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Ecosystem Service Mapping

National scale mapping of ecosystem services in Israel - genetic resources, pollination and cultural services

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Abstract

The Israel - National Ecosystem Assessment (I-NEA) project aims to present a comprehensive picture of the state and trends of Israel's ecosystem services across all ecosystems, by integrating existing data and information collected from a wide range of sources. Although there is a lack of information about the spatial distribution of ecosystem services' provisioning in Israel, their mapping constitutes an important part of the assessment.

In this paper, we present a national-scale mapping of three ecosystem services, each of them implemented using different methods: 1) Genetic resources service, mapped using spatial observations of the Crop Wild Relatives species; 2) potential of pollination service, which is provided by wild bees, mapped using an expert-based habitat model related to land use and land cover; and 3) cultural service of recreation, mapped by analysing the distribution of geotagged digital photographs uploaded to social media resources. The derived maps visualise, for the first time in Israel, the spatially distributed values of the three ecosystem services. Supply hotspots with high values for all three services were identified, as well as spatial differences amongst the ecosystem services. These national-scale maps provide overlooked insights and can be very useful for strategic discussions of stakeholders and decision-makers but should be regarded with caution given existing knowledge gaps and possible inaccuracies due to data scarcity and low resolution.

Keywords

Ecosystem services mapping, national ecosystem assessment, crop wild relatives, wild bees, cultural ecosystem services, recreation, geotagged photos, ESMERALDA

Introduction

Nationwide assessment and mapping of ecosystem services (ES) are considered as key elements for supporting the maintenance and restoration of ecosystems and their services at the national scale and, therefore, are part of several EU initiatives (Maes et al. 2016). Maps of ES can help spatial planning and decision-making by indicating where to improve ES provision and where to prioritise nature and biodiversity conservation (Burkhard and Maes 2017), questions which are of high importance in a densely populated country such as Israel. In addition, mapping ES has several advantages as an advocacy and awareness-raising tool (Jacobs et al. 2016). However, the number of studies that deal with ES in Israel, though rising, is still relatively low, especially those that include mapping, and all of them have been conducted at a local or landscape spatial scale. These include stakeholders, management and planning (e.g. Cohen-Shacham et al. 2011, Orenstein et al. 2012, Portman and Elhanan 2016, Sagie and Ramon 2015), economic valuation (e.g. Divinsky et al. 2017, Fleischer et al. 2018, Peled et al. 2018), modelling (e.g. Koniak et al. 2010) and mapping (e.g. Fleischer et al. 2018, Lotan et al. 2015, Portman and Elhanan 2016).

The Israel National Ecosystem Assessment (I-NEA) project was designed to increase the general public's awareness of the multifaceted values of nature and the human dependence on functioning ecosystems and to produce an information base that can assist managers, decision- and policy-makers to incorporate the value of ES and biodiversity into planning processes, land management and policy. In order to accomplish these goals, the land and marine areas of the country were classified into six types of ecosystems (Mediterranean landscape, desert, marine, inland waters, agricultural and urban) and a multidisciplinary professional assessment team – thirty-five lead authors and more than one hundred contributing authors and assistants – was recruited. Following the Millennium Assessment (MEA 2005) and the UK-NEA (UK-NEA 2011), the Israeli project aims to integrate all relevant existing data and information collected from a wide range of sources. The I-NEA is led by HaMaarag (Israel's National Nature Assessment Program) and the working process is supervised by a scientific committee. A stakeholder council, composed of representatives from various national and local government departments and other authorities as well as NGOs, escort the assessment work. During the initial stage of the process, the conceptual framework, as well as a list of nine provisioning services, ten regulating services and three types of cultural services, were established. Some of the key findings from all chapters are already presented in an interim report that was published at 2017 (Lotan et al. 2017).

As part of the I-NEA, we have mapped the different types of Israeli diverse ecosystems and, for the first time for Israel, several national-scale ES. Since the national-scale spatial information in Israel is limited and there is a lack of maps for ES in an Israeli context, the main goals of this work were to present the ability to produce reliable maps of nationwide ES in Israel and to visualise some of the assessment findings in a spatial manner. In this paper, we present the process and method used for mapping three ES, representing the three categories of ES – provisioning (genetic resources), regulating (pollination) and cultural (recreation). These services were chosen in order to provide a diverse example of services types and methods and are also based on existing data and the needed expertise.

Genetic resources

Under the scope of provisioning ES, genetic resources in the form of Crop Wild Relatives (CWRs) are considered an important benefit to human well-being. CWR are wild species which are closely related to domesticated crops, with genetic traits that might aid to crop improvement. Israel is considered a global CWR hotspot (Castañeda-Álvarez et al. 2016, Vincent et al. 2013). Located within a geographical transitional zone with four climatic regions, it is home to some 2,700 plant species, of which over 300 have been identified as CWR (Barazani et al. 2008). The main use of the genetic resources of CWR in Israel is for R&D purposes, including selective breeding with an emphasis on pest tolerance abilities and various diseases or development of unique products. Such utilisation renders Israel's genetic resources as an intermediate ecosystem service, contributing to final provisioning ES such as food crops or ornamental products (Anikster et al. 2005, Hadas et al. 2009, Leonard et al. 2004).

Pollination

Pollination plays a key role in maintaining the functional integrity of most terrestrial ecosystems: an estimated 88% of all angiosperm species are animal-pollinated (Ollerton et al. 2011) and the reproduction in many plant populations is by pollen, limited and likely affected by changes in pollinator communities (Ashman et al. 2004). Pollination is also critical for human food supply: 77% of the leading global food crops depend on animal pollinators to produce yield (Klein et al. 2007). These include the majority of edible fruits, nuts and seeds. Yield quantity and quality are positively affected by adequate pollination, including the number, weight, size, shape, nutritional value and shelf life of fruits or seeds (Eilers et al. 2011, Brittain et al. 2014, Klatt et al. 2013).

Crop pollination relies mainly on managed colonies of the domesticated honey bee (*Apis mellifera*) (Delaplane and Mayer 2000). However, this species is becoming increasingly difficult to manage mainly due to the combined effects of parasites, diseases and pesticides (Williams et al. 2010, Smith et al. 2013). In addition, honey bees do not pollinate all crops efficiently and supplementary pollination may be needed (Garibaldi et al. 2013). Wild bees have been shown to contribute substantially to the pollination of a variety of crops (Klein et al. 2007) and to provide a safety net in the event of honey bee colony collapses (Winfree et al. 2007). The diversity of wild pollinator communities can make them more efficient than a single pollinator species (Blüthgen and Klein 2011) and more resistant to environmental changes (Winfree and Kremen 2009, Garibaldi et al. 2011). Hence, there are functional benefits attached to conservation of diverse pollinator communities in arable landscapes.

In Israel, a hot spot of bee diversity (Delaplane and Mayer 2000), rich and abundant bee communities were found inhabiting agricultural landscapes (Pisanty and Mandelik 2015). Wild bees were found to contribute significantly to the pollination of some crops, mostly in fields surrounded by natural and semi-natural habitats (Pisanty et al. 2014, Pisanty et al. 2016). Main crop pollinators were found to be generalist foragers, ground nesters, of small and medium body size (Pisanty and Mandelik 2015).

Cultural services

The main benefits that people gain from open spaces and nature in Israel are physical (recreation, travels and sports activities) alongside aesthetics (experiencing the natural view and landscapes) and educational outputs (Central Bureau of Statistics (CBS) 2016a). These open spaces and natural areas are mainly located outside the urban areas of Israel and are characterised by an amalgam of man-made (agriculture) and natural ecosystems (Mediterranean landscape, desert, marine and inland water).

Tourism and recreation can be assessed quantitatively and frequently considered as tangible dimensions of cultural ES (Hernández-Morcillo et al. 2013). Previous analysis of tourism and recreation as benefits of cultural ES in Israel revealed that they are mainly consumed by domestic tourists and recreationists. The National Park Authority data revealed that only 15 percent of more than 4M visitors to natural sites were international tourists and only 17% of the 2M nights in rural accommodation were booked by international tourists (Central Bureau of Statistics (CBS) 2016b). However, the accessibility to cultural ES in Israel is dependent on the availability of private cars, due to only partial coverage of the public transportation system and to the state legislation that restricts public transport services in weekends and Jewish religious holidays.

The above information and more were collected throughout the I-NEA in order to have an idea about cultural ES use in Israel. However, none of these data could be expressed in a continuous, spatial manner and not in a national scale.

Materials and Methods

The three mapping processes were based on existing data and knowledge but, in each of them, a different method was used: plant-species observation density for genetic resources; expert-based habitat model for pollination; and geotagged photo density for recreation. All analyses and production of maps were performed using ArcGIS 10.4 (ESRI 2016).

Genetic resources

Mapping of CWR in Israel was based on species with genetic similarity to known cultivated crops, as classified by Barazani et al. (2008), which included 323 species. Amongst them, 137 species were selected based on their ability to breed with cultivated species with varying success rates. These CWR species were used as a proxy for the potential of genetic resources of Israel's flora. Distribution data of these species were gathered from the Israeli Biodiversity Information System (BioGIS) website (http://www.biogis.huji.ac.il), which hosts various datasets of species observations and collections. A total number of 19,829 plant observations were selected from 1985-2017, including observations for which no specific date was specified and their coordinates were imported to a GIS software. Duplicate observations of the same species over different periods were omitted. In addition, past observations in natural areas, which today are urban, were also removed. The land of Israel was divided into 25 km^2-sized grid cells and the density of the selected CWR species occurrences was then calculated for each grid cell.

Pollination

For mapping the potential of wild bee pollination service on a national scale, we used a Land Use/Land Cover (LULC) map that was produced for the I-NEA as part of the mapping of Israel ecosystems (see Table 1 for the LULC types and more details in Lotan et al. 2017). In order to evaluate the contribution of different LULC types to the richness and abundance of wild bee communities, as a proxy to their delivery of pollination service to agriculture, we followed Kennedy et al. (2013) and focused on the seasonal availability of two main resources, known to shape pollinator communities (Michener 2007).

1. Foraging resources – for each LULC type, we estimated a) the relative amount of time during which flowers are available out of the overall wild bee activity period in Israel (February till October); and b) the relative abundance of flowers per unit area on average (0-1 scale). To obtain a score for foraging resources, we multiplied the relative time by the relative abundance estimates for each LULC category.
2. Nesting resources – for each LULC type, we estimated the relative availability of nesting resources for above- and below-ground nesters (0-1 scale). We averaged the values for the two nesting guilds to obtain a final score for nesting resources.

Finally, for each LULC category, we averaged its foraging and its nesting scores to obtain a final score of LULC-suitability for wild bees. In the Agricultural land-uses, we deducted a relative “pesticide penalty” (0-1 scale) from the scoring obtained, that was determined based on expert opinion. The final scores were then converted to relative ranks (Table 1) that were used for the creation of the map.

Table 1.

Land use/land cover types used in this work, their final scoring and relative rank, representing their expected relative contribution to wild bee richness and abundance, as a proxy to the delivery of pollination service (from 1- the lowest to 11- the highest). Scoring is based on the seasonal availability of foraging and nesting resources while accounting for pesticide use (see the method section for more information).

Land use/land cover type	Final scoring	Relative rank
Vegetable fields	0.01	1
Cereal fields*1	0.03	2
Deciduous orchards	0.03	3
Olive groves*1	0.08	4
Non-deciduous (evergreen) orchards*2	0.09	5
Dense coniferous (mainly pine) forest	0.20	6
Fallow and disturbed land	0.36	7
Mediterranean shrubland (Maquis)	0.47	8
Dwarf shrubland (‘Batha’, dominated by perennials)	0.51	9
Sparse coniferous (mainly pine) forest with understorey vegetation	0.51	10
Grassland (dominated by annuals)	0.59	11

An underlying assumption in our work is that there is a positive relation between bee richness and abundance in land-uses surrounding agricultural fields and the delivery of pollination services to these fields. In making this assumption, we relied on the tendency of main crop pollinators to enter agricultural fields from the surrounding natural/semi-natural habitats (Pisanty and Mandelik 2015) and on the high spatio-temporal complementarity found in pollination activity of main wild crop pollinators (Pisanty et al. 2016).

Cultural services

Cultural ecosystem services are difficult to assess due to their intangible nature and measuring or mapping the potential, demand and flow are not trivial (Burkhard et al. 2014). One inherent difficulty is to establish a clear relationship between possible cultural ecosystem service and certain elements of the ecosystem and its functions (Hernández-Morcillo et al. 2013). For example, the reason that brings a visitor to a certain site could be either aesthetic, spiritual or recreational activity or even all three of these.

While the open spaces of Israel are a valuable source of cultural ecosystems services, the actual number of their beneficiaries is unknown, especially in free of charge areas (such as beaches, inland water bodies, forests and the desert). Therefore, the cultural ecosystems evaluation required proxies for usage patterns and visitation numbers in open spaces.

One of the indirect options to evaluate the use of physical environments, including natural ones, is using big data, more specifically geotagged photos (Oteros-Rozas et al. 2017). Social media websites (e.g. Flicker) were found before as reliable sources for estimating the number of visitors to natural areas in several studies (for a short review, Tenkanen et al. 2017). Therefore, this approach was used to estimate visitation patterns in the present study. The advantage of relying on photo-related metrics associated with cultural ecotourism was derived from their being based on comparable units (number of photos) with specific spatial identifications. Thus, it enables the comparison of different ecosystems. Furthermore, sharing photos of ecosystems and biodiversity by social media indicates aesthetic and inspirational importance of these elements. Nevertheless, here we consider the geotagged photo density as a proxy for recreational use pattern of Israel open spaces.

Using Panoramio, a location-centric landscape-orientated photo sharing service owned by Google (closed in November 2016), all geotagged photos that were taken between 2005-2016 in the open areas of Israel (protected, non-protected, natural and man-made) were imported to GIS software. Photos that were taken within urban areas (including small settlements) were excluded due to the high representation of manmade, artificial objects. The remaining photos (~ 27,000 photos), representing various types of nature-orientated recreational activities, were used for the mapping. The density of these photos was mapped using the kernel function (Silverman 1986) with a search radius (bandwidth) of 5 km and a resolution (cell size) of 100 m.

Results

Genetic resources

Fig. 1 presents the mapping of 137 CWR species in Israel, based on the classification of Barazani et al. (2008). According to the produced map, several hotspots are clearly visible, mainly in the Golan Heights, the Upper Galilee, Mount Carmel and the area close to Jerusalem. The observed distribution of CWR is in accordance with spatial land use patterns, where developmental pressure is low in the observed hotspots. In addition, the distribution pattern adheres to certain geographic and climatic factors observed in Israel: the majority of the hotspots are characterised by relatively high-altitude locations and high precipitation. The observed hotspots also correspond to spatial concentrations of general species richness (Levin and Shmida 2007).

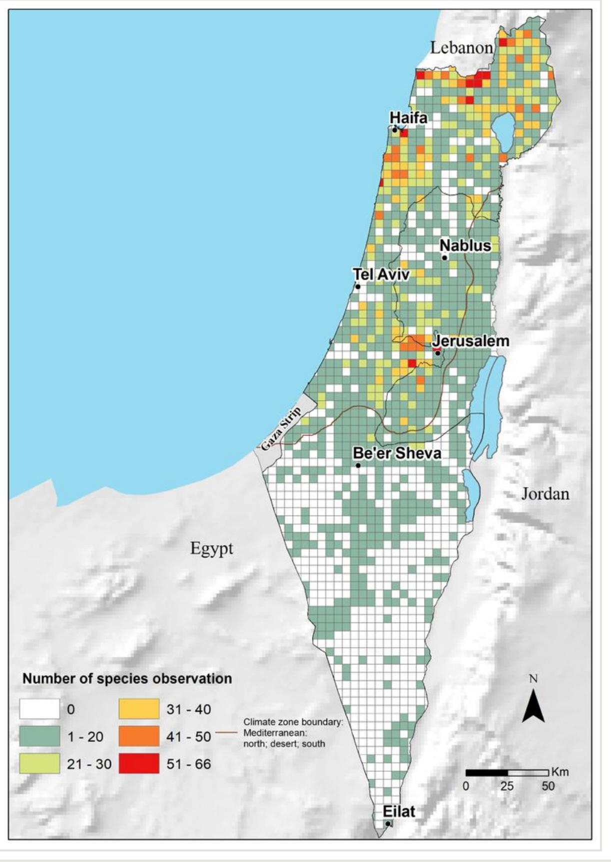

Figure 1.

Density of Crop Wild Relative (CWR) species, having relatively high breeding capability with domesticated species, in 25 km^2 area units. Mapping is based on plant species observations taken from BioGIS website (1985-2017).

Pollination

The mapping of pollination service by wild bees in Israel was based on a scoring and ranking approach. We found that different land-use categories may vary considerably in their expected contribution to the richness and abundance of wild bee communities (Table 1). Two main patterns emerged from our scoring process. First, agricultural land-uses are ranked lower compared to natural and semi-natural land-use types. This is due to the "pesticide penalty" applied to the agricultural land-uses and their relative short bloom period compared to natural/semi-natural land-uses. Second, regenerating semi-natural habitats, namely sparse pine forests with regenerating understorey vegetation, may have higher value for wild bees compared to natural perennial-dominated land-uses. Accordingly, mapping the contribution of different land-uses to wild bee richness and abundance and to the expected delivery of pollination service, shows the highest values in regions characterised by dwarf shrubland dominated by annuals, as in the Golan Heights (Fig. 2). Areas with high amounts of natural/semi-natural habitats, such as the Judean foothills and upper Galilee have also high values, while areas that are developed and/or used for agriculture, such as most of the coastal plains and the northern valleys, have the lowest contribution to wild bee communities and pollination services.

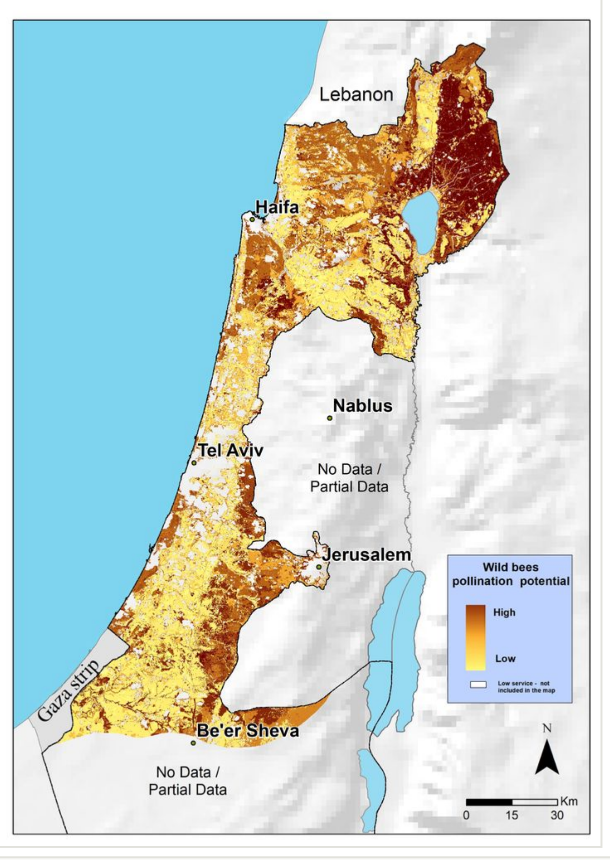

Figure 2.

Relative contribution of Israel’s open landscapes to wild bee communities as a proxy for the delivery of wild bees pollination service. The LULC-related ranks are presented in Table 1.

Cultural services

The map of Panoramio-geotagged photos in open spaces in Israel (Fig. 3) shows an irregular pattern of distribution of photos. The two most popular natural environments are pine forests (which are mostly man-made) that are surrounding the urban centres of Israel (Tel Aviv, Jerusalem and Haifa) and natural inland water bodies (Sea of Galilee and the Dead Sea). Additionally, water springs in northern Israel and the Golan Heights and oases in the desert attracted many photos and consequently suggested many visitors.

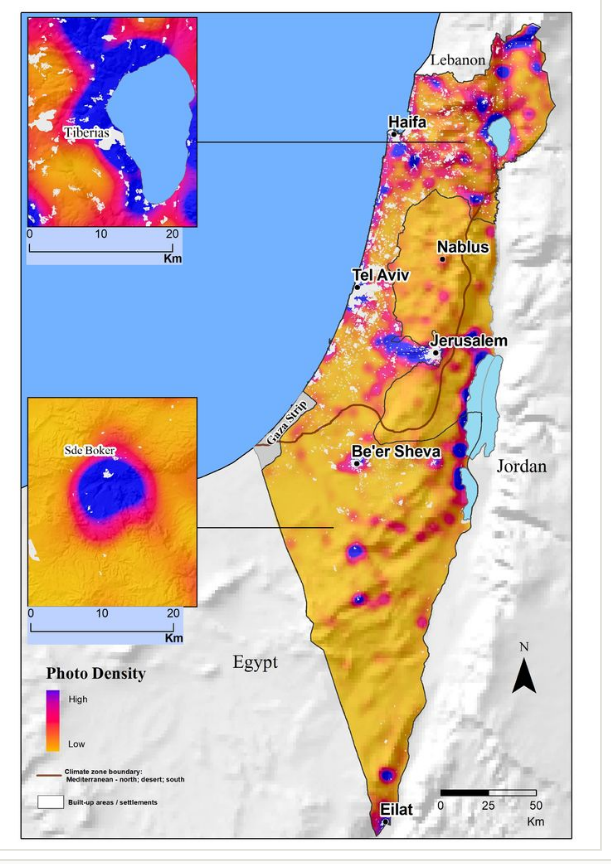

Figure 3.

Density of geotagged photo taken from Panoramio website (2005-2016). Mapping was done using kernel function with a search radius of 5 km and a resolution of 100 m.

Discussion

In this paper, we present the mapping of three ES on a national scale for the first time for Israel. However, the methods that were carried out display some drawbacks as well as advantages. Regarding **genetic resources**, the benefit of the mapping method presented in this article is its reliance on observed *in-situ* occurrences of CWR species, as opposed to modelling methods such as Species Distribution Modelling. The main drawback, however, is that observed records are, in part, the result of collection and cataloguing priorities, which might give skewed values. In addition, the product of this analysis is limited to current genetic potential of CWR species and does not include future discoveries. The analysis also does not include the quantifiable rarity of CWR species. Therefore, it is advised that such mapping procedure will be enhanced by complementary modelling methods.

While the mapping process of the **pollination** service is based on the ecology of wild bees of Israel, it has some practical and conceptual limitations; these limitations should be addressed in future work:

1. Pollinator classification: A) There is no distinction between different pollinators in their potential contribution to crop pollination. However, we know that wild bee species vary considerably in their tendency to enter agricultural fields and their efficiency in pollinating crops (Pisanty and Mandelik 2015). B) We assume that all pollinators inhabit natural/semi-natural habitats and only enter agricultural fields to forage; however, some of the main crop pollinators in Israel were found to nest within fields (Pisanty and Mandelik 2015), thereby decreasing their dependency on surrounding natural/semi-natural habitats.
2. Scoring: A) The ranking fails to reflect the scale of change found in the actual scores of the different LULC categories (see Table 1). B) Risks and threats posed to pollinators in non-agricultural land-uses were not incorporated. C) The foraging score relies on the abundance and not the diversity of foraging plants.

Using the geotagged photos as a proxy for **recreational use** of Israel's open spaces revealed a spatial visitation pattern that could not be discovered with other existing data. However, this pattern also raises the concern about the pressure of human activity on Israels' ecosystems, mainly the planted pine forests and inland water bodies, which exhibit high popularity. Man-made pine forests were planted to provide, at least in part, recreational and other cultural benefits and, therefore, can accommodate large numbers of visitors with limited ecological effect. However, inland water bodies represent fragile ecosystems, affected by the burden of visitors and their ongoing protection is dependent on the regulation of the number of visits. In light of this limitation, restricting the access to cultural ES of inland water bodies, which is already constrained due to partial services of public transportation in Israel, raises moral and social concerns. The Mediterranean beaches of Israel, which are very popular but located in urban areas, were excluded from this analysis of open spaces. Their absence represents one major disadvantage of the method.

The use of geotagged photos' analysis for the evaluation of **cultural services** has been summarised before (Santos-Martín et al. 2018, Tenkanen et al. 2017). This method efficiently helps to estimate the number of visitors in open spaces on a national scale; it enables the comparison of the number of visitors to different sites and ecosystems; it opens a window to the value of the aesthetic benefits (uploading a photo to the social media as a "trophy" of aesthetic interaction) and other cultural benefits; and it is a relatively low-resouces method. However, the method is not free from downsides: it cannot tell how many visitors uploaded photos (e.g. multiple uploading of photos by a single visitor) and it cannot define the true subject of the content of the photo (wide landscape, a single flower or a human historical monument) unless a further investigation takes place. In addition, as this big-data method is focused mainly on density, it has shortcomings when providing insights on the exact benefits that are derived from the interaction between people and cultural ES. Geotagged photos can be added to traditional methods for cultural ecosystem services evaluation (e.g. social survey) and, thus, have an added value to evaluations at national or other large scales. However, it should be complementary to traditional evaluation methods of cultural services.

In the broader view, even though the maps presented here are of three different types of services, some similarities can be seen. Some areas were observed, especially in the Mediterranean climate zone at the northern part of the country, to present relatively higher potential for pollination service as well as CWR diversity and are also preferred for recreational activities as concluded from the geotagged photo map. In the southern and arid part of the country, where vegetation is sparse, the link between cultural, biodiversity and other ES is probably weaker. Although genetic resources and pollination service are both related to biodiversity and, therefore, it is reasonable to see some overlaps in their hotspots, there are some major spatial differences. Some differences can be related to the fact that these two ES are based on different components of biodiversity, but others are due to method differences. On one hand, the pollination service was mapped using a model that can be easily extrapolated for the whole territory, but does not necessarily present the actual provisioning of the service. On the other hand, genetic resources were mapped based on observations representing real occurrences of the various species, but not necessarily the full picture due to partial and skewed sampling distribution.

It is also important to note that, in the present study, only the potential (pollination and genetic resources) and the real use (recreation) of ES were mapped. We have not quantified and mapped the demand for (all three) and the flow of (pollination and recreation) these services. Further data collection and research is needed for bridging the knowledge gap of these important aspects (Burkhard et al. 2014) in Israel. Therefore, in order to obtain a broader picture of the spatial distribution of ES provisioning in Israel, there is a need to overcome some of the drawbacks of the three mapped ones and to complete mapping of other ES, including their demand and flows, on the national scale. This full spatial picture of Israeli ES could raise the awareness of ES and their hotspots and would contribute to strategic decision-making for nature and open spaces at the country level.

Conclusions

The mapping methods presented here are rather simple and require relatively little resources – manpower and data – in relation to the large area they cover. This simplification enables the visualisation of the value of important ES at a national scale that could not be achieved if more sophisticated techniques were used. However, its advantage is also its drawback. The resolution of the output is relatively low and its accuracy tends to be low as well, especially when inspecting particular areas or ecosystems. Thus, in sub-national discussion and planning, this type of maps provides limited usage and could be misused. In other words, maps of ES at the national - or other large - scale (‘simple’ maps) can be very useful for strategic discussions amongst stakeholders and decision-makers and as a first step towards more complex and local mapping, but should be presented in their context in order to achieve their social and strategic purposes and to minimise their possible negative effects.

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Endnotes

*1 assumed to provide very little or no foraging resources for bees

*2 assumed to provide foraging resources for bees