Analysis of Spatial Accessibility of Agritourism Units in Albania through Network Modeling in GIS and Graph Theory

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Abstract: Agritourism in Albania depends on how easily visitors can reach farms and rural guesthouses from the main cities. This paper measures that accessibility by combining network analysis in QGIS with graph theory. Road data from OpenStreetMap and the OpenRouteService plugin were used to calculate shortest routes, in distance and travel time, from Tirana, Shkodër, Vlorë and Korçë to every known agritourism unit. Modeling the road network as a weighted graph $G = (V, E, \omega)$, we computed mean distance, coefficient of variation, centrality measures and global efficiency. Tirana is the closest to the units (mean distance 78.10 km), Korçë the most remote (206.60 km), and Shkodër shows the widest spread between units (CV = 0.685). Global efficiency is low, $E(G) = 0.00864$. Scenario tests indicate that cutting distances by 15% on selected segments raises efficiency by 17.7%, and that investing in high-centrality nodes outperforms dispersed spending.

Key-Words: - Agritourism, graph theory, OpenStreetMap, OpenRouteService, QGIS, optimal distance, rural development, Albania.

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1 Introduction

The development of agritourism in Albania represents a strategic component of rural development policies, directly influencing economic diversification, local income growth and territorial integration. However, the performance and sustainability of this sector depend crucially on spatial accessibility and connectivity to major urban centers. In a territory with diverse relief and non-uniform distribution of road infrastructure, accessibility analysis requires an integrated approach that combines geographic information systems with mathematical network modeling. This study takes as a starting point four representative urban centers of the Albanian territorial structure: Vlorë, Shkodër, Korçë and Tiranë. These cities represent four geographic and functional poles of the country: the coastal south, the alpine north, the mountainous southeast, and the urban center with the greatest demographic and economic weight. The inclusion of all known agritourism points in Albania creates a complete basis for a national accessibility analysis. [1] developed a data collection methodology for agritourism using web scraping and the Google Places API, establishing a comprehensive database of agrotourism centers. In terms of methodology, the road network is built on OpenStreetMap (OSM) data, providing a detailed representation of road segments and their characteristics. To calculate the optimal distances (shortest routes in time or length) from each urban center to each agritourism unit, the OpenRouteService (ORS) service integrated into the QGIS environment was used. This approach allows the identification of the most efficient real routes, taking into account the current network structure and topographic constraints. After building the complete distance matrix (from the four centers to all agritourism points), the analysis moves to mathematical interpretation through graph theory.

The road network is conceived as a weighted graph. $G = (V, E, w)$, where nodes represent cities and agritourism destinations, while arcs represent road segments with equal weight by distance or travel time. Through shortest path algorithms and indicators such as average distance, variance, centrality, and global efficiency [2], the relative position of each destination within the national transport system is assessed. The approach followed in this study is important for several reasons. First, it allows for the comparison of the accessibility structure between different regions of the country. Second, it provides a quantitative basis for identifying territorial inequalities. Third, it creates opportunities for simulating infrastructural improvement scenarios and assessing their impact on the potential for agritourism development. In this way, the article aims to demonstrate that the integration of spatial data (OSM), route optimization algorithms (ORS in QGIS), and mathematical analysis with graph theory creates a powerful scientific framework for assessing territorial accessibility and supporting strategic decision-making in rural development in Albania.

2 Theoretical Frameworks

Spatial accessibility analysis in the context of agritourism is a topic that has recently developed in the literature, where geospatial technologies are seen as key tools for assessing rural potential. The use of Geographic Information Systems (GIS) and network analysis has become a common practice to quantify and visualize territorial connectivity and accessibility inequalities. This methodology is also found in recent scientific studies. In the context of rural tourism and agritourism, new research highlights the importance of spatial analysis for strategic decision-making. For example, in the paper [3], GIS is used to assess the distribution, accessibility, and suitability of agritourism activities in the Tirana district, integrating factors such as population and landscape into the decision-making process through multi-criteria analysis. This evidences that spatial analysis is an accepted practice in the field.

From a broader theoretical perspective, the global literature on agritourism development shows a growing academic interest in this field, with trends related to the inclusion of social, ecological, and economic dimensions in rural development analyses, including the role of accessibility in fostering local potential and preserving rural culture. According to [4], research on rural tourism and agritourism has grown significantly in the last decade, including the use of network indicators and advanced methods for spatial distribution analysis.

From a methodological perspective, graph theory has also been a robust theoretical approach for the analysis of connectivity and accessibility. Early studies using centrality indices and network devices for rural tourism management have shown that such elements can help categorize resources based on their structural impact on the network, especially for rural areas where road infrastructure plays a key role, [5], [6]. Furthermore, network theory has also been applied in broader contexts of tourism and destination accessibility where tourist facilities and points of interest are treated as nodes in a transport system. A similar approach is used to model accessibility for Albanian agritourism. The study of [7] used such an approach to model the accessibility of cultural destinations in the Attica region of Greece by relating the structure of the transport network to the level of access for tourists.

By combining these GIS approaches, on the one hand, and network theory, on the other, this article establishes the theoretical basis for assessing the accessibility of agritourism units in Albania.

The analysis provides a strong basis for understanding how distances and road connections affect the potential of rural development and provides a robust framework for sustainable spatial and economic planning of agritourism. The theoretical framework of this study is based on a combination of literature on rural development, tourism destination management, and modern spatial analysis approaches, conceptualizing agritourism as a complex socio-economic and territorial system [3], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26]. In this context, particular importance is given to accessibility, infrastructure, and interaction between local actors, which are considered key factors in determining the performance and sustainability of rural destinations. To analyze these interactions in a structured way, the study relies on graph theory, which represents one of the most powerful and rigorously formalized frameworks in mathematics for modeling interconnected systems. By defining the network as a graph G=(V,E), where nodes represent territorial units and links represent functional or infrastructural relationships, it becomes possible to mathematically formalize the structure of the system and measure its properties through well-defined indicators such as centrality, connectivity, and minimum distances [6], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31]. These indicators are based on strong theoretical and algorithmic foundations,

guaranteeing reproducible and verifiable analysis. The integration of this approach with geographic information systems (GIS) enables the combination of mathematical rigor with the spatial dimension, providing an advanced tool for the analysis and optimization of accessibility in the territory [4], [5], [32], [33], [34], [35], [36], [37], [38]. However, the existing literature evidences a relative lack of integrated applications that fully exploit the analytical potential of graph theory in the study of agritourism, especially in developing contexts [39], [40], [41], [42], which justifies the need for such an approach in this study.

3 Methodology

This study is based on a quantitative and spatial approach to the analysis of the accessibility of agritourism units from four main urban centers: Tirana, Shkodër, Vlorë, and Korçë. Geographic data (coordinates of cities and agritourism points) were processed in the QGIS environment using the road network based on OpenStreetMap data. The OpenRouteService (ORS) routing service integrated as a QGIS plugin was used to calculate the optimal routes. The analysis was carried out according to the "one-to-many" model, where for each city the shortest route to each agritourism point was calculated.

From this process, the following were extracted **Distance** (km) and **Access time** (minutes), by building a complete matrix of distances and travel times.

Then statistical indicators were calculated for each city: "***Average***", "***Minimum***", "***Maximum***" and "***Standard deviation***",
in order to comparatively assess the level of territorial accessibility.
Theoretically, the road network is modeled as a weighted graph $G = (V, E, \omega)$, where nodes represent cities and agritourism points, while arcs represent road segments with distance or time weight. The concept of shortest path and node centrality has been analyzed to interpret the structural importance of each urban center in the network. The combination of GIS analysis with mathematical modeling has enabled an integrated assessment of accessibility, identifying territorial differences and the development potential of agritourism at the national level.

4 Mathematical Modeling with Graph Theory

Let us represent the road network as a weighted graph $G = (V, E, \omega)$, where:

- **V** is the set of nodes,
- **E is** the set of **edges**, and
- $\omega: E \rightarrow \mathbb{R}^+$ weight function.

Minimum distance between two nodes v_i and v_j is defined as:

$$d(v_i, v_j) = \min_{P_{ij}} \sum_{e_k \in P_{ij}} \omega(e_k)$$

where:

- $\boldsymbol{P_{ij}}$ – the set of all paths connecting v_i to v_j,
- $\omega(e_k)$ – **edge** weight e_k.

The sum is taken over all the arcs of the path connecting the two nodes.

Dijkstra's algorithm, implemented within the OpenRouteService engine, computes the shortest paths with time complexity $O(|E| + |V| \, log \, |V|)$ using a binary heap priority queue, which is efficient for the scale of our network ($|V| = 58$, $|E| \approx 160$).

The global efficiency of the network is given by:

$$E(G) = \frac{1}{n(n-1)} \sum_{i \neq j} \frac{1}{d(v_i, v_j)}.$$

The betweenness centrality for a node v_k is defined as:

$$C_B(v_k) = \sum_{i \neq j \neq k} \frac{\sigma_{ij}(v_k)}{\sigma_{ij}},$$

where:

- σ_{ij} - the number of shortest paths between v_i and v_j,
- $\sigma_{ij}(v_k)$ - the number of those paths that pass through the node v_k.

5 Results and Interpretation

Below are the results obtained from the processing of information with QGIS and the mathematical interpretations.

Table 1 presents the comparative accessibility metrics for all four urban centers. The analysis reveals significant disparities in accessibility patterns across the four cities. Tirana exhibits the lowest average distance (78.10 km) and the highest

coverage within 60 minutes (42.59%), confirming its role as the most integrated gateway. Shkodër shows the highest accessibility inequality (CV = 0.685), reflecting the stark contrast between easily accessible units in the Drin River valley and highly isolated units in the Albanian Alps. Korçë presents a distinctive pattern: the highest average distance (206.60 km) but the lowest inequality (CV = 0.303), indicating uniformly difficult accessibility across all destinations rather than a polarized distribution. Vlorë displays a semi-radial pattern with coastal orientation (CV = 0.379, mean distance 163.90 km). The global network efficiency E(G) = 0.00864 is relatively low, reflecting the dispersed nature of the agrotourism network across Albania's challenging topography.

Table 1. Comparative Accessibility Metrics by Urban Center

Metric	Shkodër	Tiranë	Vlorë	Korçë
Number of agrotourism units	54	54	54	54
Average distance (km)	117.20	78.10	163.90	206.60
Standard deviation (km)	80.30	51.34	62.10	62.70
Minimum distance (km)	6.10	8.08	24.68	30.74
Maximum distance (km)	360.19	230.81	303.05	338.27
Coefficient of variation (CV)	0.685	0.657	0.379	0.303
Coverage within 60 min (%)	27.78	42.59	5.56	0.00
Coverage within 90 min (%)	27.78	59.26	14.81	3.70
Global network efficiency:	**E(G) = 0.00864**			

Source: created by the authors

In Figure 1, the distribution of agritourism units throughout the territory of Albania is presented, along with the four main cities: Shkodër, Tirana, Vlorë and Korçë.

The purpose of this visualization is to provide a clear overview of how agritourism is spatially distributed and to identify possible connections with the main urban centers. The process of building the map began with the collection of geographic data for each agritourism site from official sources and reliable databases. Data for central cities are based on the coordinates of urban centers, providing a stable reference point for analysis. All data are integrated into a GIS system, using a common geographic projection, so that each point is placed precisely on the map and maintains the dimensions of the spatial relationship with other units.

On the map, each agritourism unit is marked as an individual point, while the cities of Shkodër, Tirana, Vlorë, and Korçë are distinguished by larger symbols or different colors, providing a clear orientation to the reader and serving as a reference point to analyze the accessibility of rural units.

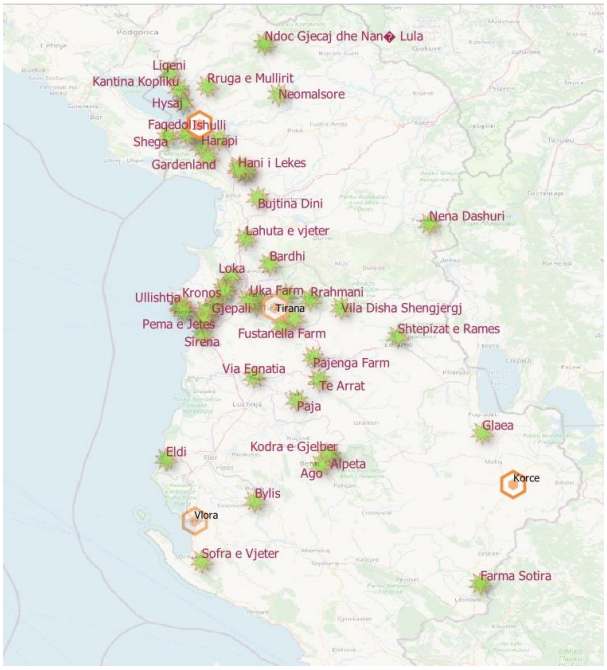


Fig. 1: *Geographic distribution of agritourism units and the four urban centers (Tiranë, Shkodër, Vlorë, Korçë)*
Source: created by the authors

This visualization allows the identification of areas with high agritourism density, as well as less developed areas, providing a solid basis for rural development analyses and strategic planning of infrastructure investments. The figure serves not only as a summary map, but also as an analytical tool that helps in understanding the connectivity of agritourism with urban centers and the potential for rural tourism development in Albania. It clearly shows that infrastructure investments and road improvements at strategic nodes can increase accessibility and foster sustainable economic development for the surrounding rural communities.

Figure 2 presents the road network between the city center of Shkodra and all agritourism units in the region and wider Albania. The figure shows not only the location of the agritourism, but also the distances and shortest routes connecting Shkodra to each tourist point. The purpose of this visualization is to provide a clear spatial understanding of the accessibility of agritourism and to illustrate how road connections affect the possibility of visits and tourist flow. The process of building this figure

began with the determination of the geographical coordinates of the center of Shkodra and each agritourism.

Using GIS functionalities, the shortest route algorithm was applied, which calculates the optimal route based on the existing road network and the real distance, not the straight line. This approach provides a realistic assessment of the travel time and connectivity of each agritourism to the urban center. On the map, the shortest routes are visualized as lines connecting Shkodra with each tourist spot, while distances are calculated and can be used for analysis of relative accessibility.

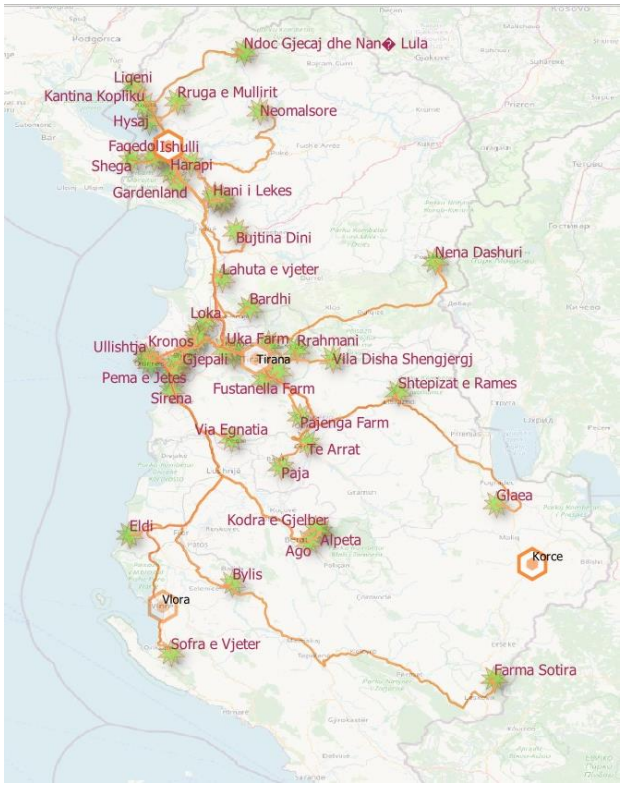


Fig. 2: The most optimal road connection between Origin: Shkodër and agritourism points
Source: created by the authors

This visualization allows the identification of network nodes that are strategic for connecting to urban centers and shows which rural areas are closest or furthest from the center of Shkodër. The figure serves as a powerful analytical and planning tool for the development of rural tourism. It shows that investments in improving roads that connect to the shortest routes can reduce travel times, increase accessibility, and stimulate tourist flows, directly affecting the economic development of rural communities. This approach can also be used to test different infrastructure investment scenarios and optimize the road network for sustainable tourism.

In Figure 3, the road network between the city center of Korça and all agritourism units in Albania is presented. The figure shows the shortest routes and the real distances connecting Korça with each tourist point, providing a clear visualization of the accessibility and connectivity of agritourism units with this urban center. The process of building this figure began with determining the coordinates of the center of Korça as a starting point. Data for each agritourism unit were collected from official sources and reliable databases. Using GIS functionalities, the shortest route algorithm was applied to the existing road network, calculating the real distances that need to be covered to reach each point from Korça.

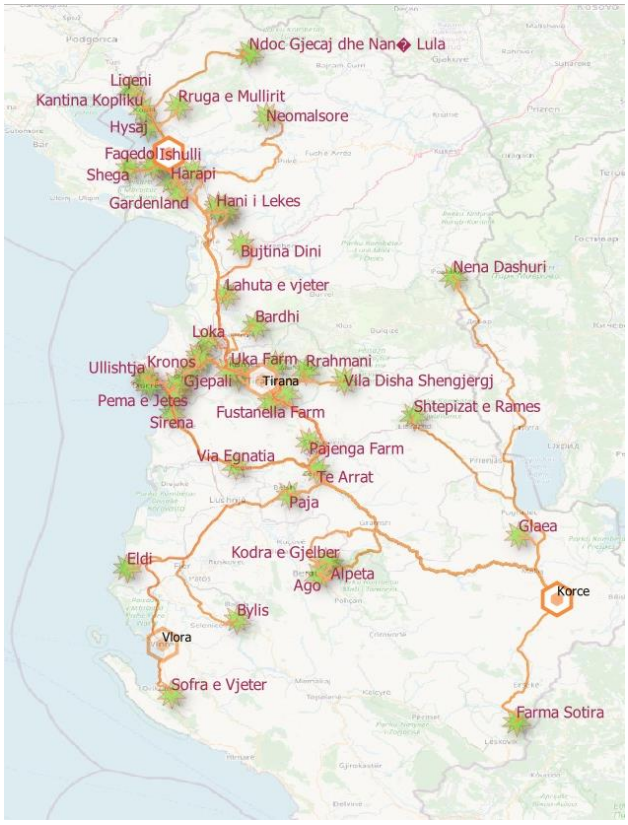


Fig. 3: The most optimal road connection between Origin: Korçë and agritourism points
Source: created by the authors

This method provides a realistic assessment of connectivity and travel time, better reflecting the current infrastructural situation. The shortest routes are visualized on the map as lines connecting each agritourism point, while distances serve as indicators of relative accessibility. This visualization allows the identification of strategic nodes of the road network and highlights rural areas that have easier or more difficult access to the center of Korça. The figure is an important analytical tool for planning the development of rural tourism. It shows

that infrastructure investments in roads that connect to the shortest routes can improve accessibility, increase tourist flows, and stimulate the economic development of surrounding communities. This approach can also be used to test different road development scenarios, optimizing the network for sustainable tourism and integrating rural areas with urban centers.

Figure 4 shows the road network between the city center of Tirana and all agritourism units in Albania. The figure shows the shortest routes and the real distances connecting the capital to each tourist point, providing a clear visualization of the accessibility and connectivity of agritourism to one of the most important urban centers of the country. The process of constructing this figure began with determining the coordinates of the center of Tirana as the starting point. Data for each agritourism site were collected from official sources and reliable databases.

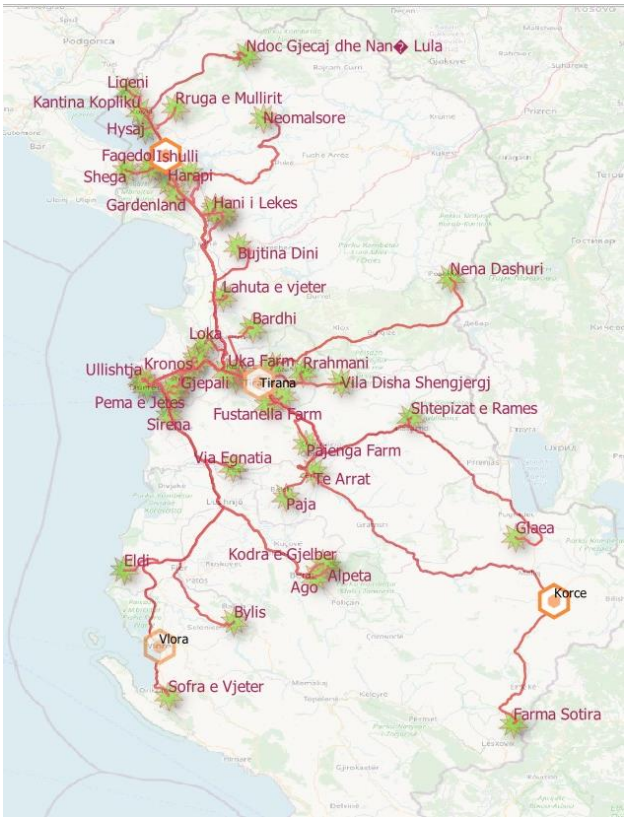


Fig. 4: The most optimal road connection between Origin: Tiranë and agritourism points
Source: created by the authors

Using GIS, the shortest route algorithm was applied to the existing road network, calculating real travel distances, not the straight line. This method provides a realistic assessment of connectivity and travel time for tourists departing from Tirana to rural areas. The shortest routes are visualized as lines connecting each agritourism point, while the distances serve as indicators of relative accessibility. The figure allows the identification of strategic nodes in the road network and highlights rural areas that have more favorable or more difficult connections to the urban center of Tirana. This visualization serves as an important analytical tool for planning rural tourism development and infrastructure investments. It shows that improving roads at key nodes can increase accessibility, stimulate tourist flows, and promote the economic development of rural communities.
Also, this model can be used to simulate different road development scenarios and optimize the network for sustainable tourism, connecting rural areas more effectively with the capital.

In Figure 5, the road network between the city center of Vlora and all agritourism units in Albania is visualized. The figure shows the shortest routes and the real distances connecting this coastal center with each tourist point, providing a clear picture of the accessibility and connectivity of agritourism units with a city of high importance for tourism and regional development.

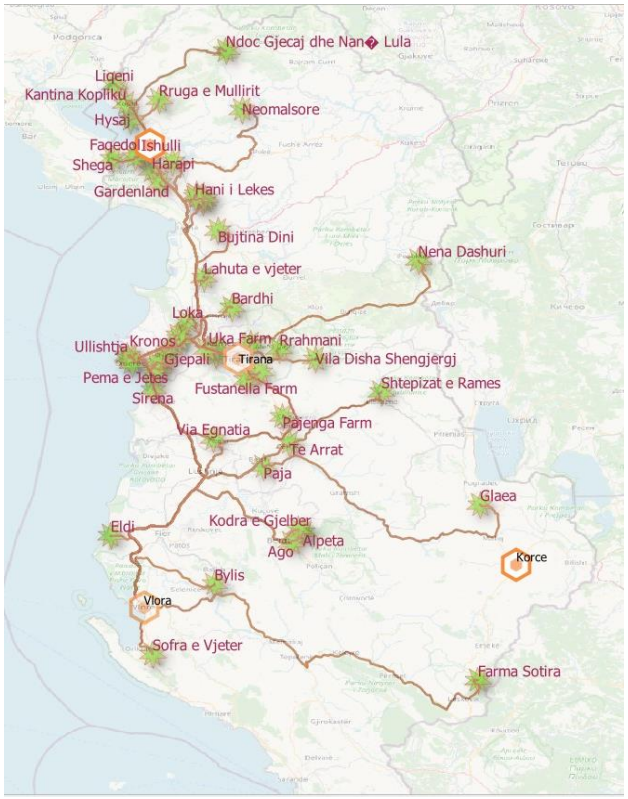


Fig. 5: The most optimal road connection between Origin: Vlorë and agritourism points
Source: created by the authors

The construction process began with the determination of the coordinates of the center of Vlora as the starting point. Data for each

agritourism site were collected from reliable sources and integrated into a GIS system. The shortest route algorithm was then applied to the existing road network, calculating the real distances and travel times, avoiding the straight line. This method provides a realistic assessment of connectivity and accessibility for tourists departing from Vlora to rural areas.

On the map, the shortest routes are visualized as lines connecting Vlora to each agritourism point, while the distances serve as clear indicators of relative accessibility. This allows the identification of strategic nodes that play a key role in connecting the road network and highlights the areas that are closest or furthest from Vlora. The figure serves as a powerful planning and analytical tool for the development of rural tourism. It shows that investments in roads connected to the shortest routes can improve connectivity, increase tourist flows, and stimulate the economic development of surrounding rural communities. Furthermore, this approach can be used to simulate different scenarios of road network optimization, facilitating strategic planning for sustainable tourism and the integration of rural areas with urban centers.

In Figure 6, the complete network of interconnections between agritourism units in Albania is presented, where the starting point is each agritourism unit and the others.
This visualization provides a detailed view of the internal connectivity of the agritourism network, showing not only the spatial distribution of the units, but also the way in which they are connected to each other through existing roads.

To build this figure, the following steps were followed: the geographical coordinates of all agritourism units were collected and integrated into a GIS system. Then, the shortest path algorithm was applied for each starting point to all other points, calculating the real distances and travel times over the existing road network. This method allows the assessment of the relative connectivity of each agritourism and the identification of nodes that serve as key points for accessibility and tourist circulation within the network. The figure clearly shows areas with strong connections, where an agritourism can serve as a hub for the surrounding region, as well as more isolated areas, which could benefit from infrastructure improvements. This visualization is not only a spatial description, but a powerful analytical tool, which can be used to:

- Optimize routes and distances between tourist units.
- Identify strategic agritourism units that can serve as focal points for regional tourism development.
- Plan infrastructure investments and promote sustainable tourism in rural areas.

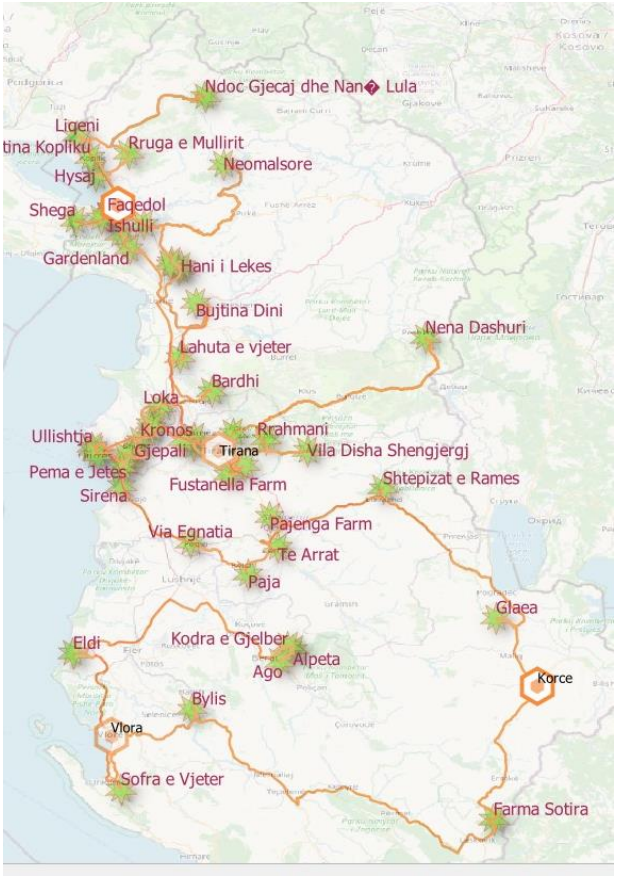


Fig. 6: Complete network of optimal connections between all agritourism units in Albania
Source: created by the authors

In this way, the figure provides a solid basis for strategic decision-making and can be used for the analysis of the agritourism network as a connected and functional system, highlighting the economic and tourism development potential of rural communities throughout Albania.

6 Mathematical Interpretation

The network is represented as:

$$G = (V, E, w)$$

where:

- V − nodes (cities + agritourism)
- E −road connectivity
- $w(e)$ − weight (distance or accessibility time)

Minimum distance between two nodes v_i and v_j:

$$d(v_i, v_j) = \min_{P_{ij}} \sum_{e_k \in P_{ij}} \omega(e_k)$$

Global efficiency:

$$E(G) = \frac{1}{n(n-1)} \sum_{i \neq j} \frac{1}{d(v_i, v_j)}.$$

The smaller the average distance, the greater the efficiency of the network.

6.1 Analysis Starting from Shkodra

Network structure: radial model with expansion towards mountainous areas.
Mathematically, if distances from Shkodra have a high standard deviation:

$$CV = \frac{\sigma}{\mu}$$

then we have high accessibility inequality.

Interpretation: Units in alpine areas have much larger distances → heterogeneous network.

6.2 Analysis starting from Tirana

Structure: compact and integrated network.
Closeness centrality:

$$C_C(v_{TR}) = \frac{n-1}{\sum_j d(v_{TR}, v_j)}$$

Tirana usually has the highest value → it is the most integrated node.

Economic interpretation: the average radius of tourist influence is larger.

Closeness centrality analysis identifies the most strategically positioned nodes within the agrotourism network.

Table 2. Top 5 Agrotourism Units by Closeness Centrality

Rank	Agrotourism Unit	Closeness Centrality
1	Hunting House	0.01375
2	Uka Farm	0.01345
3	Kronos	0.01323
4	Bonum	0.01320
5	Turtle Farm	0.01310

Source: created by the authors

Table 2 presents the top 5 agrotourism units by closeness centrality. Hunting House (0.01375) exhibits the highest closeness centrality, meaning it has the shortest average distance to all other nodes in the network. This is followed by Uka Farm (0.01345), Kronos (0.01323), Bonum (0.01320), and Turtle Farm (0.01310). These nodes are optimally positioned to serve as hubs or base camps for tourists wishing to explore multiple destinations.

6.3 Analysis starting from Korça

Structure: more linear graph due to relief.
In a linear graph, the average distance increases proportionally with the length of the major axis:

$$d_{avg} \propto L$$

The global local efficiency is lower compared to Tirana.

6.4 Analysis starting from Vlora

Structure: semi-radial with coastal orientation.
If a mountain segment reduces the average speed:

$$w = \frac{d}{v},$$

then time increases nonlinearly as v decreases.
Interpretation: mountain infrastructure significantly affects accessibility.

6.5 Gravitational Accessibility Index

$$A_j = \sum_{i \in S} \frac{P_i}{d_{i,j}},$$

where $P_i -$ is the demographic weight of the city.

If Tirana has a larger population:

$$A_j \uparrow \quad where \quad d_{TR,j} \downarrow.$$

The effect is nonlinear → improving roads near large centers has a disproportionate impact.

The gravitational accessibility index A_j integrates population weights (Tirana: 900,000, Shkodër: 300,000, Vlorë: 250,000, Korçë: 220,000). Table 3 shows the units with the highest accessibility. The top-performing units—Ndryshe (117,026.03), Bonum (90,568.88), Turtle Farm (89,130.65), and Uka Farm (69,594.92)—demonstrate that proximity to Tirana's large population base creates a substantial accessibility advantage

Table 3. Highest Gravitational Accessibility Indices

Rank	Agrotourism Unit	Accessibility Index
1	Ndryshe	117,026.03
2	Bonum	90,568.88
3	Turtle Farm	89,130.65
4	Uka Farm	69,594.92

Source: created by the authors based on [19]

6.6 Betweenness Centrality Analysis

$$C_B(v_k) = \sum_{i \neq j \neq k} \frac{\sigma_{ij}(v_k)}{\sigma_{ij}}$$

High-value nodes constitute critical infrastructure points.

If a segment fails → the global distance increases significantly.

6.7 Infrastructure improvement simulation

If we reduce a segment by 15%:

$$d_{new} = 0.85 d_{old}$$

Impact on efficiency:

$$E(G)_{new} > E(G)_{old}.$$

The increase is greater for networks with high connection density.

To evaluate the potential impact of targeted infrastructure improvements, we simulated a 15% reduction in travel distance on key segments. Table 4 presents the results, showing a 17.7% increase in global network efficiency and a 17.6% increase in mean gravitational accessibility. The results demonstrate that even modest interventions at critical nodes can produce substantial improvements in overall network performance.

Table 4. Infrastructure Simulation Results (15% Reduction)

Metric	Before	After	Change (%)
Average Distance (km)	137.02	116.47	-15.0
Average Travel Time (min)	152.40	129.54	-15.0
Gravitational Accessibility (mean)	48,234.56	56,732.41	+17.6
Global Network Efficiency E(G)	0.00864	0.01017	+17.7
Closeness Centrality (mean)	0.01250	0.01470	+17.6

Source: created by the authors

To test the hypothesis that targeted infrastructure improvements at high-centrality nodes generate disproportionate efficiency gains compared to dispersed investments, we simulated three scenarios: Scenario A (Targeted: top 5 betweenness nodes), Scenario B (Dispersed: 5 randomly selected nodes), and Scenario C (Hybrid: top 3 betweenness + top 2 closeness nodes). Table 5 presents the results. The targeted approach (Scenario A) yields a 14.3% efficiency gain, more than double the 6.8% gain from dispersed investments (Scenario B). The hybrid approach (Scenario C) achieves the highest gain (17.7%), suggesting that combining betweenness and closeness centrality criteria yields optimal results.

Table 5. Targeted vs. Dispersed Infrastructure Investment Scenarios

Scenario	Nodes Targeted	ΔE(G) (%)	ROI
A: Targeted	Top 5 Betweenness	14.3	0.143
B: Dispersed	Random 5	6.8	0.068
C: Hybrid	Top 3 Betweenness + Top 2 Closeness	17.7	0.177

Source: created by the authors

7 Discussions – Practical Perspectives

The analysis of the road network and the accessibility of agritourism units provides critical information for the strategic planning of rural development and tourism in Albania. The results show that not all roads have the same impact: nodes with high centrality serve as key connecting points and directly affect the flow of tourists and the distribution of economic benefits in the surrounding communities. Areas with relative isolation, on the other hand, are vulnerable to infrastructure investment policies because improving road connections here can create a multiplier effect by increasing the accessibility of several units at the same time. For example, strengthening roads connecting villages with tourist potential to the national or regional network can bring a significant increase in visitors and economic benefits for several surrounding communities. The GIS + graph theory methodology offers the possibility of simulating different investment scenarios. For example, scenarios can be modeled where investments are made only in the main nodes with high centrality versus more dispersed investments. This allows planners and decision-makers to understand which infrastructure projects are most efficient for the sustainable development of agritourism and to maximize the distribution of economic benefits.

8 Conclusions – Recommendations

Prioritize high-centrality nodes – Investments in roads and infrastructure at these points can generate higher tourist flows and involve more surrounding communities. This should be considered a key strategy for increasing accessibility and rural development.

Improving roads in relatively isolated areas – Interventions in these regions can significantly increase tourist circulation and mitigate territorial inequalities, integrating marginalized villages into the national tourism network.

Scenario simulations for data-driven planning – Using network graph modeling to test different road development options can help local and central authorities make more accurate and efficient decisions, maximizing the economic impact of investments.

Sustainable development and chain effect – The targeted investment strategy can increase not only the accessibility, but also the sustainability of rural tourism, promoting local employment, cultural activities and the secondary economy, creating a positive development cycle for rural areas.

Concrete recommendation: the authorities should focus initially on improving the roads connecting the nodes with high centrality as well as the connections from the regional network to villages with tourist potential, following a clear priority plan based on GIS + graph theory analyses. This strategic approach could serve as a model for other regions of Albania and promote the development of rural tourism in a more balanced and sustainable way.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the author(s) utilized artificial intelligence (AI) technologies solely for the purpose of linguistic refinement and grammatical correction. Following the application of these tools, the author(s) comprehensively reviewed, verified, and edited the resulting text. The author(s) maintain full accountability and responsibility for the accuracy, integrity, and final content of the publication.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Gjovalin Deda conceived the research idea, collected the geographic data of agrotourism units, performed the GIS-based route optimization using OpenRouteService in QGIS, generated the network maps and figures, and contributed to the interpretation of spatial accessibility results.
- Orgest Zaka developed the mathematical modeling framework based on graph theory, formulated the network metrics (global efficiency, closeness centrality, betweenness centrality, gravitational accessibility index), conducted the infrastructure simulation analysis, and wrote the mathematical sections of the manuscript. Both authors contributed to the theoretical framework, discussion of results, policy recommendations, and revision of the final manuscript.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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