

Moroccan Mountains: Forest Ecosystems and Biodiversity Conservation Strategies

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Abstract—Forest ecosystems in Morocco are subject increasingly to natural and human pressures. Conscious of this problem, Morocco set a strategy that focuses on programs of *in-situ* and *ex-situ* biodiversity conservation. This study is the result of a synthesis of various existing studies on biodiversity and forest ecosystems. It gives an overview of Moroccan mountain forest ecosystems and flora diversity. It also focuses on the efforts made by Morocco to conserve and sustainably manage biodiversity.

Keywords—Mountain, forest, ecosystems, conservation, Morocco.

I. INTRODUCTION

LOCATED at the northwest corner of the African continent between 21° and 36° north latitude and between the 1st and the 17th degree of west longitude, Morocco is characterized by a privileged position with a coastline of 3446 km exposed to Mediterranean sea and Atlantic ocean influences and diverse orography with four major high mountains: Rif, Middle Atlas, High Atlas and Anti-Atlas with altitudes respectively exceed 2000 m, 3000 m and 4000 m and 3000 m [7], [10].

Morocco's climate is typically Mediterranean, essentially characterized by two distinct seasons: A hot, dry summer and a short winter with brutal and concentrated precipitation. Thus, average annual temperatures are around 10 °C, while the average maximum temperature can reach 45 °C in the center of the country and 50 °C within the Saharan regions. The average annual minimum temperatures ranges from 5 to 15 °C (might even go down to -3 to -10°C) in high mountains [7], [10].

Rainfall, in general, decreases from north to south. It exceeds 2000 mm in high mountains of the Rif. It is less than 150 mm in the pre-Saharan and Saharan regions [7], [10].

II. METHODOLOGY

The methodology is mainly based on a literature review of principal theses and projects for the conservation of flora and vegetation.

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Fig. 1 General view of forest ecosystems in Morocco

III. RESULTS

A. Overview of Plant Genetic Resources

The remarkable diversity of topography and climate has allowed the development of a rich flora and many remarkable forest ecosystems.

1. Forest Ecosystem Diversity

The main natural forest ecosystems of Morocco are organized by the fir (*Abies maroccana*), the Atlas cedar (*Cedrus libani* subsp. *atlantica*), the holm oak (*Quercus rotundifolia*), the cork oak (*Quercus suber*), red juniper (*Juniperus phoenicea*), cade juniper (*Juniperus thurifera*), the pines (*Pinus halepensis* and *Pinus pinaster*), Thuja (*Tetraclinis articulata*), the Atlas Cypress (*Cupressus atlantica*), the argan tree (*Argania spinosa*) [5], [9].

Steppe ecosystems are organized by *Juniperus communis*, *Ceratonia siliqua*, *Pistacia atlantica*, *Stipa tenacissima*, *Artemisia* spp., spiny xerophytics (*Alyssum spinosum*, *Bupleurum spinosum*, *Erinacea anthyllis*, *Vella mairei* and *Cytisus balansae*) and Saharan Acacias (*Acacia raddiana*, *Acacia seyal* and *Acacia ehrenbergiana*) [4], [5], [7].

TABLE I
AREA OF THE MAIN MOUNTAIN ECOSYSTEMS IN MOROCCO [9]

Ecosystems	Area (ha)
<i>Quercus rotundifolia</i>	1 415 201
<i>Cedrus atlantica</i>	133 653
<i>Argania spinosa</i>	871 210
<i>Quercus suber</i>	377 482
<i>Juniperus</i> spp. (<i>J. thurifera</i> , <i>J. phoenicea</i> and <i>J. oxycedrus</i>)	244 837
Reforestation	490 518
Others	102 207
<i>Tetraclinis articulata</i>	565 798
<i>Pinus</i> spp. (<i>P. halepensis</i> , <i>P. maritima</i> , ...)	82 115
<i>Quercus faginea</i>	9 091
<i>Abies maroccana</i>	3 174
Others	5 764
<i>Acacia</i> ssp.	1 000 000
Total	5 301 050

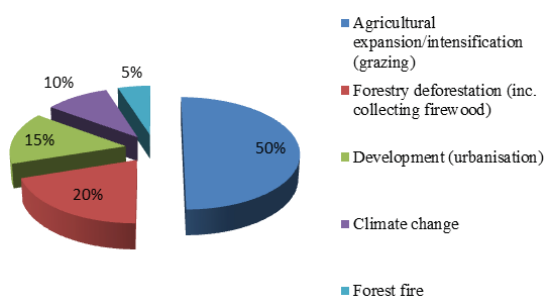


Fig. 2 Main threats to the Moroccan forest ecosystems [6]



Fig. 3 Biosphere Reserve of *Argania spinosa*

2. Flora Diversity

The vascular flora of Morocco has 3913 species and 1298 subspecies, distributed among 155 families and 981 genera. The endemic flora is evaluated to 951 species and subspecies (18% of the total vascular flora). The rare or endangered flora species are estimated to be 463 and 1284 subspecies [2], [3]. This species richness is heavily represented in the forest ecosystem, where nearly two-thirds of the species, and the remaining third is divided mainly between the steppe formations and wetland habitats. The mountainous regions of

the Rif and Atlas are the most important sectors in terms of endemism.

Mushrooms and lichens are also relatively well represented with respectively around 820 and 700 species. Multicellular algae have nearly 700 species with 489 macro-algae and nearly 200 species of phytoplankton [2]. However, this flora and forest ecosystem diversity has been subject to increasing pressure by human and climatic conditions characterized by a succession of droughts.

Major Threats to Forest Ecosystems

The main threats to the Moroccan forest ecosystems are overgrazing, deforestation, urbanization and climate change. Degradation of vegetation cover is accompanied by the rarefaction of species up sometimes at risk of extinction and also soil erosion [6].

Conscious of threats to biodiversity, Morocco has implemented a strategy of *in-situ* conservation based on a network of protected areas.

In-situ Conservation

The High Commission for Water and Forests and Combating Desertification (Morocco) has established a conservation strategy of forest genetic resources [8]. This strategy is based on *in-situ* conservation (National Parks, Nature Reserves and Biosphere Reserves) and *ex-situ* conservation (Botanical Gardens, plant collections etc.). The main objective of this network focuses on the following outcomes:

- Secure the conservation of a representative sample of biodiversity, ecosystems and the most remarkable natural landscapes;
- Manage and develop these protected areas so as to harmonize conservation and local development;
- Promote participatory and partnership approach to co-management of protected areas;

Morocco currently has a large number of protected areas, including 10 national parks and 146 sites of biological and ecological interest classified as nature reserves, 138 in continental domain (including 29 wetlands) and 38 reserves in coastal area. 21% of SBEI receive support for facilities and management and 91% are subject to restrictions necessary for sustainable management of natural resources such as the prohibition of hunting, fishing, opening careers or massive exploitation [1]. Some of biological and ecological interest sites are biosphere reserves. To strengthen this network of national parks, Morocco has created four biosphere reserves [8], which are promoting solutions reconciling biodiversity conservation and sustainable use. They are:

- Biosphere Reserve of *Argania spinosa* [8], with an area of 2.5 million hectares in the South West.
- Biosphere Reserve of Southern Oasis Morocco [8], with, an area of about 7.2 million hectares.
- Intercontinental Mediterranean Biosphere Reserve [8], with an area of nearly one million hectares.
- Biosphere Reserve of cedar ecosystem [8], with an area of 500 000 hectares.

TABLE II
MAIN MOUNTAIN PROTECTED AREAS[6]

Protected Areas	Remarkable ecosystems	Flora diversity
Bouhachem mountain	<i>Quercus faginea, Quercus pyrenaica, Quercus suber, Pinus pinaster, Cedrus atlantica.</i>	16 endemic taxa; 14 rare taxa; 20 very rare taxa
Parc National de Talassemtane	<i>Abies maroccana, Cedrus atlantica, Quercus ilex, Quercus suber, Pinus halepensis, Pinus nigra, Pinus pinaster, Tetrclinis articulata.</i>	47 endemic taxa; 19 rare taxa; 26 very rare taxa
Bou-Naceur mountain	<i>Cedrusatlantica, Quercusrotundifolia, Juniperusthurifera, Juniperus phenicea, Pinus halepensis, xerophytes.</i>	556 taxa; 92 endemic taxa; 5 rare taxa; 10 very rare taxa
Boulblane mountain	<i>Cedrus atlantica, Quercus rotundifolia, Juniperus thurifera, Juniperus phenicea, xerophytes.</i>	500 taxa; 25 endemic taxa; 9 rare taxa; 8 very rare taxa
National Park of Tazekka	<i>Cedrus atlantica, Quercus rotundifolia, Quercus suber.</i>	500 taxa; 31 endemic taxa; 18 rare taxa; 31 very rare taxa
Tichoukt mountain	<i>Cedrus atlantica, Quercus rotundifolia, Juniperus thurifera, Juniperus phenicea, Juniperus communis, xerophytes.</i>	300 taxa; 22 endemic taxa; 7 rare taxa; 9 very rare taxa
National Park of Ifrane	<i>Cedrus atlantica, Quercus rotundifolia, Juniperus thurifera, xerophytes</i>	1015 taxa; 1/4 endemic taxa (25% are special to the Park); 13 rare taxa; 24 very rare taxa
Easter High Atlas National Park	<i>Cedrusatlantica, Quercusrotundifolia, Juniperusthurifera, Juniperus phenicea, Pinus halepensis, xerophytes.</i>	More than 400 taxa; 66 endemic taxa; 13 rare taxa; 6 very rare taxa
Ayachi mountain	<i>Cedrus atlantica, Quercus rotundifolia, Juniperus thurifera, Juniperus communis, xerophytes.</i>	260 taxa; 75 endemic taxa; 9 rare taxa; 4 very rare taxa
Maâsker mountain	<i>Cedrus atlantica, Quercus rotundifolia, Juniperus thurifera, Juniperus phenicea, Juniperus communis, xerophytes.</i>	150 taxa; 34 endemic taxa; 7 rare taxa; 3 very rare taxa
Krouz mountain	<i>Juniperus phoenicea, Pistacia atlantica.</i>	261 taxa; 2 endemic taxa; 7 rare taxa; 7 very rare taxa
Mgoun mountain	<i>Quercus rotundifolia, Juniperus thurifera, Pinus halepensis, Pinus maritima, Tetrclinis articulata, xerophytes.</i>	500 taxa; 54 endemic taxa; 7 rare taxa; 10 very rare taxa
Tamga forest	<i>Pinus halepensis, Quercus rotundifolia, Tetrclinis articulata, Juniperus phoenicea</i>	366 taxa; 33 endemic taxa
National Park of Toubkal	<i>Quercus rotundifolia, Juniperus thurifera, xerophytes.</i>	536 taxa; 164 endemic taxa
Aghbar forest	<i>Cupressus atlantica, Quercus rotundifolia, Juniperus phoenicea, Tetrclinis articulata.</i>	45 endemic taxa; 7 rare taxa; 13 very rare taxa
Kest, Anezi and Imzi mountains	<i>Dracaena dracosp.ajgal, Quercus rotundifolia, Tetrclinis articulata.</i>	17 endemic taxa; 2 rare taxa; 5 very rare taxa
Maamora forest	<i>Quercus suber.</i>	408 taxa; 26 endemic taxa; 29 rare taxa; 35 very rare taxa



Fig. 4 Biosphere Reserve of Southern Oasis Morocco

The geographical distribution of protected areas [8] covers all regions of the country with a very satisfactory representation of major ecosystems and major habitat types.



Fig. 5 Intercontinental Mediterranean Biosphere Reserve [8]



Fig. 6 Biosphere Reserve of cedar ecosystem

Protected areas distributed throughout Morocco cover the majority of natural ecosystems [8]. A significant number of protected areas are located in mountainous areas and are created for the conservation of biodiversity and some remarkable ecosystems as *Cedrus atlantica*, *Cupressus atlantica*, *Dracena draco* subsp. *ajgal* and *Abies maroccana*. Talassemtane National Park, National Park of Tazekka, National Park of Ifrane, Easter High Atlas National Park and Toubkal National Park are the most important protected areas in mountains. In addition to these national parks, other interesting sites like Bou Hachem, Bou Naceur, Bou Iblane, Tichoukt, Ayachi, Maasker, Mgoun, Tamga, Krouz, Kest and Aghbar mountains and Mamora forest are identified by Morocco as sites of biological and ecological interest and as Important Plant Areas (IPAs) due to the presence of remarkable ecosystems and flora with a high degree of endemism [6].

IV.CONCLUSION

Morocco has a great geographical diversity (plains, low, medium and high mountains, valleys, cliffs etc.) accompanied by climate variability has led to the installation and development of several natural ecosystems occupying large areas of the mountains and a rich and varied flora. The flora of the mountainous areas is characterized by a high degree of endemism and rarity especially on the high peaks that are refuges for rare and endemic flora. This richness is increasingly subject to natural disturbances (drought, parasites, etc.) and anthropogenic pressures (agricultural land clearing, timber harvesting, harvesting of aromatic and medicinal plants, grazing etc.). To reverse these trends, Morocco has developed a strategy for biodiversity conservation based on a network of Protected Areas covering major ecosystems. These protected areas are an effective means for the conservation and sustainable management of biodiversity and also for the development of local populations. Despite the achievements in biodiversity conservation, much remains to be done to relieve the pressures of degradation of ecosystems and the flora of mountainous areas for the development of local populations and ensure the availability of natural resources for future generations.

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