A Critical Evaluation of Ecological, Environmental, and Legal Consequences of Cedrus libani Afforestation and Monoculture Plantations in Lebanon: The Case of Mount Sannine

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Cedrus libani (Cedar of Lebanon) is ecologically and culturally significant, but vulnerable due to historical decline and ongoing threats. This has driven extensive *afforestation and reforestation* efforts in Lebanon. Initiatives like the Sannine Project, however, often utilize large-scale monoculture plantations, frequently as *afforestation* on land without confirmed historical dense forest cover. This study critically evaluates this approach, synthesizing peer-reviewed literature, project-related public communications and reports, data from the authors' botanical surveys of the affected Sannine area, and relevant legal frameworks.. Our analysis indicates that monocultures, particularly when implemented with damaging techniques like heavy machinery on these often naturally open mountain habitats, pose significant ecological risks. These include soil degradation (exacerbated by allelopathy), altered hydrology, suppression of native understory, substantial biodiversity loss (especially unique endemics adapted to open habitats), and reduced ecosystem resilience. Furthermore, such projects reportedly proceed without mandatory prior Environmental Impact Assessments, violating Lebanese law and undermining effective environmental governance. These practices contradict sound ecological restoration principles that prioritize biodiversity, ecosystem function, and site-specific appropriateness ("beyond hectares"). We conclude that a fundamental shift towards mixed-species, ecologically sound planting, guided by site-specific assessments, robust monitoring, adaptive management, and strict legal compliance, is essential for the sustainable restoration of *C. libani* and the protection of Lebanon's vital mountain landscapes, recognizing the importance of conserving existing non-forest habitats.

Keywords: *Cedrus libani*, Monoculture Plantations, Afforestation, Ecological Restoration, Biodiversity, Endemism, Environmental Law, Lebanon

1. Introduction

Cedrus libani, the iconic Cedar of Lebanon, stands as a potent national symbol and a keystone species within the country's mountain ecosystems, embodying immense ecological, cultural, and historical value. Historically, extensive cedar forests covered vast areas of the Mount Lebanon range. However, centuries of deforestation, coupled with overgrazing, habitat fragmentation, and

increasingly, the impacts of climate change, have drastically reduced its distribution (Hajar et al., 2010; Ministry of Environment/UNDP, 2016). This decline has led to *C. libani* being classified as Vulnerable on the IUCN Red List (Gardner, 2013), prompting numerous, often large-scale, afforestation and reforestation initiatives aimed at reversing this trend.

While increasing tree cover is a valid conservation goal, the dominant strategy in Lebanon, exemplified by projects such as the Sannine Reforestation Project, frequently involves the establishment of extensive, high-density monoculture plantations of *C. libani*. This approach, while potentially effective at rapidly increasing tree numbers, raises significant ecological concerns and its long-term sustainability, particularly in complex mountain environments, is subject to ongoing debate (Kelty, 2006; Jactel et al., 2009). Ecologically sound forest restoration emphasizes not just tree cover, but the recovery of ecosystem function, biodiversity, and resilience (Brancalion et al., 2019; Holl & Brancalion, 2020). Monoculture plantations inherently simplify ecosystems and are particularly vulnerable to species-specific pests, diseases, and climatic extremes like severe drought (Jactel et al., 2005). Furthermore, coniferous species, including cedars, are known to release allelochemicals that can inhibit the growth of other plants, potentially suppressing native understory diversity (Teixeira da Silva et al., 2015 ; Binkley & Giardina, 1998).

Moreover, applying large-scale tree planting in areas that were not historically dense forest, such as certain high-altitude grasslands, shrublands, or rocky outcrops, constitutes *inappropriate afforestation*. This can actively damage unique, non-forest ecosystems and imperil specialized flora adapted to open conditions (Winberg et al. 2024; Gómez-Aparicioet al., 2009). Mount Sannine, as our botanical surveys demonstrate, harbors exceptional levels of endemic plant species, many of which are adapted to these open mountain habitats.

This paper critically evaluates the ecological and environmental consequences of the prevailing *C. libani* monoculture reforestation strategy in Lebanon, using the Sannine Reforestation Project as a detailed case study. We synthesize existing ecological knowledge, drawing on global research on plantation impacts, and analyze the project's practices in light of national environmental policies and international best practices for ecological restoration. We aim to highlight the potential limitations and risks associated with a monoculture approach, particularly in a biodiversity hotspot like Mount Sannine, and propose evidence-based recommendations for a more ecologically sound and legally compliant restoration framework for Lebanon.

Objectives

Building upon the identified concerns regarding current reforestation practices, the specific objectives of this paper are to:

1. Synthesize the ecological arguments comparing monoculture versus mixed-species planting approaches, including mechanisms like allelopathy, and their implications for biodiversity and ecosystem function, particularly for slow-growing, high-conservation-value species like *Cedrus libani*.
2. Analyze the extent to which large-scale reforestation practices, using the Sannine Reforestation Project as a case study, align with key Lebanese environmental legal

frameworks (notably Law 444/2002 and Decree 8633/2012) and international best-practice guidelines for ecological restoration (e.g., the Society for Ecological Restoration's International Standards, Convention on Biological Diversity commitments).

3. Identify the key ecological shortcomings and potential long-term risks associated with the large-scale deployment of the cedar monoculture model and associated planting techniques observed at the Sannine Reforestation Project, including soil degradation, alteration of hydrology, and loss of endemic and understory biodiversity.
4. Propose evidence-based recommendations for shifting towards more resilient, biodiverse, ecologically appropriate, and legally compliant forest restoration strategies in Lebanon, emphasizing site-specific approaches and the conservation of existing valuable habitats.

2. Methods

This study employed a qualitative approach based on the synthesis and critical analysis of secondary data sources to evaluate the *Cedrus libani* monoculture reforestation strategy in Lebanon, focusing on the Sannine Reforestation Project as a case study.

2.1. Study Area / Case Study Context

Our analysis focuses on reforestation efforts in three main areas on Mount Sannine: the Qanat Bakish region on the mountain's eastern slopes (approximately 34.04° N, 35.86° E), a site above Sayyidat al-ʻāli (approximately 33.93° N, 35.85° E), and a privately owned parcel in Mtayn village (approximately 33.92° N, 35.86° E). These sites are located within the Mount Lebanon range, characterized by rocky limestone terrain, thin soils, and a Mediterranean montane climate with cold, snowy winters and dry, mild summers. Historically, these slopes have been used for seasonal grazing and have experienced other anthropogenic pressures, shaping the current landscape. The specific initiative referred to as the Sannine Reforestation Project, carried out from 2018 onwards primarily by the Lebanon Reforestation Initiative (LRI) in collaboration with local partners and government ministries (MoA, MoE), aims to plant *Cedrus libani* at elevations ranging from 1,600 to 1,900 meters.

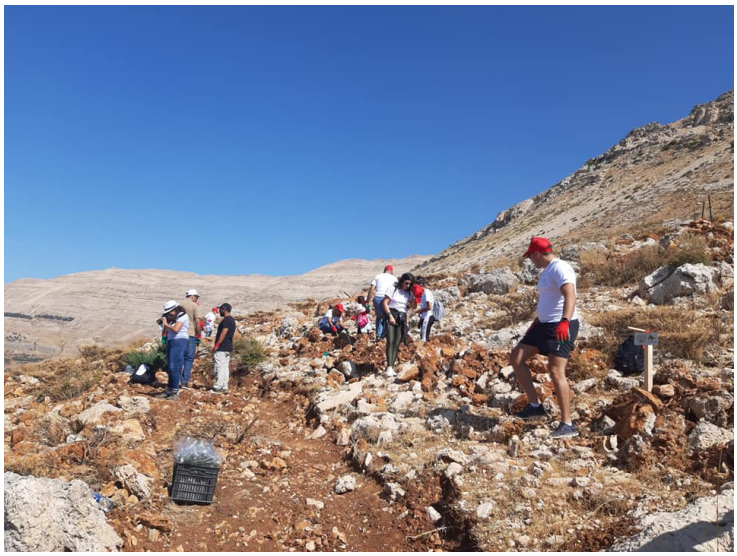
LRI is a Lebanese non-governmental organization (NGO) registered in 2014 and an IUCN member since 2019. Its origins trace back to 2011 when the US Forest Service (USFS) International Program launched the Lebanon Reforestation Initiative (LRI) as a multi-year, US $12 million project (CBD, 2015). The initial aims of this USFS-led initiative included planting 300,000 native tree seedlings, improving seedling quality, and increasing awareness of forest protection issues. By June 2015, LRI reported significant accomplishments, including the planting of over 545,000 seedlings from more than 20 native tree species across 750 ha, achieving a 76% survival rate, improving nursery practices through the establishment of the Cooperative of Native Tree Producers of Lebanon (CNTPL), and developing Lebanon-specific reforestation protocols (CBD, 2015). While LRI transitioned to an NGO in 2014 and has since received support from various national and international partners, including governmental agencies from Germany, Australia, and the Republic of Korea, as well as UN agencies like ILO and WFP, as listed on LRI's official communications and website (Spirit of America; KAS Lebanon; HSS; IKI Small Grants; Australian

Embassy Lebanon; Embassy of the Republic of Korea in Lebanon, ; IUCN, UN Decade on Ecosystem Restoration, UN Department of Economic and Social Affairs) and many more.

While regional paleoecological evidence suggests *C. libani* was historically more widespread in Mount Lebanon (Hajar et al., 2010), direct site-specific paleoecological or archaeological data definitively confirming extensive dense cedar forests on Sannine itself are lacking. Therefore, references to "historically deforested high-elevation lands" in Sannine remain an inference based on broader regional patterns, not site-specific proof (Hajar et al., 2010).

Figure 1: Extensive ground disturbance across Mount Sannine resulting from site preparation for *Cedrus libani* monoculture plantations. Satellite imagery reveals newly constructed access roads (orange lines) and widespread, regularly spaced planting pits created by heavy machinery, leading to significant soil disruption, habitat fragmentation, and alteration of natural topography. (Image source: Google Maps, 2024).

Figure 2: Ground-level view of a planting site on Mount Sannine, illustrating the severe soil disturbance and alteration of the natural rocky terrain resulting from site preparation techniques. Such conditions can lead to increased erosion, loss of existing vegetation and soil seed banks, and challenges for ecosystem recovery. (Image source: Lebanon Reforestation Initiative Facebook page, 2023).



2.2. Information Gathering and Document Analysis

We conducted a comprehensive review and critical analysis of secondary data sources. This included:

- **Peer-reviewed scientific literature:** Accessed via Web of Science, Scopus, Google Scholar, Researchgate, and Sciencedirect. Keyword searches included "Cedrus libani", "reforestation", "afforestation", "monoculture", "mixed-species planting", "ecological restoration", "biodiversity", "ecosystem services", "allelopathy conifers", "inappropriate afforestation", "Lebanon", "Mount Sannine", "environmental policy Lebanon", and relevant author names (e.g., Brancalion, Holl). We focused on publications from 2010 to 2024 addressing ecological impacts of planting strategies, *C. libani* ecology, restoration best practices, allelopathy in conifers, impacts on soil/biodiversity, and relevant legal/policy analyses.
- **Grey literature and project documentation:** This included project proposals and annual reports from LRI's website (LRI, 2021), available documentation on Environmental Impact Assessments (EIAs) or Initial Environmental Examinations (IEEs) related to the project, official government communications (e.g., from the Ministry of Environment and the municipality of Baskinta), planting records (species lists, density, survival rates) where available, publications from local and national level NGOs (e.g., Baskinta Baytouna,

Cultural Movement of Baskinta, T.E.R.R.E. Liban), press releases from donor agencies (e.g., USAID, FAO), and news articles covering the Sannine reforestation (e.g., Nidaa Al-Watan). Acquisition involved searching public online sources (LRI website, Daleel Madani), lodging official requests, and reviewing partner websites. The reported absence of readily available EIAs or IEEs prior to implementation was a key finding factored into the assessment of regulatory compliance.

- **Site-specific botanical data:** Data regarding current plant species richness, endemism levels, and conservation statuses on the western slopes of Mount Sannine are derived from the author's ongoing botanical surveys initiated in 2018 (Annex 1).

2.3. Analytical Framework

We systematically analyzed the collected information using a comparative framework, contrasting the reforestation practices at the Sannine Reforestation Project with:

1. **Established ecological principles for forest restoration:** Including concepts of biodiversity, ecosystem resilience, soil health, understory dynamics, and the avoidance of inappropriate afforestation (Fisher & Binkley, 2000; Gamfeldt et al., 2013; Brancalion et al., 2019; Holl & Brancalion, 2020). We specifically incorporated principles related to allelopathy in conifer plantations and its effects on understory and soil biota (Teixeira da Silva, 2015; Zhou, X. et al., 2017).
2. **Key Lebanese environmental legislation:** Notably Law 444/2002 (Environmental Protection Law) and Decree 8633/2012 (on EIAs), focusing on whether project activities, particularly in sensitive mountain ecosystems, required environmental assessments.
3. **Relevant international guidelines:** Such as the Society for Ecological Restoration (SER) International Standards and Lebanon's commitments under the Convention on Biological Diversity (CBD), assessing alignment with global best-practice restoration principles (e.g., prioritizing native species diversity, site-specific design, consideration of the restoration continuum beyond just tree cover).
4. **National Biodiversity Strategies and Goals:** Assessing the Sannine Reforestation Project's alignment with Lebanon's stated national commitments to biodiversity conservation, ecosystem stability, and sustainable forest management, as articulated in documents like the 1998 National Biodiversity Strategy and Action Plan (NBSAP) and the country's reports to the Convention on Biological Diversity (e.g., CBD, 2015).

Through this comparative analysis, we identified ecological gaps inherent in *C. libani* monoculture plantings, assessed the project's regulatory alignment, and developed evidence-based recommendations for more resilient, biodiverse, ecologically appropriate, and legally compliant reforestation strategies in Lebanon.

3. Ecological Impacts of *Cedrus libani* Monocultures and Associated Practices

Our analysis indicates that large-scale *Cedrus libani* monoculture plantations, especially when implemented with certain techniques reportedly used in Lebanon, pose significant ecological risks, amplifying the inherent drawbacks of single-species stands.

3.1. Soil Health Degradation

Coniferous trees like pines and cedars naturally alter soil chemistry through the slow decomposition of acidic, lignin-rich needle litter. This process leads to the accumulation of organic acids, depletion of base cations, and long-term soil acidification, which negatively affects nutrient availability and biological activity. In monoculture systems, these effects are amplified (Binkley & Giardina, 1998; Hummes et al., 2024). Furthermore, coniferous species, including *C. libani*, are known to produce allelochemicals released through leaf litter and root exudates. These compounds can inhibit the growth and germination of other plant species (Teixeira da Silva, 2015), and also alter soil microbial communities, typically reducing their richness and changing community composition due to the acidic, low-nutrient environment created by the litter (Zhou, X. et al., 2017; Zhu et al., 2021). These chemical changes, combined with the lack of diverse leaf litter from other species in a monoculture, create a less fertile and less biologically active soil environment compared to mixed stands (Fisher & Binkley, 2000).

Moreover, the physical methods reportedly employed in large-scale cedar planting projects in Lebanon appear to exacerbate soil degradation significantly:

- **Intensive Soil Disturbance:** The documented use of heavy machinery to dig extensive, closely spaced pits and the creation of new access roads cause severe soil compaction, destroy existing soil structure, disrupt subsurface water flow, increase erosion risk manifold, and eliminate existing vegetation and seed banks over large areas (Fig. 1 and fig. 2). This physical damage can have long-lasting negative consequences on soil fertility, structure, and stability, especially on fragile mountain slopes with thin soils.
- **Compounded Negative Effects:** These severe physical impacts occur alongside the chemical and biological changes induced by cedar monocultures (acidification, altered nutrient cycling, reduced microbial diversity, allelopathic effects), creating a compounded negative effect on overall soil health and its capacity to support a diverse and resilient ecosystem (Fisher & Binkley, 2000; Xu et al., 2021; Hummes et al., 2024).

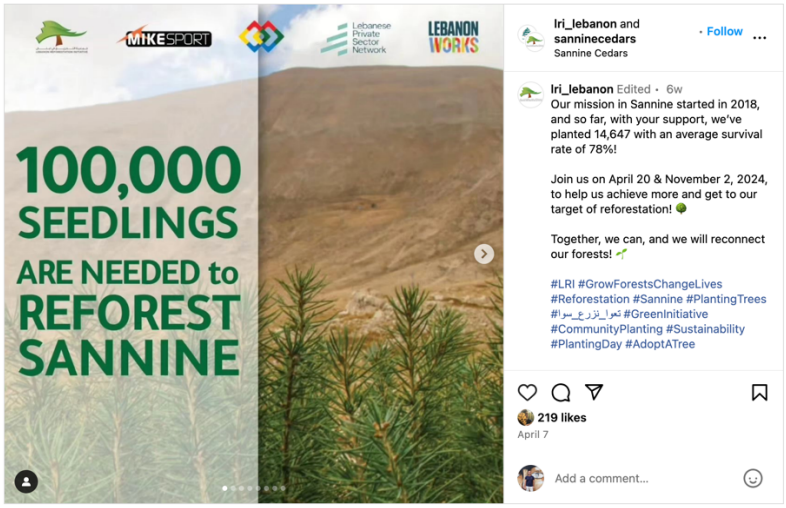
3.2. Alteration of Water Cycles and Hydrology

Dense cedar canopies reduce groundwater recharge through high interception and evapotranspiration rates compared to less dense or different vegetation types (Boulet et al., 2021). Associated damaging planting practices add further hydrological disruption:

- **Altered Runoff Patterns:** Soil compaction from heavy machinery and the creation of impermeable road surfaces drastically increase surface runoff, potentially leading to flashier stream responses, reduced infiltration, and increased erosion and downstream sedimentation (Fisher & Binkley, 2000).
- **Disruption of Wetlands/Seeps:** Road construction and large-scale soil disturbance risk draining or disrupting sensitive mountain micro-habitats like seeps and wetlands, which serve as critical water sources in the landscape.
- **Threat to Specialized Flora:** This disruption poses a severe threat to specialized flora adapted to these moist conditions, such as the Critically Endangered (IUCN) microendemic *Alchemilla diademata* Rothm. Its habitat in wetlands downslope from the

plantations near Sayyidat al-ʿĀli is directly impacted by any changes in the quantity or chemical composition of water runoff originating from the project site (El Zein & Kahale, 2022).

Figure 3: Promotional material for the Mount Sannine reforestation efforts highlighting a target of 100,000 seedlings. This exemplifies the emphasis on large-scale, quantifiable planting metrics often favored in reforestation initiatives, which can overshadow considerations of ecological appropriateness and biodiversity outcomes. (Image source: Lebanon Reforestation Initiative page on Facebook, April 07, 2025).



3.3. Biodiversity Loss

The western slopes of Mount Sannine, the area subject to the afforestation projects under review, represent a critical reservoir of plant biodiversity of national and international importance. Our ongoing botanical surveys, initiated in 2018, have documented a rich flora characterized by exceptional levels of endemism and a high concentration of threatened species (see Annex 1 for a detailed preliminary inventory and conservation status of recorded taxa).

Key findings from these surveys (summarized from Annex 1) underscore Mount Sannine's status as a vital, yet unprotected, center for plant diversity in Lebanon (Bou Dagher-Kharrat et al., 2018; El Zein & Kahale, 2022):

- Over 430 vascular plant species are estimated for the area, with 330 species photographically documented and accessible online (see Methods section 2.2 and Annex 1 for details).
- The area harbors at least 28 plant taxa strictly endemic to Lebanon, including 3 species currently known only from Mount Sannine itself, such as the Critically Endangered (CR) *Alchemilla diademata* and the newly identified *Onosma sanninensis* (preliminarily assessed as CR). These Lebanese endemics represent approximately 30% of the country's total endemic flora.
- A significant number of species endemic to the wider region (e.g., Lebanon-Syria, Lebanon-Turkey) are also present.

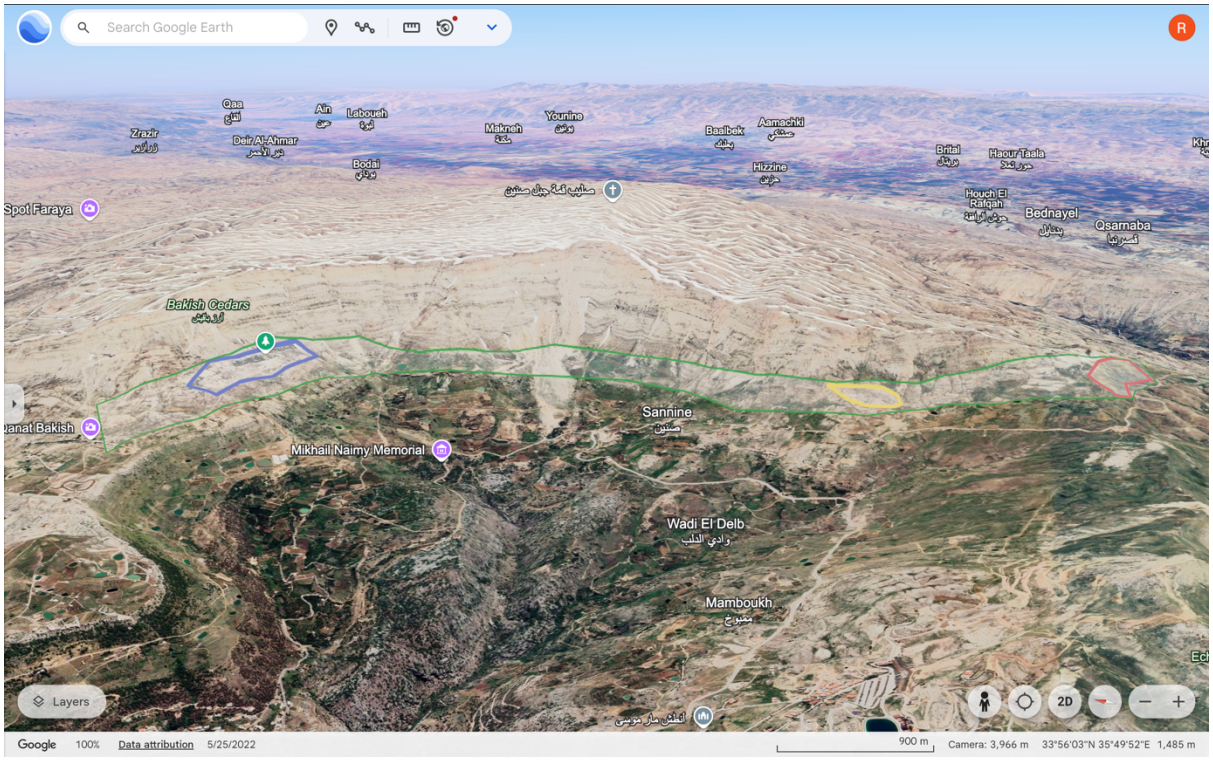
- At least 30 plant taxa recorded on these slopes are considered at risk according to IUCN criteria or preliminary assessments (CR, EN, VU, NT), constituting roughly 28% of all endangered plant species currently recognized in Lebanon. This includes multiple Critically Endangered and Endangered species, with several potentially already extinct in the area (e.g., *Tripleurospermum sannineum*).

This documented high biodiversity, concentration of narrow endemics, and significant number of threatened species unequivocally establish the western slopes of Mount Sannine as a crucial national biodiversity hotspot. It is particularly vulnerable to the impacts of large-scale land use changes like monoculture plantations. Monocultures inherently simplify such ecosystems and reduce biodiversity (Gamfeldt et al., 2013; Zangy et al., 2021). When implemented with invasive techniques in biodiversity hotspots like Mount Sannine, the damage is amplified through several mechanisms:

- **Habitat Destruction:** The use of heavy machinery and road building for site preparation does not just shade out understory plants; it physically destroys existing habitats and plant communities, including potentially rare or endemic species present on the site *before* the cedars even grow. This represents direct elimination of biodiversity.
- **Understory Suppression (Shade and Allelopathy):** Dense cedar canopies cast heavy shade, severely limiting light availability for ground flora (Zangy et al., 2021). Coupled with the accumulation of acidic cedar needle litter and the release of allelochemicals (Teixeira da Silva, 2015), the understory in dense cedar monocultures becomes depauperate, often consisting of very few or no native herbs and shrubs (Zhou, X. et al., 2017; Liphshiz, C., 2022). This directly contrasts with the rich, diverse understories found in more natural, mixed forests or open habitats.
- **Exacerbated Impact on Heliophilous Endemics:** For sun-loving endemics like *Cephalaria cedrorum* (found in the Shouf Cedar reserve) and other species specific to Mount Sannine (some identified in our surveys as Critically Endangered or potentially extinct), the initial habitat destruction by machinery, followed by the eventual canopy closure and allelopathic effects of a dense cedar monoculture, represents a double blow from which recovery is highly unlikely (El Zein & Kahale, 2022; Bou Dagher-Kharrat et al., 2018). Imposing a dense forest structure through afforestation onto historically open habitats like rocky outcrops, grasslands, or sparse shrublands, where many endemics are adapted to thrive, is particularly damaging and constitutes inappropriate afforestation (Winberg et al., 2024; Gómez-Aparicio et al., 2009). Such monocultures can effectively become "biological deserts" compared to the diverse native plant communities they replace (Gómez-Aparicio et al., 2009).
- **Conflict with Endemic Conservation:** The case of Mount Sannine, demonstrated by our findings as one of Lebanon's most critical areas for plant endemism, is particularly concerning. The implementation of large-scale (e.g., LRI's reportedly targeted 100,000 trees for the Sannine Reforestation Project) cedar monoculture projects using these damaging techniques, in an unprotected area vital for Critically Endangered microendemics, starkly illustrates the conflict between volume-based planting targets and biodiversity conservation (Bou Dagher-Kharrat et al., 2018; LRI Promotional Material, 2023). This practice prioritizes planting a single, vulnerable species (*C. libani*) at the potential expense of much rarer, critically threatened flora documented in the area. The

focus on simply counting trees or hectares planted ("beyond hectares" critique by Brancalion et al., 2019) overlooks the crucial need for species diversity and the conservation of existing, non-forest habitats.

Figure 4: Map of the western slopes of Mount Sannine illustrating the designated "Cedar Corridor" (bounded by green lines) as outlined in national afforestation and reforestation plans. Colored clusters represent major *Cedrus libani* afforestation sites implemented by the Lebanon Reforestation Initiative (LRI). Elevation ranges from 1,450 to 2,050 meters. Base imagery: Google Earth, acquired on 25 May 2025.



3.4. Reduced Ecological Resilience and Functionality

Monocultures are inherently less resilient to disturbances such as pests, diseases, drought, and fire compared to mixed-species stands (Jactel et al., 2005; Pausas et al., 2004). The methods used can further compromise long-term success and overall ecosystem functionality:

- **Compromised Establishment and Growth:** Severe soil compaction and disruption caused by heavy machinery can hinder the long-term growth and health of the planted cedars themselves, potentially reducing the ultimate success rate and resilience of the plantation to stressors.
- **Inhibition of Natural Succession:** The combination of dense monoculture planting, severe ground disturbance, understory suppression by shade and allelopathy, and the lack of diverse seed sources actively inhibits natural ecological succession and the potential future colonization by other native plant and associated faunal species (Zhu et al., 2023; Pérez-Gómez et al., 2024). This locks the site into a simplified, low-diversity, and low-resilience state, failing to restore the full complexity and functionality of a native

forest ecosystem, including critical processes like pollination and nutrient cycling which depend on diverse plant and soil life (Gamfeldt et al., 2013; Zhou, X. et al. 2017).

- **Increased Fire Risk:** Dense monocultures, especially of conifers which produce flammable litter, can be highly susceptible to wildfires, particularly in Mediterranean climates (Liphshiz, C., 2022). A single fire can devastate a large, uniform plantation, highlighting the lack of resilience inherent in this structure.

4. Legal, Procedural, and Socioeconomic Context

Beyond direct ecological impacts, the implementation of large-scale cedar planting projects raises significant concerns regarding legal compliance, environmental governance, and underlying socioeconomic drivers.

4.1. Legal and Procedural Concerns: Environmental Assessments

Lebanese Environmental Law 444/2002 (Article 25) and its implementing Decree 8633/2012 on Environmental Impact Assessment clearly mandate that projects involving agriculture and forestry, specifically "reforestation and afforestation projects" (Decree 8633, Annex 1, Category 4), require at least an Initial Environmental Examination (IEE). Furthermore, projects located in environmentally sensitive areas (Decree 8633, Annex 3), which explicitly include habitats for threatened species like those found in the high mountains of Mount Lebanon, including Sannine, are flagged as requiring assessment, potentially escalating to a full EIA if significant impacts are likely (Decree 8633, Article 5c).

The critical importance of this legal requirement for prior assessment in sensitive mountain ecosystems is underscored by the existence of extremely localized and threatened endemic species on Mount Sannine. A stark example from another area is *Chaerophyllum syriacum* Hoffmanns. & Link, a Critically Endangered plant endemic exclusively to Mount Lebanon, once thought extinct but rediscovered in a single small location (IUCN, 2019). The potential presence of such highly vulnerable, potentially unknown, or poorly documented species highlights the absolute necessity of conducting thorough, site-specific environmental assessments before initiating ground-disturbing activities like large-scale reforestation involving heavy machinery or extensive site preparation. Failure to adhere to the legal requirement for prior IEE/EIA risks inadvertently causing irreversible ecological damage, including the potential extinction of unique endemic species, the very outcome these laws are designed to prevent. This is particularly concerning given Lebanon's national goals under its NBSAP to protect terrestrial biodiversity, conserve biodiversity under natural conditions, and establish ecological equilibrium (CBD, 2015).

Reported Non-Compliance and Delayed Assessments: Despite these clear legal requirements, official responses from the Ministry of Environment have reportedly confirmed that the necessary IEE studies were not submitted for approval prior to the initiation of major cedar planting operations in Mount Sannine by organizations like LRI (Nidaa Al-Watan, 2024). LRI publicly issued a Request for Proposals (RFP No. 20240011) seeking consultancy to prepare an IEE for its Sannine sites only on July 15, 2024, meaning the bulk of on-the-ground work for the Sannine Reforestation Project had already been underway for 7 years (LRI RFP 2024; Daleel Madani,

2024). Local NGO partners as well as the municipality of Baskinta also reportedly proceeded with planting prior to completing required assessments. Undertaking such projects without the legally mandated prior environmental assessment and approval constitutes a violation of Law 444/2002 (Article 58 penalizes implementation without required assessment).

Systemic Governance Gaps: Multiple international agencies (e.g., IUCN, USAID, FAO) are reported to have provided funding or support often without confirming that environmental assessments were performed beforehand. This underscores a systemic gap whereby projects, even those coordinated with government ministries (MoE, MoA), could move forward in apparent violation of environmental laws. Critics argue that such omissions undermine the purpose of these laws: preventing ecological damage through assessment and consultation (Nidaa Al-Watan, 2024).

Consequences of Post-Hoc Assessments: These delayed EIAs/IEEs contravene the law (requiring *prior* approval) and limit meaningful project modification. By the time reviews occur, substantial damage (planting, land alteration, road construction) may be irreversible, rendering the assessment an exercise in documentation rather than prevention.

As highlighted by Roy et al. (2022), afforestation efforts that focus solely on tree planting—particularly through monocultures—fail to restore ecological processes or biodiversity. In Lebanon, large-scale *Cedrus libani* plantations exemplify this flawed approach, where symbolic reforestation is prioritized at the expense of long-term ecosystem resilience, soil health, and the recovery of native habitats. Supporting this concern, research from Hong Kong has shown that monoculture plantations can significantly obstruct forest regeneration by limiting native species recruitment and overall biodiversity (Zhu et al., 2023). The reliance on *Cedrus libani* as a single-species afforestation model in Lebanon may thus similarly undermine the re-establishment of dynamic, diverse forest ecosystems and diminish the ecological integrity of restored landscapes. The principles articulated by Brancalion et al. (2019), advocating for restoration "beyond hectares" and prioritizing species diversity, ecological function, and long-term resilience, stand in stark contrast to the monoculture model observed.

A notable point of contrast emerges from LRI's official profile as an IUCN member. The organization states its contributions include substantial improvements to 'best practices' in reforestation and forest management across Lebanon (IUCN, 2.2). This assertion stands in stark contrast to the findings of this study regarding the Sannine Reforestation Project, which indicate the use of ecologically damaging techniques (Section 3) and apparent non-compliance with mandatory environmental assessment procedures (Section 4.1). This discrepancy raises critical questions about the definition, application, and verification of 'best practices' in the context of large-scale reforestation initiatives in Lebanon.

4.2. Factors Impeding Legal Enforcement

Multiple governance and institutional factors likely impede consistent enforcement of EIA requirements for reforestation projects in Lebanon:

- **Institutional Capacity:** Ministries may lack sufficient resources, funding, or specialized personnel to thoroughly review numerous EIA/IEE submissions and effectively monitor compliance across vast mountainous terrains.
- **Ambiguity or Interpretation:** Large-scale reforestation might sometimes be perceived as inherently "positive greening," potentially leading to informal exemptions or interpretations that downplay the need for the same level of scrutiny applied to other development projects. The focus on increasing tree cover might overshadow concerns about the *ecological appropriateness* of the planting strategy and location.
- **Political & Funding Pressures:** Projects with high visibility, strong political backing, or driven by donor targets focused on simple metrics like tree numbers or hectares planted (as critiqued by Brancalion et al., 2019) may face pressure to prioritize speed and visible results over thorough (and potentially time-consuming) environmental scrutiny and legal compliance.
- **Accountability Gaps:** Limited avenues for meaningful public consultation during project planning and assessment, insufficient legal recourse for challenging non-compliance, or fragmented oversight among different agencies can hamper effective enforcement of environmental laws.

4.3. Socioeconomic Drivers of Monoculture Persistence

Despite ecological drawbacks, the persistence of monoculture practices stems from interconnected socioeconomic factors:

- **Funding and Incentives:** Many donors and funding programs emphasize easily quantifiable metrics like “trees planted” or “hectares covered,” implicitly favoring simpler, single-species programs that demonstrate quick, visible results over more complex, ecologically-focused initiatives that prioritize metrics like biodiversity gains or soil health (Jouzour Loubnan, 2025; Brancalion et al., 2019). This creates a direct incentive structure that runs counter to the call for restoration "beyond hectares". National initiatives like the '40 million trees programme' (CBD, 2015), while aiming for significant green cover increase, could inadvertently reinforce such metric-driven approaches if ecological quality and diversity are not equally prioritized.
- **Logistical and Economic Considerations:** Producing large volumes of a single species (*C. libani*) can be more cost-effective for nurseries. Planting them en masse using standardized techniques is often perceived as logistically simpler and less expensive initially than managing diverse species mixes with potentially varied propagation and planting requirements. Nurseries may specialize in cedar, creating a supply-side push for monocultures.
- **Appearing Diverse vs. Being Diverse:** Compounding the focus on easily quantifiable metrics and logistics, there is reported awareness among implementing organizations regarding the ecological critiques of monocultures. This has, in some cases, led to the strategic inclusion of a minimal percentage of other native tree or shrub species within predominantly cedar plantings. While this might be promoted as 'mixed-species' planting in communications (e.g., LRI promotional material), field surveys conducted for this study in the Sannine project area reveal that *C. libani* still constitutes the overwhelming majority of planted trees (reportedly over 95% in certain areas), indicating a significant discrepancy

between stated practice and the actual planting composition (Maalouf, unpublished data; LRI promotional material, 2023). This suggests that in some instances, the token inclusion of other species serves more as a response to criticism and a tool for perceived compliance or promotional messaging, rather than a genuine ecological shift towards diverse, resilient forest structures.

- **Stakeholder Interests:** Government bodies, NGOs, and local authorities might have diverse motivations, ranging from genuine conservation desire to enhancing political visibility through rapid "greenning" efforts, or fostering community pride in re-establishing Lebanon's emblematic cedar. These goals, while understandable, can sometimes override ecological considerations when under pressure to demonstrate easily measurable results or conform to perceived best practices superficially.
- **Community Engagement:** If local inhabitants or municipalities have limited involvement in project planning or see minimal direct benefits (e.g., few livelihood opportunities linked to the project that integrate biodiversity concerns), they may be less likely to advocate for or support more intricate, potentially slower, mixed-species initiatives that require greater technical input and adaptive management.

The persistence of monoculture practices, as observed in the Sannine project, may also be influenced by the operational models of key implementing organizations and potentially a shift from their foundational approaches. LRI's origins as a US Forest Service-launched and funded initiative (US $12 million from 2011) (CBD, 2015) initially emphasized broader goals, including the reported planting of over 20 native tree species by 2015 (CBD, 2015). This earlier diverse planting strategy under direct USFS guidance contrasts with the subsequent monoculture focus in projects like Sannine, undertaken after LRI's establishment as an independent NGO in 2014. This shift could reflect evolving funding priorities, logistical simplifications, or a departure from its initial, more ecologically-aligned mandate. International development and forestry programs often prioritize quantifiable metrics like seedling numbers and hectares planted, which can inadvertently favour logistically simpler monoculture schemes over more complex, site-specific mixed plantings, especially in the early phases of organizational development. Overcoming the inertia favoring monocultures requires targeted policy revisions, funding reorientation, and strong community partnerships that highlight the long-term ecological and potential economic benefits of diversified plantings.

4.4. Limitations of the Study

This analysis relies primarily on secondary data (official documents, NGO reports, grey literature, news articles) rather than firsthand field assessments of soil health, or microclimatic variables at the Sannine site. Hence, conclusions regarding on-the-ground ecological conditions or precise compliance status are contingent on the accuracy and completeness of the available project records and reports. Additionally, the confirmed lack of direct archaeological or palynological studies specifically for Sannine's slopes means that assumptions about historical dense cedar forest cover remain inferences based on regional data, not site-specific proof. Finally, this case study's focus on one specific project (the Sannine Reforestation Project) may limit the broader applicability of findings, although the identified issues (monoculture risks, allelopathy concerns, inappropriate afforestation potential, procedural lapses, socioeconomic drivers) likely resonate with other reforestation initiatives in Lebanon, particularly in similar sensitive high-altitude zones.

5. Conclusion

This critical evaluation illustrates that while the Sannine Reforestation Project seeks to bolster *Cedrus libani* populations—an undeniably important ecological and cultural goal—the dominant monoculture paradigm employed, particularly when implemented using ecologically damaging techniques and reportedly bypassing mandatory environmental assessments, raises significant concerns regarding ecosystem resilience, biodiversity protection, soil and water resources, and regulatory compliance.

Practices documented at the Sannine project, involving exclusive cedar planting, heavy machinery, road construction, and the apparent lack of prior legal assessment, demonstrably degrade soil, alter hydrology, directly destroy habitat, severely threaten Lebanon's unique and often Critically Endangered endemic flora, and create ecologically fragile systems. This approach is particularly concerning when contrasted with earlier LRI phases under USFS guidance, which reported more diverse, multi-species native planting efforts (CBD, 2015).

The analysis has shown how planting dense, single-species conifer stands like *C. libani* can lead to soil degradation exacerbated by allelopathy and reduced microbial diversity, alter hydrological patterns, and severely suppress native understory vegetation through combined shade, litter, and chemical effects. When applied in high-altitude biodiversity hotspots like Mount Sannine, which harbors unique endemic flora adapted to open habitats, this approach constitutes inappropriate afforestation that physically destroys existing valuable plant communities and prevents the recovery of a diverse understory vital for overall ecosystem function. Practices documented at the Sannine project—involving exclusive cedar planting, heavy machinery, road construction, and the apparent lack of prior legal assessment—demonstrably degrade soil, alter hydrology, directly destroy habitat, severely threaten Lebanon's unique and often Critically Endangered endemic flora, and create ecologically fragile systems.

This highlights a critical disconnect between stated conservation intentions and on-the-ground actions, undermining both ecological integrity and environmental governance. Furthermore, it suggests a deviation from Lebanon's own long-standing national biodiversity goals aimed at protecting diverse ecosystems and ensuring their natural evolution (NBSAP 1998; CBD, 2015). The focus on quantifiable tree-planting metrics ("beyond hectares") often overshadows the need for scientifically informed, ecologically appropriate restoration that prioritizes native biodiversity, ecosystem function, and long-term resilience. A fundamental paradigm shift, moving away from simplistic afforestation targets towards holistic ecological restoration rooted in site-specific knowledge, biodiversity conservation, and strict legal adherence, is urgently needed to ensure that reforestation efforts in Lebanon truly benefit the environment and honor the country's rich natural heritage.

6. Recommendations for Lebanon

Addressing the ecological and procedural shortcomings highlighted necessitates a significant reorientation of policy and practice away from current large-scale monoculture planting. Based on this analysis, we argue against the prevailing approach, particularly in sensitive, unprotected high-mountain areas like Mount Sannine. Rather than prioritizing blanket reforestation or

afforestation with *Cedrus libani*, we advocate for an approach centered on protecting these unique ecosystems and their existing biodiversity. Any consideration of tree planting should be strictly conditional upon clear scientific evidence (paleoecological, historical) demonstrating prior forest cover on the *specific site*, considering that many mountain areas are naturally non-forested open habitats. Where native species are documented to be in decline *within* appropriate habitats, interventions should follow careful assessment and focus on targeted assistance to bolster existing populations and enhance their habitat, not large-scale, single-species introductions or planting on non-forest land.

Therefore, our recommendations focus on establishing protection, ensuring rigorous assessment, and promoting ecologically appropriate management:

6.1. Strategic Shift Toward Mixed-Species & Ecologically Sound Restoration

1. **Mandate Mixed-Species and Structurally Diverse Planting:** Shift national policy and funding criteria to explicitly mandate and prioritize the use of diverse mixes of native trees, shrubs, and herbaceous species appropriate to site conditions. Prohibit large-scale monoculture planting, especially in sensitive ecological zones (IPAs, high altitudes). Explicitly define "mixed-species planting" with minimum percentage requirements for non-*Cedrus libani* native species (e.g., minimum 30-40% non-cedar native species by stem count), moving beyond token inclusion. Promote planting designs that mimic natural heterogeneity (variable density, clustering, species mixing) to counteract the negative effects of allelopathy and dense shade, promoting a healthy understory and diverse soil biota. Specifically for high-altitude planting (e.g., covering ranges from ~1800m up towards 3000m where appropriate) efforts should move beyond cedar-only approaches. Suitable native woody companions could include high-altitude oaks (*Quercus look* Kotschy, *Q. kotschyana* O.Schwarz), maples (*Acer hyrcanum* subsp. *tauricola* (Boiss. & Balansa) Yalt., *A. monspessulanum* subsp. *microphyllum* (Boiss.) Bornm.), mountain ash relatives (*Sorbus flabellifolia* (Spach) C.K.Schneid.), wild plums (*Prunus ursina* Kotschy, *P. mahaleb* L., *P. microcarpa* C.A.Mey.), junipers (*Juniperus deltoides* R.P.Adams), cotoneaster (*Cotoneaster nummularius* Fisch. & C.A.Mey.), and buckthorns (*Rhamnus libanotica* Boiss.). Critically, restoration must also integrate the characteristic herbaceous flora, including various species of *Phlomis* (e.g., *P. brevilabris* Ehrenb. ex Boiss., *P. kurdica* Rech.f.), *Onosma* (e.g., *O. caerulescens* Boiss., *O. roussaei* DC., *O. sericea* Willd., *O. aucheriana* DC.), milkvetches (*Astragalus hermoneus* Boiss., *A. cruentiflorus* Boiss., *A. kurnet-es-saudae* Eig), and threatened endemics requiring specific conditions like *Cephalaria cedrorum* Mouterde, *C. kesruanica* Mouterde, *Iris sofarana* Foster, *Linum carnosulum* Boiss., and *Alchemilla diademata* Rothm. Identifying and supporting local nurseries capable of propagating this wide range of native species is essential for implementing this holistic, ecosystem-based approach.
1. **Prohibit Damaging Planting Techniques:** Explicitly prohibit the use of heavy machinery for large-scale pit digging and the unnecessary construction of new access roads in reforestation/afforestation projects, particularly in mountainous and sensitive terrain. Mandate the use of low-impact methods (manual planting, appropriate site preparation

using minimal disturbance, use of existing access routes) to minimize soil compaction, habitat destruction, and hydrological disruption.

2. **Integrate Site-Specific Ecological Knowledge, IPA Data, and Open Habitat Conservation:** Base all planting designs on thorough ecological assessments, identifying reference ecosystems, and explicitly incorporating Important Plant Area (IPA) data and threatened species habitat requirements (Bou Dagher-Kharrat et al., 2018; El Zein & Kahale, 2022). Actively incorporate the conservation of existing ecologically valuable open habitats (e.g., rocky outcrops, grasslands, seeps supporting endemics) within project designs, rather than targeting blanket forest cover. Recognize that appropriate restoration may involve enhancing non-forest ecosystems or creating mosaics of open and wooded areas.
3. **Prioritize Conservation of Highly Threatened Endemics:** Recognize that conserving Critically Endangered microendemics (like those on Sannine) may require preventing certain types of planting activities, including agriculture and inappropriate afforestation, in their specific habitats. Conservation priorities should be scientifically determined based on biodiversity value and threat level, and may, in some locations, outweigh generalized reforestation targets. Pursue formal protection (e.g., 'Hima', nature reserve status) for sensitive areas like Mount Sannine urgently.
4. **Develop Practical Guidelines:** Synthesize results from pilot sites and scientific literature to produce user-friendly, region-specific guides for practitioners on mixed-species planting layouts, low-impact site preparation, maintenance protocols, and species selection attuned to local soil and climate conditions.

6.2. Policy, Governance, and Enforcement Reform

1. **Strict Enforcement of Environmental Laws:** Government authorities, particularly the Ministry of Environment, must strictly enforce Law 444/2002 and Decree 8633/2012. No reforestation or afforestation project, regardless of the implementer (NGO, private, public), should commence without prior submission and approval of a scientifically sound IEE or EIA, especially in IPAs, high-altitude zones, or other sensitive areas. Assessments must be publicly available, and penalties for non-compliance rigorously applied. Retroactive assessments are insufficient.
2. **Revise Funding Criteria:** Engage donors and government agencies to revise funding requirements and tender processes to prioritize ecological metrics (e.g., biodiversity gains, soil health improvement, structural complexity, native species diversity targets, understory recovery, habitat restoration) rather than simply counting trees planted or hectares covered, thereby encouraging restoration "beyond hectares."
3. **Promote Transparency, Collaborative Oversight, and Stakeholder Education:** Increase transparency regarding all aspects of reforestation projects (funding sources, methods, assessments, monitoring data). Foster stronger cooperation and oversight mechanisms involving MoE, MoA, municipalities, scientific experts, and civil society to ensure transparent review of proposals and post-planting monitoring. Educate stakeholders (donors, public, implementers) about the ecological risks of inappropriate methods (allelopathy, inappropriate afforestation, damaging techniques) and the benefits of scientifically sound, biodiverse restoration that complies with environmental law.

4. **Capacity Building:** Implement training programs for forestry professionals, nursery managers, environmental consultants, and local communities on the principles and practices of mixed-species reforestation, low-impact techniques, ecological monitoring, and adaptive management, including the specific challenges and opportunities in sensitive mountain ecosystems with high endemism.

6.3. Monitoring and Adaptive Management

1. **Implement Independent Long-Term Monitoring:** Establish independent, scientifically rigorous long-term monitoring programs for major planting projects. Monitoring must assess impacts on soil, water, full biodiversity (including non-target endemic tracking, understory vegetation diversity, insect pollinators, soil macroinvertebrates), and overall ecosystem function, not just cedar survival. Monitoring should employ standardized, quantitative metrics for objective comparison between different planting approaches (monoculture vs. mixed-species) and track ecosystem development over time. Key indicators should include:
    - **Vegetation Structure & Composition:** Regular assessment of survival rates, growth parameters (height, diameter at breast height), health status of planted trees. Crucially, quantify recruitment, abundance, and diversity (e.g., Shannon index, species richness) of naturally regenerating native plant species (trees, shrubs, herbs) within planted areas using permanent plots, paying particular attention to understory recovery.
    - **Biodiversity Indicators:** Periodic surveys of key faunal groups known to respond to habitat structure and plant diversity (e.g., specific forest bird guilds, insect pollinators, soil macroinvertebrates) using standardized methods.
    - **Soil Health:** Measurement of key soil parameters (e.g., soil organic carbon content, total N and P levels, pH, soil bulk density, water infiltration rates, microbial diversity) comparing changes over time and between different plot types (monoculture vs. mixed, control sites).
    - **Allelopathy Assessment:** If feasible, monitor the concentration of key allelochemicals in soil and litter in monoculture plots compared to mixed or control plots and correlate with understory suppression.
2. **Adaptive Management Framework:** Use monitoring data within a clear adaptive management framework to refine planting densities, species composition, maintenance schedules, and other practices over time. Adjust strategies if early signs indicate poor understory recovery, pest vulnerability, poor establishment of non-cedar species, or soil degradation.

6.4. Learning from Global Experience

1. **Mediterranean Examples:** Look to analogous mountain ecosystems in Spain or Italy, where mixed plantings have improved post-fire regeneration, drought resistance, and ecosystem services compared to monocultures (Pausas et al., 2004). Study successful approaches to restoring diverse, resilient Mediterranean forests, not just tree cover.

2. **Ecological Restoration Principles:** Apply lessons from global ecological restoration science, such as the "Beyond Hectares" framework, which emphasizes species diversity, ecosystem function, and long-term resilience over simple planting numbers (Brancalion et al., 2019).
3. **Scaling Success & Regional Collaboration:** Share best practices and lessons learned regionally. Lebanon's unique mountainous terrain and cultural reverence for the cedar can help guide the development of ecologically robust, community-centric reforestation models applicable elsewhere in the Middle East, provided they are based on sound ecological principles.

By integrating scientific rigor, community engagement, legal oversight, and adaptive management, Lebanon can pivot away from simplistic monocultures and damaging practices toward truly resilient, biodiverse, and sustainable forest restoration efforts—ultimately honoring both the heritage of the cedar and the broader ecological tapestry of its irreplaceable mountain landscapes. As a member organization of the IUCN since 2019, LRI is well-positioned to lead by example in adopting and promoting restoration approaches that fully align with international conservation standards, emphasizing biodiversity, ecological integrity, legal compliance, and participatory processes.

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Annex 1: Preliminary Botanical Inventory and Conservation Significance of the Western Slopes of Mount Sannine (Afforestation Project Areas)

The following data represent a preliminary inventory of vascular plant taxa and their conservation significance, recorded during ongoing botanical surveys (2018-Present) on the western slopes of Mount Sannine where the *Cedrus libani* afforestation projects discussed in this paper is taking place. Identifications are based on established regional floras (e.g., Mouterde, Tohme), comparative herbarium studies, and photographic documentation. All photographed species (330 taxa) are accessible via the online database: https://www.florafauna.life/lebanon-flora (filter by project "Sannine"). Conservation statuses are derived from IUCN Red List assessments where available (global or regional), national assessments, or preliminary assessments by the author based on IUCN criteria if formal assessments are lacking. Nomenclature largely follows established taxonomic databases (e.g., World Flora Online, The Plant List). The discovery of *Onosma sanninensis*, a new species to science and preliminarily assessed as Critically Endangered (CR), highlights the unique and under-documented biodiversity of this crucial area. This annex underscores the western slopes of Mount Sannine as a significant national hotspot for plant endemism and threatened species.

Summary of Key Findings for the Surveyed Area:

- **Estimated Total Vascular Plant Species:** Approximately 420
- **Located and Photographed Species:** 330
- **Total Species Endemic to Lebanon Recorded:** 28 (Table 1). This represents approximately **30% of Lebanon's total recognized endemic flora**.
- **Species Strictly Endemic to Mount Sannine:** 3 (Table 1)
- **Total Regional Endemics Recorded (Lebanon & other countries):**
  - Endemic to Lebanon and Syria: 23 species
  - Endemic to Lebanon and Turkey: 3 species
  - Endemic to Lebanon, Syria, and Palestine: 2 species
  - Endemic to Lebanon, Syria, and Turkey: 27 species
- **Total Documented Plant Taxa at Risk (CR, EN, VU, NT categories):** 30 (excluding the globally Vulnerable status of the planted *Cedrus libani* itself). This concentration represents approximately **28% of all endangered plant species recognized in Lebanon**.
  - Critically Endangered (CR): 2 (plus *Onosma sanninensis* preliminarily assessed as CR)
  - Endangered (EN): 19
  - Vulnerable (VU): 6
  - Near Threatened (NT): 3
- **Potentially Extinct Species within the Survey Area:** 2 species may already be extinct *Tripleurospermum sannineum* and *Lepidium culminicola*.

Table 1: Plant Taxa Endemic to Mount Sannine or Lebanon Recorded on the Western Slopes of Mount Sannine

Family	Scientific Name (with Authority)	Endemic Status	IUCN / Prelim. Status	Notes
Strictly Endemic to Mount Sannine				
Rosaceae	*Alchemilla diademata* Rothm.	Sannine Endemic	CR	
Asteraceae	*Tripleurospermum sannineum* (Bornm.) Bornm.	Sannine Endemic	CR	potentially extinct in the wild (PEW)
Polygonaceae	*Rumex angustifolius* subsp. *libanoticus* (Mouterde) Mouterde	Sannine Endemic		
Boraginaceae	*Onosma sanninensis* Maaouf & Binzet, 2025	Sannine Endemic	CR (Preliminary)	New species from Sannine,
Endemic to Lebanon				
Caryophyllaceae	*Cherleria rupestris* (Labill.) A.J.Moore & Dillenb.	Lebanon Endemic	EN	
Lamiaceae	*Clinopodium nummulariifolium* (Boiss.) Kuntze	Lebanon Endemic	EN	
Orchidaceae	*Dactylorhiza phoenissa* (B.Baumann & H.Baumann) H.Baumann & R.Lorenz	Lebanon Endemic		
Geraniaceae	*Erodium trichomanifolium* (Cav.) L'Hér.	Lebanon Endemic		
Rubiaceae	*Galium libanoticum* Boiss.	Lebanon Endemic		
Asteraceae	*Leontodon libanoticus* Boiss.	Lebanon Endemic	VU	
Orobanchaceae	*Orobanche astragali* Mouterde	Lebanon Endemic	EN	
Rosaceae	*Potentilla geranioides* subsp. *syriaca* (Boiss. & Gaill.) Mouterde	Lebanon Endemic		Subspecies
Lamiaceae	*Stachys ehrenbergii* Boiss.	Lebanon Endemic	VU	
Violaceae	*Viola libanotica* Boiss.	Lebanon Endemic	EN	
Caryophyllaceae	*Dianthus karami* (Mouterde) Mouterde	Lebanon Endemic	EN	
Brassicaceae	*Rorippa macrocarpa* (Boiss. & Gaill.) Meikle (Syn. *Barbarea macrocarpa* Boiss.)	Lebanon Endemic		
Amaryllidaceae	*Allium pseudocalyptratum* Mouterde	Lebanon Endemic	EN	
Asteraceae	*Hieracium schmidtii* subsp. *libanoticum* (Boiss. & Kotschy) Zahn	Lebanon Endemic		Subspecies

Cistaceae	*Cistus umbellatus* subsp. *libani* (Demoly) Greuter & Burdet	Lebanon Endemic		
Geraniaceae	*Geranium crenophilum* Boiss.	Lebanon Endemic		Aedo et al., 2017
Asteraceae	*Scorzonera libanotica* Boiss.	Lebanon Endemic	EN	
Caryophyllaceae	*Minuartia libanotica* (Boiss.) Bornm.	Lebanon Endemic	EN	
Amaryllidaceae	*Allium makmelianum* Post	Lebanon Endemic	NT	
Lamiaceae	*Clinopodium libanoticum* (Boiss.) Kuntze	Lebanon Endemic	EN	
Fabaceae	*Trifolium sannineum* Mouterde	Lebanon Endemic	EN	
Fabaceae	*Astragalus hirsutissimus* DC.	Lebanon Endemic	EN	
Brassicaceae	*Lepidium culminicola* Mouterde (Syn. *Noccaea rubescens* subsp. *culminicola* (Mouterde) Al-Shehbaz)	Lebanon Endemic		Potentially Extinct (EX/PEW)
Brassicaceae	*Erophila gilgiana* Muschl.	Lebanon Endemic		

Table 2: Selected Other Threatened or Regionally Endemic Plant Taxa of Note Recorded on the Western Slopes of Mount Sannine

Family	**Scientific Name (with Authority)**	**Endemic Status (if applicable)**	**IUCN / Prelim. Status**	**Notes**
Brassicaceae	*Draba oxycarpa* Boiss. & Heldr.		EN	Rare
Fabaceae	*Trifolium modestum* Boiss.	Possibly Lebanon Endemic		Rare, requires further study
Amaryllidaceae	*Allium sannineum* Gomb.	Lebanon and mount Hermon	EN	
Amaryllidaceae	*Allium pseudostamineum* Kollmann & Shmida	Leb. Syr. Pal. Endemic		Also found on Hermon

Table 3: Taxa Recorded on Sannine Previously Considered Endemic to Lebanon – Clarification of Taxonomic Status

Family	Scientific Name (with Authority)	Current Understanding / Notes
Geraniaceae	*Geranium libanoticum* (Boiss.) Schenk	Now considered to have a wider distribution
Asparagaceae	*Puschkinia scilloides* var. *libanotica* (Zucc.) Boiss.	Variety not widely recognized; considered within *Puschkinia scilloides* Adams.
Colchicaceae	*Colchicum libanoticum* (Ehrenb.) K.Perss.	Considered a synonym or part of *Colchicum szovitsii* subsp. *brachyphyllum* (Boiss. & Hausskn.) K.Perss.
Fabaceae	*Dorycnium anatolicum* var. *libanoticum* (Boiss.) Mouterde	Variety not widely recognized; often considered within *Lotus hirsutus* L. Needs revision
Brassicaceae	*Erysimum libanoticum* Post	Often considered a synonym of *Erysimum oleifolium* J.Gay.
Amaryllidaceae	*Allium rupicolum* Boiss.	Misidentification by Tohmé for Sannine populations.
Fabaceae	*Cicer incisum* subsp. *libanoticum* (Bornm.) P.H.Davis	Subspecies not widely recognized; generally included within *Cicer incisum* (Willd.) K.Malý.
Linaceae	*Linum toxicum* Boiss.	Reported from Palestine/Israel and Jordan
Asteraceae	*Cousinia libanotica* DC.	VU Taxonomic status/endemism requires review.
Lamiaceae	*Marrubium globosum subsp. libanoticum (Boiss.) P.H.Davis*	Lebanon, Syria and Palestine/Israel
Fabaceae	*Astragalus angulosus* DC.	VU; status re-evaluation suggests wider distribution than strictly endemic.
Brassicaceae	*Arabis thyrsoidea* Griseb.	=*Arabis caucasica* Willd.
Amaryllidaceae	*Allium libani* Opphr. & *Allium libani* var. *tannourinensis* Feinbrun	NT
Orobanchaceae	*Orobanche hermonis* Boiss.	=*Orobanche camptolepis* Boiss. & Reut.?

Note: This annex provides a snapshot based on current knowledge and ongoing research. Taxonomic classifications and conservation statuses are dynamic and may be subject to revision as further research is conducted. The primary aim is to highlight the significant, documented biodiversity value of the specific areas under consideration for afforestation. Among the threatened species present in Sannine but not mentioned in the previous tables are *Romulea nivalis* (Boiss. & Kotschy) Klatt (VU), *Hypericum libanoticum* N.Robson (VU), *Gagea micrantha* (Boiss.) Pascher (VU), *Astragalus lanatus* Labill. (VU), and *Papaver libanoticum* Boiss. (EN).