INTERCONNECTING KARST DOLINES WITH HIGH ECOLOGICAL VALUE THROUGH TOURIST ROUTES FOR ENHANCING PUBLIC RECREATION

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Abstract
Planning technical interventions in areas of high landscape and environmental importance requires the convergence of integrated multiple skills. Particularly when these areas find significant opportunities for tourist valorization, this planning activity is extremely important and requires an appropriate technical approach. With the aim to enhance public recreation in the rural land, in this paper, some areas of peculiar environmental, landscape and archaeological value - such as the karst dolines (in Italian, so-called: "*Puli*") – have been analyzed. This type of karst formation originated as a result of the collapse of the vault of underground cavities, excavated by the erosive and corrosive action of water infiltrating the limestone substrata. Through the implementation of a GIS tool, some touristic routes, connecting three different *„Puli"* located in the Apulia region (Southern Italy), have been examined. These three areas are very interesting as for their historical-archaeological value and their geological nature, as well as for their naturalistic assets - both faunal and botanical biodiversity, including several ecosystems. The final results coming from this research may support in sustainably enhancing public recreation in the rural landscape along specific touristic routes, helping to assess the environmental and social impact of tourism activities along those trails as well.

Key words: Karst dolines, biodiversity preservation, landscape protection, GIS tools, touristic routes.

Introduction

Rural tourism is progressively growing in several areas all over the World, thanks to its characteristics to noticeably combine naturalistic, cultural and eno-gastronomic opportunities. It could be defined as a type of tourism located in agro-forestry areas, identified by some key characteristics (location, between countryside and small towns; small accommodation facilities scale; close relations with the local population; interaction with the surrounding environment, history, culture, etc.) (Belligiano et al., 2021). Tourism activities related to these rural structures are currently expanding, so incentivizing the arrival of more tourists and valorizing the rural land. Most of the studied routes are in Europe and focused on the theme of food and drinks at a regional level (Pedrosa et al., 2025). One of the elements of the rural landscape that could be improved to further spreading, is the network of old sheep-tracks especially in Southern Italy and some sites of special historical and archaeological interest (Picuno C.A. et al., 2017). This article examines three sites of unique environmental, scenic, and archaeological importance, such as the karst dolines (also known as "Puli" in Italian), with the goal of improving public enjoyment in rural areas. The erosive and corrosive action of water seeping into the limestone substrata, caused the vault of subsurface caverns to collapse, giving rise to this kind of karst formation. These 3 locations, highly intriguing due to their geological characteristics, historical-archaeological significance, and naturalistic qualities, which include a variety of ecosystems and biodiversity in both plants and animals, were investigated through the use of a GIS application, aimed to assess their possibility of mutual connection, so as to create innovative itineraries for rural tourism (Fig. 1).

Material and methods

A GIS methodology may be applied to provide a useful tool to guarantee the integrity of the landscape and to select the best strategies for the valorisation of the rural territory (Statuto et al., 2013). In particular, three particular sites in the Apulia region were related. They are:

- PULO OF ALTAMURA - THE GREAT KARST CRATER

With a diameter of about 700 meters and a depth of 90 meters, the Pulo of Altamura is among the largest and most scenic dolines in Italy (Fig. 2 left). This geological site, one of the most important in the „Alta Murgia" hilly area, was generated by the collapse of a karst cave system and shaped by the force of rainwater. It represents an exceptional expression of surface karst, characterized by the presence of caves along the steep walls. On the northern side, there is a swallowhole consisting of several wells. Archaeological evidence found in the cavities demonstrates human habitation from the Late Paleolithic to the Middle Ages.

Fig. 5: Study area in Apulia Region

This site is located in a protected area (integral reserve zone). It is home to important endemic species, thanks to a favorable microclimate, even in the driest periods. The area that can be visited by the public has several equipped walking trails, two parking areas and a picnic area. Some small shelters are freely accessible, but expert cavers are recommended to visit the caves. The bottom of the sinkhole allows the growth of endemic plants and provides shelter for wildlife during dry periods.

Fig. 6: Top view of the „Pulo di Altamura“ (left) and view of „Pulicchio di Gravina“ (right)

- PULICCHIO DI GRAVINA

Along the Murgia ridge, at 550 m above sea level, a chasm opens up, one of the largest karstic dolines in Puglia, with a perimeter of 1600 m and a depth of almost 90 m. The shape is funnel-shaped, unlike the bowl-shaped Pulo di Altamura, and inside there is a 1950s reforestation of pine and cypress trees (Fig. 2 right). It is located into the territory of Gravina in Puglia, at about 10 kilometers north of the latter, close to the border with Altamura's territory. The doline is shaped like an egg and it is highly regular, with the slope almost constant on all its sides (as shown on the map's level curves). The path along the perimeter is easily accessible and allows to appreciate numerous species of trees, orchids, especially in the springtime, and numerous specimens of buzzards and imperial crows that frequent the present rocky ridge.

- PULO DI MOLFETTA

It is a doline with unusual naturalistic and archeological features, that spans an area of roughly 3 Ha and is about 35 m deep (Fig. 3). The erosive and corrosive action of water seeping into the limestone substrata caused the vault of subsurface cavities to collapse, giving rise to this type of surface karst formations. The remains of an old saltpeter factory, which the Bourbons used to make gunpowder in the 19th century, can be found in the flat bottom of this doline (Radina, 2007).

From a naturalistic perspective, the millennial interactions between man and a distinct natural environment - both in terms of vegetation and microclimate -make this region a hotspot of biological diversity. Pulo di Molfetta is a unique location with an historical, cultural, and environmental legacy, that has to be maintained because of its floristic richness, ecosystem complexity, and historical, archaeological, and cultural significance. Particularly in recent years, these regions have also been vulnerable to processes of degradation and transformation, as a result of anthropogenic and natural disturbances brought on by more harsh climatic events. This has resulted in fast changes in the floristic composition and at the ecosystem level (Picuno et al., 2024).

Fig. 3: Orthophoto of the area generated by a photogrammetric process

Thanks to the potential and the interoperability of the GIS with other tools for analysing and representing the territory (*QGis*, *Google Maps* and *Google Earth*), it was possible to define a possible route that could be cycled and to calculate the height profile and travel time. But this is only one of several possibilities; QGIS, thanks to its plugins, makes it possible to calculate much more, *e.g.*: thanks to „*Network analysis Processing Toolbox*“ it is possible to calculate the shortest path, the fastest route and the shortest route with speed limit.

Results and Discussion

The first result coming from the implemented methodology has been an integrated database with geo-referenced environmental and landscape heritage of south of Italy. In particular, the map that was created (Fig. 4) highlights a possible route connecting the three sites by a cycle path. In addition, the same figure also shows the dense network of historical sheep tracks, (so-called, "*tratturi*") a network of ancient roads used for animal grazing and trade, stretching for miles across the region's countryside and mountains. These routes are becoming a popular destination for lovers of hiking and outdoor adventure, because of their unique naturalistic and cultural features (Statuto et al., 2023).

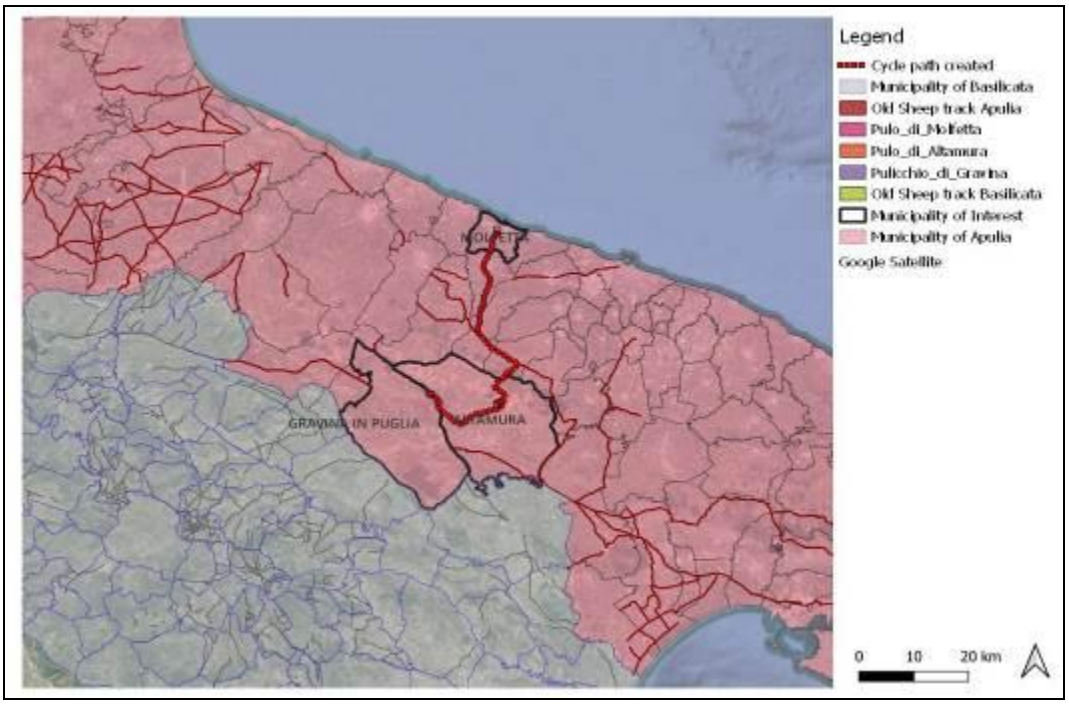

Fig. 4: cycle path created between the 3 points of interest

By using Google earth and Google Maps, it was possible to visualize the elevation profile of the hypothesized route, and it can be seen that the slope is not excessive (Fig. 5), so that the route is also practicable for less-experienced people. The length of the route was calculated to be 66 km and the cycling time was estimated to be approximately 3 hours.

Fig. 5: Elevation profile and calculation of cycling time

Conclusion

The three investigated "Puli" areas, characterized by important geological, historical, ecosystems and biodiversity characteristics, has showed that their interconnection through eco-friendly routes may be a very interesting option for improving public recreation in rural areas, social and environmental enhancement of rural tourism, and sustainable tourism routes.

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Souhrn
Tento článek analyzuje krasové doliny v oblasti Apulie, zaměřuje se na jejich environmentální, krajinářskou a archeologickou hodnotu a jejich propojení cyklostezkou. Krasové útvary, známé jako „Puli“, vznikly v důsledku propadání podzemních dutin. Použití nástroje GIS a jeho interoperabilita s dalšími nástroji může zlepšit ovčí stezky pro cestovní ruch a podpořit kulturní a environmentální dědictví oblasti. Umožňuje vytvářet turistické trasy na míru, integrovat místní tradice, historii, flóru a faunu. Cílem výzkumu je posílit veřejnou rekreaci ve venkovské krajině podél specifických turistických tras, posoudit environmentální a sociální dopady turistických aktivit, které mají zásadní význam pro udržitelný rozvoj a zajišťují lepší budoucnost místních komunit.

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