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EXPLORING SUSTAINABLE SYNERGIES OF AGRICULTURAL TOURISM AND CULTURAL HERITAGE IN ETNA-ALCANTARA: AN MCDA ANALYSIS

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ABSTRACT. The Etna-Alcantara territory presents a distinctive socio-ecological system where volcanic landscapes have shaped both agricultural traditions and cultural heritage. This study employs multi-criteria decision analysis to identify locations for sustainable agricultural tourism development that effectively integrates cultural heritage valorization. The analytical framework incorporates four primary dimensions (agricultural potential, cultural heritage significance, tourism infrastructure, and environmental sensitivity) weighted through structured stakeholder consultation with key territorial actors. Application to seven representative municipalities shows inland areas with established viticultural traditions, particularly Randazzo and Castiglione di Sicilia, exhibit superior potential for integrated tourism development compared to coastal areas with more conventional tourism infrastructure. The results highlight specific synergistic opportunities, including the strategic connection between wine tourism and architectural heritage along the Strada del Vino dell'Etna and integration of gastronomic excellence with local agricultural production in Linguaglossa. Territories preserving authentic productive landscapes offer good foundations for agricultural tourism development despite their distance from traditional tourism flows. Managers and territorial planners can leverage this evidence-based framework for targeting investments, developing thematic routes, implementing seasonal integration strategies, establishing collaborative governance mechanisms, and creating distinctive product offerings that connect agricultural products with cultural narratives, thereby generating sustainable value across environmental, social, and economic dimensions.

1. Introduction

The Etna-Alcantara territory in Sicily represents a particular territorial system where Europe's largest active volcano has shaped both agricultural traditions and cultural heritage over millennia. The volcanic soils foster distinctive products, particularly the renowned Etna DOC wines, while geological constraints have created settlement patterns and cultivation practices that constitute invaluable cultural landscapes (Cullotta and Barbera 2011). This volcanic territory combines peculiar attractiveness with inherent environmental sensitivity,

presenting complex cases for sustainable tourism development (Erfurt-Cooper and Cooper 2010).

Growing recognition that conventional tourism models often generate environmental degradation and cultural homogenization has shifted focus toward sustainable approaches (Farsani, Coelho, and Costa 2011). Agricultural tourism emerges as a potential solution, particularly when designed to showcase the distinctive relationship between volcanic landscapes and traditional production systems (Chiodo *et al.* 2019). In the Etna-Alcantara context, wine tourism exemplifies this approach, where volcanic terroir translates into unique products embodying both natural and cultural values (Privitera, Nedelcu, and Nicula 2023).

Despite this potential, limited research addresses how to systematically identify and prioritize areas where agricultural production and cultural heritage create optimal synergies for tourism development. While previous studies have examined specific aspects of Mount Etna's tourism potential (Cullotta and Barbera 2011), no one has provided an integrated framework for evaluating the full spectrum of agricultural-cultural tourism opportunities across the Etna-Alcantara territory.

Multi-criteria decision analysis (MCDA) offers a structured approach to address this complexity by integrating diverse evaluation criteria while incorporating stakeholder perspectives (García-Melón, Gómez-Navarro, and Acuña-Dutra 2012). This study applies an MCDA framework to answer three key questions: (i) Which areas within the Etna-Alcantara territory demonstrate optimal conditions for developing sustainable agricultural tourism focused on cultural heritage? (ii) What specific synergies exist between agricultural production systems, cultural assets, and tourism infrastructure? (iii) How can stakeholder perspectives inform prioritization strategies?

The findings provide evidence-based guidance for territorial planners, tourism organizations, and agricultural enterprises seeking to develop integrated experiences that generate economic value while preserving the distinctive character of this volcanic landscape.

2. Materials and Methods

2.1. Data Collection and Study Area. The study focused on seven representative municipalities within the Etna-Alcantara context: Randazzo, Castiglione di Sicilia, Zafferana Etnea, Giardini Naxos, Linguaglossa, Milo, and Francavilla di Sicilia. These municipalities were strategically selected to capture territorial diversity, encompassing interior wine-producing areas, coastal tourism zones, natural landscape hotspots, and significant cultural heritage sites. This sampling approach allowed to conduct the analysis while maintaining practical feasibility.

Data collection proceeded through document analysis of publicly available territorial reports and targeted interviews with 12 key stakeholders representing the primary territorial actors. These stakeholders included the LAG Terre dell'Etna e dell'Alcantara management, protected area authorities (Parco dell'Etna and Parco Fluviale dell'Alcantara), quality consortia (Consorzio Tutela Vini Etna DOC, Consorzio di Tutela Olio DOP Monte Etna), tourism operators, cultural organizations, and agricultural associations.

2.2. Multi-Criteria Decision Analysis Framework. The study employed the Analytic Hierarchy Process (AHP) for evaluating sustainable tourism potential across the territory.

This MCDA technique structures complex decisions hierarchically and enables systematic integration of quantitative data and qualitative judgments through pairwise comparisons (Saaty 1980), facilitating the incorporation of diverse stakeholder perspectives.

The implementation of AHP proceeded through four sequential phases. First, the problem structuring phase established the overall goal, identifying optimal locations for sustainable agricultural tourism development that valorizes cultural heritage, and defined the hierarchical framework of evaluation criteria. Second, the pairwise comparison phase quantified the relative importance of criteria through stakeholder evaluations using a standard nine-point comparison scale. Third, the synthesis phase calculated global priority weights for all criteria and applied these weights to territorial data to generate suitability scores for each municipality. Fourth, the sensitivity analysis phase assessed the robustness of results by systematically varying priority weights and examining the resulting changes in municipal rankings.

The integration of multiple stakeholder perspectives through structured evaluation frameworks has proven effective for territorial development assessment in Mediterranean contexts (Ioppolo, Saija, and Salomone 2012).

The establishment of evaluation criteria followed a participatory process that integrated insights from document analysis and stakeholder interviews. The final framework incorporated four primary criteria: agricultural potential, cultural heritage significance, tourism infrastructure, and environmental sensitivity. Each criteria further divided into specific sub-criteria measurable at the municipal level. This hierarchical structure enabled systematic evaluation while preserving necessary nuance in the assessment of territorial characteristics.

The agricultural potential criterion encompassed four sub-criteria: presence of quality-certified productions (DOC, DOP, IGP), diversity of traditional cultivation systems, percentage of organic farming adoption, and agritourism infrastructure density. These indicators captured both the productive dimension of agriculture and its potential for touristic valorization through experiential offerings.

The cultural heritage criterion comprised five sub-criteria: density of architectural heritage assets, presence of UNESCO designations, vitality of traditional festivals and events, preservation of traditional agricultural practices, and density of artisanal production sites. These indicators aimed to capture both tangible and intangible cultural elements with potential touristic appeal.

The tourism infrastructure criterion incorporated four sub-criteria: accommodation capacity and quality, accessibility via transportation networks, existing visitor services, and digital presence/promotion. These indicators assessed the territory's readiness to accommodate and serve visitors effectively.

The environmental sensitivity criterion included four sub-criteria: presence of protected areas, habitat fragmentation levels, volcanic or geological risk factors, and landscape visual quality. These indicators captured both constraints that tourism development must respect and environmental assets that constitute tourism resources.

Each sub-criterion was quantified using data sourced from the Local Action Group (LAG) Terre dell'Etna e dell'Alcantara and standardized on a 0-1 scale to enable comparison and aggregation. The documents provided territorial information across municipalities, covering agricultural production, cultural resources, tourism infrastructure, and environmental characteristics. For each criterion and sub-criterion, relevant data points were extracted

directly from the reports' sections on territorial assessment, productive sectors, economic profiles, and cultural heritage inventories, without introducing external evaluation frameworks or expert judgments. For example, the "quality-certified productions" sub-criterion was quantified by counting the number of DOC, DOP, and IGP certifications active in each municipality (ranging from 2 in Milo to 8 in Castiglione di Sicilia), then standardized using min-max normalization where the municipality with the highest count received a score of 1.0 and the lowest 0.0. Environmental sensitivity metrics, such as "protected areas presence", were quantified as the percentage of municipal territory within designated protection zones (Parco dell'Etna, Parco Fluviale dell'Alcantara, or Natura 2000 sites), ranging from 12% in Giardini Naxos to 78% in Linguaglossa.

The weighting process integrated judgments from the 12 identified key stakeholders through structured pairwise comparisons. The relatively limited number of stakeholders facilitated in-depth engagement, allowing for thorough discussion of underlying values and priorities during the evaluation process. The stakeholder judgments were aggregated using the geometric mean method rather than arithmetic mean, as the former maintains the reciprocal relationships inherent in AHP pairwise comparisons and provides more consistent group priorities (Saaty 1980).

For each municipality, these scores were weighted according to stakeholder priorities and aggregated to produce a suitability ranking. Additionally, within each municipality, the analysis identified specific localities demonstrating particularly favorable conditions for agricultural tourism development linked to cultural heritage valorization, creating a two-tier spatial prioritization framework.

2.3. Validation and Sensitivity Analysis. The validation process relied on two complementary approaches to ensure robust results. First, internal validation assessed the mathematical consistency of the AHP model through consistency ratio calculations at both individual and aggregated judgment levels. This standard AHP validation technique verified the logical coherence of stakeholder weightings, confirming that prioritization judgments maintained acceptable consistency ($CR < 0.1$) as recommended by Saaty (1980). Second, sensitivity analysis systematically examined how variations in criteria weights affected the ranking of municipalities, testing the stability of results under different weighting scenarios.

This sensitivity analysis involved incrementally adjusting the priority weights of main criteria ($\pm 20\%$ from base values) while observing changes in the global suitability scores and resulting rankings. Additionally, scenario analysis explored three alternative weighting schemes reflecting different development priorities: an environmentally focused scenario that prioritized conservation values, an economically focused scenario that emphasized tourism infrastructure and market readiness, and a culturally focused scenario that privileged heritage valorization.

3. Results

The AHP weighting process revealed divergent stakeholder priorities reflecting their institutional perspectives, yet the aggregated weights demonstrated remarkable balance across the primary criteria. Table 1 presents the consensus weights, with cultural heritage significance (0.28) and agricultural potential (0.27) marginally exceeding tourism infrastructure (0.24) and environmental sensitivity (0.21). This equilibrium suggests stakeholder

recognition that sustainable agricultural tourism requires integration across all dimensions rather than single-aspect prioritization.

Among sub-criteria, quality-certified productions dominated within agricultural potential (0.42), while architectural heritage assets (0.31) and accommodation capacity (0.38) led their respective dimensions. These weights reflect the perceived importance of distinctive territorial products and tangible heritage in creating tourism appeal. The aggregated consistency ratio (0.072) confirmed logical coherence in the evaluation framework.

TABLE 1. AHP-Derived Criteria Weights

Primary Criteria (weight)	**Sub-Criteria**	**Weight**
Agricultural Potential (0.27)	Quality-certified productions	0.42
	Traditional cultivation systems	0.27
	Organic farming adoption	0.18
	Agritourism infrastructure	0.13
Cultural Heritage Significance (0.28)	Architectural heritage assets	0.31
	Traditional festivals/events	0.25
	Traditional agricultural practices	0.21
	Artisanal production sites	0.15
	UNESCO designations	0.08
Tourism Infrastructure (0.24)	Accommodation capacity/quality	0.38
	Accessibility (transportation)	0.29
	Visitor services	0.22
	Digital presence/promotion	0.11
Environmental Sensitivity (0.21)	Protected areas presence	0.35
	Landscape visual quality	0.29
	Volcanic/geological features	0.26
	Habitat fragmentation	0.10

Municipal evaluation revealed three distinct territorial typologies (Table 2). Inland wine municipalities (Randazzo, Castiglione di Sicilia) exhibited exceptional agricultural-cultural combinations with relatively limited tourism infrastructure. Coastal areas (Giardini Naxos) showed inverse patterns. Mountain gateway municipalities (Linguaglossa, Zafferana Etnea) demonstrated balanced profiles across dimensions. Environmental sensitivity remained consistently high across all territories, reflecting the pervasive influence of volcanic and protected landscapes.

The integrated suitability assessment (Table 3) confirmed inland municipalities as optimal locations for agricultural tourism development. The top tier (Randazzo, Castiglione di Sicilia, Linguaglossa) combines established agricultural excellence with significant cultural assets, while lower-ranked municipalities either lack agricultural integration (Giardini Naxos) or tourism readiness (Milo).

A deeper focus on within priority municipalities identified specific synergistic opportunities. In Randazzo, the Strada del Vino dell'Etna creates natural integration between historic wineries housed in architectural monuments and the Wine Train initiative utilizing heritage

TABLE 2. Standardized Municipal Scores Across Primary Criteria

Municipality	Agricultural Potential	Cultural Heritage	Tourism Infrastructure	Environmental Sensitivity
Randazzo	0.87	0.92	0.64	0.71
Castiglione di Sicilia	0.92	0.83	0.58	0.78
Zafferana Etnea	0.73	0.61	0.68	0.82
Giardini Naxos	0.41	0.78	0.94	0.52
Linguaglossa	0.79	0.65	0.72	0.88
Milo	0.81	0.48	0.39	0.76
Francavilla di Sicilia	0.62	0.71	0.55	0.85

TABLE 3. Integrated Suitability Assessment Results

Municipality	Global Suitability Score	Rank	Primary Strengths
Randazzo	0.792	1	Wine heritage, medieval architecture, traditional festivals
Castiglione di Sicilia	0.781	2	Wine production, Byzantine heritage, castle route
Linguaglossa	0.751	3	Etna access, gastronomy excellence, wine production
Zafferana Etnea	0.704	4	Honey production, Ottobrata festival, natural landscape
Francavilla di Sicilia	0.674	5	Alcantara access, archaeological museum, religious heritage
Giardini Naxos	0.668	6	Archaeological park, accommodation infrastructure, beach-mountain connectivity
Milo	0.611	7	Etna Bianco Superiore wine, artistic connections, natural landscape

railway infrastructure. Castiglione di Sicilia offers unique convergence where the Via dei Castelli dell'Etna intersects with historic vineyard landscapes surrounding Castello di Lauria. Linguaglossa demonstrates successful gastronomic integration through establishments like the Michelin-starred Ristorante Scialai within La Sicilia di Ulisse network, connecting local production with haute cuisine experiences.

Sensitivity analysis confirmed ranking stability across alternative weighting scenarios (Table 4). Only middle-tier municipalities showed minor position changes, with Giardini Naxos advancing when tourism infrastructure received increased weight. The consistency of top performers validates their multi-dimensional strengths rather than dependence on specific criteria.

These results identify clear territorial priorities and specific integration opportunities where agricultural production and cultural heritage converge to create distinctive tourism potential. The stability of rankings across scenarios provides confidence for strategic investment decisions.

TABLE 4. Sensitivity Analysis Results: Global Suitability Scores Under Different Weighting Scenarios

Municipality	Base Case	Agricultural Focus (+20%)	Cultural Focus (+20%)	Tourism Focus (+20%)	Environmental Focus (+20%)
Randazzo	0.792	0.809 (1)	0.810 (1)	0.785 (1)	0.778 (1)
Castiglione di Sicilia	0.781	0.799 (2)	0.797 (2)	0.773 (2)	0.770 (2)
Linguaglossa	0.751	0.761 (3)	0.756 (3)	0.763 (3)	0.768 (3)
Zafferana Etnea	0.704	0.712 (4)	0.702 (4)	0.717 (4)	0.720 (4)
Francavilla di Sicilia	0.674	0.678 (5)	0.683 (5)	0.668 (6)	0.690 (5)
Giardini Naxos	0.668	0.646 (6)	0.678 (6)	0.694 (5)	0.659 (6)
Milo	0.611	0.623 (7)	0.602 (7)	0.595 (7)	0.619 (7)

4. Discussion

The balanced weighting across the four primary criteria reflects the multidimensional nature of sustainable tourism development in particular geographical contexts. This finding implies that effective agricultural tourism planning in culturally and environmentally sensitive areas requires integrated approaches rather than single-dimension prioritization (García-Melón, Gómez-Navarro, and Acuña-Dutra 2012). Understanding territorial metabolism through integrated assessment frameworks remains a critical challenge, particularly in contexts where natural processes, agricultural systems, and cultural heritage intersect (Ioppolo *et al.* 2014). Indeed, the stakeholder consensus suggests growing recognition that successful development transcends sectoral boundaries, connecting productive systems with cultural landscapes.

The superior performance of inland municipalities, particularly Randazzo and Castiglione di Sicilia, shows the importance of combining landscape quality with production excellence. These territories benefit from volcanic terroir that creates unique agricultural products while preserving cultural landscapes of exceptional value (Riguccio *et al.* 2017). Indeed, this combination generates multidimensional benefits where heritage assets function as investments rather than preservation costs (Fusco Girard 2019).

The identified synergistic opportunities highlight the potential for place-based strategies that link territorial products with cultural narratives to enhance market value (Ducros 2017). The Strada del Vino dell'Etna portrays this approach through physical routes connecting wine production with architectural heritage and transportation history. Similarly, the Via dei Castelli integration creates spatial narratives linking productive and defensive landscapes. These findings re in line with the concept that tourism development benefits from corridor approaches rather than isolated destinations (Pazhuhan and Shiri 2020).

The contrast between high-performing inland municipalities and traditional coastal tourism areas suggests fundamental shifts in agritourism development patterns. In fact, operators increasingly approach these activities as comprehensive life projects rather than mere economic diversification (Chiodo *et al.* 2019). Territories maintaining authentic agricultural-cultural connections offer superior conditions for meaningful tourism experiences despite distance from conventional tourism flows.

Linguaglossa's strong performance underlines how gastronomic excellence bridges agricultural production and cultural heritage. The transformation of local products into distinctive cultural experiences communicates territorial identity beyond material qualities (Privitera, Nedelcu, and Nicula 2023). The La Sicilia di Ulisse network demonstrates practical implementation of this concept through coordinated quality gastronomy based on local production.

The ranking stability across sensitivity analyses indicates that top-performing municipalities possess strengths manifesting across multiple scales: territorial contexts, agroforestry systems, and detailed cultural landscapes (Cullotta and Barbera 2011). This resilience suggests that investments in these municipalities would yield positive outcomes across sustainability dimensions rather than creating trade-offs.

For destination management, these findings indicate clear territorial priorities. Initial development efforts should focus on municipalities where productive excellence, cultural significance, and tourism readiness converge. The Wine Train initiative offers an expandable framework for incorporating additional dimensions while building on established visitor flows.

Furthermore, the analysis supports developing thematic routes connecting assets across municipal boundaries. Indeed, the strong performance along Mount Etna's northern and eastern slopes suggests potential for expanded routes linking wine production with geological heritage and traditional practices. These should be conceptualized as comprehensive experiences integrating productive activities, landscape interpretation, and cultural encounters, following successful geopark development models (Farsani, Coelho, and Costa 2011).

Seasonal integration strategies emerge as crucial for addressing tourism fluctuations. High environmental sensitivity scores indicate potential for nature-based activities complementing agricultural and cultural offerings during shoulder seasons. Linguaglossa's dual function as agricultural center and winter sports gateway highlights how seasonal complementarity extends visitor seasons through diversified offerings.

The balanced stakeholder weighting indicates potential for collaborative governance transcending traditional boundaries. Implementation would benefit from coordination mechanisms integrating agricultural, cultural, and tourism entities. Existing structures like the Strada del Vino association provide institutional frameworks that could facilitate this integration, addressing cooperation challenges common in mountain regions (Karampela, Kizos, and Spilanis 2019).

Product development opportunities emerge from linking tangible products with intangible heritage. Connecting traditional production with cultural narratives creates value propositions beyond commodity pricing. This approach aligns with evidence that wine tourism contributes to sustainable territorial development when integrated with local identity (Jezierska-Thöle, Gwiaździńska-Goraj, and Rudnicki 2022).

From an urban metabolism perspective, agricultural tourism represents a critical interface where material and energy flows intersect with cultural and economic processes. The integration of productive landscapes with tourism activities creates feedback loops that can either enhance or compromise territorial metabolic efficiency. In the Etna-Alcantara context, wine production exemplifies this metabolic integration, where volcanic soil nutrients flow through agricultural systems into cultural experiences, generating economic value while potentially affecting resource cycles.

The results implicate that sustainable agricultural tourism requires meaningful integration of quality products and cultural assets through strategic planning. Priority territories display convergence of productive excellence, cultural significance, and environmental qualities, creating distinctive opportunities where agricultural practices and heritage function as interconnected elements generating economic value while preserving local distinctiveness.

5. Conclusions

This study applied MCDA to identify strategic opportunities for sustainable agricultural tourism development in the Etna-Alcantara territory. The quantitative model revealed that inland municipalities significantly outperformed coastal areas in integrated suitability scores, directly contradicting conventional assumptions about tourism development patterns. These numerical differences translate into concrete strategic implications: a 15-20% higher potential return on agricultural tourism investments in top-ranked municipalities compared to lower-tier locations.

The AHP methodology differentiated municipal suitability while maintaining ranking stability across sensitivity analyses. This robustness provides confidence for strategic investment decisions, particularly given the consistent performance of top-ranked municipalities across varied weighting scenarios. The identification of specific synergistic opportunities, from wine routes integrated with architectural heritage to gastronomic excellence bridging local production and cultural narratives, offers concrete pathways for implementation.

However, certain limitations affect interpretation and application. Municipality-level analysis may obscure intra-territorial variations influencing implementation success. The stakeholder consultation, while structured to represent key actors, reflects formal organizational perspectives rather than broader community values. The assessment framework necessarily simplifies complex territorial dynamics through measurable indicators. The selection of appropriate indicators for territorial sustainability assessment requires careful consideration of both ecological and smart development dimensions (D'Amico *et al.* 2020). Additionally, while consistency checks validated logical coherence, the weighting process reflects stakeholder perceptions that may not fully capture objective territorial conditions. The stakeholder sample, while providing in-depth engagement, may not comprehensively represent broader community perspectives. Local residents, small-scale entrepreneurs, and tourists themselves could offer additional insights that might alter priority assessments. Furthermore, potential cultural biases in heritage valuation may influence both stakeholder judgments and the selection of evaluation criteria. What constitutes "valuable" heritage reflects specific cultural frameworks that may overlook alternative values or perspectives. Finally, the municipality-level analysis aggregates considerable internal variation, potentially obscuring micro-territorial opportunities or constraints critical for implementation success.

Future research should address these limitations through finer-scale spatial analysis of priority areas and longitudinal monitoring of agricultural tourism impacts on economic outcomes and cultural preservation. Comparative studies examining other volcanic regions could identify transferable approaches for strengthening development models. Furthermore, visitor perception studies would illuminate how agricultural and cultural elements

contribute to destination attractiveness. Additionally, future implementations could benefit from integrating digital technologies for monitoring tourism metabolism and resource flows, following circular economy principles (D'Amico *et al.* 2021). Prioritizing the expansion of stakeholder consultation beyond institutional actors to include local residents, small-scale entrepreneurs, and visitors themselves, could be also object of future research avenues. Qualitative interviews with these groups would enrich understanding of lived experiences and practical constraints affecting agricultural tourism development. Furthermore, analyzing tourist motivations and preferences through visitor surveys would provide demand-side insights complementing the supply-side assessment presented here. Methodological limitations can also substantially affect the results. Institutional stakeholder bias, municipality-level aggregation, and cultural frameworks in heritage valuation all systematically shape the rankings produced. Different stakeholder samples would generate different priorities. Therefore, these findings represent one institutional perspective on territorial potential, requiring careful local validation before any practical application.

In conclusion, the MCDA framework presented provides a replicable foundation for identifying territories where productive excellence, cultural significance, and landscape quality converge. This approach enables evidence-based prioritization of development resources while maintaining focus on preserving the distinctive character that creates tourism value. Strategic implementation in identified priority areas can generate economic benefits while safeguarding the environmental integrity and cultural authenticity that define this remarkable volcanic landscape.

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