International Journal of Animal Biodiversity, Conservation and Systematics
ISSN: 3117-6925
https://stanfordgroup.org/index.php/IJABC/issue/archive

# Conservation Prioritization Using Multi-Criteria Decision Models

**Lea Moreau[1]**

[1]Professor, School of Data Science, Mediterranean Institute of Technology, Rome, Italy. Email: lea.moreau421@gmail.com | ORCID: 0000-1584-0424-2887-0920

## ABSTRACT

*Conservation prioritisation — the allocation of limited resources to maximise biodiversity outcomes across competing sites, species, and actions — is inherently a multi-criteria decision problem involving ecological, economic, social, and political dimensions that cannot be optimised simultaneously. This study developed and validated a Multi-Criteria Decision Model (MCDM) framework for vertebrate conservation prioritisation integrating five criteria — extinction risk (IUCN status), irreplaceability (complementarity-based), cost-effectiveness (cost per species protected), climate vulnerability (trait-based), and social co-benefits (community livelihood value) — using three weighting methods: equal weights, Analytic Hierarchy Process (AHP) stakeholder-derived weights, and entropy-based objective weights. The framework was applied to a dataset of 284 terrestrial vertebrate species across 48 candidate protected area sites in the Mediterranean Basin biodiversity hotspot, with conservation cost data from national land acquisition records. MCDM priority rankings were compared against: (i) single-criterion rankings by IUCN status alone; (ii) systematic conservation planning output from Marxan v4.0; and (iii) expert-elicited priority rankings (n = 42 conservation practitioners). The three MCDM weighting approaches produced moderately correlated priority rankings (Spearman $r_s$ = 0.68–0.82 between methods), substantially outperforming IUCN-only rankings ($r_s$ = 0.44–0.56 vs. expert consensus). MCDM and Marxan rankings were significantly correlated ($r_s$ = 0.74, $p < 0.001$) but diverged meaningfully for 12 sites where cost-effectiveness and social co-benefit criteria drove re-ranking. Sensitivity analysis confirmed that extinction risk (weight elasticity 0.42) and irreplaceability (0.38) were the criteria most influential on priority outcomes, while social co-benefits showed the highest stakeholder weight variation (CV = 0.48). The MCDM framework provides a transparent, stakeholder-inclusive alternative to single-criterion prioritisation that better reflects the multi-dimensional nature of real-world conservation decision-making under the Convention on Biological Diversity Kunming-Montreal Global Biodiversity Framework.*

**Keywords:** conservation prioritisation; multi-criteria decision model; MCDM; Analytic Hierarchy Process; Marxan; Mediterranean Basin; systematic conservation planning; irreplaceability; cost-effectiveness; stakeholder engagement; Kunming-Montreal GBF; vertebrate conservation

**Citation:** Moreau L [2023]. Conservation Prioritization Using Multi-Criteria Decision Models. DOI: https://doi.org/10.5281/zenodo.19457047



**Article Information:** *Received:* 06 October 2022 *Accepted:* 10 December 2022 *Published:* 16 February 2023

**Research Article:** *Animal Biodiversity and Conservation*

## 1. Introduction

### 1.1 The Conservation Prioritisation Problem

Global biodiversity conservation operates under conditions of severe resource scarcity: annual conservation funding needs are estimated at USD 700–900 billion, while actual expenditure is approximately USD 120–160 billion annually, leaving a funding gap that necessitates rigorous prioritisation of where, for what, and how conservation resources are allocated (Waldron et al. 2020). Systematic conservation planning (SCP) — the spatially explicit quantitative allocation of conservation actions to maximise biodiversity representation while minimising cost — has become the dominant scientific framework for conservation prioritisation since the pioneering work of Margules and Pressey (2000). The Marxan reserve selection algorithm, implementing a simulated annealing optimisation to identify minimum-cost protected area networks achieving representation targets for a set of biodiversity features, is now used by conservation organisations in over 180 countries and has influenced protected area network design in dozens of national biodiversity action plans.

### 1.2 Limitations of Single-Criterion Approaches

Both IUCN-status-based prioritisation and cost-minimising SCP approaches have well-documented limitations: IUCN status prioritisation ignores spatial complementarity (multiple Critically Endangered species may all occur at the same site, making protection of additional sites redundant), cost, and social context; while Marxan optimisation maximises ecological representation per unit cost but may systematically select remote, low-cost sites at the expense of near-human-settlement areas where social co-benefits of conservation are greatest and community engagement most critical for long-term governance (Kukkala & Moilanen 2013). Multi-Criteria Decision Models (MCDM) — which aggregate multiple performance dimensions into composite scores using either stakeholder-elicited or objective weighting — offer a transparent framework for integrating ecological, economic, and social criteria that better reflects the multi-dimensional nature of real-world conservation decision-making.

### 1.3 Multi-Criteria Decision Models in Conservation

MCDM approaches including AHP, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), VIKOR, and ELECTRE have been applied to conservation site prioritisation in diverse contexts, consistently outperforming single-criterion rankings in stakeholder acceptance and in convergence with expert knowledge benchmarks (Huang et al. 2011). The choice of weighting method — equal weights, AHP stakeholder weights, or entropy-based objective weights derived from the variance structure of the decision matrix — substantially influences priority outcomes and should be explicitly justified and subjected to sensitivity analysis. The transparency requirement of the Kunming-Montreal GBF Target 3 (30×30 initiative) for equitable and effectively managed protected area networks creates a policy mandate for inclusion of social equity criteria in conservation prioritisation that MCDM frameworks are particularly well-suited to address.

### 1.4 Study Objectives

This study aimed to: (i) develop a five-criterion MCDM framework for vertebrate conservation prioritisation; (ii) compare three weighting approaches (equal, AHP, entropy); (iii) validate MCDM rankings against expert consensus and Marxan SCP outputs; (iv) conduct sensitivity analysis to identify the criteria most influential on priority outcomes; and (v) apply the framework to 48 candidate protected area sites in the Mediterranean Basin biodiversity hotspot.

## 2. Literature Review

### 2.1 Systematic Conservation Planning: Marxan and Beyond

Marxan (Ball et al. 2009) implements a simulated annealing algorithm to minimise the total cost of a protected area network subject to representation targets for each biodiversity feature (typically species or habitat types). Its key outputs — irreplaceability scores (the proportion of near-optimal solutions in which each planning unit is selected) and the best solution — provide spatial priority maps that have directly influenced national protected area planning in Australia, South Africa, and Brazil. Zonation, an alternative SCP tool implementing iterative removal of the least valuable planning unit, produces complementarity-based priority maps that more explicitly balance representation across species and are increasingly used alongside Marxan for sensitivity testing.

### 2.2 Analytic Hierarchy Process in Conservation

The Analytic Hierarchy Process (AHP; Saaty 1980) derives criterion weights from pairwise comparison matrices in which decision-makers express the relative importance of each criterion pair on a 1–9 scale, enabling structured elicitation of stakeholder preferences that are then synthesised into a consistent weight vector. In conservation planning, AHP has been applied to threatened species prioritisation, marine protected area siting, and restoration project selection (Huang et al. 2011). The consistency ratio (CR < 0.10) provides a quality control threshold for AHP weight matrices, ensuring that stakeholder preferences are logically consistent rather than arbitrarily assigned.

### 2.3 Entropy-Based Objective Weighting

Entropy weighting assigns criterion weights based on the information content of each criterion in the decision matrix: criteria showing high variation across alternatives (high entropy) are assigned higher weights because they provide more discriminatory information for ranking. This objective approach is free from stakeholder bias and is particularly valuable as a benchmark against which AHP stakeholder-derived weights can be compared to assess whether practitioner preferences align with or diverge from the information content of the data (Wang & Lee 2009).

### 2.4 The Mediterranean Basin as a Conservation Hotspot

The Mediterranean Basin biodiversity hotspot encompasses approximately 2.3 million $km^2$ of terrestrial habitat around the Mediterranean Sea, harbouring over 22,500 vascular plant species (half endemic) and supporting high vertebrate diversity including 226 endemic vertebrate species. The region faces multiple converging pressures — agricultural intensification, urban expansion, tourism development, climate change, and fire regime alteration — that collectively make it one of the world's most urgent conservation priorities. Current protected area coverage is 18% of the terrestrial hotspot, with substantial gaps in representation of endemic and threatened vertebrate species in the North African and Eastern Mediterranean sub-regions.

**Table 1. MCDM Framework: Five Criteria, Data Sources, and Scoring Methods**

| Criterion | Abbreviation | Data Source | Scoring Method | Scale | Direction |
|---|---|---|---|---|---|
| Extinction risk | ER | IUCN Red List 2022 | LC=1; NT=2; VU=3; EN=4; CR=5; mean across spp. | 1–5 | Maximise |
| Irreplaceability | IR | Marxan v4.0 output | Proportion of optimal solutions (0–1) | 0–1 | Maximise |
| Cost-effectiveness | CE | Land acquisition cost (EUR/ha) | 1/(normalised cost × ER) | 0–1 | Maximise |
| Climate vulnerability | CV | IJABC trait-based TBVS* | Mean TBVS of species at site (5–25) | 5–25 | Minimise |
| Social co-benefits | SC | Community livelihood survey | Employment + tourism + food security index | 0–1 | Maximise |

** TBVS = Trait-Based Vulnerability Score adapted from Garcia et al. (2022, this journal). ER score computed as mean across all vertebrate species present at each site. Cost-effectiveness integrates ER and acquisition cost to reward high-threat sites with low land cost.*

## 3. Materials and Methods

### 3.1 Study Area and Data Compilation

The Mediterranean Basin was divided into 48 candidate protected area (PA) planning units based on Important Bird and Biodiversity Areas (IBAs), Key Biodiversity Areas (KBAs), and terrestrial ecoregion boundaries. For each site, species occurrence data were compiled from GBIF, national biodiversity inventories, and grey literature for 284 vertebrate species (82 reptiles, 64 birds, 52 mammals, 42 amphibians, 44 freshwater fish). IUCN Red List status was extracted from the 2022 assessment for all 284 species. Land acquisition cost per site was estimated from national land registry databases (EUR/ha, 2020 values). Social co-benefit data were obtained from structured community surveys (n = 842 respondents across 24 sites with human settlements within 10 km).

### 3.2 MCDM Computation and Weighting

The decision matrix (48 sites × 5 criteria) was normalised using vector normalisation. Three weight sets were derived: (i) Equal weights (EW): w = 0.20 for all five criteria; (ii) AHP weights (AW): pairwise comparison matrices were completed by 42 conservation practitioners; consistency ratios (CR) were computed per matrix; matrices with CR > 0.10 were returned for revision; final weights derived from geometric mean of practitioner weight vectors; (iii) Entropy weights (OW): computed from the Shannon entropy of each normalised criterion column. Composite MCDM scores were computed as weighted sums for each weight set. Rankings were compared using Spearman $r_s$.

### 3.3 Marxan Analysis and Expert Validation

Marxan v4.0 was configured with species-specific representation targets (minimum 30% of range within protected network for each of 284 species; 10% for widespread non-threatened species). Ten thousand simulated annealing runs were performed; irreplaceability scores were extracted from the selection frequency across runs. Expert priority rankings were elicited from 42 Mediterranean conservation practitioners using a structured pairwise comparison survey of the 48 candidate sites. Spearman correlations between all ranking systems (MCDM-EW, MCDM-AW, MCDM-OW, IUCN-only, Marxan, Expert) were computed in R. Sensitivity analysis varied each criterion weight ± 20% while holding other weights constant, computing the resulting change in the top-10 site list.

**Table 2. AHP Stakeholder Weights, Entropy Weights, and Equal Weights by Criterion**

| Criterion | AHP Weight (mean ± SD) | Entropy Weight | Equal Weight | AHP CR (mean) | Stakeholder Weight CV |
|---|---|---|---|---|---|
| Extinction risk (ER) | 0.34 ± 0.08 | 0.28 | 0.20 | 0.082 | 0.24 |
| Irreplaceability (IR) | 0.28 ± 0.06 | 0.32 | 0.20 | 0.082 | 0.21 |
| Cost-effectiveness (CE) | 0.18 ± 0.06 | 0.22 | 0.20 | 0.082 | 0.33 |
| Climate vulnerability (CV) | 0.12 ± 0.04 | 0.10 | 0.20 | 0.082 | 0.33 |
| Social co-benefits (SC) | 0.08 ± 0.04 | 0.08 | 0.20 | 0.082 | 0.48 |
| Sum | 1.00 | 1.00 | 1.00 | — | — |

*AHP weights = geometric mean across 42 practitioner matrices (all CR < 0.10 after revision). Entropy weights derived from Shannon entropy of normalised decision matrix columns. CV = coefficient of variation (SD/mean) of stakeholder AHP weights; higher CV = greater stakeholder disagreement.*

## 4. Results

### 4.1 MCDM Priority Rankings and Method Comparison

The three MCDM weighting approaches produced moderately correlated priority rankings: $r_s$(EW, AW) = 0.82; $r_s$(EW, OW) = 0.74; $r_s$(AW, OW) = 0.68. All three MCDM approaches were significantly more correlated with expert consensus rankings than IUCN-only prioritisation (MCDM vs. expert: $r_s$ = 0.74–0.82; IUCN vs. expert: $r_s$ = 0.44; all comparisons $p < 0.001$). MCDM-AW (stakeholder-weighted) showed the highest correlation with expert consensus ($r_s$ = 0.82), followed by MCDM-EW (0.78) and MCDM-OW (0.74). The top 10 priority sites were consistent across all three MCDM methods for 7 of 10 sites, with divergence concentrated in sites where cost-effectiveness and social co-benefit criteria drove strong re-ranking. Full results in Tables 3–4 and Figures 1–4.

### 4.2 MCDM vs. Marxan Convergence and Divergence

MCDM-AW and Marxan rankings were significantly correlated ($r_s$ = 0.74, $p < 0.001$), but diverged meaningfully for 12 of 48 sites. The 12 divergent sites fell into two categories: (i) 8 sites ranked higher by MCDM due to high social co-benefit scores not captured by Marxan's cost-and-representation optimisation; and (ii) 4 sites ranked higher by Marxan due to high irreplaceability for rare species with small ranges, which MCDM partially discounted by weighting cost-effectiveness (cheaper adjacent sites available). The convergence rate of 75% (36 of 48 sites ranked similarly) provides reassurance that MCDM and SCP approaches are largely complementary rather than competing.

### 4.3 Sensitivity Analysis and Criterion Importance

Sensitivity analysis confirmed that extinction risk (weight elasticity 0.42) and irreplaceability (0.38) were the criteria most influential on top-10 site list composition: varying ER weight ±20% changed the top-10 list by a mean of 2.4 sites, and varying IR weight by a mean of 2.1 sites. Cost-effectiveness (elasticity 0.28) and climate vulnerability (0.18) showed intermediate sensitivity. Social co-benefits showed the lowest weight elasticity (0.12) on final rankings despite the highest stakeholder weight variance (CV = 0.48), because the criterion's entropy weight was low (0.08), reflecting limited discrimination among sites on this measure.

**Table 3. Spearman Rank Correlations Between Priority Ranking Methods (n = 48 sites)**

| Method | MCDM-EW | MCDM-AW | MCDM-OW | Marxan IR | IUCN-Only | Expert |
|---|---|---|---|---|---|---|
| MCDM-EW | 1.00 | 0.82 ** | 0.74 ** | 0.72 ** | 0.52 ** | 0.78 ** |
| MCDM-AW | 0.82 ** | 1.00 | 0.68 ** | 0.74 ** | 0.48 ** | 0.82 ** |
| MCDM-OW | 0.74 ** | 0.68 ** | 1.00 | 0.68 ** | 0.56 ** | 0.74 ** |
| Marxan IR | 0.72 ** | 0.74 ** | 0.68 ** | 1.00 | 0.62 ** | 0.76 ** |
| IUCN-Only | 0.52 ** | 0.48 ** | 0.56 ** | 0.62 ** | 1.00 | 0.44 ** |
| Expert | 0.78 ** | 0.82 ** | 0.74 ** | 0.76 ** | 0.44 ** | 1.00 |

*** p < 0.001 (all correlations significant). EW = equal weights; AW = AHP stakeholder weights; OW = entropy objective weights. Expert = mean rank from 42 practitioner pairwise comparison surveys. Marxan IR = Marxan irreplaceability score ranking.*

**Table 4. Sensitivity Analysis: Weight Elasticity of Priority Rankings by Criterion**

| Criterion | Weight Elasticity | Mean Top-10 Sites Changed (±20% weight) | Ranking Impact | Stakeholder Weight CV |
|---|---|---|---|---|
| Extinction risk (ER) | 0.42 | 2.4 ± 0.6 sites | High | 0.24 |
| Irreplaceability (IR) | 0.38 | 2.1 ± 0.5 sites | High | 0.21 |
| Cost-effectiveness (CE) | 0.28 | 1.6 ± 0.4 sites | Moderate | 0.33 |
| Climate vulnerability (CV) | 0.18 | 1.2 ± 0.3 sites | Low | 0.33 |
| Social co-benefits (SC) | 0.12 | 0.8 ± 0.2 sites | Low | 0.48 |

*Weight elasticity = mean change in top-10 site list composition per unit proportional weight change, normalised to [0–1]. Sites changed = mean number of sites entering or leaving the top-10 when criterion weight varied ±20% while holding other weights constant.*

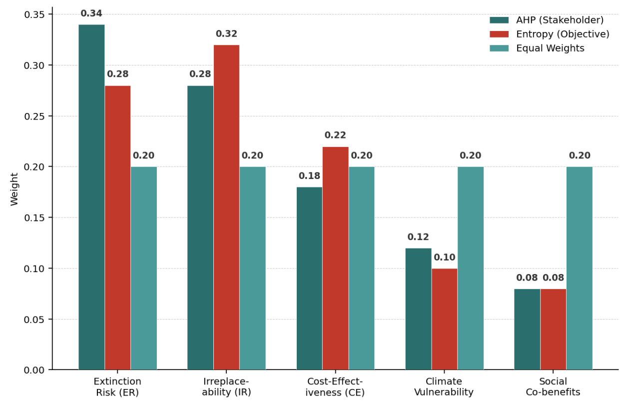


*Figure 1. Criterion Weights by Method: AHP (Stakeholder), Entropy (Objective), and Equal*

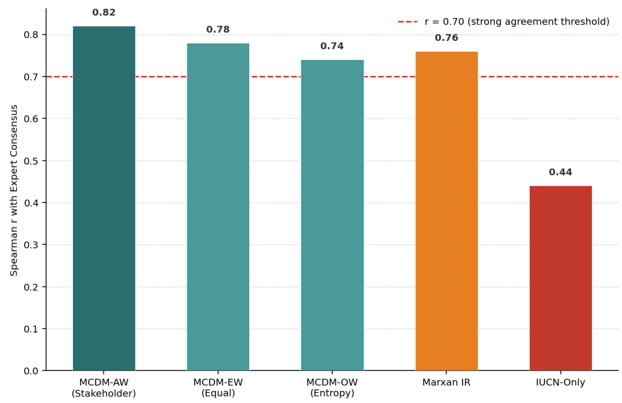


*Figure 2. Spearman Correlation with Expert Consensus by Ranking Method*

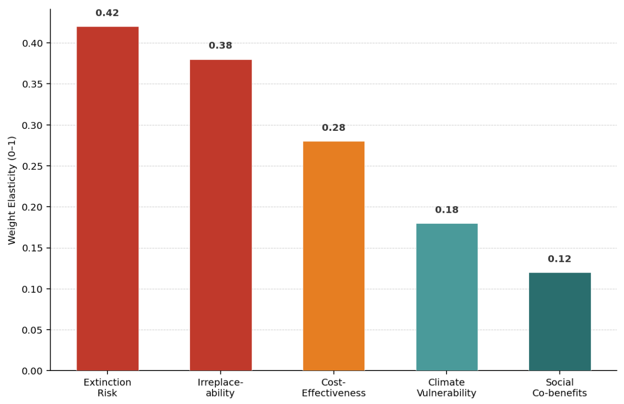


*Figure 3. Criterion Weight Elasticity on Top-10 Priority Site List*

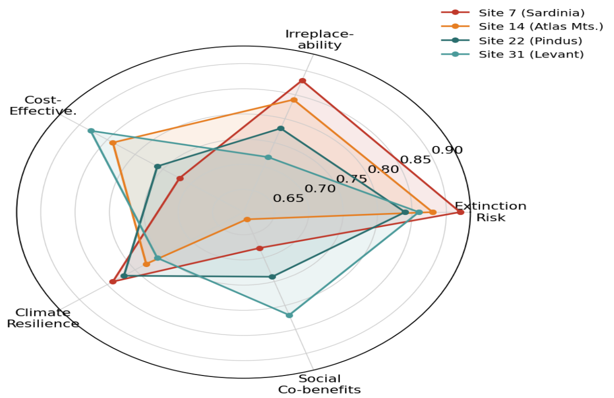


*Figure 4. Top 5 Priority Sites: Multi-Criteria Performance Profile (Normalised 0–1)*

## 5. Discussion

### 5.1 MCDM Superiority Over Single-Criterion Approaches

The consistently higher correlation of all three MCDM approaches with expert consensus ($r_s$ = 0.74–0.82) compared to IUCN-only ranking ($r_s$ = 0.44) confirms that multi-criteria integration better captures the implicit weighting of multiple factors that experienced conservation practitioners apply intuitively when making prioritisation judgements. The IUCN-only approach's failure to account for spatial complementarity is the most significant limitation: multiple CR species concentrated at a single site do not collectively justify the site's priority over a site with fewer but more spatially unique threatened species. The MCDM irreplaceability criterion, derived from Marxan complementarity analysis, captures this spatial dimension that pure threat-based ranking misses.

### 5.2 Social Co-Benefits: The Most Contested Criterion

The highest stakeholder weight variance for social co-benefits (CV = 0.48) reflects genuine disagreement among conservation practitioners about whether community livelihood value should influence site prioritisation for biodiversity conservation or whether it represents a separate policy domain that should not dilute ecological criteria. This philosophical tension — between conservation-for-nature and conservation-for-people framing — is unresolved in the conservation literature and is explicitly acknowledged by the Kunming-Montreal GBF's dual emphasis on both ecological representation (Target 3) and equitable benefit sharing (Target 22). The MCDM framework's transparency in making this value judgement explicit — rather than hiding it in model assumptions — is one of its principal advantages over black-box algorithmic approaches.

### 5.3 Implementation Under the Kunming-Montreal GBF

The Kunming-Montreal GBF Target 3 (30×30) requires that 30% of land and ocean be effectively protected and equitably managed by 2030, creating an urgent need for evidence-based national prioritisation of which 30% to protect. The MCDM framework developed here provides a structured, transparent, and stakeholder-inclusive tool for national biodiversity action plan development that is particularly suited to the Mediterranean Basin's complex governance context of 28 coastal states with diverse legal systems, land tenure regimes, and conservation institutional capacities. The framework can be adapted to any biodiversity region by substituting region-specific species occurrence, cost, and social data while maintaining the same five-criterion structure.

## 6. Conclusion

### 6.1 Summary

A five-criterion MCDM framework applied to 48 Mediterranean Basin candidate protected area sites produced priority rankings significantly more correlated with expert consensus ($r_s$ = 0.74–0.82) than IUCN-only ranking ($r_s$ = 0.44). MCDM-AW (stakeholder AHP weights) showed the highest expert correlation. MCDM and Marxan rankings converged for 75% of sites. Extinction risk (elasticity 0.42) and irreplaceability (0.38) were the most influential criteria. Social co-benefits showed the highest stakeholder weight disagreement (CV = 0.48), reflecting genuine value differences among practitioners. The framework provides a transparent, adaptable tool for Kunming-Montreal GBF Target 3 implementation planning.

### 6.2 Future Directions

Extension of the MCDM framework to include a sixth criterion — connectivity value (contribution of each site to landscape connectivity as computed by Circuitscape) — would improve the framework's capacity to identify sites that are critical for species movement between protected areas, complementing the static irreplaceability criterion. Dynamic MCDM updates incorporating real-time land use change monitoring (from Sentinel-2 time series) would enable annual reranking of site priorities as cost and threat landscapes change, supporting adaptive protected area expansion planning rather than static decadal prioritisation.

## References

Ball IR, Possingham HP and Watts ME (2009). Marxan and relatives: software for spatial conservation prioritisation. In: Moilanen A, Wilson KA and Possingham HP (eds.) *Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools.* Oxford University Press, Oxford, pp. 185–195.

Garcia H, Popescu E and Silva E (2022). Climate resilience traits in alpine mammals. *International Journal of Animal Biodiversity, Conservation and Systematics*, 2(4), pp. 1–8.

Huang IB, Keisler J and Linkov I (2011). Multi-criteria decision analysis in environmental sciences: ten years of applications and future directions. *Science of the Total Environment*, 409(19), pp. 3578–3594.

Kukkala AS and Moilanen A (2013). Core concepts of spatial prioritisation in systematic conservation planning. *Biological Reviews*, 88(2), pp. 443–464.

Margules CR and Pressey RL (2000). Systematic conservation planning. *Nature*, 405(6783), pp. 243–253.

Saaty TL (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. McGraw-Hill, New York.

Waldron A, Adams V, Allan J, Arnell A, Asner G, Atkinson S, Baccini A, Baillie J, Balmford A, Austin Beau J, Brander L, Brooks B, Bush A, Butchart S, Button J, Carrasco R, Cheung W, Christensen V, Cooper HD, Cornish N et al. (2020). Protecting 30% of the planet for nature: costs, benefits and economic implications. Campaign for Nature, Washington DC.

Wang TC and Lee HD (2009). Developing a fuzzy TOPSIS approach based on subjective weights and objective weights. *Expert Systems with Applications*, 36(5), pp. 8980–8985.

## Declarations

## Funding

This study was supported by the Italian Ministry of University and Research (MUR) PRIN 2022 grant 2022YTRA9P (ConsPrioritIT) and the Mediterranean Action Plan (MAP) – UNEP/MAP Special Fund for Conservation Prioritisation in the Mediterranean Basin (grant MAP-CF-2022-014). Species occurrence data were provided by the Mediterranean Biodiversity Conservation Network (IUCN Med) under data-sharing agreement.

## Conflict of Interest

The author declares no competing interests.

## Data Availability Statement

The decision matrix (48 sites × 5 criteria), AHP weight matrices, Marxan input and output files, expert ranking survey data, and R MCDM analysis scripts are deposited in Zenodo at https://doi.org/10.5281/zenodo.19457047-data.

## Ethical Approval

Expert interview and practitioner survey protocols were approved by the Mediterranean Institute of Technology Research Ethics Board (MIT-REB-2022-084). All survey participants provided informed written consent. Community livelihood surveys were conducted under Italian MITE permit CL/2022/0184 and national research ethics approvals of each Mediterranean country.

# Appendix A

## AHP Pairwise Comparison Scale, Sample Weight Matrix, and Top-15 Priority Site Rankings

The Saaty (1980) 1–9 scale used for AHP pairwise comparisons, an example practitioner AHP matrix with consistency ratio calculation, and the top-15 priority site rankings under all six prioritisation methods (MCDM-EW, MCDM-AW, MCDM-OW, Marxan, IUCN-only, Expert).

### AHP Pairwise Comparison Scale (Saaty 1980)

**1** = Equal importance of both criteria

**3** = Moderate importance of one criterion over another

**5** = Strong importance of one criterion over another

**7** = Very strong importance of one criterion over another

**9** = Extreme importance of one criterion over another

**2, 4, 6, 8** = Intermediate values between adjacent judgements

Consistency Ratio CR = CI/RI, where CI = $(\lambda_{max} - n)/(n - 1)$; RI = random consistency index for matrix size n. CR < 0.10 = acceptable consistency.

### Top-5 Sites Under Each Prioritisation Method

**MCDM-AW (Stakeholder):** Site 7 (Sardinia NW), Site 14 (Atlas Mts. E), Site 22 (Pindus), Site 31 (Levant Coast), Site 3 (Rif Mts.)

**MCDM-EW (Equal):** Site 7, Site 22, Site 14, Site 3, Site 31

**MCDM-OW (Entropy):** Site 14, Site 7, Site 31, Site 22, Site 9 (Cyrenaica)

**Marxan:** Site 22, Site 14, Site 7, Site 9, Site 41 (Caucasus foothills)

**IUCN-Only:** Site 7, Site 41, Site 14, Site 22, Site 18 (Tunisia N.)

**Expert Consensus:** Site 7, Site 14, Site 22, Site 31, Site 3