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ORIGINAL PAPER

Rapid risk assessment to harvesting of wild medicinal and aromatic plant species in Morocco for conservation and sustainable management purposes

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Abstract The increased demand for natural products from wild aromatic and medicinal plants has stimulated several research projects focusing on phytochemistry, ethnobotany, pharmacognosy and many other sub-disciplines related to medicine and pharmacy or cosmetology and chemical industry in general. Morocco is one of the richest Mediterranean countries whose flora is well known and many of its plant resources and products very demanded by consumers and manufacturers but there is an urgent need to deal with wild medicinal and aromatic plants namely found on public lands. In this study, we attempt to identify and assess the wild species to overharvesting especially those in forest lands and then identify priority ones. A rapid vulnerability assessment approach was applied to 182 species inventoried referring to its biological, ecological and chorological criteria then combined to trade data. We obtained three groups of MAP species depending on its vulnerability ranked from high to very low vulnerability and their availability at national level. A list of 25 priority species was sorted on its economic value for export and then only the most representative ones within each region was identified to analyze its corresponding actions. These insights could be applied to improve the conservation policies and guide the sustainable management and economic valuation plans to implement the Moroccan Medicinal and aromatic plants strategy.

Keywords Conservation · Sustainable harvesting · Vulnerability assessment · Medicinal and aromatic plants · Morocco

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Introduction

According to the World Health Organization (WHO), more than 80% of global human population depends on traditional medicine as a source of primary health care (WHO, IUCN and WWF 1993). Traditional medicine is an important healthcare system in Africa with 20–30% of the population depending almost entirely on traditional medicine and almost a similar proportion using both allopathic and traditional medicine to varying degrees (Maundu et al. 2006). The African continent embraces a high diversity of Medicinal and Aromatic Plants (MAP); thus, among the 300,000 plant species recorded worldwide, more than 200,000 species are found in tropical African countries and have medicinal properties (SOFOWORA 1993). Roberson (2008) pointed out that at least 15,000 may face extinction due to overharvesting and habitat loss as it was also stated by the World Conservation Union (IUCN) (see ISSC-MAP Medicinal Plant Specialist Group 2007; IUCN Species Survival Commission Medicinal Plant Specialist Group 2007). In addition to the loss of access to traditional remedies by indigenous peoples, over-collection of species poses a significant threat to some commercially valuable wild species.

The increasing scarcity of plant resources alarmed both the users and the administration in charge of natural resources conservation and management and has pushed some actors to promote agricultural alternatives and many researchers to develop some techniques of cultural domestication in order to produce enough biomass. However, they did not satisfy completely the needs of the consumers and transformers either in terms of availability or quality of the biomass and derived products because wild MAP species are always preferred than the cultivated ones (Schippmann et al. 2006). Wild species are found on both forest lands and other public lands which are under the tenure of different governmental authorities. A national strategy specific to wild MAP species was conceived while another one was conceived and implemented for the cultivated ones (MAPM, HCEFLCD and USAID 2008).

In developing countries, insecure tenurial and rights arrangements of local communities over forest resources are believed to be at the root of extant free riding and the resultant tragedy of the commons. Sometimes, traders use outsiders to extract medicinal plants from open access forests or wild lands. These conditions, compounded by absence of effective conservation policies and action and monitorable regulatory frameworks, have led to severe declines in wild populations of medicinal plants (Vinay Tandon 2006). The economic, bio-ecological and chorological data for this sector are isolated, non-exhaustive and often incomplete. It is also imperative to point out that the evolution and dynamics of MAP harvesting is very irregular and fluctuates according to several factors, in particular, from one species to another, on the dynamic of supply on forest, on demand market (local, regional, national and international) and on user awareness (media coverage). Unsustainability in the use of medicinal plants can be attributed to many factors such as High population growth rate; land use shift from natural vegetation to other forms of land use such as agriculture; Increasing commercialization of traditional medicine; Increasing demand in the local and world market; Lack of appropriate policies and legislation/or failure to enforce them; Poverty and high unemployment rate; Unsustainable methods of harvesting; (Maundu et al. 2006).

Medicinal plant resources are being harvested in increasing volumes, largely from wild populations. Indeed, demand for wild resources has increased by 8–15% per year in Europe, North America, and Asia in recent decades (Bentley 2010; Ross 2005). There is a threshold below which species reproductive capacity becomes irreversibly

reduced (Soule et al. 2005; Semwal et al. 2007). With the growing market demands and the promise of quick returns, harvesters are being encouraged to concentrate on species with higher economic value. The current worldwide demand for medicinal animal parts is unprecedented, and the implications for many wildlife populations in Asia and Africa at least are not good. Various sets of recommendations relating to the conservation of medicinal plants have been developed, such as providing both in situ and ex situ conservation (Huang 2011; Liu et al. 2011). The geographic distribution and biological characteristics of medicinal plants must be known to guide conservation activities, e.g. to assess whether species conservation should take place in nature or in a nursery (Fig. 1).

Threat assessment of MAP species has emerged clearly as one of the most important activities in conservation planning and management. Experiences of different methodologies of threat assessment such as the exercises of Conservation, Assessment Management and Planning (CAMP) and Rapid Vulnerability Assessment (RVA) have been gathered and shared (Shrestha and Shrestha 2012; Yildiz and Kraki 2003; Bhattarai and Karki 2003). Threat assessments carried out by different stakeholder groups have been documented and disseminated (Schippmann et al. 2002; Cunningham 2001). The conservation and sustainable use of medicinal plants have been studied extensively (Larsen and Olsen 2007; Uprety et al. 2012). Various sets of recommendations have been compiled regarding their conservation, including the establishment of systems for species inventorying and status monitoring, and the need for coordinated conservation practices based on both in situ and ex situ strategies (Hamilton 2004). For medicinal plants with increasingly limited supplies, sustainable use of wild resources can be an effective conservation alternative.

The geographical position of Morocco, its geological and bioclimatic diversity offer a significant diversity of vegetation and flora. In fact, it embraces 4200 vascular plant species among which 800 species are endemic ones (Fennane et al. 1999, 2007, 2014) distributed among more than 40 different terrestrial ecosystems (Benabid 2000). As many other African countries, Moroccan population has an ancestral traditional knowledge and use of plant for medicinal and health care which is actually documented through a series of ethnobotanical studies. Both local population and visitors harvest wild MAP from open access forest and common lands except if authorization is required. These collectors may be single or organized into cooperatives or associations that sold the harvested fresh or dry biomass to either herbalists or manufacturers as intermediates based in the nearest villages. A major part of the accumulated biomass in the villages is moved to the cities where is dispatched to national and international herbalists and manufacturers to be transformed into other products which are sold worldwide. Some products are returned back and sold in the country under different trademarks. In Morocco, the MAP chain value is one the richest business due to the potential development namely for export. Nowadays, the country is ranked as 12th international exporter of MAP either as dried material or extracted products as essential oils with almost 87 million dollars from cultivated and native species (Hamimaz et al. 2015). Morocco still owns an important potential for an increasing international market estimated to 15 billion dollars.

During the last decade, the Moroccan government has initiated the development of a national strategy for the development of wild MAP sector (MAPM, HCEFLCD and USAID 2008), but very few actions were implemented due to some interference between actors and misinterpretation of the wildness of some species, their availability at national or regional level and the knowledge of their threat risk. Therefore, the stakeholder in charge of natural resource management is confronted with the difficulty of knowing the types of plants present exclusively on forest lands and the choice of priority species among the large

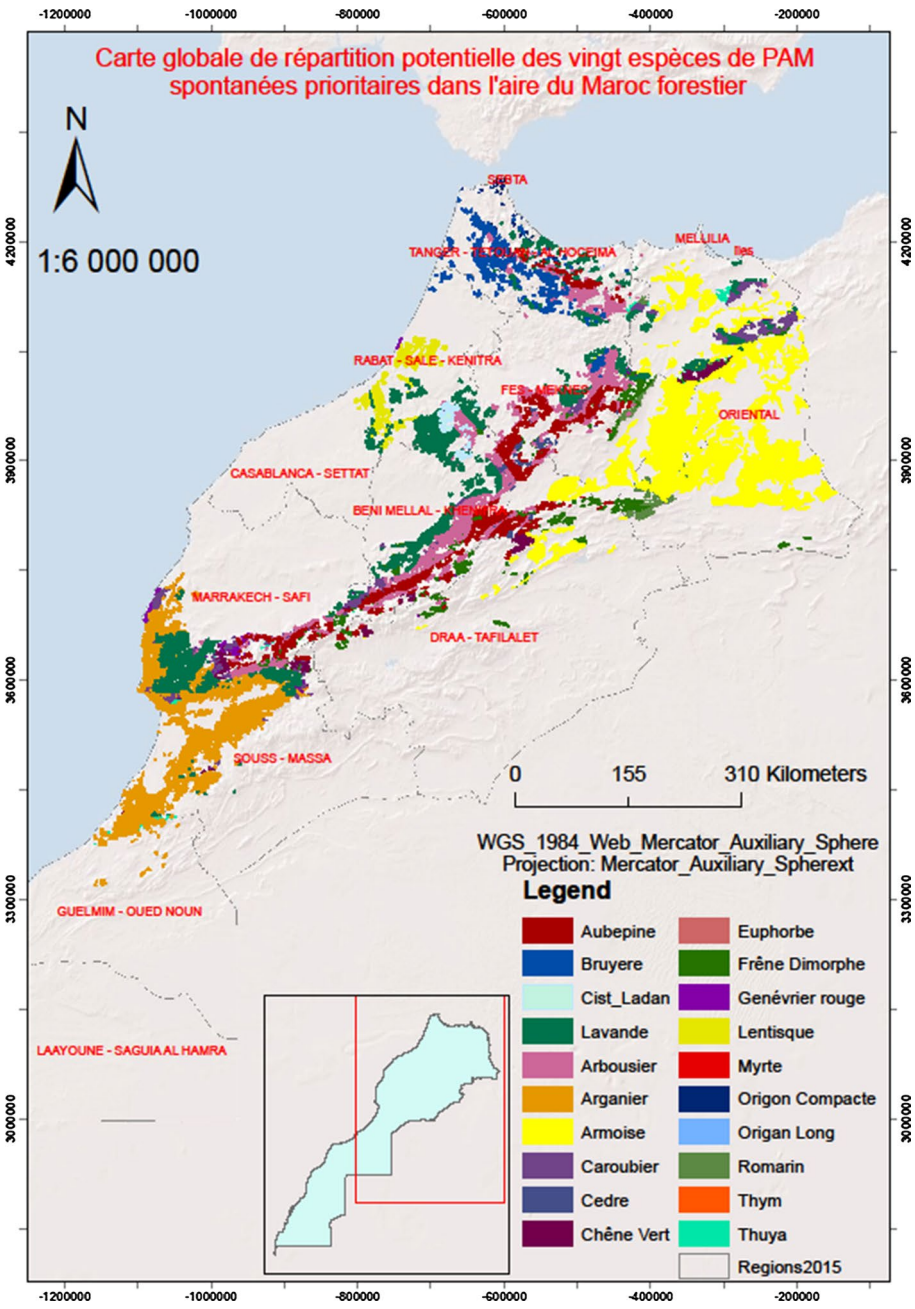

Fig. 1 Map of potential distribution of 20 wild aromatic and medicinal plants through the administrative forest regions of Morocco Kingdom

number of MAPs for which he can plan a conservation and sustainable program with priority actions to implement during the next decade.

In this context, the present paper aims to identify priority MAP species present on forest lands following a threat risk assessment approach based on its biological, ecological, chorological traits; its availability within natural areas and its demand on the market. Each MAP species was assessed and some ones are choosed as priority ones with their corresponding priority actions to provide guidance for the formulation of the future specific plans of conservation, restoration and sustainable management. A regional declination of these actions is proposed to guide each region to formulate its own specific plans for the main wild MAP species present on its territory.

Methodology

Study area

The study area corresponds to the kingdom of Morocco with 12 regions as the highest administrative divisions. Its relief is structured from NE to SW by the Atlas Mountains and limited on the west by the Atlantic Ocean and by the Mediterranean Sea on the north. The country exhibits considerable variation in altitude up to 4165 m.a.s.l and in geological substrates. Mediterranean climate with oceanic influences along the western part and with dry-hot summers and wet-cold winters denote the main climatic conditions with a mean annual rainfall varying from 25 mm in desertic areas up to 2500 mm in the wettest mountains (Benabid 2000). Mediterranean vegetation is dominated by sclerophyllous forests and matorrals followed by conifers then deciduous species. It is also one of the hotspots of biodiversity in Mediterranean region with the richest flora after Turkey with a high number of endemic species (Medail and Quezel 1997). Forest lands cover about 9 million hectares among which 3 million hectares corresponds to steppe formations in semi-arid and arid conditions (HCEFLCD 2005). On the other hand, traditional use of plants in Morocco is as old as mentioned in historical documents (IUCN 2005) or in recent ethnobotanical studies (Bellakhdar 1997, 2006; Lahsissene and Kahouadji 2010; Benkhnigue et al. 2011; Tahri et al. 2012; El Hassani et al. 2013; Benlamdini et al. 2014; Rhattas et al. 2016; Bachar et al. 2016).

Methodological approach

The first step consisted in the preparation of reference lists of plants with known and referenced aromatic and/or medicinal potential use. The reference list was built from the thousand plants listed in the work of the traditional Moroccan pharmacopoeia and then completed by data from local or regional ethnobotanical studies on aromatic and medicinal plants (Bellakhdar 1997, 2006; Benjilali and Zrira 2005; IUCN 2005; Ennabili et al. 2006; Salhi et al. 2010; Lahsissene and Kahouadji 2010; Benkhnigue et al. 2011; Tahri et al. 2012; El Hassani et al. 2013; Benlamdini et al. 2014; Rhattas et al. 2016; Bachar et al. 2016; Ouziki and Taiqui 2016). For correct identification of MAP, we referred to the Practical Vascular Flora of Morocco (Fennane et al. 1999, 2007, 2014), to the Inventory and Chorology of Vascular Plants (Fennane and Ibn Tattou 2005, 2008) and the recent inventory of Moroccan MAP (Jamaleddine et al. 2017). Non-vascular plants and aquatic species that have or may have aromatic or medicinal properties have

been excluded from this study mainly due to the lack or widespread of information. Cultivated MAP are also excluded in order to focus on the wild ones occurring on forest lands because of their tenure by the Ministry of Water and Forests and Fights against Desertification responsible of the implementation and coordination of conservation, management and valuation measures, action plans and programs regarding wild plants including MAP ones.

Secondly, exclusion criteria which may restrict harvesting from natural populations of wild plants has been taken into account on the basis of protection status of the plants referring to many sources as IUCN Red List namely for Morocco (IUCN Redlist - Morocco – Plants 2010; Allen et al. 2014) as critically endangered, endangered or vulnerable. Furthermore, are also discarded those subjected to Moroccan authorization for trade as annexed in the decree of the law 29.05 related to the implementation of the CITES convention. Also, we refer to rare, very rare and endemic species in Morocco identified as species having a very reduced area (Fennane and Ibn Tattou 1998). This first screening allowed us to produce a group of species whose natural populations will be excluded from any harvesting as MAP. Thereafter, the remaining ones able to be harvested were then assessed.

Vulnerability assessment was conducted on the basis of biological, ecological and chorological criteria referring to the available data completed by our field knowledge and expertise. The applied criteria are plant-Life form, the part(s) used of the plant as MAP and the available quantity of species on natural areas focusing on those demanded for export (Lamrani-Alaoui et al. 2015; Hamimaz et al. 2015). As referred to some assessment protocols applied to MAP's (Cunningham 2001; Schippmann et al. 2002; Allen et al. 2014; Chen et al. 2016), we adopted a scoring system to sort MAP species according to their biological and ecological traits. Regarding their life-form, the maximum score (3) was assigned to conifers due to its reduced extension and diversity at the country level. The middle score (2) was assigned to sclerophyllous trees and shrubs which represent the main vegetation wide represented in the country. Finally the lower score (1) was assigned to all herbaceous plants due to their large presence on the territory and their life-form type. For the used part of the plant, a distinction was made between the vegetative parts and the reproductive ones. Maximum score (3) was assigned to underground parts (root, rhizome, bulb, etc.) mainly for conifers and geophytes and to reproductive parts (fruits and seeds) for chamephytes, nanophanerophytes and therophytes. Minimum score (1) was assigned to aerial parts of herbaceous species while middle score (2) was assigned to flowering parts of trees, shrub and herbaceous species (Table 1). Theses scores indicate the magnitude of vulnerability of the species according to the role of the used part into its survival and self-renewal in natural habitats. The total score corresponds to the sum of that relating to the biological type and the vulnerability of the plant to the harvested part giving an estimate of its vulnerability. The total score will corresponds to five different categories as very high risk; high risk; medium risk; low risk and very low risk respectively for the values 6, 5, 4, 3 and 2.

To select priority species that can be harvested, each species was analyzed based on the combination of both its vulnerability assessment and availability at national level. All species with sufficient availability have been selected while, among those of limited availability, only the species with high risk were discarded since their vulnerability can be accentuated. Then selected species was sorted following the exported volume during the last twelve years (2002–2014) (Hamimaz et al. 2015) following the data available and compiled by EACC (Autonomous Office for Export Control and Coordination), OC (Exchange Office), CBI (Centre for the Promotion of Imports from developing countries) and ITC (International Trade Center). Due to the imprecision of some data of exports in terms of

Table 1 Scoring scale of species according to their biological type and the degree of vulnerability in relation to the part used (high numbers are risky than lower)

Life form and type	Score	Used part	Score	Vulnerability score
Trees				
Conifers	3	Aerial	2	5
		Subterranean	3	6
		Flowers	1	3
		Fruits–seeds	2	5
Hardwood	3	Aerial	1	4
		Subterranean	2	5
		Flowers	2	5
		Fruits–seeds	2	5
Shrubs				
Chamephytes and nanophanerophytes	2	Aerial	2	4
		Subterranean	2	4
		Flowers	2	4
		Fruits–seeds	3	5
Herbaeous				
Therophytes	1	Aerial	1	2
		Subterranean	1	2
		Flowers	2	3
		Fruits–seeds	3	4
Hemicryptophytes	1	Aerial	1	2
		Subterranean	2	3
		Flowers	2	3
		Fruits–seeds	2	3
Geophytes	2	Aerial	1	3
		Subterranean	3	5
		Flowers	1	4
		Fruits–seeds	1	3

species identity, only the species clearly known as traded were choosen among the species of a given genus.

To deal with a reasonable number of MAP species to be concerned by an action plan, the 25 top list of priority species have been choosed. Not all species have the same needs in terms of conservation and restoration, sustainable management or valuation and promotion, thus we identify priority actions for each species combining both its regional availability and exported volume as a pressure indicator on the plant resource. Species with high demand for export and with either low or medium availability will be recommended for conservation and restoration actions as those with medium demand and low availability. Species with high demand and high availability will be concerned by sustainable management actions as those with medium demand and with either medium or high availability. Finally, species with low demand pressure will be concerned by valuation and promotion. However, not all priority species are present in all regions and not all regions present the same availability for a given MAP priority species. We identified for each of the twelve regions of the country up to four species depending on its exclusivity and

dominance within each region based on its natural distribution or on its associated ecosystems (Lamrani-Alaoui et al. 2015). Then we sorted the kind of actions to be recommended for each species into three types: (1) conservation/restoration and sustainable management; (2) organization of the chain sector and capacity building of the actors and the third one related to valuation and promotion of MAP.

Results

Wild medicinal and aromatic plant species in forest lands

We focused on wild MAP species on forest lands as they refer to the territories within the country under the tenure of the governmental authority in charge of the conservation and management of natural resources. A preliminary list of 814 plant species with an aromatic and/or medicinal use in Morocco was produced including spontaneous, subspontaneous, acclimatized, naturalized or whose varieties are cultivated but whose spontaneous strain still exists in the natural environment. Spontaneous or wild MAP species (s.l) represent a total of 555 among which some species were excluded as there is no precise information on the part used as MAP resulting in a reference list of 498 wild MAP species. The application of protection criteria allowed the identification of 86 species of wild MAPs to be discarded actually from any kind of harvesting as some of them are listed on the IUCN Red List as critically endangered, endangered or vulnerable. Furthermore, are also discarded those mentioned on the CITES list for Morocco as plant species subjected to trade authorization. Among the remaining 412 wild MAP species, only 182 species are harvested on forest lands.

Vulnerability risk assessment

Table 2 shows the results of vulnerability risk assessment allowing us to define four categories of MAP species: a first category with high risk represented by 26 species among which 73% are shrubs and 27% are conifers. A second category of wild MAP species with medium risk is represented by 92 species among which 8 are endemic. Their biological spectrum indicates a composition with 65% of shrubs, 16% of tree species, 9% of annual plants and 10% of geophytes. The third category of spontaneous MAP species with low-risk is represented by 24 species, including 9 phanerophytes, 10 hemicryptophytes and 5

Table 2 Number of wild MAP species by risk category indicating both the total number and the corresponding exported ones

MAP species		Limited availability		Sufficient availability	
Risk category	Total species	Total species	Exported species	Total species	Exported species
High	26	18	10	8	4
Medium	92	70	11	22	16
Low	24	24	5	0	0
Very low	40	38	5	1	1
Total	182	151	31	31	21

therophytes. The fourth category corresponds to those at very low risk with 40 species, all herbaceous apportioned among therophytes, hemicryptophytes and geophytes with 63, 30 and 7% respectively. Regarding the availability of each species we distinguish between a total of 151 wild MAP species with limited availability and 31 wild MAP species available in sufficient quantities. The biological spectrum of the first ones consists of 14% of phanerophytes, 38% of chamephytes, 25% of therophytes, 14% of hemicryptophytes and 8% of geophytes, whereas the second group consists of 68% shrubs, 29% trees and only 3% hemicryptophytes.

Selecting only those demanded for export we identify three groups of wild MAP: Among a total of 182 species, the first group of 17 species was identified and discarded due to its protection status following the international or national criteria. Table 3 shows the identity of these species and both their biological spectrum and category of risk. The second group corresponds to 31 species exported with limited availability, nine of which are endemic and whose spectrum is distributed between 68% of woody trees, 13% annual and biennial and 19% hemicryptophytes (Table 4). Ten species among this group with high risk were discarded due to their limited availability from wild ecosystems and hence to be restricted from export trade. These species will join the first group of species to be protected. The remaining 21 species may be harvested without major risk. The third group composed by 21 woody species with sufficient availability is all included in the selection process (Table 5) and has a biological spectrum with predominance of shrubs (66.6%) followed by trees with 28.6% and a only 5% of hemicryptophytes. At the end of this screening process, we obtained a set of 42 priority MAP species sorted in a decreasing order of their exported volume. Additional considerations have been taken into account to discard some few species due to their low potential for export, their presence on collective lands (lands belonging to a group of local populations) or on wetlands and the vagueness of the export

Table 3 List and risk categories of exported wild MAP species to be protected

MAP species	French name	Risk level
Laurus azorica	Laurier sauce des Açores	High
Laurus nobilis	Laurier noble	
Abies maroccana[a]	Sapin du Maroc	Medium
Artemisia atlantica var *maroccana*[a]	–	
Artemisia negrei[a]	Armoise	
Thymus capitatus	–	
Thymus broussonettii[a]	Thym de broussonet	
Thymus cilliatus (*T. munbyanus*)[a]	–	
Thymus maroccanus[a]	–	
Thymus pallidus[a]	–	
Thymus riatarum[a]	–	
Calendula algeriensis (*C. stellata*)	Souci	Low
Origanum grossii[a]	Origan	
Satureja vulgaris	Sariette	
Pistacia atlantica	Pistachier de l'Atlas	
Salvia argentea	–	Very low
Salvia tingitana[a]	Amargo	

[a]Endemic

Table 4 List and risk category of exported wild MAP species at limited availability

MAP species	French name	Risk level
Cistus albidus	Cistes	High
Cistus crispus	Cistes	
Cistus salvifolius	Cistes	
Cupressus atlantica[a]	Cyprès de l'Atlas	
Asparagus acutifolius	Asperge	
Asparagus albus	Asperge	
Asparagus altissimus[a]	Asperge	
Asparagus pastorianus[a]	Asperge	
Asparagus stipularis (*horridus*)	Asperge	
Rosa canina	Eglantier	
Ormenis africana (*Santolina chamaecyparissus var. africana*)	–	Medium
Cistus ladaniferus	Ciste ladanifère	
Erica mutiflora	Bruyère	
Erica scoparia	Bruyère	
Lavandula atlantica[a]	Lavande	
Lavandula stoechas	Lavande	
Salvia aegyptiaca	–	
Origanum compactum[a]	Origan à inflorescence compacte	
Fraxinus angustifolia	Frêne	
Fraxinus dimorpha[a]	Frêne dimorphe	
Crataegus monogyna	Aubépine	
Centaurea calcitrapa	–	Low
Centaurea maroccana	–	
Anacyclus pyrethrum	Pyrèthre d'Afrique	
Malva rotundifolia (*neglecta*)	Mauve	
Malva sylvestris (*subacaulis*)[a]	Mauve	
Salvia mouretii[a]	–	Very low
Mentha longifolia (*M. sylvestris*)	Menthe à feuilles longues, Menthe sylvestre	
Mentha gatefossei[a]	Menthe de gatefossé	
Salvia phlomoides	–	
Malva parviflora	Mauve	

[a]Endemic

data. Finally, the 25 top list of priority wild MAP species with economic value for export are selected (Table 6).

Priority actions for priority MAP species

The 25 species identified at the end of the sorting process present different needs in terms of actions for their conservation, restoration, sustainable management, chain organization and valuation. A total of six species have urgent needs for conservation, restoration and sustainable management, namely *Thymus satureoides*, *Lavandula dentata*, *Origanum*

Table 5 List and risk category of exported spontaneous MAP species with sufficient availability

MAP species	French name	Risk category
Cistus monspeliensis	Ciste de Montpelier	High
Myrtus communis	Myrte	
Chamaerops humilis	Palmier nain	
Cedrus atlantica[a]	Cèdre de l'Atlas	
Junipeus phoenicea	Genévrier de phénicie	
Pistacia lentiscus	Lentisque	Medium
Ormenis scariosa[a]	Camomille sauvage	
Artemisia herba alba	Armoise blanche	
Artemisia mesatlantica[a]	Armoise atlasique	
Ceratonia siliqua	Caroubier	
Erica arborea	Bruyère	
Lavandula dentata	Lavande à feuilles dentée	
Rosmarinus officinalis	Romarin	
Origanum elongatum[a]	Origan à feuilles longues	
Thymus satureoides[a]	Thym sariette	
Crataegus laciniata	Aubépine	
Quercus rotundifolia	Chêne vert	
Argania spinosa[a]	Arganier	
Euphorbia echinus[a]	Euphorbe	
Arbutus unedo	Arbousier	
Mentha pulegium	Menthe pouliot	Very low

[a]Endémic

compactum, *Origanum elongatum*, *Rosmarinus officinalis and Fraxinus dimorpha*. The same six species need urgent actions in terms of chain organization and capacity building of the involved actors except for the large natural steppes of *Rosmarinus officinalis*. *Crataegus monogyna* shows more needs on its chain organization and capacity building of the involved actors rather than on restoration or promotion. Valuation and promotion are identified as priority actions for five MAP species: *Ceratonia siliqua*, *Argania spinosa*, *Rosmarinus officinalis*, *Pistacia lentiscus and Tetraclinis articulata*. Table 7 shows the priority MAP species specific for each region that can be harvested without major risk indicating its associated ecosystems and the ranking of the three types of actions.

Discussion

Vulnerability and risk assessment of MAP species in forest lands

Almost all non-timber forest products (NTFP) as MAP found on forest lands are open access in Morocco except for those subjected to a specific regulations as for *Argania spinosa* and *Rosmarinus officinalis*. Collected species are carried towards herbalist and/or trade agents who accumulate the needed biomass for manufacturers of essential oils or other derived products used in medicine, in pharmacy or para-pharmacy. The increasing demand of MAP at local, national and international levels induced an overharvesting and

Table 6 List of priority wild PAM species according to the total export value, the mean value in MAD (Moroccan Dirhams) and the % of its corresponding value (10 MAD = 1US$)

Scientific name	Total value exported between 2002 and 2014	Average value of annual exports (× 1000 Dhs)	% of value related to mean annual value
Ceratonia siliqua	2,904,884.50	212,390.00	54.08
Thymus satureoides[a]	853,316.61	35,385.79	9.01
Rosmarinus officinalis	825,999.72	63,538.44	16.18
Lavandula dentata	20,970.08	1613.00	0.41
Myrtus communis	19,200.35	1477.00	0.38
Crataegus laciniata	3109.94	239.23	0.06
Erica arborea	2423.14	186.40	0.05
Cedrus atlantica[a]	1150.92	88.53	0.02
Ormenis scariosa[a]	1033.85	–	–
Artemisia herba alba	180.23	13.86	0.00
Cistus monspeliensis	17.45	1.34	0.00
Pistacia lentiscus	–	–	–
Quercus rotundifolia	–	–	–
Euphorbia echinus	55.73	4.29	0.00
Arbutus unedo	31.15	2.40	0.00
Juniperus oxycedrus	–	–	–
Tetraclinis articulata	–	–	–
Rhus pentaphylla	–	–	–
Argania spinosa	996,932.65	76,687.13	19.53
Juniperus phoenicea	0.5	0.04	0.00
Lavandula stoechas	20,970.08	1616.00	0.41
Origanum compactum[a]	12,200.63	938.51	0.24
Origanum elongatum[a]			
Fraxinus dimorpha	1951.33	150.10	0.04
Cistus ladaniferus	17.45	1.34	0.00

[a]Endemic

an increasing of sale prices. This situation has carried some species to a critical status of both their populations and associated ecosystems as the case of *Laurus*, *Thymus*, *Lavandula* and *Calendula* species. This study allowed in a first time an inventory of wild MAP species found on public forest lands sorted into four categories of risk following their vulnerability to the used part and ranked into three groups based on their availability and on trade demand for export. The knowledge of which and how many species are there on each land type is basic and fundamental for each institutional entity that's why the present study focused on wild MAP species found on forest lands giving a specific and useful database for the development of program and action plans fitting the conservation priorities of each stakeholder.

As all medicinal plants are not all affected in the same way by harvesting pressures (Wagh and Jain 2013; Andel and Havinga 2008), overharvesting, indiscriminate collection, uncontrolled deforestation, and habitat destruction all affect species rarity, but are insufficient to explain individual species susceptibility or resilience to harvest pressure. Multiple biological characters correlate with extinction risk, such as habitat specificity, distribution

Table 7 Prioritization of wild MAP species by region indicating the type of actions (I, II and III corresponding to conservation, organization and valorization respectively) sorted into three priority levels

Region	Associated ecosystems	Priority species most representative in the region	I	II	III
BENI MELLAL - KHENIFRA	Qr	*Quercus rotundifolia*	3	3	2
	Fd	*Fraxinus dimorpha*	1	1	2
	Qr-Oe	*Ceratonia siliqua*	3	3	1
CASABLANCA - SETTAT	Qs	*Myrtus communis*	2	2	3
		Pistacia lentiscus	2	2	3
		Rhus pentaphylla			
DRAA – TAFILALET	–	*Artemisia herba alba*	2	2	3
	Cd	*Cedrus atlántica*	3	3	2
FES – MEKNES	Qr-Cd	*Crataegus monogyna*	2	1	2
	Cd	*Cedrus atlantica*	3	3	2
GUELMIM – OUED NOUN	As	*Arganis spinosa*	3	3	1
	As	*Euphorbia echinus*	3	3	3
MARRAKECH – SAFI	Ta	*Tetraclinis articulata*	3	3	1
	Ta	*Thymus satureoides*	1	1	2
	Jp	*Juniperus phoenicea*	3	3	2
ORIENTAL	–	*Artemisia herba alba*	2	2	3
	Ta, Jp	*Rosmarinus officinalis*	1	2	1
RABAT-SALE-KENITRA	Qr, Qs, Ta,Jp	*Pistacia lentiscus*	3	2	1
	Qs	*Cistus ladaniferus*	3	3	3
	Ta	*Tetraclinis articulata*	3	3	1
		Rhus pentaphylla			
SOUSS – MASSA	As	*Argania spinosa*	3	3	1
	Ta	*Thyms saturoides*	1	1	2
	As	*Euphorbia echinus*	3	3	3
TANGER-TETOUAN- AL HOCEIMA	Qr-Qs	*Arbutus unedo*	2	2	3
	Qs	*Erica scoparia*	2	2	3
	Qs	*Cistus ladaniferus*	3	3	3
	Qs	*Origanum compactum*	1	1	2

Qr Quercus rotundifolia, *Fd Fraxinus dimorpha*, *Oe Olea europea sylvestris*, *Qs Quercus suber*, *Cd Cedrus atlantica*, *As Argania spinosa*, *Ta Tetraclinis articulata*, *Jp Juniperus phoenicea*

range, population size, species diversity, growth rate, and reproductive system (Chen et al. 2016). In order to maintain a dynamic equilibrium between the demand and the offer of wild MAP species we referred to a set of criteria and considerations following the principles of precaution, protection and regulation. Precaution was adopted regarding the lack or incomplete data, the protection regarding threatened species and the regulation regarding potential harvested species. Similar approaches were used to assess the degree of vulnerability of medicinal and aromatic plants (Cunningham and Mbenkum 1993; Cunningham 2001; Schippmann et al. 2002; Yildiz and Kraki 2003; Negi et al. 2015; Chen et al. 2016) in other countries in Africa, Europe and Asia.

Wild MAP species mentioned on international lists as IUCN or CITES were excluded from harvesting but those with high or medium vulnerability at limited availability were identified as species to be protected. The market demand has to be satisfied from nurseries

or alternative products and specific control on wild populations and trade pathways has to be realized. Furthermore, finer studies have to be undertaken to improve the domestication of cultivars. Our study could identify a set of 27 species belonging to this category but not all with the same level of vulnerability to harvesting pressure; a major attention has to be paid to those with high and medium risk while those with low and very low vulnerability have to be regulated very closely and carefully depending on their national availability. Otherwise, they have to be listed on the annexes of MAP species subjected to authorization and shared with all interesting actors both at national and international levels.

Limited availability of some MAP species as *Asparagus*, *Cistus*, *Lavandula*, *Erica*, *Origanum* and *Rosa* but with low or very low vulnerability to harvesting pressure may be allowed to be harvested under some rules of good practices of harvesting and respect of the biological and ecological limitations of each species as the case of *Anacyclus pyrethrum*. This species shows a strong pressure in some sites in Morocco (Ouarghidi et al. 2017) but not in all sites where is potentially found. In fact, for plants with limited abundance and slow growth, destructive harvesting generally results in resource exhaustion and even species extinction (Larsen and Olsen 2007; Baker et al. 2007). Root and whole-plant harvesting is more destructive to medicinal plants (e.g. herbs, shrubs and trees) than collecting their leaves and flowers or buds. For herbal drugs made of whole plants or roots, using their leaves as a remedy can be a benign alternative (Schippmann et al. 2002; Teklehaymanot and Giday 2007). Sometimes, the knowledge of any medical or pharmaceutical virtue of a given plant induces a harvesting dynamic exceeding the capacity of the existing natural populations. If the access becomes difficult or time-consuming, the prices grow up and non-wise harvesting practices become the most common.

In case of species with sufficient availability, the precaution is still needed especially for those with high vulnerability as *Chamaerops humilis*, *Cedrus atlantica*, *Myrtus communis or Juniperus phoenicea.* For instance, only the leaves of palmito shrub were traditionally used while now we are observing the sales of its fresh roots. Species with medium or very low vulnerability have to be monitored to prevent their excessive collection especially for the most exported ones which also are used locally and seasonally for nutritional and therapeutic purposes as *Argania spinosa*, *Ceratonia siliqua*, *Rosmarinus officinalils*, *Crataegus laciniata*, *Artemisia herba alba*, *Ormenis scariosa and Thymus satureoides*. Moreover, not all species are in the same ecological conditions and under the same threat, hence the difference in terms of types of actions towards each species. Identifying species that need priority attention and prioritizing conservation areas are ones of the main measures to mitigate the effect of overharvesting pressure.

Overharvesting and priority actions

The national strategy specific to spontaneous MAP could be implemented by formulating the corresponding national or regional action plans on the basis of the sorting and ranking of priority species and priority actions proposed in the present work. In fact, the regions of Souss-Massa and Marrakech-Safi are the most concerned by the conservation, restoration and sustainable management of *Thymus satureoides* while the regions of Fes-Meknes and Tanger-Tetouan-Al Hoceima have to focus on the organization of the sector and capacity building of the actors interested in both *Crataegus monogyna* and *Origanum compactum* respectively. *Argania spinosa* and *Ceratonia siliqua* have to be of interest respectively of Souss-Massa and Beni Mellal-Khenifra regions regarding their promotion and valuation. The technical and financial needs can be covered when focusing on the most representative

species limited to up to two or three species by a region as identified in the present study. To reinforce the proposed actions, we recommend also using priority MAP species as flagship around which a communication strategy can be designed and implemented either at national or regional level. On the other hand, attention has to be paid also to traditional know-how and the economic spin-offs on the local rural populations that contribute to the preservation of the MAP resource upstream in order to slow down its erosion.

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