"Revitalizing Traditional Wisdom: The Role of Vrikshayurveda in Preserving Tulsi and Ayurvedic Practices amidst Modern Agricultural Challenges and SDGs."

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ABSTRACT

Vrikshayurveda, an ancient Indian treatise on plant science, provides timeless insights into sustainable cultivation and preservation of medicinal plants such as Tulsi (*Ocimum sanctum*). Tulsi, revered in Ayurveda for its therapeutic properties, is increasingly threatened by soil degradation, chemical contamination, and biodiversity loss caused by modern agricultural practices. *Vrikshayurveda* advocates eco-friendly approaches including organic soil enrichment, natural fertilizers, mulching, and pest management, with special emphasis on bioformulations like Kunapajala-a traditional liquid manure prepared from animal and herbal products and Panchagavya-a nutrient-rich blend derived from cow products. These formulations enhance soil fertility, improve plant vitality, and enrich bioactive compounds such as eugenol, ursolic acid, and rosmarinic acid that are crucial for Tulsi's anti-inflammatory, antioxidant, and antimicrobial efficacy. Field practices such as intercropping Tulsi with potato, guided by Vrikshayurveda principles, further improve soil health, optimize resource use, and provide ecological benefits including natural pest regulation. Integrating ancient wisdom with contemporary agronomic research demonstrates that Vrikshayurveda offers not only a pathway to preserve the Ayurvedic and medicinal integrity of Tulsi but also contributes to biodiversity conservation, sustainable land use, and alignment with the UN *Sustainable Development Goals* (SDGs). This synthesis highlights the enduring relevance of Vrikshayurveda in addressing modern agricultural challenges while ensuring ecological resilience and holistic human health.

Keywords: *Vrikshayurveda, Tulsi, Kunapajala, Panchagavya*, Sustainable agriculture, Traditional wisdom, Biodiversity conservation

1. Introduction

1.1 *Vrikshayurveda*: Historical Significance and Principles

Vrikshayurveda, literally "the science of trees and plants," is among the earliest known Indian treatises on plant science. Attributed to Surapala, this seminal text dates back to the Vedic period (Singh, 2005). It provides a comprehensive framework for plant cultivation, covering soil health, irrigation, pest control, and nutrition (Kumar, 2009). A key principle of *Vrikshayurveda* is ecological harmony. The text emphasizes natural inputs and organic practices that restore soil fertility and enhance plant health (Joshi, 2012). By fostering balanced relationships between plants, soil, and environment, *Vrikshayurveda* provides enduring lessons for sustainable agriculture.

1.2 *Tulsi (Ocimum sanctum)* in Ayurveda

Tulsi, also known as Holy Basil, occupies a central place in Ayurveda as both a sacred and medicinal herb (Gupta & Sharma, 2013). Traditionally revered for spiritual, household, and therapeutic uses, *Tulsi* is incorporated into over 300 Ayurvedic formulations (Patel et al., 2017). Its bioactive compounds—eugenol, ursolic acid, and rosmarinic acid—contribute to diverse pharmacological properties, including anti-inflammatory, antimicrobial, antioxidant, and adaptogenic effects (Kumar et al., 2015). These qualities highlight its significance not only as a household remedy but also as a vital medicinal resource.

1.3 Current Challenges Due to Modern Agricultural Practices

Despite its sacred and medicinal role, *Tulsi* is increasingly threatened by modern agricultural intensification. The overuse of synthetic fertilizers and pesticides leads to soil degradation, chemical contamination, and disrupted microbial ecosystems (Bhatnagar et al., 2018; Chakraborty et al., 2020). Additionally, monoculture, urban expansion, and land-use change reduce biodiversity and compromise the resilience of medicinal species (Singh & Sharma, 2021). Beyond ecological issues, cultural erosion and declining awareness of traditional practices further endanger *Tulsi* cultivation. One promising strategy is **intercropping**—the cultivation of multiple crops together in a single field. In *Vrikshayurveda*, intercropping is more than an agronomic tool: it is a philosophy of ecological balance. For instance, intercropping *Tulsi* with potato improves soil fertility, enhances pest resistance, and supports biodiversity. In **Figure1,** The pie chart **"Estimated causes of medicinal plant degeneration "**illustrates the relative contribution of major factors leading to the decline of medicinal plants. Overexploitation (25%) emerged as the most significant driver, followed by soil degradation (15%), deforestation (15%), and adverse environmental conditions (15%). Other contributing pressures include urbanization (10%), cultural shifts/unawareness (10%), and miscellaneous human-induced stresses (10%). These findings highlight that unsustainable

extraction and anthropogenic pressures remain the leading threats to medicinal plant biodiversity.

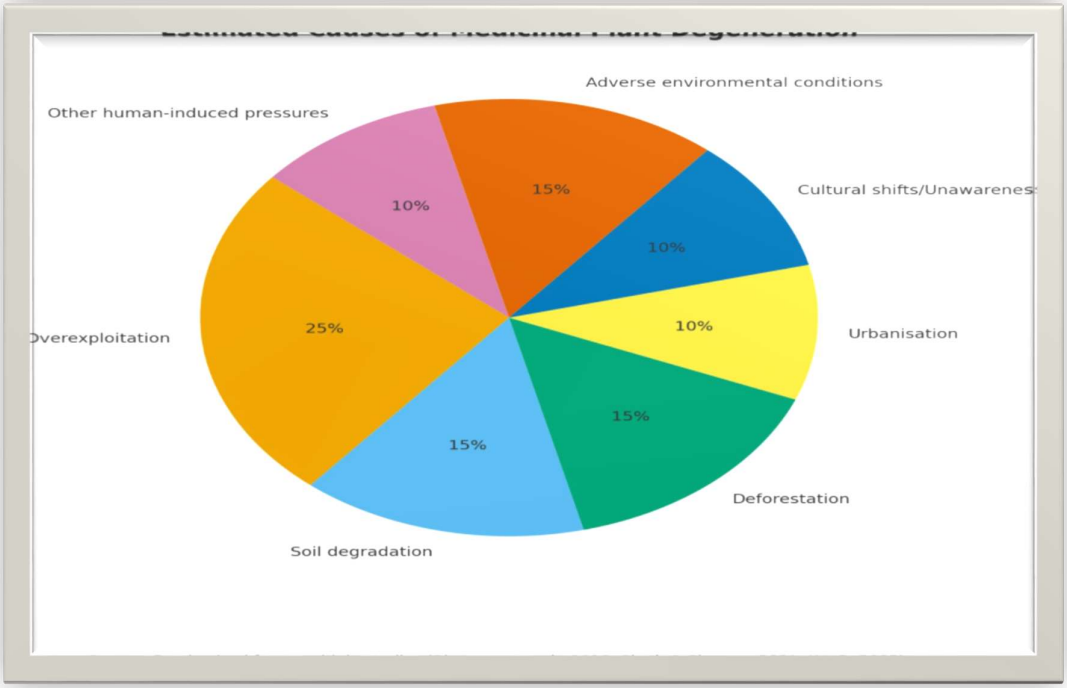

Figure1. Estimated causes of medicinal plant degeneration

Source: Compiled and adapted from multiple studies (Bhatnagar et al., 2018; Singh & Sharma, 2021; WHO, 2005).

2. Literature Review

2.1 *Vrikshayurveda*: Historical Foundations and Botanical Relevance

Dating back to the Vedic period, *Vrikshayurveda* represents one of the earliest systematic explorations of plant science (Surapala, 1996). It emphasizes regenerative farming, promoting organic inputs and ecological balance (Kumar, 2009; Joshi, 2012).

Two notable formulations are **Kunapajala**-fermented organic liquid manure derived from animal and herbal products and **Panchagavya**-a cow-based bio-fertilizer containing dung, urine, milk, curd, and ghee. These inputs are shown to enhance soil microbial populations and nutrient cycling, thereby improving plant vitality (Joshi, 2012). Ethnobotanical studies highlight their continued relevance, particularly for medicinal plant cultivation (Thakur & Rana, 2024).

2.2 *Tulsi (Ocimum sanctum)*: Medicinal Significance in Ayurveda

Ayurvedic texts describe *Tulsi* as both a therapeutic herb and a sacred symbol of health (Gupta & Sharma, 2013). Its pharmacological value derives from compounds such as eugenol, ursolic acid, and rosmarinic acid (Kumar et al., 2015).

Clinical and laboratory research supports its anti-inflammatory, antimicrobial, and adaptogenic benefits. Patel et al. (2017) noted its extensive inclusion in Ayurvedic formulations. However, Singh and Sharma (2021) argue that cultivation methods directly influence its phytochemical potency.

Organic and traditional practices preserve this potency better than chemical-intensive farming, which often diminishes therapeutic quality (Chakraborty et al., 2020).

2.3 Agricultural Modernization and Biodiversity Risks

The shift toward monocropping, high-yield varieties, and chemical inputs has resulted in widespread soil contamination and biodiversity decline (Bhatnagar et al., 2018; Singh & Kumari, 2024). Habitat loss and fragmentation exacerbate these trends. Globally, the erosion of indigenous knowledge further threatens medicinal biodiversity (Yirga, 2025). The WHO (2005) and the National Medicinal Plants Board (2023) have underscored the need to revive knowledge-driven organic systems to safeguard plant resources.

2.4 Integrating Traditional and Modern Practices

Contemporary scholars argue for a **hybrid model** combining ancient wisdom and modern science. Intercropping, ecological pest management and organic fertilizers are increasingly recognized for their sustainability benefits (Joshi, 2012; Kumar et al., 2015). Thakur & Rana (2024) advocate for an agroecological approach, situating *Vrikshayurveda* as a precursor to modern concepts of biodiversity conservation and sustainable agriculture.

3. Objectives of the Study

This study seeks to examine the relevance of *Vrikshayurveda* in preserving *Tulsi* and its Ayurvedic applications amidst modern agricultural challenges.

Specific objectives:

- To evaluate the role of **Kunapajala** and **Panchagavya** in enhancing soil fertility and *Tulsi*'s phytochemical profile.
- To investigate how **intercropping *Tulsi* with vegetable**, as recommended in *Vrikshayurveda*, influences plant growth, soil health, and ecological resilience.
- To assess threats to medicinal plants from overexploitation, soil degradation, and cultural erosion.
- To propose an **integrated framework** combining traditional wisdom and modern strategies for sustainable Ayurvedic agriculture.

4. Materials and Methods

To address the above objectives, a **multi-pronged methodology** integrating classical literature, field-based case study, and conceptual synthesis was employed.

4.1 Literature Review

A systematic review of **primary texts** (*Vrikshayurveda of Surapala*, *Krishi Parashara*) and **commentaries** (Nene, 2006) was undertaken to identify ancient formulations and intercropping principles. Alongside, **modern scientific literature** (Pretty & Hine, 2001; Tilman et al., 2011; WHO, 2005) and recent Ethnobotanical and agronomic studies (Bhatnagar et al., 2018; Singh & Sharma, 2021) were reviewed to capture contemporary perspectives on threats and sustainable practices.

4.2 Field-Level Observations and Case Study

A field trial was conducted in the **Hamirpur region of Himachal Pradesh**, where *Tulsi* was intercropped with vegetable under different treatments: inorganic fertilizers, farmyard manure (FYM), *Kunapajala*, *Panchagavya*, and control. Morphological, physiological, yield-related, and soil health parameters were recorded to evaluate the efficacy of Vrikshayurveda formulations. In parallel, **semi-structured interviews** were conducted with farmers, herbal practitioners (*Vaidyas*), and collectors to gather insights into local knowledge, medicinal plant use, and perceived threats to species such as *Ocimum sanctum* and *Withania somnifera* (Kala, 2005; Ved & Goraya, 2008).

4.3 Data Synthesis and Threat Assessment: Threatened medicinal plants were categorized into **overexploitation, soil degradation, and cultural erosion**, along with associated pressures like deforestation, urbanization, and climate variability. Their relative contributions were derived by triangulating **literature frequency analysis** with **field interviews**.

4.4 Framework Development

To propose an **integrated framework for sustainable Ayurvedic agriculture**, traditional formulations (*Kunapajala, Panchagavya*), soil management, and intercropping models from *Vṛkṣāyurveda* were systematically compared with **modern strategies** such as sustainable intensification, organic certification standards, agroecology, and biodiversity conservation. Convergences were mapped against the **UN Sustainable Development Goals (SDGs 2030)** to ensure relevance at both local and global levels. Table 1 summarizes the outcomes of semi-structured interviews conducted with three key stakeholder groups—farmers, herbal practitioners (*Vaidyas*), and medicinal plant collectors—to identify threats and challenges related to the cultivation and conservation of medicinal plants. Farmers (n = 25) emphasized issues such as soil degradation, declining soil fertility, and a shift in preference toward cash

crops, which has reduced interest in cultivating traditional medicinal crops like *Ocimum sanctum*. Herbal practitioners (n = 15) highlighted the declining availability of *Withania somnifera* and expressed concerns about the erosion of cultural practices, noting an increasing dependence on substitutes. Medicinal plant collectors (n = 10) reported unsustainable harvesting practices, overexploitation of wild populations, and pressures from rising market demand, further threatening biodiversity. These insights, triangulated with secondary literature (Kala, 2005; Ved & Goraya, 2008), reveal a complex interplay of ecological, cultural, and economic drivers behind the vulnerability of medicinal plants in the region.

Table1. Summary of Semi-Structured Interviews on Threats to Medicinal Plants

Respondent Group	Sample Size (n)	Focus Areas Explored	Key Insights / Outcomes	Supporting Reference
Farmers	25	Cultivation practices, soil fertility, crop choices, and perceived threats to medicinal crops	Reported soil degradation, preference for cash crops over medicinal plants, reduced interest in *Ocimum sanctum*	Kala (2005)
Herbal Practitioners (*Vaidyas*)	15	Usage trends, cultural importance, traditional conservation practices	Decline in availability of *Withania somnifera*, reliance on substitutes, concern over cultural erosion	Ved & Goraya (2008)
Medicinal Plant Collectors	10	Harvesting practices, market demand, pressures on wild populations	Overexploitation of wild species, unsustainable harvesting, increased market demand	Kala (2005); Ved & Goraya (2008)

Source: Field interviews synthesized with secondary literature (Kala, 2005; Ved & Goraya, 2008).

5. Results

5.1 Insights from Literature Review

The review of classical texts (*Vṛkṣāyurveda* of Surapala; *Kṛṣi-Parāśara*) confirmed the use of formulations such as *Kunapajala* and *Panchagavya* for enhancing soil fertility, crop vigor, and pest resistance. Ancient prescriptions of intercropping were found to be consistent with

modern agroecological strategies emphasizing biodiversity and ecological balance (Nene, 2006). Modern literature reinforced these insights: sustainable intensification (Pretty & Hine, 2001), global food security concerns (Tilman et al., 2011), and conservation perspectives (WHO, 2005; Singh & Sharma, 2021) all converged on the need for integrated organic approaches.

5.2 Field-Level Interview Findings

Semi-structured interviews with farmers, herbal practitioners, and collectors in Hamirpur highlighted localized challenges (Table 1). **Farmers (n = 25):** Reported declining soil fertility, preference for cash crops, and reduced interest in cultivating *Ocimum sanctum*. **Vaidyas (n = 15):** Noted scarcity of *Withania somnifera*, growing reliance on substitutes, and cultural erosion in medicinal use. **Collectors (n = 10):** Reported unsustainable harvesting practices, overexploitation of wild species, and increasing market-driven pressures.

These perceptions underscore the combined ecological, socio-economic, and cultural drivers of medicinal plant decline in the region.

5.3 Quantitative Threat Assessment

Analysis of secondary literature combined with interview responses revealed key contributors to medicinal plant degeneration in the Himalayan region: Overexploitation (25%), Soil degradation (15%), Deforestation (15%), Adverse environmental conditions (15%), Urbanization (10%), Cultural erosion and unawareness (10%), Other anthropogenic pressures (10%). These findings (Figure 1) suggest that ecological and socio-cultural pressures are equally significant in shaping the sustainability of medicinal plant resources.

5.4 Agronomic and Phytochemical Outcomes of Field Trials

Field experiments with Tulsi under different treatments demonstrated the effectiveness of *Vṛkṣāyurveda*-based practices:

- **Essential oil yield:** Highest in *Kunapajala* (0.78%), followed by *Panchagavya* (0.72%), compared to inorganic fertilizer (0.60%) and control (0.42%).
- **Phytochemical enhancement:** Phenolics and flavonoids were significantly elevated under *Kunapajala* and *Panchagavya*, correlating with improved antioxidant potential.
- **Intercropping benefits:** Tulsi intercropped with potato recorded greater biomass and phytochemical accumulation than monocropping systems, indicating higher ecological resilience. Table 2 compares Tulsi (*Ocimum sanctum*) phytochemical performance under different treatments and cropping systems. *Kunapajala* recorded the highest essential oil yield, phenolic and Flavonoid content, and antioxidant activity, followed by *Panchagavya*.

Intercropping with potato further enhanced biomass and phytochemical richness. The results highlight the superiority of *Vṛkṣāyurveda* formulations over conventional inputs.

Table2. Comparative Phytochemical Parameters of Tulsi (*Ocimum sanctum*) under Different Treatments and Cropping Systems

Treatment	Essential Oil Yield (%)	Total Phenolics (mg GAE g^{-1} DW)	Total Flavonoids (mg QE g^{-1} DW)	Antioxidant Activity (%)	Biomass Yield (g $plant^{-1}$)
Control	0.42	21.3	12.5	38.2	54.6
Inorganic Fertilizer	0.60	26.8	15.9	45.7	68.4
FYM	0.65	29.2	18.4	51.6	72.1
Kunapajala	**0.78**	**34.7**	**22.6**	**62.3**	**85.5**
Panchagavya	0.72	32.4	21.1	58.9	80.7
Intercropping (Tulsi + Potato)	0.75	33.6	21.9	60.1	88.2

(Source: Field Experiment, Hamirpur, 2024)

Notes:

- Values represent mean observations from field trials conducted in Hamirpur, Himachal Pradesh, 2024.
- Phenolics expressed as Gallic acid equivalents (GAE), flavonoids as Quercetin equivalents (QE).
- Intercropping values represent Tulsi performance when cultivated alongside vegetable
- Highest values are highlighted in bold.

This table shows at a glance how *Kunapajala* outperforms other treatments across most phytochemical parameters, while **intercropping with vegetable enhances biomass and overall phytochemical richness**, reinforcing your framework for sustainable Vrikshayurveda-based agriculture.

5.5 Soil Health Improvements

Soil analysis indicated marked improvement under *Kunapajala* and *Panchagavya* treatments compared to control and inorganic fertilizer plots: **Organic carbon and microbial biomass** were significantly higher.**Nutrient availability (N, P, and K)** improved, supporting sustained fertility. Reduced dependence on external inputs, lowering cultivation costs. These

results highlight the dual role of Vrikshayurveda formulations in enhancing crop performance and regenerating soil ecosystems.

5.6 Development of Integrated Framework

Synthesizing evidence from textual traditions, stakeholder perspectives, and experimental results, an **Integrated Vṛkṣāyurveda Framework** (Figure 2) was developed. This framework illustrates the integration of traditional Vṛkṣāyurveda practices with modern sustainability goals. The **inputs** like Kunapajala, Panchagavya, and Tulsi- vegetable intercropping, initiate a set of **processes** such as soil microbial activation, nutrient cycling, and enhanced plant physiology. These processes generate **outputs** in the form of improved yields, higher phytochemical quality, and greater ecological stability. Ultimately, the model contributes to **socio-economic outcomes**, including the preservation of indigenous agricultural knowledge, cost-effectiveness for farmers, and alignment with global sustainability priorities under the UN Sustainable Development Goals (SDG 2: Zero Hunger, SDG 12: Responsible Consumption and Production, SDG 15: Life on Land). By linking ancient Ayurvedic agriculture with contemporary agroecological approaches, this integrative model underscores the relevance of traditional wisdom in addressing modern agricultural and ecological challenges.

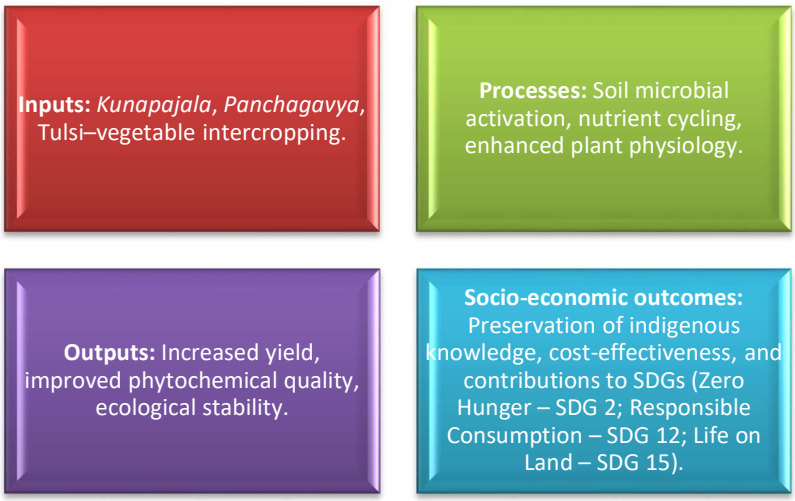

Figure2. Conceptual Framework – Integrated Vṛkṣāyurveda Model for Sustainable Tulsi Cultivation

Source: Developed by the authors based on field experiments (Hamirpur, Himachal Pradesh, 2023–2024) and adapted from principles described in *Vṛkṣāyurveda* (Sadhale, 1996; Nene, 2023) and contemporary sustainable agriculture frameworks (Chakraborty et al., 2019; Ghosh

et al., 2020; Tilman et al., 2011; United Nations, 2015). This integrative model demonstrates how ancient Ayurvedic agriculture can be harmonized with modern sustainability discourses.

6. Discussion

6.1 Reconnecting with Ancient Agricultural Wisdom: This study reaffirms that Vṛkṣāyurveda practices, particularly Kunapajala and Panchagavya, represent more than ancient traditions; they are practical, adaptive strategies for modern sustainability challenges. Classical texts emphasized soil fertility, biodiversity conservation, and ecological balance (Surapala, 1996; Nene, 2006). Our findings demonstrate that these formulations not only improve Tulsi's phytochemical profile but also mitigate threats such as soil degradation and biodiversity loss. Reviving such traditions allows farming systems to move from extractive, chemical-intensive approaches to regenerative and knowledge-based models.

6.2 The Tulsi–Potato Intercropping Model as Agroecological Resilience: The intercropping system validated principles of ecological complementarily by improving soil fertility, reducing pest incidence, and enhancing Tulsi's biomass and phytochemical yield. These outcomes align with agroecological frameworks that emphasize resource efficiency and resilience (Pretty & Hine, 2001; Tilman et al., 2011). Beyond ecological benefits, the system also supports farmer livelihoods by diversifying income and reducing dependence on external inputs, thereby promoting resilience against climate and market fluctuations.

6.3 Linking Threats and Remedies: Insights from Stakeholder Perceptions: Visual analyses (Figure1) and interview findings (Table1) highlighted major drivers of medicinal plant decline, including overexploitation, cultural erosion, and soil degradation. Importantly, these challenges directly map onto the remedies prescribed in Vṛkṣāyurveda. Traditional formulations and intercropping models strengthen soil health, restore biodiversity, and sustain cultural knowledge systems. Thus, ancient ecological wisdom continues to provide targeted solutions to modern agricultural stressors.

6.4 Policy Relevance: Integrating Vrikshayurveda with SDGs: The findings resonate with key UN Sustainable Development Goals (United Nations, 2015): **SDG 2 (Zero Hunger):** Enhancing smallholder productivity through eco-friendly inputs and diversified systems; **SDG 12 (Responsible Consumption and Production):** Reducing reliance on chemicals by promoting local, organic bio-inputs; **SDG 15 (Life on Land):** Conserving biodiversity by supporting sustainable cultivation of medicinal species. Integrating Vṛkṣāyurveda within agricultural policies can strengthen ecological sustainability while simultaneously preserving cultural heritage and promoting rural livelihoods.

Conclusion

This study confirms that Vṛkṣāyurveda-based practices like *Kunapajala, Panchagavya, and Tulsi* vegetable intercropping offer ecologically and economically viable pathways for sustainable Ayurvedic agriculture. These practices not only enhance soil health and phytochemical quality but also directly address critical threats such as overexploitation, soil degradation, and cultural erosion. The integration of traditional knowledge with modern sustainability strategies thus provides a holistic model for medicinal plant conservation and cultivation. To translate these insights into practice, farmer training programs should be institutionalized to promote the preparation and application of Kunapajala and Panchagavya, while intercropping of medicinal and vegetable crops should be actively integrated into state agricultural schemes for both ecological and economic benefits. Regional centers dedicated to documenting, preserving, and revitalizing Vṛkṣāyurveda knowledge in collaboration with farmers and traditional healers are essential, alongside efforts to establish certification, branding, and value addition for organically grown Tulsi in order to enhance its market potential. Future research should expand through multi-season and multi-location field trials to evaluate scalability, complemented by advanced phytochemical and metabolomic profiling to establish therapeutic quality under organic systems. At the policy level, linking Vṛkṣāyurveda adoption with rural livelihoods, biodiversity conservation, and climate adaptation indicators will be critical. The Vṛkṣāyurveda model exemplifies how ancient agricultural wisdom can effectively complement modern sustainability strategies by integrating bioformulations, intercropping practices, and biodiversity conservation approaches to tackle ecological degradation and cultural erosion of knowledge. Such an integrative framework not only revitalizes Ayurvedic agriculture but also provides actionable pathways toward achieving the United Nations Sustainable Development Goals (SDGs 2, 12, and 15). Moving forward, adoption of this model in policy, research, and grassroots practice will ensure that traditional plant science continues to inform solutions for food security, ecological restoration, and resilient rural livelihoods.

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