Traditional Knowledge and Climate-Resilient Agrobiodiversity: Pathways to Sustainable Food Systems in Lebanon

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Abstract. Lebanon's diverse agroecosystems sustain rich agrobiodiversity, shaped by centuries of traditional knowledge (TK) that underpins climate-resilient and multifunctional food systems. This study documents TK across coastal plains, inland valleys, mountain terraces, and highland pastures, highlighting how farmers, pastoralists, and women's networks maintain crop diversity, local livestock breeds, and wild edible plants. Key practices include terracing, agroforestry, intercropping, seed saving and exchange, rotational grazing, water harvesting, and traditional food systems, which collectively enhance soil fertility, conserve resources, support ecosystem services, and buffer communities against climatic variability. TK is deeply embedded in socio-cultural systems: women and elders act as custodians of seeds, culinary traditions, and ecological knowledge, while pastoralist networks sustain rotational grazing and landscape stewardship. Agrobiodiversity traditional food reinforces circular economy pathways linking crop, livestock, and wild plant management in closed-loop systems that support sustainable livelihoods. Farm-to-fork initiatives and agritourism further integrate TK with economic resilience and heritage preservation. Despite its adaptive value, TK faces growing threats from climate change, rural outmigration, and generational knowledge gaps. Strengthening intergenerational transfer, policy support, and market-oriented approaches is essential to safeguard Lebanon agrobiodiversity heritage and enhance the resilience of its food systems under a changing climate.

Keywords: Lebanon; Agrobiodiversity; Traditional knowledge; Climate resilience practices; Traditional food; Circular economy.

1 Introduction

Agrobiodiversity encompasses the full spectrum of biological diversity that sustains agricultural systems. It includes the genetic resources of domesticated species like

A. M. Bozdoğan et al. (eds .), *Proceedings of the 5th International Conference on Research of Agricultural and Food Technologies (I-CRAFT 2025)*, Atlantis Highlights in Sustainable Development 8,
https://doi.org/10.2991/978-94-6239-666-1_46

crops, trees, livestock, and fish, as well as their wild relatives which are a critical resource for breeding climate-resilient varieties, associated wild and semi-wild species, including a rich diversity of wild edible plants (WEPs) and medicinal plants, soil microorganisms, pollinators, and the ecological processes linking them (FAO, 1999). Beyond cultivated species, agrobiodiversity extends to landscapes, including those within protected areas, which act as vital reservoirs for crop wild relatives (CWRs) and wild harvested species, ecosystems, and cultural practices that have co-evolved with farming over millennia (Altieri, 2004).

Agrobiodiversity is both a biophysical resource represented by genetic pools and a living cultural heritage, shaped by traditional knowledge (TK) and farming practices (Agnoletti and Santoro, 2022). It plays a vital role in ensuring adaptability to environmental change, maintaining ecosystem integrity, and sustaining multifunctional agriculture as a source of food, livelihoods, cultural identity, and ecological balance (Jarvis et al., 2011).

Traditional knowledge is central to this process shaping local practices. Unlike formal scientific approaches, TK integrates ecological, biocultural, and social dimensions, making it indispensable for the sustainable management of agricultural systems (Adefila et al., 2024; Baydoun et al., 2024). Practices such as seed saving, landrace selection, grafting, and the exchange of planting materials maintain dynamic genetic pools that adapt continuously to environmental variability (Azeez et al., 2018; Salgotra et al., 2023). TK also ensures ecological sustainability through crop rotation, polyculture, agroforestry, and enhancing soil fertility, supporting pollinators, and reducing vulnerability to pests and diseases (Brookfield et al., 2002; Borah et al., 2024).

Lebanon, positioned at the crossroads of the Middle East and the Mediterranean, is a biodiversity hotspot in the Eastern Mediterranean, characterized by rugged topography, steep elevation gradients, and diverse microclimates (Stephan et al., 2025). Despite its small size (~10,452 km²), the country spans humid coastal plains, snow-covered mountains, and semi-arid valleys. This ecological heterogeneity, combined with centuries of terracing and irrigation, has created numerous agro-ecological niches that sustain distinct crop systems and unique landraces, including durum wheat, barley, lentils, chickpeas, and ancient grape varieties (Chalak et al., 2011).

Agricultural production in Lebanon is highly diverse and closely linked to the country's varied landscapes and climates. Coastal areas of South Lebanon and Akkar in the North favor citrus, bananas, and vegetables; while the Bekaa Valley serves as the main breadbasket, producing cereals, pulses, vineyards, apples, and potatoes. Mountain terraces sustain olives, cherries, apples, and grapes, reflecting long-standing agrobiodiversity traditions, whereas southern and northern regions maintain combinations of olives, citrus, pears, and legumes. Animal production, particularly goats, sheep, and dairy cattle, complements crop diversity and contributes to rural livelihoods. Traditional agrobiodiversity practices, including intercropping, crop rotation, agroforestry, mixed crop–livestock systems, and terracing, enhance ecosystem services, optimize resource use, and strengthen the resilience of farming systems to environmental stresses.

These diverse agricultural systems are embedded within unique agroecosystems, such as the high-altitude region of Mount Hermon, which hosts distinct assemblages of endemic and culturally significant species (Baydoun et al., 2023; Sayde et al., 2024; El

Zein et al., 2024). UNESCO-designated biosphere reserves, including Jabal Moussa and the Shouf Biosphere Reserve, integrate Mediterranean forests, terraced agroecosystems, diverse traditional crops and fruit trees, and rich endemic flora (Sattout, 2020). Together, these landscapes exemplify the close interplay between natural and human-shaped environments, where centuries of adaptive management have preserved genetic resources, cultural heritage, and the functional diversity that underpins Lebanon's agricultural resilience.

However, Lebanon's agrobiodiversity and associated TK face increasing pressures from climate change, urbanization, land fragmentation, socio-economic instability, rural outmigration, globalization, and generational gaps (Chalak et al., 2011; Baydoun et al., 2024). Rising temperatures, shifting precipitation patterns, droughts, and extreme weather events threaten crop yields, water availability, and the viability of traditional farming systems (Chalak et al., 2020; Al Dirani et al., 2021). The erosion of TK directly affects the conservation and use of crop wild relatives, landraces, and wild harvested plants, disrupting sustainable community–landscape interactions (Chalak et al., 2011; Sayde et al., 2023; Baydoun et al., 2024). This loss of TK and associated management practices, including seed saving, terracing, rotational grazing, and mixed cropping, threatens the resilience of Lebanon's agroecosystems, undermining the preservation of cultural heritage and jeopardizing food security**.** Against this backdrop, this study presents a comprehensive documentation of climate-resilient agrobiodiversity TK and investigates how TK contributes to sustainable food systems in Lebanon, including pathways through farm-to-fork practices, agritourism, and circular economy approaches.

2 Materials and Methods

2.1 Study Sites

This study was conducted across Lebanon's diverse agroecosystems to capture a wide range of agrobiodiversity climate resilient TK practices. Site selection was purposive, ensuring representation of key ecological zones and farming systems and integrating smallholder, pastoralist, and mixed farming systems. The survey covered in total 57 sites across Lebanon (Fig. 1) including 11 in the Bekaa, 16 in Mount Lebanon, 12 in the North, 5 in the South, 4 in Akkar, 3 in Nabattieh and 6 in Baalbek-Hermel governorate. Of these, 16 are located in Hima, defined as traditional, community-managed conservation areas often overseen in collaboration with local municipalities, and 10 are located in UNESCO-recognized Shouf Biosphere Reserve and Jabal Moussa Biosphere Reserve, and Horsh Ehden Nature Reserve.

2.2 Preliminary Desk Analysis

Prior to fieldwork, a comprehensive desk analysis was conducted to inform the research design. This involved compiling existing knowledge on Lebanese agrobiodiversity, including crops, livestock, landraces, and crop wild relatives, by reviewing scientific literature, institutional reports, and grey literature (Hosri and Nehme, 2006; Chalak, 2014; Chalak et al., 2014a,b,c; Chalak and Hamadeh, 2015; Chalak et al., 2015a,b; Arnold et al., 2015; Baydoun et al., 2015; Chalak et al., 2016a; Mzid et al., 2016; Chalak et al., 2016; Dandachi et al., 2017; Baydoun et al., 2017; Hamadeh et al., 2018; Chami et al., 2018; Chalak et al., 2018a; El Riachy et al., 2018a,b,2019; Chalak et al., 2020a,b; Baydoun et al., 2020a,b,c; Merheb et al., 2020; Sattout, 2020; Chalak et al., 2021; Hani et al., 2021; Jalkh, 2022; Chalak et al., 2023a,b; Sayde et al., 2023; Chami et al., 2023; Ghossain et al., 2023; Nasser et al., 2023; Massaad et al., 2023; Al Achkar et al., 2024; Merheb et al., 2024a,b,c; Sayde et al., 2024a,b; Baydoun et al., 2024a,b; El Zein et al., 2024; Chalak and Ghorra Chamoun, 2025; Merheb et al., 2025a,b). Traditional agricultural and pastoral practices were examined with respect to biodiversity conservation, climate adaptation, and sustainable agriculture. Furthermore, the analysis identified socio-economic initiatives linking TK to farm-to-fork activities, local processing, agritourism, and circular economy models. The insights from this phase directly guided the final site selection, survey design, and identification of key informants.

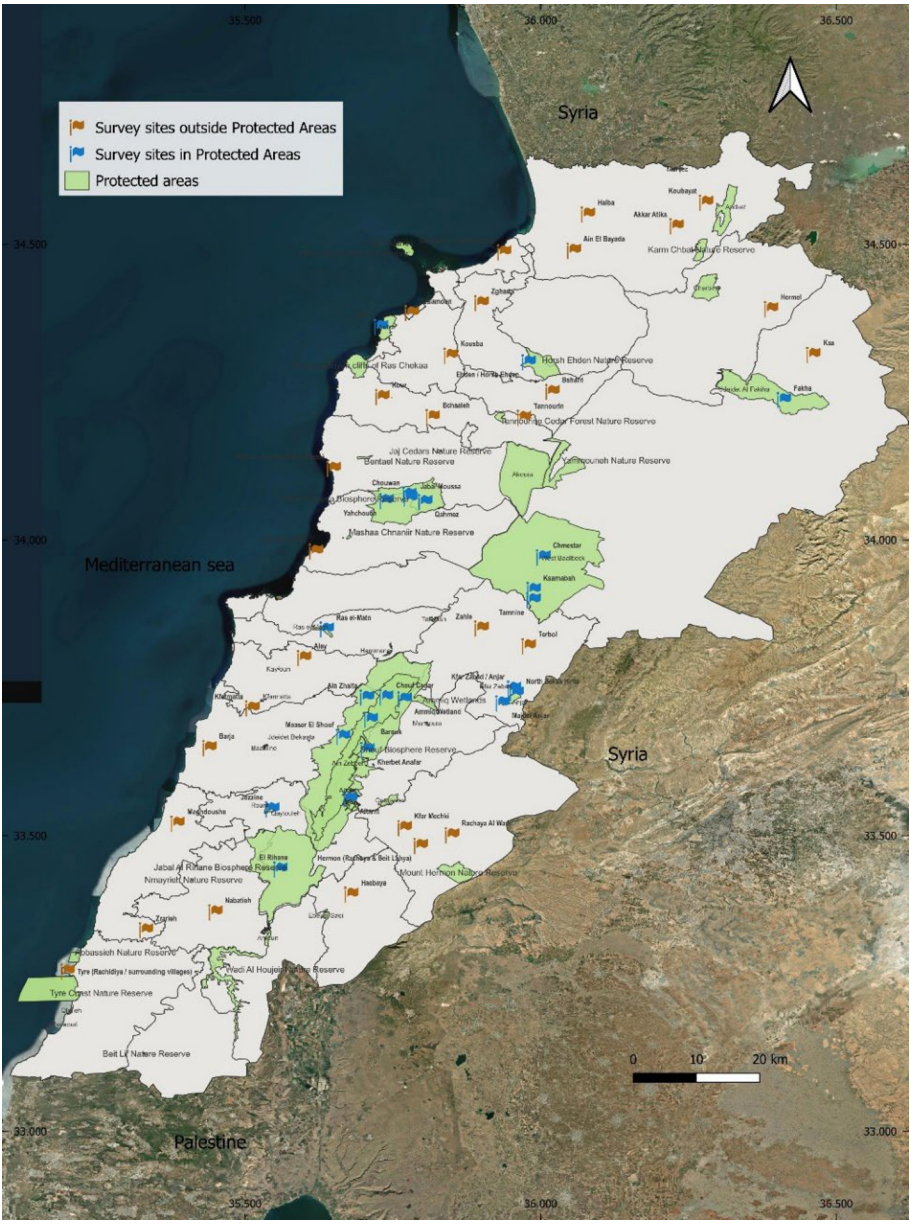

Fig. 1. Sites selected in Lebanon for assessing the agrobiodiversity traditional knowledge.

2.3 Data Collection

Field data were collected during 2022-2025 through semi-structured interviews and focus group discussions across the **57 sites.** On average, five informants were engaged per site, covering a broad spectrum of traditional knowledge holders. The survey included elderly villagers (88 men and women above 60 years), farmers of different age groups (90 informants), pastoralists (22 informants, mainly in rangeland-dependent areas), small-scale traditional food processors (55 women), and municipality representatives (30 informants), with 285 informants in total.
The survey questionnaire covered key dimensions of traditional knowledge, including agrobiodiversity climate resilient practices (crop varieties, livestock breeds, and wild edible plants), land and water management techniques (terracing, agroforestry, intercropping, seed saving, grazing systems, and water harvesting), and traditional food processing. It further explored the social aspects of knowledge transmission, as well as the local perceptions of gaps and challenges threatening the sustainability of agrobiodiversity TK.

2.4 Data Analysis

Qualitative data from interviews and focus groups were transcribed and subjected to thematic analysis to identify patterns in traditional knowledge, its transmission pathways, and its socio-economic integration. This process involved systematically assigning codes and categories to relevant data sections that represented key ideas or emerging themes (Christou, 2023). Comparable codes were then arranged into broader groups covering the major thematic areas. From these categories and codes, a structured analytical framework was developed to evaluate the data in relation to the research questions, investigate relationships between categories, uncover recurring patterns, and draw meaning from these connections.

3 Results

The survey across Lebanon's diverse agroecosystems, from coastal plains to high mountain terraces, revealed a rich spectrum of traditional knowledge (TK) practices supporting climate-resilient agriculture. The results document the most cited interconnected TK practices (Table 1): agrobiodiversity practices; livestock and silvopastoral systems; crop, soil, and water management; local food systems; traditional beverages and distilled products; animal traditional products; Lebanese traditional dishes; and circular economy practices. These areas capture geographical and ecological patterns of TK, its sociocultural significance, in addition to farmers' perceptions of emerging threats.

3.1 Agrobiodiversity practices supporting climate resilience

Terracing. Terracing remains a cornerstone of mountain agriculture in Lebanon, enabling cultivation on steep slopes, controlling erosion, and sustaining soil fertility. Terraces are constructed using dry-stone walls, reshaped soil, and integrated vegetation to stabilize slopes, reduce runoff, and retain organic matter. Farmers from Shouf, Jabal Moussa (1,200–1,700 m), Ehden, and Zgharta emphasized: "Without these stone walls, our orchards, vineyards, and cereal plots would wash away with the rains." Terraces support multifunctional agroecosystems. Olives, grapevines, figs, pome and stone fruits, pines, walnuts, aromatic herbs, and vegetables are intercropped within terrace plots, enhancing biodiversity, microclimates, and resilience. Traditional crops such as wheat and barley are cultivated to produce bulgur, boiled wheat, and bread, while olives provide oil for consumption and sale, and grapes are transformed into jams and arak. Terraces historically supported mulberry cultivation for the silk industry, and modern restoration initiatives, such as the Reviving Traditional Agricultural Practices in Biosphere Reserves project, have revitalized abandoned terraces, reinforcing soil conservation, water retention, and habitat for pollinators and wild plants. Farmers highlighted gendered roles: "Men build and repair the terraces, while women cultivate the olives, figs, and vegetables." Terraces also provide niches for wild edible plants and leafy vegetables, linking traditional land management with both agrobiodiversity conservation and food security.

Agroforestry and tree-crop integration. Agroforestry is a key climate-adaptive strategy throughout Lebanon. Farmers integrate trees such as olives, figs, almonds, plums, pears, walnuts, mulberries, pines, carobs, and native oaks with cereals, legumes, and fodder crops, creating multifunctional systems that enhance soil fertility, provide shade, and sustain livestock. "We plant our olives, figs, and almonds together with cereals and legumes to make the most of the land and protect the soil," reported a farmer in Kfarmishki. Silvopastoral practices are widespread, with Baladi goats, Awassi sheep, and local cattle grazing under tree canopies, depositing manure that enriches soil fertility. Seasonal rotations and transhumance prevent overgrazing and maintain pasture quality. Projects such as LIVINGAGRO and the Lebanon Reforestation Initiative (LRI) have reinforced agroforestry by introducing native tree plantings, restoring degraded lands, and improving microclimates for crops and livestock. Farmers observed: "The new olive, oak and fruit trees provide shade for our animals and improve the grass for grazing."

Landraces. Farmers actively cultivate a wide range of locally adapted landraces tailored to site-specific environmental stresses, including drought, elevated temperatures, frost, and pest pressures. Wheat landraces in the Bekaa Valley—such as Jouri, Bekaii, Salamouni, Douchani, and Hourani—and barley varieties like Rihan, Assi, and Litani are commonly intercropped with vetch for fodder. These cereals remain central to household consumption and local food processing, transformed into bulgur, boiled wheat, Frikeh, and fermented preparations. Farmers emphasize resilience: "Our old

wheat and barley survive where modern seeds fail; they are the backbone of our families and our heritage," explained a farmer from Deir El Ahmar. Olive cultivation is deeply embedded in cultural heritage and livelihoods. Families maintain terraced olive groves on steep, marginal lands, adapted to local agroecological conditions and providing environmental and economic resilience. Local varieties such as Baladi, Soury, and Abou Chawkeh are favored for rainfed adaptation, pest resistance, and flavor profiles. Traditional management—pruning, organic fertilization, and water harvesting from terraces—reflects generations of knowledge. A farmer from Koura emphasized: "Our olive trees survive on these terraces with little water. Modern methods fail here, but traditional practices keep our groves alive and our families nourished." Grapevine landraces like Oubeidi, Merwah, Beitamouni, Obeidi, Zitani, and Halbouti thrive in the Bekaa and Mount Lebanon, while Meksasi prevails in southern terraces. Other fruit landraces include cherries and apples in Shouf and Ehden, figs and vines in Annaya and Rachaya, and mulberries in the mid-hills, all providing diversified harvests that buffer households against climatic variability. Traditional vegetables in Tyre and Akkar complement diets, while legumes, aromatic herbs, and leafy greens enhance soil fertility and ecological stability. Farmers note: "We maintain our local seeds each season because they keep our traditions alive, are adapted to our land, secure our harvests, and help us stay independent from costly commercial seeds."

Seed saving, propagation, and exchange. Seed saving, propagation, and exchange are central to maintaining locally adapted crop varieties and preserving agrobiodiversity. Farmers select seeds from the healthiest plants, clean and store them in granaries, clay pots, or woven baskets in cool, dry locations. Propagation includes intercropping cereals with legumes, nurturing fruit seedlings, and seasonal vegetable propagation. Seed exchange networks support households, reinforce trust, and enhance genetic diversity. A farmer from Rachaya remarked: "We keep the best wheat seeds every year, those that survive the frost and are stronger than any seed we can buy." Women are central to seed management, overseeing cleaning, propagation, nursery management, and storage. "We teach our daughters which seeds to keep, how to store them, and which ones survive the heat and frost; this knowledge is our inheritance and our insurance for the future," explained an elder from Shouf.

Domestication of wild edible plants. Farmers increasingly domesticate wild edible plants across agroecological zones. Oregano (Origanum syriacum) and Hindbeh (Cichorium sp.) in Akkar and the Bekaa illustrate culinary and market roles. Akkoub (Gundelia sp.) in the Shouf Biosphere Reserve is integrated into home gardens and agroforestry plots, used in traditional dishes and marketed for supplementary income. Pine (Pinus pinea) in Jezzine (Bekassine) and Sumac (Rhus coriaria) are managed and cultivated for economic and ecological benefits. "With help from the reserve, we collect and save wild seeds to grow them in our fields because they are well adapted against changing weather," said a farmer from Maasser El Shouf.

3.2 Livestock and Silvopastoral Systems

Local livestock breeds. Farmers emphasized the resilience of local goats and sheep, which are uniquely adapted to Lebanon's drylands and mountainous regions. Baladi goats and Awassi sheep thrive on steep, rocky slopes with limited water, tolerating heat and frost. "Our Baladi goats survive drought and steep pastures where other animals cannot," explained a farmer, highlighting their hardiness. These breeds forage efficiently on sparse vegetation, shrubs, and weeds, contributing to rangeland management and controlling invasive species. Their small, agile bodies reduce pressure on fragile terraces and steep pastures, while reproductive efficiency ensures herd continuity under challenging conditions. Farmers stressed: "Our local goats and sheep are hardy, give us milk and meat, and even provide manure, making them essential to our farms and traditions. By rotating grazing, choosing the right animals, and knowing which plants to feed them, we also keep our terraces, orchards, and forests healthy while protecting our livestock for the future."

Transhumance and seasonal grazing. Seasonal movement of herds from lowland winter pastures to upland summer ranges maintains pasture heterogeneity, prevents overgrazing, and promotes nutrient cycling. "Winter grazing uses our crop residues, and summer pastures are full of herbs and shrubs that keep our livestock healthy," explained a farmer in Rachaya. Aromatic and medicinal herbs in upland summer pastures enhance livestock health and productivity, while lowland winter areas utilize harvested crop residues and agro-industrial by-products, exemplifying circular nutrient flow. Farmers valued both practical and social benefits: "Moving our herds with the seasons lets us find the best pastures and take care of our animals properly. It also brings us together with other communities, where we share knowledge on herd management, breeding, and coping with changing weather, keeping our traditions and livelihoods strong."

3.3 Crop, Soil, and Water Management

Crop and soil management. Traditional knowledge in crop and soil management remains a cornerstone of resilient agrobiodiversity practices, especially in semi-arid and mountainous zones. Organic amendments maintain soil health: "The soil lives only when it receives manure and compost," explained a farmer from Rachaya. Manure, often composted or mixed with crop residues, olive mill by-products, and household organic waste, increases nutrient availability, improves soil structure, enhances water retention, and closes nutrient loops between livestock and crops. "Everything is connected: the goats help the soil, and the soil feeds the crops."

Crop rotation and intercropping are widely practiced. In Hermel, Deir El Ahmar, and Zahle, cereals rotate with legumes such as chickpeas and lentils, while barley interplanted with vetch provides fodder. Polyculture and companion planting in mid-elevation zones (Koura, Annaya) combine olives, grapevines, figs, and fruit trees with legumes, aromatic herbs, and vegetables to enhance soil fertility, microclimate, and biodiversity. "Planting thyme or chickpeas between our olive trees keeps the soil alive and protects the roots from drought," explained a Koura farmer. Terracing and contour plowing in Shouf, Ehden, Zgharta, and Jabal Moussa prevent soil erosion. Women,

especially in Tyre and Akkar, oversee seed selection, composting, and irrigation, linking crop diversity with sustainable soil fertility management.
Water management. Traditional water management sustains agroecosystems, particularly in dry zones such as Hermel, Rachaya, and Mount Lebanon. Cisterns, canals, terraces, ponds, and small-scale reservoirs collect and distribute rainwater and snowmelt, reducing erosion and ensuring year-round availability for crops and livestock. Ponds, often stone-lined with capacities from hundreds to over a thousand cubic meters, provide supplemental irrigation. "When the rains stop early, our pond keeps the grapevines and fig trees alive until harvest," noted a farmer in Kfar Selwan. Community-based Hima management, including water-sharing protocols, ensures equitable access: "We follow Hima rules for water use so everyone's crops survive the dry season," said a farmer from Rachaya. Farmers highlighted the synergy of local knowledge and technical assistance: "The engineers helped us line the pond, but we showed them where the water flows in winter," from Mount Lebanon.

3.4 Local Food Systems

Cereal landraces and staple foods: Wheat and barley landraces are central to Lebanese diets and cultural heritage, cultivated across diverse agroecological zones from Akkar to Mount Lebanon and the Bekaa Valley. Farmers maintain multiple landraces, each with unique traits such as growth cycle, grain quality, and resilience to stresses, ensuring reliable harvests, dietary diversity, and adaptation to local conditions. Wheat is often stone-milled into flour, preserving its nutritional integrity. Bulgur, a cracked wheat partially boiled, dried, and ground, is widely incorporated into pilafs, soups, salads, and vegetarian dishes, prized for its long shelf life, high fiber content, and digestibility. Frikeh, made from roasted green durum wheat, offers high protein, rich fiber, a smoky flavor, and long-term storage value, often cooked with chicken or meat or incorporated in various salads. Jreesh, a traditional whole wheat product that is hulled and coarsely ground but not pre-cooked, is widely used in South Lebanon villages to make the famous Meshtah or flatbread (Meshtah el Jreesh), rich in fiber, iron, and magnesium. Barley landraces such as Rihan, Assi, and Litani are cultivated in rainfed and marginal environments to feed livestock, with farmers describing barley as "the grain of endurance, sustaining herds during difficult years." "Barley feeds our goats and sheep. Without it, we could not survive the hard years," explained a farmer from Hermel.
Olive oil: Olives are harvested mainly in late autumn and early winter, often by hand, with family members and seasonal workers joining the collective effort. The harvested olives are pressed traditionally in stone or wooden mills, and increasingly in modern mechanical presses, to produce extra virgin olive oil renowned for its purity, low acidity, and distinctive flavor. Farmers emphasize that the quality of their oil is a matter of family pride and reputation. Olive oil is central to daily nutrition in Lebanon, used in salads, stews, dressings, and festive foods, while also serving as a symbol of hospitality

and abundance. “The olive tree is not only our food but our history. Caring for it connects us to our land and our ancestors. Every harvest is a celebration of our work and our heritage,” explained a farmer from Bchaaleh.

Molasses and regional specialties: Molasses production transforms local fruits into nutrient-rich, shelf-stable products with culinary and medicinal applications. Carob molasses, produced in south, north and Mount Lebanon villages, serves as a natural sweetener in desserts, pastries, and traditional breads. Grape molasses, including sweet syrup from ripe grapes and acidic syrup from unripe green berries, is common in the Bekaa and Mount Lebanon, enhancing baked goods, salads, dressings, and savory stews. Pomegranate molasses, prevalent in the Bekaa, North, and South Lebanon, adds a characteristic sour-sweet flavor to salads, marinades, glazes for meat, vegetables, and pastries. Farmers highlighted: “Grape molasses is part of our daily life—it sweetens our meals, preserves the fruit, and reminds us of our ancestors.”

Pines and nuts: Nuts such as almonds, walnuts, and pine nuts are central to local diets, culinary heritage, and agrobiodiversity-based food systems. Pinus pinea trees provide pine nuts with delicate flavor and high economic value. Almonds enrich pastries, desserts, and traditional sweets, while walnuts, concentrated in the North, South, and Mount Lebanon, feature prominently in both savory and sweet dishes. Farmers emphasized: “These nuts are wanted all over the country, and using them in our pastries and desserts helps feed our families, preserve traditions, and support our livelihoods.”

Dried fruits and foraged wild fruits: Dried fruits ensure year-round access to nutrition. Raisins, produced from seedless grapes in the Bekaa, are sun-dried on rooftops or terraces. Dried figs, harvested from Mount Lebanon, Bekaa, and the South, are pressed into cakes or stuffed with walnuts. In high mountain zones, dried cherries, plums, apricots, and mulberries enrich seasonal diets. Foraged wild fruits such as *zaarour* (*Crataegus azarolus*) and wild myrtle (*Myrtus communis*) are consumed fresh, dried, or transformed into jams and syrups, diversifying local diets.

Wild and semi-cultivated species in diets: Wild and semi-cultivated species also contribute significantly to traditional diets. *Sumac* (*Rhus coriaria*), leafy greens such as *sorrel* (*Rumex acetosa*), *mallow* (*Malva sp.*), *hindbeh* (*Cichorium intybus*), *garlic* (*Allium ampeloprasum*), *haliyoun* (*Asparagus acutifolius*), *choumar* (*Foeniculum vulgare*), *purslane* (*Portulaca oleracea*), *akkoub* (*Gundelia tournefortii*), *eryngo* (*Eryngium creticum*), *Lebanese salsify* (*Pseudopodospermum libanoticum*), and *mashy* (*Scorzonera mollis*) constitute the seasonal mix of *slika*, incorporated into fresh salads and cooked dishes. *Akkoub* is particularly prized for its nutritional and cultural roles: *“When the season of Akkoub comes, we all go to the hills together—it is part of our life, our food, and our memories. Now, we also hope to benefit economically from this plant, which is prized by all Lebanese and tourists alike, by selling it sustainably in the markets.”*

3.5 Traditional Beverages and Distilled Products

Herbal infusions **and household beverages.** Families across Lebanon continue preparing herbal teas and infusions (*Zuhoorat*) from cultivated and wild plants, including

sage (*Salvia fruticosa*), *anise* (*Pimpinella anisum*), *chamomile* (*Matricaria chamomilla*), *micromeria* (*Micromeria fruticosa*), *thyme* (*Thymus spp.*), and *carob pods* (*Ceratonia siliqua*). These beverages serve as everyday staples and remedies for digestive, respiratory, or calming purposes. They are dried and stored for year-round use. *"When a child has a cough, we never go first to the pharmacy; we boil zaatar or sage. These herbs are our pharmacy, our tea, and our daily comfort,"* shared an elderly woman in Shouf. Such practices illustrate how biodiversity integrates into diets and community health systems while reducing dependence on industrial pharmaceuticals.

Floral waters and fruit syrups. Distilled floral waters are celebrated in Lebanese culture. *Rosa damascena*, cultivated in *Shmustar*, *Ksarnaba*, and *Tamnine* (Bekaa Valley), is harvested for artisanal *rose blossom water* (*ma' ward*), *rose syrup*, *rose oil*, and *rose petal jams*. These products are embedded in local diets and festivities, used in sweets such as *Malban* and *Mouhallabieh*. *Orange blossom water* (*Ma' zaher*), derived from *Citrus aurantium*, is produced in *Kalamoun* (North Lebanon) and *Maghduche* (South Lebanon), symbolizing regional identity. *"When we distill the orange blossoms, the whole village smells of spring. It is not only a drink; it is our season, our memory, our pride,"* explained a farmer. Orange blossom water flavors desserts, beverages, and household remedies.

Artisanal vinegar, arak, and wine. Lebanon's viticultural heritage is reflected in local grape varieties, particularly *Merwah* and *Obeidi*, used to produce vinegar and artisanal alcoholic beverages. Vinegar is fermented slowly in clay jars or wooden barrels, prized for cooking and medicinal uses. *Arak*, the anise-flavored spirit distilled in copper alembics, remains central to social gatherings: *"Our fathers taught us how to distill arak, step by step, drop by drop. It is not only alcohol, it is heritage in a glass,"* explained a winemaker in Zahle. Artisanal winemaking with *Obeidi* and *Merwah* preserves indigenous grape varieties and strengthens rural livelihoods. A notable example is *Château St. Thomas* in Bekaa, producing 100% *Obeidi* wine, with citrus and floral notes reflecting terroir.

3.6 Animal Traditional Products

Lebanon's silvopastoral dairy products are closely linked to diverse grazing systems. Herds of goats and sheep feed on terraces, aromatic shrublands, and semi-arid slopes, producing milk for cheeses and fermented products. *Labneh*, a tangy strained yogurt, reflects the aromatic pastures of Mount Lebanon and Bekaa. *"The labneh from our goats tastes of the hills where they graze—it cannot be replicated in the city,"* noted a farmer from Shouf. *Chanklish*, semi-hard fermented cheese coated with *thyme*, *oregano*, or other herbs, and *Baladiye*, soft fresh cheese from mixed goat and sheep milk, are widely produced. Higher-altitude areas produce *Darfieh*, semi-hard cheese with mountain herb flavors, and *Ariche*, preserved brined cheese. *Ashta*, clotted cream, and *Shmandour*, a soft fermented milk product, reflect local microbial diversity. *Ambariz*, dried or semi-hard cheese from southern and Mount Lebanon terraces, benefits from

microclimates for long-term storage and distinctive flavor. *Samneh*, clarified butter, captures pasture-fed milk qualities.
Kishk, fermented yogurt and bulgur, integrates terrace-grown cereals and pasture-fed milk, providing winter food security. *"Kishk is our winter insurance; when snow covers the terraces, it feeds our family for months,"* reported a farmer from Deir El Ahmar. Women play a central role in processing, overseeing straining, fermentation, brining, drying, and flavoring with herbs: *"We teach our daughters how to make Chanklish and Kishk, preserving the taste of our mountains and the knowledge of our mothers."*

3.7 Lebanese *Mezze* and Traditional Dishes: Culinary Expressions of Agrobiodiversity

The Lebanese *Mezze* illustrates agrobiodiversity on the table, combining fresh vegetables, herbs, legumes, grains, preserved foods, and dairy, often sourced from landraces and wild foraged plants. *Stuffed grapevine leaves* (*Waraq Inab*) use tender local grape leaves with rice, bulgur, chickpeas, or lentils and herbs. *Makdous*, eggplants stuffed with walnuts, garlic, and chili, demonstrate seasonal preservation. *Hummus* from local chickpeas, *Baba ghanouj*, *Tabbouleh*, and *Fattoush* highlight cultivated and wild greens. Pomegranate juice or *Hosrom molasses* adds tang and nutritional value. Other dishes include *Fatayer Slika* (pastries with wild leafy vegetables), *Hindbeh* stew, and *Kebbe* in *Kishk*, combining grains, dairy, and meat. *Falafel*, made from ground chickpeas and/or fava beans blended with herbs and spices, *Mujadara,* a wholesome mix of lentils, bulgur, and caramelized onions, and *Loubié bi zeit*, tender green beans stewed in olive oil, are also emblematic dishes of the Lebanese *Mezze* and indispensable in households in rural areas as affordable nourishing meals.
Mezze preparations rely on TK showcasing seasonal, locally adapted crops and livestock products, harvest timing, and preservation knowhow, using local olive oil, dried herbs, pickled vegetables, fruit preserves, and fermented dairy. They anchor dishes in rural landscapes, embody the richness of local agrobiodiversity, the wisdom of traditional foodways, and stand as vital expressions of the Lebanese Mediterranean diet. At the same time, the Lebanese *Mezze*, often described as the queen of the table in restaurants across the country, brings together such dishes in colorful variety, shared in a spirit of conviviality and frequently accompanied by a glass of Arak or Lebanese wine.

3.8 Circularity, Climate Resilience, and Socio-Economic Benefits

Circularity is central in Lebanese agrobiodiversity systems, linking ecological sustainability, cultural heritage, and livelihoods. Farmers reuse whey, fruit peels, olive residues, and crop stems as feed, compost, or biofuel: *"Nothing is thrown away, the olive pulp feeds our sheep, and the whey goes back to the goats,"* explained a farmer from

Koura. Traditional processing practices such as drying, fermenting, and pickling valorize farm outputs into olive oil, dried fruits, herbs, molasses, and vinegar, supporting household consumption and local markets. *These practices converge in the long-standing tradition of Mouneh (Mune)—the preparation and preservation of seasonal surpluses into winter provisions—which functions as a living system of food security, knowledge transmission, and livelihood sustainability. Through Mouneh, households not only reduce waste and ensure year-round access to nutritious food, but also maintain a cultural identity rooted in resource efficiency and ecological balance.*

Farm-to-fork initiatives and agritourism further demonstrate the embeddedness of circularity in local food systems. At Tawlet Ammiq (Bekaa), terraces, polyculture gardens, and silvopastoral systems showcase sustainable harvesting, composting, and manure recycling. Visitors experience *Mouneh* staples such as olive oil, pickled olives, *Zaatar, Burgul*, *Frike, Kishk*, *Chanklish*, *Darfieh*, *Ambariz*, *Samneh*, and linking sensory appreciation with the ecological and cultural cycles that sustain them: *"The food tastes of the land; we can see how care for the soil and animals transforms into the dishes on our plate."*

Projects such as the Lebanon Reforestation Initiative (LRI), LIVINGAGRO, and Reviving Traditional Agricultural Practices promote agroforestry, terrace restoration, and native tree planting, enhancing soil fertility, water retention, and biodiversity. PASTINNOVA provides policy guidance linking traditional knowledge to circular economy strategies. Together, these initiatives not only improve soil and ecosystem health, but also reinforce the role of *Mouneh* as a climate-resilient strategy that boosts production of locally adapted crops and livestock products, strengthens household and community economies, and safeguards both cultural and biological diversity.

Table 1. Agrobiodiversity climate resilient traditional practices in Lebanon.

Category	Practice / Strategy	Key Species / Landraces	Purpose / Function	Role of Gender / Community	Climate / Ecosystem Benefit
Terracing & Slope Management	Dry-stone terraces, contour plowing	Olives, figs, grapes, pome & stone fruits, cereals, vegetables, aromatic herbs	Soil stabilization, erosion control, enhanced water retention, habitat for wild plants	Men: construction/repair; Women: cultivation of crops	Microclimate regulation, pollinator habitats, biodiversity support
Agroforestry / Tree-Crop Integration	Intercropping trees with cereals, legumes, fodder	Olives, figs, almonds, pines, mulberries, oak	Shade, soil fertility, livestock feed, diversified harvests	Women manage understory crops, home gardens	Soil fertility, carbon sequestration, climate-adaptive diversification
Landrace Cultivation	Site-specific crop selection, traditional varieties	Wheat (Jouri, Salamouni, Douchani), Barley (Rihan, Assi, Litani),	Resilient food production, cultural preservation	Women: seed selection, storage, processing	Drought/frost tolerance, reduced dependence on commercial seeds

Category	Practice / Strategy	Key Species / Landraces	Purpose / Function	Role of Gender / Community	Climate / Ecosystem Benefit
		Grapes (Oubeidi, Merwah), Local olives (Baladi, Soury)			
Seed Saving & Exchange	Seed selection, household storage, propagation, farmer-to-farmer exchange	Cereals, legumes, vegetables, fruit trees	Genetic diversity, adaptation to local microclimates	Women central in seed care and transmission	Community-level resilience, crop diversity maintenance
Domestication of Wild Edibles	Cultivation of wild herbs & vegetables	*Oregano*, *Hindbeh*, *Akkoub*, *Pine*, *Sumac*	Culinary use, supplemental income, ecological restoration	Community-led collection and planting	Conservation of wild species, diversification of agroecosystems
Livestock & Silvopastoral Systems	Seasonal grazing, transhumance	Baladi goats, Awassi sheep, local cattle	Milk, meat, manure; pasture management	Community knowledge-sharing, rotational grazing	Soil fertility, control of invasive species, rangeland resilience
Soil & Crop Management	Crop rotation, intercropping, organic fertilization	Cereals, legumes, olives, fruit trees, vegetables	Maintain soil fertility, reduce pests, enhance productivity	Women: composting, seed management	Nutrient cycling, reduced erosion, adaptive to semi-arid conditions
Water Management	Cisterns, canals, ponds, Hima governance	Olives, figs, grapes, cereals	Irrigation, drought resilience	Community: shared management; farmers guide technical input	Improved water availability, runoff reduction, ecosystem resilience
Local Foods & Culinary Practices	Traditional food production & processing	Wheat/barley products, olive oil, molasses, nuts, dried fruits, wild greens	Dietary diversity, cultural continuity, market income	Women: processing & preservation, cooperative marketing	Nutritional security, intergenerational knowledge transfer
Beverages & Distilled Products	Herbal infusions, floral waters, *Arak*, wine, vinegar	Sage, thyme, rose, orange blossom, grape varieties	Daily consumption, festive use, medicinal/culinary purposes	Women: tea/herbal preparation; Men: distillation	Cultural resilience, biodiversity valorization

Category	Practice / Strategy	Key Species / Landraces	Purpose / Function	Role of Gender / Community	Climate / Ecosystem Benefit
Animal Traditional Products	Dairy processing (*Labneh*, *Chanklish*, *Kishk*, etc.)	Goat & sheep milk	Flavorful, shelf-stable products, household nutrition	Women: cheese/dairy production & knowledge transmission	Preservation of genetic diversity, dietary resilience
Traditional Dishes / Mezze	Integration of crops, livestock, and wild species	Grapevine leaves, chickpeas, lentils, wild herbs, local dairy	Seasonal culinary expression, dietary diversity, cultural identity	Household and community preparation	Maintains crop/livestock diversity, promotes ecological stewardship
Circular Practices	Reuse of crop residues, olive pulp, whey, manure; composting; value-added processing; farm-to-fork & agritourism	Cereals, vegetables, fruits, olive products, livestock products	Nutrient recycling, animal feed, compost, value-added product creation, farm-to-fork experiences, tourism	Community and family-led implementation; women manage processing and preservation	Enhances soil fertility, reduces waste, strengthens farm-to-fork systems and agritourism, promotes sustainability

3.9 Geographical and Ecological Patterns of TK

Building on the extensive survey of traditional knowledge and climate-resilient practices across Lebanon's agroecosystems, the geographical and ecological distribution of TK illustrates how crop diversity, terrace management, agroforestry, livestock systems, and food processing are organized along altitudinal and climatic and socio-cultural gradients (Fig. 2; Table 2). These patterns reflect a dynamic interaction between ecological conditions and cultural practices, demonstrating Lebanon's position as a Mediterranean hotspot of biocultural diversity.

In the **coastal zones and lowland plains** (0–400 m), TK emphasizes intensive crop production supported by small-scale irrigation and community-based water management systems such as cisterns, canals, and the *Hima*. Olive and citrus groves dominate, sustained through pruning, grafting, and organic pest control transmitted over generations. Household gardens provide vegetables, legumes, and herbs, where women play

a central role in cultivation, seed care, and processing. The domestication and cultivation of wild species such as oregano, Hindbeh, and sumac further enrich diets, link coastal communities to local markets, and strengthen resilience to seasonal and economic fluctuations.

The **inland Bekaa Valley and mid-altitude zones** form another center of TK, where cereal and pulse landraces (wheat, barley, lentils, chickpeas) are maintained through robust seed selection, storage, and farmer-to-farmer exchange. Vineyards (e.g., Obeidi, Merwah, Meksasi) and fruit orchards reflect centuries of grafting, pruning, and adaptation to semi-arid conditions. Food processing traditions, such as wine, arak, molasses, and dried fruits, anchor this region in both national identity and regional markets. Women play a crucial role in processing and preservation, ensuring year-round household food security and intergenerational transfer of knowledge.

In the **mountain terraces and mid-to-high altitudes** (up to 1,700 m), TK is most visibly expressed in the construction and maintenance of dry-stone terraces, which prevent erosion, retain water, and sustain soil fertility on steep slopes. Intercropping of cereals, legumes, fruit trees, and aromatic herbs maximizes productivity in fragmented plots while supporting pollinators and soil health. Orchards of figs, mulberries, and almonds thrive at mid-elevations, sustained by traditional grafting and pruning knowledge. Women's home gardens, rich in vegetables and medicinal plants, reinforce dietary diversity and household resilience, while also serving as repositories of genetic resources.

At the **highest altitudes and rangelands**, pastoral and silvopastoral systems dominate. Shepherds and pastoralist families practice rotational grazing and seasonal herd movements (transhumance), which maintain rangeland productivity and conserve livestock genetic diversity, particularly in Baladi goats and Awassi sheep adapted to marginal environments. These practices are complemented by selective breeding and by the seasonal foraging of wild plants such as thyme, sage, and mallow, which serve both culinary and medicinal purposes. In these marginal zones, TK directly links biodiversity conservation with household resilience to climate variability and market dependence.

Across all ecological zones, TK is not only a set of adaptive practices but also a foundation of cultural identity, food sovereignty, and socio-economic resilience. Its eco-geographic distribution demonstrates how steep ecological gradients, from coastal plains to high mountain pastures, intersect with centuries of human innovation to generate resilient, multifunctional landscapes. Yet this knowledge is increasingly threatened by outmigration, climate stress, and modernization, particularly in marginal highland and pastoral systems where it is most critical for sustaining resilience and biocultural diversity.

Table 2. Ecogeographic distribution of traditional knowledge (TK) across Lebanon

Eco-Zone	Altitude / Ecology	Dominant TK Practices	Key Species / Landraces	Gender / Community Roles	Ecosystem & Resilience Contributions
Coastal zones & lowland plains	0–400 m; Mediterranean climate; irrigated plots & home gardens	Intercropping, crop rotation, small-scale irrigation (*cisterns, canals, Hima*), orchard management, wild edible domestication	Olives, citrus, vegetables, herbs (oregano, Hindbeh, sumac), legumes	Women: home gardens, herbs, seed care; Men: orchards, irrigation infrastructure	Soil fertility, pest reduction, dietary diversity, resilience to market fluctuations
Inland Bekaa Valley & mid-altitudes	400–1,200 m; semi-arid plains	Seed selection & exchange, cereal & pulse cultivation, vineyard & orchard management, food processing (wine, arak, molasses, dried fruits)	Wheat (Jouri, Salamouni), Barley (Rihan, Assi), Lentils, Chickpeas, Grapes (Obeidi, Merwah), Fruits	Women: seed storage, processing, preservation; Men: orchards, vineyards	Landrace conservation, drought/frost adaptation, food sovereignty, integration into local & export markets
Mountain terraces & mid-high altitudes	800–1,700 m; steep slopes; rainfall-dependent	Terrace construction/maintenance, agroforestry, intercropping, grafting & pruning, medicinal & vegetable home gardens	Figs, almonds, mulberries, cereals, legumes, aromatic herbs	Men: terrace building, tree orchards; Women: gardens, medicinal plants, seed saving	Erosion control, water retention, pollinator habitats, household food security
High-altitude rangelands & uplands	>1,200 m; marginal pastures	Transhumance, rotational grazing, silvopastoral systems, selective breeding, wild plant foraging	Baladi goats, Awassi sheep, local cattle; Wild herbs (thyme, sage, mallow)	Pastoralist families: herd management; Women: dairy transformation (labneh, kishk, chanklish)	Livestock genetic diversity, rangeland resilience, soil fertility via manure, biodiversity conservation

3.10 Sociocultural Significance and Continuity

Survey findings demonstrate that the continuity of TK in Lebanon is deeply embedded in socio-cultural practices that regulate planting, grazing, and harvesting, thereby buff-

ering climatic risks and reinforcing intergenerational transfer. This knowledge is maintained through everyday practices and community-based mechanisms rather than formal education, with women, elders, and pastoralist networks playing pivotal roles across agroecosystem.

Women emerged as central custodians of household and garden biodiversity. Through family mentorship, they transmit skills of seed saving, home gardening, food processing, and wild plant foraging to daughters and grandchildren. *"I keep the best seeds from each harvest and pass them to my daughters, just as my mother did, so the taste and strength of our crops never disappear,"* explained a woman in Deir El Ahmar. Their responsibilities extend into communal spaces—collective cooking, seasonal foraging, food preservation, and drying of herbs, fruits, and vegetables—where cultural values and ecological knowledge are reinforced. By carefully selecting seeds for culinary quality, drought tolerance, and storability, women safeguard local landraces and link biodiversity conservation to food culture and household resilience.

Elders serve as living archives of memory and ecological experience. Through oral traditions, storytelling, and seasonal rituals, they transmit knowledge of orchard pruning, terrace cultivation, and livestock care. As one male elder in the Shouf stressed: *"We know which tree to prune after the first snow and when to move the herd up the mountain; this knowledge cannot be learned from books, only from experience."* Their authority as keepers of ancestral wisdom provides continuity with past generations, though respondents highlighted that urban migration and modernization threaten this role, leaving the ecological memory of older generations at risk of erosion.

Community and pastoralist networks remain critical for sustaining TK in shared landscapes. Seasonal festivals, cooperative terrace restoration, and rotational grazing systems provide spaces for learning through observation and participation. Farmers described how *"when we repair terraces together, the young watch and learn the right way to build and maintain them."* Similarly, pastoralist groups transmit expertise in grazing routes, herd management, and silvopastoral integration through apprenticeship and collective practice, enabling younger generations to adopt adaptive strategies that sustain rangeland productivity and biodiversity.

3.11 Farmers Perceptions of Threats and Knowledge Gaps

Although TK is widely transmitted across generations through observation, apprenticeship, and communal practices, farmers across Lebanon perceive multiple, interlinked threats (Table 3) that increasingly challenge its continuity and effectiveness. Sometimes corroborated by local municipalities, these perceptions highlight ecological pressures, socio-economic transformations, cultural shifts, and institutional gaps that constrain the adaptation of TK to climate and development changes.

Ecological pressures were frequently cited, including irregular rainfall, extended droughts, and extreme weather events that disrupt seasonal rhythms essential for planting, transhumance, and wild plant foraging. Land degradation, soil erosion, and water scarcity further threaten both crop and livestock systems, with some farmers noting:

"We never know exactly when to plant or move the goats; the weather changes too quickly."

Socio-economic transformations are also evident. Rural outmigration, particularly of youth, reduces the number of knowledgeable hands available to sustain intergenerational learning. Market pressures push toward uniform, high-yield crops, undermining local landraces and low-input practices. Municipal representatives confirm that economic crises and labor shifts prioritize short-term survival over conservation-oriented strategies.

Cultural and social changes compound these challenges. Farmers report a decline in demand for traditional crops and wild foods due to shifting dietary preferences influenced by globalization: *"People prefer imported vegetables and packaged foods; our wild herbs are now less appreciated,"* noted one farmer. Communal governance systems, such as seed-sharing networks and customary grazing agreements, have weakened in many regions.

Institutional gaps further exacerbate the situation. Farmers and municipalities agree that limited documentation, research, and policy integration leave TK undervalued in development and conservation programs. Weak extension services and insufficient support for community-based initiatives reduce the capacity to sustain traditional practices, while the absence of legal protection for farmers' seeds and breeds exposes agrobiodiversity to industrial pressures.

Importantly, farmers in protected areas report a more positive situation. Here, community-based management, formal protection, and locally adapted governance help maintain seed diversity, safeguard transhumance routes, and preserve wild edible and medicinal plants. Farmers emphasize that intergenerational knowledge transfer remains strong, and landraces are better retained. One farmer from a Hima area noted: *"In our Hima, we still plant old varieties and share seeds; the rules help us protect both the land and our traditions."* These sites illustrate how formal protection combined with active local stewardship can mitigate broader threats and reinforce TK and agrobiodiversity resilience.

Table 3. Threats **and gaps undermining traditional knowledge systems in Lebanon.**

Dimension	Observed Threats and Gaps	Implications for Agrobiodiversity and TK
Ecological	Climate variability (drought, irregular rainfall, extreme events); soil erosion; land degradation; water scarcity	Disrupts seasonal calendars and adaptive practices; reduces productivity of landraces; threatens livestock and forage diversity
Socio-Economic	Rural outmigration and youth disinterest; economic crisis; market pressures for uniform crops	Weakens intergenerational transmission; undermines viability of low-input practices; reduces resilience of rural households

Dimension	Observed Threats and Gaps	Implications for Agrobiodiversity and TK
Cultural	Shifting diets toward imported/processed foods; weakening of communal governance systems; erosion of oral traditions	Declines in demand for traditional crops, wild foods, and artisanal products; fragmentation of collective resource management
Institutional	Lack of documentation and research; weak policy integration; insufficient extension services; absence of seed/landrace protection	TK undervalued in policy frameworks; inadequate support for conservation; vulnerability to external appropriation
Generational threat	Reduced transmission of TK from elders to youth; loss of experiential knowledge	Accelerated erosion of farming, foraging, and pastoral knowledge; decline in adaptive strategies to climate variability

4 Discussion

This study highlights the critical role of TK in supporting climate-resilient and sustainable food systems across Lebanon's heterogeneous agroecosystems. TK emerges as a multidimensional system encompassing crop and livestock management, seed selection, wild plant foraging, food processing, and landscape engineering, all finely adapted to local ecological conditions. Embedded within socio-cultural networks and intergenerational transmission pathways, these practices provide both ecological and cultural resilience. Importantly, TK underpins emerging circular economy strategies, farm-to-fork initiatives, and agritourism, illustrating its potential to support sustainable rural development and heritage conservation (Cramer et al., 2018; Turtureanu et al., 2025).

4.1 TK As A Foundation for Resilience and Agrobiodiversity Conservation

Lebanese farmers and pastoralists maintain integrated practices that combine crop, livestock, and wild plant management to create multifunctional agroecosystems. Seed saving, exchange, and selection of cereals, pulses, and vegetables maintain adaptive genetic pools, enhancing resilience to drought, pests, and other climate-related stresses (Calvet-Mir et al., 2012; Kiran Babu Rampal, 2024). Orchard and tree management practices of olive, grape, fig and other fruit trees including grafting and pruning, conserve fruit tree landraces while sustaining culturally significant diets and rituals. Intercropping, crop rotation, and polyculture improve soil fertility, reduce pest pressure, and decrease dependence on external inputs (Somashekar, 2024; Terán-Samaniego et al., 2025). Terrace cultivation exemplifies the synergy of ecological and technical

knowledge, embedding erosion control and water management in centuries-old landscape engineering (Bevan & Conolly, 2011; Hani et al., 2021; Zoumides et al., 2025).
Silvopastoralism constitutes a central pillar of Lebanon's upland and mountain systems. By integrating trees, shrubs, and pastures with rotational grazing, pastoralists maintain adaptive livestock breeds, conserve multipurpose trees, and support nutrient cycling, wildfire prevention, and pollinator habitats. These systems produce milk, artisanal cheeses, and other animal products tied to food heritage, demonstrating how TK simultaneously supports biodiversity, livelihoods, and cultural identity. When combined with wild plant foraging, these practices extend dietary diversity and enhance resilience against market shocks or climate variability (Dubeuf et al., 2023; Lecegui et al., 2024; UN, 2024).
Importantly, TK-based systems also **safeguard crop wild relatives (CWR),** wild species genetically related to cultivated crops that are critical for breeding future climate-resilient varieties. Wild plants such as sumac, chicory, and local legumes in terraces, orchards, and rangelands contribute both to dietary diversity and to the maintenance of adaptive traits (Chalak et al., 2011; 2020; Sayde et al., 2025). However, farmers generally **do not recognize these plants as "CWR";** their conservation occurs implicitly through traditional practices, such as rotational grazing, wild plant foraging, and maintenance of field margins. Establishing **in situ and ex situ genetic reserves** could complement TK, ensuring these genetic resources are protected against climate change, habitat loss, and genetic erosion, and remain available for crop improvement programs.

4.2 Socio-Cultural Embedding and Circular Economy Pathways

TK in Lebanon is maintained through complex social networks involving women, elders, pastoralists, and community gatherings. Women transmit knowledge of seed saving, home gardening, food processing, and foraging through household mentorship and communal activities, while elders preserve orchard, livestock, and terrace management techniques via oral traditions. Pastoralist networks sustain landscape-level knowledge through apprenticeship and cooperative grazing, ensuring continuity of adaptive practices and agrobiodiversity (Delêtre et al., 2015).
Circular economy principles are strongly embedded in these practices. Olive oil production, a culturally and economically central activity, exemplifies this integration: residues are repurposed as fodder or biofuel, closing nutrient loops and reducing waste. Traditional food processing—including drying, fermenting, and pickling—extends shelf life, reduces dependence on external markets, and generates added income through artisanal products such as arak, kishk, dried figs, and herbal teas. The integration of TK into **farm-to-fork initiatives and agritourism** further strengthens these circular systems, allowing visitors to experience terraces, olive groves, vineyards, and pastoral landscapes while providing rural households with alternative income streams. These initiatives also serve as **educational platforms for sustainability**, where students, local communities, and visitors learn about biodiversity conservation, landscape

management, and sustainable food production, reinforcing both ecological awareness and cultural identity (Gebru et al., 2019; Liu et al., 2022).

4.3 Geographical and Ecological Differentiation

TK is highly context-specific, shaped by distinct ecological zones. Coastal plains and lowlands emphasize intensive crop production and orchards, with women managing home gardens and herbs to diversify diets. Inland valleys, such as the Bekaa, host cereal, pulse, vineyard, and orchard systems with strong seed saving and landrace conservation, anchoring Lebanon's agrifood identity in wine, arak, and dried fruit production. Mountain terraces combine intercropping, terrace maintenance, and orchard management to optimize fragmented landscapes, while highland pastures rely on silvopastoral practices and wild plant foraging to maintain rangeland productivity and genetic diversity (Oikonomou et al., 2023). This ecological specificity underscores Lebanon's status as a Mediterranean hotspot of biocultural diversity, where adaptation to steep gradients and variable microclimates has generated a mosaic of resilient agroecosystems (Brummer et al., 2019).

4.4 Threats and Knowledge Gaps

Despite its resilience, TK faces multiple interlinked threats. Climate variability, land degradation, and water scarcity disrupt ecological rhythms essential for planting, grazing, and foraging (Nketsang et al., 2025). Rural outmigration, youth disinterest, and urbanization weaken intergenerational knowledge transmission, while economic pressures favor uniform, high-yield crops over low-input landraces (Zhang et al., 2025). Cultural shifts toward imported or processed foods reduce demand for traditional crops, and erosion of communal labor and oral traditions further compromises transmission pathways (FAO, 2019; 2023). Institutional gaps, including insufficient documentation, policy integration, and legal protection for seeds and breeds, leave TK undervalued and vulnerable, threatening both biodiversity and food sovereignty, particularly in highland and pastoral systems.

4.5 Implications for Policy and Sustainable Food Systems

The findings suggest several pathways to reinforce TK as a pillar of climate-resilient food systems. Policies should support intergenerational knowledge transfer, protect seed and breed diversity, and integrate TK into climate adaptation and rural development frameworks (Johns et al., 2013). Circular economy approaches, farm-to-fork initiatives, and agritourism create economic incentives that align heritage practices with market opportunities, enhancing cultural and ecological sustainability (Ingrassia et al.,

2023). Scientific research and extension services should complement TK by providing tools for improved resource management while respecting local expertise (Scaramuzzi et al, 2021). Such hybrid approaches can strengthen agroecosystem adaptive capacity and safeguard Lebanon rich biocultural heritage.

5 Conclusion

Traditional knowledge in Lebanon represents a dynamic, site-specific system that sustains agrobiodiversity, reinforces ecological resilience, and underpins culturally embedded food systems. Practices such as seed saving, intercropping, rotational grazing, and wild plant foraging maintain adaptive genetic pools, enhance ecosystem services, and support multifunctional landscapes across diverse ecological zones. Women, elders, and pastoralist networks play central roles in transmitting TK, ensuring its continuity despite the growing anthropogenic threats and climatic pressures. TK also facilitates circular economy pathways through food processing, residue reuse, and value-added production, while integration with agritourism and farm-to-fork initiatives links heritage practices to sustainable livelihoods and market opportunities.
However, to cope with and adapt to growing threats from climate variability and various pressures that jeopardize intergenerational knowledge transfer and the viability of climate-resilient practices, TK must be integrated into policy frameworks, supported through community-based initiatives, and incentivized for sustainable agrobiodiversity stewardship. Documenting, valorizing, and linking TK to circular economy approaches should be aligned with market-oriented strategies to maximize its role in climate-resilient food systems, rural sustainability, and the preservation of Lebanon's biocultural heritage, providing a strong foundation for participatory interventions and evidence-based policy support.

Acknowledgments. The author gratefully acknowledges Dr. Safa Baydoun (Beirut Arab University, Lebanon) and Dr. Eliane Sayde (University of Perugia, Italy) and for their pertinent revision, constructive comments, and insightful suggestions, which greatly enhanced the clarity and scientific depth of this manuscript. The author also thanks the team of young students from the Faculty of Agronomy at the Lebanese University who actively contributed to conducting the survey and engaging with farming communities. The authors would like to deeply thank all informants, including farmers and municipalities, for their time, knowledge, and participation.

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