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Setting conservation priorities for Lebanese flora—Identification of important plant areas

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ABSTRACT

Considered as a hotspot for biodiversity in the Mediterranean Basin, Lebanon is currently witnessing anarchic urbanization and unprecedented destruction of its natural habitats. Unregulated urbanization is also compounded by the surge in Lebanon's population due to the unabated influx of Syrian refugees since 2012. This work aims to define Important Plant Areas (IPAs) with exceptional botanical richness. These IPAs should constitute the priority zones for conservation, contributing to the fulfillment of national targets in the framework of the Aichi Biodiversity Targets.

A customised methodology was developed to suit to the Lebanese geomorphological characteristics, using an approach that combined three indicators: species richness; species conservation value including endemism and rarity; and, the habitat conservation value. Out of the characterized 1250 cells of 3 km × 3 km covering Lebanon, 11 were ranked as IPAs of very high importance and 20 as IPAs of high importance. These 31 top ranked cells covered 3% of Lebanon's area. These IPAs contained diverse habitat mosaics, including forests, mountain screes, cliffs and grasslands and host a total of 2386 species amounting to 79% of the flora of Lebanon and 80% of the species endemic to Lebanon. Seven of these top ranked cells contained species strictly endemic to Lebanon. Only 26% of these IPAs were already designated as protected areas and hosted 45% of Lebanon's plant species.

This map of IPAs provides important information for stakeholders, practitioners and politicians involved in conservation in Lebanon to protect endangered zones and develop rational strategies for their conservation.

1. Introduction

Human pressures on the environment are having both spatial and temporal impact with severe consequences on biodiversity as well as on the human economies. While natural resources and ecosystem services underpin social and economic performances (Costanza et al., 2014), excessive human development has eroded these resources with overexploitation of natural resources and destruction of natural habitats (Kareiva, Watts, McDonald, & Boucher, 2007).

The relatively preserved natural habitats are being lost at an unprecedented pace as expanding human population are converting these habitats to urban areas, roads and industrial zones (Anderson, 2002). As these habitats are altered, numerous species are disappearing before they have been discovered and described by scientists.

Lebanon, which is considered as a hotspot for biodiversity in the Mediterranean Basin (Médail & Quézel, 1997; Myers, Mittermeier, Mittermeier, Fonseca, & Kent, 2000), is characterized by the coexistence of plants with diverse biogeographical origins and a large number of narrow endemic taxa. It is considered a key area of geological activity and climatic changes and recognized as a melting-pot of human cultures. The combination of geological variation and altitude, along with strong climatic variation among different slopes, created a marked heterogeneity in the ecological forces acting on the evolution of plant differentiation. Its floristic richness is estimated at 2612 vascular plant taxa, of which 108 are endemic to Lebanon (Tohmé & Tohmé, 2004, 2011, 2014).

The reconstruction period after the Lebanese civil war (1975–1991) led to a massive increase in unplanned urbanization, extending to the surrounding countryside and mountains, colonizing river sides and borders, mountain peaks and any remaining coastland; it transformed profoundly the land cover and cities of Lebanon (Faour, 2015).

More recently, the Syrian conflict has sparked an influx of refugees

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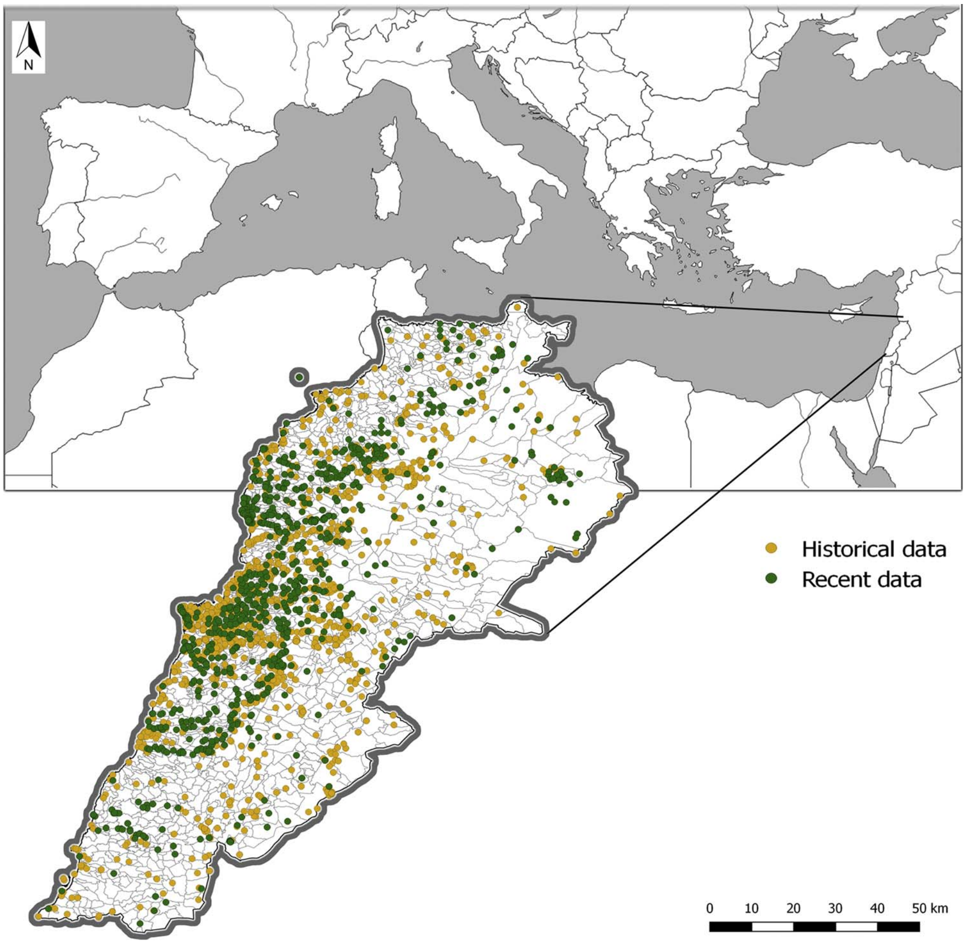

Fig. 1. Distribution of vascular plants data: historical data (orange) and recent data (green). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

into Lebanon. From 2011–2013, Lebanon witnessed an unprecedented increase of its population by 30% (Ammar et al., 2016). Large population expansions within a short time frame have often resulted in impacts on the environment leading to significant losses in biodiversity (Kareiva et al., 2007). Population density is proportional to the threat on biodiversity as ecological services are exhausted to satisfy the people's needs (Luck, 2007).

Destroying natural habitats that are essential for the survival of species is considered as one of the most important causes of species extinction (Sodhi, Brook, & Bradshaw, 2009). It is widely accepted that setting priority sites for conservation is crucial to minimizing loss in biodiversity and maximizing the effectiveness of limited conservation resources.

Therefore, knowing precisely where biodiversity is concentrated within a region is of high importance for setting priority sites for conservation and for spatial planning (Venter et al., 2016). This will ultimately contribute to sustainable development efforts undertaken.

Target 5 of the Convention on Biological Diversity (CBD) Global Strategy for Plant Conservation (GSPC) endorses the conservation of Important Plant Areas (IPAs). IPAs are areas identified at national level using internationally standardized criteria such as the presence of endemic threatened species, botanical richness, and the presence of threatened habitats (Anderson, 2002). Hence, conservation plans must always be based on reliable data about the distribution and the vulnerability status of each species (Grand, Cummings, Rebelo, Ricketts, & Neel, 2007).

The GSPC recognizes the importance of conserving plant diversity and has stimulated botanical and conservation communities at global, regional and national levels. Lebanon ratified the CBD in 1994 and since created 36 protected areas (MoE/UNEP/GEF, 2016). Each of these protected areas was created following an *ad hoc* demand from the local communities or national experts. In fact, aside from the bibliographical study of Radford et al. (2011), there is no current information on the IPAs in Lebanon.

The aim of this study is to update the IPAs map with a high precision grid-based ranking system to detect hot-spots for plant diversity at the national level. The high precision map that this study is providing could be used as a decision tool for stakeholders, practitioners and decision-makers involved in plant conservation.

2. Material & methods

2.1. Vascular plants occurrence data

Occurrence data were gathered from a wide range of sources and divided in two sets using a temporal scale: historical data; and, recent data. The historical data mainly consisted of herbarium specimens collected before 1980 and reported into the *Flora of Lebanon and Syria* by Paul Mouterde (Mouterde, 1966; Mouterde, 1970, 1984). From this publication, 246 collectors including P. Mouterde himself, reported the occurrence of 29848 plants records. The period of collection for the samples reported in this flora extended from 1828 to 1972. The historical data also included 1652 observations gathered from the herbarium collection of the National Museum of Natural History of France (MNHN). Some of the recent data were extracted from the Illustrated Flora of Lebanon (Tohmé & Tohmé, 2014) and from the online database Lebanon flora (http://www.lebanon-flora.org) gathering records of 30 contributors. The recent data set totaled 26082 records.

Lebanese flora nomenclature is not yet updated as per Angiosperm phylogeny classification of flowering plants (APG IV 2016), thus all

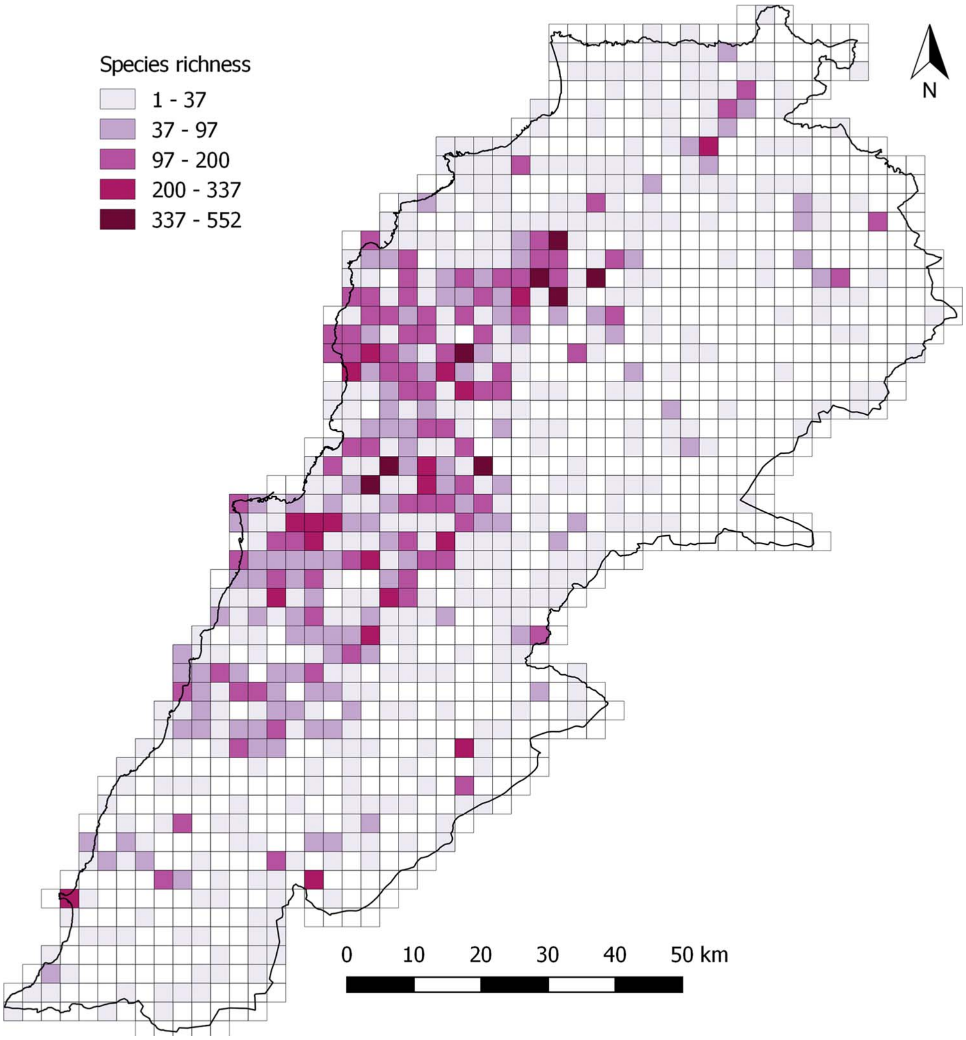

Fig. 2. Map of plant species richness.

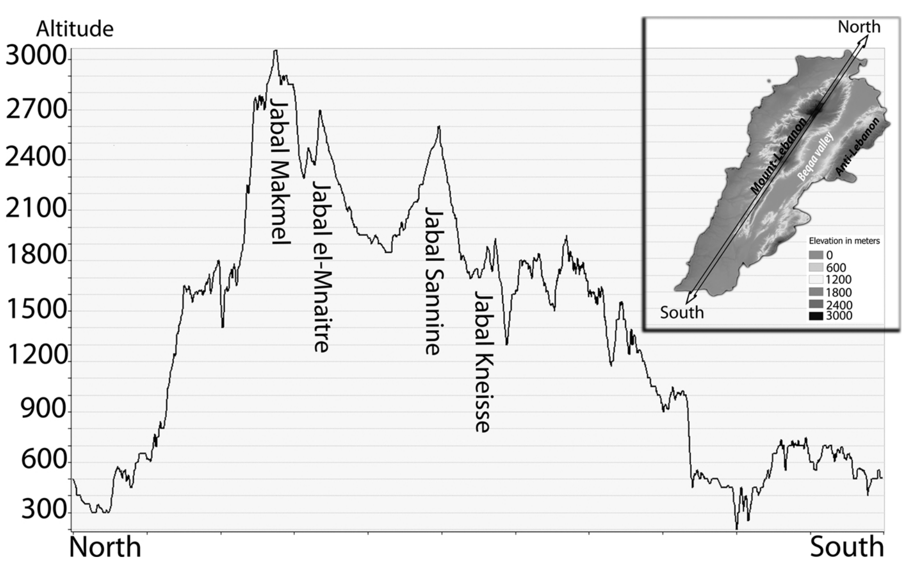

Fig. 3. Elevation profile map for the longitudinal section of Mount-Lebanon range.

species names mentioned in this article follow the taxonomy used by Mouterde (1984).

All species that did not originate from the Mediterranean region were considered exotic species. Among the historical dataset, a total of 10302 herbarium samples collected in towns where important urbanization occurred during the last decades (for instance Baalbek, Beirut and its suburbs, Beirut Airport, Jounieh, Saida, Tripoli, Zahle) (Faour, 2015) were not considered. For this purpose, we used the Land Use Land Cover map for Lebanon (Dar Al Handasah, 2002), which was built using Landsat and IRS satellite images acquired in 1998.

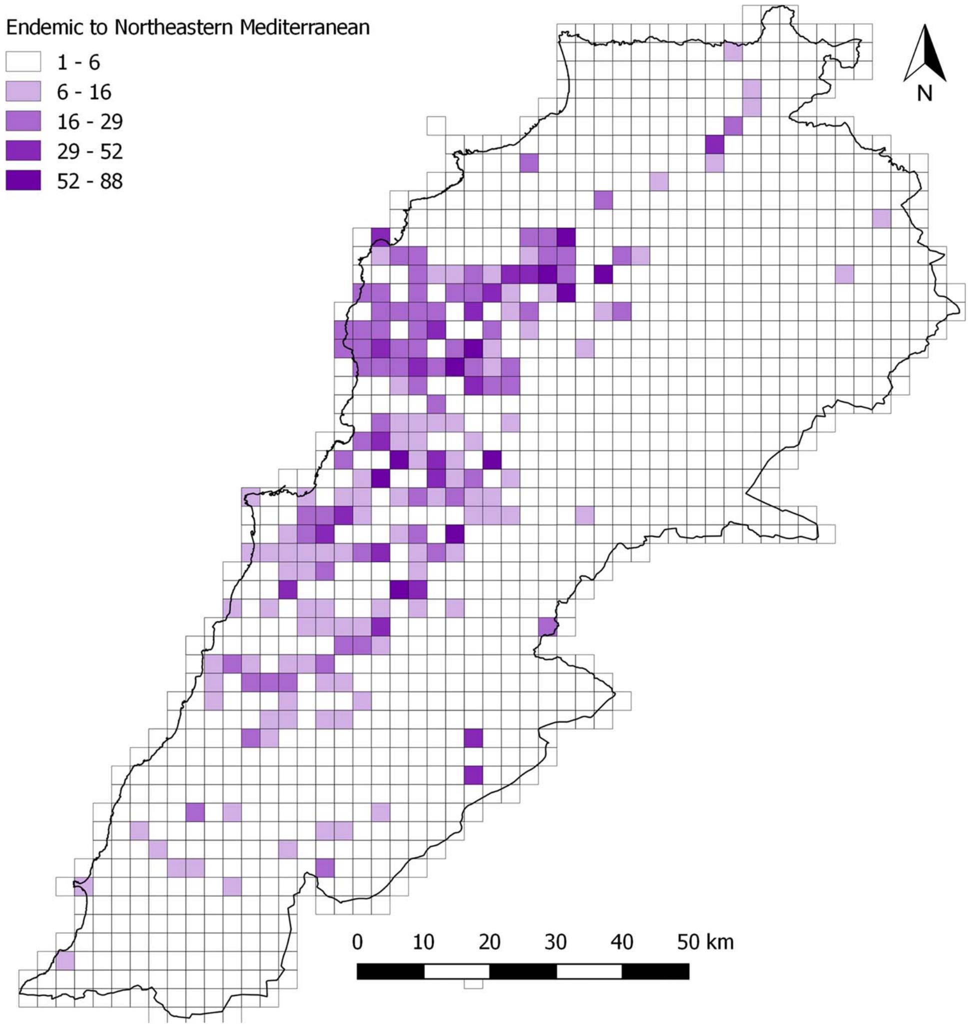

Fig. 4. Map of the Northeastern Mediterranean endemic plants.

2.2. Lebanon map grid

Considering the accuracy of the geo-referenced data, the sampling effort and the geomorphological heterogeneity of Lebanon, a grid of 3 km × 3 km cells was considered to be the most appropriate scale. It enabled mapping and visualization of data with good accuracy. A total of 1250 cells of 9 km^2 each covered Lebanon. All data were harmonized and each plant observation was geo-referenced, and unequivocally assigned to one of the 1250 square cells. The grid of 3 km × 3 km cells drawn over Lebanon allowed us to map all the historical data and to easily identify the cells lacking botanical data. This gap analysis revealed the cells where no observations were previously reported. These underexplored regions were considered as a priority for fieldwork. They were visited from March 2013 to October 2016 and their flora was documented.

All maps were created using the software (QGIS, 2016) and the shape files were downloaded from DIVA-GIS website (Hijmans et al., 2004).

2.3. Definition criteria for important plant areas

Our methodology to identify IPAs in Lebanon followed Plantlife International guidelines (Anderson, 2002) and other IPA methodologies applied in different countries (Blasi et al., 2011; Marignani et al., 2014; Senterre & Henriette, 2015). The three basic principles mentioned by Plant Life to qualify IPAs (criterion A for threatened species, criterion B for species richness, and C for threatened habitats) were integrated into three calculated indicators (species richness, species conservation value and habitat conservation value) and then combined to rank each cell of the grid.

The number of species within each cell was reported as the species richness (SP_RICHNESS), which was then transformed into a RICHNESS_INDEX scored into five levels from 0 to 5 using the Jenks natural breaks classification method (1967) allowing users to maximize the variance between classes and minimize the average of the variance within each class. The cells with no species observation were scored 0, and cells with the highest species richness scored 5. Then the habitat index (HAB_INDEX) was noted for each habitat type according to the rarity, richness and uniqueness of the habitat. Dense forests of cedars, or firs and alpine rocks and cliffs were scored 3, sparse forests of cedars, or junipers, or other kind of dense mixed forest, and rocks and cliffs from the coast to the high mountains were scored 2, all other kind of woodlands, shrubby and herbaceous vegetation types, coastal dunes and wetlands were scored 1. All other kind of agricultural habitat types were scored 0.

A specific index (SP_INDEX) was calculated for each plant species using an arbitrary scale taking into account endemism (E) and rarity (R). Endemism (E) was considered at four levels and each species was scored according to its level of endemism. The species strictly endemic to Lebanon (*Endemic*), were scored 3 (highest value), species endemic to Lebanon and Syria, or to Lebanon and Palestine, or to Lebanon, Syria, and Palestine, or to Lebanon, Syria, Palestine and Jordan (*Levant-Eastern Mediterranean Endemics)* were scored 2, species endemic to the Levant and to Turkey, or to the Levant and Cyprus, or to the Levant,

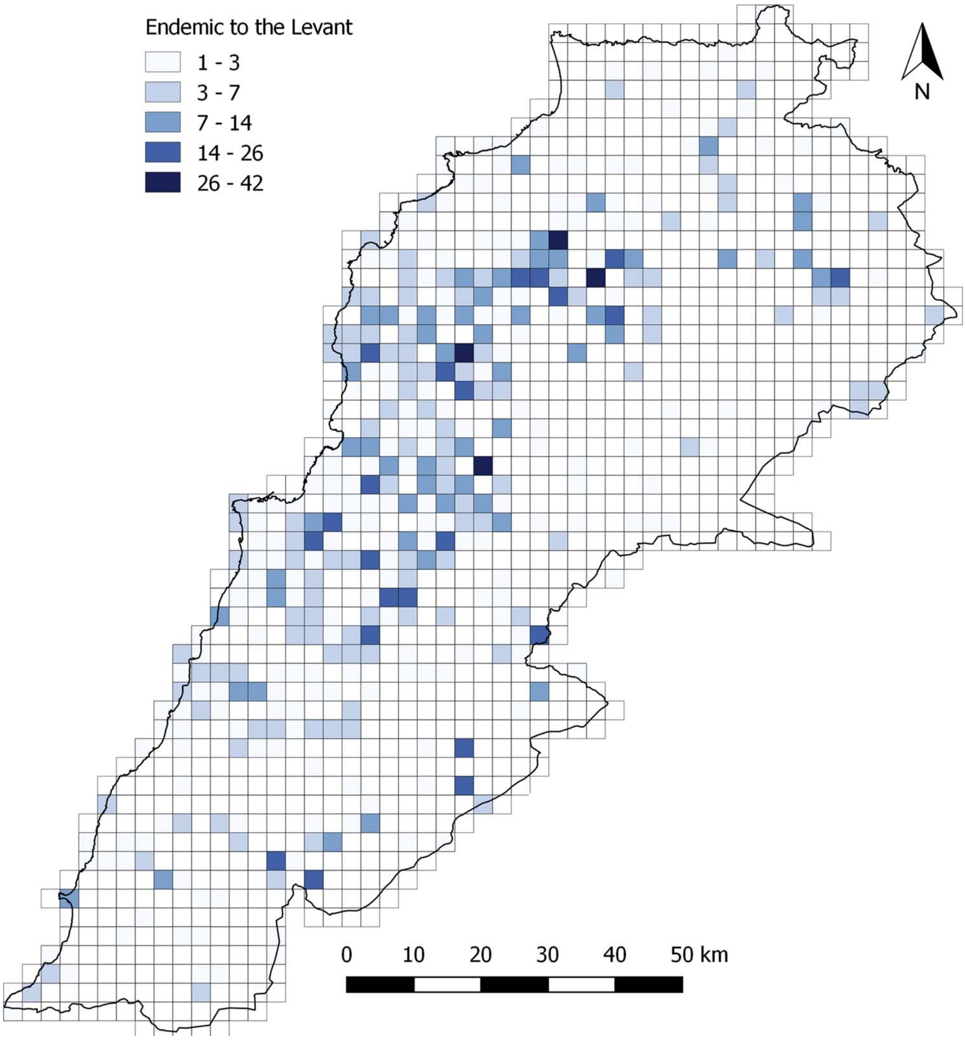

Fig. 5. Map of the Levant endemic plants.

Table 1
List of rare endemic plants species that were reported in only one, two or three cells. IPAs numbered from 1 to 31 correspond to cells with high (class 4) and very high (class 5) values. IPAs numbered from 32 to 48 correspond to cells that were ranked with important, medium or low value.

Taxon	Number of cells	IPA cell number (Fig. 7)	Localities name
Alchemilla diademata Rothm.	1	3	Jabal Sannine
Alkanna maleolens Bornm.	1	14	Nahr Beirut
Anthemis didymaea Mouterde	1	32	Towmat Jezzine
Hieracium kneissaeum Mouterde	1	6	Jabal Kneisse
Salvia peyronii Boiss. ex Post	1	45	Jabal Moussa
Senecio mouterdei Arenes	1	33	Wadi Jhannam
Tripleurospermum sannineum (Thieb.) Mouterde	1	3	Jabal Sannine
Allium sannineum Gombault	2	3–6	Jabal Sannine and Jabal Kneisse
Alyssum libanoticum Nyaradi	2	29–40	Qammouaa and Laqlouq
Astragalus ehdenensis Mouterde	2	2–36	Ehden and Qarn Aitou
Cephalaria cedrorum Mouterde	2	21–19	Ain Zhalta and Barouk
Erysimum verrucosum Boiss. & Gaill.	2	11–17	Jabal Hermon
Iris cedreti Dinsm.	2	1–7	Arz Bcharre and Hasroun
Johrenia westii Post	2	25–44	Nahr el-Assi and Ouadi Taniyat er-Ras
Sagina libanotica Rech. f.	2	34–35	Nabaa el-Qamar and Ainata
Centaurea heterocarpa Boiss. & Gaill. ex Boiss.	3	41–42–43	Barr Elias, Aytanit and Marjayoun
Linum carnosulum Boiss.	3	1–22–46	Qornet el-Aachara, Jabal Makmel and Jurd Bcharre
Prunus agrestis (Boiss.) Mouterde	3	37–38–39	Aarsal, Riyeq and Wadi el-Qarn
Senecio exilis Blanche ex Boiss.	3	22–47–48	Jabal Makmel, Qornet es-Sawda and Qornat el-Jamal

Turkey and Cyprus (*North Eastern Mediterranean)* were scored 1, and all other were scored 0 (lowest value). The application of this criterion is based on the assumption that the narrower the range of a given taxon, the greater its conservation priority.

Rarity (R) was also considered at four levels, the species that are known in less than 5 localities within Lebanon were considered very rare (VRARE) and scored 3 (highest value), the species known in 5–10 localities were considered quite rare (QRARE) and scored 2, and the

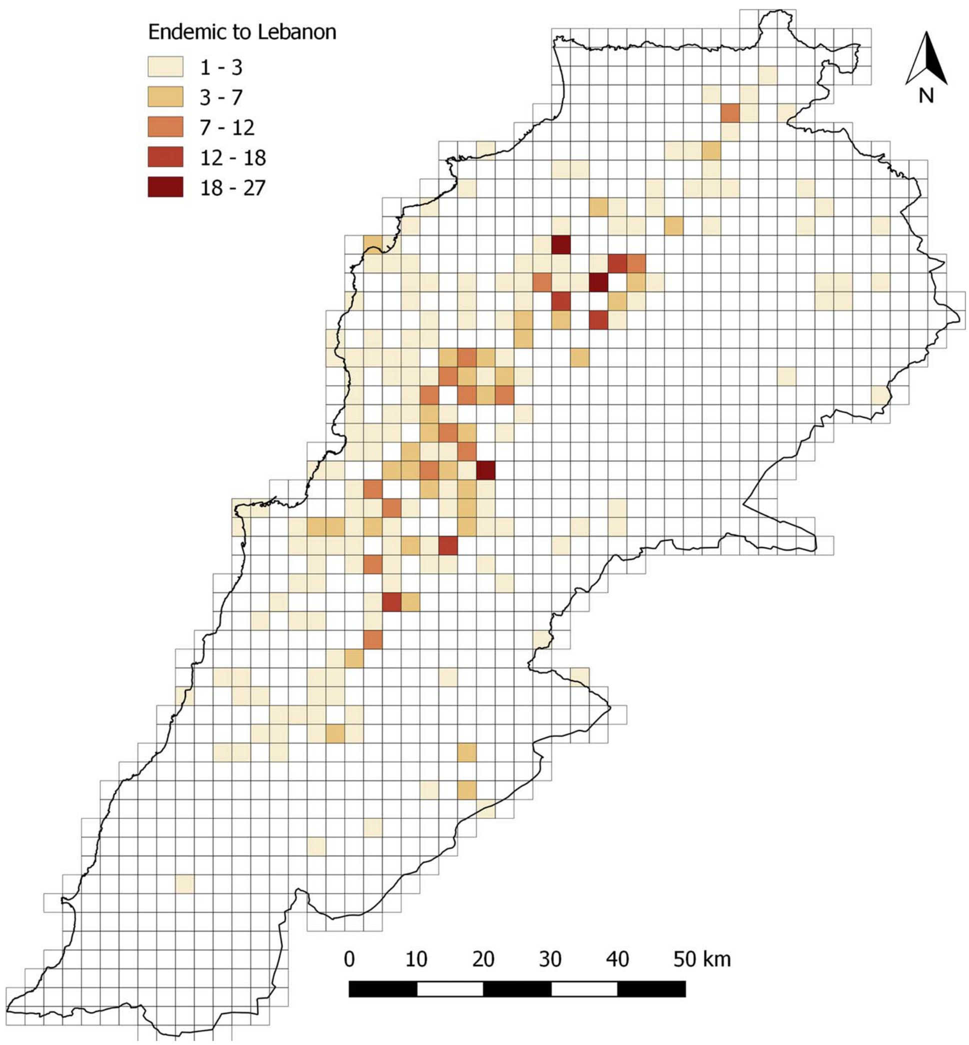

Fig. 6. Map of Lebanon endemic plants.

species known in 10–15 localities were considered rare (RARE) and scored 1. The species known in more than 15 localities were scored 0 (lowest value).

The IPA index was calculated by adding the value of the species richness per cell with all the species and habitat indexes relative to the species and habitats present in each cell.

The IPA index was divided into five classes using the Jenks natural breaks classification method. Class 5 corresponded to very high values of IPA index whereas 1 corresponds to the lowest values.

3. Results

A total of 57582 plant species observations (historical and new data) were gathered to identify the IPAs of Lebanon. This constituted the most comprehensive nationwide dataset available to date.

After initial mapping of the historical data, gap analysis revealed important disparities on botanical knowledge across Lebanon. Further to these observations new fieldwork was carried out from March 2013 to October 2016 in some of the underexplored regions to fill these gaps (Fig. 1). Our field data totalized 18925 new records.

After our fieldwork was completed, many regions still lacked botanical data and 609 cells over 1250 lacked species occurrence. For the 641 cells containing observations, species richness values ranged between 1 and 552 species per cell (Fig. 2). Eight cells had species richness values ranging from 363 to 552 species, 22 cells had values ranging from 200 to 336 species, 82 cells had values ranging from 200 to 100 species, and the remaining 529 cells had values ranging from 1 to 100 species. The cells with the highest species richness were located around Wadi Qadisha area, in the region of Ehmej-Jaj, in the three valleys of Nahr el-Kalb and in Jabal Sannine. The map of the Northeastern Mediterranean endemic plants (Fig. 3) revealed that these endemic species were mostly located on the western slopes of Mount Lebanon, from the coastline to the summits. The map of the Levant endemic plants (Fig. 4) showed that the species were located on both western and eastern slopes of Mount Lebanon from the coastline to the summits, and also on the western slopes of Anti-Lebanon. The map of Lebanon endemic plants (Fig. 5) showed that these species are mainly located in the Mount Lebanon range, on both western and eastern slopes but with a more important density on the highest summits of the mountain range. The highest concentration of species endemic to Lebanon were found in Jabal Sannine with 27 species, in Jabal Makmel with 23 species, in Jabal el-Mnaitre with 18 species and in Jabal Kneisse with 18 species. Only eight species endemic to Lebanon were reported in Jabal Hermon. Species endemic to Lebanon were present in 226 cells, species endemic to the Levant were present in 423 cells, and species endemic to the Northeastern Mediterranean were present in 459 cells. Seven species endemic to Lebanon were present only in one cell, 8 species were present only in two cells and 4 were present only in three cells (Table 1). Eleven of these species were present in 16 cells that were not ranked into class 4 or 5. They were added on the map and numbered from 32 to 48.

Table 2
List of the 31 top ranked IPAs. From 1 to 11 IPA index class 5, from 12 to 31 IPA index class 4. Each IPA is characterized by its IPA-INDEX, species index (SP_INDEX); species richness (SP_RICHNESS); RICHNESS_INDEX; habitat index (HAB_INDEX); N, number of species endemic to Lebanon; Habitat types: A − Cedar forest, rocky mountain slopes; B − Coastal area; C − Dense mountain woodland; D- High mountain plateau; E − High mountain plateau, cedar forest; F − Junipers, fir and cedar forest; G − Sparse mountain woodland; H − Steep and relatively preserved valley; I − Sub-arid mountain slopes.

IPA cell rank	Localities	IPA INDEX	SP_INDEX	SP_RICHNESS	RICHNESS_INDEX	HAB_INDEX	N	Habitat types
1	Jabal Makmel, Bcharre Cedars	760	748	490	5	7	23	E
2	Ehden, Foum el-Mizab	752	742	552	5	5	22	E
3	Jabal Sannine	673	664	363	5	4	27	D
4	Nahr el-Kalb	586	573	446	5	8	5	H
5	Wadi Qadisha	525	514	418	5	6	11	H
6	Jabal Kneisse	495	488	300	4	3	18	D
7	Jbal Mneitre, Jourd Hasroun	485	479	374	5	1	18	D
8	Tyr Coast	471	465	253	4	2	0	B
9	Nahr el-Kalb, Bikfaya, Hemlaya	461	446	431	5	10	9	H
10	Ehmej, Jaj	455	442	417	5	8	10	G
11	Jabal Hermon, Rachaya	435	426	259	4	5	4	D
12	Nahr Beirut	395	381	336	4	10	2	H
13	Nahr Beirut	393	380	285	4	9	5	H
14	Nahr Beirut	363	352	261	4	7	6	H
15	Saofar, Qraye, Roueissat	353	341	296	4	8	8	G
16	Nahr el-Kalb, Baskinta	348	336	327	4	8	10	H
17	Jabal Hermon	332	327	191	3	2	7	D
18	Ehmej	317	305	329	4	8	12	C
19	Jabal Barouk, Maaser ech-Chouf	306	292	264	4	10	8	A
20	Nahr Ibrahim, Lessa, Janne, Qartaba	300	283	295	4	13	11	H
21	Ain Zhalta, Ain Dara, Bmahray	293	275	305	4	14	13	A
22	Jabal Makmel	289	284	125	3	2	16	D
23	Wadi el-Harir	286	279	138	3	4	1	I
24	Nahr Damour	284	271	317	4	9	1	H
25	Wadi Taniyat er-Ras, Ras Baalbek	277	272	116	3	2	2	I
26	Hadeth el-Jebbe Cedars, Tannourine	270	254	275	4	12	2	A
27	Jbeil Coast	262	248	219	4	10	3	B
28	Bmahray	259	249	190	3	7	5	A
29	Jabal Akkar, Qammouaa	254	238	211	4	12	4	F, A
30	Qobayat	250	238	120	3	9	4	F
31	Qaa	242	239	104	3	0	2	I

3.1. Number of ranked cells

The IPA index values ranged between 0 and 760 and it was divided into five classes using the Jenks natural breaks classification method. Jenks natural breaks classification method (1967) that maximizes the variance between classes and minimizes the average of the variance within each class gave the best representation of IPAs since our data set is not distributed uniformly (Basher et al., 2017; Mendoza-Fernandez et al., 2010). This method classified 11 cells in class 5 (very high value) of IPA index ranging from 396 to 760, 20 cells into class 4 (high values) ranging from 225 to 396, 61 cells into class 3 (important values) ranging from 101 to 225, 182 cells were classified into the class 2 (medium values) ranging from 29 to 101 and the 956 other cells were classified into the class 1 (low values) ranging from 0 to 29 (Fig. 6). The details of the top ranking cells are reported in Table 2. The cells ranked in class 5 contained a total of 1827 species, including 56 species endemic to Lebanon amounting to 61% of the species of the flora of Lebanon along with 69% of the 91 national endemic species. Cells ranked in classes 4 and 5 contained a total of 2386 species amounting to 79% of the flora of Lebanon and 80% of the species endemic to Lebanon.

3.2. Natural protected areas preserve some IPAs

The 36 protected areas of Lebanon (MoE/UNEP/GEF, 2016), including natural reserve and protected sites, but excluding *himas* (community based protection), had an area that covered 2.8% of the total area of the country. A comprehensive map of protected areas is shown together with IPAs localization in Fig. 7. Only five of the protected areas were partially or totally included into four of the cells with an IPA index of class 5 (very high value). These protected areas were Horsh Ehden, Bcharre Cedars, Jaj Cedars, Ehmej Dichar and Tyre Coast. Four protected areas were partially or totally included into five cells of class 4 (high IPA index value), which were Hadeth el-Jebbe Cedars, Tannourine Cedars, Qammoua and Al-Chouf Cedars which intersected with three cells in Bmahray, Ain Zhalta, Jabal Barouk, Barouk and Maaser ech-Chouf. Only 26% of the 31 cells of very high value and high value were already designated as protected areas and these hosted 1362 species equating to about 45% of Lebanon plant species. Seven cells with a very high value and 15 with a high value were outside any protected areas. One hundred seventy-eight km^2 distributed into 22 cells (15 cells of class 4 and 7 cells of class 5) each with an area of $9\,km^2$, lacked legal protection. Eleven other protected areas were partially or totally included into twelve cells of important value (class 3), which were Horsh Ehden, Tannourine Cedars, Yammoune, Ras Chekka cliffs, Bentael, Jabal Moussa, Machaa Chnaniir, Ammiq wetlands, Al-Chouf Cedars (two cells including Dahr el-Baidar and Qabb Elias), Debbin and Sarada Metropolite Geawargios Haddad. Two protected areas, Jabal Rihan and Wadi Houjair, lacked data and their cells were not ranked.

4. Discussion

A map of plant distribution based on historical and new data was generated and covered 55% of Lebanon's surface area. A customised methodology to identify IPAs was developed to suit the scale and geomorphological complexity of Lebanon. The narrower the range of a given taxon, the greater its conservation priority and the local responsibility (Gauthier, Debussche, & Thompson, 2010). As envisioned, the grid of $3 \times 3\,km^2$ used to generate the map is precise enough to be used as a decision tool for stakeholders, practitioners and politicians involved in biodiversity conservation at district (caza) and municipality levels.

Thirty-one cells ranked into classes 4 and 5 were considered to be the most Important Plant Areas in Lebanon. They were mainly steep

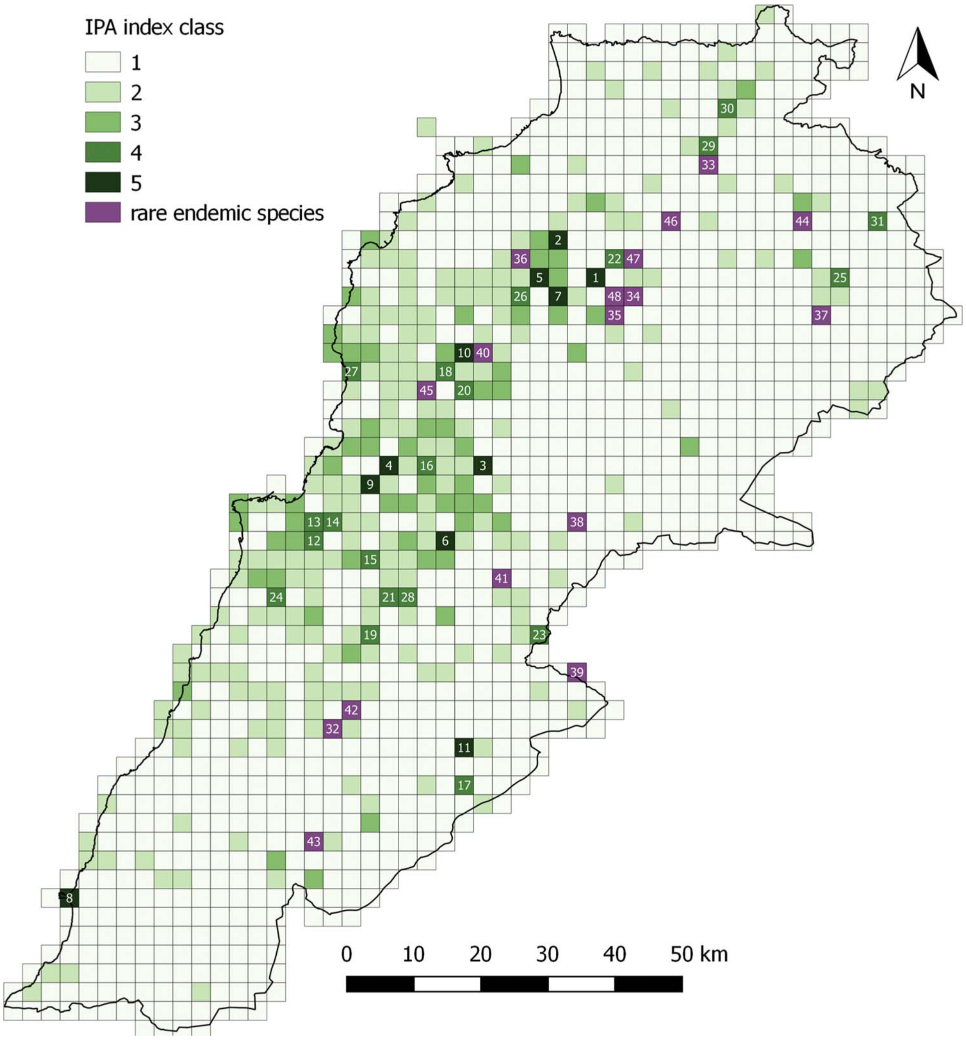

Fig. 7. Important Plant Areas in Lebanon using data on vascular plants and habitats. The color indicates the ranking of the cells: in dark green high ranking, in light green the low ranking cells. White cells contain no data.

and relatively preserved valleys (28% of the IPAs), high mountain plateaus (19% of the IPAs), cedars forests sub-arid slopes and two coastline areas. High mountain screes and deep limestone gorge habitats are of particular importance in the region as they are home to unique vegetation, including relict species from the tertiary era (Bou Dagher-Kharrat et al., 2013). Many unexplored regions however hide likely important plant diversity and are yet to be surveyed. For example, the eastern slopes of Mount Lebanon that have representative natural habitats, like the slopes of Wadi el-Fouara, or the woodlands of *Juniperus excelsa* M. Bieb of Barqa and on the Jurd of Hermel will undoubtedly include areas of high plant diversity (Fig. 8).

More than 48% of the cells lacked species occurrence data. These gaps could lead to shortcomings in protected areas design (Grand et al., 2007). Many regions located near Lebanon's borderlines, were not visited due to security concerns and thus historical references constituted most of the data for these parts. The sampling effort gave priority to the most preserved areas from the coast to the highest summits, whereas little priority was given to the intensively cultivated areas, explaining the lack of data from the plains of Akkar, Koura, South Lebanon and the Beqaa. The urbanized regions were also mostly avoided except if located next to preserved valleys and rivers.

Our results showed that 74% of the 31 top ranked cells (classes 4 and 5) lacked governmental official protection. These cells should be placed on top of the national conservation plans to ensure the preservation of the endangered species and habitats types located in these areas.

Plant species endemic to Lebanon that were reported only in one, two or three cells were not always present in cells having very high or high IPA index values. Eleven of these species were present into 18 cells that were ranked with important, medium or low values (Fig. 6). The areas sheltering such rare endemic species should also be considered as priority areas for conservation, although the absence of exhaustive botanical data didn't rank them as IPAs (Table 1).

Many herbarium samples from the historical data set lacked precise geographical coordinates. The ranking of some cells should be extended to neighbouring cells. In the case of mountain IPAs only one cell had an important ranking whereas most part of the plateau should be ranked equally. The same problem is encountered with river valleys; the ranking should be extended to the neighbouring cells covering the entire valley and should be considered as an individual IPA.

Mount Hermon (Jabal ech-Cheikh) like the entire Anti-Lebanon mountain range was the less explored region due to security reasons and also lacked historical and recent data. This mountain range is recognized as IPAs since it shelters many species characteristics to a sub-arid climate that are endemic to both Lebanon and Syria. Talaat Moussa and the Jurd of Nahle were especially representative of this under-explored richness.

When comparing our results to a previous bibliographic study that featured 20 IPAs of Lebanon (Radford et al., 2011), we conclude that four of these IPAs are not highlighted in our study. Two of them, Mengez (Nahr el-Kabir) and Jabal Rihan did not stand out as IPAs in our results due to the lack of factual botanical data on these regions. The remaining two, Beirut coast and the Palm Islands were not considered in our study. The Beirut coast used to be an Important Plant Area;

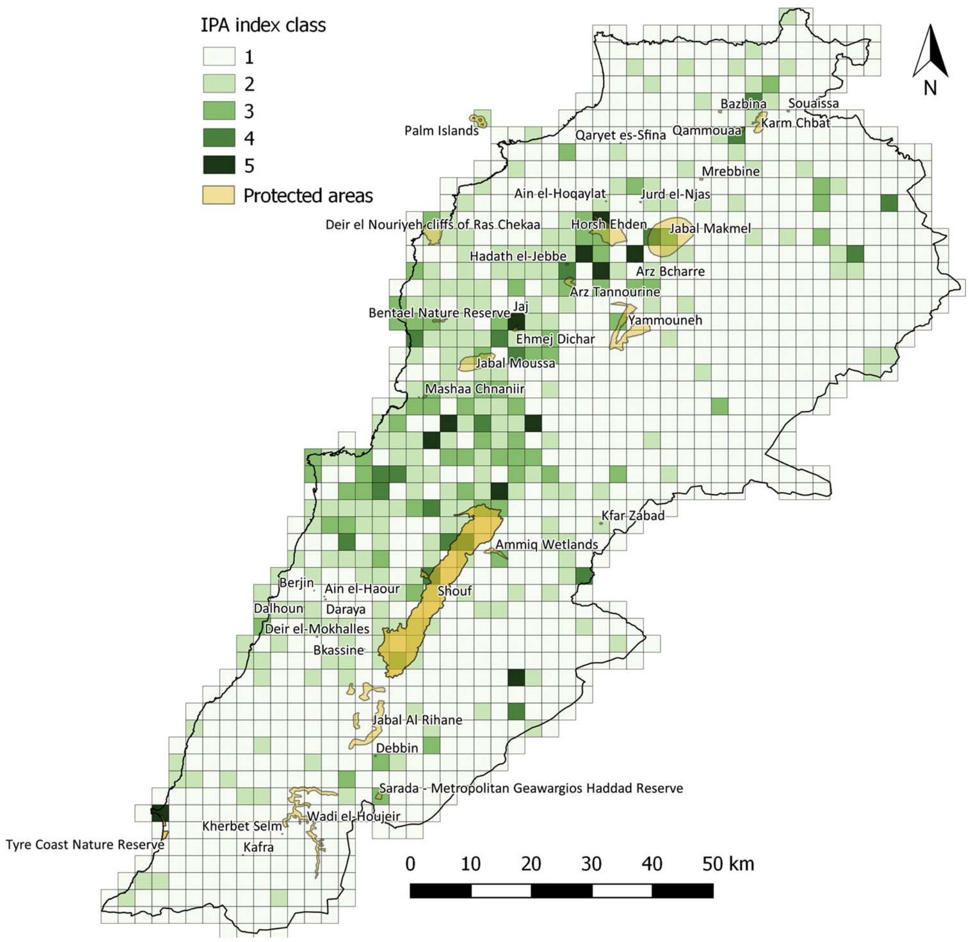

Fig. 8. Important Plant Areas and protected sites in Lebanon.

however, its natural coastal habitats that are rich in endemic species were completely destroyed by urbanization (Bou Dagher Kharrat et al., 2015; Ladki & El Meouchi, 2013). Few scattered pouches that shelter rare species like *Matthiola crassifolia* Boiss. & Gaill., an endemic species to the coast of Lebanon, still exist in Beirut. Urgent conservation measures must be taken to save these species in Beirut. The flora observed in Palm Islands does not contain trigger species and was not recognized as an IPA. However, these islands should be systematically monitored to preserve the rich and threatened fauna that they shelter (MOA-PNUE, 1996).

5. Conclusion

Anthropogenic disturbances jeopardize, as elsewhere, biodiversity conservation within the Lebanese biodiversity micro-hotspot (Cincotta, Wisnewski, & Engelman, 2000). Cognizant of the necessity to conserve the degrading ecosystem and the depleting biodiversity of Lebanon and given constrained resources, priorities must be set for conserving species and habitats. Collecting and organizing reliable distributional data is the first and crucial stage of any conservation planning action: without reliable information of where species live, it is impossible to know which taxa are endangered and where to concentrate efforts to preserve them (Grand et al., 2007). IPAs are intended to identify areas of exceptional botanical richness with viable populations using standard criteria. They provide a framework to assess the effectiveness of conservation activities for plants, and target sites for future conservation action (Palmer & Smart, 2001).

The mapping of IPAs constitutes a spatial planning and rational tool for decision-makers in preserving our natural heritage for future generations. Our results highlighted the fact that many IPAs lacked governmental protection. Conservation measures should be taken quickly as these natural areas are facing imminent threat from unregulated urbanization. Still, many underexplored regions shelter important plant diversity and botanical surveys must be urgently conducted to promote conservation priorities. This study demonstrated the usefulness of continuously evaluating IPAs since unexplored regions can be newly designated as plant hotspots whereas previously recognized IPAs no longer exist.

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References

Ammar, W., Kdouh, O., Hammoud, R., Hamadeh, R., Harb, H., Ammar, Z., et al. (2016). Health system resilience: Lebanon and the Syrian refugee crisis. *Journal of Global Health, 6*, 1–9.

Anderson, C. L. (2002). *Identifying important plant areas: A site selection manual for europe, and a basis for developing guidelines for other regions of the world.* Plantlife International.

Basher, K., Nieto-Hipolito, J., Leon, M., Vazquez-Briseno, M., López, J., & Mariscal, R. (2017). Major existing classification matrices and future directions for internet of

things. *Advances in Internet of Things, 7*, 9.
Blasi, C., Marignani, M., Copiz, R., Fipaldini, M., Bonacquisti, S., Del Vico, E., et al. (2011). Important plant areas in Italy: From data to mapping. *Biological Conservation, 144*, 220–226.
Bou Dagher Kharrat, M., El Zein, R., El Jeitani, S., Khater, K., Ghossoub, R., Mansour, S., et al. (2015). Prioritizing areas for the conservation of mediterranean coastal biodiversity under high urbanization pressure. *Generating a risk and ecological analysis toolkit for the mediterranean, Final Dissemination Conference*.
Bou Dagher-Kharrat, M., Abdel Samad, N., Douaihy, B., Bourge, M., Siljak-Yakovlev, S., & Brown, S. C. (2013). Nuclear DNA C-values for biodiversity screening: Case of the Lebanese flora. *Plant Biosystems, 147*, 1228–1237.
Cincotta, R. P., Wisnewski, J., & Engelman, R. (2000). Human population in the biodiversity hotspots. *Nature, 404*, 990–992.
Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., et al. (2014). Changes in the global value of ecosystem services. *Global Environmental Change, 26*, 152–158.
Al Handasah, D. (2002). In I. I.d.a.e.d.u.d.l.r. d'ile-de-France (Ed.). *Land use land cover map*Beirut: Lebanon Ministry of Agriculture & National Council for Scientific Research [pp. mapped using Landsat and IRS satellite images acquired in 1998].
Faour, G. (2015). Evaluating urban expansion using remotely-sensed data in Lebanon. *Lebanese Science Journal, 16*, 23–32.
Gauthier, P., Debussche, M., & Thompson, J. D. (2010). Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation, 143*, 1501–1509.
Grand, J., Cummings, M., Rebelo, T. G., Ricketts, T. H., & Neel, M. C. (2007). Biased data reduce efficiency and effectiveness of conservation reserve networks. *Ecology Letters, 10*, 364–374.
Hijmans, R. J., Guarino, L., Bussink, C., Mathur, P., Cruz, M., Barrentes, I., et al. (2004). *A geographic information system for the analysis of species distribution data.* [Vsn. 5.0. ed.].
Kareiva, P., Watts, S., McDonald, R., & Boucher, T. (2007). Domesticated nature: Shaping landscapes and ecosystems for human welfare. *Science, 316*, 1866–1869.
Ladki, S., & El Meouchi, P. (2013). Assessment of coastal resorts development: The case of Lebanon. *Journal of Tourism and Hospitality Management, 1*, 36–43.
Luck, G. W. (2007). A review of the relationships between human population density and biodiversity. *Biological Reviews, 82*, 607–645.
Médail, F., & Quézel, P. (1997). Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. *Annals of the Missouri Botanical Garden, 84*, 112–127.
MOA-PNUE. (1996). Etude de la diversité biologique du Liban. Projet GF/6105-92-72. In M. d. l. a. P. d. N. U. p. l'Environnement (Ed.).
Marignani, M., Bacchetta, G., Bagella, S., Caria, M. C., Delogu, F., Farris, E., et al. (2014). Is time on our side? Strengthening the link between field efforts and conservation needs. *Biodiversity and Conservation, 23*, 421–431.
Mendoza-Fernandez, A., Pérez-Garcia, F. J., Medina-Cazorla, J. M., Martinez-Hernandez, F., Garrido-Becerra, J. A., Sanchez, E. S., et al. (2010). Gap Analysis and selection of reserves for the threatened flora of eastern Andalusia: A hot spot in the eastern Mediterranean region. *Acta Botanica Gallica, 157*, 749–767.
MoE/UNEP/GEF. (2016), National Biodiversity Strategy and Action Plan − NBSAP. In M. o. Environment (Ed.). Beirut: Ministry of Environment.Mouterde P. 1966. *Nouvelle flore du Liban et de la Syrie* [New flora of Lebanon and Syria], Vol. 1. Beyrouth: Éditions de l'Imprimerie Catholique.
Mouterde, P. (1970). *Nouvelle flore du Liban et de la Syrie [New flora of Lebanon and Syria], vol. 2*. Beyrouth: Dar El-Machreq.
Mouterde, P. (1966). *Nouvelle flore du Liban et de la Syrie [New flora of Lebanon and Syria], vol. 1*. Beyrouth: Dar El-Machreq.
Mouterde, P. (1984). *Nouvelle flore du Liban et de la Syrie. [New flora of Lebanon and Syria], Vol. 3*. Beyrouth: Dar El-Machreq (Imprimerie Caholique).
Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*, 853–858.
Palmer, M., & Smart, J. (2001). Guidelines to the selection of important plant areas in Europe. *Planta Europa*.
QGIS (2016), QGIS Geographic Information System, O.S.G.F. Project (ed.).
Radford, E. A., Catullo, G., & de Montmollin, B. (2011). In I. Malaga (Ed.). *Important Plant Areas of the south and east Mediterranean region: Priority sites for conservation*.
Senterre, B., Henriette, E., (2015). Key Biodiversity Areas (KBAs) of the main granitic islands of Seychelles: An illustrated booklet. In (Government of Seychelles, UNDP-PCU ed.). Seycehlles.
Sodhi, N.S., Brook, B.W., Bradshaw, C.J.A., (2009). Causes and consequences of species extinctions. In S.e.C. Levin, S.R., H.C.J., Godfray, A.P., Kinzig, M., Loreau, J.B., Losos, B., Walker, D.S. Wilcove (assoc. eds.). (Ed.), The Princeton Guide to Ecology (pp. 514-520). Princeton, New Jersey, USA: Princeton University Press.
Tohmé, G., & Tohmé, H. (2004). Recherches sur le statut actuel des plantes endémiques du Liban. *Archeology & History in Lebanon,* 64–69.
Tohmé, G., & Tohmé, H. (2011). Nouvelles recherches sur la flore endémique et naturalisée du Liban. *Lebanese Science Journal, 12*, 133–141.
Tohmé, G., & Tohmé, H. (2014). *Illustrated flora of Lebanon* (2 ed.). CNRSL.
Venter, O., Sanderson, E. W., Magrach, A., Allan, J. R., Beher, J., Jones, K. R., et al. (2016). Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nature Communications, 7*, 12558.