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# Farm Trees as Cultural Keystone Species: Bridging Biocultural Conservation and Sustainable Development in the Morocco High Atlas Mountains

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*In many southern Mediterranean mountain areas, the livelihoods of subsistence farmers are threatened by increasing drought periods that affect agroecosystems and cause rapid socioeconomic deterioration. Current initiatives to address this through ecosystem restoration often overlook the cultural significance of different tree species that play an important role in farmers' livelihoods. This may result in the erosion of biocultural diversity and loss of local and Indigenous knowledge. We used the cultural keystone species (CKS) framework to appraise the cultural and livelihood importance of 5 farm tree species—almond, ash, holm oak, olive, and walnut—in Morocco's central High Atlas mountains. Twenty-five structured interviews with knowledgeable farmers revealed that olive trees remain central to local residents' culture. This species met all CKS criteria, whereas walnut and almond trees met many criteria, but they have increasingly lost their cultural importance. Ash and holm oak are prevalent fodder species but do not directly bolster household cash incomes, and they are absent from cultural narratives, ceremonies, and symbolism. Our findings emphasize the importance of considering farm trees' cultural status in developing a culturally sensitive approach to conservation, stewardship of existing trees, and sustainable development in the Mediterranean mountains.*

***Keywords:*** *cultural keystone species; Indigenous and local knowledge; Mediterranean ecosystems; mountain development and conservation; Amazigh communities; Morocco.*

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## Introduction

Tree-based agricultural systems have a long tradition in Mediterranean mountain agroecosystems (Wolpert et al 2020). The integration of diverse tree species into croplands and grazing lands provides multiple ecosystem services and enhances the overall resilience of agroecosystems, particularly in the face of ongoing climate and other environmental changes (Pantera et al 2021; Santos et al 2023). The active management of farm tree systems over time has played a pivotal role in shaping Mediterranean cultural landscapes. Typical tree species integrated into farmlands include olive, cork oak, holm oak, chestnut, carob, almond, cherry, and other fruit trees (García-Martín et al 2021). The multifunctional and pivotal role of farm trees in their natural environments has led to the recognition of certain tree species as ecological keystone species (Manning et al 2006). In addition to their ecological roles, these trees can also have a substantial impact on their sociocultural environments. Yet, the cultural values associated with farm trees have rarely been fully acknowledged.

In recent decades, a decline of farm trees has been observed worldwide as a consequence of changes in land management and increased physiological stress, most notably through drought and soil compaction (Gibbons et al 2008). In the Mediterranean region, farm trees have often lost their social and economic importance in the course of urbanization and agricultural intensification processes, and they have therefore been neglected (Quintas-Soriano et al 2023). These factors collectively contribute to the progressive degradation of Mediterranean agroecosystems, posing a threat to their ecological integrity and multifunctional nature (Pantera et al 2021). The lack of recognition of the ecological and cultural values of trees in farming landscapes has far-reaching consequences for the preservation of traditional practices and knowledge, and for the resilience of local communities to social–ecological crises (cf Tidball 2014).

Many mountain landscapes have been targeted for restoration through tree planting, particularly in response to ongoing socioeconomic transformations and the need for



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sustainable rural development. In the past 2 decades, Morocco has implemented tree planting campaigns aimed at combating climate change and restoring native ecosystems. However, these efforts have often overlooked the conservation or revalorization of existing trees. Instead, the focus has been on large-scale plantations and providing subsidies and tree seedlings to farmers (Faysse 2015; ANEF 2020), leading to the establishment of monocultures and unproductive plantations in mountain and marginal regions. Local mountain communities have criticized the unsuitability of the species selected and the lack of compatibility of these programs with their livelihoods (Kmoch et al 2024).

The cultural keystone species (CKS) framework aims to identify species of plants and animals crucial to the long-term identity of a cultural group. This includes tree species of exceptional importance in a community's language, cultural practices, traditions, diet, medicinal practices, and history that influence the social values and identity of a community (Garibaldi and Turner 2004). The CKS framework is useful for sustainable development as it incorporates Indigenous and local knowledge into conservation and management practices (Uprety et al 2017). At the same time, it aims to support social justice, the continuation of Indigenous practices, and inclusive social–ecological management (Platten and Henfrey 2009; Lukawiecki et al 2024). It resonates well with the discussion of multifunctionality and biocultural importance that is prevalent in Mediterranean landscape literature (eg Nieto-Romero et al 2014; Plieninger et al 2023). However, a CKS perspective on trees in Mediterranean mountain agroecosystems has not been applied so far. While, for example, holm oak has been characterized as a "keystone" and "engineer" species from an ecological standpoint, fulfilling functions crucial for various species and entire ecosystems (Hernández-Agüero et al 2022), its equivalent importance across various cultural dimensions is notably underexplored.

The objective of this study was to assess and compare multiple cultural dimensions of 5 species of farm trees in a Mediterranean mountain agroecosystem. Centered on a rural community in the High Atlas of Morocco, we explored how the cultural values of native trees might inform restoration and sustainable development in mountainous regions and particularly the conservation of existing trees. We addressed 3 research questions:

1. What are the different cultural values of farm trees in the High Atlas?
2. How do CKS characteristics differ between 5 common farm tree species?
3. What are the implications of the loss of these tree species for sustainable mountain development?

## Material and methods

### Conceptual framework

The biocultural dimension of nature conservation and landscape development has gained importance (Hanspach et al 2020). Today, as understanding of the multiple human–nature connections is growing (Ives et al 2017), application of concepts such as CKS is increasingly vital to socially inclusive restoration schemes (Cocks 2010; Goolmeer et al 2022; Lukawiecki et al 2024). The CKS framework, as defined by Garibaldi and Turner (2004), defines culturally salient species that shape in a major way the cultural identity of a people and can play roles ranging from utilitarian to symbolic; whether for food, construction, traditional clothing, or medicine, societies may rely heavily on these species and identify themselves closely with them. Relationships to CKS can manifest in the development of ceremonies, stories, traditions, rich vocabularies, or performative arts associated with the species.

Previous research adopting the CKS framework has been criticized for failing to test its predictive capacity and for omitting to report standardized measures of a species' keystone status (Coe and Gaoue 2020). Though we agree that CKS studies should be valid and rigorous, we do not subscribe to the view that index-based approaches should take precedence over qualitative CKS research. The latter can indeed engage with CKS theory in a "serious systematic way" (Coe and Gaoue 2020: 9), when judged for its analytical transparency and trustworthiness as key evaluation criteria for this type of research (Bryman 2016). Further, while the CKS framework has frequently been used for understanding human–nature relationships, we acknowledge that various alternative frameworks exist. These frameworks, such as biocultural diversity (Elands et al 2019), landscape values (Stephenson 2008), or connectedness to nature (Ives et al 2018), typically refer to ecosystems, landscapes, or nature as a whole, however. In contrast, the CKS framework is uniquely centered on the multiple interactions between animal and plant species and the social–ecological systems in which they are embedded (Mattalia et al 2024).

In this study, we used the CKS framework of Garibaldi and Turner (2004: 4) as a heuristic for identifying trees as cultural keystone species, based on 6 criteria: "(1) intensity, type, and multiplicity of use; (2) naming and terminology in a language, including the use as seasonal or phenological indicators; (3) role in narratives, ceremonies, or symbolism; (4) persistence and memory of use in relationship to cultural change; (5) level of unique position in culture, eg it is difficult to replace with other available native species; and (6) extent to which it provides opportunities for resource acquisition from beyond the territory."

### Study area

The study area (Figure 1A), Ait Blal commune, is located in Morocco's High Atlas mountains (31°41′20″N; 6°42′29″W). This mountain range constitutes a barrier between the southern Saharan conditions and the northern Mediterranean climate. It comprises up to 800,000 ha of irrigated farmland and plays an essential role in the livelihoods of a third of the country's population. It is cherished as the "backbone" of Morocco (Montanari 2013). The High Atlas mountains have particularly high biological diversity, which is accompanied by historical, cultural, and linguistic heterogeneity (Medail and Quezel 1997; HCP 2014).

Indigenous Amazigh communities have inhabited these mountains for centuries, modifying the landscape through traditional land management practices. Past challenges, including political marginalization, limited access to external resources, and infrastructural and geographical



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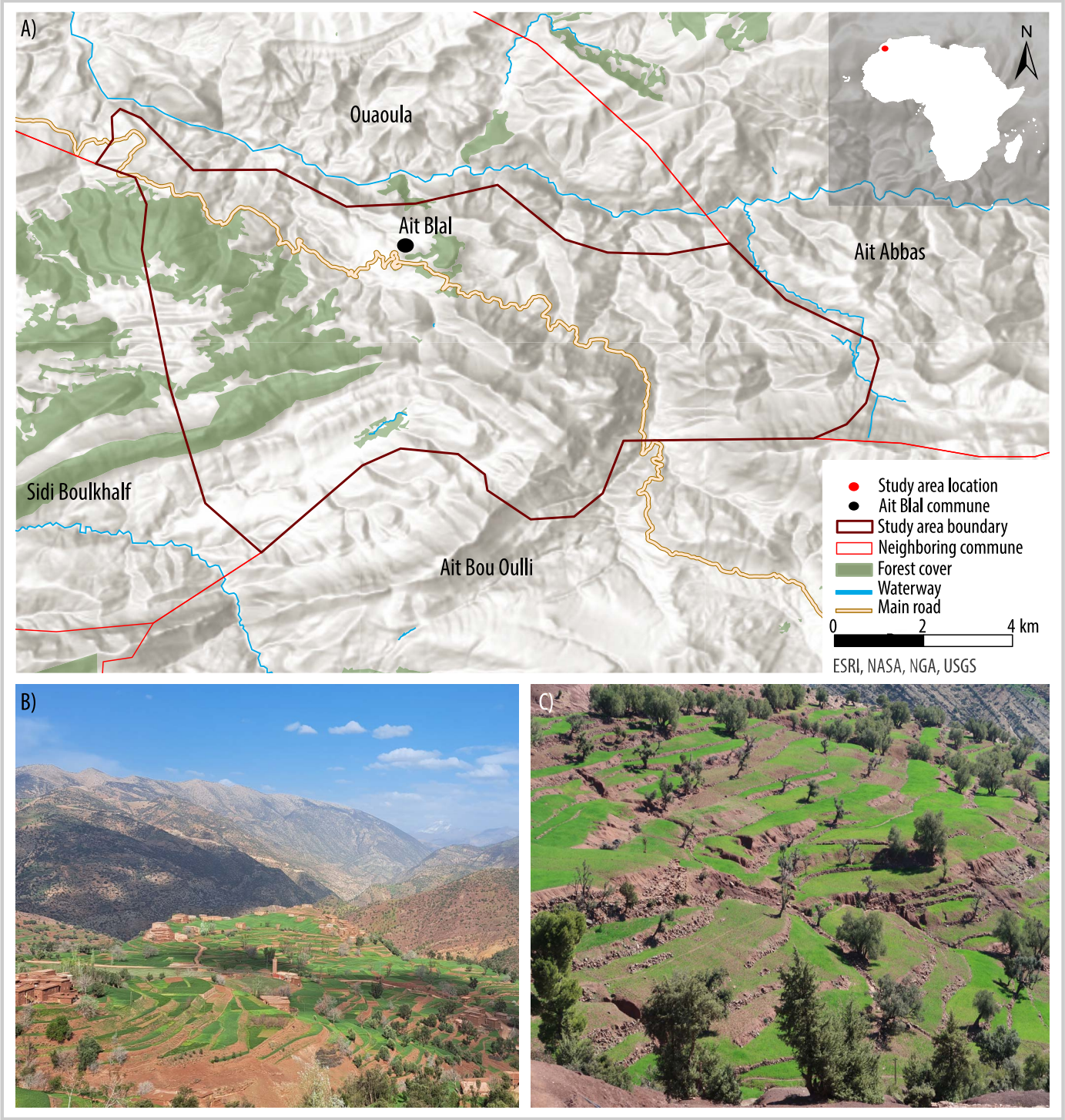
**FIGURE 1** Overview of study area: (A) Map of Ait Blal and neighboring communes; (B) small village in Ait Blal surrounded by farmland; (C) terraced tree-crop landscape in Ait Blal. (Map by Chaima Mobarak; data sources: Environmental Systems Research Institute [ESRI], National Aeronautics and Space Administration [NASA], National Geospatial-Intelligence Agency [NGA], U.S. Geological Survey [USGS]; photos by Chaima Mobarak [B] and Tobias Plieninger [C])




barriers (Auclair et al 2011; Montanari 2013), have been compounded by more recent ones, such as climate change, urbanization, and the increasing integration of communities into global markets. These processes have intensified vulnerabilities associated with the traditional mountain livelihoods (Montanari and Teixidor-Toneu 2022).

Ait Blal is a commune-level administrative center for 23 surrounding villages. It spans an area of 12,000 ha and is home to 1334 households (HCP 2024). The climate is semiarid, marked by extreme temperature changes and snowfall at higher elevations, but only in a few months during winter. Families or individuals own small plots of farmland, typically with several different tree species



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**FIGURE 2** Common farm tree species in Ait Blal: (A) almond, (B) ash, (C) holm oak, (D) olive, (E) walnut. (Photos by Chaima Mobarak [A, D], Tobias Plieninger [B, C], and Liliana Hatoum [E])

(Figure 1B). Donkeys, sheep, chickens, goats, and a few cattle can be found on private plots or grazing the local hillsides. Alfalfa, onion, and wheat are commonly grown crops, amid almond, apple, apricot, ash, fig, oak, and walnut trees on terraces (Figure 1C). Ait Blal is considered lush and more agrobiodiverse than neighboring communes due to a surface irrigation system (Kmoch et al 2022). Yet, water availability has declined considerably in recent drought years, leading to productivity losses and tree die-offs. Increasing youth outmigration is another dynamic that reshapes the management of family lands (Kmoch et al 2024).

## Data collection

The study focused on 5 tree species (Figure 2): almond (*Prunus dulcis*), ash (*Fraxinus dimorpha*), holm oak (*Quercus ilex*), olive (*Olea europaea*), and walnut (*Juglans regia*). These species were chosen for their frequent presence on farmlands and signs of human intervention, such as pruning, grafting, and bark harvesting.

In March 2023, in a first research stage (Table 1), series of exploratory interviews (Appendix S1, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00024.S1) were conducted with residents of Ait Blal, focusing on the management, ownership, production, threats, and seasonality of the 5 tree species. Respondents were selected based on their knowledge of each species. For example, a shepherd who was feeding oak branches to his sheep was asked questions about oak trees. The derived data provided contextual understanding and informed the seasonal calendar creation (Figure 3).

In a second stage, we selected 25 participants (15 men, 10 women) aged 26 to 80 years, with 12 participants under 50 years and 13 participants aged 50 years or older (Appendix S2, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00024.S1). Five interviews were conducted with different respondents for each of the 5 tree species, totaling 25 interviews. The interviews were carried out with the support of a translator and were recorded using a smartphone. In both stages, respondents provided free, informed consent before participating and were briefed on the study's objectives and data usage, including being assured of anonymity and the specific purpose of the recordings. Translation was provided either from Tamazight (residents' first language) or from Darija (Moroccan Arabic, residents' second language) to French and English. Garibaldi and Turner's (2004) 6 CKS criteria informed the development of the structured interview guide, including sociodemographic and open-ended questions, to appraise respondents' values and knowledge about the studied tree species. Follow-up questions were used to clarify or deepen



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**TABLE 1** Methodological steps performed for determining CKS status.

| Methodological step | Purpose |
|---|---|
| **Data collection** | |
| First stage: Exploratory interviews | Provide foundational context and key themes for further inquiry and inform seasonal calendar creation |
| Second stage: Structured interviews with follow-up questions | Gather detailed information related to the CKC, supplemented by follow-up questions for clarification |
| **Data analysis** | |
| Transcription and coding | Convert recorded interviews into written text; apply thematic coding based on CKC |
| Data organization | Arrange data in categories by tree species, gender, and age |
| Comparative analysis | Identify recurring patterns and relationships across groups and species |
| Thematic analysis | Synthesize overarching themes, trends, and challenges related to tree species |
| Interpretation | Draw connections between codes and contextualize findings in relation to CKC |
| Response classification | Classify responses according to relevance in terms of CKC |

respondents' reflections during the interviews (Appendix S1, *Supplemental material*, https://doi.org/10.1659/mrd.2024.00024.S1).

### Data analysis

Data were qualitatively analyzed using MAXQDA software (MAXQDA software, Berlin, Germany). Codes were created according to the 6 cultural keystone criteria (CKC). These dimensions served as the main categories, with corresponding subcodes created to delve into more specific aspects within each CKC. The transcripts were organized into sets based on tree species (almond, ash, oak, olive, walnut), gender of respondent (male, female), and age of respondent (<50 years, ≥50 years) to facilitate comparisons between sets and codes.

## Results

Almond trees, which are less common than olive and walnut trees, require occasional manure application and irrigation for optimal fruit production (Figure 3). Ash and oak trees thrive independently in forests, providing essential wildlife habitats and contributing to soil stability. Both olive and walnut trees are abundant on terraces and farmlands and need minimal management, with walnuts requiring extra care during warm months to prevent fruit damage. Almond,

**FIGURE 3** Seasonal calendar of tree management.

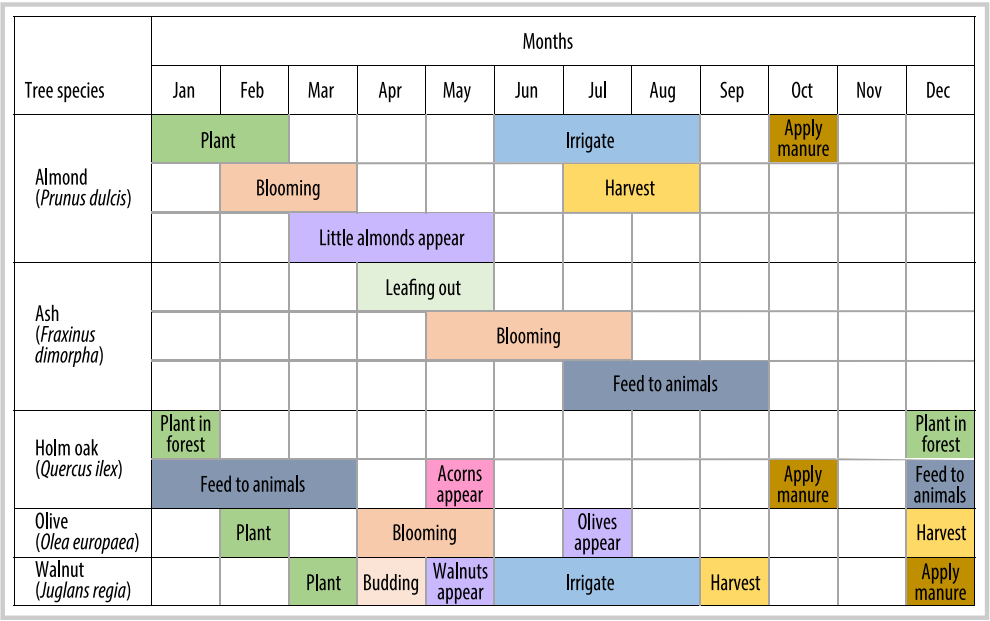




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**FIGURE 4** Tree species and the extent to which they meet each CKC.

| CKC | Tree species | | | | |
|---|---|---|---|---|---|
| | Almond (*Prunus dulcis*) | Ash (*Fraxinus dimorpha*) | Holm oak (*Quercus ilex*) | Olive (*Olea europaea*) | Walnut (*Juglans regia*) |
| 1a. Is the species used intensively (routinely, and/or in large quantities)? | Nuts consumed only at special events | Used regularly for forage in summer and firewood in winter | Used regularly for forage and firewood in winter | Oil and cured olives consumed daily | Nuts consumed only at special events; wood used somewhat regularly for *siwak* and artisanal products; leaves used for forage in autumn |
| 1b. Does the species have multiple uses? | Food, firewood, forage, medicine | Forage, firewood, construction, textile dye, grapevine support | Forage, firewood, construction, leather tint, medicine | Food, firewood, forage | Food, *siwak* artisanship, firewood, construction, forage |
| 2. Does the language incorporate names and specialized vocabulary? | Expressions; use as a seasonal indicator | Use as a seasonal indicator | Multiple names; use as a seasonal indicator | Multiple names; specialized vocabulary | Multiple names; specialized vocabulary |
| 3. Is it featured in narratives, ceremonies, dances, songs, or as a symbol? | Nuts served as a symbol of appreciation | No role and no significance | No role and no significance | Festive harvest; products served at special events; use as decorative motifs; religious significance | Collective harvest; nuts served as a regional symbol of welcome; religious significance of *siwak* |
| 4. Is the species ubiquitous in the collective cultural consciousness and frequently discussed? | Ubiquitous awareness but perceived diminishing importance | Still in use but not widely discussed | Still in use but not widely discussed | Ubiquitous awareness and appreciation of the tree and its products | Ubiquitous awareness of the tree's symbolism but perceived diminishing importance |
| 5. Would it be hard to replace with another available native species? | Cannot be exactly replaced but alternatives exist for nuts | Could be replaced by *aslen* for forage; oak for firewood | Ash, *aslen*, or *tiqqi* could replace firewood and forage, but only in summer | Tree and products could not be replaced | Wood and *siwak* cannot be replaced; nuts might be replaced by almonds |
| 6. Is this species used as a trade item for other groups? | Almonds sold at markets | Tree products are generally not sold; artisanal ashwood goods rarely sold at markets | Tree products are generally not sold; surplus wood may be sold | Products are kept for personal use or sold when in surplus; wood may be sold | Nuts and artisanal products sold at markets to provide for basic needs; wood may be sold |

Color codes: CKC fulfilled; CKC partly fulfilled; CKC not fulfilled

walnut, and olive trees are often surrounded by wildflowers, grasses, or crops like alfalfa, onion, and wheat. Livestock are often grazed on hillsides or on private plots, strengthening the link between the agricultural and natural ecosystems.

## Almond

Almonds are eaten whole, used in pastries like *amlou* (a national dish made typically from almond paste and argan oil), or presented as gifts (Figure 4). They are mainly consumed during the harvest season or sold and are not commonly bought otherwise due to their high price. The tree is also used for firewood but only when it stops producing fruit. The region has 2 types of almonds: sweet and bitter. The latter are known for their medicinal properties that help in the treatment of diabetes. Another common practice is to infuse almond leaves in oil to treat ear infections in infants (CKC 1).

The tree is referred to solely by the Arabic word *loz*. Tamazight speakers use it as a metaphor for kindness or affection, such as "sweet like an almond" or "beautiful like an almond." A similar proverb is used to indicate dislike of a person, comparing one's relationship to them to "the stone with the almond," derived from the act of breaking the hard shell of the nut (CKC 2).

The almond blossom signals the end of the cold season, while the harvest indicates the hottest period. Almond nuts symbolize hospitality and warmth and are often served



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**FIGURE 5** Tree species and examples of how they meet each CKC. (A) Almonds and walnuts served among other local foods during an interview. (B) A special tool used to cut ash branches for animal feed. (C) Holm oak branches cut for firewood. (D) A traditional stone press used to extract olive oil. (E) A traditional couscous bowl made from walnut wood by women of Ait Blal. (Photos by Chaima Mobarak [A, C, D] and Liliana Hatoum [B, E])

along walnuts to esteemed guests or at celebrations (Figure 5A). They are valued for their ability to stimulate the appetite. Although widely used in Ramadan for their sweetness or in *zmita* (a national dish eaten during Ramadan), almonds have no religious significance (CKC 3).

Despite divergent opinions about the resilience of almonds against multiple ecological and socioeconomic challenges, residents valued the tree for its fruit, and some mentioned that they would like to have their own tree. While knowledge of the tree is passed down through generations, there was broad concern that it may be disappearing (CKC 4).

Most respondents worried how the loss of the trees' nuts would affect their lives. One lamented that the absence of the species would touch her: "We need this tree, whether for the tree or nature itself." While some feared the environmental consequences, predicting a desert landscape with no trees to support rainfall, others feared losing it as an income source. "People here think of things which could generate money; if the almond tree disappears, they'll grow something else," explained one respondent. As for alternatives, respondents often suggested apples, carob, figs, olives, or walnuts, due to their desirable products and economic benefits (CKC 5).

Most of the fruits (shelled or unshelled; in sweet or bitter varieties) are sold during the harvest season, with intermediaries involved in buying the almonds for resale at larger markets. Income from the sales is often used to cover households' basic needs (CKC 6).

## Ash

When fully developed, ash leaves are harvested with a special tool (Figure 5B) and used to produce a dye for wool. They can be consumed as summer fodder for sheep and goats up to twice a day alongside barley and hay. The defoliated ash twigs and branches are then dried for use as firewood. Ash wood in good condition can also be used in construction and craftwork, or the trunk can be utilized to trellis grapes, although the latter practice is less widespread in the region (CKC 1).

The ash tree is called *imts* in Tamazight. Its flowering signals warm weather, while its fruiting signals the maize harvest or early fall. No specific expressions or places have been named after it (CKC 2).

The species holds no significance in local narratives. Respondents dismissed the idea with laughter, exclaiming, "ash has no role," and "the tree is only useful for animals" (CKC 3).

Some believed that its abundance is declining due to drought, the division of inherited trees between family members, and its removal from farmland to make room for other crops. Others claimed that its importance remains unchanged due to its constant use. They suggested that knowledge about the tree is declining due to the lack of interest among younger generations and changes in pastoral practices (CKC 4).

The tree has no unique position in culture, with oak and a local elm tree, *aslen* in Tamazight, being considered potential replacements. Though oaks can provide forage in



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winter, ash does so only in summer. Both fulfill the functions of feed and firewood. Many residents did not express concern about the potential loss of ash trees. Some suggested buying extra fodder as an alternative and planting apple or olive trees instead. Some, however, recognized the loss of shade, food, wood, and support that the ash tree provides to grapevines (CKC 5).

Ash is not commonly sold due to its scarcity. Trees are inherited from previous generations and only used by those who have them on their land. Handicrafts, such as couscous bowls, can be made from ash wood, but these are rarely sold due to their perceived low quality (CKC 6).

### Holm oak

Oak leaves and small branches serve as supplementary feed during winter. Bitter acorns are also occasionally fed to animals, whereas humans may consume the sweet ones, which are known for their medicinal properties in regulating blood sugar levels. Oak wood is used for heating (Figure 5C), cooking, or construction, including traditional ceilings and roofs. The bark is used to dye leather bags utilized for yogurt making or to dye wool for carpet weaving (CKC 1).

Different names are used for the tree. In Arabic, it is known as *carrouj*, while in Tamazight, it is known as *tassaft*. The acorns are called *bellot* in Arabic and *addern* in Tamazight. No other expressions or places have been named after it (CKC 2).

The tree does not feature in narratives, ceremonies, or symbolism (CKC 3).

Older people remembered the tree being used more widely for building houses and turning acorns into flour in the past. Its persistence is thought to be declining due to factors such as drought and overharvesting for firewood. Knowledge about the tree is passed down through generations, although younger generations do not necessarily show interest unless encouraged to do so by their elders (CKC 4).

Ash, *aslen*, and sharp cedar, called *tiqqi* in Tamazight, were suggested as alternatives to feed if the species were to disappear. Some believed that the loss of the tree would have a minimal impact on them, as they did not use it themselves. One woman said: "I'll still sleep," explaining that her animals could eat other crops and that she would not have to go to collect oak. Yet, others considered the tree irreplaceable. One explained that oak trees naturally grow in forest areas that are unsuitable for other crops (CKC 5).

The sale of oak and its products is uncommon. People collect it from the forest, as many do not have it on their land. Surplus wood in good condition is occasionally sold to hammams or local craftsmen to make traditional couscous bowls (CKC 6).

### Olive

Olive is grown for its fruit, which can be cured and eaten whole or used to produce olive oil, a staple of the local diet served with bread and used in traditional local dishes. Olive oil is produced by the traditional method of using a stone press (Figure 5D) and stored at home for use throughout the year. The leaves and small branches are also appreciated by animals, but only as feed during the harvest period. Cutting down trees is forbidden; only cuttings and fallen branches are stored for heating during the winter, as are dead trees (CKC 1).

The olive tree is called *zaytoon* in Arabic, while olive oil is called *zayt zaytoon*. Uncured olives are called *takheit*, meaning something bad or bitter in Tamazight, while cured olives are called *mashkook* in Arabic. Black olives are referred to as *tamosht*, which means dark or black in Tamazight. The harvest period is uniquely called *n'ayr*. There is no other specific seasonal indicator or place named after the tree (CKC 2).

People sing during the olive harvest, but there are no specific stories or dedicated songs. When asked about the role of olive oil in traditions, some said that "without olive oil, there is no celebration, no marriage." It is served with rice or bread at festivals and celebrations. The tree motifs are sometimes depicted on carpets and in home decorations. Although it is not a religious symbol, the tree is mentioned in the Quran as "a testimony to God's greatness," which one of the interviewees mentioned when reflecting on the tree's importance (CKC 3).

The importance of the olive tree remains unchanged across generations, with olive oil being a fundamental part of the local diet; as one respondent expressed, "If there is no olive oil, there is nothing." It was also described as "fuel for life," and respondents consistently reported its health benefits. Knowledge of the tree and its benefits is passed on through generations, but some linked a decline in oil production to the lack of interest among the younger generation. One person said he insisted that his children grow the tree (CKC 4).

Respondents stressed the irreplaceable role of olive trees and their unique position in the culture, expressing a deep attachment and seeing them as essential to life or as the "source of life" for all the residents. A hypothetical loss of the species would be deeply felt, with substantial impacts on diets and cultural practices. When asked what would happen if olive oil could no longer be produced in the area, many replied that they would not know what to do or that they would need to buy it from outside the region, feeling "ashamed" (CKC 5).

The sale of olive products depends on individual production levels, with surplus products being kept for later use or sold to supplement incomes. In general, more is stored than sold. Due to the small size of the plots and the scarcity of water, people now produce and sell less. Customers come from the region and afar, reflecting olive products' importance in the local economy. Olive wood can also be sold to hammams and bakeries (CKC 6).

### Walnut

Walnut trees are primarily cultivated for their fruits. The nuts are eaten whole after cracking the hard outer shell and used in sweets and traditional dishes. Walnut oil can be produced, but this is not a common practice. Walnut leaves are used as supplemental forage, particularly in fall when they turn yellow and dry. The species' bark and twigs are used to make *siwak*, a traditional Islamic tooth-cleaning tool, which is often given as a gift at special events. Walnut wood is highly valued for its hardness and density. Women use it to craft couscous bowls, cups, spoons, and plates (Figure 5E). Larger wood pieces can be used for construction or making tools, and the waste pieces are burned for heating. Walnuts



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are also known locally for their benefits in treating urinary illness (CKC 1).

The tree is known as *tswee* or *tswight* in Tamazight and *gergaa* in Arabic. The nuts are called *tiboora* in Tamazight. There are no additional expressions or terminologies specific to the walnut tree, nor are there places or things named after it (CKC 2).

Although there are no specific songs or dances linked to the species, it plays an important role in local traditions and celebrations. Walnuts are served to guests alongside almonds at special occasions as a symbol of hospitality. Harvesting the nuts is sometimes seen as a festival, with communities coming together to gather the fruit. One individual noted that one elected person per village, named *aassa* in Arabic (which translates to *the observer),* watches the trees and informs people when the fruits can be harvested, so that the village can prepare. The walnut tree is also associated with Islam, as it is used to make *siwak* (CKC 3).

Walnut has maintained its importance across generations; however, its value is increasingly affected by droughts that diminish the species' productivity. While older generations recall abundant walnut trees and products, young people are less familiar with its significance. One individual expressed that children no longer sought knowledge and did not consult elders. Therefore, they would not know about the importance of the tree (CKC 4).

Respondents believed that no other species could fully replace the walnut tree. Some lamented its hypothetical loss, citing their enjoyment of the fruits and their importance as a revenue source. When asked for alternatives, people named cereals and fruit trees, such as almonds and olives. Respondents also mentioned that nothing could replace its special wood, which gives women a material to work with. One respondent also explained that *siwak* could not be made with any other species (CKC 5).

Sales depend on individual production levels. While some sell their harvest for additional income, others prefer to keep it for personal use or as gifts. Walnut wood is sold to bakeries, hammams, and artisans. Artisanal products from the area, such as couscous bowls and dishes, are sold at the local market or to intermediaries. Decreased production and economic factors have diminished the revenue generated, however. Hence, walnut is no longer a big income source for Ait Blal's residents (CKC 6).

## Discussion

Drawing on rural people's perceptions in Ait Blal, our research aimed to appraise the extent to which native farm trees shape the cultural landscape of Amazigh communities in Morocco's High Atlas. We based our research on the rationale that tree-related interventions play a key role in development-oriented strategies in the Moroccan High Atlas and throughout the Mediterranean region.

While there were no notable age-related differences in respondents' perceptions, men tended to focus on the economic value of tree products, whereas women highlighted seasonal indicators and the symbolic meanings of the trees. This aligns with previous research (eg Pieroni 2003; Montanari 2013; Teixidor-Toneu et al 2020), which suggests that men and women hold complementary knowledge regarding species. These insights underscore the importance of including both genders in development planning to ensure comprehensiveness and inclusiveness.

### CKS patterns and cultural significance

As our findings suggest, olive trees, which emerged as a strong CKS, fully meeting the criteria, are deeply integrated into the local culture and crucial for maintaining landscape resilience and supporting livelihoods through olive and olive oil production. They are endemic to the Mediterranean and define the region (Tissot 1937), representing a biocultural heritage dating back centuries (Kaniewski et al 2012). Olive trees feature in various Mediterranean religions, symbolizing peace, blessings, and resilience (Grego 2022), and are considered the region's most extensive perennial agroecosystem (Mairech et al 2021). Although now found in other parts of the world (Angles 2000; Besnard et al 2007), olive products remain central to Mediterranean diets and culinary heritage, including in Morocco's High Atlas.

The nut trees, almond and walnut, were also identified as CKS, meeting most of the criteria. These species are cherished by the local community for their economic benefits. They feature prominently in traditional dishes and hospitality customs and are celebrated in festivals across the High Atlas (eg the Almond Blossom Festival in Tafraout and Walnut Harvest in Asni). They have been part of the landscape for centuries; Dresch (1941) described almonds as "robust trees" capable of surviving in higher elevations without irrigation and walnuts as "the fruit trees of the high mountains," thriving in valleys and ravines at relatively high elevations. Their biological resilience and the ability to store nuts or sell them have historically provided vital sustenance during severe winters, integrating these species into the local diet and culture. Research underscores their significance not only in the Mediterranean region (Salas-Salvadó et al 2011) but globally, where they are integral to various diets, customs, and traditions (Martinoli and Jacomet 2004; Avanzato and Vassallo 2006).

The fodder trees, ash and holm oak, do not qualify as CKS, as they meet only few criteria. While these trees are essential for forage, firewood, and construction materials, they lack the direct cultural and culinary significance that defines CKS status. Historically found in mixed forests, these species have been used in the High Atlas for centuries (Taïbi et al 2019) and were valued for their many uses; however, they generally do not provide sufficient sustenance for livestock alone (Dresch 1941; Genin and Alifriqui 2016). Their limited cultural role in our study area contrasts with other regions, where ash is recognized as a keystone species and local specialty, linked to traditional practices like pruning and pollarding, with significant material and ecological value (Genin et al 2018; Genin and Alifriqui 2019). Holm oak, meanwhile, has been recognized as a CKS in northern Mediterranean ecosystems, featuring in human and animal diets for centuries (Sirami et al 2008; Pérez-Ramos et al 2013; Hernández-Agüero et al 2022). This indicates that the CKS status of these species depends on the context, varying across regions based on local ecological and cultural conditions.



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### Drivers influencing CKS status

Some of our assessment criteria developed from Garibaldi and Turner (2004), such as criteria 3 and 4, which focus on narratives, symbolism, and species' unique cultural position, emphasize aspects of particular importance to olive and nut trees. In consequence, our respondents perceived fodder trees, which are not directly linked to human consumption, as less important. Moreover, criterion 1 on multiplicity and intensity of use is rather broad, and many trees of the High Atlas and of the Mediterranean region have been recognized for their multifunctionality (Genin and Alifriqui 2016). This criterion furthermore overlaps with criterion 6 relating to resource acquisition, given that multiple uses often result in multiple sources of income. Other studies have shown that similar indices might be intercorrelated and can therefore unduly influence assessments of species' cultural status (eg Coe and Gaoue 2020).

Our findings highlight that CKS status is not static, but rather it is influenced by factors such as drought, increasing physiological stress, changing agricultural and management practices, decreasing interest across generations, and labor outmigration. Criterion 6 on resource acquisition is particularly affected in this regard. Motivated by economic interests, younger people are losing interest in maintaining existing trees and tend to replace them with commercial crops, though this often proves unsustainable. The persistence of tree species is thus dependent on their ability to generate resources, a crucial factor for development efforts.

Our study is a classic example of how these drivers, previously referred to as "erosive phenomena" (Fay 1986) or "destabilization processes" (Bencherifa 1983), continue to impact the equilibrium of the High Atlas ecosystems and societies. Over several decades, they have caused significant changes (eg Parish and Funnell 1999; Taïbi et al 2019; Kmoch et al 2024). These drivers are also disrupting other mountain systems in the Mediterranean region (Levers et al 2015; Kuemmerle et al 2016; Jiménez-Olivencia et al 2021) and around the globe (Lavorel et al 2023). Recognizing these local threats to both biological diversity and cultural heritage is critical in halting the degradation of these biocultural systems (Cuerrier et al 2015).

### Implications for conservation policies and stewardship of existing trees

The loss of native tree species has profound implications not only for ecological systems but also for the cultural fabric of High Atlas communities. As CKS, these trees are deeply embedded in the daily lives, languages, and traditions of local people, shaping cultural identity through their multiple uses, roles in ceremonies, and ties to generational knowledge. Their disappearance threatens to erode traditional ecological knowledge, disrupt cultural practices, and weaken the community's connection to the land. Trees such as olive, almond, and walnut, which meet key CKS criteria, provide resources vital to both livelihoods and cultural continuity.

Furthermore, restoration efforts that prioritize afforestation and the introduction of nonnative species risk transforming unique agroecosystems into monocultures, potentially failing in resource-limited environments by depleting scarce land and water while threatening biodiversity (Messerschmidt 1987; Dhakal et al 2022; Suarez and Gwozdz 2023). These programs also threaten cultural identity by overlooking the significance of native species, risking the loss of biocultural richness in the High Atlas (Teixidor-Toneu et al 2020). Since native trees are deeply tied to traditional ecological knowledge and are crucial for sustaining mountain agroecosystems, preserving them is not only an ecological necessity but also a critical strategy for maintaining cultural resilience and ensuring the long-term stability of these landscapes (Montanari 2024).

Products linked to social–ecological values are often marketed with geographic indication labels, emphasizing local origins and cultural significance (Flinzberger et al 2022). In the northern Mediterranean, products like olive oil, almonds, and walnuts from the Spanish *dehesa* are marketed as local, boosting their appeal. Similarly, Moroccan policies have recognized argan products as national heritage, raising awareness of their cultural and economic value (Aït Errays and Hattabou 2015). While there have been efforts to promote other tree products like olives, almonds, and walnuts as "terroir products," emphasizing their connection to local landscapes (MAPM 2016; CESE 2017), campaigns based on the cultural significance of tree species remain limited in Morocco.

A key challenge in the High Atlas is poor tree management due to economic struggles and declining interest in farming. New development strategies must prioritize social inclusion and offer better incentives for stewardship of native trees. Encouraging younger generations to blend traditional and modern techniques will be crucial for reducing youth outmigration and for sustainable development and social stability (Bossenbroek et al 2015; Srairi 2021). Experts have long emphasized the need to integrate local biocultural practices into mountain restoration. Bencherifa (1983) proposed a "mountain promotion program" focused on sustainable incomes and local tourism. We echo this call for a holistic, inclusive approach to mountain development that integrates both etic and emic perspectives, accounts for gender roles, and engages younger generations. To guide development strategies, we recommend employing culturally sensitive frameworks such as CKS to identify species that support biocultural practices and are significant in local contexts. This approach not only recognizes and helps to preserve biocultural heritage, but it also resolves the disconnect between development programs and local livelihoods and interests (Kmoch et al 2024). Additionally, it fosters community participation, as CKS are often easily recognized and maintained by locals (Min et al 2022).

Due to our targeted sample size and the specific focus on the biocultural dynamics of the High Atlas, our results are not intended to be generalized to broader rural contexts. Although these dynamics resonate with many smallholder mountain communities throughout the Mediterranean in which the cultural ties to trees are similarly strong and may be at risk, the cultural keystone status is dependent on a local community or group perspective, and regional differentiation in applying our findings is thus recommended.

## Conclusion

Our study sheds light on the cultural significance of 5 Mediterranean farm tree species, emphasizing the



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importance of olive, almond, and walnut trees in shaping the biocultural landscape of the Ait Blal Amazigh community in the High Atlas. While these species play a central role in local diets, customs, and traditions, fodder trees such as ash and holm oak do not share the same cultural significance. It is important to note that the role of these species is determined by local context, and value perceptions may differ in other mountainous regions of the country and throughout the Mediterranean.

Moreover, our results highlight the dynamic nature of species' CKS status, influenced by various socioeconomic and environmental factors. Further research is necessary to better understand these evolving dynamics and to raise key questions for the future of native tree species. To address the complex challenges facing mountain ecosystems and communities, development actors should integrate cultural values into conservation and restoration initiatives, ensuring that tree-related biocultural heritage is preserved rather than replaced by nonnative species or monocultures. By promoting products linked to CKS, such as olive and nut trees, both conservation and socioeconomic development can be enhanced.

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## Supplemental material

**APPENDIX S1** Exploratory interview and cultural keystone assessment questionnaires.
**APPENDIX S2** Demographic characteristics of respondents.

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