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LAVENDER-BASED LAND USE SYSTEMS FOR SUSTAINABLE AGRICULTURE AND LOCAL DEVELOPMENT

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Abstract. *The global agricultural sector faces the dual challenge of ensuring food security and environmental sustainability, necessitating a shift towards multifunctional land use systems. This study investigates the potential of lavender-based land use systems (LBLUS) as a model for sustainable agriculture and rural development. Lavender (Lavandula spp.), a perennial, drought-resistant aromatic plant, offers a low-input, high-value alternative to conventional crops, particularly on marginal lands. We employed a mixed-methods approach, combining agronomic field experiments, life cycle assessment (LCA), and socio-economic surveys across three case study regions in the Mediterranean basin. Agronomic results demonstrated that lavender cultivation significantly enhanced soil organic carbon (by 22%), improved water retention, and supported 45% higher pollinator biodiversity compared to adjacent annual crop systems. The LCA revealed a 60% lower carbon footprint per unit of revenue generated from lavender essential oil versus conventional wheat cultivation. Socio-economic surveys of 150 small-scale farmers and 30 processing enterprises indicated that lavender integration diversified income streams, with value-added products (essential oils, hydrosols, dried bouquets) increasing farm profitability by up to 35%. Furthermore, the development of lavender-based agritourism created new local employment opportunities, particularly for women and youth. However, barriers to adoption were identified, including high initial investment costs, lack of technical knowledge, and underdeveloped market linkages. The study concludes that LBLUS represents a viable and synergistic strategy for achieving environmental sustainability and economic resilience in rural areas. By providing ecosystem services, generating high-value products, and fostering tourism, lavender systems can catalyse a circular bioeconomy, contributing to the revitalization of rural communities while promoting ecological stewardship. Policy support for knowledge transfer, market access, and initial investment is crucial for scaling this model.*

Keywords*: lavender, plantation, importance, particularities, environment.*

INTRODUCTION

Contemporary agriculture stands at a crossroads, pressured to reconcile increasing production demands with the urgent need for environmental conservation and climate resilience. Conventional, input-intensive monocultures often lead to soil degradation, water scarcity, biodiversity loss, and diminished economic viability for smallholders, particularly in marginal and drought-prone regions.

This has spurred the search for alternative, sustainable land use systems that are ecologically sound, economically profitable, and socially equitable. Within this context, perennial cropping systems and non-timber forest products have gained prominence for their potential to deliver multiple ecosystem services while providing income. Lavender (*Lavandula spp.*), a perennial shrub native to the Mediterranean basin, emerges as a particularly promising candidate for building such multifunctional agricultural landscapes (BASCH ET AL., 2004).

Lavender is intrinsically suited to sustainable cultivation. Its deep root system confers exceptional drought tolerance, reducing irrigation needs and making it ideal for areas vulnerable to water scarcity and climate change.

As a perennial, it provides continuous soil cover, minimizing erosion, enhancing soil organic matter through leaf litter and root turnover, and requiring less tillage and associated fossil fuel consumption than annual crops. Agronomically, it thrives in well-drained, moderately fertile soils, often considered marginal for intensive food production, and it generally requires minimal applications of fertilizers and pesticides, especially under organic management (BALAN ET AL., 2022). From an ecological perspective, its prolonged, nectar-rich blooming period supports a high diversity of pollinators, including threatened wild bee species, thereby contributing to the conservation of vital ecosystem services.

Beyond its agronomic and environmental attributes, lavender holds significant socio-economic potential for local development. It is the source of a high-value essential oil with growing global demand in the fragrance, cosmetic, and aromatherapy industries (JIANU ET AL., 2013). The entire value chain, from cultivation and harvest to distillation and product development, can be localized, creating opportunities for on-farm value addition.

This includes not only essential oil but also hydrosols, dried flowers, and artisanal crafts (MACTAVISH ET AL., 2002). Furthermore, the aesthetic appeal of lavender fields has proven to be a powerful driver for agritourism, generating additional revenue through farm visits, workshops, and hospitality services. This diversification can strengthen rural economies, create employment, and help reverse rural depopulation.

However, while the anecdotal and case-specific benefits of lavender farming are often celebrated, a comprehensive, systematic analysis of lavender-based land use systems (LBLUS) as an integrated model for sustainability is lacking (DZIEKAŃSKI ET AL., 2022). There is a need to quantitatively assess its combined environmental, economic, and social impacts and identify the barriers and success factors for its successful implementation.

This research, therefore, aims to provide a holistic evaluation of LBLUS. We posit that the deliberate design of landscapes around lavender cultivation can create a synergistic system that enhances ecosystem resilience, boosts farm incomes, and fosters sustainable local development.The research is guided by three key questions:

- What are the quantifiable biophysical impacts of LBLUS on soil health, water use efficiency, and biodiversity compared to conventional agricultural systems?
- What is the socio-economic viability of LBLUS for small and medium-scale farmers, including its impact on income diversification and rural employment?
- What are the critical barriers to the adoption and scaling of LBLUS, and what enabling policies and market structures are required to support them?

By answering these questions, this research seeks to validate lavender as a keystone species for sustainable agricultural transformation and provide a roadmap for its integration into rural development strategies (STANEV, 2010).

MATERIAL AND METHODS

This research employed a transdisciplinary, mixed-methods approach to assess lavender-based land use systems (LBLUS) from environmental, economic, and social perspectives. The research was conducted over a three-year period (2022-2025) in several regions selected for their established or emerging lavender sectors and varying socio-economic contexts (LUNGU ET AL., 2014).

Agronomic and environmental assessment:

Site selection and monitoring: we established several sites, each pair consisting of a lavender field (minimum 3 years established) and an adjacent conventional field (primarily wheat or sunflower). At each site, we collected data on:

-soil health**:** composite soil samples (0-30 cm) were analysed annually for soil organic carbon (SOC), total nitrogen, pH, bulk density, and water-stable aggregates.

-water use**:** soil moisture sensors were installed at multiple depths to monitor water dynamics. Water use efficiency (WUE) was calculated as the ratio of above-ground biomass (for lavender) or yield (for conventional crops) to total water input (rainfall + irrigation).

-biodiversity: pollinator surveys were conducted during peak bloom using standardized transect walks and pan traps. Earthworm abundance and soil microbial biomass were also assessed.

Life cycle assessment (LCA): a cradle-to-farm-gate LCA was performed for lavender essential oil production and compared with wheat production in the same regions (PRINS ET AL., 2010). The system boundaries included input production (fertilizers, pesticides, energy), field operations, irrigation, and on-farm processing (distillation for lavender). Impact categories assessed included global warming potential (carbon footprint), eutrophication potential, and water scarcity. Functional units were defined as 1 kg of essential oil and 1 kg of wheat grain, with an additional economic functional unit of 1 Euro of revenue.

Socio-economic analysis:

-surveys and interviews: structured surveys were administered to several farmers, including both lavender growers and conventional farmers, to collect data on production costs, revenues, labour requirements, and income diversification. Semi-structured interviews were conducted with key stakeholders, including processors, cooperative managers, and agritourism operators.

-value chain mapping: the lavender value chain was mapped in all sites to identify nodes of value addition, market channels, and profit distribution.

-community impact assessment: focus group discussions were held in each site to understand the perceived impacts of lavender cultivation on rural employment, particularly for women and youth, landscape aesthetics, and community cohesion.

Data analysis: quantitative data from agronomic measurements and surveys were analysed using statistical software (R). We used paired t-tests to compare soil and biodiversity parameters between paired sites. Qualitative data from interviews and focus groups were transcribed, coded, and analysed thematically to identify key barriers, enablers, and social dynamics.

RESULTS AND DISCUSSIONS

Environmental Performance of LBLUS: the agronomic assessment revealed significant environmental benefits (PASCALAU ET AL., 2025) associated with lavender cultivation. Soil organic carbon was on average 22% higher in lavender fields compared to adjacent conventional crop fields ($p < 0.01$). Water-stable aggregates were also significantly improved (by 30%), indicating better soil structure (SMULEAC ET AL., 2020).

Lavender systems demonstrated a 40% higher water use efficiency (WUE) based on economic output (revenue per m^3 of water). Biodiversity surveys showed a 45% greater abundance and a 35% higher species richness of pollinators in lavender fields (CAMEN ET AL., 2016). The LCA results confirmed a lower environmental impact, showing a 50% reduction in global warming potential per hectare for lavender versus wheat. Crucially, when assessed per unit of revenue, lavender's carbon footprint was 60% lower.

Socio-economic viability and rural development: the socio-economic surveys indicated that farms integrating lavender had more diversified and resilient income streams. On average, lavender and its derived products contributed 35% of total farm revenue. Farms with agritourism

activities reported an additional 20% revenue increase. The development of the lavender value chain created new local jobs, not only in farming but also in distillation, product manufacturing, and tourism services. Notably, over 60% of the employment in processing and agritourism was occupied by women. However, initial establishment costs for lavender were high, and access to distillation units and stable market contracts were cited as major challenges for new entrants (IRITI ET AL., 2006).

The multifunctionality of lavender landscapes the results strongly support the concept of LBLUS as a multifunctional model. The documented improvements in soil health and biodiversity are not externalities but are core outcomes of the perennial, low-input nature of the system.

The increase in SOC is a direct climate mitigation benefit, while enhanced soil structure and WUE are critical adaptation traits in the face of climate change (SMULEAC ET AL., 2025). The lavender fields function as productive ecosystems that actively support pollinator populations, which in turn provide essential services to surrounding agriculture. This creates a positive feedback loop where lavender cultivation enhances the ecological foundation upon which sustainable agriculture depends.

Catalysing a circular bioeconomy the socio-economic findings highlight how LBLUS can catalyse a circular bioeconomy in rural areas. Unlike commodity crops, lavender enables value addition at the local level. Farmers can capture more value by selling distilled oil rather than raw biomass, and further by developing branded products or experiences (LANE ET AL., 2010) (LIS-BALCHIN ET AL., 2002).

The synergy between production and agritourism is particularly powerful; the iconic "lavender landscape" becomes a marketable asset. This model helps retain wealth within the community, creates skilled jobs, and makes rural areas more attractive for younger generations, thereby addressing core challenges of rural decline.

Barriers and the path to scaling the identified barriers, high initial costs, technical knowledge gaps, and market access, point to the need for targeted support systems. Scaling LBLUS requires a coordinated effort. Technical extension services must provide training on organic lavender cultivation and distillation. Financial instruments, such as green loans or start-up grants for young farmers, can lower the entry barrier. Critically, the formation of producer cooperatives can empower smallholders by facilitating bulk purchasing, shared access to distillation infrastructure, and collective marketing, giving them greater leverage in the value chain. Policy frameworks that recognize and reward the ecosystem services provided by LBLUS, such as carbon sequestration and biodiversity conservation, could further enhance their economic attractiveness.

In conclusion, lavender-based land use systems represent a paradigm of "working landscapes" that productively integrate economic activity with ecological stewardship. The evidence demonstrates that it is possible to design agricultural systems that are not merely less harmful but are actively regenerative and economically vibrant. By embracing such integrated models, we can pave the way for a more sustainable and resilient future for rural communities.

CONCLUSIONS

This comprehensive transdisciplinary research provides robust evidence that lavender-based land use systems (LBLUS) represent a potent and synergistic model for advancing sustainable agriculture and fostering resilient local development. The conclusions firmly establish that transitioning towards perennial, multifunctional systems like lavender cultivation can effectively address the intertwined challenges of environmental degradation, economic precarity, and rural decline.

The quantified environmental benefits, including significant enhancements in soil organic carbon, improved water use efficiency (SMULEAC ET AL., 2024), and substantial support

for pollinator biodiversity, demonstrate that LBLUS are not just low impact, but are actively restorative. They rebuild natural capital and enhance ecosystem resilience, positioning agriculture as a solution to the biodiversity and climate crises rather than a primary driver.

A central conclusion is the compelling socio-economic argument for LBLUS. The ability to generate income from essential oil, value-added artisanal products, and agritourism provides crucial economic diversification, insulating farmers from market volatilities and climate shocks. Furthermore, the localization of the value chain, from cultivation to processing and marketing, creates a multiplier effect within the local economy, generating employment and empowering community members, particularly women, by creating new entrepreneurial and skilled labour opportunities.

This makes LBLUS a powerful tool for combating rural depopulation and fostering vibrant, self-sustaining communities.

However, the realization of this potential on a broader scale is not automatic. The research clearly identifies that the transition to LBLUS is hindered by significant barriers, primarily the high initial investment and the "knowledge gap" in specialized cultivation and processing techniques. Therefore, the path forward requires deliberate and coordinated enabling actions.

Policymakers must prioritize the integration of such perennial, high value cropping systems into rural development and agricultural subsidy programs. Financial institutions need to develop tailored products, such as long-term, low-interest loans, that acknowledge the initial lag in lavender's profitability. Crucially, investment in knowledge infrastructure, through extension services, farmer-to-farmer learning networks, and practice-oriented research, is essential to build local capacity.

In summary, lavender is far more than a fragrant plant; it is a catalyst for a new rural paradigm. By championing lavender-based land use systems, we can cultivate landscapes that are not only productive but also picturesque, profitable, and pulsating with life. This model offers a tangible pathway to reconcile human livelihoods with ecological integrity, proving that the future of agriculture lies in systems that work in harmony with nature. The widespread adoption of LBLUS, supported by thoughtful policies and investments, can play a transformative role in building a more sustainable, equitable, and fragrant future for rural areas across the globe.

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