International Journal of Environmental Science and Technology (2023) 20:9465–9480
https://doi.org/10.1007/s13762-023-04981-y

ORIGINAL PAPER

Analysis of Iran's biosphere reserves based on representative criteria and proposal of new options

M. Alborzi Manesh[2] · J. Imani Harsini[2] · A. DanehKar[3] · M. Robati[2] · A. Alambeigi[4]

Received: 15 November 2022 / Revised: 27 March 2023 / Accepted: 5 May 2023 / Published online: 12 July 2023

Abstract

Man and the Biosphere Program (MaB) was established by UNESCO in the early 1970s to resolve the conflict between humans and nature. The biogeography representative was determined by UNESCO/MaB as one of the main criteria for registering an area as a biosphere reserve (BR). Therefore, countries require selecting appropriate areas for BRs to complete the criterion of representativeness of the global biogeography protection network. This study aimed to analyze the study process of biogeography representatives at the global and national levels based on the research objectives. The results revealed the necessity of combining the map of Iran's biogeography produced at the global level with the map of the macroecosystems of national production to identify the representative ecosystem units (REUs). The production of this map led to the identification of 112 REUs in the country. The compliance maps of BRs and REUs showed that 13 BRs of the country have covered only 23% of Iran's REUs. The results of the studies of biogeography provenances, biological hot spots and ecoregions led to the definition of 5 quantitative indicators for screening and prioritizing the country's REU. The description of this issue, which is very brief in the abstract, is given in the text of the article. A total of 18 REUs were specified with priority for selecting new BRs using identified indicators and Entropy Shannon VIKOR models. Based on the results, 27% of the REUs proposed can be covered by modifying existing BRs boundaries. All proposed BRs could select more than one REU. In addition, 15 REUs with about 17% of the country's area may be covered with the registration of seven new priority BRs.

Keywords Representative ecosystem units · Biogeography · Ecoregion · Representative criterion · Iran biosphere reserves

Introduction

UNESCO (1964) defined a 5-year program at the global level under the title "Biological foundations of productivity and human well-being" UNESCO 2022; Udvardy 1975). This research program aimed to develop studies on the dynamics of ecosystems in their biogeography system and the consequences of their destruction on life. The necessity of preservation of the diversity of the inhabited biogeographic system based on this research became the basis of the World Conference of Biosphere in 1968 (UNESCO 1993). The results of this conference showed the destructive effects of human activities on biogeographic Realms and biomes that support biodiversity and life in the biosphere and also the conflict between the interests of people and protected areas. In addition, a new conservation program called Man and the Biosphere (MaB) was introduced (UNESCO 1964) and the biosphere reserves were registered in 1976 by UNESCO. The MaB program pioneered the approach of protecting the biogeographical system of the world along

Editorial responsibility: Samareh Mirkia.

✉ J. Imani Harsini
jalil.imani@srbiau.ac.ir

1 Environmental Land Use Planning, Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran

2 Department of Environmental and Forest Sciences, Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran

3 Environment Department, Agriculture and Natural Resources Campus, University of Tehran, Tehran, Iran

4 Economics and Agricultural Development, Department of Agricultural Extension and Education, Agriculture and Natural Resources Campus, University of Tehran, Tehran, Iran

5 Tehran, Iran

with sustainable development and protecting biocultural values, which abandoned the one-dimensional approach of protecting nature and paid attention to humans as well (UNESCO 1977; Meffe et al. 1995). The MaB program is an intergovernmental scientific program for creating a scientific foundation to strengthen the relationship between people and their natural environment. The MaB combines natural and social sciences to protect natural ecosystems and improve human livelihoods creatively and innovatively in land management. Therefore, innovative approaches are promoted in this program for economic development, which are socially and culturally appropriate and environmentally sustainable (UNESCO 2022). Biosphere Reserves are areas of terrestrial, coastal, or marine ecosystems with the objectives of conservation, sustainable economic development, research, and education based on triple zoning (UNESCO 2020). The representative criterion of global biogeographical diversity is one of the basic policy conditions of the MaB program for registering BRs (WNBRMinsk, 1983; UNESCO/MaB, 2013)[1].

In the 1960s and 1970s, selecting areas and even appropriate conservation titles was rarely based on the evaluation of biogeographic representative areas (Margules and Sarkar 2000; Rodrigues et al. 2004). Therefore, the protected areas were mainly selected from among the natural habitats that had little contribution to biodiversity protection (Soul and Terborgh 1999; Alborzimanesh et al. 2021; Margules et al. 2002).

Institutions such as WWF, IUCN, UNESCO/MaB, and Ramsar Convention aim to establish global scientific foundations of theorizing to identify the biogeography diversity, and land protection classifications, and monitor the challenges, create a global communication network for the exchange of experiences. The responsibility of the countries as the constituent parts of the unit body for protecting biogeographical values is to select, introduce, register, and manage different protection titles in the specific field of the countries.

Three spatial approaches in land conservation planning, including biogeographic provinces (186 provinces), biological hot patches (2.3% of the Earth's surface), and ecoregions, were developed to select and introduce protected areas on a global scale and over time. The origins of the biogeography provinces approach included the Dasmann-Udvardy framework, which was developed between 1970 and 1975. The biological Hot patches and the International Endemic Bird Area approaches (IUCN-WWF) were developed between 1982 and 1992.

In addition, the ecoregion approach was developed based on Omernik and Bailey and WWF frameworks between 1985—2001. The map of ecoregions provides comprehensive coverage (867 ecoregions) for global and regional conservation planning (Olson et al. 2001).

The studies of Sayer (2020) continued the previous studies (Sayre et al. 2014, 2017), to identify and introduce 431 global terrestrial ecosystems based on the variables of temperature, humidity, landform, vegetation and land use. These studies have emphasized that many governments or non-governmental organizations use WWF ecoregions to select conservation areas. At the same time, it is more efficient to identify ecosystems at the local and national levels. In a case comparison for Kenya, the ecosystems that were identified based on these studies were 98 ecosystems against 13 WWF ecoregions.

When each country's biodiversity covers its network of protected areas in appropriate locations, it can act as an ecosystem representative unit and complete the global protection network. The approach of representing the network of protected areas is based on the diversity of genes, species, and biological communities, as well as the processes and functions which support the potential of the evolution of natural systems to cover a complete variety of independent ecosystems in their geographical area (Olson et al. 2001). Representativeness for selecting protected areas has been emphasized in several studies (IUCN, Dasmann 1972, 73, IUCN 1974, 1978, 1980, 1992; Salm and Price 1995; Olson et al. 2001; Chape et al. 2005; IMO 2005; Dinerstein et al. 2017; Sayer 2020; Takhtajan 1986; Longhurst 2007; Baile 2009; Metzger et al. 2013; Sayre et al. 2014, 2017). In most of these studies, while emphasizing the importance of global divisions of biogeography as the basis of studies, the exploitation of regional and national studies has been emphasized to identify representative ecosystems of biogeography.

Some countries have identified representativeness in the range of biogeographical diversity of their country to select protected areas while paying attention to global classifications (Shrestha et al. 2010; Djamali et al. 2011; Azizi Jalilian et al. 2021, Blasi et al. 2014, 2017; Aycrigg et al. 2013; Herbada et al. 2011; Rogers and Singers 2014, Capotorti et al. 2012).

Iran as one of the countries in the Asia and Pacific MaB region joined the MaB program in 1976 and has registered 13 BRs by 2022, all of which have other national protection titles. Table 1 shows the characteristics of BRs in Iran (Goshtasb et al. 2018).

The representativeness criterion of biogeography has not been identified in the resources related to the BRs of Iran. Recent studies in which the divisions of Iran's biogeography are presented in the form of a map include the ecoregions

[1] World Network of Biosphere Reserves (WNBR).

Table 1 Characteristics of Iran's Biosphere Reserves (UNESCO 2022)*

No	Name of BR	Area (ha)	Degree of protection in Iran	Year of admission in MaB
1	Arasbaran	80,646.5	NP & PA	1976
2	Arjan and Paridhan	91,860	PA & RS	1976
3	Urmia	1,077,900	NP & RS	1976
4	Golestan	155,804	NP & PA	1976
5	Miankaleh	96,678	WR& RS	1976
6	Harra	206,243	PA & RS	1976
7	Genov	81,582	PA	1976
8	Touran	145,950.55	NP & WR& PA	1976
9	Kavir	691,163	NP & PA	1976
10	Dena	255,537	NP & PA	2010
11	Tange Sayad and Sabzkoh	559,878	NP & PA	2015
12	Hamoun	977,167	WR& RS	2016
13	Kopet Dagh	34,484	PA	2018
Total		5,768,448	10 national parks, 10 protected areas, 3 wildlife Refuges, 5 Ramsar sites	1976–2018
Occupancy level in Iran		0.36%		

*https://en.unesco.org/biosphere/wnbr.2022

NP: National Park WR: Wildlife Refuge PA: Protected Area RS: Ramsar Site

(Olson et al. 2001) and the macroecosystems studies of Iran (Azizi et al. 2020). Based on the results of the review of the sources, none of these studies alone are sufficient to select the representative biosphere reserves in the country. Olson's ecoregions based on two features, the distribution of species and the distribution of ecosystem units based on biogeography and ecological regions, have been produced, but in accordance with the topographical map of Iran, it is not accurate enough to introduce biogeographical divisions. Azizi Jalilian macroecosystems have been produced based on the Country's landform, 30 climates, and the latest vegetation information, and are more accurate at the national level. In the studies of Sayre et al. (2020), it has been emphasized that the exploitation of WWF ecoregions in conservation planning is not sufficient and there is a need to exploit ecosystems at the national level as well.

Therefore, this study aimed to design a suitable biogeographical classification spatial framework to evaluate the representativeness criterion as a basic condition for selecting and covering natural ecosystems by BRs and predicting the capacity of new BRs for future decisions which has not been done for Iran so far.

Materials and methods

This analytical-documentary study was based on a map of representative ecosystem units (REU). Although the performance of this study is evaluated for the country of Iran, its results can facilitate the selection process of BRs at the international level. First, the most well-known divisions of biogeography that can be used to select BRs were reviewed, and the common coverage of existing BRs with them was considered. Then, the REU was determined for the country of Iran, the common coverage of BRs and the selection of future BRs were evaluated, and a decision algorithm was prepared.

The biogeography provinces of Udvardy's, which were emphasized in the documents of the MaB for BRs selection, were examined. This macroscopic classification can be used on a global scale. Udvardy presented the biogeography approach based on biogeography provinces identification (186 units) in the form of 8 Realms and 14 biomes.

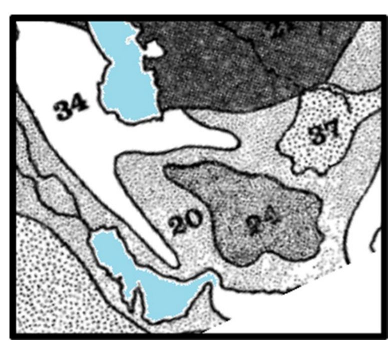

Fig. 1 General location of biogeographic provinces in the territory of Iran (Udvardy 1975) code 20: Anatolian-Iranian Desert; code 21: Turanian; code 34: Caucaso-Iranian Highlands

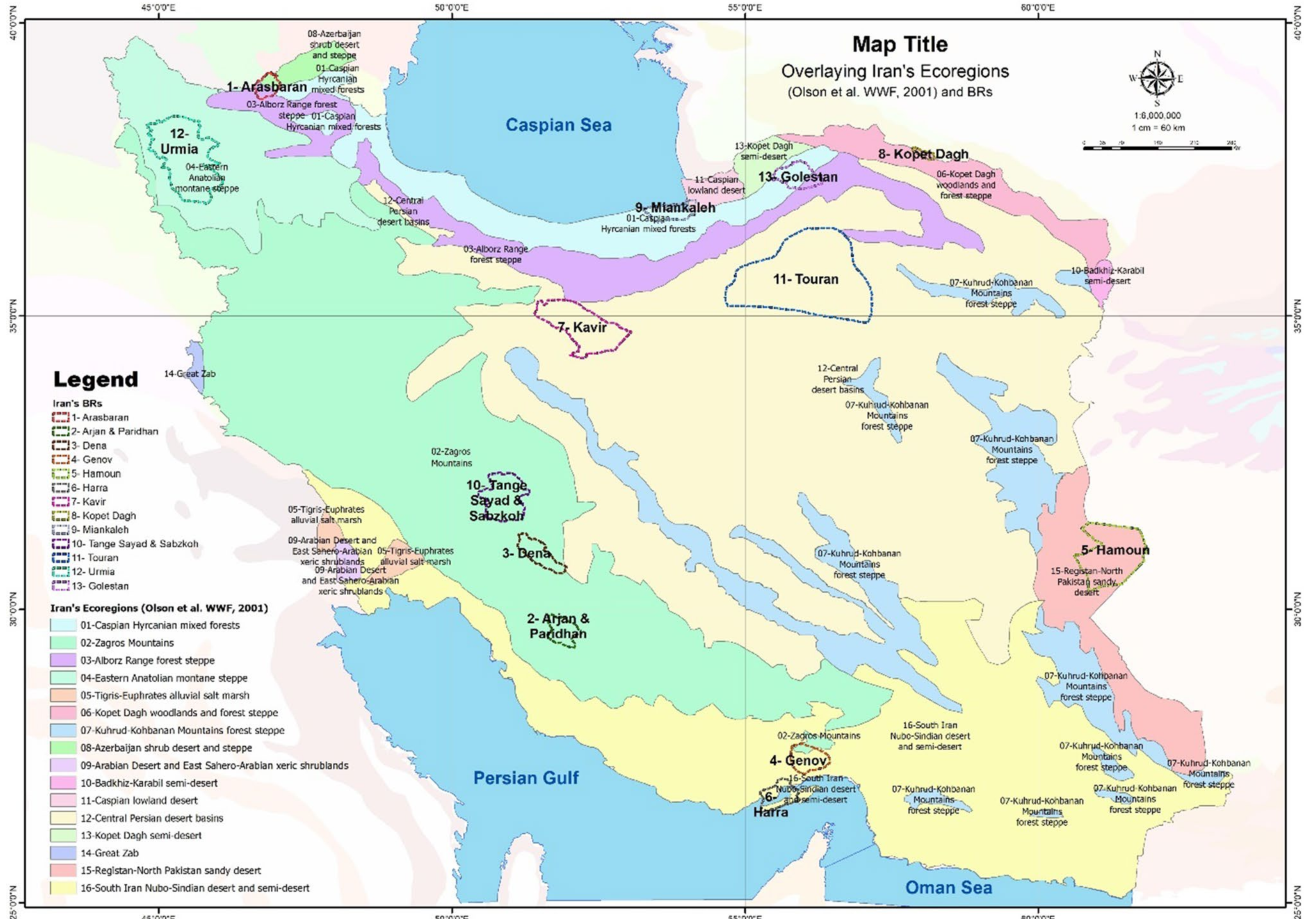

Fig. 2 Ecoregions identified in Iran (Dinerstein 2017; Olson 2001) along with Iran's BRs

Table 2 Ecoregions of Iran (Olson et al. 2001; Dinerstein, et al. 2017)

Biome	Ecoregion	Abbreviations
1.Palearctic Temperate Broadleaf and Mixed Forests	1.Caspian Hyrcanian Mixed Forests	CHM
	2.Zagros Mountains Forest Steppe	ZMF
2.Palearctic Temperate Coniferous Forests	3. Alburz Range Forest Steppe	ARF
3.Palearctic Temperate Grasslands, Savannas, And Shrublands	4.Eastern Anatolian Montane Steppe	EAM
4.Palearctic Flooded Grasslands and Savannas	5.Tigris–Euphrates Alluvial Salt Marsh	TEA
5.Palearctic Montane Grasslands and Shrublands	6.Kopet Dag Woodlands and Forest Steppe	KDW
	7.Kuh Rud and Eastern Iran Montane Woodlands	KRE
6.Palearctic Deserts and Xeric Shrublands	8.Azerbaijan Shrub Desert and Steppe	ASD
	9.Arabian Desert	ADE
	10.Badghyz and Karabil Semi-Desert	BKS
	11.Caspian Lowland Desert	CLD
	12.Central Persian Desert Basins	CPD
	13.Kopet Dag Semi-Desert	KDS
	14.Mesopotamian Shrub Desert	MSD
	15.Registan–North Pakistan Sandy Desert	RNP
	16.South Iran Nubo–Sindian Desert and Semi-Desert	SIN

Table 3 Terrestrial ecosystems of Iran at the National level (Azizi Jalilian et al. 2020)

Code	Ecosystem name	Dominant vegetation type	Abbreviations
01	Humid & Semi-Humid Forests Ecosystem	Carpinus betulus	HSF
02	Arid & Semi-Arid Forests Ecosystem	Quercus brantii	ASF
03	Cold—Desert Woodland & Shrublands Ecosystem	Amygdalus spp.	CDW
04	Warm—Desert Woodland & Shrublands Ecosystem	Haloxylon sp	WDW
05	Moderate—Desert Woodland & Shrublands Ecosystem	Acacia tortilis	MDW
06	Arid Scrubland & Halophytes Ecosystem	Artemisia sieberi–Salsola spp.	ASH
07	Cold—Desert Steppe Scrubland Ecosystem	Artemisia sieberi–Zygophyllum sp.	CDS
08	Cold & Arid Semi-steppe Scrubland & Grasslands Ecosystem	Astragalus spp.	CAS
09	Warm & Arid Shrubland & Scrublands Ecosystem	averniera spp.–Tephrosia sp.	WAS
10	Cold & Humid Prairies Ecosystem	Trifolium spp.	CHP
11	Cold & Humid Cushion Scrublands Ecosystem	Astragalus spp.–Daphne sp.	CHC
12	Moderate—Semi-humid Bare Lowlands Ecosystem	–	MSB
13	Warm & Arid Bare Hills Ecosystem	–	WAB
14	Humid & Moderate Bare Hill Lowlands Ecosystem	–	HMB
15	Semi-arid & Cold Bare Mixed Plains Ecosystem	–	SCB
16	Warm & Arid Bare Mountain Hills Ecosystem	–	WAM
17	Moderate & Arid Bare Mountain Plains Ecosystem	–	MAM
18	Moderate & Arid Bare diverse land forms Ecosystem	–	MAD
19	Moderate & Arid Bare Sparse Mountains Ecosystem	–	MAS
20	Cold & Arid Bare Mountains Ecosystem	–	CAM
21	Warm—Desert Bare Hill Mountains Ecosystem	–	WDB

Figure 1 presents the range of three geographical provinces of Udvardy in Iran .

Olson's ecoregions map as a regional classification indicated that Iran is in the Palearctic realmand includes 16 terrestrial ecoregions (Table 2) ((Dinerstein 2017; Olson 2001). Figure2 demonstrates the location of 16 ecoregions identified in Iran and registered BRs in Iran.

Azizi Jalilian et al. (2020) published their research at the national level in this regard. This study used the information layers of the landform, the 30 climates of the country, and the vegetation map (Natural Resources and Watershed Organization) with a scale of 1:1,000,000 to divide Iran's macroecosystems. Based on the results, 21 macroecosystems units were achieved in Iran. Table 3 presents the identified ecosystems, and Fig. 3 shows the 21 divisions of Iran's macroecosystems in these studies along with the registered BRs in Iran.

Both maps overlapped at the national level to integrate Olson et al. ecoregions and Jalilian et al. macroecosystems within Iran's borders. The Minimum Legible Delineation (MLD) was determined to be 40 square millimeters according to the Cornell University group method after overlapping these two maps (Forbes et al. 1982). Given that this study was performed at the national level and on a scale of 1:1,000,000, patches smaller than 4000 hectares were eliminated in the neighboring patch. Table 4 shows the overlap matrix of these two maps. The integrated units identified are the representative ecosystem unit (REU) used to select the BRS. Then, the current location of BRS was overlaid with the REU map.

Decision-making indicators of the representativeness of BRS

Iran's REUs were identified based on two principles and prioritized based on 5 indicators.

Selection principles

The representativeness was used to select BRs based on the following two principles:

- Use approaches from similar experiences

According to Olson et al., ecoregion units cover about 15 million hectares or about 0.1% of the earth's terrestrial. The average units of biogeographic provinces in Udvardy's (1975) classification are about 74 million hectares and about 0.5% of the earth's terrestrial. To identify wildlife hot spots on the planet, Myers et al. (2000) used subdivision units 79 million hectares, about 0.5% of the Earth's terrestrial.

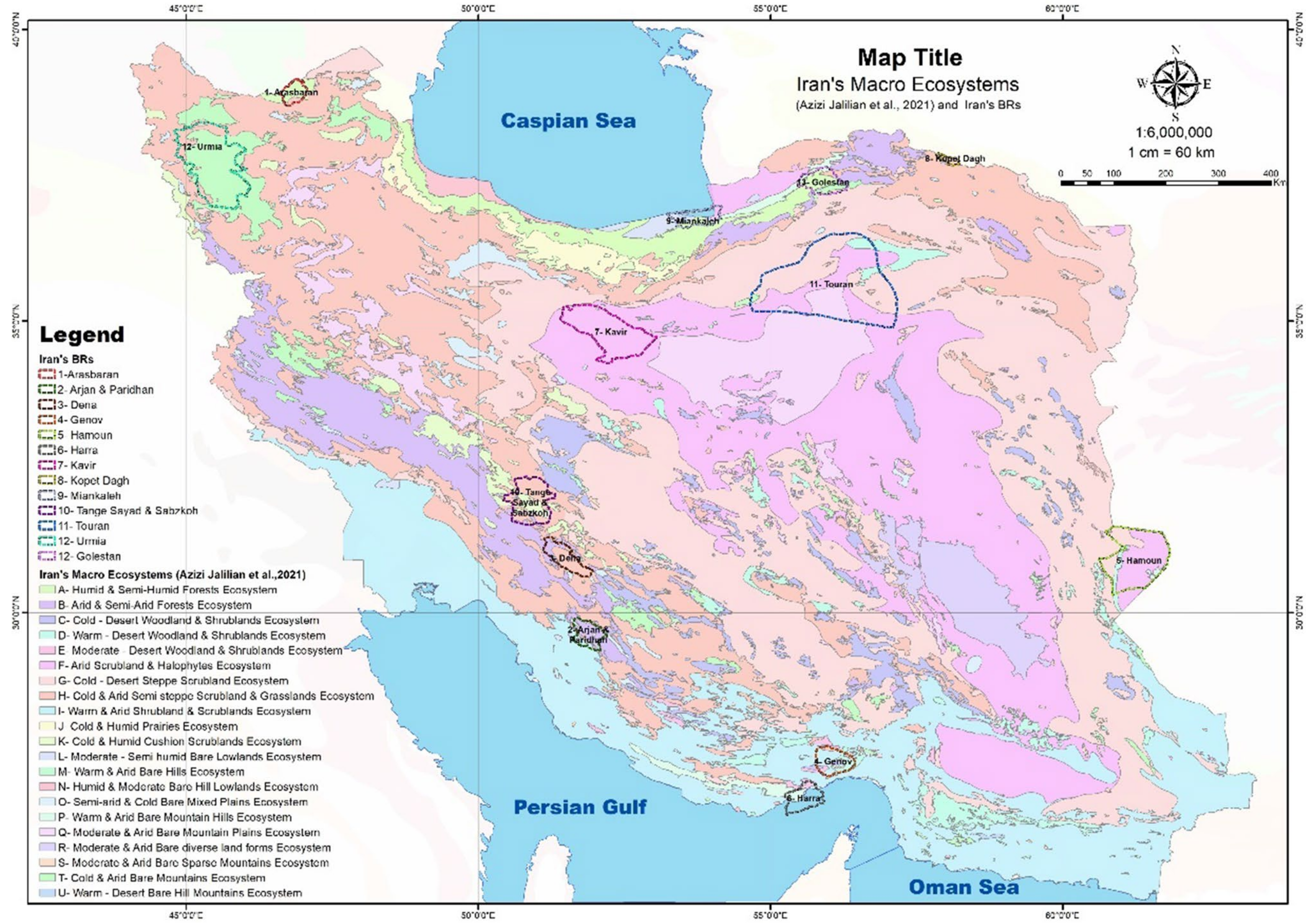

Fig. 3 Macroecosystem units in Iran (Azizi Jalilian et al. 2020) along with Iran's BRs

Therefore, REU is representative for selecting the BR when the total area of its patches is more than 0.5% of the country's size (Derived from the approach Myers et al., 2000; Udvardy 1975), and the area of its largest patch should be at least 0.1% of the country's size (Derived from the approach Dinerstein et al. 2017; Olson et al. 2001).

- Attaining the minimum area that is possible to select Core Zone in REU

The Core Zone occupancy level of the BR is recommended between 5 and 25% in global experiences in the field of zoning of BRs (Germany MaB-National Committee 2007; Günter 2013; Labourdette 2010; Dudley et al. 2013; Lourival et al. 2011; Naughton 2007). Therefore, the common area of the BRs with REU should be recognizable as the minimum area allocated to the Core Zone (5%).

For this purpose, if the common season of the existing BRs with REU is less than 20%, it is not considered representative.

Prioritization indicators

The prioritization of identified REUs for the proposal to register a new BR consists of the following five indicators:

- The number of patches for each REU was used as a limitation index based on Diamond's principles and geometric scales (Diamond 1975) for planning nature reserves, which was approved by the World Conservation Strategy (WCS 1980).
- When the relative occupancy level of REUs in a country increases, it becomes a stronger factor indicator.

Table 4 matrix of ecoregions and ecosystems of Iran for defining the integration map

Olson ecoregions/ Azizi Jalilian ecosystems	CLD	CHM	ARF	EAM	ZMF	ASD	TEA	KDW	KDS	KRE	ADE	BKS	CPD	MSD	RNP	SIN
HSF		001	002			003										
ASF		004	005		006			007					008			
CDW			009		010			011		012		013	014		015	016
WDW					017					018			019		020	021
MDW					022					023						024
ASH	025							026	027	028			029		030	031
CDS			032	033	034	035		036		037		038	039	040	041	042
CAS			043	044	045	046		047	048	049			050	051	052	053
WAS					054		055			056	057				058	059
CHP		060	061	062												
CHC		063	064	065	066					067			068			
MSB	069	070			071											072
WAB													073			074
HMB		075														
SCB			076	077	078			079		080			081		082	083
WAM	084								085							086
MAM			087	088	089					090			091			092
MAD										093			094			095
MAS			096	097	098	099				100			101		102	103
CAM			104	105	106	107				108			109		110	111
WDB																112

Table 5 Provinces of biogeography (Udvardy, 1975) and distribution of BRs

Code	Provinces name	IBRS
20	Anatolian-Iranian Desert	Geno, Hara
21	Turanian	Touran, Kavir, Hamoun, Dena, Tang-e Sayad-Sabz Kouh
34	Caucaso-Iranian Highlands	Arasbaran, Golestan, Kopet Dagh, Miankaleh, Urmia, Arjan

- Larger relative area of the largest REU patch in the country makes the indicator more representative with higher priority as a factor indicator.
- More adjacent REUs led to a higher priority for selection as a factor indicator.
- The presence of existing BRs inside the mentioned REU with a low occupancy level (less than 20%) was considered as a restriction indicator.

Table 6 The occupancy level of ecoregions in Iran (Olson et al. 2001) and distribution of BRs

No	Ecoregion	Patch no	Land coverage (%)	BRs
1	CHM	2	3.4	Miankaleh, Arasbaran, Golestan
2	ZMF	2	21.8	Dena, Arjan, Sabz Kouh, Geno
3	ARF	2	4.3	Arasbaran, Golestan/Needed
4	EAM	1	4.6	Urmia
5	TEA	2	0.4	It is not necessary
6	KDW	1	1.6	Kopet Dagh
7	KRE	10	7.5	Needed
8	ASD	1	0.4	Arasbaran
9	ADE	1	0.1	It is not necessary
10	BKS	1	0.1	It is not necessary
11	CLD	1	0.3	Miankaleh
12	CPD	2	34.7	Touran, Kavir
13	KDS	1	0.4	It is not necessary
14	MSD	1	0.1	It is not necessary
15	RNP	1	3	Hamoun
16	SIN	2	17.3	Geno, Hara

Table 7 The occupancy level of macroecosystem units in Iran (Azizi et al. 2020) and the distribution of BRs

No	Abbreviations	Macroecosystem units in Iran	Pach no	Land Coverage (%)	BRs
1	HSF	Humid & Semi-Humid Forests Ecosystem	7	1.54	Miankaleh, Arasbaran, Golestan
2	ASF	Arid & Semi-Arid Forests Ecosystem	34	4.89	Golestan, Dena, Arjan, Sabz Kouh, Kopet Dagh
3	CDW	Cold-Desert Woodland & Shrublands Ecosystem	177	2.98	Arjan, Geno
4	WDW	Warm—Desert Woodland & Shrublands Ecosystem	89	1.7	Geno, Touran, Hamoun
5	MDW	Moderate—Desert Woodland & Shrublands Ecosystem	19	0.2	Geno, Hara
6	ASH	Arid Scrubland & Halophytes Ecosystem	76	16.27	Geno, Touran, Kavir, Hamoun, Miankaleh
7	CDS	Cold-Desert Steppe Scrubland Ecosystem	141	25.04	Golestan, Geno, Touran, Urmia, Hamoun
8	CAS	Cold & Arid Semi-steppe Scrubland & Grasslands Ecosystem	235	19.74	Arasbaran,Golestan, KopetDagh, Geno, Touran, Urmia,Dena, Arjan, Sabz Kouh
9	WAS	Warm & Arid Shrubland & Scrublands Ecosystem	29	14.26	Geno, Hara, Hamoun, Arjan
10	CHP	Cold & Humid Prairies Ecosystem	2	0.82	Needed
11	CHC	Cold & Humid Cushion Scrublands Ecosystem	44	1.29	Sabz Kouh,
12	MSB	Moderate–Semi-humid Bare Lowlands Ecosystem	10	0.26	Miankaleh
13	WAB	Warm & Arid Bare Hills Ecosystem	29	0.04	It is not necessary
14	HMB	Humid & Moderate Bare Hill Lowlands Ecosystem	3	0.32	It is not necessary
15	SCB	Semi-arid & Cold Bare Mixed Plains Ecosystem	128	1.13	Hamoun, Arjan
16	WAM	Warm & Arid Bare Mountain Hills Ecosystem	2	0.44	Golestan, Hara
17	MAM	Moderate & Arid Bare Mountain Plains Ecosystem	24	4.42	Touran
18	MAD	Moderate & Arid Bare diverse landforms Ecosystem	2	1.91	Needed
19	MAS	Moderate & Arid Bare Sparse Mountains Ecosystem	140	0.23	Touran, Urmia
20	CAM	Cold & Arid Bare Mountains Ecosystem	74	2.51	Golestan, Touran, Urmia
21	WDB	Warm—Desert Bare Hill Mountains Ecosystem	1	0.02	It is not necessary

Entropy-VIKOR was used to prioritize REU based on the mentioned indicators. The Shannon entropy model weighted each index was applied in the VIKOR model in order to determine the factors and limitations of the indicators for VIKOR ranking (Q). The VIKOR model is one of the multi-criteria decision-making methods for prioritizing options, which was used for criteria with different and even contradictory measurement units. The lowest VIKOR index rank (Q) has the highest priority (Saner et al. 2022; Sunarsih et al. 2020; Zavadskas and Bausys 2015).

Results and discussion

Table 5 shows the results of Iran's BRs on Udvardy biogeography provinces. Based on the knowledge of Iran's natural geography, many natural ecosystems do not correspond to the mentioned geographical provinces. Therefore, the inadequacy of the Udvardy system to express the representativeness of BRs is observed at the national level. For example, the Golestan forests cannot be considered representative of the Caucasian-Iranian highlands, and the Miankaleh wetland or Urmia lake can also be considered in the same geographical provinces.

Comparing Iran's ecoregions (Olson et al. 2001; Dinerstein et al. 2017) and the BRs showed that 10 of 16 ecoregions identified in Iran currently have BRs (Table 6). However, 5 of 6 ecoregions without BR occupy less than 0.5% of the country's areas. The lack of BRs in These ecoregions cannot be considered a deficiency in their representativeness since their small size cannot provide them with suitable representatives for ecological units in Iran.

Biosphere reserves should represent terrestrial and aquatic ecosystems in each ecoregion. According to the ecoregion of Dinerstein et al. (2017), only the aquatic ecosystem in the Eastern Anatolian Montane Steppe and Registan–North Pakistan Sandy Desert ecoregions has BRs (Urmia and Hamoun BRs) with no representative of enough terrestrial ecosystem. As shown in Table 6, the Alborz Range forest steppe ecoregion with 3.4% of the area in Iran includes 2 different patches, which represent the smaller patch of Arasbaran BR well. However, only

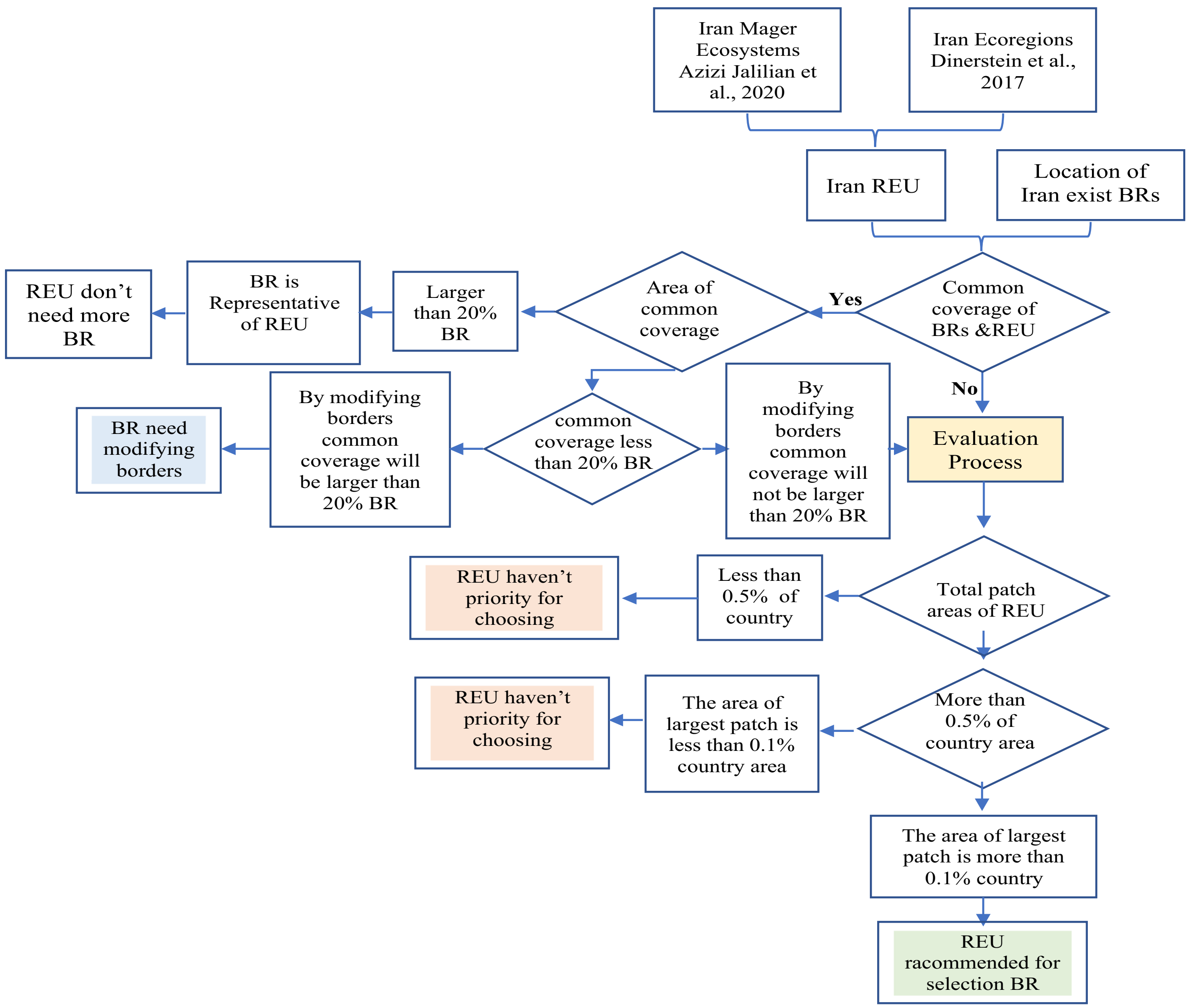

Fig. 4 The proposed decision-making algorithm for identifying and determining REUs to select the BRs at the national level

a small part of the Golestan BR is located in the larger patch, which can be doubted based on the exact matching of the topographical position by matching the DEM map of the Alborz mountain range to this ecoregion. Therefore, it seems necessary to select and register the BR in this ecoregion.

Based on the results in Table 6 and ecoregions (Dinerstein et al. 2017) in Iran, the following units are suitable for introducing the BRs:

- Kuh Rud and Eastern Iran Montane Woodlands (KRD) Ecoregion with an area of about 7.5% of the country
- Alborz Range forest steppe (ARF) Ecoregion with an area of about 3.4% of the country

The adaptation results of BRs and Iran's macroecosystems (Azizi et al. 2020) (Table 7) indicated that 17 of 21 identified ecosystems in Iran have BRs. In addition, the following macroecosystems do not have BRs:

- Moderate and Arid Bare diverse landforms Ecosystem (MAD) (1.91% of the size of the country),
- Cold and Humid Prairies Ecosystem (CAM) (0.82% of the country)
- Humid and Moderate Bare Hill Lowlands Ecosystem (HMB) (0.32% of the country)
- Warm and Arid Bare Hills Ecosystem (WAB) (0.04% of the country)
- Warm—Desert Bare Hill Mountains Ecosystem (WDB) (0.02% of the country)

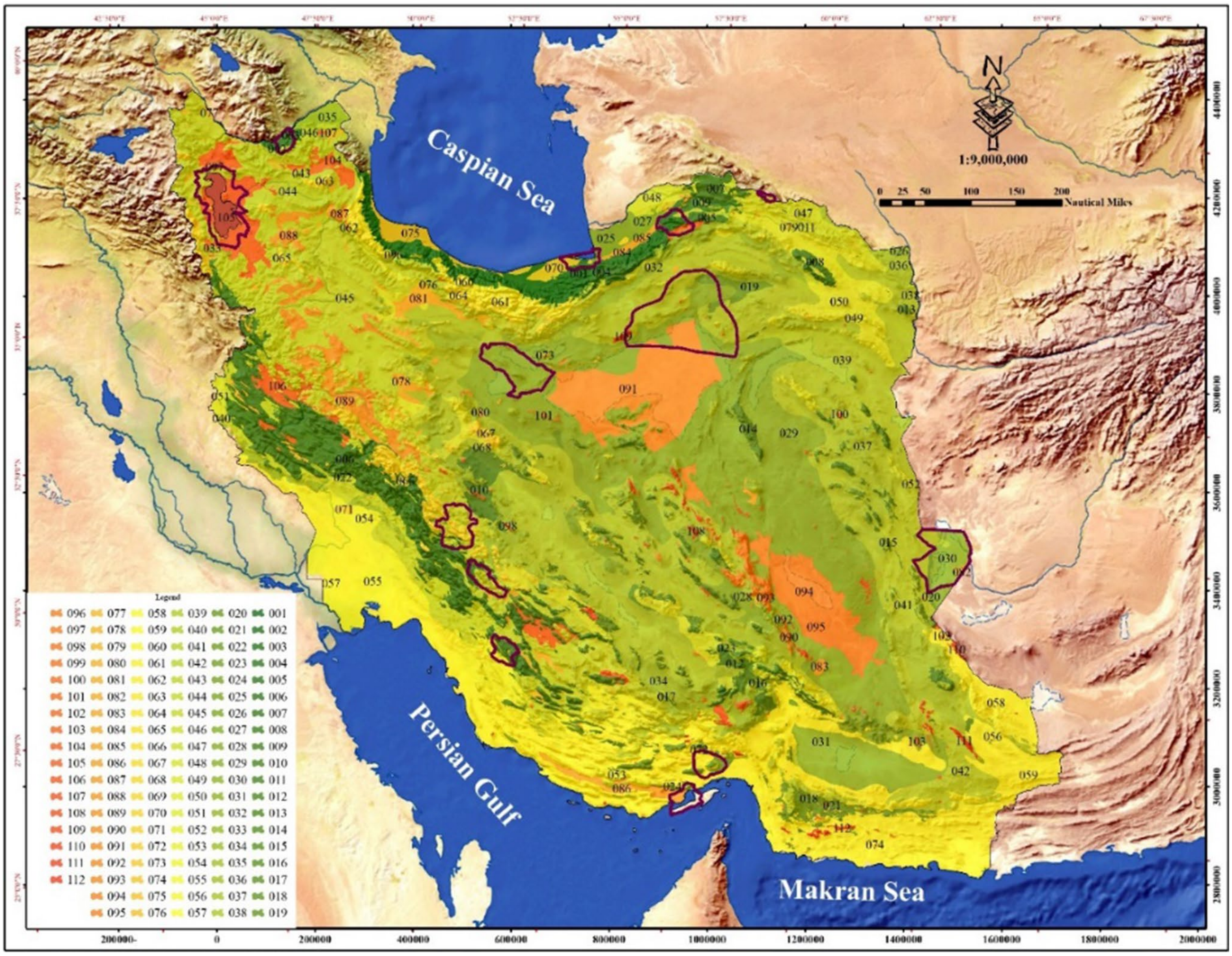

Fig. 5 Map of REU with guide codes and the location of the BRs in the country

HMB, WAB and WDB are not given priority for choosing due to the size and occupancy level of the above ecosystems (occupancy level is less than 0.5%). Nevertheless, choosing the BRs among the CAM and MAD ecosystems is a priority due to their level of occupation in the country.

The research indicators are depicted in Fig. 4 step-by-step to generate the REU map and screen the decision-making stages for evaluating the existing BRs and selecting new BRs schematically in the logical framework of the decision-making algorithm. This algorithm shows the ways to achieve the results for prioritizing the location and features of the selected REU and facilitates the exploitation of the results of this research by users and decision-makers.

Figure 5 displays the REU map and the location of BRs in Iran. Table 8 presents those REUs that has an area of more than 0.5% of the country's area, and the largest patch is at least 0.1% of the area in Iran. The results revealed that 33 REU can be identified at this stage. As shown in Table 9, Iran's BRs are located in 26 REUs, but only 15 REUs are consistent with the considered indicators and the decision algorithm (Fig. 4). Therefore, this decision-making algorithm led to the identification of 18 REUs in Iran for future BRs.

The prioritization results based on Entropy-Shannon in Table 10 represent the area of the largest patch, the number of patches in each REU, the percentage of REU occupancy in the country, the proximity of REUs, and the presence of a BR with an occupancy level of less than 20% in REU can affect the selection of REUs for BRs. As shown in Table 11, the priority of REUs for selecting BRs based on representative criteria is displayed based on VIKOR's method and based on the weight of the indicators in Table 10. Figure 6 shows the map of REUs based on priority.

Table 8 Famous REUs for the selection of BRs according to the defined indicators

No	Code	Occupancy (%)	Number of patches	Area of the biggest patch	No	Code	Occupancy (%)	Number of patches	Area of the biggest patch
1	1	1.50	3	2,427,860	18	44	2.75	4	4,223,270
2	6	3.97	13	5,840,770	19	45	9.16	45	6,567,140
3	10	1.09	33	571,726	20	47	0.86	5	1,241,770
4	12	0.76	31	224,647	21	49	0.73	22	281,425
5	14	1.01	60	240,565	22	50	3.02	54	2,509,820
6	19	0.54	17	379,505	23	53	0.54	14	230,116
7	21	0.84	18	745,643	24	54	2.01	12	1,509,550
8	28	0.64	22	280,410	25	58	0.95	5	1,408,620
9	29	11.56	23	17,795,500	26	59	10.29	15	15,171,900
10	31	3.12	5	5,056,970	27	61	0.51	3	471,017
11	32	1.00	11	767,136	28	66	0.79	20	632,752
12	34	2.34	25	1,002,430	29	89	1.14	9	714,429
13	37	4.53	52	2,107,120	30	91	2.90	6	4,505,210
14	39	13.07	37	6,528,960	31	94	1.38	4	2,218,960
15	41	1.53	3	2,414,940	32	105	1.18	4	1,608,960
16	42	2.10	39	1,997,800	33	106	0.65	15	452,170
17	43	2.23	24	1,460,030					

Table 9 REUs covered by the BRs of the country

No	Code	Number of patches	Occupancy (%)	BRs	No	Code	Number of patches	Occupancy (%)	BRs
1	001	3	1.50	Miankaleh, Golestan, Arasbaran	14	041	3	1.53	Hamoun
2	002	3	0.06	Golestan, Arasbaran	15	045	45	9.16	Dena, Arjan, Tang Sayad
3	003	1	0.06	Arasbaran	16	047	5	0.86	Kopet Dag
4	006	13	3.97	Dena, Arjan, Tang Sayad	17	054	12	2.01	Arjan
5	016	10	0.17	Genov	18	059	15	10.29	Harra, Genov
6	019	17	0.54	Touran	19	066	20	0.79	Tang Sayad
7	020	10	0.16	Hamoun	20	070	3	0.2	Miankaleh
8	021	18	0.84	Genov	21	082	1	0.02	Hamoun
9	024	8	0.16	Harra, Genov	22	086	1	0.27	Harra
10	025	1	0.26	Miankaleh	23	091	6	2.9	Touran, Kavir
11	029	23	11.56	Touran, Kavir	24	101	6	0.09	Touran
12	030	3	0.48	Hamoun	25	104	5	0.28	Golestan
13	039	37	13.07	Touran	26	105	4	1.18	Urmia

Based on the defined indicators prepared by the decision-making algorithm, it is possible to achieve the approach of comprehensive planning of the national system of BRs to help protect the representative ecosystems of the world

Conclusion

Biogeography representative is considered one of the keys and basic criteria for selecting BRs, which affects the zoning pattern of the BRs, especially the location and number of the core zones. Representation of BRs can be done at different levels as global, regional, and national levels. However, the relationship between these levels is based on the use of almost similar criteria but on different scales. Udvardy biogeographical provinces (1975) is considered the first attempt to create a global network of ecological units that is acceptable for imaging and arrangement of ecosystems at the global level. Udvardy introduced biogeographic provinces based on plant types representative of biomes in different realms; however, this study has been conducted on a global scale. The results of this research identified representative ecosystem units, where the presence or absence of vegetation,

Table 10 The results of calculating the weights of criteria using the Shannon entropy model

Indicator	Occupancy (%)	Number of patches	Area of the largest patch	Reserve	Adjacent
Indicator weight	0.176	0.307	0.447	0.019	0.051
Options					
REU 10	1.09	33	571,726	2	3
REU 12	0.76	31	224,647	1	2
REU 14	1.01	60	240,565	1	3
REU 28	0.64	22	280,410	1	2
REU 31	3.12	5	5,056,970	1	4
REU 32	1.0	11	767,136	1	3
REU 34	2.34	25	1,002,430	1	3
REU 42	2.1	39	1,997,800	1	3
REU 43	2.23	24	1,460,030	1	2
REU 44	2.75	4	4,223,270	1	3
REU 49	0.73	22	281,425	1	2
REU 50	3.02	54	2,509,820	1	3
REU 53	0.54	14	230,116	1	3
REU 58	0.95	5	1,408,620	1	1
REU 61	0.51	3	471,017	1	3
REU 89	1.14	9	714,429	1	1
REU 94	1.38	4	2,218,960	1	2
REU 106	0.65	15	452,170	1	3

Table 11 VIKOR model for the priority of REU requiring biosphere reserve in Iran

Options	Si		Ri		Qi	Priority
REU 31	0.010762	1	0.010762	1	0	1
REU 44	0.09938	2	0.077119	2	0.134482	2
REU 94	0.301663	3	0.262521	3	0.480351	3
REU 42	0.49358	9	0.282978	5	0.630332	4
REU 58	0.398882	4	0.337479	7	0.630363	5
REU 50	0.526934	13	0.274438	4	0.642534	6
REU 43	0.479488	7	0.332723	6	0.678057	7
REU 32	0.456746	6	0.396817	9	0.736526	8
REU 34	0.510317	11	0.375052	8	0.746899	9
REU 61	0.441089	5	0.424208	12	0.757598	10
REU 89	0.48462	8	0.401692	10	0.760491	11
REU 106	0.507406	10	0.425952	13	0.803319	12
REU 53	0.522565	12	0.446492	17	0.836857	13
REU 10	0.612558	16	0.414893	11	0.859972	14
REU 49	0.577748	14	0.441746	14	0.8678	15
REU 28	0.577842	15	0.44184	15	0.867969	16
REU 12	0.631431	17	0.446998	18	0.909213	17
REU 14	0.769131	18	0.445526	16	0.998312	18

type, and coverage is one of the components of ecosystem unit recognition, similar to Udvardy's studies. Nevertheless, the identified REU has a national resolution and is more accurate than the Udvardyan classification in terms of scale. The identified REU in this study is a combination of the ecoregion (Olson et al. 2001) for Iran at the regional level and macroecosystems identified in Iran (Azizi Jalilian et al. 2020). These REUs combined ecological aspects with habitat functions, which were more effective than the two mentioned classifications for identifying REUs at the national level and associated with more classes and more precise diagnosis compared to the two previous classifications which

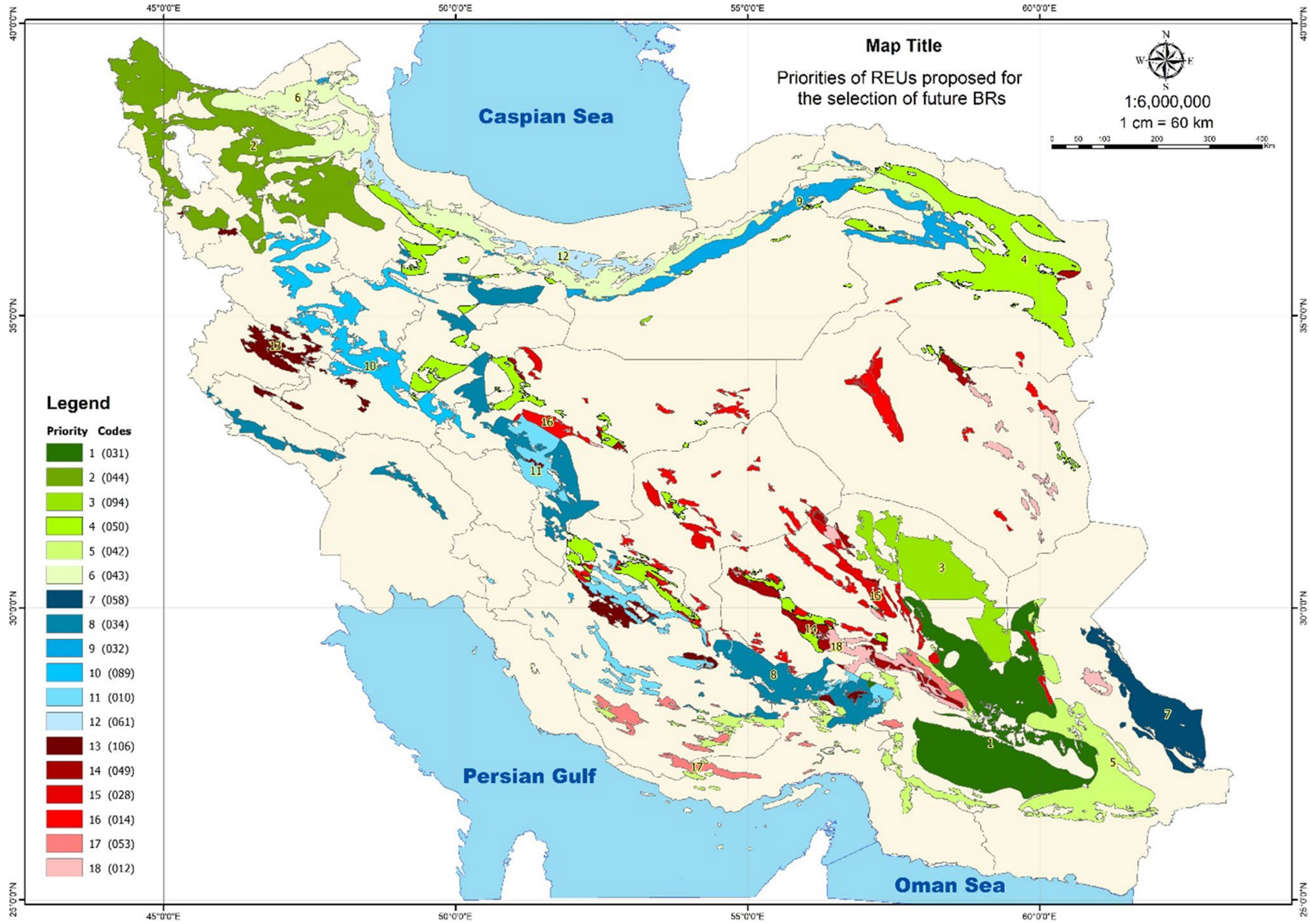

Fig. 6 The priority of the REUs for selecting the country's new BRs

Integration of ecological and ecosystem functions. In this study, the identified REUs are indicative of choosing a BR at the national level when the total area of its patches is greater than 0.5% of the country's size, which is consistent with the approach of Myers et al. (2000) and Udvardy (1975). Selecting representative REUs for the BRs was also dependent on the area of the largest patch, which was considered to be more than 0.1% of the country and in line with Dinerstein et al. (2017) and Olson et al. (2001). One of the bases for selecting REU for the selection of future BRs is the spatial occupation level of an existing BRs with REU and the minimum intersection of 20%, which is similar to the study of Dudley (2013) and Labourdette (2010).

Based on the results, selecting representative BRs should be based on a more accurate ecosystem separation at the national level, as well as trans-national performance. Udvardy's approach is acceptable and promising only when there is no integrated national information. The conformity of Olson ecoregions with physiographic units requires more detailed investigations for national application despite the arrangement of ecological units from the global to regional level. Relying on national ecological classifications is the best situation for the typology of macroecosystems. The countries which have made such a classification have created the chance to select the BRs based on the exact reality of the biomes from the bottom up and link the accuracy of the selection to the global network while maintaining the national performance.

This study provided a framework to select the BRs based on the criterion of representativeness at the national level, which was introduced in the form of a decision algorithm (Fig. 4) to select the mechanism of the BRs in a methodical and integrated manner. Occupancy percentage criteria, number and area of REU patches, REU's contiguity, and the level of occupancy of existing BRs were used to prioritize the selected REUs for selecting the BRs. The arrangement of suitable REUs is also suggested to be considered for selecting large multi-core BRs to be more effective than smaller and single-core BRs as the basis of other studies for the future. In addition, the present study represented the capacities of selecting transboundary BRs. Adapting the map of REUs to the existing BRs according to Fig. 7 also showed

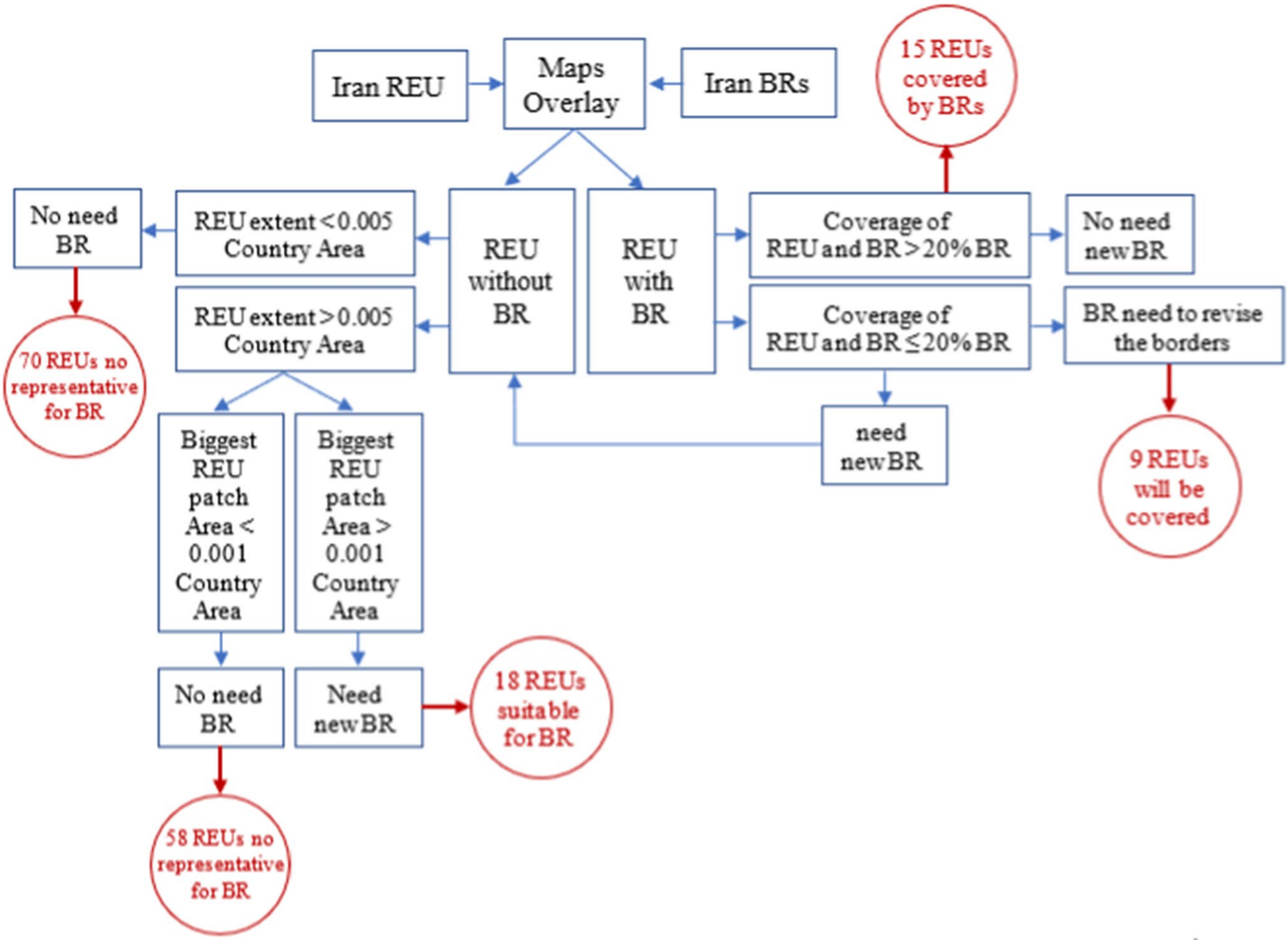

Fig. 7 Result of Iran's BR representativeness based on REU map and decision-making algorithm

that the representative capacity of the BRs can be improved by modifying some boundaries.

All proposed BRs can be selected in more than one REU and provide the possibility to cover ecosystem diversity by selecting fewer BRs. The registration of seven new priority BRs covers 15 REUs with about 17% of the country's area.

The production of the independent REU map at the national level enables countries to use the appropriate representative biogeography coverage to select the network of protected areas in their country, which is also recommended for Iran. The result of this approach potentially enables the network of national protected areas to play the transnational role and function for the protection of biogeography at the global level.

Declarations

Conflict of interest The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

References

Alborzimanesh M, Imani J, Danehkar A, Robati M, Alambeigi A (2021) An analytical survey of the adaptation of biosphere reserve zoning with the zoning of protected areas in Iran. J Sus Dev Env 2(3):1–19

Aycrigg JL, Davidson A, Svancara LK, Gergely KJ, McKerrow A, Scott JM (2013) Representation of ecological systems within the protected areas network of the continental United States. PLoS ONE 8(1):e54689. https://doi.org/10.1371/journal.pone.0054689

Azizi JM et al (2020) Anew ecosystem-based land classification of Iran for conservation goals. Environ Monit Assess. https://doi.org/10.1007/s10661-020-8145-1

Blasi C, Capotorti G, Copiz R, Guida D, Mollo B, Smiraglia D, Zavattero L (2014) Classification and mapping of the ecoregions of Italy. Plant Biosystems 3504:37–41. https://doi.org/10.1080/11263504.2014.985756

Blasi C, Capotorti G, AlósOrtí MM, Anzellotti I, Attorre F, Azzella MM, Caril E, Copiz R, Garfi V, Manes F, Marando F, Marchetti M, Mollo B, Zavattero L (2017) Ecosystem mapping for the implementation of the European biodiversity strategy at the national level: the case of Italy. Environ Sci Policy 78:173–184. https://doi.org/10.1016/j.envsci.2017.09.002

Chape S, Harrison J, Spalding M, Lysenko I (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos Trans Royal Soc Biol Sci 360(1454):443–455. https://doi.org/10.1098/rstb.2004.1592

Dasmann RF (1973) A system for defining and classifying natural regions for purpose of conservation. IUCN 1973:47p

Dasrnann RF (1972) Define the role, purpose, and conservation criteria for various protected areas llth general assembly of IUCN in Banff. Canada 1972:28p

Deniz K, Frye C, Sayre R, Breyer S, Aniello P, Vaughan R, Wright D (2017) Modeling global Hammond landform regions from 250-m elevation data. Trans GIS 21(5):1040–1060. https://doi.org/10.1111/tgis.12265

Diamond JM (1975) The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol Cons 7:129–146

Dinerstein E, Olson D et al (2017) An ecoregion-based approach to protecting half the terrestrial realm. Bioscience 67(6):534–545. https://doi.org/10.1093/biosci/bix014

Djamali M, Akhani H, Khoshravesh R (2011) Application of the global bioclimatic classification to Iran: implications for understanding the modern vegetation and biogeography. Ecologia Mediterranean Année 2011(37–1):91–114

Dudley N, Shadie P, Stolton S (2013) Guidelines for applying protected area management categories IUCN publications services IUCN publications services. Best Pract Prot Area Guidel Series 21:31

Forbes TR, Rossiter D, Van Wambeke A.1987. Guidelines for evaluating the adequacy of soil resource inventories. printing ed. SMSS Technical Monograph #4. 1982, Ithaca, NY: Cornell University Department of Agronomy. 51.

Germany MaB-National Committee. 2007. Legal and administrative aspects of the UNESCO MaB Program in Germany

Goshtasb H, Bali A, Esteghamat M. 2018. Principles and Management of Biosphere Reserves, Definition, Strategies and Introduction of Biosphere Reserves in Iran. UNESCO/Persian National Committee. Publication of knowledge. 199p

Günter K (2013) 40 years of the UNESCO Man and the Biosphere Program in Austria – a success story of ecological basic research and flagship of transdisciplinary. Austrian MaB Report, Austrian Man and the Biosphere (MAB) research program

Herbada D, González JH, Torres RM, Pinilla JS, Martín RH, Xqlwv J (2011) An environmental land classification of Spain. Fitosociologia 48(2):101–110

IMO/MEPC. 2005. Guideline for the Identification and design nation of particularly sensitive sea areas. Adopted on 1 December 2005. 13p

International coordinating council of the program on man and biosphere (MaB)- Paris 1984- MAB report series No. 58. report of Minsk.

IUCN. 1978. Categories Objectives and Criteria for Pas. 25p

IUCN. 1992. Parks for Life. report of the fourth World Congress on National Parks and Protected Areas, 10–21 February 1992 Caracas. 134p

IUCN Secretariat. 1974. Biotic Provinces of the World. (IUCN, 1974, Occasional Paper No. 9).

IUCN/UNEP/WWF. 1980. World Conservation Strategy. 77p

Labourdette DR et al (2010) Zoning a protected area: proposal based on a multi-thematic approach and final decision. Environ Modeling Assess 15:531–547

Lourival R, Watts M, Phillip H (2011) What is Missing in Biosphere Reserves Accountability? Braz J Nat Conserv 9(2):160–178. https://doi.org/10.4322/natcon.2011.022

Margules C, Sarkar S (2000) Systematic conservation planning. Nature 405:243–253

Margules C, Pressey RL, Williams PH (2002) Representing biodiversity: data and procedures for identifying priority areas for conservation. J Biosci 27:309–326

Meffe et al (1995) Combining science and policy in conservation biology. Wildl Soc Bull 23:327–332

Myers N, Russel A, Mittermeier C, Mittermeier G, Gustav AB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858 (2000)

Naughton L. 2007. Collaborative land use planning: Zoning for Conservation and Development in Protected Areas. The University of Wisconsin-Madison. Land tenure center, no 4:1–16. http://digital.library.wisc.edu/1793/22153

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, Amico D, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR (2001) Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 11:933–938

Phillips A, Kelleher G.1999.Guideline for marine protected areas. ISBN: 978-2-8317-0505-7. 2-8317-0505-3.

Rodrigues ASL, Andelman SJ, Bakarr MI, Boitani L et al (2004) Effectiveness of the global protected area network in representing species diversity. Nature 428:640–643

Salm R, Price A. 1995. Selection of Marine Protected Areas: Principles of Techniques for Managing. Edited by Susan Gubbay. Chapman Hall, London.232p

Saner HS, Yucesan M, Gul M (2022) A Bayesian BWM and VIKOR-based model for assessing hospital preparedness in the face of disasters. Nat Hazards 111:1603–1635. https://doi.org/10.1007/s11069-021-05108-7

Sayer R et al (2020) An assessment of the representation of ecosystems in global protected areas using new maps of world climate regions and world ecosystems. Global Ecol Conserv 21(2020):e00860

Shrestha UB, Shrestha S, Chaudhary P, Chaudhary RP (2010) How representative is the protected areas system of Nepal? Mt Res Dev 30(3):282–294. https://doi.org/10.1659/MRD-JOURNAL-D-10-00019.1

Singers NJD, Rogers GM (2014) A classification of New Zealand's terrestrial ecosystems. Sci Conserv 325:1–87

Soulé ME, Terborgh J (1999) Continental conservation: scientific foundations of regional reserve networks. Island Press, Washington, DC

Sunarsih S et al (2020) Analysis of priority scale for watershed reforestation using Trapezo dal Fuzzy VIKOR method: a case study in Semarang Central Java Indonesia. Symmetry 12(4):507. https://doi.org/10.3390/sym12040507

Udvardy MDF (1975) A Classification of the biogeographical provinces of the world. UNESCO's Man and the Biosphere Program Project No. 8.49p

UNESCO jointly UNEP. 1964. Task force on criteria and guidelines for the choice and establishment of biosphere reserves final report. http://npshistory.com/publications/mab/unesco-mab-report/22.pdf. 63p

UNESCO (1977) Man and his environment, an overview of UNESCO's evolvement. UNESCO, Paris 1979:65

UNESCO (1993) The biosphere conference 25 years later. UNESCO, Paris 1993:34p

UNESCO.2020.Technical Guidelines for Biosphere Reserves (TGBR). Accesed:20.11.2020. https://unesdoc.unesco.org/ark:/48223/pf0000253591

UNESCO. 2022. History of biosphere reserves creation of the international biological program. https://en.unesco.org/mab/50years/history-2022

WCS (1980) World Conservation Strategy: living resource conservation for sustainable development / prepared by the International

Union for Conservation of Nature and Natural Resources. IUCN-UNEP-WWF, Gland, Switzerland, p 78

Zavadskas KE, Bausys R (2015) Multicriteria decision-making approach by VIKOR under interval neutrosophic set environment. Article in Econ Comput Econ Cybern Studies Res Acad Econ Studies 49(4):33–48