

Article

Traditional Knowledge, Gendered Practices, and Agro-Biodiversity Conservation: A Case Study of Pomegranate in Moroccan Pre-Saharan Oases

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Abstract

This study assesses and inventories agrodiversity within eleven representative oases of the pre-Saharan regions of Morocco, ecosystems that are particularly vulnerable to climate change and socio-economic pressures. The findings highlight the central role of fruit tree diversity in structuring and sustaining the resilience of oasis agroecosystems, complementing cereal and fodder crops. Special attention was given to the pomegranate (*Punica granatum* L.), a secondary but underutilized fruit species in Moroccan agriculture, which was found to hold a significant position in the surveyed oases. Farmer and community surveys identified five local denominations or varieties, including an original form known as “Guersmoum” or “Hamed,” distinguished by its spontaneous, non-cultivated character. This unique case exemplifies the remarkable coexistence between wild and domesticated forms, reflecting the complex dynamics between cultivated and wild biodiversity. The presence and use of this variety are closely linked to the production of a traditional local agri-food product, pomegranate molasses (“Amaghousse”), an artisanal know-how transmitted across generations and primarily preserved by women. The study documents several aspects of this practice, including processing techniques, yield ratios, and marketing channels, emphasizing both the economic and cultural significance of this local product. The discussion underscores the close interconnections between traditional knowledge, gendered practices, and the conservation of genetic diversity, showing how the promotion of local resources contributes not only to the preservation of agrodiversity but also to the maintenance of oasis cultural identities. Finally, the study highlights the broader implications of these findings for development initiatives, particularly through the recognition and promotion of distinctive local agri-food products, the integration of women in local conservation strategies, and the implementation of sustainable management approaches for fruit genetic resources.

Keywords: oases; pomegranate; agrobiodiversity; traditional knowledge; gender; Morocco



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1. Introduction

Oases constitute centers of agricultural production in arid and hostile environments, such as those found in the pre-Saharan regions of Morocco [1,2]. These agroecosystems provide essential ecosystem services to local populations and play a crucial role in biodiversity conservation. These services encompass provisioning services, such as food, fodder, and raw materials; regulating services, including microclimate regulation, soil fertility maintenance, and water retention; supporting services, such as nutrient cycling and pollination; and cultural services, which cover spiritual values, local identity, and traditional practices that have been maintained for centuries [3]. In recognition of their ecological, cultural, and socio-economic importance, the oases of southern Morocco have been designated as the Southern Moroccan Oasis Biosphere Reserve (RBOSM), recognized by UNESCO in 2000. They represent intensive agroecosystems structured around complex social organizations for water management and spatial planning [4,5]. These social systems, built upon traditional rules of cooperation, are particularly evident in the management of irrigation infrastructures, including khetaras (subterranean channels), seguias (irrigation canals), and collective water-sharing institutions, which ensure the sustainable allocation of scarce water resources in these arid environments. At their core, oasis agroecosystems rely on a keystone species, the date palm (*Phoenix dactylifera* L.), which provides both ecological and socio-economic foundations for the system. The date palm not only produces a staple food and valuable market commodity but also plays a protective role by creating a favorable microclimate that allows other crops to thrive under harsh desert conditions. The system is typically organized in a three-layer vertical structure: the first layer, dominated by date palms, provides windbreaks, shade, and protection for the underlying crops; the second layer consists of fruit trees such as pomegranate, fig, and olive, which contribute to dietary diversity and household income; and the third, herbaceous layer is composed of understory crops such as cereals, alfalfa, and vegetables [6,7]. This multilayered structure reflects a highly adaptive form of traditional agroecological knowledge, where spatial and functional complementarities among species maximize resource use efficiency while buffering against environmental stress.

Moroccan oases harbor immense potential in terms of cultural heritage and agrobiodiversity [8]. In the pre-Saharan oases, it has been shown that the richness and diversity of crops and cultivated varieties contribute to the conservation of genetic resources, notably through the persistence of marginal crops that are increasingly neglected [9,10]. This is particularly evident in fruit trees, with 17 species and 54 varieties recorded in this region [7]. One of the distinctive features of fruit tree diversity in traditional agroecosystems is the coexistence of spontaneous forms with domesticated–cultivated forms. Such dynamics have been observed for fig trees in traditional mountain agroecosystems [11], for apricot trees in oases [12,13], and for date palms, with the local denomination Khelt referring to palms originating from seed propagation [14]. In addition, such dynamics have been recorded for wild and domesticated olive trees in traditional agroecosystems in North Morocco [15], highlighting their importance in maintaining genetic resources of fruit tree species. The distinction between domesticated–cultivated forms and spontaneous ones is primarily determined by the mode of reproduction: vegetative propagation in the former and spontaneous seed germination in the latter. The coexistence of these two forms creates a favorable dynamic for genetic diversity conservation by maintaining both compartments, wild and cultivated, connected through gene flow. However, oasis agroecosystems are highly vulnerable to aridification driven by climate change, which is transforming their steppe environment into desert [9]. Current projections suggest a significant decline in precipitation accompanied by rising temperatures and an increase in extreme climatic events [9,16,17]. Additionally, the rapid rate of changing climate is likely to affect the

long-term persistence and resilience of oasis agroecosystems [3]. At the same time, the modernization of agriculture and the changing lifestyles of farmers are threatening traditional practices and knowledge that safeguard local genetic resources [7]. It is widely acknowledged that there is an intrinsic link between biological and cultural diversity [18]. In this context, the erosion of traditional agricultural knowledge represents a direct threat to the conservation of agrobiodiversity, particularly for neglected and underutilized crops.

In this case study, we focus on traditional practices surrounding the pomegranate, considered a secondary and underutilized fruit crop in Morocco [19] and in oasis agroecosystems [7]. The pomegranate (*Punica granatum* L.), belonging to the monogeneric family Punicaceae, is cultivated across a wide range of climatic zones, including Mediterranean, subtropical, and tropical regions [20]. The species' center of origin and diversification, where cultivated forms coexist with wild relatives, extends across northern Iran, Afghanistan, Central Asia, and northern India [21,22]. It is believed that pomegranate cultivation dates back to prehistoric times, with domestication beginning in the Neolithic era in Transcaucasia and along the Caspian Sea [23–25]. The Mediterranean Basin is considered a secondary center, formed through the westward introduction of the species from its original homeland [24]. The diffusion of pomegranate into the western Mediterranean was likely linked to Phoenician expansion, where it first reached western Sicily and North Africa [26].

Although pomegranate remains a secondary fruit crop, agrobiodiversity inventories in oases show that it is a frequent component of oasis orchards [7]. In certain oases, pomegranate is of particular interest as it is associated with an ancestral traditional practice: the production of a molasses known locally as Amaghousse, recognized by herbalists as a traditional remedy [27].

In this study, we assess the agrobiodiversity of oases in the pre-Saharan zones of the southwestern Anti-Atlas to determine the relative importance of pomegranate and its varietal diversity within oasis agroecosystems. Through surveys and field investigations, we identify and map the production and marketing areas of pomegranate molasses. Finally, we explore the links between traditional knowledge associated with this practice and the conservation of varietal diversity in the species.

2. Materials and Methods

2.1. Study Area

The study area is located in southern Morocco, in the pre-Saharan zones on the southern flank of the Anti-Atlas Mountains (Figure 1), covering the provinces of Tata to the east and Guelmim to the west. The field surveys encompassed 11 oases and four urban centers. The surveyed oases include Tagant, Tighmert, Fask, Ifrane of the Anti-Atlas, and Taghjiit in the province of Guelmim, as well as Fom Lahcen, Ait Ouabelli, Akka, Tagmoute, Tissint, and Fom Zguid in the province of Tata. In general, this area is characterized by a Saharan climate, with annual rainfall rarely exceeding 100 mm. However, the availability of water resources varies among oases depending on specific local conditions. For instance, some oases located at higher altitudes, such as Tagmoute and Ifrane of the Anti-Atlas, benefit from more favorable climatic conditions. Meanwhile, traditional local irrigation systems known as Khettaras (underground galleries designed to convey water by gravity from the foothills of the mountains to the surface) and seguias (irrigation channels) are used in the surveyed oasis primarily for agricultural activities. However, for domestic consumption, locals rely on groundwater extracted from pump wells or on water supplied by governmental agencies [7]. These oases play a major socio-economic role, as they represent an essential source of local agricultural production and serve as a key marketplace

for local farmers and communities. The urban centers of Agadir, Tiznit, Guelmim, Tafraout, and Tata were also included in the survey.

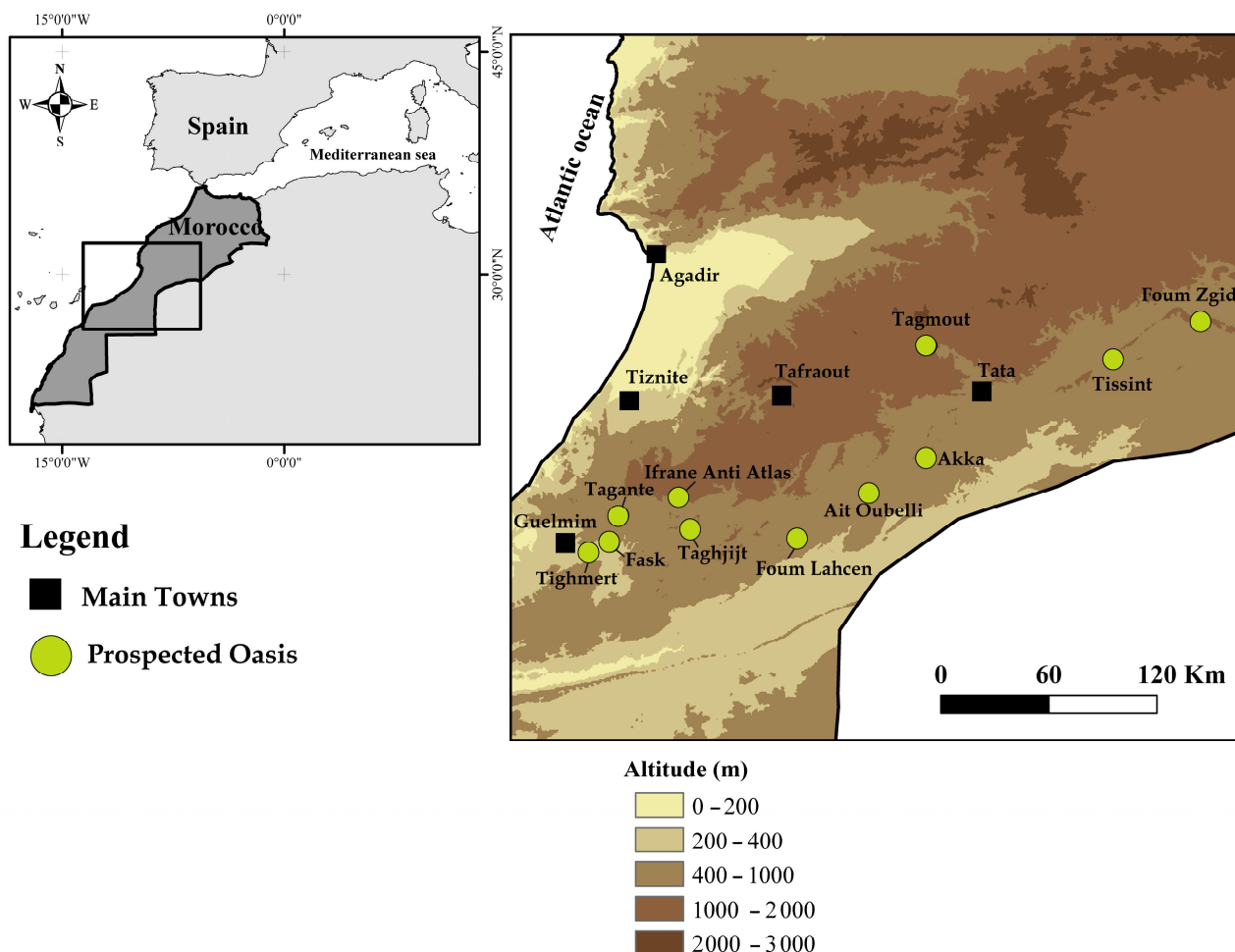


Figure 1. Geographical delimitation of the study area and location of the principal surveyed oases and urban centers.

2.2. Data Collection

Data collection was based on field surveys using a semi-structured interview approach supported by questionnaires (Tables S1–S3). These questionnaires were carefully designed to capture both general information about respondents, such as socio-demographic data, farming experience, and household characteristics, and specific data directly related to the research objectives. A total of 328 individuals were surveyed. The first set of surveys focused on the characterization of fruit tree agrobiodiversity within oasis agroecosystems and the identification of production sites. This part involved 220 farmers across 11 oases, with 20 interviews conducted per site, and aimed at documenting the diversity of cultivated fruit tree species, their relative abundance, and the importance of pomegranate compared to other fruit species in oasis farming systems. A second set of surveys was dedicated to the characterization of pomegranate molasses (e.g., Amaghousse) production, carried out with 32 identified producers. Here, the emphasis was placed on documenting local nomenclature of varieties, the traditional and technical steps of the production process, production scales and yields, marketing practices, and the nutritional, medicinal, and cultural uses of the product. Finally, the characterization of product marketing was undertaken with 76 merchants, including herbalists and grocery store owners in the surveyed urban centers. This part of the investigation provided insights into the distribution channels of

pomegranate molasses, pricing strategies, consumer demand, and the integration of these products into local and regional markets. The questionnaires were initially prepared in English, but to ensure effective communication and cultural appropriateness, they were translated into Arabic or Amazigh during the interviews, depending on the language most familiar to the respondents. The translation into Arabic was carried out directly by the research team, while the Amazigh translation was performed by a local interpreter who also facilitated first contact and trust-building with local communities. This approach ensured that respondents could fully express their knowledge and experiences without linguistic barriers. All respondents were adults (over 18 years old) and agreed to participate voluntarily. To respect ethical standards, interviews were conducted under conditions of anonymity, and all information was collected with prior informed consent. Respondents were clearly informed of the study objectives, and data collection was carried out in accordance with principles of ethical research practices and respect for local cultural norms.

3. Results and Discussion

3.1. The Role of Pomegranate in Oasis Fruit Tree Agrobiodiversity

Agriculture in Morocco's pre-Saharan oases is generally traditional and subsistence oriented [7]. The surveyed oases follow this pattern, characterized by polyculture, with 43 cultivated species identified. These include 15 fruit trees, 13 vegetables, six cereals, five legumes, two spices, and two forage crops (Table S5). This profile is comparable to what has been reported in other oases, both in the region [7,9] and more broadly across North Africa [28–32]. Fruit trees form the arboreal stratum beneath the date palm canopy, playing a central role in maintaining the balance of oasis agroecosystems. They represent the most diverse group, accounting for 34.5% (39 varieties) of total varietal richness, excluding date palm diversity (Figure 2, Table S4). Figure (*Ficus carica* L.) shows the greatest diversity with 11 varieties, followed by pomegranate (*Punica granatum* L.) and grapevine (*Vitis vinifera* L.) (Figure 3, Table S4).

In the surveyed oases, five pomegranate varieties were identified: Beldi, found in all 11 oases; Al Hamed or Guersmoum, in 10 oases; Sefri, in five oases; Roudani, in three oases; and Elâadmi, in only one oasis (Table S4, Figure 3). A broader study covering Guelmim, Tata, and the Draa and Tafilalt oases [7] reported seven varieties, two of which (Elâansri and Kherifi) were not recorded in our study area. Except for Sefri, which is widely recognized in the Béni Mellal region as the typical Moroccan variety [33] and a candidate for Protected Geographical Indication (PGI) labeling [34], the other denominations are primarily local.

Pomegranates in Morocco are generally classified into two groups [35,36]: (i) soft-seeded varieties, mainly consumed fresh, and (ii) hard-seeded, often acidic varieties, mainly used for processing. In terms of varietal richness in the study area, the proportion of sweet varieties (67%) was found to be significantly higher than that of acid varieties (33%). This classification applies to the oasis varieties: Sefri, Roudani, Roumi and Beldi are soft-seeded, while Al Hamed and Lâadmi are hard-seeded. However, the term “variety” here reflects farmer-recognized denominations rather than strict botanical varieties. These denominations often correspond to polyclonal genotypes, as reported for pomegranate [37,38] and for other fruit trees such as olive [39], fig [40], and grapevine [41]. Farmers assign names based on geographical origin, fruit shape and color, or seed hardness. Among the local denominations, Beldi is the most widespread. Farmers describe Beldi pomegranates as local varieties propagated locally, as opposed to introduced ones. However, this denomination is not uniform, as it encompasses considerable variability in tree and fruit characteristics. The denomination Roudani likely refers to a geographical origin linked to the city of Taroudant. Lâadmi, literally meaning “hard-seeded,” is considered synonymous with the variety Bouaâdim, reported in the Azilal region [37,42].

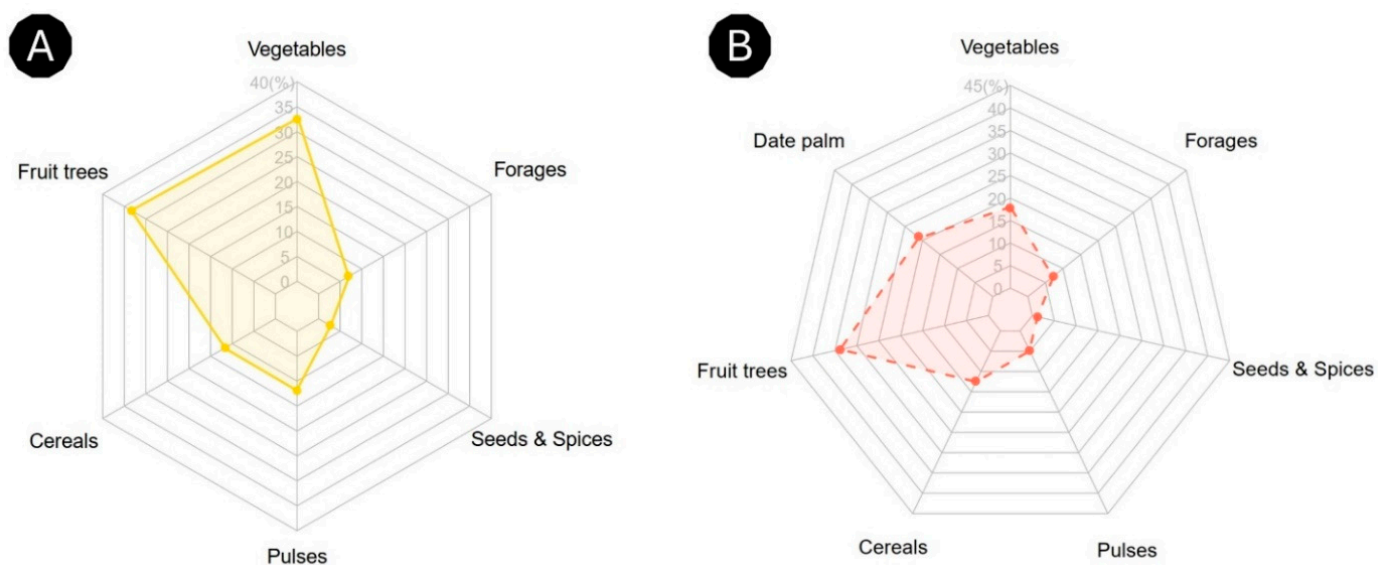


Figure 2. Species richness (A) and varietal richness (B) in the studied oases.

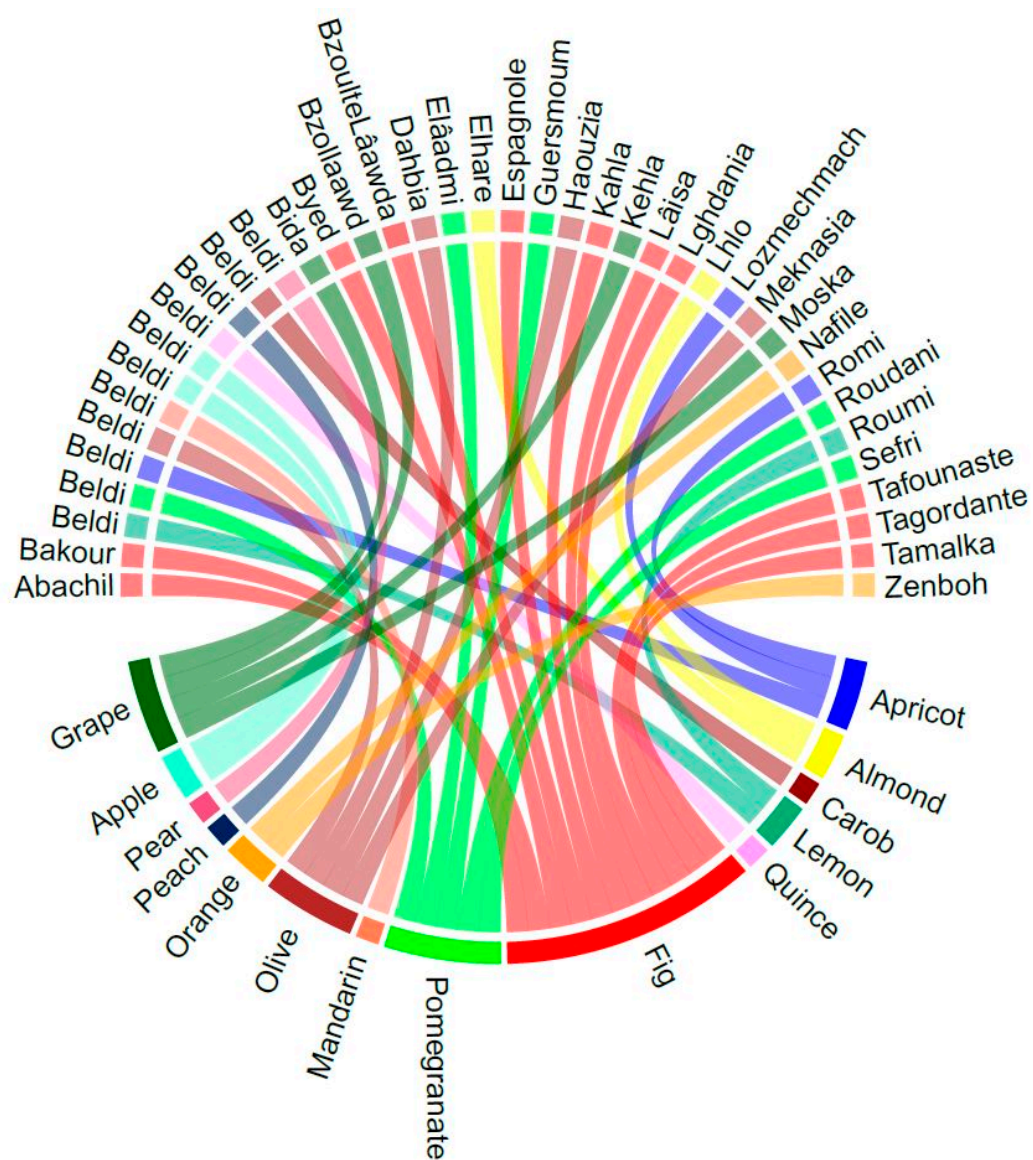


Figure 3. Varietal diversity recorded for each cultivated fruit tree species in the studied oases.

3.2. Special Case of the Guersmoum Variety

The denomination “Guersmoum” is used by Berber-speaking farmers, whereas Arabic-speaking farmers use the synonym “Al Hamed”; both terms mean “acid” (Figure 4). The term “Hamed” has also been reported in traditional agroecosystems in the Bzou and Demnate regions at the foothills of the High Atlas [37,42].

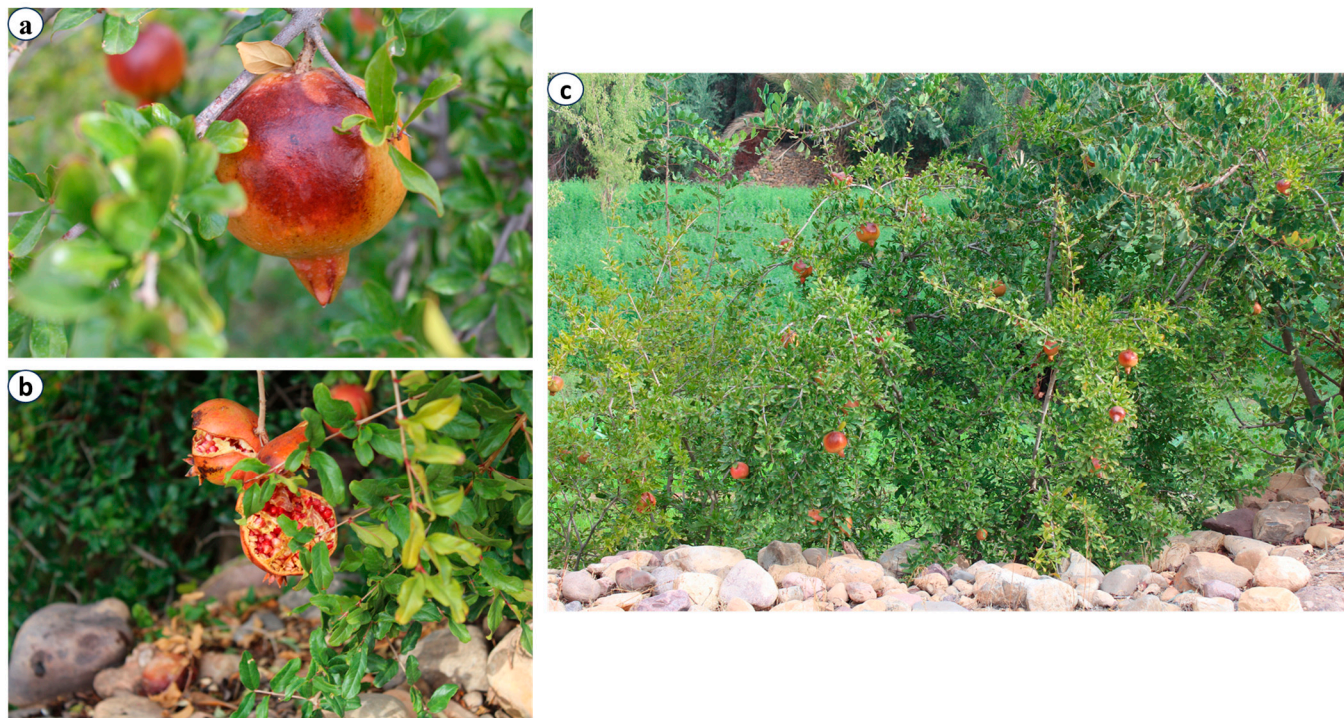


Figure 4. The Guersmoum variety of acidic pomegranate, photographed in the Tagmoute palm grove, with a close-up of pomegranate fruit (a), fruit split at maturity (b), and pomegranate shrub (c).

In oasis agroecosystems, Guersmoum does not correspond to a propagated variety but rather to spontaneous seedlings. Spontaneous pomegranate forms are well documented, especially in regions near the species’ center of origin (Afghanistan, Pakistan, India, and Iran) [43], but they are also observed in Mediterranean areas near human settlements, including in Morocco [44]. In the surveyed oases, Guersmoum shrubs often invade field edges and are generally considered undesirable, although tolerated in some places. A comparable situation was reported in the Algarve region of Portugal, where spontaneous forms occur around orchards [20]. Their fruits split at maturity, are acidic, and have hard seeds, traits similar to wild forms [45,46]. In Tagmoute oasis, they are particularly abundant, as women use their fruits for molasses production. The coexistence of spontaneous and cultivated forms mirrors other oasis fruit trees, such as date palm (*Phoenix dactylifera* L.), where seedlings are grouped under the generic name Khelt [47], and apricot (*Prunus armeniaca* L.) [12,48].

3.3. Amaghousse: A Traditional Distinctive Local Agri-Food Product

Although pomegranate cultivation occurs in all 11 surveyed oases, molasses production was recorded exclusively in Tagmoute oasis. This oasis, located in the Tata province at the southeastern foothills of the Anti-Atlas, benefits from more favorable climatic and water conditions, which may explain the abundance of spontaneous fruit tree forms, including Guersmoum pomegranate. The molasses, locally called Amaghousse (a Berber term meaning “concentrated” or “reduced”), is obtained by reducing pomegranate juice through heating (Figure 5). Unlike Eastern Mediterranean molasses, known as Dibs arroman in

Lebanon and Syria, or Nar ekşisi in Turkey [49], which is produced from cultivated varieties such as Katirbazi and Hicaz, Amaghousse is made from the acidic fruits of Guersmoum forms. Similarly, in Central Asia, molasses is produced from acidic wild fruits, locally called Narsharab in Azerbaijan [50].



Figure 5. The production process of Amaghousse: (a) pomegranate storage before processing; (b) fruit peeling; (c) juice extraction; (d) juice filtration; (e) traditional cooking; (f) final molasses product.

Production is entirely carried out by women, from harvesting to processing. Approximately 62.5% of interviewed women reported participating, with each producer managing an average of 60 trees. Women primarily harvest pomegranates from family-owned plots (75% of cases); however, they are also allowed by owners of other plots to collect acidic fruits in exchange for a portion of the production. Production typically begins in October and may extend over several months, depending on the timing and priorities of other agricultural activities. Fruits are harvested late and can reach up to two tons per family, arils extracted manually, and juice pressed using a stone mill. The juice is then slowly cooked over a wood fire in terracotta jars (Guedra) for six–ten hours, with regular skimming.

Producing one liter of Amaghousse requires approximately 10 kg of fruit. Production per family ranges from five to 50 L (Figure 6).

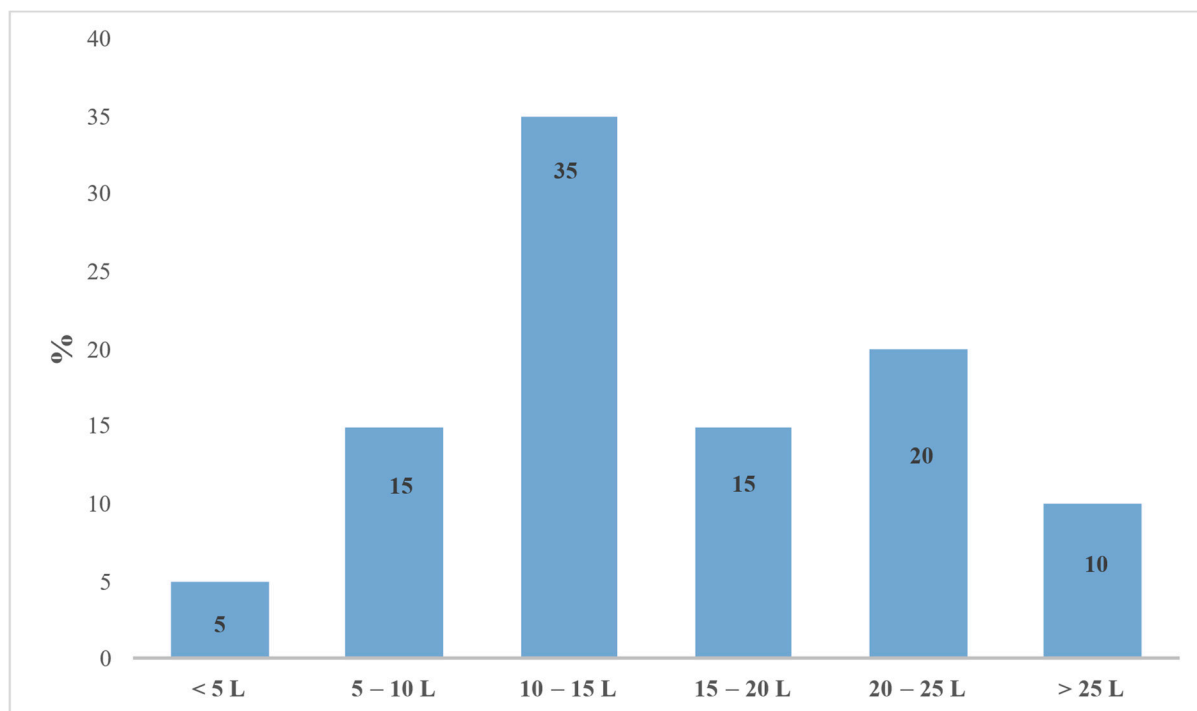


Figure 6. Average seasonal production of Amaghousse per family.

3.4. Uses and Commercialization of Amaghousse

The typology of Amaghousse uses can be classified into three main categories: medicinal, culinary, and cosmetic. Medicinal use is by far the most significant, accounting for 73% of mentions. The product is part of the local traditional pharmacopeia and is applied in various therapies, the most frequently cited being diabetes (95%), anti-inflammatory purposes (80%), digestive disorders (75%), respiratory diseases (35%), and hypertension (10%). The literature supports these uses, reporting the hypoglycemic effects of pomegranate fruit and juice [51–54], as well as antioxidant and anti-inflammatory properties [55,56], and a reduced risk of cardiovascular diseases [55,57]. By contrast, in the Eastern Mediterranean and Central Asia, the most common use of pomegranate molasses is culinary, where it serves as a condiment or sauce accompanying local dishes and salads. The only documented medicinal use for gastrointestinal disorders outside the region was observed in rural and urban communities of the Swat Valley in Pakistan, where wild pomegranate fruits are used to relieve stomach aches, colic, control dysentery, and improve digestion [58].

The commercialization of Amaghousse remains very limited. A survey of traders (grocers and herbalists) in the study area showed that only 18% reported selling it. The marketing chain is very short, reflecting its status as an authentic local product with strong territorial roots. Sales occur mainly in the Tagmoute oasis, the production site (66% of traders), and in Tata, the nearest urban center (35% of traders). In Tata, the product is sold exclusively by herbalists, confirming its primarily medicinal use, whereas in the Tagmoute oasis, it is marketed by herbalists, grocers, and a cooperative. Demand can be considered low to moderate, with limited quantities sold, averaging six liters per transaction (ranging from 2 to 15 L), and the selling price remains modest, between 60 and 70 MAD (Moroccan Dirham) per liter.

3.5. Traditional Knowledge, Gender, and Biodiversity Conservation

The Food and Agriculture Organization of the United Nations (FAO) defines wild food plants as species that grow spontaneously, independently of direct human intervention [59]. These plants are often considered weeds, even though they form part of the diet of certain populations [60,61]. In this context, the Guersmoum variety can be regarded as part of the local assemblage of wild edible plants. Local practices associated with its harvesting and processing can be unequivocally considered traditional knowledge, as defined by the Convention on Biological Diversity (CBD), which describes traditional knowledge as “the knowledge, innovations, and practices of indigenous and local communities around the world.”

This traditional knowledge also carries a strong gender dimension, stemming from the specific role of women in Amaghousse production. This aspect reflects the socio-cultural norms of oasis communities, which determine the division of labor and resource use along gender lines. It is widely acknowledged that labor organization and resource use are structured by gender [62,63]. Women’s role as custodians of plant genetic resources is linked to their preference for local varieties, which are adapted to agroecological conditions and meet diverse non-food needs. In the Tagmout oasis, women’s harvesting of Guersmoum fruits contributes to the conservation of pomegranate genetic resources, driven by uses rooted in traditional knowledge rather than food or market value. Thus, the link between cultural diversity, expressed through local knowledge, and biological diversity is clear. The conservation of local pomegranate genetic resources ultimately depends on preserving traditional knowledge within the oasis agroecosystem. However, given the low commercial value and highly localized nature of Amaghousse production, the preservation of this heritage depends on concrete action to promote it.

4. Conclusions

The results of this case study clearly highlight the strong relationship between local knowledge and the conservation of genetic resources. Moreover, the close connection between women and plants plays a key role in preserving both traditional knowledge and biodiversity within the agroecosystem. In light of the multiple threats undermining the resilience and sustainability of oasis agroecosystems, development projects and initiatives should place greater emphasis on integrating traditional knowledge. Importantly, there is no inherent conflict between pursuing development and improving livelihoods and conserving diversity through the promotion of local knowledge. This dynamic is further strengthened by the gender dimension, as rural women are deeply engaged in agro-social processes related to the selection, management, processing, and conservation of agricultural diversity. Beyond its local importance, the case of pomegranate cultivation and molasses production in pre-Saharan oases illustrates how the maintenance of underutilized crops contributes to both ecological resilience and cultural identity. The persistence of such practices demonstrates that oasis communities are not only curators of biodiversity but also active agents in its dynamic management through cultural transmission, adaptation, and innovation. Recognizing and supporting this role is essential for ensuring that agrobiodiversity continues to serve as a buffer against climatic uncertainties and socioeconomic change. In the current context of accelerating climate change and agricultural modernization, the conservation of varietal diversity cannot rely solely on ex situ strategies or market-oriented approaches. Instead, it requires the reinforcement of in situ practices embedded in local knowledge systems and cultural traditions. Policies that integrate gender-sensitive approaches, promote participatory conservation, and foster the promotion of traditional products such as Amaghousse can enhance both the resilience of agroecosystems and the livelihoods of local communities. Ultimately, the safeguarding of oasis agrobiodiversity

hinges on recognizing the interdependence between cultural heritage and biological resources. By bridging traditional practices with contemporary sustainability strategies, it is possible to secure the dual goals of conserving diversity and supporting rural development. The case of the pomegranate thus provides a compelling example of how local knowledge can inform broader strategies for agrobiodiversity conservation in fragile environments such as the Moroccan pre-Saharan oases.

Building on these findings, future actions should aim to translate traditional knowledge and pomegranate diversity into tangible strategies for sustainable development. Priority could be given to participatory research programs that engage local farmers, particularly women, in the characterization, selection, and conservation of local varieties. The establishment of women-led cooperatives for Amaghousse production, supported by quality labeling or geographical indication schemes, would enhance both market value and biodiversity conservation. At the policy level, integrating these heritage-based practices into conservation of agrobiodiversity and climate adaptation strategies could reinforce the resilience of oasis systems. Finally, educational initiatives and local documentation projects would ensure the transmission of ancestral knowledge to younger generations, securing its continuity within evolving socio-economic contexts.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/conservation5040066/s1>, Table S1: Survey with Farmers, Table S2: Producer survey (Amaghousse); Table S3: Trader survey (Amaghousse); Table S4: Summary of species and varietal richness of fruit trees present in the studied oasis agroecosystems; and Table S5: Crops and Varieties Identified in the Studied Oases.

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Informed Consent Statement: Verbal informed consent was obtained from participants. Verbal consent was preferred over written consent because it was deemed more appropriate for this study, as it is consistent with cultural norms and reduces the potential intimidation associated with signing documents. It also offers flexibility in field conditions where written consent may be impractical due to the educational level of farmers. Furthermore, the creation of signed documents compromises participant confidentiality.

Data Availability Statement: Data supporting findings are available within Supplementary Materials.

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Conflicts of Interest: The authors declare no conflicts of interest.

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