Towards sustainable management of medicinal and aromatic plants in Morocco: Typology and priority actions

Salma El Amane[1,2], *Eric* Imbert[2], and *Abdelilah* Rahou[1]

[1]Laboratory of Biotechnology and Bio-Resources Valorisation, Department of biology, Moulay Ismail University, Meknes, Morocco
[2]ISEM, Univ Montpellier, CNRS, IRD, Montpellier, France

Abstract. Threats from overharvesting, habitat degradation, and climate change have made the sustainable management of medicinal and aromatic plants (MAPs) in Morocco increasingly important. These species are essential in traditional medicine, biodiversity, and the livelihoods of local communities. In response, the Moroccan government has expanded its network of protected areas, enacted new laws, and made international commitments to improve its institutional and legal frameworks. The study focused on 20 MAPs and used 22 interviews from 12 stakeholder organizations—86.4% of which are in the public sector—to evaluate the effectiveness of these initiatives. According to the findings, 75% of the taxa require conservation actions, while the remaining 25% need measures aimed at enhancing knowledge. Typifying these actions enables to develop specific measures that are adapted to the specific needs of each species. The results highlight the importance of a coordinated approach involving several actors in order to protect ecosystems and traditional knowledge.

1 Introduction

Morocco is known for its rich biodiversity, especially its medicinal plants, but it also faces major challenges in their conservation. As a signatory to the Convention on Biological Diversity since 1992, the country has developed national strategies supported by the Global Environment Facility. Morocco has more than 250 legal texts related to biodiversity, which reflects an increasing adherence to the preservation of natural resources [1]. However, these laws are not always fully effective, mainly because regulations are slow to be implemented and people are not always aware of how important biodiversity is. The creation of protected areas started with the Dahir of 1934, which led to the identification of 154 Sites of Biological and Ecological Interest [1]. These efforts, which involve both private and public organizations, highlight the necessity of effective management of MAPs. Key questions remain about current conservation actions, protection measures, how stakeholders see these issues, the threats to species, and the partnerships needed to conserve MAPs.

2 Methods

To better understand their objectives, and missions in the conservation of Morocco's medicinal plant species, a structured questionnaire was created and distributed to important biodiversity stakeholders. The survey examined perceived threats to 20 threatened species, current programs and projects as well as management and conservation efforts. Respondents were grouped into three main categories: (1) public administrations, including ministerial departments, agencies, and research institutions; (2) economic actors involved in the utilization or trade of plant resources; and (3) non-governmental and international organizations active in biodiversity management.
Data from the questionnaire were analyzed using a modified version of the decision-tree typology method proposed by Le Berre et al. (2020). This method links each taxon to a major category of conservation action: knowledge enhancement, knowledge assessment, station assessment, action planning, monitoring, or surveillance. Each species was examined to determine whether conservation actions or protection measures had already been implemented and whether they were adequate (Figure 1).

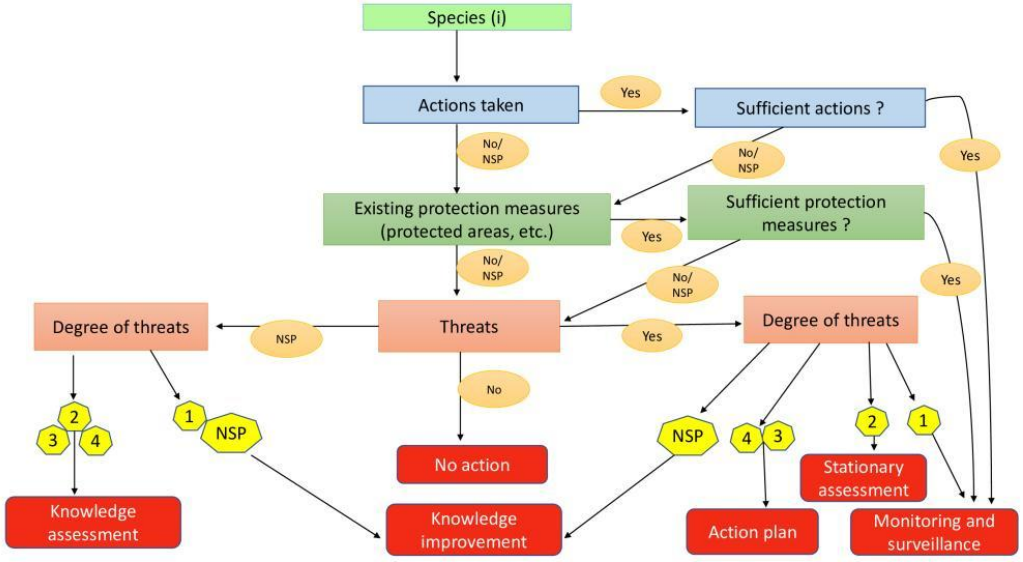

Fig. 1. Decision tree adapted to our study, allowing the assignment of a project to each species (NSP : Unknown).

3 Results and discussion

3.1 Analysis of survey results

A total of 22 consultations were conducted with 12 organizations involved in the MAP sector. Most respondents (86.4%) were public actors, including governmental departments (Environment, Water and Forests, Sustainable Development), national agencies, and research institutes (e.g., ANEF, INRA, Scientific Institute, ONSSA). The remaining participants were Moroccan associations (APMA, AVPMA, AMPP).

Public institutions play a leading role in MAP management and conservation through technical support, planning, capacity building, and policy development. Nineteen actors provide technical assistance and training for the sustainable cultivation and valorization of MAPs, while twelve are engaged in integrated planning and resource management. Eight institutions focus on public education and communication, six on research and inverstigating, six on funding mobilization, and five on the implementation of regulations. Together, these actions contribute to a coordinated structure for sustainable use and MAP conservation.

On the other hand, international and private actors are underrepresented. None of the six organizations surveyed are involved in conservation efforts, and all are focused on commercial activities. Similarly, only two of the seven NGOs contacted, and international organizations such as WWF and Greenpeace did not directly participate in MAP management. This disparity shows that it is important to strengthen cooperation between sectors and to encourage greater involvement of private and international stakeholders in MAP conservation efforts.

3.2 Evaluation of the presence or absence of conservation actions

For the first question, no species received 100% positive or negative responses. However, three species (*Anacyclus pyrethrum*, *Rosmarinus officinalis*, and *Tetraclinis articulata*) received most of the positive responses (Table 1). Bibliographic data shared by respondents revealed two major MAP projects in Morocco. In order to ensure sustainable production, biodiversity conservation, and capacity building within the MAP value chain, the first was initiated in 2012 by the High Commission for Water, Forests, and Desertification Control (HCEFLD) and its partners. It targeted four regions and five species. The second project, which was started in 2015, focused on developing an action plan for the sustainable management and conservation of 20 overexploited species, seven of which have been identified in the study area.

Eight species from these projects are present in the study area, but none of them received 100% positive responses. *T. saturejoides* received fewer positive responses than *R. officinalis* and *O. compactum*. This difference may be due to the limited results of these projects, which are mainly managed by the HCEFLD, with minimal participation or involvement from other actors. In addition, most of the bibliographic information focuses on strategies and plans rather than concrete results, which raises questions about how effective these projects really are. The study followed by looking at the conservation measures implemented and the presence of species in protected areas because all respondents believed that the current conservation efforts were insufficient.

Table 1. Responses of the 22 participants to the question on conservation actions and the mention of species in the two MAP projects.

Species	YES	NO	Unknown	NA	PAM 2012	PAM 2015
Rosmarinus officinalis	10	9	3	0	*	*
Origanum compactum	9	10	3	0	*	*
Anacyclus pyrethrum	8	6	3	5	*	
Artemisia herba-alba	8	9	2	3		*
Tetraclinis articulata	7	4	3	8		*
Thymus saturejoides	6	13	3	0	*	*
Lavandula dentata	5	12	3	2		*
Myrtus communis	5	11	3	3		*
Clinopodium nepeta	3	8	3	8		
Corrigiola telephiifolia	3	9	4	6		
Laurus nobilis	3	10	3	6		
Chamaemelum nobile	1	9	4	8		
Diplotaxis viminea	1	1	7	13		
Ziziphus lotus	1	10	3	8		
Aristolochia baetica	0	6	5	11		
Chamaerops humilis	0	10	4	8		
Ferula communis	0	5	5	12		
Lavandula multifida	0	10	5	7		
Rhamnus alaternus	0	4	6	12		
Ruta chalepensis	0	6	5	11		

3.3 Evaluation of existing protection measures or presence in protected areas

Except for *Tetraclinis articulata*, the majority of respondents gave negative answers to this question for every species. Like many other countries, Morocco prioritizes tree species and animals over herbaceous plants in protected areas. Trees are valued for their ecological roles in providing habitat, regulating water, and storing carbon, while charismatic animals receive more attention and funding [2]. The only species for which respondents indicated substantial protection was *T. articulata*, a tree species found in Moroccan protected areas. However, this does not imply other species are absent from these areas; rather, the lack of detailed botanical inventories limits knowledge and management decisions regarding herbaceous plants, particularly MAPs. Enhancing botanical surveys and species mapping is therefore essential to improve conservation planning. Since the current measures were insufficient, the analysis proceeded to the question of threats.

3.4 Threat assessment

Most responses indicate that the majority of species, along with their populations and habitats, are facing threats. However, for five species (*R. chalepensis*, *A. baetica*, *R. alaternus*, *D. viminea*, and *F. communis*), most respondents did not express an opinion. These species are rarely used and have a limited presence in Moroccan markets, which may have led to uncertainty among respondents regarding threats other than medicinal overharvesting.

Except for *D. viminea*, the primary use of the other four species involves their roots, making them particularly vulnerable. For *D. viminea*, its high biogeographic score suggests that its rarity is more related to distributional constraints than to ethnobotanical exploitation. This implies that a species may be threatened not only by medicinal use but also by ecological or biogeographic factors affecting its long-term viability.

There are substantial differences between IUCN threat categories and expert opinions (Table 2). Most experts rated *A. pyrethrum* and *O. compactum*, both vulnerable species and conservation priorities, as highly threatened (level 4). *T. saturejoides* and *L. nobilis* were mostly rated at levels 3 and 2, respectively, while *D. viminea* received no clear consensus. Among Near Threatened species, *C. telephiifolia* and *M. communis* were rated level 2, and *R. officinalis* level 3.

Table 2. The degree of threat according to the majority of respondents and the IUCN status of the species.

Species	Degree of threat according to the majority of responses	IUCN status
Anacyclus pyrethrum	4	VU
Origanum compactum	4	VU
Salvia rosmarinus	3	NT
Thymus saturejoides	3	VU
Lavandula dentata	2	LC
Myrtus communis	2	NT
Artemisia herba-alba	2	DD
Chamaemelum nobile	2	LC
Laurus nobilis	2	VU
Ziziphus lotus	2	LC
Corrigiola telephiifolia	2	NT
Ferula communis	2	LC
Tetraclinis articulata	1	LC
Ruta chalepensis	1	LC
Diplotaxis viminea	1	VU
Rhamnus alaternus	1	LC
Aristolochia baetica	NSP (2)	LC
Chamaerops humilis	NSP (2)	LC
Clinopodium nepeta	NSP (2)	LC

Lavandula multifida	NSP (2)	LC

3.5 Definition and typification of actions

The analysis of the 20 medicinal plant species indicates that 15 taxa (75%) require conservation actions including 5 Vulnerable (VU), 6 Least Concern (LC), 3 Near Threatened (NT), and 1 Data Deficient (DD) taxa. In addition, 5 taxa (25%) require knowledge-related actions, comprising 4 LC and 1 DD species.

More specifically, among the conservation actions, 40% of the species were categorized under population assessment, 20% under the development and implementation of action plans, and 15% under monitoring and surveillance. Regarding knowledge-related actions, 20% of the species were categorized under knowledge improvement and 1% under knowledge assessment.

3.5.1 Knowledge improvement

Knowledge improvement involves collecting new data on the biology, ecology, distribution, and uses of target species [3]. These actions mainly concern Least Concern taxa, such as *C. nepeta*, *C. humilis*, and *L. multifida*, as well as *A. baetica*, which exhibits notable data deficiency. Similar knowledge gaps particularly regarding life history, reproduction, dispersal, pollination, and genetics have been reported for protected species in France [4]. Reevaluating these taxa within the framework of conservation decisions requires addressing these deficiencies and identifying potential threats.

3.5.2 Knowledge assessment

Knowledge assessments involve synthesizing information from bibliographic sources, expert interviews, institutional managers, and databases to provide an overview of existing knowledge and, if necessary, to identify potential threats [5]. Only *F. communis*, a species classified as Least Concern on the Red List and ranked 16th on our priority list, is proposed for such an assessment. Conducting a knowledge review for this species is relevant to identify data gaps and to improve understanding of potential threats that could influence its conservation status.

3.5.3 Stationary assessment

Stationary assessment method involves surveying all confirmed and historical sites or a representative sample if more than 20 to record detailed information on the status of the target species [5,6,7]. The conservation status of the species is also evaluated by this assessment. Location, altitude, exposure, geology, habitat extent, population size or estimates, phenological stage, current threats, and protective measures are among the data gathered at each site.

Eight species are proposed for stationary assessments and belong to different Red List categories: 3 LC, 2 VU, 2 NT, and 1 DD species. These lists should be carried out gradually, giving priority to the most endangered taxa due to logistical limitations.Priority species

include *C. telephiifolia*, *C. nobile*, *L. nobilis*, and *M. communis*, followed by *D. viminea*, *A. herba-alba*, *L. dentata*, and *Z. lotus*. Regional conservation strategies and priorities should be based on local biogeographical and ethnobotanical factors.

3.5.4 Monitoring and surveillance

Monitoring involves regularly returning to the same sites and collecting repeated measurements over time to track how populations change and to assess whether management objectives are being achieved. It generally focuses on detailed data collection on individual plants within permanent plots, in order to better understand population dynamics and demographic trends [7].

Surveillance is based on simple, regular measurements to identify changes without testing specific hypotheses. It uses basic biological or environmental indicators, following standardized, long-term, and easy protocols [5,8].

Three taxa are proposed for these actions: *T. articulata* (LC), *R. alaternus* (LC), and *R. chalepensis* (LC), the last two being mainly threatened by root harvesting. Monitoring strategies should be adapted together with site managers, according with the ecology of each species.

3.5.5 Action plan

An action plan is a coordinated framework for implementing conservation, protection, and knowledge measures to restore or preserve a favorable conservation status for a target species [5]. It usually consists of three main steps: (1) knowledge and site assessments; (2) specialized analyses to create action sheets; and (3) carrying out these actions with specific conservation goals and methods. These plans are usually designed for a 10-year period. Their goals are to advance research, improve protection, reduce threats, restore populations and habitats, track progress, support ex situ conservation, and increase awareness among stakeholders.

Action plans are suggested for four species, including *S. rosmarinus* (NT) and *A. pyrethrum*, *O. compactum*, and *T. saturejoides* (all vulnerable according to IUCN status). These species need urgent and targeted conservation actions.

4 Conclusion

Through new legislative initiatives, international commitments, and the growth of protected areas, the Moroccan government has reinforced biodiversity conservation. Despite these efforts, the two MAP action plans that have been in place since 2012 and 2015 have produced only modest and insufficiently evaluated results. Using an action typology helps design targeted interventions for each priority species, by distinguishing clearly between actions to improve knowledge and concrete conservation measures, in order to support sustainable MAP management. These results represent the current state of knowledge and should be updated as new data and conservation measures emerge. Future priorities should be defined based on the importance of each species, local conditions, available resources, and funding opportunities, to ensure effective and flexible conservation strategies.

References

1. S. Bensalem, C. Bigard, C. Barbier, Évaluation de la biodiversité et des services écosystémiques au Maroc, Master Thesis, AgroParisTech, France, 2020
2. F. Ducarme, G.M. Luque, F. Courchamp, What are "charismatic species" for conservation biologists. BioSciences Master Reviews. **10**, 8 (2013).
3. V. Noble, J. Van Es, Ajustement de la liste rouge de la flore vasculaire de la région Provence-Alpes-Côte d'Azur et bilan des espèces DD. CBNMed. **21,** 13 (2017).
4. J. Ducrettet, S. Maurice, E. Imbert, How much do we know and how much do we care about genetic diversity of threatened plants ? A case study from the French flora. Botany Letters. **170**, 110 (2023).
5. M. Le Berre, V. Noble, M. Pires, F. Médail, K. Diadema, How to hierarchise species to determine priorities for conservation action ? A critical analysis. Biodiversity and Conservation. **28**, 3051 (2019).
6. C. N. Bianchi, C. Morri, M. Chiantore, M. Montefalcone, V. Parravicini, A. Rovere, Mediterranean Sea biodiversity between the legacy from the past and a future of change. Life in the Mediterranean Sea: a look at habitat changes. **1**, 55 (2012).
7. V. Bonnet, N. Fort, C. Dentant, R. Bonet, P. Salomez, I. Till-Bottraud, A methodology for monitoring rare plant species designed by a network of conservation stakeholders. Acta Botanica Gallica. **162**, 27 (2015).
8. J. Thompson, J. Touroult, N. Debaive, A. Destombes, A. Douard, Suivi des populations-Techniques, méthodes et perspectives. Espaces naturels. **41**, 21 (2013).