Combining habitat requirements of endemic bird species and other ecosystem services may synergistically enhance conservation efforts

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Abstract

Biodiversity conservation and the optimisation of other ecosystem service delivery as a contribution to human well-being are often tackled as mutually alternative targets. Modern agriculture is a great challenge for the fulfilment of both. Here, we explore the potential benefits of integrating biodiversity conservation and the preservation of wider ecosystem services, considering the conservation of an endemic species (Moltoni's warbler *Sylvia subalpina*; Aves: Sylvidae) and soil erosion control (a final ecosystem service) in intensive vineyards in Italy.

We modelled factors affecting warbler occurrence and abundance at 71 study plots by means of N-mixture models, and estimated soil erosion at the same plots by means of the Universal Soil Loss Equation. Shrub cover had positive effects on both warbler abundance and soil retention, whereas higher slopes promote warbler abundance as well as soil erosion. Creating shrub patches over sloping sites would be at the same time particularly suited for warblers and for soil retention.

We simulated three alternative conservation strategies: exclusive focus on warbler conservation (1), exclusive focus on soil preservation (2), integration of the two targets (3). Strategies assumed the creation of 1.5-ha shrub patches over 5% of the total area covered by plots and targeted either at wildlife or soil conservation. The exclusive strategies would allow an increase of 105 individuals and the preservation of 783 tons ha^{-1} year^{-1}, respectively. Each individual strategy would ensure benefits for the other target corresponding to 61-64% of the above totals.

The integrated strategy would allow for the achievement of 91-93% of the benefits (96 warblers and 729 tons ha^{-1} year^{-1}) of the individual strategies.

The integration of the two approaches could provide important synergies, allowing to broaden the effects of conservation strategies, such as agri-environmental schemes that could be drawn from our results (and which are particularly urgent for intensive permanent crops).

Keywords

Agri-environmental schemes; erosion; Mediterranean; permanent crops; soil loss; *Sylvia moltonii*

1. Introduction

Biodiversity conservation and the optimisation of ecosystem service delivery (or ecosystem management) as a contribution to human well-being are often tackled as mutually alternative targets in landscape planning (Mace et al., 2012), which is frequently focused only on biodiversity or exclusively on (other) ecosystem services, even if the strict link between biodiversity and ecosystem functions is inextricable (Butler et al., 2007). Biodiversity can be a regulator of ecosystem processes, as well as a final ecosystem service itself or a good (Mace et al., 2012), and biodiversity conservation could contribute to (other) ecosystem service supply (Christie & Rayment, 2012), and vice versa (Goldman et al., 2008). Considering that biodiversity conservation schemes, aimed at preserving certain species or habitats, may have either positive or negative impacts on wider ecosystem services (Austin et al., 2016), it is essential to integrate biodiversity conservation and delivery of ecosystem services into an effective strategy for ecosystem management (Mace et al., 2012).

Biodiversity and other ecosystem services can be integrated into landscape and conservation planning by means of spatial conservation prioritization (e.g. Goldman et al., 2008; Geneletti, 2011). Several examples of trade-offs between regulating and supporting services (e.g. Geneletti, 2013) and between biodiversity and other ecosystem services have been reported (e.g. mammal conservation and carbon stocking, Budiharta et al., 2014), but the ones between biodiversity and many provisioning services are particularly challenging (Reyers et al., 2012) and have caused a dramatic loss of biodiversity during the last decades (Millennium Ecosystem Assessment, 2005) by means of the human land use associated with many provisioning services (especially agriculture; Tilman, 1999; Foley et al., 2005). Agricultural ecosystems (agroecosystems) support indeed essential provisioning services, but agriculture is also the cause of disservices (Power, 2010) and may have a strong impact on biodiversity leading to severe conflicts (e.g. Henle et al., 2008). These conflicts are expected to exacerbate in the next future as a response to the increase in global population and food demand. There is thus a need to increase food production and maintain it at that higher level through time, while ensuring environmental and social sustainability, conserving biodiversity and ecosystem services (Godfray et al., 2010; Tilman et al., 2002).

Modern agriculture is thus a great challenge to the conservation of both biodiversity and ecosystem services, with agricultural intensification thought to be the main reason for the dramatic population declines experienced by many wild species in the last decades in Europe (Chamberlain et al., 2000; Donald et al., 2001). Recent assessments at the European and global scale showed that farming is (and will be) the single biggest source of threat to bird species, especially in developing countries (BirdLife International, 2015; Green et al., 2005). Agriculture intensification and agricultural land-uses are thus at the heart of the current biodiversity crisis, as well as of the reduction of many ecosystem services different from provisioning ones (Foley et al., 2005; Tilman, 1999).

The aim of our paper is, therefore, to hypothesize potential conservation strategies in an agricultural landscape for wildlife and (other) ecosystem services within the same area, and to explore how the integration of biodiversity conservation and the preservation of (other) ecosystem services could lead to a ‘win-win’ strategy in landscape planning. We used as models two ‘classic’ examples: the conservation of a single wild species of particular concern on the basis of its habitat requirement and the soil erosion control (soil retention) in intensively farmed areas. We aim to evaluate whether species conservation and soil retention could be part of an integrated strategy, and how the latter would perform compared to individual strategies mutually focused on biodiversity or soil.

We focus on vineyards, which are characterised nowadays by a highly intensive management and almost invariably have a high impact on biodiversity (Viers et al., 2013), with reported impacts on several different groups (e.g. Schmitt et al., 2008; Trivellone et al., 2012; Assandri et al., 2017). In addition to such an impact on wildlife, vineyards in hilly areas are often also associated with very high risks of soil loss (Galati et al., 2015; Van der Knijff et al., 2000). Soil erosion is indeed a key factor for land degradation in general and in particular it has a severe impact on agricultural sustainability (Cerdà et al., 2010, 2009).

2. Material and methods

2.1. Model environment

In the Mediterranean basin, vineyard is a typical crop and viticulture had a preeminent role in creating impressive "cultural landscapes" (Cohen et al., 2015), characterised by extensive and traditionally terraced areas supported by dry stone-walls (Petit et al., 2012), which also supported a high level of biodiversity (Kizos et al., 2012). The European CAP induced intensification and restructuring of vineyards, with strong impacts on landscape structure especially in the Mediterranean region (Martínez-Casasnovas et al., 2010). One of the most striking effects of vineyard intensification on Mediterranean slopes is soil erosion, which could be particularly high in such environmental contexts (Martínez-Casasnovas and Ramos, 2006), because of an unfavourable combination of slope, rainfall intensity and continuous tillage of ground vegetation (Novara et al., 2011; Prosdocimi et al., 2016a; Ries, 2010; Ruiz-Colmenero et al., 2013; Tarolli et al., 2015). The intensification that viticulture is experiencing and the expansion of areas devoted to vine production is also resulting in homogeneous monocultures (Martínez-Casasnovas et al., 2010) and in a substantial reduction of natural habitats in the Mediterranean biome (Viers et al., 2013). Due to their high economic value and in response to climate change pressure, vineyards are rapidly expanding, also in areas where historically they never occurred (Hannah et al., 2013; Winkler and Nicholas, 2016). Such an expansion is occurring especially at the expense of more natural ecosystems, in particular in the Mediterranean basin, the second largest biodiversity hotspot in the world (Critical Ecosystem Partnership Fund, 2011).

2.2. Study area

Our study was carried out within the Oltrepò pavese area, located in the southern extreme of Lombardy, Northern Italy. Oltrepò pavese extends from the Po river to the Apennines mountains, from 50 to 1724 m asl. We focused on the vineyard belt, which is largely comprised between 70 and 500 m asl, in the Apennine foothill. Dominant habitats are vineyards, broadleaved woodlands, heterogeneous farming systems including mown grassland, cereal crops and fodder (mostly lucerne). The density of towns and villages decreases from lowland to upper elevations. The climate is temperate (rainfall c. 700–1500 mm/year, average year temperature 5°–12° C; Bogliani et al., 2003; Abeli et al., 2012).

Vineyards in Oltrepò pavese are managed under an intensive regime, and the intensification has led to structural changes in plantations in hilly areas (where virtually no terraced landscapes occur). Vine plants in sloping areas were once planted in rows aligned perpendicularly to the maximum slope, to prevent erosion and to promote soil stability (known as “girapoggio” system). However, such a type of plantation is hardly accessible by machineries, and thus vines on slopes are now aligned along the maximum slope (“ritocchino” system) to promote access by tractors; the shift from the former to the latter system has resulted in increased soil erosion and instability, with frequent landslides (Persichillo et al., 2017). These processes are also determining frequent abandonment of cultivated fields (Brambilla et al., 2016b), including vineyards (Persichillo et al., 2017), in less accessible areas, both because of economic constraints (as they are less remunerative) and because of higher risks of erosion and landslides and associated higher management costs.

2.3. Conservation targets: Moltoni's warbler and soil erosion

A conservation priority species for the Mediterranean region and in particular for the central-western part of the region is the endemic Moltoni's warbler (*Sylvia subalpina* syn. *Sylvia moltonii*; Aves: Sylvidae; Brambilla et al., 2008a, 2008b). Italy hosts at least two thirds of its global population (Nardelli et al., 2015), thus the conservation of this species is a true priority at the national level (Gustin et al., 2016; Peronace et al., 2012). Moltoni's warblers arrive on their breeding grounds in the second half of April – early May, usually remaining until the end of August-early September. The species breeds in shrubland, at forest edge with shrubs, within large hedgerows and also in vineyards with scattered bushes (although it does not feed or nest on vines), with shrub availability being the most important factor affecting species habitat use (Brambilla et al., 2007). The average territory size of breeding pairs is around 2,500 m2 (M. Brambilla, unpubl. data). The preferred habitats of the species, i.e. shrubland and small patches of shrubs and trees, frequently occur interspersed within the vineyard matrix in many Mediterranean regions, and could be readily occupied by the species as vineyards mimic the semi-open and rather low vegetation usually inhabited by the species (Brambilla et al., 2006). These habitats are associated with high levels of soil preservation (e.g. García-Ruiz et al., 2010), and their recovery over once cultivated areas often lead to a reduction of soil erosion (e.g. (Keesstra, 2007). Therefore, the re-establishment of patches of natural vegetation over vineyards in the sites most prone to soil loss can be seen as a promising way to reduce losses due to erosion in sloping sites.

One of the main environmental impacts associated with vine cultivation in the Mediterranean region is indeed the high soil erosion associated with vineyards on slopes (Prosdocimi et al., 2016a; see also above). Agricultural practices in hilly and mountain areas are generally associated with high risk of soil erosion, as the soil is compacted by machine use and the ground cover provided by natural vegetation is removed, thus favouring landslides and instability. Vineyards are indeed among the land use associated with the highest risk of soil loss (Van der Knijff et al., 2000), and are likely the most erosive crop type in the Mediterranean region (Kosmas et al., 1997; Tropeano, 1983). Soil loss in Mediterranean vineyards could have also relevant economic costs (Martínez-Casasnovas and Ramos, 2006), and soil loss in vineyards in several hilly areas, including Oltrepò pavese, has increased because of recent planting of vines parallel to maximum slopes, performed to allow machine access to the fields (Persichillo et al., 2017). Vineyards and abandoned vineyards are often subjected to shallow landslides or other forms of slope instability (also within the study area; Meisina et al., 2015), which could be exacerbated by high soil erosion rates. Therefore, preventing or reducing soil erosion in vineyards is a priority and many strategies have been proposed or tested (e.g. Marques et al., 2010; Ramos et al., 2015; Prosdocimi et al., 2016b).

2.4. Warbler counts and recording of habitat variables

We counted Moltoni's warblers along line transects scattered within all the vineyard belt in Oltrepò pavese. Counts were conducted in the morning, between dawn and 11 a.m., over 71 different linear transects, each one 200-m long, as done in other studies focusing on farmland (Brambilla et al., 2012) and vineyard birds in particular (Assandri et al., 2016). Transects were almost regularly scattered over all the vineyard belt in the study area, and they were mostly placed over pre-existing tracks or paths. Birds were counted within a 100 m buffer from the transect (hereafter 'plot', corresponding to a censused area equal to 7.15 ha), by means of two different visits to each transect (first visit: 16 May – 30 May 2015; second visit: 10 June – 19 June 2015). Heavy rain and strong wind conditions were avoided. Most individuals were located thanks to their song or calls (Moltoni's warblers are often hard to see, but highly vocal). Once found, each individual was carefully followed by the observer to above double counting of the same birds (Assandri et al., 2016).

At each plot, we estimated very carefully the proportional cover of the following habitats: vineyards, abandoned vineyards, shrubland, other abandoned areas (former arable land and pastures), forest, grassland, grassland with trees, arable land, urban areas, marginal habitats (e.g. hedgerows, field margins; Assandri et al., 2016). The proportional cover of the habitat variables was estimated in a GIS environment after digitalizing a land-cover map drawn in the field, using detailed aerial images (1:2,000) as a basis. The final output was checked against a coarser (scale 1:10,000, minimum mapping unit 20 m and 0.16 ha) land-cover map (DUSAF 4, developed by

ERSAF - Regional Agency for Services to Agriculture and Forestry in 2012 and based on the Corine Land Cover legend, available on www.geoportale.regione.lombardia.it; see e.g. Brambilla & Ronchi, 2016 for a research application based on that map), to be sure that no habitat type was left out. In a GIS environment (GRASS 6.4, Neteler et al., 2012), we also estimated for each plot the average values of slope (°), total solar radiation (taking 21st June as reference day) and elevation, using a 20-m resolution Digital Elevation Model of the study area.

2.5. Modelling warbler occurrence and abundance

We worked with N-mixture models (Royle, 2004) to evaluate the effect of habitat characteristics on the occurrence and abundance of Moltoni's warblers correcting for imperfect detection. We evaluated the factors affecting the 'true' occurrence and abundance of our target species at transects by means of a hierarchical approach, modelling the latent presence and density of the species. We used the package 'unmarked' (Fiske & Chandler, 2011) in R 3.3.1 (R Core Team, 2016) to built models for occurrence (command 'occu') and abundance ('pcount').

As we focused on a single season, we assumed population closure. We considered the following factors as potentially impacting on the observation process and thus affecting the detection probability: hour of the day, date of the census, cloud cover (categorical variable with three levels: no clouds, partial, complete), duration (minutes used to census a given plot), rain (categorical variable with three levels: no rain, slightly raining, raining), wind (categorical variable with three levels: no wind, weak, moderate or higher).

As factors potentially affecting occurrence or abundance, we entered in the models the habitat variables recorded at plots (habitat cover and topographic variables). To reduce the number of predictors tested in the models, we selected the habitat variables potentially more important for the species based on previous knowledge (Brambilla et al., 2007) and of the relative average cover over the plots: shrubland, broadleaved forests, abandoned fields and pastures, abandoned vineyards, urban areas. All variables were standardized (centred around zero and scaled by the standard deviations) before the analyses to enable the comparison of the relative effects (Schielzeth, 2010). The importance of this procedure before running regression analyses had been recently highlighted (Cade, 2015).

Then, by means of the package ‘MuMIn’ (Bartoń, 2016), we computed the AICc value of all the possible models for occurrence and abundance (Supplementary material). We firstly built detection only models. For occurrence, there was a single most supported model and two additional models with ΔAICc < 2 including ‘uninformative parameters’ (Arnold, 2010; Jedlikowski et al., 2016), i.e. those variables included exclusively in models comprising more parsimonious, simpler models as nested ones (Brambilla et al., 2016a; Ficetola et al., 2011). Therefore, we took the most supported model. For abundance, we selected the variables significantly affecting the detected abundance according to model averaging carried out on the most supported models (ΔAICc > 2) with the exclusion of the uninformative parameters.

Then, we built hierarchical models using the above selected detection factors and the habitat variables (habitat cover, slope, solar radiation, elevation).

For both occurrence and abundance hierarchical models, the single most supported N-mixture models were substantially more supported than all other models (ΔAICc > 2 for all other models excluding those including only uninformative parameters in addition to the variables included in the most supported model), and were thus selected as ‘final’ models.

2.6. Modelling potential erosion risk

The potential erosion risk in our study area is very high (Meisina et al., 2015; Van der Knijff et al., 2000). To estimate the average potential soil loss within our study site, we adopted the commonly employed Universal Soil Loss Equation. The USLE is an empirical equation used to predict average annual erosion (A) in terms of six factors (Wischmeier and Smith, 1978). USLE is expressed as:

$$A = R \times K \times L \times S \times C \times P$$

where A is soil loss (t ha^{-1} y^{-1}); R is a rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}); K is a soil erodibility factor (t h MJ^{-1} mm-1); LS is a combined slope length (L) and slope steepness (S) factor (non-dimensional); C is a cover management factor (non-dimensional); and P is a support practice factor (non-dimensional).

We considered only the three main types of land-cover (vineyards, forests, and shrubs), which together covered 81% ± 19 SD of the plot surface and included both the type most (vineyard) and less (forest) prone to soil erosion. We derived the value of the C factor from the literature (Panagos et al., 2015), taking the values proposed for the individual land-cover type for Italy (vineyards: 0.3454, shrub: 0.0242, broad-leaved forest: 0.0013). For each plot, we calculated a C factor according to the relative cover of these three land-cover types (rescaled as they occupied together 100% of the plot surface).

We calculated the LS according to the unit contributing area method (UCA) proposed by (Moore and Wilson, 1992), following (Moore et al., 1993) and (Van der Knijff et al., 2000):

$$L=1.4(As/22.13)^{0.4}$$

$$S=(\sin \theta/0.0896)^{1.3}$$

where As is the unit contributing area (m) and θ is the slope in radians.

The topographic factor (LS) and the cover management factor (C) are the two factors that have the greatest influence on USLE model overall efficiency (Risse et al., 1993). The former in particular is of key importance (Oliveira et al., 2015; Risse et al., 1993). We applied a simplified model for soil erosion in vineyard landscapes, basically considering the potential effect of slope and ground cover on the estimated soil loss. We deliberately did not include the potential effect of vineyard ground cover and management (see Prosdocimi et al., 2016), as this is highly variable in the study area, totally depending on farmer’s will (but note that in c. 65% of the vineyard area within our study transects, ground vegetation was mechanically removed by farmers). As we aimed to provide a general evaluation of the benefits of including different land-cover types, we also did not include the age of vineyards among the factors affecting soil loss and considered R and K as constant (which incidentally is quite likely to be true within our study area). R was set to 850 (MJ mm ha^{-1} h^{-1} y^{-1}) and K to 0.04 following Van der Knijff et al. (2000). P was set to 1. L was set as constant (200). L and S describe the effect of topography on soil erosion. Increments in slope length and in slope steepness are associated with higher velocities of overland flow and thus to a higher soil erosion (Haan et al., 1994). Importantly, gross soil loss has been reported to be in general more sensitive to variation in slope steepness, rather than to different values of slope length (McCool et al., 1987).

2.7. Evaluating the benefits of exclusive and synergistic conservation synergies

We simulated three alternative conservation strategies targeted at the study plots and focusing in a mutually exclusive way on warbler conservation (1) or reduction of soil erosion (2), or integrating the two (3). In each case, we supposed that a portion of vineyards corresponding to c. 5% of the total area covered by the plots (analogous to the 5% of the surface subjected to Ecological Focus Areas in non-permanent crops according to the ‘greening’ requirements of the Common Agricultural Policy now in force) could be retired from production. We considered a simple potential agri-environmental scheme, consisting in the conversion within a plot of a 1.5-ha patch of vineyard into shrubland, dedicated to wildlife or soil conservation (in addition to the already existing non-cultivated portions). We allowed one patch per plot, over 16 plots (for a total 24 ha, approaching the 5% of the whole area covered by plots). We did not consider the potential creation of forest patches, even if they would be effective both as warbler habitat and for the prevention of soil erosion, as they occurrence within vineyards would potentially limit solar radiation to vines and because it has been reported that spontaneous secondary woodlands grown over abandoned vineyards (monospecific stands of black locust *Robinia pseudoacacia*) are more susceptible to shallow landslides (Bordoni et al., 2016). In addition, shrub patches are likely to be even more suitable for warblers and other species of conservation concern inhabiting the semi-open landscapes of the area (Bogliani et al., 2003; Brambilla, 2015; Brambilla et al., 2016b, 2016c, 2010, 2007), thus are likely to be a more suitable conservation measure for the area.

Within the vineyard belt in Oltrepò pavese, Moltoni's warbler is rather widespread and occurs in sites with suitable habitats (shrub patches or forest margins with shrubs) throughout all the area. Therefore, we considered the entire study area as potentially suitable in terms of climate and focused only on topographical and habitat factors deemed as important by the analyses. According to the warbler conservation simulated strategy, we selected the 16 plots where the conversion of 1.5 ha of vineyards into shrubland may maximize warbler abundance (after calculating the potential increase in warblers associated with the patch creation for each transect, by means of the abundance model). Soil and climate are also rather uniform across the vineyard belt, thus we considered soil erosion as mainly dependent on topography and land cover. In the soil preservation strategy, we identified those sites that could maximize soil conservation through the creation of the 1.5-ha shrubland patches (after calculating the potential reduction in soil loss associated with the patch creation for each transect). In the integrated conservation strategy, we selected sites for conservation to maximize the potential combined effects, i.e. the best compromise for both warbler and soil conservation.

For each strategy, we estimated the potential increase in the number of warblers within the plots and in tons of soil preserved from erosion compared to the current conditions. Then we compared the relative efficacy of the three alternative strategies, as the percentage of benefit that could be achieved with alternative strategies compared to the exclusive one (e.g. the increase in the number of warblers achievable with the soil strategy compared with the increase expected from the warbler strategy). If synergies are possible, the combined conservation strategy should enable to reach globally higher targets than the specific strategies.

3. Results

3.1. Factors affecting warbler occurrence and abundance

The mean number of warblers per occupied transect was 1.94±1.00 SD (min. 1, max. 5, mode and median 2). The most supported model (occurrence intercept: -1.98±0.47; detection intercept: 1.09±0.67) for latent occurrence revealed a positive effect of slope (1.44±0.60, z=2.39, P=0.017) and solar radiation (0.96±0.43, z=2.23, P=0.025) on warbler occurrence probability; the detected warbler occurrence was affected by a marginally significant effect of date (-1.47±0.88, z=-1.66, P=0.096).

The most supported model for latent abundance suggested that the local (i.e. at the plot scale) abundance of Moltoni's warbler was driven by positive and significant effects of slope, solar radiation, shrub cover and forest cover (Table 1), whereas the number of warblers counted was affected by count duration (the higher the time spent on a transect, the higher the number of warblers found; Table 1).

The most supported N-mixture models for both occurrence and abundance are reported in Supplementary material.

3.2. Erosion risks in the vineyard landscape

The potential soil loss due to erosion within each 7.15-ha plot varied from 1 (on a flat vineyard) to 191 tons ha^{-1} yr^{-1} (for a plot with an average slope of 20°), being on average (± SD) equal to 78±32 tons ha^{-1} yr^{-1}.

3.3. Evaluation of potential conservation strategies

The positive effect of shrub cover on both Moltoni's warbler abundance and on soil retention made conservation synergies actually possible (Fig. 2). In addition, higher slope values promote warblers' abundance as well as soil erosion (Fig. 3); this suggests that creating shrub patches over sloping sites would be at the same time particularly suitable for warblers and particularly important to limit soil erosion.

According to the simulated conservation strategies, the warbler conservation strategies (i.e. creating shrub patches within the 16 most suited plots) would allow an increase of 105 Moltoni's warblers within the study area (and would result as a side effect in the retention of c. 479 tons of soil per ha per year). The soil-oriented strategy would allow the preservation of c. 783 tons ha^{-1} $year^{-1}$ (and to the potential establishment of further c. 68 individuals of Moltoni's warbler). Therefore, each individual strategy applied to the study plots would ensure benefits for the other conservation target corresponding to 61-64% of the benefits ensured by the individual strategy for the latter. The integrated strategy was globally more efficient, allowing for the achievement of 91-93% of the benefits (with an increase of 96 warblers and a soil preservation equal to 729 tons ha^{-1} $year^{-1}$) of the individual strategies for each conservation target (Table 2).

4. Discussion

4.1. Biodiversity conservation and other ecosystem services

Decisions about ecosystem management usually come with trade-offs among ecosystem services (Mace et al., 2012). Biodiversity conservation and the supply of (other) ecosystem services, either provisioning, regulating, cultural or supporting, are usually treated as alternative approaches, with often different conservation objectives, which may either conflict or reinforce each other (Balvanera et al., 2001). In fact, the relationship between biodiversity and ecosystem services is often multifaceted and in many instances still unclear and poorly considered in spatial planning (Mace et al., 2012). Nevertheless, it is clear that strategies focusing on the same set of targets for biodiversity and other ecosystem services may lead to both wins, losses or trade-off results (Persha et al., 2011). Large-scale mapping of spatial proxies for both biodiversity and other ecosystem services reported a positive correlation between the selected indicators for biodiversity and ecosystem services (Maes et al., 2012). The same study showed how the relationship between biodiversity and ecosystem services was affected by spatial trade-offs between different ecosystem services (particularly crop production vs. regulating services) and how habitats in a favourable conservation status may better provide both biodiversity and regulating and cultural services (Maes et al., 2012). Despite the extremely complex relationships between biodiversity and ecosystem services (and among the different services themselves) and the multiple roles of biodiversity in ecosystem services, a synergy between biodiversity conservation and the supply of other ecosystem service is thus possible and should be ideally pursued, within comprehensive management plan (Mace et al., 2012), aligning different incentives for conservation (Balvanera et al., 2001).

Here we regard the conservation of an endemic Mediterranean bird species (a good) and soil preservation (a final ecosystem service) in vineyards as complementary conservation objectives within an integrated conservation strategy. Moltoni's warblers mostly occur on (relatively) steep (and well exposed to solar radiation) areas, and their abundance is indeed promoted by slope and shrub cover. Slope is also an important predictor of soil loss (in vineyards and in general), being one of the factors mostly affecting the amount of soil erosion (McCool et al., 1987; Moore and Wilson, 1992). Given that both warbler and soil loss are particularly related to the steeper slopes in the study area, and that shrub occurrence may favour both warbler abundance and soil retention, the two conservation objectives may be part of an integrated conservation strategy. Our simulation indeed show that integrated conservation strategies for species and soil preservation could provide important synergies, allowing to broaden the effects of conservation strategies, maximizing their potential benefits. Potentially similar effects of some zoning strategies on species habitat and soil retention have been reported also at very different spatial scales and geographical contexts (Geneletti, 2013).

4.2. Modelling pros and cons

Our modelling approach allowed us to estimate the factors affecting the 'true' abundance of Moltoni's warblers in vineyard-dominated landscapes, providing results coherent with the previous knowledge and further highlighting the importance of both habitat and topographical characteristics. The estimation of potential soil erosion was carried out according to a well-established and reliable method, which also when applied in other areas suggested highest soil loss in vineyards located on steep slopes (Prosdocimi et al., 2016a). Despite this, in our specific case, the adopted approach was suited to obtain an estimate for the evaluation of the potential effects of different conservation strategies, but was not ideal for a site-specific evaluation of soil erosion, because of some basic assumptions we made. Even if the estimated values are generally coherent with the range of soil losses reported for vineyards in the Mediterranean region (Prosdocimi et al., 2016a), we acknowledge that keeping constant some likely varying (and important) factors, such as slope length (L) and cover management factor (C), means that for a precise estimation of local intensity of soil erosion, such values should be calculated case-by-case. However, such a generalization (which is commonly adopted e.g. to compare soil risk across different areas, see e.g. Van der Knijff et al., 2000) does not affect the general comparison of the efficacy of conservation strategies; in addition, in most of vineyard parcels the ground is largely managed by machineries (e.g. through ploughing) to prevent grass growth, thus variation in C are unlikely to have a large effect.
We are aware that further insights will contribute to a thorough planning of environmental-friendly vineyard management. At a broader scale, an evaluation of the effect of parcel management on biodiversity (e.g. Buehler et al., 2017) and soil loss (e.g. Prosdocimi et al., 2016b) would also be important. At a fine scale, site-by-site assessments are required in the case of local planning, which

should also benefit from the inclusion of an evaluation of the local risk of shallow landslides (Bordoni et al., 2016; Cuomo and Della Sala, 2015).

5. Conclusions

Effective strategies for ecosystem conservation and management, especially in the light of the increasing pressure due to human activities, should optimize both the supply of ecosystem service and the conservation of species and habitats (Mace et al., 2012). In our study system, integrating species and soil strategies could lead to maximizing the efficacy of environmental conservation, as well as of the potential agri-environmental scheme that could be drawn from our results. Such a kind of agri-environmental schemes is particularly urgent for intensive permanent crops, for which environmental prescriptions from the current CAP are almost completely lacking (Pe’er et al., 2014), and which have severe or even extreme impacts on biodiversity, ecosystem services and soil loss, especially in the Mediterranean region. Intensive farming is a major challenge for both biodiversity and the supply of other ecosystem services, at both the level it occurs, i.e. the field and the landscape scale (Fahrig et al., 2011; Tscharntke et al., 2005). A striking effect of agricultural intensification on biodiversity is given by the huge decline of many bird species in Europe (Donald et al., 2001) and elsewhere, as well as by the dramatic reduction of several ecosystem services (Power, 2010). In the Mediterranean region, intensification in vineyards has resulted also in severe soil loss, favoured by the concomitant reduction of ground vegetation over sloping terrains, in areas often characterized by high-intensity rainfall (Martínez-Casasnovas et al., 2010; Ries, 2010; Ruiz-Colmenero et al., 2013). Soil loss (and landslide risk) has been exacerbated by structural changes induced by intensification and by mechanization in particular, with a shift from vineyards perpendicular to the slope, to vines planted in rows parallel to the maximum slope, as well as by abandonment of less profitable vineyards (Persichillo et al., 2017). All those factors contribute to a highly concerning context, which makes particularly urgent the definition of strategies targeted at reducing the loss of biodiversity and ecosystem services in intensive vineyards. Preliminary discussions with individual farmers and farmers' organizations revealed a positive attitude towards a potential agri-environmental scheme promoting the creation of shrubland patches over vineyards on steepest slopes, as the latter are hard to access and manage and are frequently abandoned. This also implies that the creation of shrub patches on steep slopes would result in a moderate (likely negligible at a broad scale) reduction in crop production.

Under a broader perspective, evaluating potential synergies between the conservation of individual species and the more general optimisation of ecosystem service delivery should be regarded as a priority to formulate more efficient and appealing conservation strategies, which could simultaneously promote wildlife and (other) service supply, and be perceived as more appealing thanks to the broader benefits they could provide to the environment and people.

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Supplementary material

List of the most supported models (ΔAICc < 2) for occupancy and abundance of Moltoni's Warbler *Sylvia subalpina* along transects in vineyards.

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Table 1

Most supported model for Moltoni's warbler detection and abundance in vineyard plots.

Variable	**Estimate ± SE**	**z**	**P**
Abundance			
intercept	-0.958 ± 0.335		
shrubland	0.313 ± 0.116	2.69	0.007
forest	0.325 ± 0.140	2.32	0.020
solar radiation	0.444 ± 0.198	2.24	0.025
slope	0.440 ± 0.206	2.13	0.033
Detection			
intercept	-0.476 ± 0.477		
duration	0.882 ± 0.444	1.986	0.047

Table 2

Modelled efficacy of the individual and integrated conservation strategies. Percentage values are related to the maximum increase achievable following the individual strategies and are used to compare the combined effect of each strategy.

	Warbler strategy	**Soil strategy**	**Integrated strategy**
Warbler individual increase (%)	105.24 (100%)	67.79 (64.42%)	96.08 (91.30%)
Soil tons saved per year per ha (%)	479.02 (61.15%)	783.38 (100%)	729.37 (93.11%)
Total (sum of relative percentages)	161.15	164.42	184.41

Fig. 1. Study area: transects are shown in blue, vineyards in violet (source: DUSAF 4 database; http://www.geoportale.regione.lombardia.it/). The inset shows the location of the study area in Italy.

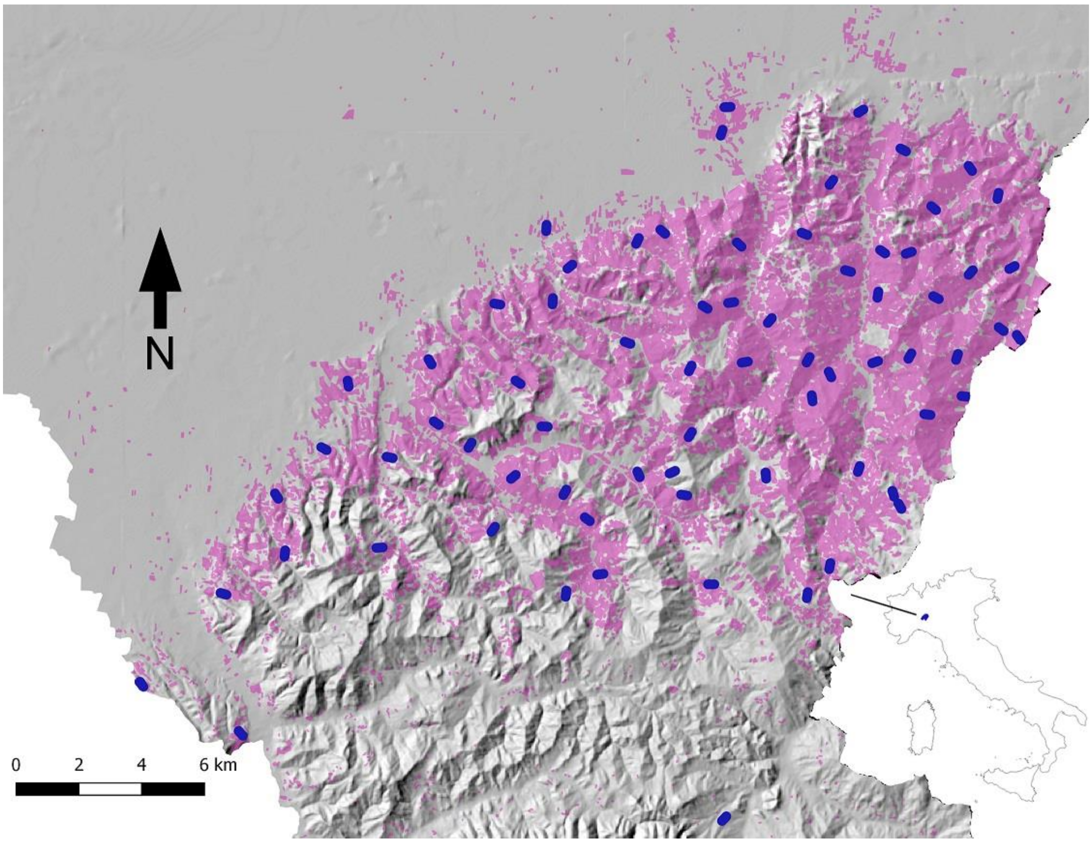

Fig. 2. Predicted abundance of Moltoni's warblers (black line, dotted lines are the 95% confidence intervals of the mean) and predicted soil loss (solid grey line) in relation to percentage shrub cover, for a hypothetical plot (7.15 ha) located on a 10° slope well exposed to sun (solar radiation 5675 W/m^2 on 21st June), with a unit contributing area of 1000.

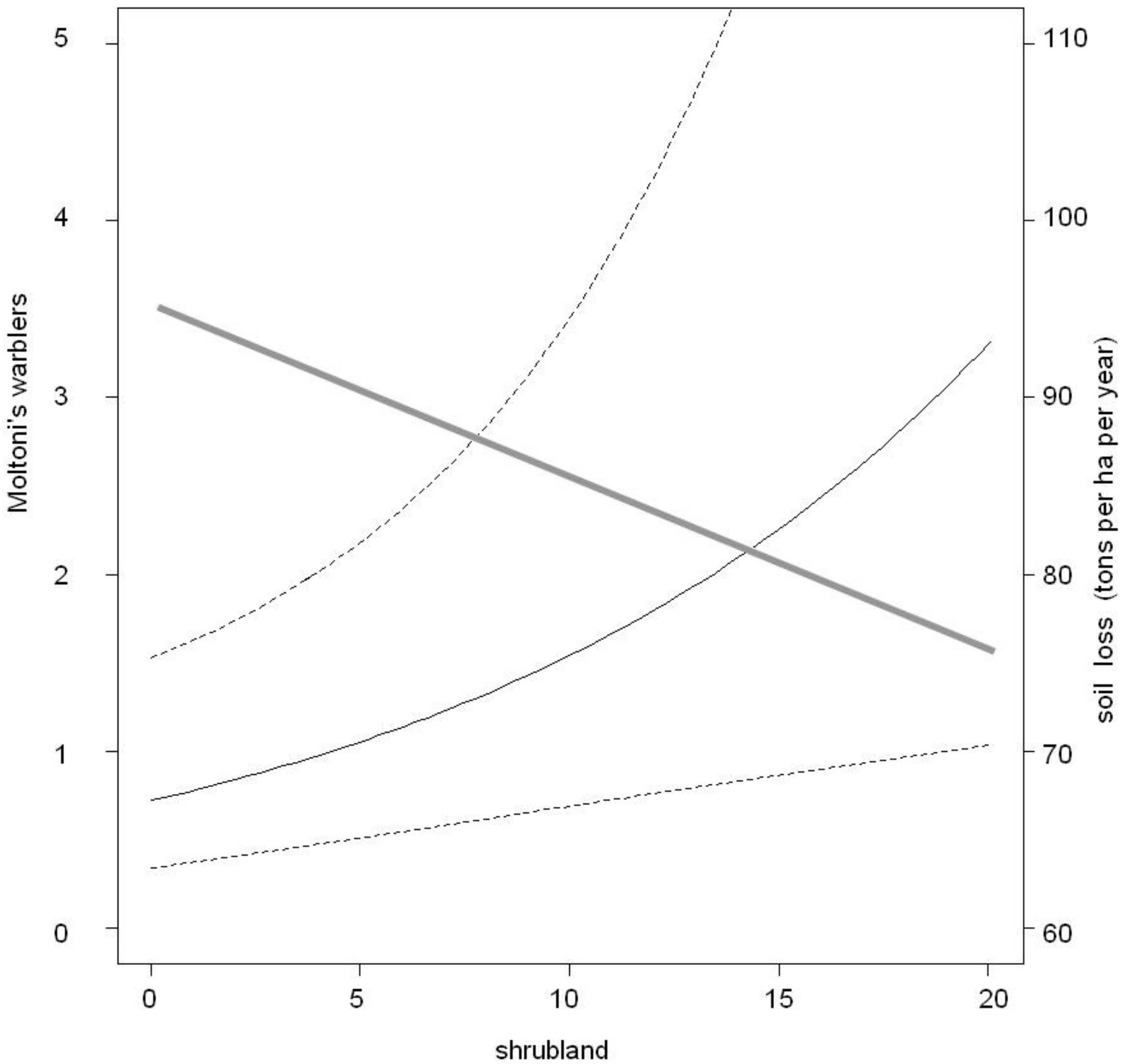

Fig. 3. Predicted abundance of Moltoni's warblers (black line, dotted lines are the 95% confidence intervals of the mean) and predicted soil loss (solid grey line) in relation to slope, for a hypothetical plot (7.15 ha) located on a site well exposed to sun (solar radiation 5675 W/m^2 on 21st June), with a unit contributing area of 1000 and a 10% shrub cover.