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Enhancing ecosystem representation in Palestine through strategic recommendations for an effective protected areas network

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Abstract. *Ali-Shtayeh MS, Abu-Zaitoun SY, Jamous RM. 2025. Enhancing ecosystem representation in Palestine through strategic recommendations for an effective protected areas network. Biodiversitas 26: 1287-1302.* Protected Areas (PAs) in the West Bank, Palestine, were established over 50 years ago to conserve the region's diverse ecosystems. However, their effectiveness remains questionable. This study uses systematic conservation planning and Geographic Information Systems (GIS) tools to evaluate the representativeness of the 2015 and 2023 Protected Areas Networks (PAsN) in conserving ecosystems and vegetation types. The assessment benchmarks these networks against global conservation standards, such as the Aichi Biodiversity Target of 17%. Indicators such as ecosystem unit representation percentage, the Biodiversity Conservation Index (BCI), and the Comparison Index (CI) were used to evaluate their conservation effectiveness. Findings reveal that key ecosystem units, such as Evergreen Mediterranean Maquis (2.15%), and key vegetation types, including Maquis and Forest (2.11%) and Park Forest (5.40%), are severely underrepresented. In contrast, Desert Salines (46.37%) and Desert Vegetation (43.06%) exceed protection targets. Although revisions to the 2023-PAsN increased PAs coverage to 10.8% of the West Bank, the network remains unevenly distributed, with western ecosystems and vegetation types under intense human pressure. Flaws in previous studies, such as incomplete biodiversity data, arbitrary conservation thresholds, and limited field validation, compromised the design and effectiveness of the national PAsN-2023. These oversights resulted in insufficient protection measures and the exclusion of vital conservation areas. To address these challenges, the study recommends expanding the PA network to ensure more equitable coverage of ecosystem units and vegetation types, reinstating omitted areas with high conservation value, establishing micro-reserves for localized protection of unique habitats and threatened plants found in non-protected natural lands, and enhancing stakeholder collaboration to ensure inclusive and sustainable management. These findings emphasize the urgency of adopting a scientifically rigorous and balanced approach to ecosystem units and vegetation conservation in Palestine.

Keywords: Biodiversity conservation, ecosystem representation, Palestine protected areas network, systematic conservation planning

INTRODUCTION

Protected Areas (PAs) are essential for global biodiversity conservation, providing refuge for species, safeguarding ecosystems, and maintaining critical ecological processes (Figueiroa et al. 2020; Dinerstein et al. 2024). They form the backbone of conservation strategies and act as benchmarks for understanding human-nature interactions (CBD 2010). PAs are critical for preventing the extinction of endemic and threatened species, emphasizing the need for representative, comprehensive, and integrated PA networks to ensure effective conservation outcomes (Kukkala and Moilane 2017; Mace et al. 2018). As of 2021, PAs cover approximately 16.64% of terrestrial ecosystems and 7.74% of coastal and marine ecosystems globally, yet their effectiveness varies widely (IUCN 2020; UNEP-WCMC IUCN 2021).

Despite their global expansion, many PAs are criticized as "paper parks"—existing in name but failing to deliver substantive conservation outcomes. The disparity between designation and effectiveness is rooted in issues such as inadequate funding, poor governance, and limited representativeness of ecosystems (Chen et al. 2023). Recent studies emphasize that achieving the conservation goals set under the Kunming-Montreal Global Biodiversity Framework (GBF) requires enhancing not only the quantity but also the quality of PAs (Allan et al. 2019; Geldmann et al. 2019). The GBF, adopted in 2022 under the Convention on Biological Diversity (CBD), sets ambitious targets, including the protection of at least 30% of terrestrial, inland water, and marine areas by 2030 (Target 3, "30x30"), alongside commitments to equitable governance, ecological connectivity, and effective management. Therefore, effective conservation planning must integrate robust methodologies to assess and improve PA networks, ensuring they mitigate human pressures while maintaining ecological integrity. Globally, PA effectiveness is often assessed through biodiversity and ecosystem services metrics (Viña and Liu 2017; Visconti et al. 2019). While species-focused conservation dominates, ecosystem-level diversity, which provides a broader measure of regional biodiversity, remains underutilized despite its significance for conservation planning (Moilanen and Arponen 2015; Dinerstein et al. 2017).

Geographic Information Systems (GIS)-based gap analysis has become a key tool for evaluating PA networks. This method identifies underrepresented ecosystem units by comparing biodiversity data with PA coverage, helping prioritize areas for conservation (Viciani et al. 2014; Hughes 2023). By focusing on ecosystem-level data, gap analysis offers a cost-effective framework for biodiversity protection,

complementing species-specific approaches (Hu et al. 2024). Once priorities are identified, further research can refine PA boundaries and management practices to maintain ecological processes (Roswell and Espíndola 2023).

In the State of Palestine (SP; West Bank and Gaza Strip), biodiversity is concentrated within natural reserves, many of which were designated under Israeli military orders with limited scientific justification (Order No. 363, 1969). These reserves, predominantly (83%) located in Area C of the West Bank, face challenges related to access, management, and representativeness (United Nations the Question of Palestine 1993-1995; UNDP 2021). Following the formalization (Cabinet Resolution No. 04/37/17/MW/RH, 2015) of 50 sites as the PAs-2015 network (Table 1), evaluations revealed significant gaps in biodiversity coverage and ecosystem representation (Ali-Shtayeh et al. 2022a) highlighting the need for a more systematic approach to conservation (Zhu et al. 2015).

In 2023, an updated assessment of Palestine's PAs using Systematic Conservation Planning (SCP) and Marxan modeling proposed expansions to the network (Table 2), increasing coverage to 10.8% of the West Bank (CEPF 2023; EQA 2023). However, this expansion largely retained the original network's limitations, with over 93% of the updated PAs located in Area C and critical gaps in ecosystem representativeness remaining unresolved. These challenges underscore the need for systematic evaluations that align local conservation efforts with global biodiversity targets.

This study employs GIS-based gap analysis to evaluate the ecosystem representativeness of Palestine's updated PAsN-2023. Building on previous assessments, it examines whether the network aligns with global conservation targets, specifically the Aichi Target 11 (which aimed for 17% terrestrial protection by 2020) and the Kunming-Montreal Global Biodiversity Framework Target 3 (which aspires to 30% protection by 2030). It also identifies gaps in ecosystem and vegetation type coverage. By emphasizing ecosystem diversity, this research provides a comprehensive framework for addressing deficiencies in the current network and proposing evidence-based recommendations for enhancing biodiversity conservation in Palestine. This study represents the first in-depth evaluation of ecosystem and vegetation representation within Palestine's PA network, offering critical insights for national conservation planning.

MATERIALS AND METHODS

Study area

The Palestinian West Bank (Pal-WB) as the main part of the State of Palestine (SP) is located within historic Palestine, with a total area of 5660 km^2 (Figure 1). The geographical coordinates of the West Bank are 31.9466°N, 35.3027°E. Despite its small area, the West Bank is categorized by a pronounced variation in topography (Fienburn-Dothan 1978-1986; Danin and Fragman-Sapir 2018) and climate.

The West Bank features five distinct topographical zones, including the Central Highlands, Semi-Coastal Region, Eastern Slopes, Jordan Rift Valley, and Coastal Region (Ali-Shtayeh et al. 2003). These geographical variations contribute to diverse climatic conditions across the region. Climatically, the West Bank is divided into two primary climatic regions: the Eu-Mediterranean climate region in the west and the Xero-Tropical climate region in the east. The Eu-Mediterranean climate region encompasses the semi-coastal plain, mountain range, and central hills. This area experiences a mild, rainy winter lasting approximately three months, with temperatures ranging from 10-15°C. Summers are warm and dry, with temperatures between 27°C and 32°C. Annual rainfall in this region varies between 350 mm and 1000 mm, providing adequate water supply for vegetation and agriculture. The Xero-Tropical climate region, on the other hand, includes the Jordan Valley, which is characterized by an arid and extremely hot climate. Winters in this region are warm, with temperatures ranging from 15-22°C, while summers are intensely hot and dry, with temperatures soaring between 35°C and 45°C. Rainfall is minimal (100-250 mm), making the conditions unsuitable for sustaining continuous plant life (Ali-Shtayeh and Hamad 1995). These climatic variations play a crucial role in shaping the region's biodiversity, agricultural potential, and water resources, influencing both ecological and socio-economic conditions in the West Bank. The Pal-WB can also be divided into four phytogeographical regions including the Mediterranean, the Irano-Turanian, the Saharo-Arabian, and the Sudanese Penetration regions. Despite the small area of the Pal-WB, this confluence of the four regions has led to the rich diversity in plant communities and their components.

The vegetation of Pal-WB comprises thirteen vegetation types (Danin 1992; Ali-Shtayeh et al. 2022b): Maquis and forest (A), Synanthropic vegetation with *Ziziphus spina-christi* trees and *Acacia raddiana* trees (B), Park forest of *Ceratonia siliqua* and *Pistacia lentiscus* (C), *Z. lotus* with herbaceous vegetation (D), Savannoid Mediterranean vegetation (E), Semi-steppe batha (F), Steppes vegetation (G), Desert vegetation (H), Swamps and reed thickets (J), Oases with Sudanian trees (K), Desert savannoid vegetation (L), Wet Salines (M), Synanthropic vegetation with *Z. spina-christi* trees (N) (Figure 1.A).

The Pal-WB landscape is reflected in its rich and diverse ecosystems. Altogether, eleven natural ecosystem (ES) units were defined in the West Bank based on climate data, morphological features or conditions, soil and geology, topography or the main pattern of the landscape, and vegetation cover that indicates the spatial pattern of vascular plants or dominant species (Rotem and Weil 2014; Ali-Shtayeh et al. 2022a). The defined ES units include eight strictly terrestrial ESs (Figure 1.B): Evergreen Mediterranean Maquis (EMM), Semi-Steppe Batha (SSB), Alluvial Valleys in Arid Climate (AVAC), Shrubby Steppes in Arid Climate (SSAC), Park Forest (PF), meanders of the S (lower) Jordan River (MSJR), Alluvial Valleys in a Mediterranean Climate (AVMC), sand dunes along the coastline (SDSC), and 3 terrestrial-waters ecosystems: Dead Sea (a hyper-saline lake) (DS), Desert Salines (DSs), and Mountain Streams (MS).

Table 1. List of original protected areas (PAsN 2015) in the West Bank, Palestine distributed by ecosystem units and vegetation type

PA name	District	IUCN **	Area (Dunum)	Ecosystem units (%) *	Vegetation type (%) **
Abu Sauda	Hebron	-	957.364	EMM (26.4%), SSB (73.6%)	A (100%)
Esh Sh. Qatrawani	Ramallah & Al-Bireh	III	6.683	EMM (100%)	A (100%)
Laturn	Ramallah & Al-Bireh	-	374.569	EMM (84.7%), AVMC (15.3%)	C (100%)
El Mari (Umm at Tut)	Jenin	IV	377.448	EMM (93.4%), AVMC (6.6%)	A (100%)
Ummer Rihan	Jenin	-	2382.658	EMM (100%)	A (100%)
Ummer Rihan (*)	Jenin	-	174.852	EMM (100%)	A (100)
El Miksar (Sirirs)	Jenin	Ia	1149.48	EMM (74%), SSB (26%)	A (100%)
En Nabi Gheit	Ramallah & Al-Bireh	-	41.516	EMM (100%)	A (100%)
Jebel el Aqra	Jenin	-	223.173	EMM (100%)	A (100%)
Jebel Taruja	Nablus	-	43.606	EMM (100%)	A (100%)
Suba	Hebron	Ia	13188.42	EMM (100%)	A (41.2%), C (58.8%)
Dhahrat Hayis	Jenin	IV	624.119	EMM (100%)	A (100%)
Ein et Tuleib	Ramallah & Al-Bireh	IV	459.24	EMM (100%)	A (100%)
Ein el Maghara	Ramallah & Al-Bireh	IV	477.111	EMM (100%)	A (100%)
Ein Dara	Ramallah & Al-Bireh	IV	101.148	EMM (100%)	A (100%)
Ein Qawabish	Ramallah & Al-Bireh	IV	377.904	EMM (100%)	A (100%)
Fuqeigis	Hebron	-	1615.345	EMM (100%)	C (100%)
Karza (kurza)	Hebron	-	3501.112	EMM (57.4%), SSB (42.6%)	C (100%)
Marj ez Za'rur	Jerusalem	-	24.514	EMM (100%)	A (100%)
Wadi el Dilb	Ramallah & Al-Bireh	IV	3131.53	EMM (100%)	A (100%)
Wadi el Quff	Hebron	V	3730.082	EMM (100%)	A (92.4%), C (7.6%)
Wadi el Makkuk	Ramallah & Al-Bireh	-	20662.67	SSB (99.2%), AVAC (0.8%)	C (7.3%), F (57.0), G (6.1%), K (29.6%)
Wadi Jannata	Ramallah & Al-Bireh	III	3356.67	EMM (100%)	A (100%)
Wadi Ein ez Zarqa el Elwi	Ramallah & Al-Bireh	IV	13317.15	EMM (100%)	A (100%)
Wadi Qana	Salfit - Qalqilya	-	16270.39	EMM (100%)	A (100%)
El Muzawqa	Tubas		21804.83	SSB (91.40%), AVAC (8.58%), MSJR (0.02%)	D (0.1%), E (23.1%), F (76.8%)
Jebel Tammun	Tubas	IV	18194.88	SSB (100%)	A (6.1%), C (66.4%), D (27.4%)
Jebel El Qarn	Hebron	Ia	679.664	SSB (100%)	A (100%)
Jebel el Kabir	Nablus	IV	25183.4	SSB (100%)	A (62.1%), C (37.9%)
Deir Razih	Hebron	IV	506.209	EMM (12.7%), SSB (87.3%)	C (100%)
Ras Umm el Kharrub	Jericho		9765.559	SSB (99.9%), AVAC (0.01%)	E (0.06%), F (99.94%)
Ras Jadir	Tubas	IV	10508.6	SSB (100%)	C (99.7%), D (0.3%)
Shubash	Tubas	IV	54485.67	SSB (87.7%), AVAC (0.0001%), PF (12.273%)	A (2.7%), C (71.8%), D (25.5%)
Ein el Auja	Ramallah & Al-Bireh	IV	12365.78	SSB (100%)	C (4.8%), F (57.4%), K (37.7%)
Ein Bassat er Rih	Jericho		666.557	AVAC (21.1%), MSJR (78.9%)	E (19.4%), K (80.6%)
Qubbat en Najama	Ramallah & Al-Bireh		719.977	SSB (100%)	F (100%)
Qarn Sartaba	Jericho		31194.01	SSB (95.8%), AVAC (4.2%)	F (83.6%), L (16.4%)
Wadi el Qilt	Jerusalem	IV	28762.95	AVAC (84.68%), SSB (10.89%), SSAC (4.42%)	A (2.6%), C (12.2%) F (65.3%), G (19.3%), L(0.6%)
Wadi er Rashshash	Nablus		8382.452	MS (100%)	F (99.4%), C (0.6%)
Yatta	Hebron		275.119	SSB (100%)	C (100%)
Tell er Rusheidiya	Jericho		2312.821	AVAC (0.18%), MSJR (10.46%), DS (89.36%)	M (100%)
El Katar	Jericho		3235.041	AVAC (100%)	M (100%)
Wadi Jauzala	Jericho		9660.268	AVAC (84.7%), MSJR (17.3%)	K (13.8%), M (86.2%)
Wadi el Ahmar	Jericho		15118.76	AVAC (93.7%), MSJR (6.3%)	L (59.6%), M (40.4%)
Wadi el Mallaha	Jericho		14356.64	AVAC (98.5%), MSJR (1.5%)	L (1.89%), M (98.11%)
Ein Jidi	Bethlehem		85540.87	AVAC (4.90%), SSAC (91.68%), DS (3.42%)	G (7.2%), H (33.7%), J (3.1%), L (56.0%)
Ein Fashkha	Bethlehem		2572.83	AVAC (14.03%), SSAC (0.06%), DS (85.91)	J (8.8%), L (91.2%)
Ein el Ghuweir	Bethlehem		1762.171	SSAC (20.2%), DS (79.8%)	J (50.5%), L (49.5%)
El Kanub	Hebron		48925.76	SSB (11.5%), SSAC (88.5%)	C (0.003%), F (49.63%), G (50.36%)
Al Kuweiyis	Hebron		13540.53	SSB (7.3%), SSAC (92.7%)	F (48.0%), G (52.0%
Bassat Wadi el Mallaha	Jericho		4746.444	AVAC (53.5%), DSs (46.5)	M (13.7%), l (86.3%)

Note: *EMM: Mediterranean Evergreen Maquis; SSB: Semi-Steppe Batha; AVAC: Alluvial Valleys in Arid Climate; SSAC: Shrubby Steppes in Arid Climate; DSs: Desert Salines; MS: Mountain Streams; PF: Park Forest; MSJR: Meanders of the S Jordan River; DS: Dead Sea; AVMC: Alluvial Valleys in Mediterranean Climate; SDSC: Sand Dunes (Soil) Along the Coastline. **A: Maquis and forest; B: Synanthropic vegetation with *Ziziphus spina-christi* trees and *Acacia raddiana* trees; C: Park forest of *Ceratonia Siliqua* and *Pistacia lentiscus*; D: *Ziziphus lotus* with herbaceous vegetation; E: Savannoid Mediterranean vegetation; F: Semi-steppe batha; G: Steppes vegetation; H: Desert vegetation; J: Swamps and reed thickets; K: Oases with Sudanian trees; L: Desert savannoid vegetation; M: Wet Salines; N: Synanthropic vegetation with *Z. spina-christi* trees

Table 2. List of new protected areas (PAsN2023) in the West Bank, Palestine distributed by ecosystem units and vegetation type

PA name	IUCN Category **	PA area	Ecosystem units (%) *	Vegetation type**
Laturn	IV	2329.355	EMM (67.8%), AVMC (32.2%)	C (100%)
El Mari (Umm at Tut)	V	405.689	EMM (90.5%), AVMC (9.5%)	A (100%)
Ummer Rihan	IV	3700.308	EMM (100%)	A (100%)
El Miksar (Sirirs)	IV	1223.403	EMM (67.6%), SSB (32.4%)	A (100%)
Ein Qawabish	V	451.695	EMM (100%)	A (100%)
Marj ez Za'rur	IV	2296.744	EMM (100%)	A (100%)
Wadi el Dilb	IV	1563.301	EMM (100%)	A (100%)
Wadi el Quff	V	3400.15	EMM (100%)	A (96.6%), C (3.4%)
Wadi Jannata	II	2801.769	EMM (100%)	A (100%)
Wadi Ein ez Zarqa el Elwi	IV	10532.903	EMM (100%)	A (100%)
Wadi Qana	II	15295.405	EMM (100%)	A (100%)
Ein el Auja	II	12365.591	SSB (100%)	C (4.8%), F (57.4%), K(37.8%)
El Muzawqa	IV	28328.006	SSB (89.53%), AVAC (10.45%), MSJR (0.02%)	D (0.2%), E (29.9%), F (69.9%)
Jebel El Qarn	V	532.876	SSB (100%)	A (100%)
Deir Razih	V	339.566	EMM (11.6%), SSB (88.4%)	C (100%)
Ras Jadir	IV	9497.049	SSB (100%)	C (86.6%), D (13.4%)
Shubash	V	52857.64	SSB (91.7%), AVAC (0.1%), PF (8.2%)	C (62.4%), D (13.4%), E (1.7%)
Qarn Sartaba	IV	31193.785	SSB (95.7%), AVAC (4.3%)	F (83.5%), L (16.5%)
Wadi el Qilt	IV	28644.007	SSB (83.8%), SSAC (11.1%), MS (5%)	A (2.3%), C (11.3%), F (65.5%), G(20.3%), L (0.6%)
wadi fasayil	II	8382.185	SSB (100%)	C (0.5%), F (99.5%)
El Kanub	IV	29009.016	SSB (4.1%), SSAC (95.9%)	F (38.5%), G (61.5%)
El Katar	V	3181.252	AVAC (100%)	M (100%)
ALAghwar	II	54521.942	AVAC (86.6%), DSs (4.5%), MSJR (8.9%)	K (3.6%), L (27.1%), M (69.3%)
Dead sea	IV	234388.757	AVAC (4.6%), SSAC (89.6%), DS (5.8%)	G (32.3%), H (32.6%), J (3.4%), L (31.7%)
Al Kuweiyis	IV	12691.385	EMM (0.001), SSB (9.44%), SSAC (90.55)	F (50.2%), G (49.8%)
Al Arqoub	V	9016.968	EMM (100%)	A (100%)
Jerusalem	Ib	52844.966	SSAC (100%)	G (84.4%), H (15.6%)

Note: *EMM: Mediterranean Evergreen Maquis; SSB: Semi-Steppe Batha; AVAC: Alluvial Valleys in Arid Climate; SSAC: Shrubby Steppes in Arid Climate; DSs: Desert Salines; MS: Mountain Streams; PF: Park Forest; MSJR: Meanders of the S Jordan River; DS: Dead Sea; AVMC: Alluvial Valleys in Mediterranean Climate; SDSC: Sand Dunes (Soil) Along the Coastline. **A: Maquis and forest; B: Synanthropic vegetation with *Ziziphus spina-christi* trees and *Acacia raddiana* trees; C: Park forest of *Ceratonia Siliqua* and *Pistacia lentiscus*; D: *Ziziphus lotus* with herbaceous vegetation; E: Savannoid Mediterranean vegetation; F: Semi-steppe batha; G: Steppes vegetation; H: Desert vegetation; J: Swamps and reed thickets; K: Oases with Sudanian trees; L: Desert savannoid vegetation; M: Wet Salines; N: Synanthropic vegetation with *Z. spina-christi* trees

The State of Palestine (SP) hosts 1826 plant taxa, distributed in 686 genera and 108 families; five taxa are gymnosperms, nine taxa are Pteridophytes, and 1812 taxa are angiosperms. An Agglomerative Hierarchical Clustering (AHC) of the Palestinian flora carried out by Ali-Shtayeh et al. (2022b) showed that the area of West Bank could be divided into two main regions, based on the existence of vascular plant taxa: Region 1 (western plant districts with 1128-1237 taxa) with higher water availability and temperate Mediterranean climate which permit the establishment of more than 65% of the total SP flora in these districts, and Region 2 (eastern plant districts with 571-698 taxa), characterized by desert and semi-desert conditions, as well as the presence of alluvial and co-alluvial soils, which allow the survival of lower numbers of plant taxa.

Procedures and data analyses

To avoid the elusive term 'ecosystem' for the mapping procedure, we use the term ecosystem-unit, which unifies extensive areas with similar environmental conditions and features or similar phenomena of flora and fauna (Rotem and Weil 2014). The ecosystem unit term will get closer to geographic terms and combine the two disciplines of habitat and ecosystem. Also, to perform spatial analysis of the ecosystem-units map, a parallel process of creating a continuous national land use map was carried out.

Data collection

The analysis utilized multiple GIS layers sourced from governmental and scientific repositories (Table 3). These layers included: A. Protected Areas Networks (PAsN-2015 and PAsN-2023) from the Environmental Quality Authority (EQA); B. land-use categories such as agricultural and built areas from the Ministry of Local Government (MOLG); C. vegetation types (Danin 1992) from EQA.

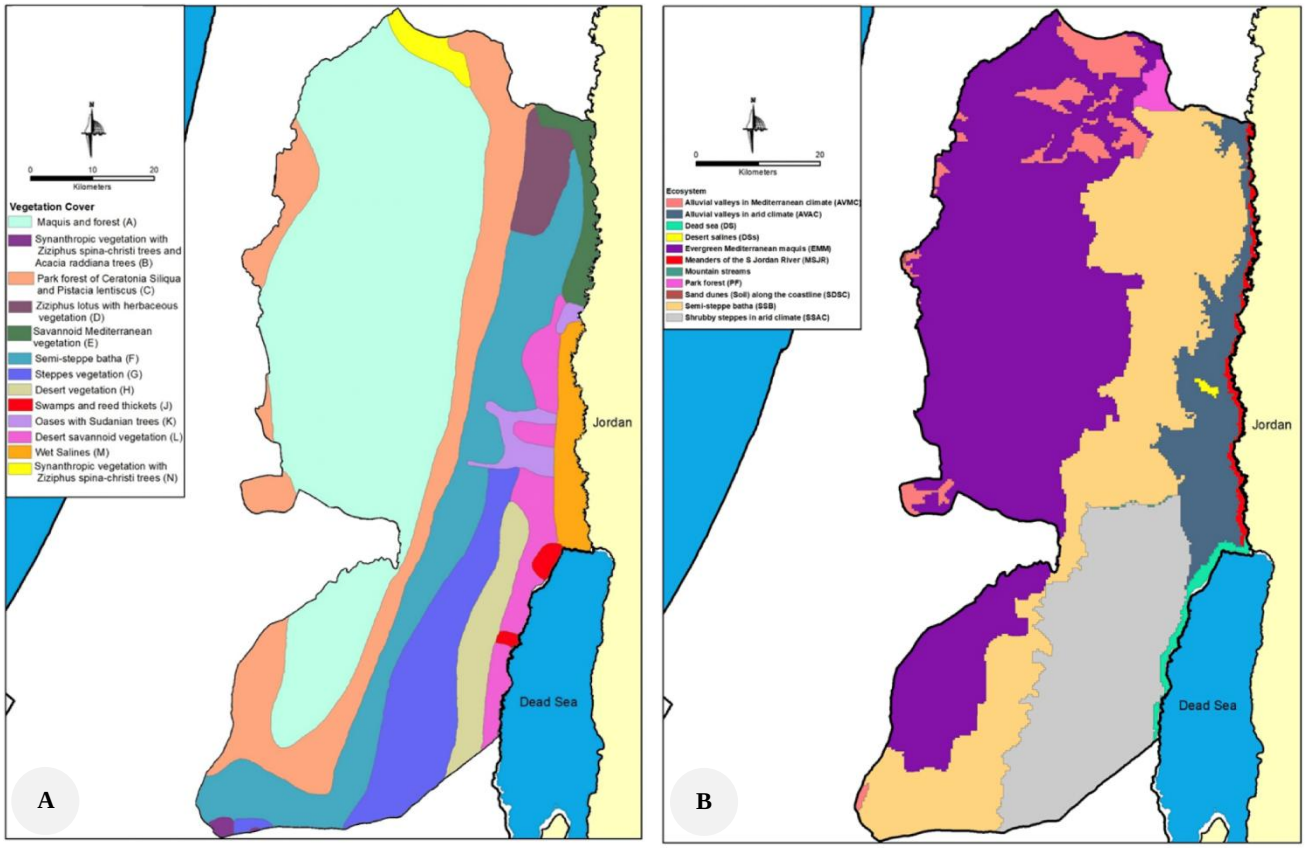

Figure 1. Palestinian West Bank, Palestine map showing the A. Diversity of vegetation types; B. Ecosystem units' diversity

Table 3. Categories list forming the land use map

Category/layer	Source	Type	Resolution
PAsN-2015/2023	EQA	Shapefiles	30 m
Vegetation types	Danin (1992), EQA	Shapefiles	30 m
Ecosystem units	BioGIS, BERC	Raster	30 m
Land use categories	MOLG, MOA	Shapefiles	30 m
Roads and infrastructure	MOLG	Vector	NA

Ecosystem units were categorized into raster datasets at a 30-meter resolution, offering detailed spatial patterns, while vegetation types were digitized into shapefiles. Additionally, a national land-use map was compiled by integrating overlapping layers and applying logical conditions to prioritize conservation-relevant features. Parallel land uses, such as agricultural activities within nature reserves, were excluded during overlay operations to ensure the accuracy of conservation assessments.

The gap analysis was conducted to evaluate the representation of ecosystem units and vegetation types within the Protected Areas Network (PAsN) and to identify critical conservation gaps. This approach provides strategic direction by pinpointing underrepresented areas that should be prioritized for conservation efforts. To assess the extent of representation and identify deficiencies within the existing protected area system, the study employed multiple indicators, including ecosystem unit representation (%), the ecosystem units Comparison Index (CI) following Hazen and Anthamatten (2004), vegetation type representation (%), the vegetation type CI, and the Overall Biodiversity Conservation Index (OBCI).

The analysis quantified ecosystem and vegetation type coverage by overlaying PAsN layers onto ecosystem and vegetation maps. Coverage percentages were computed and compared against global conservation targets, namely the 17% Aichi Biodiversity Target and the 30% Kunming-Montreal Global Biodiversity Framework Target, to assess the adequacy of representation. Representation metrics helped identify ecosystem units and vegetation types that were either underrepresented or entirely absent from the protected areas.

To address these gaps, a spatial analysis was conducted to identify unprotected areas with high conservation value, focusing on regions rich in biodiversity, endemic species, and unique ecological features. These priority areas were considered for potential inclusion in the protected areas network to enhance ecosystem representation. Additionally,

an overlay analysis incorporating land-use data was performed to refine the identification of unprotected areas. This step ensured that regions of high conservation significance with minimal human disturbance were prioritized in future conservation planning.

Overlay analysis of ES units and vegetation types versus land use as PA

To evaluate the effectiveness of ecosystem units covered by protected area, spatial analyses of the map of ES units and vegetation types were carried out, we superimposed the protected area layer with the ecosystem (Ali-Shtayeh et al. 2022a), and vegetation type layers (i.e. 11 ecosystem units and 13 vegetation types) and calculated the proportion of each natural ecosystem unit and vegetation type covered by protected area based on the West Bank PAsN-2023 (Figure 2) and the original PAsN-2015 (Figure 3).

Ecosystem units or vegetation types that were under-protected (under-represented), over-protected (over-represented), adequately protected (sufficiently represented), and unprotected (unrepresented) were then identified based on the 17% and 30% global biodiversity targets. Ecosystems (or vegetation types) representing less than 17% were considered under-protected. Ecosystems with a representation proportion of more than 17% are deemed overprotected in this study.

Overall Biodiversity Conservation Index (OBCI)

The representation of ecosystem units and vegetation types within the Palestinian Protected Areas (PAs) Network, and consequently the extent to which the country's overall biodiversity is represented, was evaluated against 17% Aichi biodiversity target, with the assumptions that 1) a well-represented system of protected areas encompassing all ecosystem units sufficiently captures the overall biodiversity of the country; 2) the contribution of overrepresented ecosystem units does not necessarily enhance overall biodiversity (CBD 2010). This assessment was conducted by calculating the overall Biodiversity Conservation Index (OBCI) for the PAs networks using the following equations:

$$\text{ESRIn} = \left[\left(\frac{\%\ \text{PAs a in ES}}{\text{BCSR}}\right) \times \left(\frac{ES\ a}{TESsA}\right)\right] \times 100$$

$$OBCI = \sum_{n=1}^{11} (\text{ESRIn})$$

Where, ESRIn: Representation Index for each ecosystem unit/vegetation type, %Pas; a: PAs representation in each ecosystem unit/vegetation type (%); BCSR: Biodiversity conservation % for sufficient representativeness (i.e. 17% or 30%); Esa: Ecosystem unit area/vegetation type; TESsA: Total ecosystems area/vegetation type; n: ecosystems unit/vegetation type number, ecosystems/vegetation type with more than 17% representation were considered (17%).

OBCI values and total biodiversity levels: 1-25 very poor; 25-50 poor; 50-75 fair; 75-100 good to comprehensive. Maximum effective representation for any ecosystem unit = target representation percentage.

Comparison Index (CI)

Comparison Index (CI) is another method applied to estimate ecosystem units or vegetation type representation in the established protected areas. The CI is calculated by dividing the percentage of protected areas in a particular ecosystem by that category's share of the country's land area as the formula below. Ecosystem units or vegetation types found to have a CI value of one or greater are well-represented while areas with CI values of less than one are deemed underrepresented (Watson et al. 2014; Geldmann et al. 2019).

$$\text{CI} = \frac{\text{Ecosystem land area/total ESs area}}{\text{Protected area in a particular ES/total area of PAs}}$$

Forecasting future natural land needs to protect biodiversity

We also analyzed the land use across all ecosystem units to identify and quantify unprotected native areas (natural areas left for each ecosystem unit) situated outside the boundaries of protected areas and forests. This analysis excluded non-native regions, such as agricultural lands, built environments, and infrastructure. The results will provide insights into potential steps to enhance conservation efforts and improve overall biodiversity representation in the West Bank.

To anticipate the requirement for preserving natural habitats to protect biodiversity in Palestine, we analyzed how well the protected areas in the West Bank represent its ecosystem units using the method of systematic conservation planning. Subsequently, we identified the necessary natural land areas to represent all ecosystem units within the protected areas, aiming to achieve the 17% Aichi Biodiversity Target and the 30% Kunming-Montreal Global Biodiversity Framework GBF target (CBD 2022).

RESULTS AND DISCUSSION

The complementarity of ecosystems plays a crucial role in enhancing biodiversity assessments for protected areas planning, especially in regions with high ecosystem diversity, such as Palestine (Ali-Shtayeh et al. 2022a). International conservation goals stress the importance of representativeness, ensuring that all ecosystem types receive adequate protection (Karadeniz and Yenilmez 2022). The 2030 Sustainable Development Goals (SDGs) also emphasize the protection of terrestrial and freshwater ecosystems. Thus, evaluating the representativeness of protected areas in conserving various natural ecosystem units is essential for effective conservation planning. In light of these considerations, our study explored the representation of ecosystem units in both the 2015 and 2023 Palestinian Protected Areas Networks by calculating each network's ecosystem unit representation, ecosystem units CI, vegetation type representation, vegetation types of CI, and the Overall Biodiversity Conservation Index (OBCI).

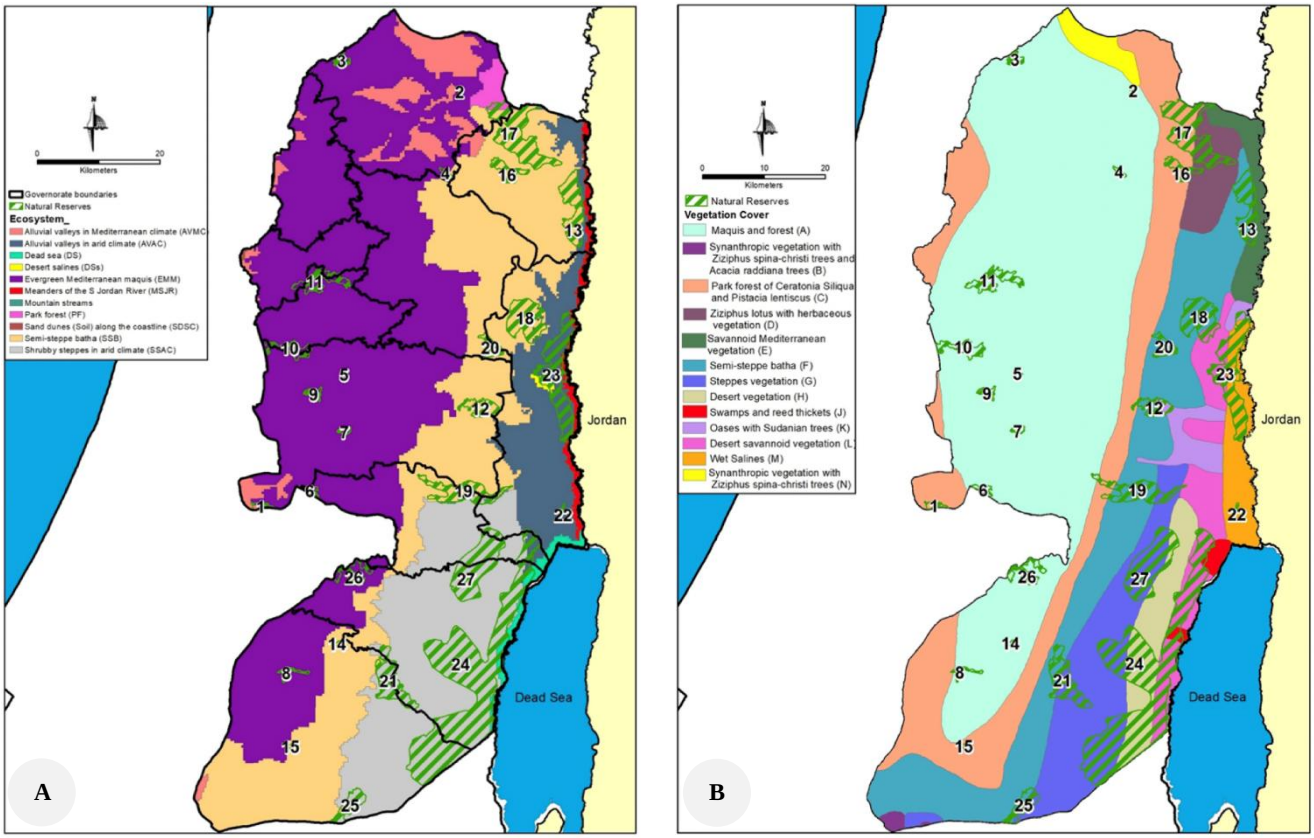

Figure 2. The distribution of the PAsN-2023 in West Bank, Palestine across A. ecosystem units; B. vegetation types

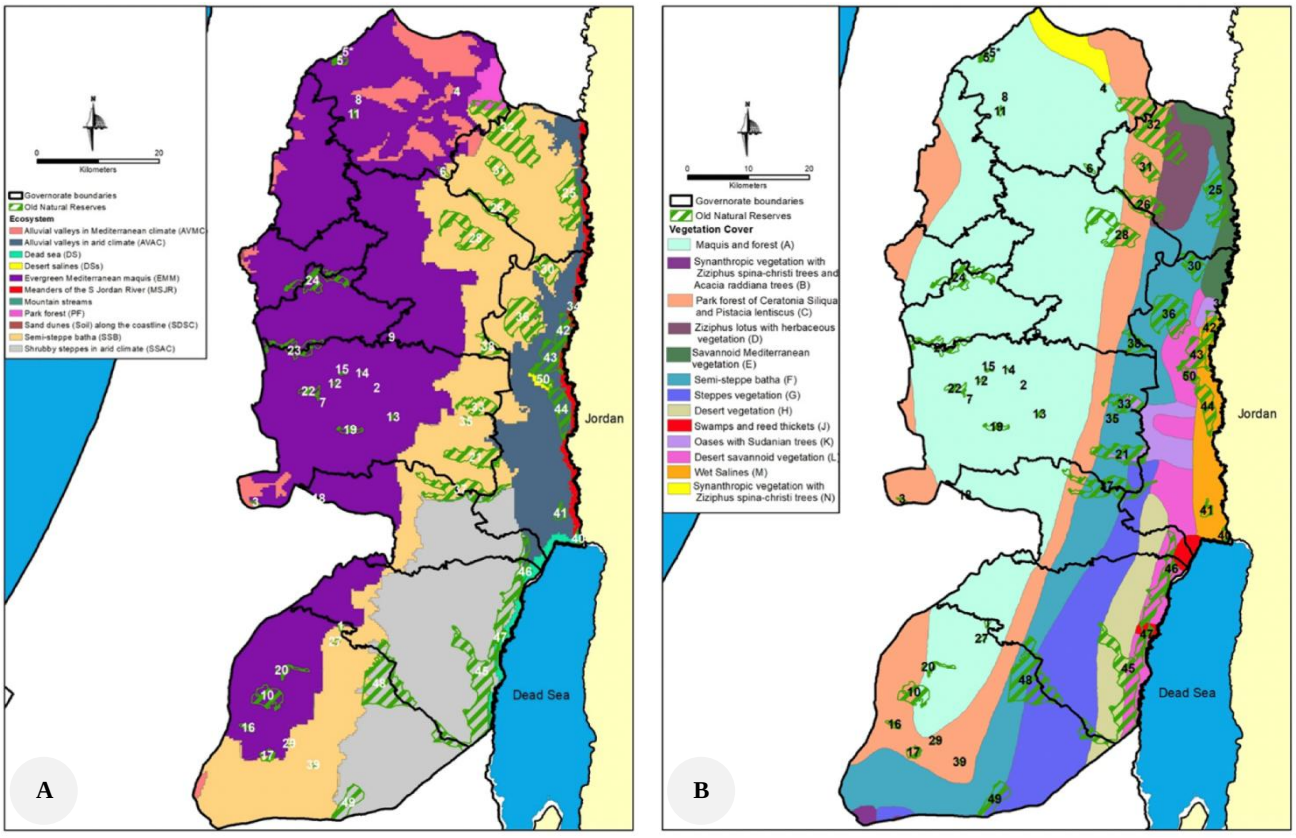

Figure 1. The distribution of the PAsN-2015 in West Bank, Palestine across A. ecosystem units; B. vegetation types

Representation of protected areas in different ecosystem units (protection status of ecosystems)

Since each ecosystem unit possesses distinct biodiversity characteristics, achieving a well-balanced representation, by protecting 17% or 30% of the terrestrial area within each ecosystem unit, would likely ensure comprehensive biodiversity conservation across the country. With this in mind, our study examined to which extent the PAsN-2023 adequately represents the West Bank's ecosystem units. Specifically, we assessed whether the proposed PAsN-2023 meets the 17% targets for protecting each ecosystem unit in comparison with the 2015 PAsN, and hence, the overall biodiversity of the country. In the West Bank, eleven natural ecosystem (ES) units were defined based on climate data, morphological features or conditions, soil and geology, topography or the main pattern of the landscape, and vegetation cover (Rotem and Weil 2014; Ali-Shtayeh et al. 2022a). These units include Evergreen Mediterranean Maquis (EMM), Semi-Steppe Batha (SSB), Alluvial Valleys in Arid Climate (AVAC), Shrubby Steppes in Arid Climate (SSAC), Park Forest (PF), Meanders of the South Jordan River (MSJR), Alluvial Valleys in a Mediterranean Climate (AVMC), Sand Dunes along the Coastline (SDSC), Dead Sea (DS), Desert Salines (DSs), and Mountain Streams (MS) (Table 4).

Among these, EMM, SSB, and SSAC together account for approximately 87% of the total area of terrestrial ecosystems in the West Bank. In comparison, the remaining eight units cover only about 13% of the total area (Figure 4*)*. Our analysis reveals that the protected areas within the PAsN-2023 are unevenly distributed across different ecosystem units (Figure 5). The highest percentage of protection is found in SSAC (39.9%), followed by SSB (26.41%) and EMM (8.48%). In contrast, several other units, such as AVMC (0.13%) and SDSC (0.00%), have little to no protection. This disparity underscores the need for targeted conservation efforts to achieve more balanced protection across all ecosystem units. Significant changes were observed in the percentage of protected areas within PAsN-2023 compared to previous network (PAsN-2015). Notably, the percentages of protected areas in SSAC increased from 26.90-49.90%, while AVAC saw a slight rise from 9.82-10.73%. However, SSB experienced a decrease from 46.56-26.41%. Minor increases were also noted in units like MSJR, DS, and AVMC, while PF, MS, and DSs saw declines (Table 4).

Table 4. Areas (Dunum) of protected areas, ecosystem units and vegetation types in the West Bank, Palestine

Ecosystem unit/vegetation type (abbreviation)	Area of ecosystem unit/vegetation type	Area of PAs (PAsN2023)	Area of PAs (PAsN2015)
Ecosystem unit			
Mediterranean Evergreen Maquis (EMM)	2414413.23	51870.71	63367.48
Semi-Steppe Batha (SSB)	1518664.07	161563.65	238531.41
Alluvial Valleys in Arid Climate (AVAC)	401846.64	65617.83	50326.31
Shrubby Steppes in Arid Climate (SSAC)	974053.99	305309.45	137806.27
Desert Salines (DSs)	5335.08	2474.12	2208.34
Mountain Streams (MS)	2217.55	1440.70	1273.51
Park Forest (PF)	32975.84	4325.47	6712.04
Meanders of the S Jordan River (MSJR)	60465.86	4831.75	3416.86
Dead Sea (DS)	41777.79	13572.47	8608.18
Alluvial Valleys in Mediterranean Climate (AVMC)	200907.49	789.55	82.19
Sand Dunes (Soil) Along the Coastline (SDSC)	1614.02	None	None
Total	**5654272**	**611795.7**	**512332.6**
Vegetation type			
Maquis and forest (A)	2452239.956	72057.9	51759.647
Synanthropic vegetation with *Ziziphus spina-christi* trees and *Acacia raddiana* trees (B)	10558.091	0	0.00
Park forest of *Ceratonia siliqua* and *Pistacia lentiscus* (C)	886424.142	91192.81	47853.571
Ziziphus lotus with herbaceous vegetation (D)	125418.301	18914.94	20285.528
Savannoid Mediterranean vegetation (E)	101846.899	5176.835	9389.889
Semi-steppe batha (F)	833620.107	130085.3	97611.938
Steppes vegetation (G)	490549.248	44667.56	150194.445
Desert vegetation (H)	196841.983	28848.73	84761.281
Swamps and reed thickets (J)	24702.583	3751.16	7919.774
Oases with Sudanian trees (K)	84516.06	12662.75	6640.343
Desert savannoid vegetation (L)	247579.784	69754.91	94407.127
Wet Salines (M)	143586.572	34723.82	40971.496
Synanthropic vegetation with *Ziziphus spina-christi* trees (N)	56329.652	0	0
Total	**5654213**	**511836.7**	**611795**

The current assessment results highlight significant variability in the protection status (as representation percentage) provided by the PAsN-2023 across different ecosystem units. Mountain Streams (MS) show the highest protection rate, with 64.97% of their area within protected regions, whereas the Evergreen Mediterranean Maquis (EMM) has the lowest, at just 2.15% (Figure 6). When examining the representation of ecosystem units in the PAsN-2023, in light of the 17% and 30% global biodiversity targets, the results revealed a range of protection levels. Some units were either unprotected (SDSC 0.0%), under-protected (less than 17%, including AVAC, PF, SSB, MSJR, AVMC, and EMM), or over-protected (more than 17%, including DSs, DS, SSAC, and MS) (Table 5). Considering the importance of the EMM ecosystem unit as a center for urbanization, agricultural land, and human activities, it does not take the highest representation which poses a challenge in establishing and expanding PAs.

Our findings also reveal a significant increase (30-65%) in the representation of protected areas within the PAsN-2023 compared to PAsN-2015 across four ecosystem units (DS, SSAC, MS, DSs) (Figure 6). This increase is largely attributed to expanding existing protected areas and the designation of new ones, such as the Jerusalem Wilderness PA (52.84 km²) in the SSAC. However, ecosystem units in the western West Bank remain poorly represented (e.g. EMM). Despite the overall increase in protected area coverage in the eastern regions, some units, like SSB, have experienced reduced protection due to the arbitrary removal of certain protected areas (e.g. PA# 28 Jebel Al-Kebir and PA#26 Tammoun) (Figures 2 and 3).

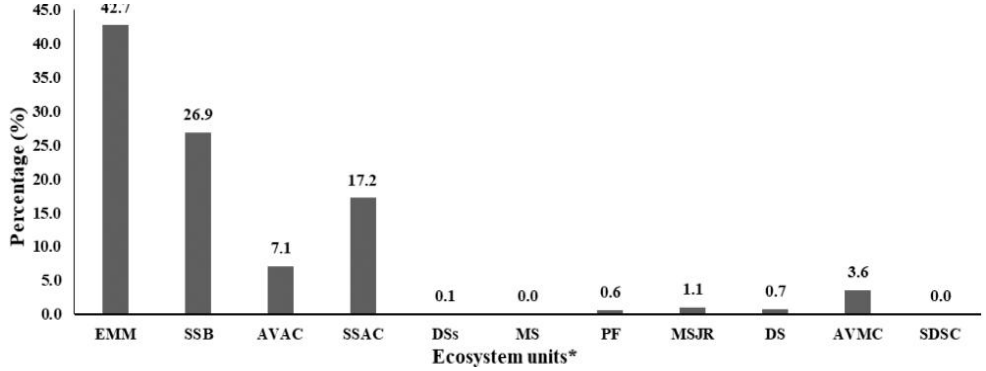

Figure 4. Percentage of ecosystem units' area to the total area of the country. *Notes: EMM: Mediterranean Evergreen Maquis; SSB: Semi-Steppe Batha; AVAC: Alluvial Valleys in Arid Climate; SSAC: Shrubby Steppes in Arid Climate; DSs: Desert Salines; MS: Mountain Streams; PF: Park Forest; MSJR: Meanders of the S (lower) Jordan River; DS: Dead Sea; AVMC: Alluvial Valleys in Mediterranean Climate; SDSC: Sand Dunes (Soil) Along the Coastline

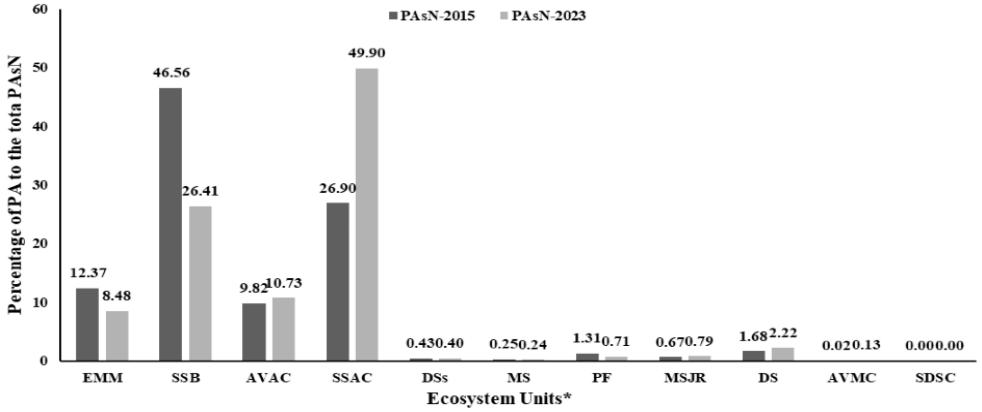

Figure 5. Percentage of PAs in each ecosystem unit in the total PAsN areas. *Notes: Abbreviations as in Figure 4

Table 5. The range of ecosystem units repersentatioin (protection) types

Representation indicator	Representation status	Range of Representation	Ecosystem units*	Ecosystem priority areas
% Representation*	Well represented	More than 17%	SSAC, DSs, MS, DS	EMM, SSB, AVAC, PF, MSJR, AVMC, SDSC
	Underrepresented	Less than 17%	EMM, SSB, AVAC, PF, MSJR, AVMC, SDSC	
Comparison index (CI)**	Well represented	One and more	AVAC, SSAC, DSs, MS, PF, DS	
	Underrepresented	Less than one	EMM, SSB, MSJR, AVMC, SDSC	

Note: *17%-level benchmark; **CI value >1 well represented, CI values≤1 indicates underrepresented. *Abbreviations as in Figure 4

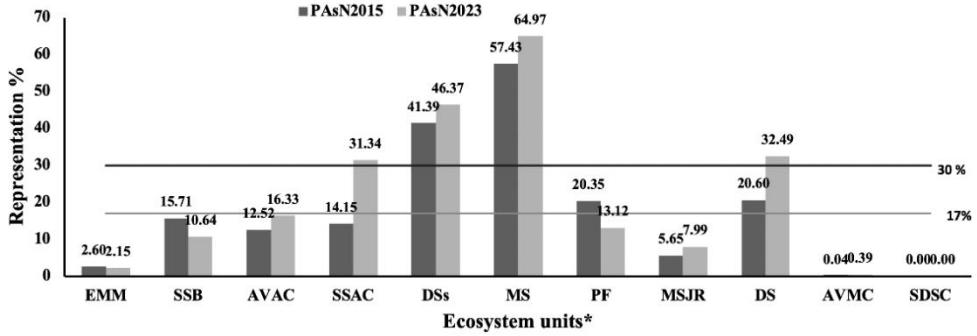

Figure 6. Representation percentages of PAsNs in different ecosystem units, the dashed pink and green lines are the 17% and 30% biodiversity conservation targets for terrestrial PAs, respectively. *Notes: Abbreviations as in Figure 4

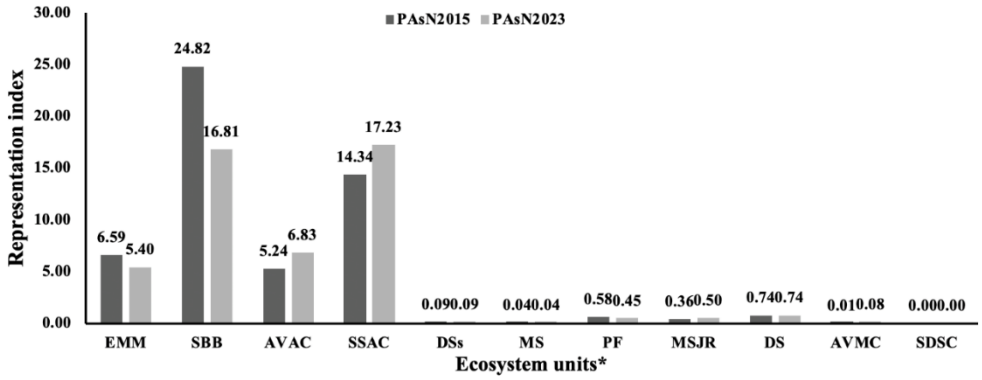

Figure 7. Representation index of PAs in the different ecosystem units in each PAsN. *Notes: Abbreviations as in Figure 4

The contribution of the PAsN-2023 to the Overall Biodiversity Conservation Index (OBCI) across the eleven ecosystem units was uneven (Figure 7), leading to a "poor" rating of 48%. The SSB and SSAC units had the highest contribution indices (17.00), followed by AVAC (6.83) and EMM (5.40). This disparity between representation percentage and ESRIn highlights the varying effectiveness of protection efforts. For example, despite MS having the highest protection rate (64.97%), its contribution to the OBCI was minimal (0.04) due to its relatively small area (2,217.5 dunums). Our analysis indicates that the new Palestinian National Protected Area Network (PAsN-2023) is unlikely to enhance the overall biodiversity representation. It demonstrated a poor overall biodiversity representation (OBCI: 48%), compared to the fair representation achieved by the original PAsN-2015 (OBCI: 53).

Moreover, using the CI method, the study found a significant imbalance in the representation of the eleven ecosystem units within protected areas. Six units (AVAC, SSAC, DSs, MS, PF, DS) were well represented (CI: 1.51, 2.90, 4.29, 6.00, 1.21, and 3.00, respectively), while five units (EMM, SSB, MSJR, AVMC, SDSC) were considerably underrepresented (CI: 0.20, 0.98, 0.74, 0.04, and 0.00, respectively) (Figure 8 and Table 5).

Compared to the PAsN-2015, there was a moderate increase in representation indicators (representation %, RI, and CI) for MSJR, AVMC, and AVAC units, due to the expansion of some protected areas (Figures 6, 7 and 8). However, there was a decline in these indicators for certain units (EMM, SSB, and PF) due to the uninformed abolition of protected areas like Jebel Al-Kebir and Tammoun, which, despite being recognized as categories IV and Ia (EQA 2023), are known to host endangered and endemic species, such as *Ferula samariae* and *Iris lortitii* var. *samariae* (https://redlist.parks.org.il/en/plants/observations/607608/, https://www.gbif.org/occurrence/3018062553). The representation of SDSC remained largely unchanged in the PAsN-2023.

These findings can guide conservation priorities for decision-makers and stakeholders in the Palestinian Authority. The focus should be placed on promoting conservation or landscape management in underrepresented ecosystem units, particularly in the western West Bank (AVAC, PF, SSB, MSJR, AVMC, and EMM) where underrepresentation gaps are most prevalent (Table 5).

Representation status of different vegetation types in the PAsN-2015 and PAsN-2023

The study also investigated how well the 2015 and 2023, PAsN capture the diversity of vegetation types in the West Bank. As a result, the evaluation assessed whether these PAs adequately cover (17%) of each vegetation type.

The representation status (representation percentages and comparison index) varies greatly among the 13 vegetation types (Figures 9 and 10). Desert vegetation H has the highest representation percentage, with 43.06% (CI: 4)

of its area within protected areas followed by desert savannoid vegetation L (38.13%, CI: 3.5), swamps and reed thickets J (32.61%, CI: 3), steppes vegetation G (30.62%, CI: 2.8), wet salines M (28.53%, CI: 2.6), *Z. lotus* with herbaceous vegetation D (16.17%, CI: 1.5), semi-steppe batha F (11.17%, CI: 1.1), savannoid Mediterranean vegetation E (9.22%, CI: 0.9), oases with Sudanian trees K (7.86%, CI: 0.7), Park forest of *C. siliqua* and *P. lentiscus* C (5.40%, CI: 0.5), Maquis and forest A (2.11%, CI: 0.2), synanthropic vegetation with *Z. spina-christi* trees and *A. raddiana* trees B (0%, CI: 0).

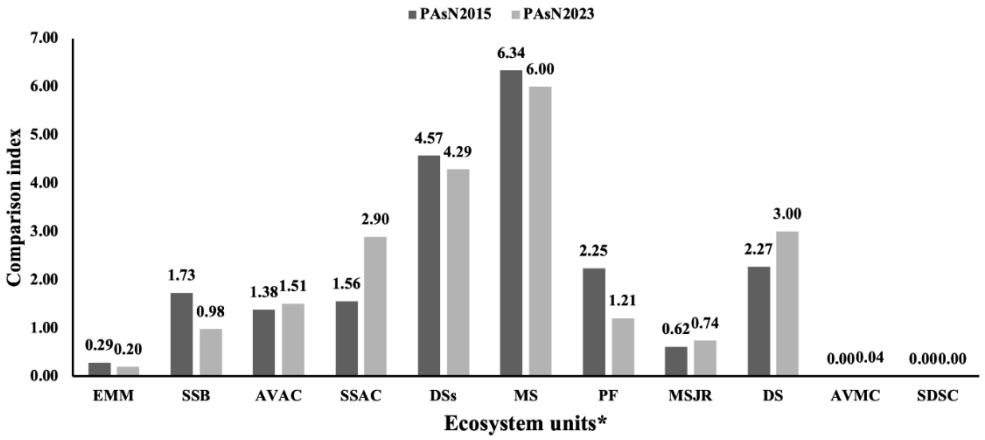

Figure 8. Comparison index of PAs in the different ecosystem units in each PAsN. *Abbreviations as in Figure 4

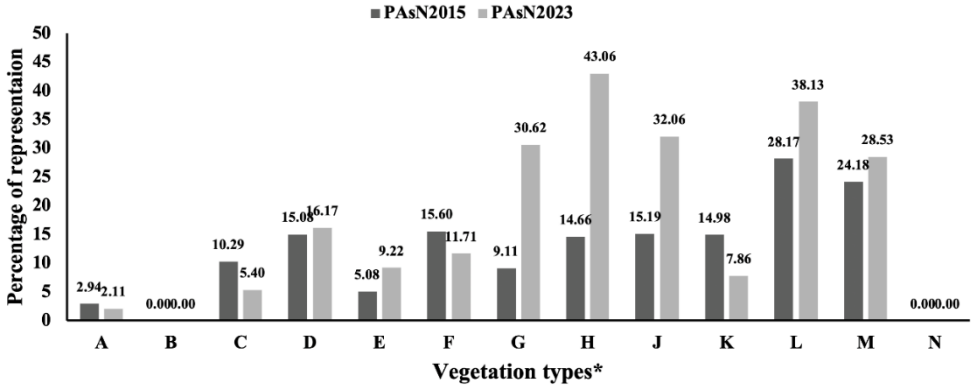

Figure 9. Percentage of representation of PAs in the different vegetation types in each PAsN. *Notes: A: Maquis and forest; B: Synanthropic vegetation with *Ziziphus spina-christi* trees and *Acacia raddiana* trees; C: Park forest of *Ceratonia Siliqua* and *Pistacia lentiscus*; D: *Ziziphus lotus* with herbaceous vegetation; E: Savannoid Mediterranean vegetation; F: Semi-steppe batha; G: Steppes vegetation; H: Desert vegetation; J: Swamps and reed thickets; K: Oases with Sudanian trees; L: Desert savannoid vegetation; M: Wet Salines; N: Synanthropic vegetation with *Z. spina-christi* trees

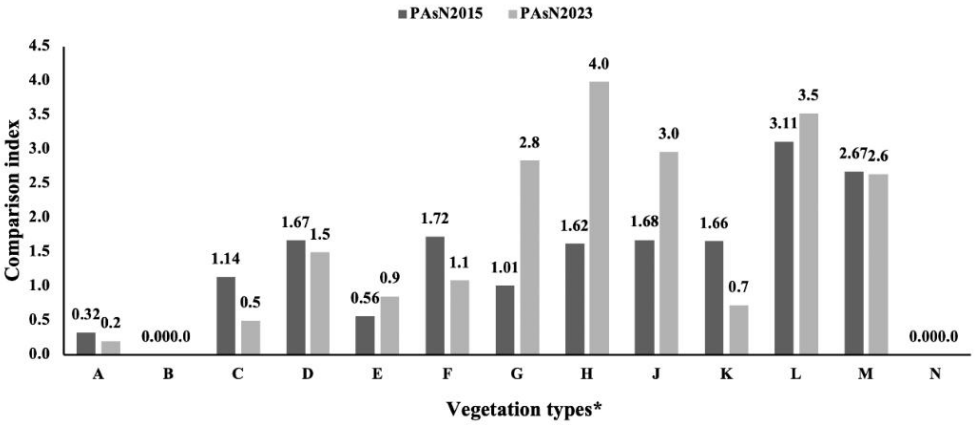

Figure 10. Comparison index of PAs in the different vegetation types in each PAsN. *Notes: Abbreviations as in Figure 9

By analyzing the representation of vegetation types in the 2023-PAsN, based on the 17% representation target, we show that these vegetation types are either not represented 0.0% (B and N), under-represented <17% (A, C, D, E, F, K), or over-represented >17% (L, M, G, H, J) (Figure 9). The comparison index results showed that seven vegetation types (D, F, G, H, J, L, M) are well represented in PAs with CI values >1 whereas six vegetation types (A, B, C, E, K, N) are under-represented with CI values ≤1 (Figure 10). The representation index of the thirteen vegetation types contributed differently to the whole Biodiversity Conservation Index (OBCI: 43%, poor). Vegetation types F and G have the highest contribution index (10.16, 8.68), followed by A (5.38), C (4.98), and L (4.38) (Figure 11).

By examining the representation indicators of vegetation types in the 2015 and 2023-PAs networks we demonstrated that the modifications applied on the PAsN-2015 did not affect the representation status of the two non-represented vegetation types (B and N, remained unrepresented). Slight changes occurred in the over-represented vegetation types >17% (L, M, G, H, J) with the later change was brought about by an excessive increase in the representation of the G, H, and J vegetation-types related PAs in the new PAsN-2023 from slightly under-represented in the original PAsN-2015 to excessively overrepresented (30-43%), with slight (if any) expected improvement on the whole area biodiversity. On the other hand, the representation of some of the largest under-represented vegetation types (A, C, F, K; 75.3% of the whole area) in the PAsN-2015 was considerably decreased with an expected comparable decrease in the whole country's biodiversity representation. This has been demonstrated by calculating the OBCI for both PAs networks where the PAs-2023 has shown a poor representation of overall biodiversity (OBCI: 43%), whereas the original PAsN-2015 show fair biodiversity representation (OBCI: 53) (Figures 9, 10 and 11).

Representation indicators demonstrated that vegetation types of the West Bank are not sufficiently represented through the new PAsN-2023, since PAs are skewed toward semi-steppe batha, and steppe vegetation leading to the low representation of other vegetation types such as maquis and forest vegetation cover, which includes small PAs (14% of the PA lands) despite that this vegetation type occupies the biggest size in the West bank (43% of the total area).

Terrestrial coverage and spatial distribution of PAsN-2023

The protected areas within the PAsN-2023 network are unevenly distributed across the region, with marked differences in ecosystem coverage between areas west and east of the Nablus-Jerusalem-Hebron Heights ridge (Figure 2). In the western region, dominated by the Evergreen Mediterranean Maquis (EMM) ecosystem, protected areas are smaller and account for approximately 8.5% of the total network. This region benefits from higher water availability and a temperate Mediterranean climate, supporting rich biodiversity, including over 65% (1237 taxa) of the West Bank's plant species (Ali-Shtayeh et al. 2022a, b).

In contrast, the eastern region comprises larger protected areas, making up 91.5% of the total network. This area includes four plant districts characterized by desert and semi-desert conditions with sparse vegetation, primarily semi-steppe batha and steppe vegetation. These harsher conditions support fewer plant species, accounting for 35% of the West Bank's flora (698 taxa) (Figure 2).

While larger areas generally support higher species richness, in this arid region, Mediterranean and sub-Mediterranean ecosystems require smaller areas for adequate biodiversity representation compared to desert ecosystems. However, underrepresentation gaps are most evident in the western West Bank, where human pressures, such as development and resource exploitation, are concentrated. Western districts, which host 75% of the population on 40% of the land, face significant challenges in implementing conservation measures, leading to limited protected area representation in Tulkarm, Qalqilyah, Salfit, and Nablus districts. These factors contribute to an uneven protection pattern and weaken the effectiveness of the overall network (Fan et al. 2023).

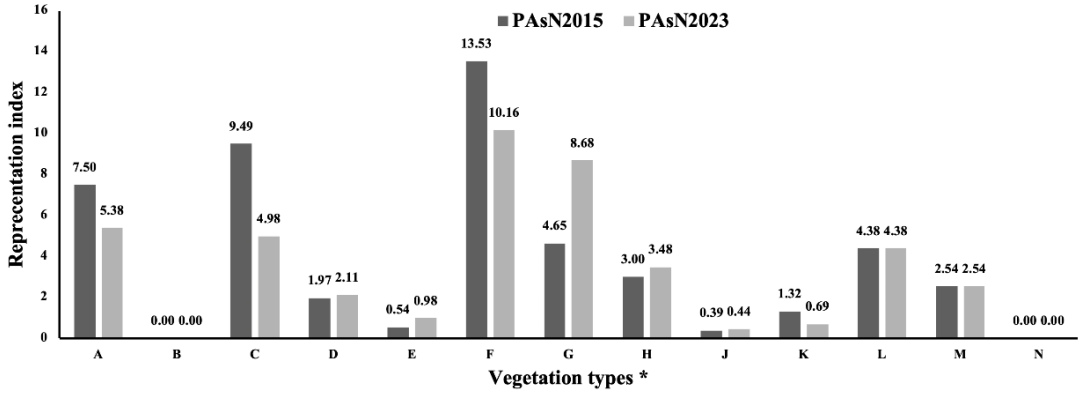

Figure 11. Representation index of PAs in the different vegetation types in each PAsN. *Notes: Abbreviations as in Figure 9

Shortcomings of the PAsN-2023 Network

Although the Palestinian Cabinet approved PAsN-2023, the network does not achieve its goal of establishing a system of protected areas that are ecologically representative, well-connected, and effectively managed (CBD 2010). Covering 10.8% of the country, the network falls short of the 17% benchmark, leaving several ecosystems and vegetation types underrepresented or unrepresented. Expansion efforts are heavily concentrated in Area C (93%), limiting accessibility for adjacent Palestinian communities and hindering practical implementation.

The 2023 assessment relied on vegetation mapping using Danin's system (Danin 1992) and MARXAN software but was constrained by limited biodiversity data (Ali-Shtayeh et al. 2022b; Qumsiyeh et al. 2023). Conservation priorities were arbitrarily set, targeting 10% of vegetation types without adequate scientific justification. As a result, the assessment failed to adhere to essential conservation principles such as representation (e.g. the 17% target for each ecosystem), persistence, and biodiversity-based quantitative targets (Jewitt 2018; Jalilian et al. 2021). This flawed methodology produced outputs that are inadequate for policy-making and conservation practice, wasting resources through poor design, biased reporting, and methodological errors (Cook et al. 2019; Ali-Shtayeh et al. 2022c).

Political and management challenges

Between August 2023 and March 2024, Israeli authorities issued military orders expanding PAsN-2015 by adding new reserves and modifying existing ones, encompassing approximately 26 km² in Area C. These politically motivated expansions further complicate the implementation of PAsN-2023 and undermine its ecological objectives. The current network fails to address ecosystem conservation priorities effectively, as detailed in Figure 12.

Strategic recommendations for biodiversity conservation

For each of the seven underrepresented ecosystem units (i.e. conservation priority ecosystems: EMM, SSB, AVAC, PF, MSJR, AVMC, and SDSC), we spatially identified the remaining unprotected native lands and calculated their respective areas (Table 6 and Figure 13). Additionally, we estimated the total unprotected native land required to meet the 17% benchmark for adequate representation of all underrepresented terrestrial ecosystems (Table 6).

Our findings reveal that sufficient unprotected land exists to achieve the 17% target for four ecosystem units: EMM, SSB, AVAC, and MSJR. This presents an opportunity to enhance the protection of these ecosystems by either expanding or adjusting existing protected areas or establishing new ones. Furthermore, we recommend creating a network of small conservation sites, safe havens, botanical gardens, and national parks to protect biodiversity and ecosystems beyond the boundaries of existing protected areas. Many of these unprotected native areas may encompass key biodiversity areas (KBAs), important bird areas (IBAs), and other biodiversity-rich regions outside protected areas. However, for ecosystem units that are adequately or overrepresented (≥17%), additional conservation measures are unnecessary.

Enhancing the ecological representativeness of protected area networks is crucial for achieving effective conservation outcomes (Aycrigg et al. 2013). However, under-representation in densely populated and cultivated areas (e.g. Tulkarm, Qalqilya, and Nablus) poses significant challenges. For instance, the Mediterranean Evergreen Maquis (EMM) ecosystem, though vulnerable, demonstrates a capacity for recovery when anthropogenic impacts are reduced.

Table 6. Ecosystem units areas, their representation percentages in the protected areas, needed areas of natural lands based on Aichi 17% representation target and the unprotected native areas

Ecosystem units*	Ecosystem unit area	Area of PAs in each ES unit (% representation)	Unprotected native areas	AICHI targets (17%)		Kunming-Montreal target (30%) by 2030	
				Total needs of natural land	Required natural land area	Total needs of natural land	Required natural land area
Underrepresented ecosystem units							
EMM	2414413.23	51870.71 (2.15%)	838670.79	410450.25	358579.54	724323.97	672453.26
SSB	1518664.07	161563.65 (10.64%)	744777.08	258172.89	51049.32	455599.22	294035.57
AVAC	401846.64	65617.83 (16.33%)	153989.65	68313.93	2696.10	120553.99	54936.16
PF	32975.84	4325.47 (13.12%)	903.50	0	1280.42	9892.75	5567.28
MSJR	60465.86	4831.75 (7.99%)	32816.21	10279.2	5447.44	18139.76	13308.00
AVMC	200907.49	789.55 (0.39%)	9315.17	34154.27	33364.72	60272.25	59482.69
SDSC	1614.02		0	274.38	274.38289	484.21	484.2051
Overrepresented ecosystem units							
SSAC	974053.99	305309.45 (31.34%)	572290.61	165589.18	0.00	292216.2	0.00
DSs	5335.08	2474.12 (46.37%)	741.60	0	0.00	0	0.00
MS	2217.55	1440.70 (64.97%)	776.85	0	0.00	0	0.00
DS	41777.79	13572.47 (32.49%)	16455.51	0	0.00	12533.34	0.00

Note: *Abbreviations as in Figure 4

Review: Critical evaluation of the PAsN-2023

The 2023 assessment (EQA 2023; Qumsiyeh et al. 2023) primarily focused on developing the protected area network through vegetation mapping based on Danin's vegetation types system (Danin 1992), utilizing MARXAN software with unreliable limited biodiversity data. The study prioritized conservation based on an arbitrary 10% threshold for entire vegetation types, rather than using the best available science to account for ecosystem diversity. Consequently, the study lacks a robust scientific methodology and occasionally relies on subjective justifications for decisions related to the abolition, redefinition, expansion, or merging of the 50 protected areas. This led to a flawed assessment, producing outcomes that lack key principles such as representation (e.g., the 17% target for each ecosystem unit), persistence, quantitative biodiversity-based targets, and conservation priority areas (Rouget et al. 2006). Such an assessment serves as a stark example of how conservation research resources can be wasted. Such wastage includes but is not limited to, (a) producing flawed outputs that are inadequate to inform policy or practice, (b) poor research design, (c) unreported data or findings, (d) biased and low-quality reporting, and (e) methodological errors (Pullin and Knight 2009). Addressing these issues is crucial for ensuring that conservation management and policy are informed by robust, evidence-based research.

The study's methodology (Qumsiyeh et al. 2023) was inadequately described, with insufficient detail to permit replication, which is a fundamental aspect of scientific research (Haddaway and Verhoeven 2015). For instance, the processes for identifying the environmental risk surface (ERS) and calculating the relative biodiversity rareness index (RBI) were poorly explained, and no credible references were provided for the risk elements and layers used in the analysis. This lack of transparency undermines the reliability of the study's findings (Powers and Hampton 2019). Moreover, there were instances of self-plagiarism, with reused material not appropriately cited, further contributing to the study's inaccessibility and lack of verifiability (Kumar et al. 2014).

The Marxan analysis employed suboptimal data, relying solely on GBIF records for species distribution. While GBIF is valuable for broad biodiversity assessments, its limitations are well-documented, particularly for conservation planning where more precise, up-to-date, and comprehensive data are needed (Ardron et al. 2010). The absence of essential metadata, including the extraction date, specific GBIF sources, and data cleaning methods, raises concerns regarding the scientific rigor and reproducibility of the analysis (Leipzig et al. 2021). Accurate and current data are critical for threatened species, and the study failed to integrate other sources or expert knowledge to supplement the GBIF data, such as the IUCN Red List or field surveys, as recommended in conservation best practices (Rodrigues et al. 2004).

The study further illustrates the risks of using Marxan with incomplete or poor-quality data, leading to unreliable outputs, overgeneralized priority areas, and inaccurate cost-effectiveness estimates (Ball et al. 2009). The lack of comprehensive data and the failure to validate results with expert input and stakeholder engagement contribute to the risk of suboptimal conservation outcomes. These challenges are particularly evident in data-sparse regions such as the West Bank, where the terrestrial ecosystems require robust ground-truthing to support effective conservation planning.

Fieldwork discrepancies also pose significant concerns. While the authors claimed to have conducted 22 field trips between March and August 2022, only four trips were documented, and these were limited to the summer months (two consecutive weeks in July and August), significantly reducing the temporal scope necessary for accurate biodiversity assessment. Moreover, the claim that 31 Protected Areas (PAs) were assessed on a single day (August 11, 2022) strains credibility, especially considering that most of these PAs are located in Area C, where access is restricted. These discrepancies suggest either misrepresentation or poor documentation, which raises serious ethical concerns about the study's integrity.

Furthermore, the study's reliance on qualitative criteria, later converted into quantitative metrics, introduces methodological issues. The subjective nature of terms such as "high threat" and "critical habitat" can lead to inconsistent interpretations and skewed results (Mace et al. 2008). Converting these ambiguous criteria into quantitative metrics without sufficient scientific justification exacerbates these issues, further undermining the validity of the study's conclusions. Additionally, the potential conflict of interest, where stakeholders involved in data collection may have had vested interests, compromises the objectivity of the research. Independent parties should have conducted field surveys to ensure impartiality and reliability (Bonn et al. 2016).

The evaluation of the study against the IUCN's six-step process for assigning protected area categories uncovers several critical issues. Firstly, it fails to specify whether specific management objectives for the newly designated protected areas were established, undermining the alignment of conservation goals with IUCN principles. Additionally, it does not clarify if a formal assessment was conducted to ensure that the sites meet IUCN standards for protected areas, creating uncertainty about their qualification. There is also a notable lack of documentation regarding site characteristics such as legal status and management objectives, raising concerns about the rigor and reliability of the designation process. Furthermore, the process for proposing management categories is not described, and no structured guidelines or selection tools are mentioned, which are essential for ensuring scientifically sound categories. While stakeholder collaboration is acknowledged, there is no evidence of a formal consultation process, which is crucial for achieving consensus. Finally, the absence of well-informed impeccable government involvement in the final decision-making process casts doubt on the legal standing and enforceability of the designations. These gaps suggest that the process may not fully adhere to IUCN guidelines, potentially compromising the credibility and effectiveness of the protected area designations.

The results of the study exhibit numerous inconsistencies and inaccuracies that suggest potential research misconduct. For example, the study reported that a cutoff score of 30 was applied to exclude areas from the Protected Areas Network (PAsN 2015), with 22 areas reportedly excluded. However, raw data analysis revealed that only 17 areas scored below 30, indicating potential data manipulation. This discrepancy suggests subjectivity in applying the cutoff criteria, casting doubt on the reliability of the exclusion process. Moreover, the biological justification for excluding several areas from the original PAsN was absent. The lack of rationale for these exclusions raises questions about whether these decisions were based on scientific evidence or were arbitrarily made. For instance, critical biodiversity hotspots that should have been prioritized for protection were excluded without adequate explanation, further suggesting potential bias or manipulation of data.

The study further claimed that the new Protected Areas Network (PAsN 2023) covers 10% of all vegetation types in Palestine. However, a review of the data indicates that two vegetation types are entirely unrepresented, and three others fall well below the 10% target. This misrepresentation is critical because it misleads stakeholders into believing the network is more comprehensive than it is, potentially leaving key ecosystems vulnerable.

Despite identifying serious challenges, such as weak governance, poor stakeholder engagement, and unsystematic planning, the authors still proposed a new protected area network. This contradiction highlights a significant flaw in the research. A reliable conservation plan cannot be proposed when the foundational data and processes are deeply flawed. The introduction of a new vegetation map, without citing previous studies that documented similar maps, also undermines the scientific contribution of this work.

In conclusion, the study is compromised by poor-quality data, methodological flaws, and potential conflicts of interest, significantly undermining the reliability of its conclusions. The authors must address these critical issues by ensuring transparent documentation, using objective criteria, and involving independent, impartial experienced parties in data collection and analyses. Strengthening these areas is essential to producing robust, reliable conservation strategies that can effectively support biodiversity conservation in Palestine (Rodrigues et al. 2004).

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Figure 12. Critical evaluation of the PAsN-2023

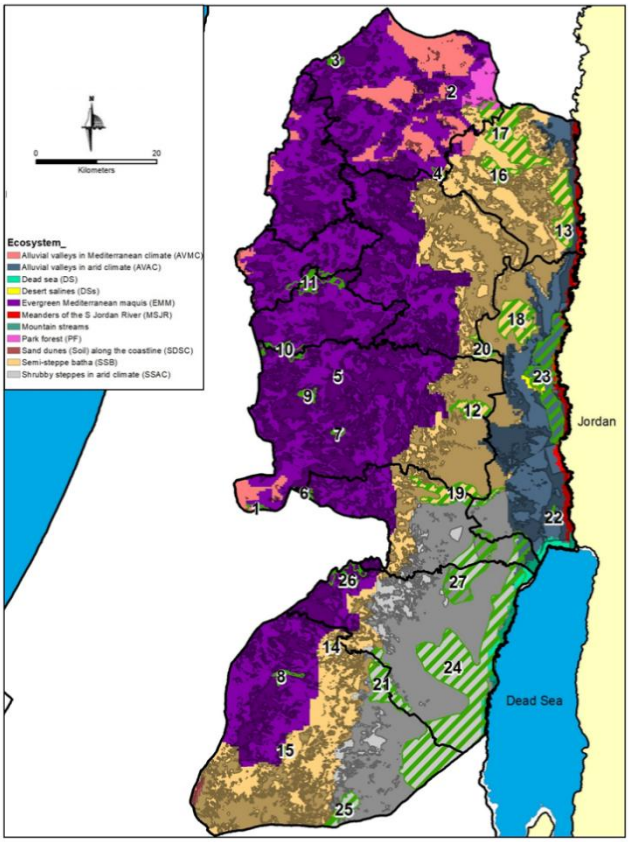

Figure 13. Unprotected native areas in each ecosystem unit in the West Bank, Palestine

Promoting new protected areas in these densely populated regions is impractical due to current political and demographic constraints. Instead, collaborative efforts with private landowners and stakeholders, including farmers, ministries, municipalities, and NGOs, are essential to improve biodiversity representation.

For ecosystem units with insufficient unprotected native areas, such as PF and AVMC, biodiversity conservation efforts should focus on establishing a network of small conservation sites. This strategy complements existing protected areas, integrates endemic and threatened plant species, and creates a comprehensive conservation system capable of preserving biodiversity outside designated protected areas.

Specific recommendations for critical ecosystems

Sand Dunes Along the Coastline (SDSC)

The entire SDSC ecosystem lies within Qalqilya city's built-up area (0.33 km²), with no remaining natural lands. While it is impossible to meet the representation benchmark, small conservation sites should be established to protect any threatened or endemic species identified through future studies. Such efforts will require collaboration with landowners and tailored agreements.

Integration of micro-reserves

Biodiversity in unprotected lands can be conserved by creating micro-reserves for critically endangered and endemic plant species, such as the Nablus Iris (*Iris lortetii* var. *samariae*). Research by Abu-Zaitoun et al. (2022) identified this species as endangered (EN), proposing specific locations for micro-reserves to prevent its extinction.

Quasi-in-situ and ex-situ conservation

To safeguard endemic Nablus Iris populations and other threatened species, quasi-in-situ conservation measures (e.g. safe havens) and ex-situ strategies (e.g. botanical gardens and gene banks) should be employed. For instance, the "Palestinian National Site for the Conservation of the Royal Iris and Threatened Plant Species" at the BERC Botanical Gardens in Tell, Nablus, is a critical site for these efforts.

Role of botanical gardens

Botanical gardens play a pivotal role in biodiversity conservation by integrating quasi-in-situ and ex-situ strategies. These gardens can expand their mission to include: A) Introducing and researching plant species; B) Safeguarding wild genetic resources is essential for climate adaptation; C) Protecting economically and socially significant wild species; D) Conserving marginal or secondary crops, including those with nutritional, medicinal, or energy potential (Ali-Shtayeh et al. 2022b).

In conclusion, the study highlights significant disparities in ecosystem representation within the Palestinian Protected Areas Networks, emphasizing the need for improved biodiversity conservation. The PAsN-2023 shows uneven conservation across ecosystem units and vegetation types, with some overrepresented while others, particularly in the western West Bank, remain severely underrepresented. This imbalance negatively impacts overall biodiversity conservation, as evidenced by a lower Overall Biodiversity Conservation Index (OBCI) in the 2023 network compared to 2015. Despite some progress in expanding protected areas in the eastern regions, issues such as political constraints, uninformed decisions, and insufficient consideration of ecosystem diversity hinder the network's effectiveness. Strategic recommendations include expanding protection in underrepresented ecosystem units, creating small conservation sites, and collaborating with private landowners to enhance biodiversity protection in densely populated areas. These steps are essential for establishing a more balanced, ecologically representative, and effective protected area system in Palestine.

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