Wildlife Service, 1981); naturalness, that measure the degree of absence of human modification (Wright, 1977; Rüdisser *et al*., 2012); and diversity, that denotes the number of different vascular plants per habitat type (Cousins and Ove, 2002; Smith and Theberge, 1986). The landscape heterogeneity indicator measures the land cover/land use fragmentation within the areas of study (Lindenmayer *et al.,* 2002; Suarez-Rubio and Thomlinson, 2009; Morelli *et al*., 2013; Riccioli *et al*., 2016). We use GIS spatial analysis to elaborate feature maps for each biodiversity indicator, and integrate them in a biodiversity map. Successively, we identify and compare High-Value Biodiversity Areas (HVBAs) with existing Sicilian protected areas network in order to quantify gaps in the coverage of biodiversity. Finally, we implement hotspots analysis to detect cluster of HVBAs as prioritized candidates for designation of new protected areas.

2. Materials and methods

2.1 Study area

Sicily's land area extends about 26,000 km^2, making it the largest island in the Mediterranean. Its wide range of flora and fauna makes Sicily a relevant global biodiversity hotspot (Medail and Quezel, 1999). The Sicilian ecosystems contain 3,252 vascular floral species, 321 of which endemic (Giardina *et al*., 2007); 43 mammal species (including bats), 155 breeding bird species, 24 reptile and amphibian species make up a diverse and valuable vertebrate fauna (Turrisi and Vaccaro 1998; AA.VV., 2008).

Sicily's mountain ranges are mainly distributed along the northern sector of the island, namely the Madonie (reaching 1,979 m a.s.l.), the Nebrodi (1,847 m a.s.l.) and the Peloritani (1,374 m a.s.l.) (see Figure 1a). In the central and southern sector the landscape is mainly characterized by a typical low relief. The highest peak is the Etna volcano (3,340 m). This considerable altitudinal heterogeneity encompasses several climate zones, from semi-arid to humid. Annual rainfall varies from 250 to 1,400 mm, whereas the average temperature is 18° C, with values below zero in the inland territory in winter, and over 40° C along the coast in summer. The smaller islands around Sicily (the Aeolian and the Aegadian archipelagos, the Pelagie, Ustica and Pantelleria) were excluded from the analysis.

2.2 Data

2.2.1 Vascular plants

The information on the distribution of Sicilian vascular species was extracted from the national database, made of 13,948 geo-referenced surveyed records, compiled by Blasi *et al*. (2010) and Rossi *et al*. (2013). Each vascular species was classified according to the *A* criterion proposed by Anderson (2002). In particular, vascular plants were categorized into five categories: globally threatened (*Ai*); European threatened (*Aii*); national endemic species with demonstrable threat (*Aiii*); near-endemic/limited range with demonstrable threat (*Aiv*); species of national and regional interest (*AA*). The dataset of Sicilian vascular plants, composed by over 600 existing data belonging to 213 different species, have been used to assess the flora richness (*F_rich*) and habitat diversity (*Hd*). The data set includes: nine species in category *A(i)*, 19 species in category *A(ii)*, 99 in category *A(iii)*, three species in category *A(iv)*, and 83 species in category *AA*.

2.2.2 Vertebrate Fauna

The information on the distribution of threatened Sicilian animal species was extracted from the 'Atlas of Sicilian Vertebrates' (AA.VV, 2008) that contains more than 21,000 records regarding the presence of vertebrates on 288 UTM grid cells of 10 x 10 km. Excluding the Chiropterans and all the vertebrates living on the surrounding small islands, the Atlas reveals that 193 species (7 Amphibians, 18 Reptiles, 147 Birds, 21 Mammals) are present in Sicily.

2.2.3 Habitats

Land cover data were based on the Italian Nature Map (*Carta della Natura*), at scale of 1:50.000, that identifies 230 habitat types categorized according to the Corine biotopes classification (European Commission, 1991). This map, based on a Minimum Mapping Unit of 1 hectare, offers a greater detail than the over widely used 2012 Corine Land Cover map, that is based on a Minimum Mapping Unit of 25 hectares. According to the Italian Nature Map, Sicily includes about 130,000 habitat patches, that are classified in 88 habitat types. As we did not consider urban areas and intensive cultivated areas (greenhouse), our analysis relied on 81 habitat types.

2.2.4 Sicilian protected areas network

The terrestrial nature protection system in Sicily consists of five regional parks (Madonie Mts., Sicani Mts., Nebrodi Mts., Alcantara River and Mt. Etna), 73 nature reserves, 234 Natura 2000 sites (171 Special Areas of Conservation (SAC), 56 Sites of Community Importance (SCI) and 29 Special Protection Areas (SPAs). It is worth noting that several protected areas overlap, making the actually protected terrestrial surface about 580,000 hectares, equal to 23% of the Sicilian terrestrial surface.

2.3 Biodiversity indicators

Three indicators, describing the distribution, the extent and the importance of vegetation, fauna, and landscape diversity, were separately estimated and successively aggregate in a GIS environment

(ESRI ArcGIS® software). For each biodiversity indicators, we elaborated a raster map, with a resolution of 100 x 100 meters and a normalization of values into a 0 - 100 numeric range. All feature maps were then aggregated into a biodiversity map by using a simple weighted overlay sum. We assigned equal weights to each indicator, since literature does not offer a univocal path regarding the choice of weights. To emphasize high biodiversity areas in biodiversity map, we used the quantile classification method because of its greater accuracy with choropleth maps over other classification methods such as natural breaks, hybrid equal intervals, or standard deviation (Brewer and Pickle, 2002). We then classified as High-Value Biodiversity Areas (HVBAs) the areas that belonged to the upper quantile. Map of HVBAs was utilized to reassess the existing protected area network in Sicily.

2.3.1 Vegetation value

The plant survey of species group, such as vascular plants, is generally considered as an important feature of biodiversity (Duelli and Obrist, 2003; Sauberer *et al*., 2004; Maes *et al*., 2005). However, a more informative assessment of this surrogate should consider other aspects, such as the naturalness and diversity of habitat patches (Wright, 1977; Rüdisser *et al*., 2012; Cousins and Ove, 2002; Smith and Theberge, 1986). In this study, the vegetation value was assessed by combining flora richness, habitat diversity, and habitat naturalness.

Flora richness (*F_rich*) of vascular plants was evaluated by assigning weights, from 1 to 5, to each Anderson‘s category in order to represent the conservation value of species (Figure 2a and Figure 2b). The highest value was assigned to species belonging to category “*A(i) -globally threatened*”, and the lowest to species belonging to category “*AA- species of national and regional interest*”. Then, in order to take into account the location and the cluster of species as well as the assigned weights, we used the ArcGis Kernel density function to calculate the vascular plant’s magnitude per unit of area. This interpolation produced a continuous raster map of 100 m resolution (Figure 2c)

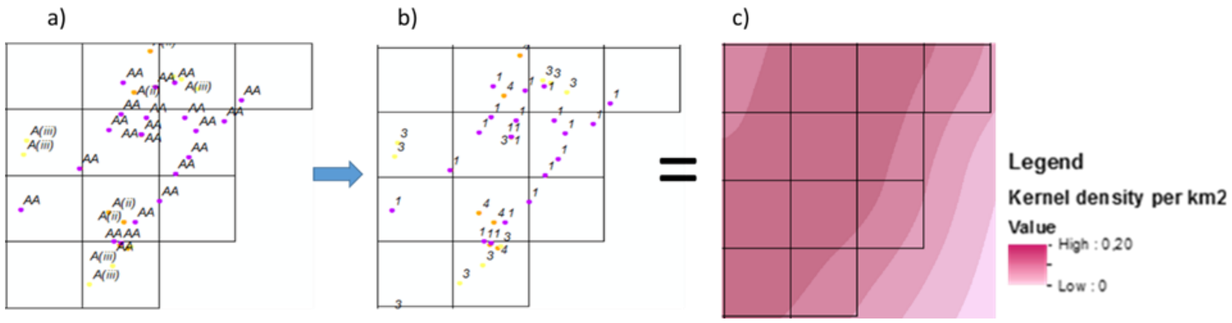

Figure 2. Vascular plants richness

Habitat diversity *(Hd)* was calculated as the ratio between the number of different vascular plant species surveyed in each habitat type *j* (*Nvpj*) and the surface *Aj* (ha) of same habitat.

$$Hdj = \frac{Nvp_j}{A_j} \qquad j = 1, \dots .81 \qquad (\text{eq.} 1)$$

The related raster map, with 1 ha cell size, was obtained by assigning the value of habitat diversity to all pixels of each habitat type.

Habitat naturalness *(Hn)* was related to the anthropogenic influence on biodiversity (Rüdisser *et al*., 2012; Bölöni *et al*., 2008; Molnár *et al*., 2007). All 81 habitat types were classified along a five staged naturalness scale, ranked from 1 to 5 (see Table 1). The threshold of each staged naturalness scale was determined by expert opinions.

Table 1. Values of naturalness of habitats

Degree of naturalness	Description	Examples of habitats in Sicily	Value of naturalness
Natural, rare and threatened	Natural system listed in the Habitat Directive EC 92/43	Abies nebrodensis forest, Coastal dunes with Juniperus spp.	5
Natural	Natural system with minimal anthropogenic influence	Forests, wetlands, bare rock	4
Semi-natural	Natural system with some characteristics altered through human pressure	Scrub and/or herbaceous vegetation associations	3
Altered	Altered system with natural elements	Pastures, arable lands	2

Strongly altered	Altered system with intense impact by anthropogenic activities	Orchards, vineyards,	1

Habitat naturalness raster map, with a cell size of 1 ha, was obtained by assigning the value of naturalness degree to all pixels of each habitat type.

The Vegetation value *(Vv_i)* map was elaborated using the following equation:

$$Vv_i = \sum_{i=0}^{n} F\_rich_i + Hn_i + Hd_i \qquad (\text{eq. } 2)$$

where:

Vv_i = Vegetation value of *i-th* pixel

F_rich_i = Vascular plants richness of the *i-th* pixel

Hn_i = Habitat naturalness of the *i-th* pixel

Hd_i = Habitat diversity of the *i-th* pixel

n= number of pixels

2.3.2 Faunal richness

The faunal richness indicator was generated from the faunal habitat value paired with the distribution of threatened Sicilian faunal species.

The faunal habitat value was elaborated from the "Carta Natura", assigning a *Habitat Suitability Index* (HSI) as proposed by U.S. Fish and Wildlife Service (1981). The HSI represents how each habitat relates to a given species; the value 0 was assigned to unsuitable habitats, 1 to suitable and 2 to highly suitable habitats (input a in Figure 3).

From all species reported in Various Authors (2008), we selected those included in the Italian Red List Categories (Peronace *et al*., 2012), in the European Birds Directive (79/409/CEE, Annex I) and in the Habitat Directive (92/43/CEE, Annex II). We considered the occurrence of four mammals, four amphibians, nine reptilians, and 129 breeding avian species. The presence of these species was reported in 146 raster layers. Bird species were categorized as "priority" and "not priority". Species included in Data Deficient (DD) and Least Concern (LC) categories of the Italian Red List were classified as not priority (input b in Figure 3).

Adding the faunal habitat values and the distribution of threatened animal species, we generated 146 habitat suitability grids (one grid for each species), resampled at a resolution of 0.1 km (Figure 3c).

(a) input * x **(b) input**** = **(c) output*****

0	1	2
0	1	2

1	1	1
0	0	0

0	1	2
0	0	0

**Faunal habitat value*: 0= unsuitable habitat, 1= suitable habitat, 2= high suitable habitat;
** *Distribution of threatened Sicilian animal species*: 1= species present, 0=species absent;
****Habitat Suitability grids* 0= unsuitable habitat or unrecognized species, 1= suitable habitat, 2= high suitable habitat.

Figure 3. Criteria used to elaborate the habitat suitability

The faunal richness indicator was then computed by aggregating the previous 146 habitat suitability grids with a weighted sum function, as reported below. Priority and not priority bird species ranks were multiplied by 0.7 and 0.3 respectively, as suggested by Riccioli *et al.* (2016) to correct for overabundance of the birds with respect to other faunal taxa:

$$F_j = \sum_{i=1}^{n} a_i + \sum_{i=1}^{m} a_i + \sum_{i=1}^{r} a_i + \sum_{i=1}^{p} a_i \cdot 0.7 + \sum_{i=1}^{q} a_i \cdot 0.3 \qquad \text{(eq. 3)}$$

where:

F_j= faunal value of the pixel

a_i = value of the *i-th* faunal species

n = 4, no. of terrestrial mammals

m = 4, no. of amphibians

r = 9, no. of reptiles

p = 50, no. of priority birds

q = 79, no. of not priority birds

2.3.3 Landscape heterogeneity

Landscape heterogeneity was measured by using the Shannon' index as it offers more information about land cover composition than simply patch richness index (Pelissier and Couteron, 2007; Riccioli *et al*., 2016). The Shannon index was calculated on the basis of spatial habitat coverage using an area of 100 hectares as reporting units. Shannon' index is equals 0 when the reporting units contains only one habitat (no diversity); it increases as the number of different habitat types increases and/or the proportional distribution of area among habitat types becomes more equitable (Duelli and Obrist, 2003).

2.4 Hotspots analysis

The HVBAs were analysed through spatial metric *Getis–Ord Gi** (or simply *Gi**) suggested by Zhu et al. (2010) to identify spatial clusters suggestive of hotspots of biodiversity value (Brown, 2004; Alessa *et al*., 2008; Noce *et al*., 2016). The "mapping cluster tool set", available in the ESRI ArcGIS® software package, was used. The tool works by comparing each feature with neighbouring ones, looking for statistically significant aggregation. Centroids of grid cells with high biodiversity value were obtained through raster-to-point conversion, then integrated and collected to reduce their number by aggregating close points. The resulting features, with the associated value representing the number of aggregated points, were used as input in Hotspots Analysis (*Getis-Ord Gi**). The analysis generates *p*-value and *z*-score (statistical significance) for clustering or hotspots identified by the *Gi** statistic. A high positive *z*-score indicates an apparent concentration of high-density values within the chosen distance. In this study, grid cells with a *z*-score greater than 1.96 were identified as hotspots of high biodiversity value at a significance level of 0.05. The grid cells with a *z*-score of less than -1.96 represented clusters of low values.

3. Results and discussion

3.1 Biodiversity indicators

Natural habitats are mainly localized in mountain areas (Peloritani, Nebrodi, Madonie, Palermo, and Iblei) (see Figure 4a), usually in coincidence with threatened species (see Figure 4b). National and regional vascular species of interest (category *AA*) were mainly distributed along coastal zones. Habitats with sporadic vegetation and cultivated areas of the lowland, showed low threatened species density.

The vegetation value map (see Figure 4c), showed high values in the south-eastern sector of Sicily, corresponding to the Hyblaean district, and in the north sector, between the Peloritani and Trapani Mounts.

The geographical distribution of the fauna (Figure 5) indicated that the highest values were localized in extensive inland agricultural hill areas.

The landscape heterogeneity map (Figure 6) showed zones with several land use typologies (dark red coloured) mainly localized in northern and south-western parts of Sicily; areas with fewer land use typologies were localized in the flood plains (Catania, Gela, Trapani) and in the central part of Sicily, in correspondence with extensive arable land (light red coloured).

Figure 7 exhibits the distribution of three biodiversity indicators respect to the elevation measured in terms of 33 altitude belts. The distribution of vegetation values follows common trend along altitude, with a very marked maximum at middle altitudes. Vegetation values increase from sea level up to 1,600 m and then decrease up to 3000, with a peak between 1500 and 1600 m altitude belts, corresponding to Oro-Mediterranean zone. Faunal richness values increase with heterogeneity of the habitat, reaching very low values over 2,500 m. These results are consistent with Basnet *et al*., (2016), Grau *et al*., (2007), and Karami *et al*. (2015).

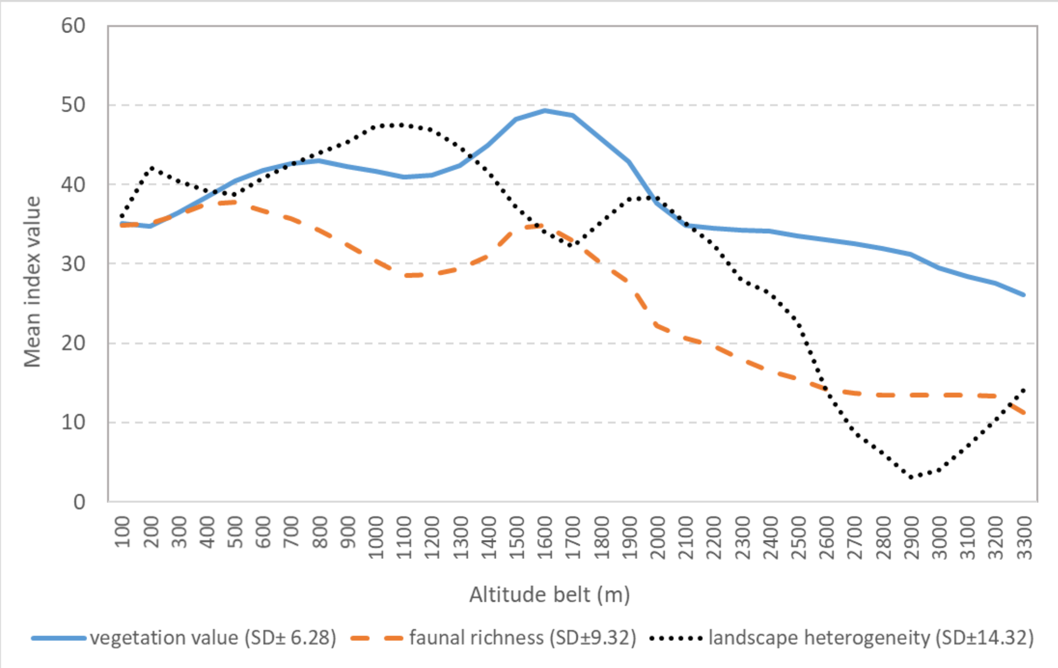

Figure 7. Mean Indicator values and altitude belts

We also estimated correlation between mean values of indicators for each altitude. As expected, the highest correlation (+ 0.85) was observed between faunal richness and landscape heterogeneity since the latter provides more ecological niches and increases resource availability (Bazzaz, 1975; Law and Dickman, 1998). High correlation was also observed between vegetation value and faunal richness (+ 0.76), and between vegetation value and landscape heterogeneity (+ 0.67).

The relations between the bioclimatic belts (Bazan *et al*., 2015), and the biodiversity distribution in Sicily are shown in Table 2. The highest values were mainly linked to the Meso-Mediterranean belt; when the percent incidence of biodiversity density is considered, the highest value fell within the Oro-Mediterranean belt.

Table 2. Bioclimatic belts and biodiversity distribution

Bioclimatic belts	**HVBAs (Km^2)**	**Bioclimatic belts (km^2)**	**Biodiversity density (%)**
Thermo-Mediterranean (0 -500 m a.s.l.)	1,980	17,242	11

Meso-Mediterranean (600 -1000 m a.s.l.)	2,238	7,080	31
Supra-Mediterranean (1000 - 1500 m a.s.l.)	453	1,247	36
Oro-Mediterranean (1500 - 2400 m a.s.l.)	109	235	46
Cryo-Mediterranean (>2400 m)	0	0	0

Our results confirmed that habitat heterogeneity and elevation were the main drivers of biodiversity richness in Mediterranean islands (Thompson, 2005; Mahdavi *et al*. 2013; Sciandrello *et al*., 2015). Estimated high values in the mountain systems were also consistent with Raimondo (1984), Gianguzzi *et al*. (2010), Baiamonte *et al*., (2015), that note the remarkable floristic richness and habitat value of the Madonie and Palermo mountains.

3.2 Biodiversity value

Figure 8 shows the biodiversity value map, obtained by aggregating vegetation value, faunal richness and landscape heterogeneity indicators. The highest values represent high numbers of threatened plants, presence of priority habitats, habitat suitable for important faunal species and high landscape heterogeneity.

The areas with highest values of biodiversity were in correspondence of mountainous areas (Madonie and Palermo Mounts, Nebrodi, Sicani, Iblei, Etna and Peloritani). In these areas, characterized by wilderness and high richness of plant and animal species, the distribution of the high biodiversity values was linked mainly to landscape and habitat heterogeneity. Low biodiversity values occurred in intensive farming areas, especially in the western sector of the island (with a predominance of vineyards), in the Agrigento province (vineyards and olive groves), and in the Catania plains (citrus fruits), as well as on the whole coastline of Sicily (greenhouse crops and urban areas). Our results highlighted the role of the extensive agro-ecosystems of the Sicilian hinterland and the plains of south-eastern Sicily, where some faunal species, especially birds, are present with important populations that are uncommon in other parts of Europe (Massa, 1997). Notably, areas of great naturalistic interest, such as a few wetlands in Eastern and Southern Sicily (De Pietro, 2011), did not emerge significantly due to their small size and the scale level adopted in our analysis.

According to the quantile classification, biodiversity values were clustered in five classes: low (values ranges from 22 to 94), medium low (values ranges from 95 to 108), medium (values ranges from 109 to 120), medium high (values ranges from 121 to 133) and high (values ranges from 134 to 239). Areas with biodiversity values higher than 133 were named as HVBAs. These areas in total cover 478,394 ha.

Table 3 reports results about representativeness of the existing protected area network in Sicily. Representativeness was measured in two ways: 1) as surface percentage of HBVAs covered by protected areas: and 2) as surface percentage of protected areas with HVBAs. With regard the first measure, only 32% was covered by to the Sicilian network of protected areas. Excluding overlaps areas among protection forms, Natura 2000 network included 30% of HVBAs, Regional parks included 16%, and Nature Reserves contributed only 4%. The uncovered 68% of HVBAs were distributed between the north-west part of the region (Palermo Mountains), the south-eastern sector of Hyblaean Mountains, and the north-eastern part of the Peloritani Mountains (Figure 9). The second measure showed that 26% of protected area network surface was composed by HVBAs. Further, no significant difference among the three forms of protection (Regional Parks, Nature Reserves and Natura 2000 sites) exist. The higher percentage of surface characterized by HVBAs was in the Madonie park (73%). Regarding the Nature Reserve networks, the top five sites hosting the highest percentage of HVBAs in order are: 1) Grotta di S. Angelo Muxaro; 2) Biviere di Gela; 3) Serra della Pizzuta; 4) Serre di Ciminna; and 5) Bagni di Cefalù Diana e Chiarastella. As it concerns Natura 2000 network, the top five sites are: 1) Monte Quacella, Monte dei Cervi, Pizzo Carbonara, Monte Ferro, Pizzo Otiero; 2) Monte Iato, Kumeta, Maganoce, Pizzo Parrino; 3) Complesso Pizzo Dipilu e Querceti su calcare; 4) Rocca di Sciara; and 5) Lecceta di San Fratello. These sites were localized in the Nebrodi, Madonie and Palermo mountain ranges.

Table 3. Percentage of HVBAs covered by protected areas, and percentage of protected areas with HBVAs

Nature protection network	**Extent (ha)**	**HVBAs covered by protected areas (%)**	**Protected areas with HVBAs (%)**
Regional Parks	228,142	*16*	*33*
Alcantara	2,015	*0.04*	*27*
Madonie	40,200	*7*	*73*
Sicani	43,715	*3*	*49*
Etna	57,438	*1*	*3*
Nebrodi	84,772	*5*	*27*
Nature Reserves	72,421	*4*	*32*
Natura 2000 network	448,171	*30*	*26*
Total	579,304*	*32*	*26*

* The total protected areas surface net of overlaps

Our results also highlighted the presence and overlap, in the northern sector of Sicily, of large areas with different protection forms (Regional parks, Nature reserves and Natura 2000 sites). This indicated a correct delimitation of areas containing high biodiversity.

3.3 Hotspot analysis

Table 4 reports output from hotspot analysis. Using a 95% confidence level, hotspots covered in total an area of about 37,299 ha. 52% of this area, corresponding to 19,573 ha, lay within the network of protected areas. At 99% confidence level, the total hotspots areas decreased to 6,423 ha; 54% of this surface fell into the network of protected areas. In the Table 4 is also reported in the last column the percentage of protected area enlargement to preserve all hotspots. Results shown that a small increment, less than 1%–in existing protected area network would include 56% (3,150 ha) of hotspots. The localisation of these hotspots is portrayed in Figure 10. Hotspots were mainly located in the northern area of Sicily, Sicani and Hyblean mountains.

Table 4. Hotspots analysis of HVBA at different confidence intervals*

Confidence level of *Gi**	Hotspots (ha) out of confidence level	Percentage of hotspots inside protected areas	Percentage of enlargement in protected area to include all hotspots
90%	80,893	50%	7%
95%	37,299	52%	3%
99%	6,423	54%	0,5%

*Only values > 0 are reported ("cold spots" are not accounted)

4. Conclusion

In this study, three biodiversity surrogate indicators of biodiversity were assessed and integrated in a GIS spatial analysis framework to measure, identify and map high value biodiversity areas (HVBAs) in Sicily. Biodiversity value map indicated that almost twenty percent of terrestrial area of Sicily was identifiable as HVBAs. These areas were mostly localized in correspondence of mountainous areas and also in the plains of south-eastern Sicily where bird populations, uncommon in other parts of Europe, are largely present. Our analysis shows that habitat heterogeneity and elevation were the main drivers of biodiversity richness in Sicily. The gap analysis shows than only thirty two percent of HVBAs was covered by the existing protected area network. Twenty six percent of total protected areas surface was characterized as HVBAs. Hotspots analysis revealed that a modest expansion, less than 2%, of current protected areas would include the 62% (corresponding to 9,390 ha) of biodiversity hotspots.

The biodiversity measurement approach implemented in this study did not consider information on other surrogates such as micro-fauna, and no vascular plants due to lack of adequate information at regional scale. Further, the analysis disregards other aspects (such as geological and heritage goals) and social and political implications of conservation planning activity. Despite these limitations, the operative framework and the spatial analysis developed and implemented in the study provide results that might usefully employed by local policy makers and land use planners in the formulation of effective expansion of the existing protected area network, and in the prioritization of actions towards commitments to halt biodiversity loss.

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List of Figures not included in the text