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Mapping the distribution of *Abies marocana*: Geospatial reference data for biogeographical research and conservation

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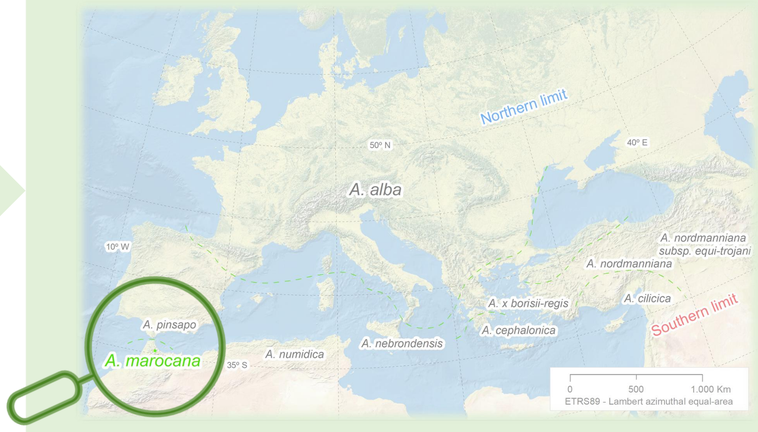
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1. SETTING THE SCENE

- *Abies marocana* Trab. (Moroccan fir) is an endemic species found in the western Rif Mountains (Morocco). (1) It is classified as endangered by the IUCN, primarily due to habitat loss and climate change. (2)
    - Although its taxonomic delimitation has been debated, recent studies support its distinction from the closely related species *Abies pinsapo* Boiss. (Spanish fir), native to the Baetic System (Spain). (3)
- Geodata on the distribution of the Moroccan fir is fragmented and outdated, lacks high spatial resolution, and is not accessible in an interoperable digital format.
- To support biogeographical research and conservation, data must be harmonised within a common Baetic–Rifan framework within the context of the Intercontinental Biosphere Reserve of the Mediterranean.

1.1. The Southern Frontier of the Circum-Mediterranean Firs (Abies, Pinaceae)

Figure 1
The circum-Mediterranean firs



A. marocana is the south-westernmost fir species in the circum-Mediterranean group and is separated from A. pinsapo by the Strait of Gibraltar. Source: Author's own work. (4)

Figure 2
Moroccan fir forest in the Rif Mountains



Talassemtane National Park (northern Morocco) hosts relict *A. marocana* forests on shaded slopes between 1,500 and 2,100 m, in humid to perhumid bioclimates marked by summer drought.

2. MAPPING THE GAP

- A GIS-based geospatial database is under development, integrating historical forest cover and environmental variables associated with *A. marocana* within a unified spatial reference system (WGS84).

2.1. Multitemporal map delineation

- *A. marocana* cover was delineated from georeferenced historical maps (from 1940) (5) and recent high-resolution satellite imagery (2023-2025). Georeferencing and delineation are original contributions of this research.

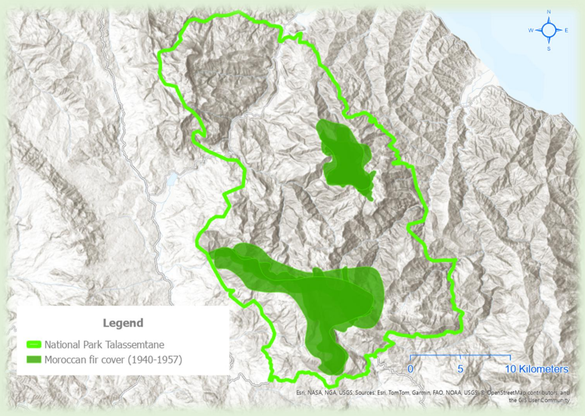
2.2. Downscaling bioclimatic data

- Bioclimatic GIS layers from WorldClim 2.1 (≈1 km) were downscaled to 100 m resolution using Geographically Weighted Regression (GWR), with NASA's SRTM DEM as spatial reference and derived topographic predictors.

3. EARLY RESULTS AND KEY INSIGHTS

3.1. Habitat loss and fragmentation

Figure 3
Historical Moroccan fir cover



Mid-20th century estimates of Moroccan fir forest extent range between 6,000 (more reliable) and 8,000 (less reliable) hectares. However, the upper values may reflect coarser cartographic generalisation. They may include areas that are likely unsuitable for *A. marocana*.

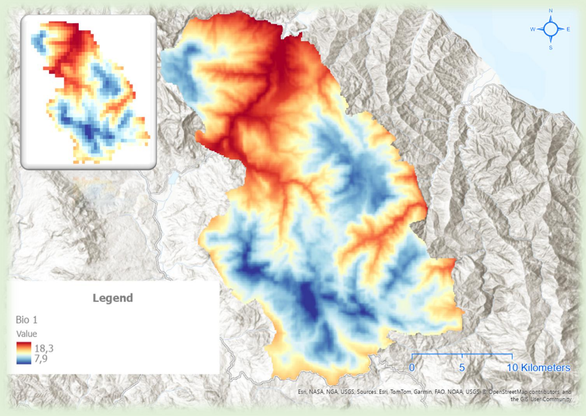
Figure 4
Current Moroccan fir cover



The current extent of Moroccan fir forests is estimated at around 4,200 hectares. This figure includes pure, mixed, and marginal stands, which are currently being further classified. Compared to historical data, a clear loss and fragmentation of habitat is observed.

3.2. Downscaled WorldClim

Figure 5
BIO1 (Annual Mean Temperature)



GWR models perform particularly well in the Talassemtane National Park area. This performance reflects the combined effect of WorldClim 2.1 station density in northwestern Morocco and the high-quality topographic detail provided by NASA's SRTM elevation data.

4. RESEARCH ROADMAP

- Further research on habitat modelling, remote sensing-based monitoring, and adaptive conservation strategies will be based on the data generated in this study.

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