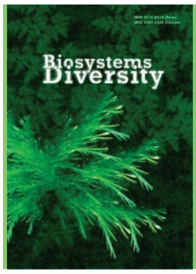

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Ecological insights and conservation imperatives for *Laurus azorica* in Morocco

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The Azores laurel *Laurus azorica* (Seub.) Franco is a highly esteemed forest species in Morocco due to its medicinal and aromatic properties. However, the natural habitats of this species are increasingly scarce, resulting in its classification as a rare species. This study comprehensively investigates the autoecology, plant communities, and distribution patterns of *L. azorica*, aiming to discern the crucial ecological factors underpinning its survival and shed light on its conservation status. Field surveys, including floristic relevés and environmental characterization, were conducted to identify the primary plant communities hosting remnants of *L. azorica*. Fieldwork and ecological analysis reveal five distinct plant communities associated with *L. azorica*: low elevation thermophilic holm oak woodland, mesophilic mid-altitude holm oak woodland, *Quercus faginea*, deciduous broadleaf mountain and *Cytisus balansae* plant communities. The study emphasizes the importance of ecological requirements such as oceanic exposure, rainfall, temperature, and forest mull soils in creating suitable habitats for *L. azorica* populations. Currently, *L. azorica* populations in Morocco are represented by small trees, shrubs, or bushes, often exhibiting distorted and damaged structures due to unregulated pruning. Natural regeneration of the species is completely absent. The value chain associated with *L. azorica* is limited, involving informal harvesters, intermediary herbalist grocers, and final consumers, due to the lack of a legal framework for resource evaluation caused by its severe depletion. To secure the survival of *L. azorica* in Morocco, it is crucial to address gaps in legislation, intensify conservation efforts, and promote sustainable development practices. Protecting and restoring the natural habitats of the species, along with implementing responsible harvesting practices, are essential steps towards conserving this valuable forest species.

Keywords: autoecology; plant communities; aromatic and medicinal plants; ecological requirements; value chain.

Introduction

The laurel forest, also known as laurisilva, is an ancient evergreen forest that originated during the Tertiary period, approximately 20 million years ago, and once covered Southern Europe and Northern Africa (Jiménez et al., 1996; Morales et al., 1996). Over the course of the Quaternary period, significant climatic changes occurred, resulting in the migration of the laurel tree (*Laurus* L.) to regions with more favourable climatic conditions for its survival (Rodríguez-Sánchez & Arroyo, 2008). It is hypothesized that *Laurus* species managed to persist in isolated refugia within the Mediterranean Basin and Macaronesia during the Pleistocene glaciations (Barbero et al., 1981; Rodríguez-Sánchez et al., 2009).

Morocco is one of the regions where *Laurus* species has managed to survive. The Laurceae family in Morocco consists of two spontaneous species, namely *Laurus nobilis* L. and *L. azorica* (Seub.) Franco (Benabid, 2000). The bay laurel is widely recognized and extensively used throughout the Mediterranean basin and has been intentionally planted beyond its natural range due to its diverse applications (Arroyo-García et al., 2001). *Laurus azorica*, on the other hand, is native to the Azores, Madeira, and Canary Islands (Bramwell & Bramwell, 1983; Jalas & Suominen, 1991), as well as Morocco (Barbero et al., 1981). It also existed in Europe in a fossil state in various locations (Roiron, 1983).

Initially, *L. azorica* in Morocco was considered a variety of *L. nobilis* and was described as *L. nobilis* L. var. *rotundifolia* Emberger & Maire (Jahandiez & Maire, 1932). However, Barbero et al. (1981) later confirmed it as a distinct species. The presence of *L. azorica* has been documented in the Elksiba Atlas (Southern Middle Atlas) and Beni Mellal (Jbel Ghnim) regions (Barbero et al., 1981). It has also been observed in the Anti-Atlas, east of Tiznite, where it exists as scattered individuals in a relictual state (Benabid & Cuzin, 1997). A more recent study (Rodríguez-Sánchez et al., 2009) based on phylogeographical analyses raised uncertainties regarding the taxonomic classification of *Laurus*, suggesting that the division into two separate species may not be entirely accurate.

These species hold significant value as aromatic and medicinal plants, both nationally and internationally. Laurel leaves are popular condiments worldwide and are commonly used as a culinary spice and flavouring agent in the food industry. The investigation of *L. azorica* has revealed that it contains metabolites of high commercial value, such as sesquiterpene lactones, which are structurally diverse and biologically active (Viveiros et al., 2022). In Morocco, the species is primarily used orally to treat various conditions, including digestive and joint disorders, neurological disorders, and ENT diseases (Zrira, 2017).

Concerning the conservation status, the population of *L. azorica* in the Azores is currently stable, but its habitat, the mesothermal laurel forest, has suffered extensive clearance for agricultural purposes, resulting in a significant decrease in the species' population size (Silva & Beech, 2017). In the 2016 assessment for the IUCN (International Union for Conservation of Nature) Red List of Threatened Species, *L. azorica* was classified as Least Concern. However, it is important to note that the populations of *L. azorica* in Morocco were not included in this assessment and their conservation status remains unspecified. Furthermore, the ecological information and conservation status pertaining to *L. azorica* in Morocco are limited. This plant species holds significant cultural and ecological value and is recognized as a highly uncommon plant (Fennane & Ibn Tattou, 1998). Unfortunately, the majority of individuals belonging to this species face a distressing predicament caused by the unlawful and excessive collection of leafy branches, which are subsequently sold for culinary purposes. Currently, there is no specific protection designation assigned to this species in Morocco, aside from the establishment of a biological and ecological interest site in 1996, which seeks to safeguard the distinctive and noteworthy *L. azorica* populations found within the country.

Officially, due to its alarming state, *L. azorica* is no longer exploitable in forestry land. However, its importance as an aromatic and medicinal plant has led the Water and Forest Services of the region and stakeholders in its value chain to propose effective reforestation efforts in collaboration with local communities, with an emphasis on highlighting its value chain. However, there is a lack of comprehensive ecological data on the potential habitat of *L. azorica*.

The present study has three main objectives. Firstly, it aims to define the ecological conditions necessary for the habitats of *L. azorica* by examining the ecological values of the plant communities that support its growth. This analysis will provide insights into the specific environmental factors crucial for the species' survival and distribution. Furthermore, the research focuses on analyzing the biogeographic distribution and chorology of laurel populations to map their potential range. By studying the geographic distribution patterns, the study aims to understand the natural distribution of the species and identify suitable areas for conservation and reforestation efforts.

In addition, the study aims to diagnose and analyze various elements of the current value chain associated with *L. azorica*. This includes assessing the processes involved in harvesting, processing, and marketing the species, as well as understanding its economic significance and potential for sustainable utilization. By addressing these objectives, the study aims to contribute to the conservation and sustainable management of this highly valued forest species.

Material and methods

Study area. The study area is situated at the junction of the Southern Middle Atlas and Central High Atlas in the Beni Mellal Khenifra administrative region of Central Morocco (Fig. 1). Geologically, the region falls within the Atlasic domain, characterized by predominantly limestone formations, and it spans an elevation range of 500 to 2300 m above sea level. Topographically, the area exhibits elongated reliefs oriented in a northeast-southwest direction, with varying degrees of slope ranging from moderate to steep.

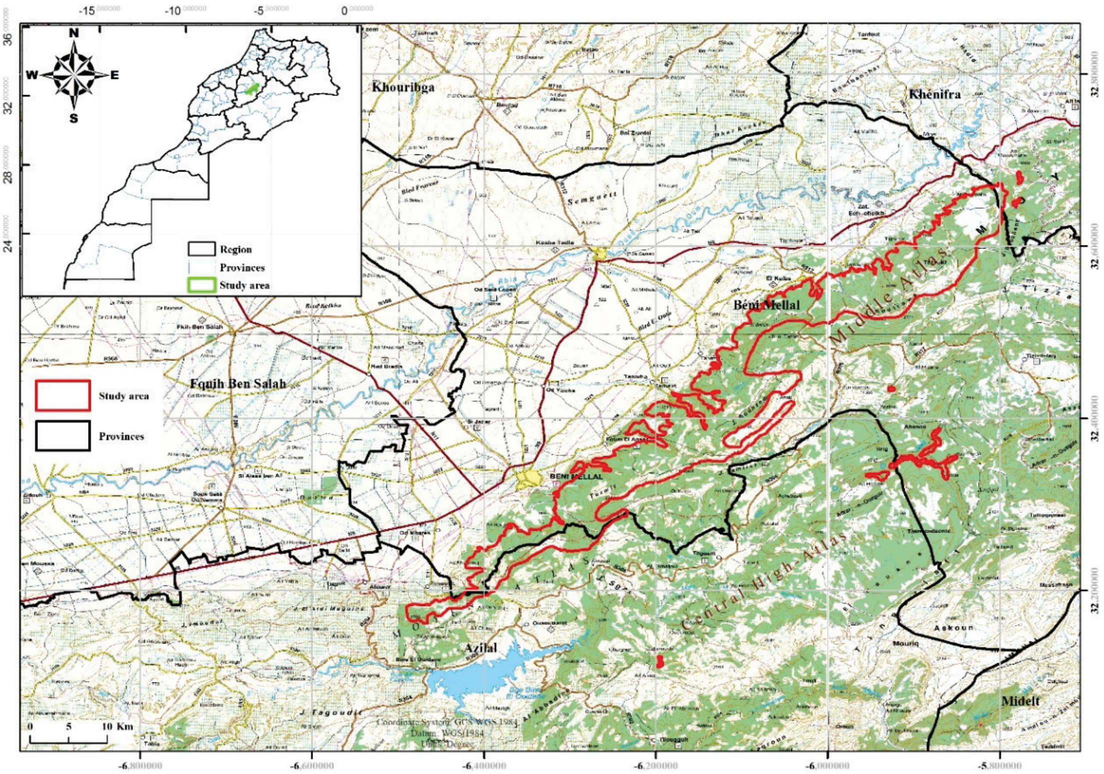

Fig. 1. Geographical situation of study area

In terms of climate, the region experiences a semi-continental climate, with cold to very cold winters and hot to very hot summers. Precipitation and temperature show a significant spatial variability, with a pronounced gradient from the plains to the mountains. The vegetation cover in the study area is highly diverse. Predominantly, there are thermophilic species, including *Pinus halipensis*, *Tetraclinis articulata*, *Quercus rotundifolia*, *Ceratonia siliqua*, *Acacia gummifera*, and *Euphorbia resinifera*. As we ascend to higher elevations, the vegetation comprises communities of *Quercus faginea* and *Laurus azorica*, which are characteristic of the upper ranges. The presence of this diverse vegetation reflects the ecological richness and complexity of the study area, highlighting the importance of examining the specific habitats and plant communities that support *L. azorica* within this context.

Autoecological study. There is limited existing literature on the presence of *L. azorica* in Morocco, with only a few references available (Jahandiez & Maire, 1932; Barbero et al., 1981; Benabid & Cuzin, 1997). To fill this research gap, the study employed a phytosociological approach that incorporated the Braun-Blanquet method and its modern extensions (Dengler et al., 2008). The field sampling was carried out along transects selected based on the variation of major climatic gradients and geological structures. Along each transect, 40 relevés were conducted whenever a change in the environment was observed, primarily regarding vegetation type, soil type, slope, geological substrate, and exposure. The phytosociology of *L. azorica* was documented through the analysis of vegetation relevés, which were then compared with vegetation data from previous studies conducted in Morocco.

Chorology and mapping of L. azorica locations. To understand the distribution of *L. azorica*, location data for populations predominantly represented by this species were integrated and interpreted within a GIS environment. Additionally, the results of the autoecological study, corresponding to different vegetation communities, were spatialized and mapped to highlight the potential distribution area of *L. azorica*.

Analysis of the current value chain. This component is carried out through simplified surveys of stakeholders operating in *L. azorica* value chain to determine the links in the resource's commercialization chain in the study area. These surveys aim to acquire information related to quantities harvested, sale prices, actors in the value chain, impacts on the resource, etc. The conducted surveys involved the water and forestry administration as the department responsible for resource management, herbalist-grocers, forest operators, and collectors (shepherds, local population).

Data analysis. The collected data, including the floristic relevés data, location data, and value chain survey responses, were subjected to data analysis. The processing of relevés data involved the creation of phytoecological summary tables grouping relevés based on the dominance and physiognomy of the species within each plant community. The map data were processed and queried using GIS software to generate a status map illustrating the current distribution of laurel populations and their main range. The map, presented on a topographic background at a scale of 1: 350,000, was enhanced with appropriate symbology.

In this study, we utilized two primary sources of data. Firstly, we employed the WorldClim dataset (Fick et al., 2017), which provides global climate layers in GeoTiff format with a spatial resolution of approximately 30 seconds (equivalent to approximately 1 km²). These climate layers were utilized to map various bioclimatic variables. Secondly, we obtained export statistics from the official website of the Moroccan Exchange Office. The data, available for download upon request on the International Trade Platform (https://services.oc.gov.ma/DataBase/Commerce Exterieur/requete.htm), provided valuable information for our analysis.

Results

Laurus azorica plant communities. L. azorica does not typically form distinct and well-defined plant communities; instead, it exists in the form of isolated patches within larger plant communities. Currently, the species is only found in the form of scattered individuals, remnants of extensive exploitation. Therefore, understanding the autoecology of *L. azorica* requires considering the plant communities that provide it with habitat and support. Through the fieldwork conducted, including the counting and analysis of various relevés, the study was able to identify and characterize the different plant communities that serve as habitats for *L. azorica*. These plant communities play a crucial role in supporting the survival and distribution of the species. By examining plant communities and their ecological characteristics, the study aims to gain insights into the specific ecological conditions required by *L. azorica* and the factors influencing its presence and distribution. This approach allows for a comprehensive understanding of the species' autoecology within the context of its surrounding plant communities.

Low elevation thermophilic holm oak woodland (Fig. 2). *Laurus azorica* is exceptionally rare within this plant community, which is located at an altitude range of 1200 to 1300 meters. This community is primarily found on the north, northwest, northeast, and west-facing slopes but is limited in extent, being observed only along the oceanic foothills from Foum El Anseur to above Zawyat Ech Cheikh. From a bioclimatic perspective, this plant community exists within a sub-humid bioclimatic zone with a temperate to fresh variant. It predominantly thrives on fersialitic red soils, which possess a well-defined humiferous horizon. These soils have developed on colluvial and alluvial deposits. Among the companion species found alongside *L. azorica* in this plant community, there are *Tetraclinis articulata*, *Juniperus oxycedrus*, *Phillyrea latifolia*, and *Smilax aspera*. These species coexist with the holm oak (*Quercus rotundifolia*) within this particular community, which can be associated with the *Smilaci mauritanicae-Quercetum rotundifoliae* Barbéro, Benabid, Quézel & Rivas-Martinez, 1981, as described by Barbéro et al. (1981). This plant community exemplifies distinct ecological characteristics and a unique species composition, showcasing the presence of *L. azorica* in limited abundance alongside other associated plant species.

Mesophilic mid-altitude holm oak woodland (Fig. 3). At an elevation ranging from 1400 to 1600 meters, there is a second group characterized as a mesophilic mid-altitude holm oak community, which exhibits the widest distribution in the Beni Mellal Atlas. This forest group is generally well-preserved and densely populated by holm oak woodland, thriving in favourable conditions along the oceanic facade. The mesophilic mid-altitude holm oak woodland can be observed across various altitudinal levels, including Mesomediterranean, Supramediterranean, and locally Mountain Mediterranean. It occupies diverse exposures and occurs on different geological substrates and soil types. Similarly, to the first group, the presence of the *L. azorica* in this plant community is in the form of isolated islets or individual specimens. The floral composition of this community includes species such as *Balansaea glaberrima*, *Phillyrea latifolia*, *Arbutus unedo*, *Vubernum tinus*, *Quercus faginea*, *Acer monspessulanum*, *Juniperus oxycedrus*, *Lonicera arborea*, and *Phlomis samia*. These species, along with the *L. azorica*, contribute to the overall biodiversity and ecological dynamics of the community.

Fig. 2. *Smilaci mauritanicae-Quercetum rotundifoliae* plant community

The mesophilic mid-altitude holm oak woodland here is classified within the *Balansaeo glaberrimae-Quercetum rotundifoliae* association, as described by Barbéro, Quézel, and Rivas-Martinez in 1981 in the Middle Atlas of Morocco. This plant community is also reported in the Rif mountains (Taleb & Fennane, 2019), demonstrating its presence in multiple locations. In the study area, the occurrence of this plant community has been documented by Ouchbani & Romane (1996), emphasizing its ecological significance and distribution within the area. *Laurus azorica* is typically restricted to steep slopes or inaccessible rocky areas such as cliffs within this plant community (Fig. 3b).

Quercus faginea plant community. It is found on the oceanic slopes of the Aït-Ouirra pass and Bou Izerfane mountain, with limited occurrences on the Koumch massif, at elevations ranging from 1600 to 1800 meters. This plant community primarily consists of a *Quercus faginea* woodland, and alongside *L. azorica*, it is characterized by species such as *Quercus rotundifolia*, *Acer monspessulanum*, and *Crataegus laciniata*. These species thrive in optimal conditions, aside from the challenges posed by human activities and grazing on *L. azorica* individuals. Additionally, there are localized endemic species present in this community, including *Linaria gattefossei*, *Delphinium favargeri*, and *Trachystoma ballii*. The *Quercus faginea* community is situated within the Mesomediterranean and Supramediterranean levels, displaying a sub-humid to humid climate with temperate and cold variants. From an edaphic perspective, this group occupies the deepest soils within the study area, indicating its preference for specific soil characteristics. This plant community corresponds to the *Paeonio maroccanae-Quercetum fagineae*, as described by Barbéro, Benabid, Quézel, and Rivas-Martinez in 1981. It highlights the coexistence of *Quercus faginea* and *L. azorica*, among other species, and their ecological interactions within the plant community.

Deciduous broadleaf mountain plant communities. These plant communities are located at higher altitudes, succeeding the previous one. They thrive in a humid bioclimatic environment. The vegetation consists of low and scattered tree communities dominated by deciduous broadleaf species such as *Crataegus laciniata*, *Berberis hispanica*, and *Fraxinus dimorpha*. Within this plant community, *L. azorica* finds refuge on the cliffs, taking advantage of the rugged terrain. This particular plant community is likely a result of the degradation of the holm oak forest. It corresponds to the *Berberido hispanicae-Fraxinetum dimorphae* community (Fig. 5a), as described by Quézel and Barbéro in 1981. At higher elevations, there is another new distinct plant community observed along the cliffs of the Laabid River and its tributaries, spanning from Boutferda in the northeast to Tiffirt N'Aït Hamza in the southwest. We describe it as *Lauro azoricae - Fraxinetum dimorphae*. This new plant community colonizes the fertile, humid, and cool soils found in the crevices of the cliffs. *Laurus azorica* within this one are typically shrubs or small trees and are well-preserved, except for a few individuals accessible to goats that may be partially damaged (Fig. 5b). Other common species in this plant community include *Quercus rotundifolia*, *Fraxinus dimorpha*, *Clematis cirrhosa*, and *Jasminum fruticans*. It exhibits a preference for cliffs exposed to the north, northwest, and west directions.

Fig. 3. *Balansaeo glaberrimae-Quercetum rotundifoliae* plant community (*b*) and *Laurus azorica* within the community (*a*)

Fig. 4. *Paeonio maroccanae-Quercetum fagineae* plant community (*b*) and *Laurus azorica* within the community (*a*)

Fig. 5. *Berberido hispanicae-Fraxinetum dimorphae* plant community (*a*) and *Laurus azorica* within the community (*b*)

Cytisus balansae plant community (Fig. 6). It is observed in certain areas of the summit portion of the entire oceanic facade of the study area. However, it is limited to very small patches characterized by very cold and humid bioclimatic conditions. This plant community thrives on rocky soils and is found at the Mountain Mediterranean range. It corresponds to the *Centaureo triumfetii-Cytisetum balansae* community, as described by Benabid in 1988 (also known as *Cerastio gibraltarici-Cytisetum balansae*). Within the areas where this plant community occurs, a few *L. azorica* trees can be observed growing on the walls of small cliffs.

Ecological requirements. The results indicate that *L. azorica* populations are primarily found in scattered locations exclusively on the oceanic-facing slopes of the ridges overlooking the cities of Beni Mellal, El Ksiba, and Zaouiat Ech-Cheikh (Fig. 7). There are very few other populations occurring in specific ecological conditions to the east of this ridge line. The dominant geographical feature in this region is the North-North-West-West reverse, which constitutes a medium mountain range with rugged reliefs. These reliefs are characterized by the presence of robust Upper Jurassic and Cretaceous rock formations, including sandy dolomites, dolomite stones, dolomitic limestone, and alternating layers of marlstone and limestone.

Fig. 6. *Cytisus balansae* plant community

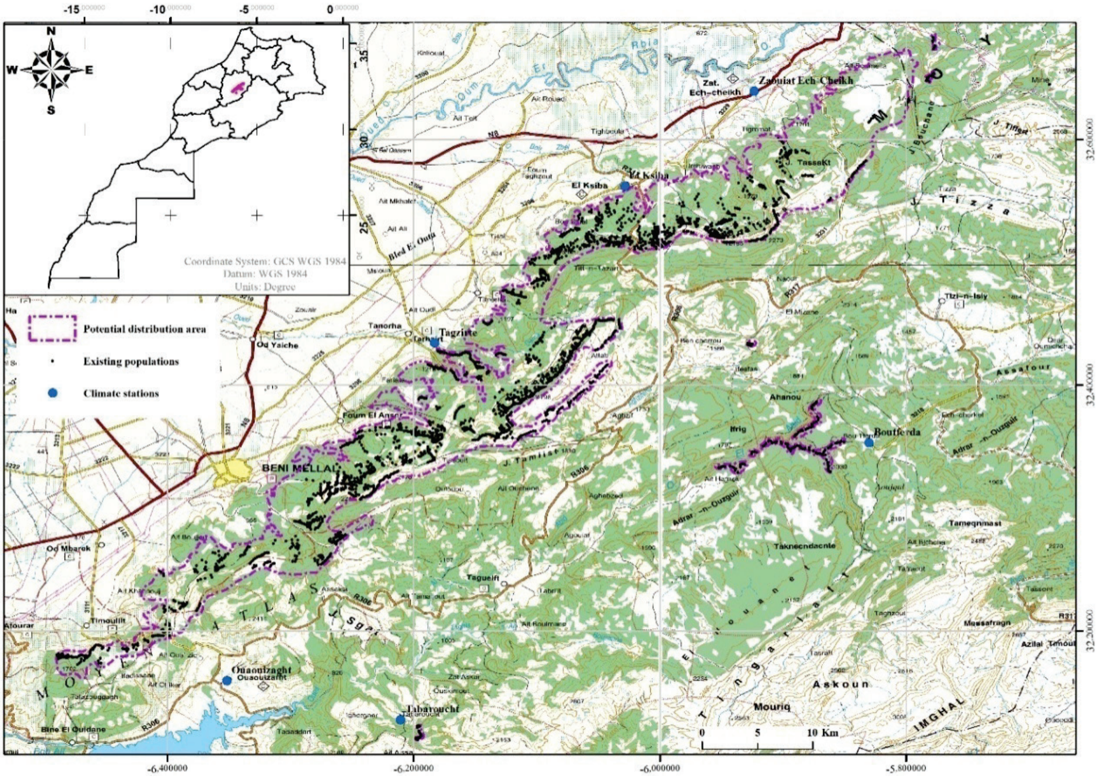

Fig. 7. Potential distribution map of *L. azorica* in the study area

The reverse is further shaped by deep ravines and torrents formed by occasional floods. It is within the ecological context of this specific geographic region, with its oceanic exposure and geological features, that *L. azorica* populations thrive and establish their habitats.

After examining the spatialized precipitation data (Table 1 and Fig. 8), it is evident that the stations located at the foot of the oceanic exposure, such as Elkisba, Tagzirte, and Zaouiat Ech-Cheikh, receive significantly higher rainfall compared to other stations that are more continental and protected from atmospheric disturbances originating from the west. Based on these data and the findings of the autoecological study, the laurel zone experiences annual rainfall ranging from 500 to 800 mm. The higher rainfall in the laurel zone can be attributed to the influence of the oceanic climate in this region. Furthermore, the tops of the laurel zone, which mark the eastern boundary, are characterized by much colder temperatures (Fig. 9). Despite the variation in elevation and exposure, the oceanic influence helps moderate the thermal differences on the western reverse, contributing to a more consistent and milder climate within the laurel zone. These climate conditions, characterized by higher rainfall and moderate temperatures, play a crucial role in creating suitable habitats for *L. azorica* populations in the study area.The *Laurus azorica* zone in the study area is characterized by the dominance of a sub-humid and humid bioclimate. This bioclimate exhibits different variants depending on the altitudinal levels. At lower and medium altitudes, the bioclimate is cool, while at higher altitudes, it becomes cold. The mountain tops within the laurel zone experience a very cold bioclimate (Fig. 9).

Regarding soil characteristics, *L. azorica* populations are found exclusively on forest mull soils. These soils are distinguished by a significant amount of organic matter, particularly near the surface, where it is well-mixed with mineral components. Forest mull soils are known for their fertility and good drainage properties, providing favourable conditions for the growth and development of *L. azorica*. It is important to note that the specific soil requirements of *L. azorica* contribute to its restricted distribution within the study area, as it primarily occurs in areas where forest mull soils are present.

Laurus azorica value chain analysis. The value chain diagnosis reveals that *L. azorica* is currently facing a critical situation due to uncontrolled and abusive exploitation. Historically, the leaves of *L. azorica* were legally harvested and sold through public tenders by the Water and Forest Administration until 2006. The average annual quantity of leaves exploited and sold during this period was 269 tons, with an average unit price of 16 MAD/kg (1.6 Dollars/kg). However, public sales were discontinued in 2006 due to resource depletion. Since then, an illegal and unregulated circuit has emerged, replacing the previous long value chain involving multiple actors.

The current chain is significantly shortened and involves only three links: gatherers, local herbalists-grocers, and local consumers. The gatherers, who are mostly unauthorized individuals such as shepherds, engage in anarchic withdrawals of *L. azorica* to supply the herbalists-grocers in urban centers. This abusive exploitation has further intensified the negative impacts already caused by the previous legal harvesting system. The local herbalists-grocers confirm that their only suppliers of local aromatic and medicinal plants, including *L. azorica*, are the unauthorized gatherers. They report a decline in the availability of *L. azorica* and other local plants in the market. The herbalists purchase the laurel at prices ranging from 20 to 30 MAD/kg (2 to 3 Dollars/kg) and sell it to consumers at prices ranging from 40 to 60 MAD/kg (4 to 6 Dollars/kg). The local consumers, mainly residents of urban centers bordering the laurel zone, constitute the primary market for *L. azorica*. The quantities obtained through unauthorized harvesting are insufficient to supply other cities in Morocco. This situation indicates a worrisome trend towards the total disappearance of the *L. azorica* resource, even in its once inaccessible cliff habitats. It highlights the urgent need for effective conservation and management measures to protect this valuable plant species from further exploitation and ensure its long-term sustainability.

According to the graph (Fig. 11), the quantities of laurel leaves exported have shown fluctuations from year to year. It indicates that there have been increases in exports starting from 2004, followed by a sharp decline in 2016. This suggests that the export market for laurel leaves has been unstable. In terms of selling prices, there seems to be an inverse relationship with the quantity exported. The graph shows that the selling price of laurel leaves increased from 27 to 93 MAD/kg (2.7 to 9.3 Dollars/kg), and then stabilized at 67 MAD/kg (6.7 Dollars/kg) in 2020. This indicates that the monetary value of laurel leaves has improved over time. It is important to note that the graph represents the exports of laurel leaves in general, including the two species, and may not solely reflect the specific situation of *L. azorica*. The fluctuations in quantity and price could be influenced by various factors, including market demand, availability of the resource, and regulatory measures.

Table 1
Bioclmatic parameters of stations closest to the *L. azorica* zone

Climate station parameters	Zaouiat Ech-Cheikh	Ouaouizaght	El Ksiba	Tagzirte	Tabaroucht	Boutferda
Elevation, m	707	940	1000	600	1450	1500
m, °C	2.9	1.5	1.1	2.8	0.4	–1.2
M, °C	32.8	33.7	31.8	33.2	33.3	31.5
P, mm	662	527	639	586	558	557
Q_2	75.9	56.1	71.4	66.1	58.2	58.4
Bioclimat	Cool sub-humid	Cool semi-arid	Cool sub-humid	Cool semi-arid	Cool sub-humid	Cold sub-humid

Note: Q_2 – Emberger Pluviothermic ratio (Emberger, 1955); m – min temperature of coldest month; M – max temperature of warmest month.

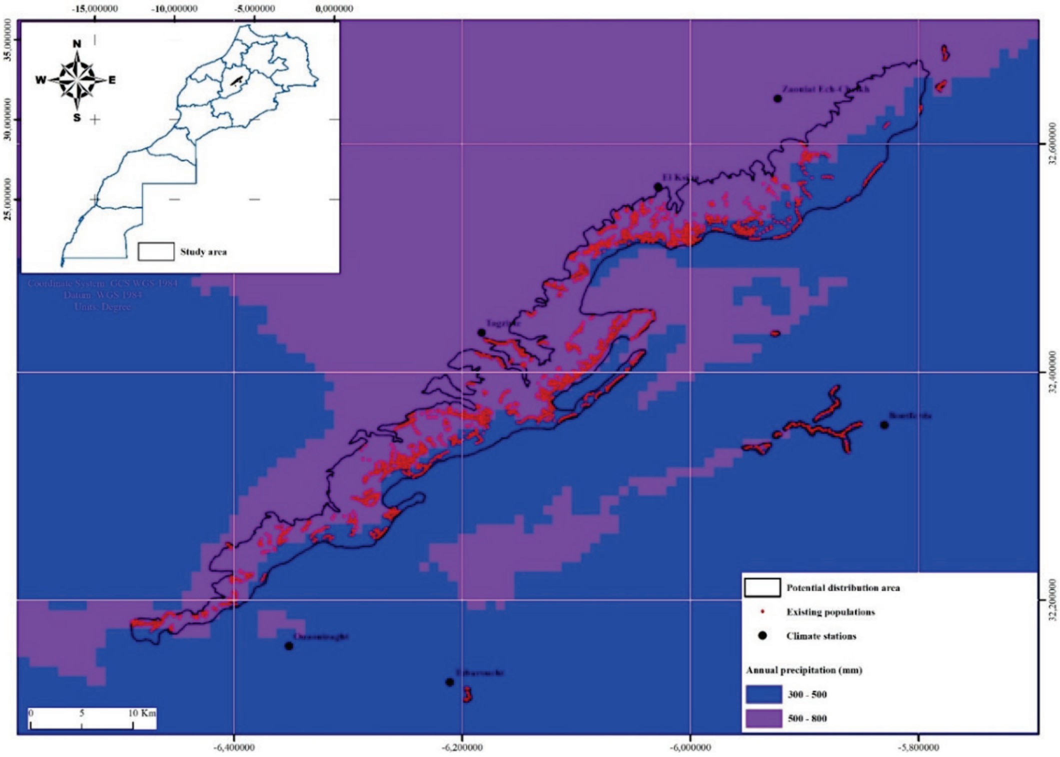

Fig. 8. Annual precipitations map

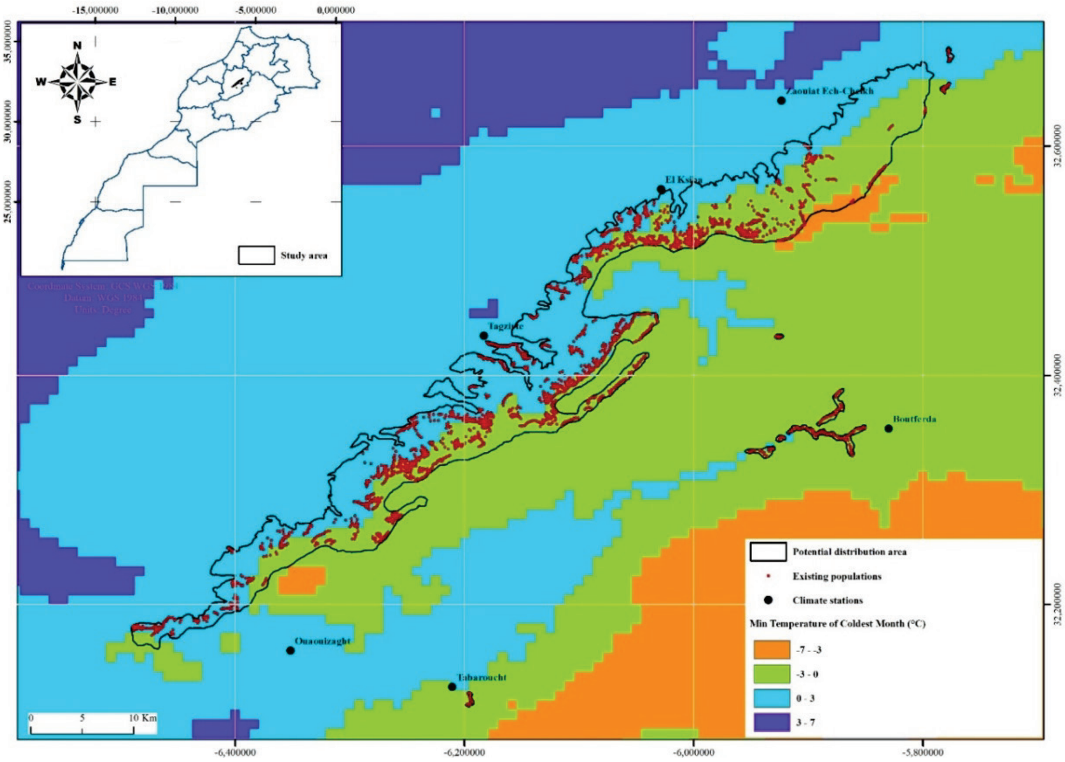

Fig. 9. Minimum temperature of coldest month map

Fig. 10. Annual change in unit price (MAD/kg) and quantities exported (Kg) of laurel leaves

Discussion

This study focuses on deepening our understanding of the ecological and biogeographic significance of *L. azorica* in Morocco, an aromatic and medicinal plant facing intense human pressure. While native to the Canary Islands, Madeira, and the Azores (Bramwell & Bramwell, 1983; Jalas & Suominen, 1991), *L. azorica* has been identified in the Atlas Mountains of North Africa (Barbero et al., 1981; Benabid & Cuzin, 1997).

Indeed, it is developing within the forestry and pre-forestry plant communities, or even locally in those of the matorrals, but often within those of the cliffs of the entire oceanic exposure of the Beni Mellal Atlas between Tazerkounte mountain and the borders of the Khenifra province, which mark the limit of the oceanic exposure favourable to the development of the species. It is also found outside its potential area, in a relatively more continental zone, on the borders of Ifasfas water sources, and on cliffs exposed to the North, North-West and West of the gorges in Laabid River as well as on those of the Chito and Abbadine mountains, Northeast of the Bine El Ouidane Dam (High Central Atlas). In all three cases, the permanent presence of water ensures freshness and a high level of atmospheric humidity in these relatively more continental areas where the ocean influence is well attenuated. This is a real compensation for the atmospheric moisture deficiency of these areas. These *L. azorica* habitats correspond to those previously described by Médail and Quézel in Southwestern Morocco. These authors underlined that *L. azorica*, a species dispersed by ornithochory, occupies mid altitude cliffs (Médail & Quézel, 1999).

The *L. azorica* zone records annual rainfall between 500 to 800 mm. It benefits from high atmospheric humidity which gives rise to a large number of foggy days and mist per year, which considerably attenuate the summer drought. Outside this oceanic zone, the laurel still occupies sheltered places in the cliffs that benefit sufficiently from the oceanic atmospheric humidity coming from the West, due to the absence of significant landforms. This climate has been reported by several authors before (Ceballos & Ortuño, 1951; Bramwell & Bramwell, 1983; Santos, 1983; Rivas-Martínez, 1987), it is similar to that which bathes laurisilva in the archipelagos of Macaronesia. This allowed them to confirm that *L. azorica* populations are found in the Atlantic islands, in humid mountainous areas with abundant fog (Rodríguez-Sánchez, 2011). In general, *L. azorica* exhibits greater similarities to plants native to humid subtropical regions rather than those found in Mediterranean climates characterized by sclerophyllous vegetation (Morales et al., 2001). *Laurus azorica* prefers only rich, humiferous, thick, black, rich, light-textured, lumpy, and well-drained soils. These soils develop on the ledges and in the cracks of the cliff's walls in exposure North, North-West and West; and on the rocks downstream of the cliffs. Everywhere, the soils of all the biotopes of *L. azorica* are always very humiferous. These edaphic conditions are particularly indispensable to the species. This typical behaviour of *L. azorica* is similar to that observed in mesic, humid and hyper-humid laurophilic forests in the Azores islands (Dias et al., 2005), where laurel grows on permeable soils on basaltic substrate or impermeable soils on pumice-stone drop deposits (Elias et al., 2016).

It was stipulated that climate change during the Quaternary Era led to a gradual decline in laurel populations over their entire range (Elias et al., 2016). These laurel forests were exuberant forest communities requiring relative humidity and being very sensitive to low temperatures. Most species were extinct before the Pleistocene, but some have managed to survive and persist today in remnant populations in the Mediterranean basin (Rodríguez-Sánchez, 2011). However, in Morocco the heavy use of the plant as an aromatic and medicinal species and its high level of palatability to goats, have led the species to a critical situation. Inaccessible individuals confined to the cracks and ledges of the cliffs are well preserved, as they are relatively free from human and livestock pressure. In the latter case, these are real self-preservation sites where *L. azorica* manages to remain itself by vegetative reproduction due to its power of asexual regeneration (Elias & Dias, 2009). The bioclimatic and edaphic data thus collected, namely areas exposed to oceanic air masses and well-watered in precipitation (between 500 and 800 mm) and minimum temperatures around 0 °C and deep soils indicate the optimal conditions for any rehabilitation of this species in its environment.

It is important to note that this dramatic state of *L. azorica* is getting worse, despite the absence of any regular selling for several years. This makes it possible to argue that informal cutting by a large number of unauthorized harvesters, which led to this serious deterioration, must have become very frequent, and extended to all accessible laurel populations, and therefore proved devastating due to the large quantities of biomass collected to satisfy the high demand for leaves. Consequently, most *L. azorica* trees fail to attain the necessary biomass for optimal photosynthesis and flowering. This hinders the natural regeneration process, considering that the spatial arrangement of trees, seedlings, and saplings of *L. azorica* relies heavily on asexual regeneration through basal sprouts and environmental conditions (Arévalo & Fernández-Palacios, 2003). It should be noted that the species is not subject to any protection legislation, nor to any regulatory provisions governing how it is exploited and used.

Through a meticulous analysis of *L. azorica*'s response to various pressures, it becomes evident that the species employs multiple strategies in its attempt to restore biomass and achieve normal growth. Firstly, it establishes a robust root system that enables it to withstand cutting. Secondly, it produces vigorous root offshoots, although their progress is swiftly hindered by excessive removal. Additionally, the species exhibits a vigorous reaction to cutting by generating numerous sprouts, which are promptly trimmed or grazed, resulting in a notable increase in branching.

The current value chain of *L. azorica* is very limited and does not allow for sustainable value creation, considering the availability of the raw material. Indeed, the significant degradation of the resource and the low level of valorization (lack of drying, packaging, and distillation units) have not led to a true valorization of the resource.

In order to secure the long-term survival of *L. azorica*, a set of recommendations is proposed. Firstly, it is crucial to establish a comprehensive legal framework that addresses the conservation and sustainable management of this species. This framework should encompass regulations for evaluating resources, promoting responsible harvesting practices, and ensuring habitat protection. The effective implementation and enforcement of these laws necessitate collaboration among government authorities, local communities, and conservation organizations. Furthermore, efforts should be concentrated on habitat restoration and safeguarding measures, including the identification and designation of protected areas, the implementation of habitat restoration programs, and the management of human activities to minimize disturbances.

Community engagement and raising awareness play a pivotal role in the conservation of *L. azorica*. Engaging local communities and stakeholders through awareness campaigns, training programs, and the provision of alternative livelihood opportunities is of utmost importance. By emphasizing the ecological significance of *L. azorica* and the benefits of its sustainable management, a sense of ownership and responsibility can be fostered among local communities. Additionally, it is recommended to continue research and monitoring programs to gather additional data on the species' ecology, population dynamics, and response to environmental and changes. This information will contribute to the development of evidence-based conservation strategies and adaptive management approaches. Overall, implementing these recommendations will contribute to the preservation and sustainable management of *Laurus azorica,* ensuring its ongoing existence and the conservation of its unique habitats in Morocco.

Conclusion

This study underscores the critical state of *L. azorica* in Morocco, as a result of indiscriminate and unregulated harvesting practices leading to the depletion of its biomass and inadequate natural regeneration. The ecological habitats of this species are inherently fragile and have been further compromised by human activities. Urgent measures are required to prioritize the conservation and ecological restoration of *L. azorica* habitats, with the aim of safeguarding Morocco's unique floristic biodiversity. Effective action should be taken promptly to ensure the long-term survival of this significant aromatic and medicinal plant. Furthermore, it is imperative to establish appropriate regulations governing the sustainable harvest and utilization of this resource, fostering the development of a responsible and environmentally conscious value chain. Active engagement and collaboration among various stakeholders, including governmental bodies, local communities, and consumers, are vital in preserving *L. azorica* and its associated ecosystem for future generations.

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References

Arévalo, J. R., & Fernández-Palacios, J. M. (2003). Spatial patterns of trees and juveniles in a laurel forest of Tenerife, Canary Islands. Plant Ecology, 165, 1–10.

Arroyo-García, R., Martínez-Zapater, J. M., Fernández Prieto, J. A., & Álvarez-Arbesú, R. (2001). AFLP evaluation of genetic similarity among laurel populations (*Laurus* L.). Euphytica, 122(1), 155–164.

Barbero, M., Benabid, A., Peyre, C., & Quézel, P. (1981). Sur la présence au Maroc de "*Laurus azorica*" (Seub.) Franco [On the presence of "*Laurus azorica*" (Seub.) Franco in Morocco]. Anales Del Jardín Botánico de Madrid, 37(2), 467–472 (in French).

Barbero, M., Quezel, P., & Rivas-Martinez, S. (1981). Contribution à l'étude des groupements forestiers et préforestiers du Maroc [Contribution to the study of forest and pre-forest groups in Morocco]. Phytocoenologia, 9(13), 311–412 (in French).

Benabid, A. (1988). Contribution à l'étude des groupements forestiers du Moyen Atlas Central (Maroc) [Contribution to the study of forest groups in the Central Middle Atlas (Morocco)]. Bulletin de l'Institut Scientifique, Rabat, 12(12), 79–98 (in French).

Benabid, A. (2000). Flore et écosystèmes du Maroc: Évaluation et préservation de la biodiversité [Flora and ecosystems of Morocco: Evaluation and preservation of biodiversity]. Ibis Press, Paris (in French).

Benabid, A., & Cuzin, F. (1997). Populations de dragonnier (*Dracaena draco* L. subsp. *ajgal* Benabid et Cuzin) au Maroc: Valeurs taxinomique, biogéographique et phytosociologique [Dragon tree (*Dracaena draco* L. subsp. *ajgal* Benabid and Cuzin) populations in Morocco: Taxonomical, biogeographical and phytosociological values]. Comptes Rendus de l'Académie des Sciences – Series III, 320(3), 267–277 (in French).

Bramwell, D., & Bramwell, Z. (1983). Flores silvestres de las Islas Canarias [Wildflowers of the Canary Islands]. Editorial Rueda, Madrid (in Spanish).

Ceballos Fernández de Córdoba, L., & Ortuño Medina, F. (1951). Estudio sobre la vegetación y la flora forestal de las Canarias occidentales [Study on the vegetation and forest flora of the western Canary Islands]. Instituto Forestal de Investigaciones y Experiencias, Madrid (in Spanish).

Dengler, J., Chytrý, M., & Ewald, J. (2008). Phytosociology. In: Encyclopedia of ecology. Five-Volume Set. Academic Press. Pp. 2767–2779.

Dias, E., Mendes, C., Melo, C., Pereira, D., & Elias, R. (2005). Azores Central Islands vegetation and flora field guide. Quercetea Portugal, 7, 123–173.

Elias, R. B., & Dias, E. (2009). Gap dynamics and regeneration strategies in *Juniperus*-*Laurus* forests of the Azores Islands. Plant Ecology, 200(2), 179–189.

Elias, R. B., Gil, A., Silva, L., Fernández-Palacios, J. M., Azevedo, E. B., & Reis, F. (2016). Natural zonal vegetation of the Azores Islands: Characterization and potential distribution. Phytocoenologia, 46(2), 107–123.

Emberger, L. (1955). Une classification biogéographique des climats [A biogeographical classification of climates]. Recueil des travaux des laboratoires de Botanique, Géologie et Zoologie de la Faculté des Sciences de Montpellier (Série Botanique), Fascicule 7, 3–43 (in French).

Fennane, M. (1988). Phytosociologie des tétraclinaies marocaines [Phytosociology of Moroccan tetraclinis communities]. Bulletin de l'Institut Scientifique, Rabat, 12, 99–148.

Fennane, M., & Ibn Tattou, M. (1998). Catalogue des plantes vasculaires rares, menacées ou endémiques du Maroc [Catalogue of rare, threatened, or endemic vascular plants of Morocco]. Bocconea, 8, 5–243 (in French).

Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology, 37(12), 4302–4315.

Jahandiez, É., & Maire, R. (1932). Catalogue des plantes du Maroc (spermatophytes et ptéridophytes) [Catalogue of the plants of Morocco (spermatophytes and pteridophytes)]. Tome 2e: Dicotylèdones, Archichlamydées [Volume 2: Dicotyledons, Archichlamydeae]. Imprimerie Minerva, Alger (in French).

Jalas, J., & Suominen, J. (Eds.). (1991). Atlas Florae Europaeae. Distribution of Vascular Plants in Europe. Vol. 9. The Committee for Mapping the Flora of Europe & Societas Biologica Fennica Vanamo, Helsinki.

Jiménez, M. S., Cermák, J., Kucera, J., & Morales, D. (1996). Laurel forests in Tenerife, Canary Islands: The annual course of sap flow in *Laurus* trees and stand. Journal of Hydrology, 183(3–4), 307–321.

Médail, F., & Quézel, P. (1999). The phytogeographical significance of S.W. Morocco compared to the Canary Islands. Plant Ecology, 140, 221–244.

Morales, D., Flexas, J., Medrano, H., & Pou, A. (2001). Diurnal courses of gas exchange in *Laurus azorica*: Ecological implications for the regeneration of laurel forest. Tree Physiology, 21(14), 1039–1046.

Morales, D., Jiménez, M. S., González-Rodríguez, A. M., & Cermák, J. (1996). Laurel forests in Tenerife, Canary Islands. Trees, 11(1), 34–40.

Ouchbani, S., & Romane, F. (1995). Gradients climatiques et répartition de la végétation dans la région de l'Atlas de Beni Mellal (Maroc) [Climatic gradients and vegetation distribution in the Beni Mellal Atlas (Morocco)]. Bulletin de l'Institut Scientifique, Rabat, 19, 53–64 (in French).

Rivas-Martinez, S. (1987). Memoria del Mapa de Series de Vegetación – de España 1:400.000 [Memoir of the Map of Vegetation Series – of Spain 1:400.000]. Ministerio de Agricultura, Pesca y Alimentación, Madrid.

Rodríguez-Sánchez, F. (2011). Un análisis integrado de la respuesta de las especies al cambio climático: Biogeografía y ecología de árboles relictos en el Mediterráneo [An integrated analysis of species response to climate change: Biogeography and ecology of relict trees in the Mediterranean]. Ecosistemas, 20(1), 177–184 (in Spanish).

Rodríguez-Sánchez, F., & Arroyo, J. (2008). Reconstructing the demise of Tethyan plants: Climate-driven range dynamics of *Laurus* since the Pliocene. Global Ecology and Biogeography, 17(6), 685–695.
Rodríguez-Sánchez, F., Guzmán, B., Valido, A., Vargas, P., & Arroyo, J. (2009). Late Neogene history of the laurel tree (*Laurus* L., Lauraceae) based on phylogeographical analyses of Mediterranean and Macaronesian populations. Journal of Biogeography, 36(7), 1270–1281.
Roiron, P. (1983). Nouvelle étude de la macroflore plio-pleistocene de Crespia [A new study of the Plio-Pleistocene macroflora of Crespia]. Geobios, 6(16), 687–715 (in French).
Santos Guerra, A. (1983). Vegetacion y flora de La Palma [Vegetation and flora of La Palma]. Editorial Interinsular Canaria, Santa Cruz de Tenerife (in Spanish).
Silva, L., & Beech, E. (2017). *Laurus azorica*. The IUCN Red List of Threatened Species 2017: e. T38397A81868030. IUCN Global Species Programme Red List Unit, Cambridge.
Taleb, M. S., & Fennane, M. (2018). Vascular plant communities of Morocco: Phytosociology, ecology and geography. Springer.
Viveiros, M. M., Barreto, M. C., & Seca, A. M. L. (2022). *Laurus azorica*: Valorization through its phytochemical study and biological activities. Separations, 9(8), 211.
Zrira, S., (2017). Some important aromatic and medicinal plants of Morocco. In: Neffati, M., Najjaa, H., & Máthé, A. (Eds.). Medicinal and aromatic plants of the world – Africa. Volume 3. Springer. Pp. 91–125.