# Protected Areas for Biodiversity Conservation in Morocco

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**Abstract:** On a global scale, human activities and unsustainable consumption and production patterns have, over the last century, led to an erosion of biodiversity, manifested by a major wave of ecosystem degradation and species extinction. Faced with this alarming situation, and in recognition of the importance of biodiversity for humanity, governments have adopted several conventions aimed essentially at conserving biodiversity. Aware of the threats of degradation to biodiversity, and in order to honor its international commitments by ratifying several conventions, Morocco has drawn up a Master Plan for Protected Areas (1996), which aims to evaluate the main natural environments over a surface area of 2.5 million hectares, and to identify 154 Sites of Biological and Ecological Interest (SIBE). The aim of this work is to present a diagnosis of the current situation, the importance and evolution of the diversity of natural ecosystems and the role of protected areas in biodiversity conservation, through case studies in Morocco.

**Keywords:** Protected areas, Biodiversity, Conservation, Degradation, Morocco.

## 1. INTRODUCTION

The earth is home to some 8.7 million plant and animal species, of which 86% of terrestrial species and 91% of marine species have yet to be discovered (Leroux et al., 2010). These biological resources are largely a potential source of income for the world's rapidly growing population.

Faced with a combination of complex natural factors, such as recurrent droughts, and man-made factors, such as the over-exploitation of natural resources, the misuse of chemical products and the introduction of exotic species to feed production systems that have remained extensive, the world's biodiversity is at risk (Vivien, 2002).

The extent of the biodiversity extinction crisis was measured by the Millennium Ecosystem Assessment. This assessment showed that, over the last fifty years, human activities have caused more rapid and extensive changes to ecosystems than at any other time in human history, resulting in a substantial loss of biological diversity on earth, often irreversible (Frankham, 2022).

Aware then, of the importance of preserving species and natural habitats, the United Nations Organization (UNO) in collaboration with the International Union for Conservation of Nature (IUCN), affiliated, over 50 years ago, the inventory of all protected areas in the world; A list of national parks and equivalent reserves was established (Deguignet et al., 2014).

This list of United Nations (UN) protected areas has since been maintained by IUCN and the United Nations Environment Programme's World Conservation Union. Other terrestrial and marine protected areas are designated, and the list is updated regularly. The aim is to have at least 17% of terrestrial and inland water areas and 10% of marine and coastal areas designated as protected areas by 2020 (Pollock et al., 2020).

## 2. BIODIVERSITY IN MOROCCO

In the Mediterranean Basin, Moroccan biodiversity is second only to that of the Anatolian region (Türkiye), with an overall endemism rate of 20% (Pollock et al., 2020). Thus, the variety of bioclimates and natural environments favors the development of very rich and diverse ecosystems of great ecological and socio-economic value.

The forty or so terrestrial ecosystems identified across the country are home to over 4,000 vascular plants, nearly 550 vertebrate species and thousands of invertebrates (Laaribya et al., 2021a). Two-thirds of these plants and one-third of the animal species live in forest environments. As a result, Moroccan forests are the foundation of the country's ecological biological wealth.

Moroccan forests cover some 9,631,896 hectares (including over 3 million hectares of alfalfa cover), or 13.5% of the national territory (IFN, 2005), and occupy different bioclimatic stages, from semi-arid to humid. They are made up of very heterogeneous, often open species with very diverse structures, divided into natural deciduous forests (Holm oak, Cork oak, Tauzin oak, Argan, Carob, Acacia, etc.) and coniferous forests (Atlas cedar, Berber cedar, Aleppo pine, Maritime pine, Black pine, Thuriferous juniper, Red juniper, etc).
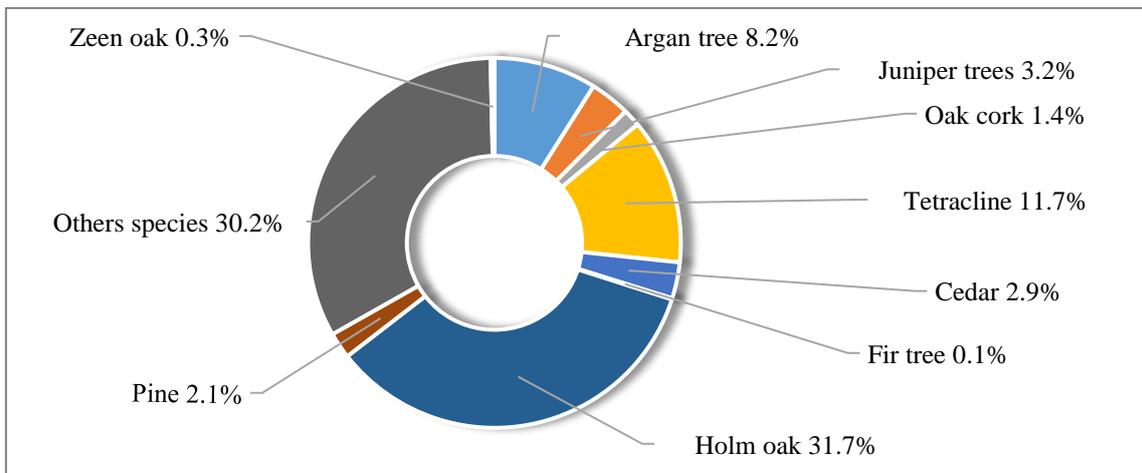


**Figure 1.** Main forest ecosystems in Morocco.

The forests are also home to a wide variety of fauna, including the cuffed moufflon, the magot monkey, the golden jackal, the wild boar, the panther and the striped hyena, the gazelle, the addax, the otter, the lynx and the African ostrich. Without mentioning all the animal species, the list is surely incomplete. They are also home to several bird species, including some rare birds of prey (Golden Eagle and Bearded Vulture), reptiles, lepidopterans and amphibians, which are represented by around a hundred species (Dobson, 1998).

In addition, the cultural resources, many of which are centuries old, combined with the natural potential, forest ecosystems offer very significant ecotourism potential and constitute a major resource for the people who live there, and a sector of economic activity in its own right.

Although Morocco's natural resources are of a high quality, they are insufficiently protected and increasingly under threat from climate change and anthropogenic pressure (Laaribya et al., 2021b). So, like all other countries, the conservation of natural environments in Morocco has become a decisive challenge.

## 3. PROTECTED AREAS AND MAINTAINING BIODIVERSITY IN MOROCCO

Aware of the threats to biodiversity and in order to meet its international commitments, Morocco has committed itself to a policy of sustainable development, which aims both to safeguard biological diversity and to develop several socio-economic axes, through the designation of sites of biological and ecological interest which, depending on their characteristics, vocation and socio-economic scope, will be assigned to one of the protected area categories (national park, nature park, biological reserve, nature reserve and natural site) defined by the law on the creation of protected areas (Mghili et al., 2023).

Following the example of other countries around the world, 154 sites of biological and ecological interest have been designated, ten national parks have been created to date and several wetlands are classified as protected areas, including 38 nature or biological reserves listed as Ramsar sites (Dakki et al., 2015).
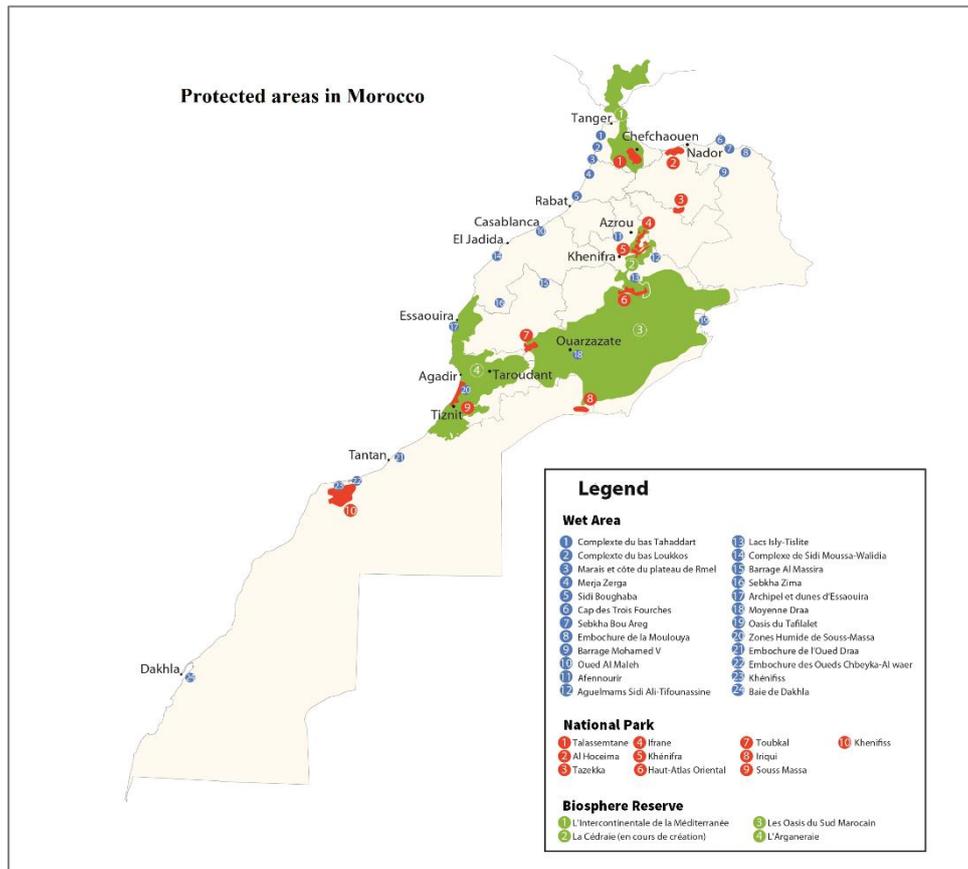
**Figure 2.** Protected areas in Morocco.

These protected areas, with their unique and highly diversified flora, contain locally endemic plant taxa, some of which are rare or threatened (Ayan et al., 2023), such as argan tree, Atlas cypress, Atlas cedar, Moroccan fir, black pine, etc. Some of these are part of the four Biosphere Reserves declared and recognized by UNESCO as world heritage sites for humanity. The aim of these reserves is to contribute to the conservation of natural resources and promote a model of sustainable development by fostering the social and economic development of rural populations through the preservation of their natural and cultural heritage (Vasseur & Siron, 2019). These include the Arganeraie Biosphere Reserve (1998), in the South-West region, covering an area of 2.5 million hectares, the Oasis Biosphere Reserve of Southern Morocco (2000), covering an area of around 7 200 000 ha, the Mediterranean Intercontinental Biosphere Reserve (2006), covering almost 1 000 000 ha, divided between the Moroccan and Spanish shores, and the Atlas Cedar Biosphere Reserve (2016), covering around 1 400 000 ha.

## 4. RESTORATION OPTIONS FOR DEGRADED ECOSYSTEMS

We have carried out research on ecosystems dominated by protected plant species with endemic and threatened characteristics. We have shown that these ecosystems can still be restored under current bioclimatic conditions by regenerating them on the scale of their projected potential areas. These include:

1. Cork oak (*Quercus suber* L.), which covers an area of almost 384 200 ha. It is a remarkable species in our forests, given its ecological and socio-economic roles. Unfortunately, the area covered by cork oak continues to decline under the influence of anthropozoogenic degradation, as well as damage caused by a number of insect pests, including Lepidoptera, and climate change. All these factors essentially threaten the world's most extensive lowland Cork oak forest (Maamora forest, 133 000 ha) with certain disappearance in the near future (Laaribya et al., 2021a).

In this study we applied the maximum entropy algorithm (MaxEnt) to estimate the current and potential distributions of cork oak (*Quercus suber* L.) in the Maarmora Forest, Morocco, in order to provide a basis for its conservation under conditions of climate change in the Mediterranean basin. A total of 1 428 spatial field records of cork oak locations were used (altitude and 19 bioclimatic environmental variables) to model the distribution potential of cork oak. We found that precipitation in the wettest quarter of the year, precipitation seasonality, altitude and seasonal temperature variations are the key factors determining cork oak distribution in Maamora forest. Most of the areas currently presenting favorable conditions for cork oak are located in the western and central Maamora forest; regions benefiting from a humid bioclimate and receiving significant sea spray from the Atlantic Ocean. Away from the ocean, humidity decreases and temperature rises, so that cork oak encounters adaptation and regeneration difficulties. The results can be used to identify high-priority areas for cork oak restoration and conservation against the expected impact of climate change.

2. The Atlas cedar (*Cedrus atlantica* Manetti) is an emblematic species of Morocco, classified by the International Union for Conservation of Nature (IUCN) in the red list of endangered species. Determining its potential range under current climatic conditions is an essential step in planning and ensuring its conservation. We modelled the distribution of the potential range in Morocco using the "MaxEnt" maximum entropy approach. The most significant variables conditioning the distribution of Atlas cedar, under current climatic conditions, are rainfall in the driest quarter, rainfall in the driest month, mean annual temperature and relative humidity. The model developed has enabled us to draw up the first map of the potential area of suitable zones for Atlas cedar in Morocco. The current mapped area of the Atlas cedar in Morocco is 138 691 hectares, while the modelled potential distribution area represents 770 605 ha, i.e. a surplus of 631,914 ha (+455%) compared with its current habitat. This result shows, on the one hand, the regression of the area occupied by Atlas cedar in the past, as a result of human and pastoral pressures, and reveals, on the other hand, the possibility of reconstituting its habitat under current climatic conditions by restoring it to the scale of its predicted potential range (Laaribya & Alaoui, 2021).

3. Moroccan fir (*Abies marocana* Trabut) located in Talassemtane National Park, is endemic species of the Moroccan Rif, classified as "endangered" in the IUCN Red List of Threatened Species. Since the beginning of the last century, this species has suffered 70% habitat loss. However, despite its bioecological, economic and social importance, Moroccan fir has received little attention from researchers. Determining the potential area under current topographic and climatic conditions is a very important step to develop conservation and sustainable management strategies for this endangered endemic species. For this purpose, the potential distribution of Moroccan fir using the maximum entropy approach (MaxEnt software 3.4.1) is presented in this work.

Our results showed that the main variables conditioning the presence of A. marocana were the average temperature of the warmest quarter and the maximum temperature of the warmest month. The potential area represents a gain of 227% compared to the current distribution of the Moroccan fir forest. Suitable areas are provided allowing management for afforestation programs and carbon sequestration in Talassemtane National Park, Morocco (Alaoui et al., 2021).

# 5. CONCLUSION

Biodiversity, as a common heritage, is of exceptional interest and remains at the heart of major global concerns. However, its decline is putting all the services provided by nature at risk.

Although they are not the only mechanism, protected areas are essential for the maintenance and sustainable use of biodiversity. They have been set up to conserve and restore habitats and species, and to enhance the value of natural and cultural assets.

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