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Geosite Assessment as a Tool for the Promotion and Conservation of Irpinia Landscape Geoheritage (Southern Italy)

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Abstract: Irpinia (Province of Avellino, Campania Region) is a historical–geographical region of Southern Italy inhabited in pre-Roman times by the ancient Samnite tribe of the Irpini, from which the name originates. This area is characterized by both low population density and high naturalness; located on the axial sector of the southern Apennine orogenic chain, the area possesses a complex hilly and mountainous orography, with predominantly agricultural and forest land uses. In this geographical context, there are many relevant geological/geomorphological sites, witnessing a wide geodiversity attributable to complex geological evolution and relief morphogenesis. The extensive bio-geodiversity has thus led to widespread geotourism practices. Irpinia is favored for its beautiful landscapes, rich cultural heritage, and typical small towns, often enhanced by quality certifications; moreover, geotourism activities are often associated with other forms of sustainable tourism. Starting from this geographical framework, the article analyzes eight attractive geosites that represent the geotouristic value of the entire Irpinia area well. The analysis was conducted using well-known qualitative and quantitative assessment methods. The results obtained, emphasizing the salient aspects of geodiversity, can be used in planning the usability of the sites and, more generally, planning for the Irpinian landscape in a geo-ecotouristic sense.

Keywords: Irpinia; geosites; geoheritage; cultural landscape; quantitative assessment; Southern Italy

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1. Introduction

Presently, there is a wealth of research addressing the fundamentally important concepts of geodiversity, geoheritage, and geotourism; such research is spread across every cultural field, utilizing a wide variety of scales of observation. Beginning in the 1990s, the concept of geodiversity has been adopted in many countries, and over the following years it became increasingly established as part of the notion of "natural heritage" [1]. In subsequent years, a substantial bibliography has developed on the subject, with valuable summary contributions explaining the evolution of the concepts of geodiversity, geoheritage, and geotourism. Many such studies [2] have been highlighted elsewhere by our working group (see, in particular, the Introduction to [3]).

The patrimonialization of nature came out of the narrow sphere of biological heritage (or bioheritage) and its corollary: biological diversity (or biodiversity) [4]. The latter was permanently joined by the concept of geoheritage, truly understood as features of actual patrimony/treasures; geoheritage as a field incorporates the idea of its protection, enhancement, and transmission to future generations.

Recognizing the importance of geoheritage—to all effects, as a lever of territorial development and cultural enhancement—other qualitative and quantitative elements were subsequently recognized (e.g., awareness, inventory, enhancement) which, even at different scales, contributed to completing the definition of this geological asset. The transposition of this concept into art, mythology, sacredness, etc., has not been neglected; thus, it adds further value to the more strictly scientific occupations with the subject [4].

Geoheritage is an integral part of planetary geodiversity. The latter is fundamental to the development of human societies because it is intimately related to the conservation of nature characterized by a long-living history [1]. The concept has become so important that the United Nations included geodiversity in the 2030 Sustainable Development Goals (SDGs) Agenda [5], and International Geodiversity Day was officially proclaimed by UNESCO in 2021, with the first one celebrated on 6 October 2022.

Among the many world examples that could be listed, it is worth mentioning the study area that will be presented in this paper: the Province of Avellino (also known as Irpinia, from the historical name of its pre-Roman inhabitants), located in the Campania Region of Southern Italy (Figure 1). The region is world-renowned for its historical–archaeological, artistic, and scenic beauty, which is closely related to the local geoheritage. Just think of Vesuvius—one of the best known geosites (see Wimbledon, 1996 [6]) in the world—and the ancient cities of Pompeii and Herculaneum which were destroyed by eruptions. Think of the islands of Ischia and Capri, and the splendid Amalfi–Sorrento coast, which take part of their spectacular beauty from geological factors [7]. These factors—tectonics, volcanism, karst, marine and coastal erosion, the climate, and its healthiness—across the Sorrento Peninsula and the Amalfi Coast ensures our appreciation of how much the present landscape of the Southern Apennines is influenced; this is especially the case in the SW, where events of extensional block faulting occurred in the Quaternary times, when the Tyrrhenian sea basin had its last pulse of enlargement. By creating high-fault scarps, truncating preexisting mature landforms, and triggering deep-fluvial dissection, the said tectonic events laid the foundations for the great physical beauty of the area. Especially along the Amalfi Coast and on Capri Island, this beauty is coupled with terrain roughness in such a way to mandate remarkable settlement limitations. This beauty is matched by the ruggedness of the terrain in such a way as to impose significant limitations on settlement. However, these limitations have been brilliantly overcome since the early Middle Ages [7]. Additionally, to give just one example in Irpinia, we point the reader to the well-known Mefite in the Ansanto Valley—a geoarchaeosite (*sensu* Lena, 2009 [8]) celebrated in literature and the arts for millennia, akin to the locations mentioned earlier, and of great importance even in the view that, today, we call scientific [3–9].

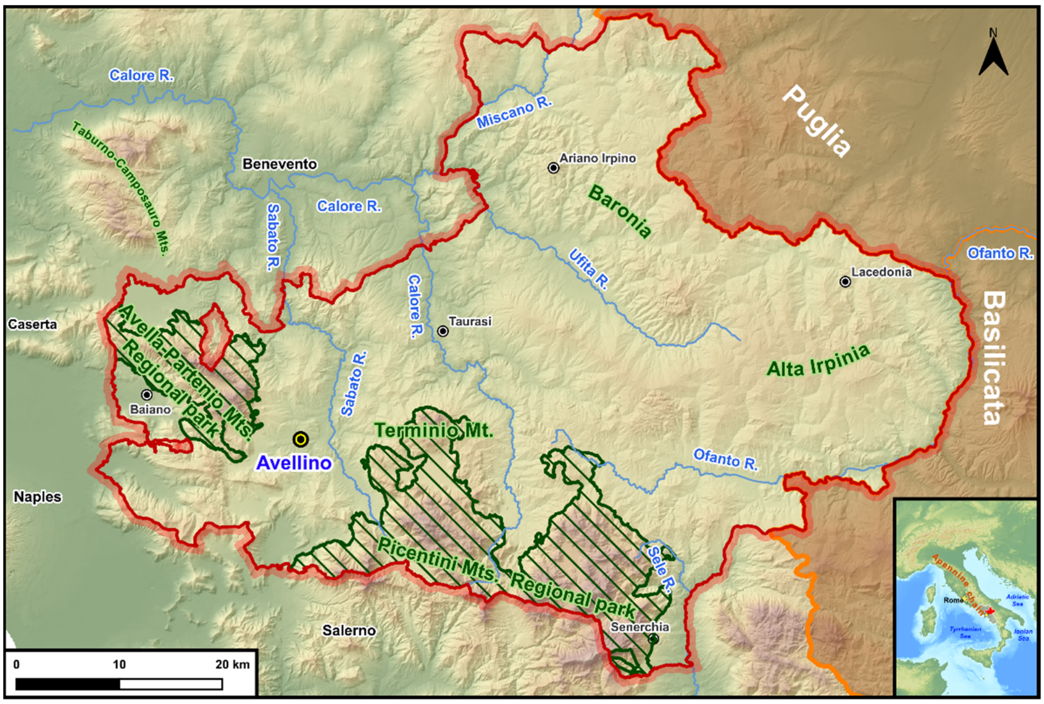


Figure 1. Digital elevation model of the study area.

The millenary experiences of visiting these places anticipated the practice of geotourism centuries ago: a phenomenon that would become a cultural fact only from the seventeenth century, contributing to enrich its resources, in situ and in museums, libraries, and archival collections [10]. The illustrious travelers of the Grand Tour who decided to move from the Tyrrhenian coast to the inland Apennines, in search of the places described by the most famous writers of Classicism, were numerous; they left valuable descriptions of the landscape of Irpinia and some of its most spectacular places (e.g., the Mefite) [10].

Continuing to expand and promote [11,12] these age-old forms of geotourism, particularly in the study area, also involves assessing the existing heritage, which will be exemplified here through eight significant geosites (Figure 1). Their evaluation will serve as a stimulus for geoconservation; this is not an end in itself but—in terms of sustainable use [10]—has taken into account the steady growth of societal interest in the geoenvironment in recent years. In many cases, such interest is closely related to new local economic and cultural growth [13].

2. The Study Area

The rich geodiversity of the study area is the result of the complex geological–structural history of this sector of the Campania Apennines and the geomorphic evolution that accompanied its construction.

The variegated landscape mosaic in which this geodiversity manifests itself is typical of the inner areas of the Southern Apennines: Irpinia has a low population density (about 142.4 inhab/km^2, in 2021), with land use alternating between human-made works, including millennia-old ones, open fields, and more natural settings, especially at higher elevations.

Extracting data on local land use [14] indicates that areas devoted to agriculture (mainly arable land and various crops) occupy 65% of the total area, while 4.5% is dedicated to pastures, with large expanses of uncultivated land. A large area is occupied by forests (more than 27%) and artificial water bodies (1%), which are very important for the naturalness of the land, and only 4.5% of the area is urbanized. Some of the small towns in the area have preserved their ancient urban structure, so much so that they have earned the prestigious certifications of the “Most beautiful villages in Italy Association”, the Orange Flags of the Italian Touring Club, and Authentic Villages of Italy, etc.

Within this diversified framework, geodiversity also takes on fundamental importance. Its elements, the geosites, have been recognized and recorded in a special public catalog, the CAREGEO (Regional Cadastre of Geosites), which was commissioned by the Campania Region in 2008 [15]. More geosites have been added to the 55 included in the regional catalog, bringing the number of surveyed geosites to more than 70, thanks to additional research conducted by our working team in recent years [16,17].

This contributes to the knowledge of the Apennines’ geological history, geomorphological processes, pedogenesis, and climate, which are essential conditions for local habitats; the contribution of georesources overall is also substantial for the survival of small local human communities [18], and this can be illustrated to the visitors of geosites.

It should also be remembered that, in this territory, geotouristic activities are not tied in exclusively with geological phenomena but are associated with other forms of sustainable and quality tourism, such as trekking, religious routes, cycle tourism, horse riding, and food and wine. The latter is undergoing considerable development in view of the high-quality local food and wine products, which are outstanding in the three DOCG-certified (Italian acronym of Denominazione di Origine Controllata e Garantita—Controlled and Guaranteed Designation of Origin) wines, and in a large number of other food quality labels such as DOC (Controlled Designation of Origin), IGP (Protected Geographical Indication), DOP (Protected Designation of Origin), acknowledged nationally and by the European Union, and the Italian regional label PAT (Traditional Agricultural Products) [19].

2.1. A Brief Outline of Geology and Geomorphology

The geology of the study area reflects the evolution of an orogenic area. In fact, the thrust belt of the Southern Apennines—a segment of the Apennines oriented approximately NW–SE—began its deformation in the lower Miocene. The accretionary prism migrated from west to east, followed by coeval extensional tectonics [20].

The subsequent evolution can be described by macro-environments, which identify as many lithological complexes as possible: the first group of deposits derives from shallow-sea areas (Figure 2), the predominantly limestone continental platforms (CO in Figure 3) of the Late Triassic–Middle Miocene age; the second consists of sediments from oceanic, siliceous, deep-sea basins (Liguride–Sicilide nappes, Lagonegro Basin, Figure 2; SO in Figure 3). In the Plio–Pleistocene period (the trust–sheet–top and marine/continental deposits in Figure 2), the deposits become markedly more clastic and detrital (gravelly–sandy–clayey), related to nearshore or decidedly continental marine environments (SS, Figure 3). The fourth group includes the more recent terrains (CC, Figure 3), which—since the middle Pleistocene—have been deposited in exclusively continental environments (fluvio–alluvial, limno–palustrine, colluvial, etc.).

The geomorphological evolution of this area has produced a considerable variety of landscapes, giving the area high naturalistic value, which at the same time gives the orography a high educational value.

The vast areas that unfold from S to NW in Figure 3 are characterized by the presence of intensely karstified tertiary carbonate massifs and sites of the most important Campania aquifers. Steep fault slopes and extensive forest cover complete the characteristic natural landscapes of these reliefs. Moving towards the NE and SE, the landscape—mainly terrigenous—assumes hilly forms with gentle slopes and wide watersheds. The landscape mosaic is completed with the few plains of the river valley, which represent about 10% of the provincial territory.

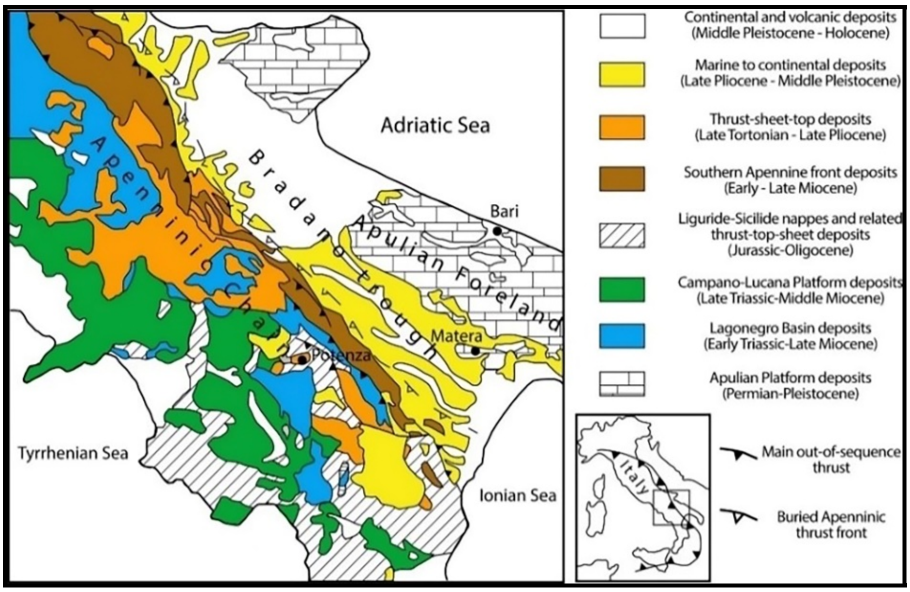


Figure 2. Schematic geological map of Southern Apennines (loosely taken from [21], with permission from the authors, 2022).

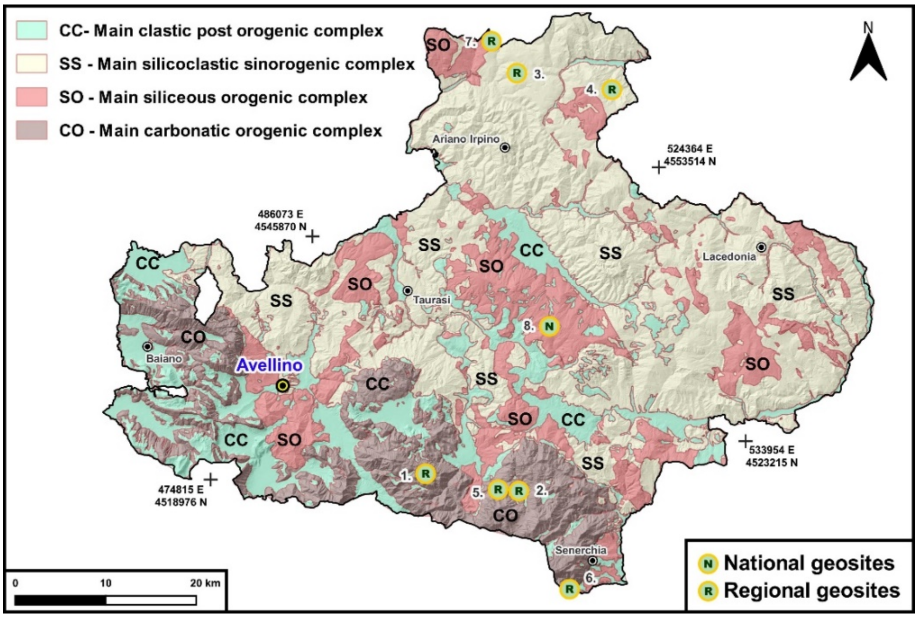


Figure 3. The Province of Avellino and its main geological complexes (source: authors' processing). The eight geosites selected in the text are labeled as follows: 1—Verteglia (V); 2—Laceno (L); 3—La Starza (S); 4—Monte Castello (MC); 5—Caliendo Cave (C); 6—Profunnata Cave (P); 7—Malvizza (Ma); 8—Mefite (Me).

2.2. Biodiversity

Italy is characterized by one of the most significant biodiversity assets in Europe, both in terms of the total number of animal and plant species and the high rate of endemism [22]. This richness is due to the great lithological, topographical, and climatic diversity at the center of the Mediterranean, which represents one of the biodiversity hotspots [19], as defined on a planetary scale. Some sectors of the Apennines, then, fall within the "high density" areas of biodiversity and endemism [22].

Irpinia, in the Southern Apennines—especially taking into account what is described in the previous paragraph—is part of this great heritage of high naturalness, preserved in two protected areas (the regional parks of the Picentini Mountains and Monte Partenio), two WWF Oasis areas, fifteen SCI areas (Site of Community Importance), and three SPAs (Special Protection Areas), partly coinciding with the regional parks [23].

The articulated hilly and mountainous orography, and the wide, open spaces or woods, also allow the presence of precious animal and plant endemisms with rare species of particular microenvironments, as well as important faunal sites (Figure 4).

Even the most-exploited agricultural areas are home to rich fauna, living in contact with the humanized environments of agroecosystems. Irpinia, akin to so many of Italy's agricultural districts, is increasingly focusing on sustainable, high-quality food products, with agricultural systems that protect biodiversity, ecological quality, and landscape preservation [24].

Overall, these practices are beginning to represent an important contributor to the economic budget of the provincial administration, and they encourage many other forms of sustainable, cultural, and high-quality tourism.

Biodiversity is based on geodiversity—in an inseparable, close relationship [25]—and it is important to emphasize this in the analysis of geoheritage, even at a local scale. As Santucci [26] has effectively mentioned, geodiversity has "an intrinsic relationship between biological diversity and geological diversity. In principle, the geologic bedrock is viewed as the foundation of the ecosystem"; this is the case in terms of both resources and processes, and in current and past environments.

Lastly, it must not be forgotten that climate change plays a fundamental role in this reciprocal relationship, to the extent that environments can respond to such changes [27];

recognizing this elicits a consideration for the close connection and dependence of humanity on the fragility of the earth's ecosystem. It has been effectively written that "understanding geodiversity will enable more effective conservation strategies for managing ecosystem responses, as well as helping to mitigate future impacts, inform appropriate policies, guide adaptive management, and contribute to the restoration of ecosystems already damaged by human activities" [28].

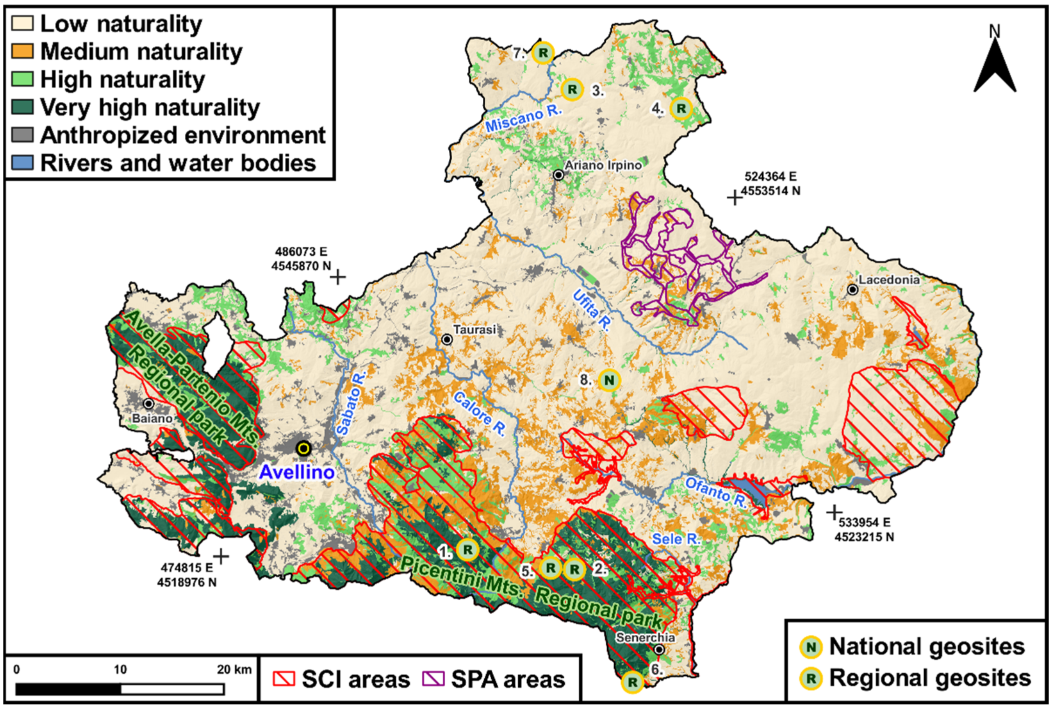


Figure 4. Map of Irpinia's naturality. SCI—Site of Community Importance; SPA—Special Protection Areas (now, both are called Special Areas of Conservation—SACs—for the Natura 2000 network), loosely taken from [17], with permission from the authors. The eight geosites selected in the text are labeled as follows: 1—Verteglia (V); 2—Laceno (L); 3—La Starza (S); 4—Monte Castello (MC); 5—Caliendo Cave (C); 6—Profunnata Cave (P); 7—Malvizza (Ma); 8—Mefite (Me).

3. Materials and Methods

The geodiversity of the study area is expressed through the striking landscapes, which vary significantly throughout the territory. These landscapes are characterized by many sites of geological interest, most of which are already registered in the regional catalogs as geosites and fall in protected areas. Others, however, are still being studied. Overall, these geosites can be grouped into distinct categories such as geological (tectono-stratigraphic, etc.), geomorphological (e.g., karst, fluvial), paleontological (fossil outcrops), and mining (active and abandoned/recovered quarries).

From this, it appears that the provincial territory of Avellino—extending 2806 km^2—has a high concentration of geosites (more than 70) both within and outside the protected areas. Within this large number, the present research has identified 8 geosites which are believed to be representative of the local geological/geomorphological reality. In this study, these 8 geosites were studied from the point of view of protection and enhancement—from the point of view of their rarity, the state they are in, representativeness, historical value, viability and accessibility, educational value, vulnerability, scenic value, and "natural beauty"—in the context of the landscape. From this study, carried out according to methods which are well-known in the specific literature, a picture of geotouristic value expressed by the sites examined emerges [29]. This testifies, once again, to the existence of a strong link between the geoenvironmental and the socioeconomic and cultural aspects that characterize the Irpinia landscape as a whole: a territory still largely uncorrupted and of high ecotourism value, which is worthy of conservation and protection. In fact, some of the selected geosites represent the most frequent tourist destinations in Irpinia (Laceno, Verteglia): they are characterized by emergencies that are not strictly geological (winter sports, equipped areas, trekking, bridleways, accommodations, and restaurants, or by strong archaeological and historical interest). In addition, the presence of high elevations and spectacularly beautiful landscapes—reflecting the geological/geomorphological complexity of this part of the Southern Apennines—offers a remarkable degree of geodiversity in these geosites (Newsome, [30]). The gaseous emission geosites (Mefite, Malvizza), on the other hand, include two localities that are well-known geoarchaeological sites, since the historical–archaeological component is comparable to the geological one and, in the case of Mephitis, the degree of interest in the geosite is at least national.

Finally, the remaining four geosites (Caliendo, Profunnata, Castello Mt., and La Starza)—although they present a marked geotouristic interest—need careful explanation and promotion to attract geotourism, since they are not currently visitable as they are unequipped caves or disused quarries [30].

Guided by the above considerations, we selected 8 geosites, as presented in Table 1.

Table 1. The 8 Irpinian geosites evaluated in this study. They are all registered with CAREGEO (Mefite in Valle d'Ansanto is also registered in the National Inventory of Geosites, http://sgi1.isprambiente.it/GFMaplet, accessed on 11 October 2022).

ID	Initial	Name of Geosite	Municipalities	Lat. N	Long. E	Classification
1	V	Verteglia	Montella	40.827593	14.983249	Geomorphosite
2	L	Laceno	Bagnoli Irpino	40.827593	14.983249	Geomorphosite
3	S	La Starza	Ariano Irpino	40.200171	15.078752	Geoarchaeosite
4	MC	Monte Castello	Savignano Irpino	41.209073	15.229721	Geosite
5	C	Caliendo Cave	Bagnoli Irpino	40.812282	15.079027	Geomorphosite
6	P	Profunnata Cave	Senerchia	40.709596	15.170905	Geomorphosite
7	Ma	Malvizza	Montecalvo Irpino	41.258622	15.070013	Geosite
8	Me	Mefite	Rocca San Felice	40.975642	15.146891	Geoarchaeosite

The 8 geosites were chosen to illustrate particular phenomena active in the study area: some are exemplary of the karstic environment, in sites of high value in terms of landscape, naturalism, and education (Verteglia, and Laceno endoreic Poljes). Two of the sites are representative of hypogeal karst phenomena, linked to important underground water outflows (Caliendo, and Profunnata Caves). In agreement with Panizza, 2001 [31], for the particular genesis of the phenomenologies present in these localities, we can speak of these as geomorphosites. Four of the localities fall within the Regional Park of the Picentini Mountains, whose peculiarities are important in the international network of the Geoparks.

In addition, some major deep-gas-emission sites in Irpinia were considered in the research: the Mefite in Ansanto Valley (which has the largest natural emission of low-temperature CO_2-rich gases—from a non-volcanic environment—which have ever been measured ([3], refer to the extensive bibliography), and the Bolle della Malvizza (methane emissions accompanying the mud volcanoes—the Malvizza Bubbles). These two emissive sites also have great historical, mythological, and archaeological importance.

Finally, the last two sites, chosen in the outcrop area of the Messinian chalks and the subject of a now-disused quarry, are also rich in archaeological evidence, especially from the Neolithic period—important evidence from which remains (Figure 5).

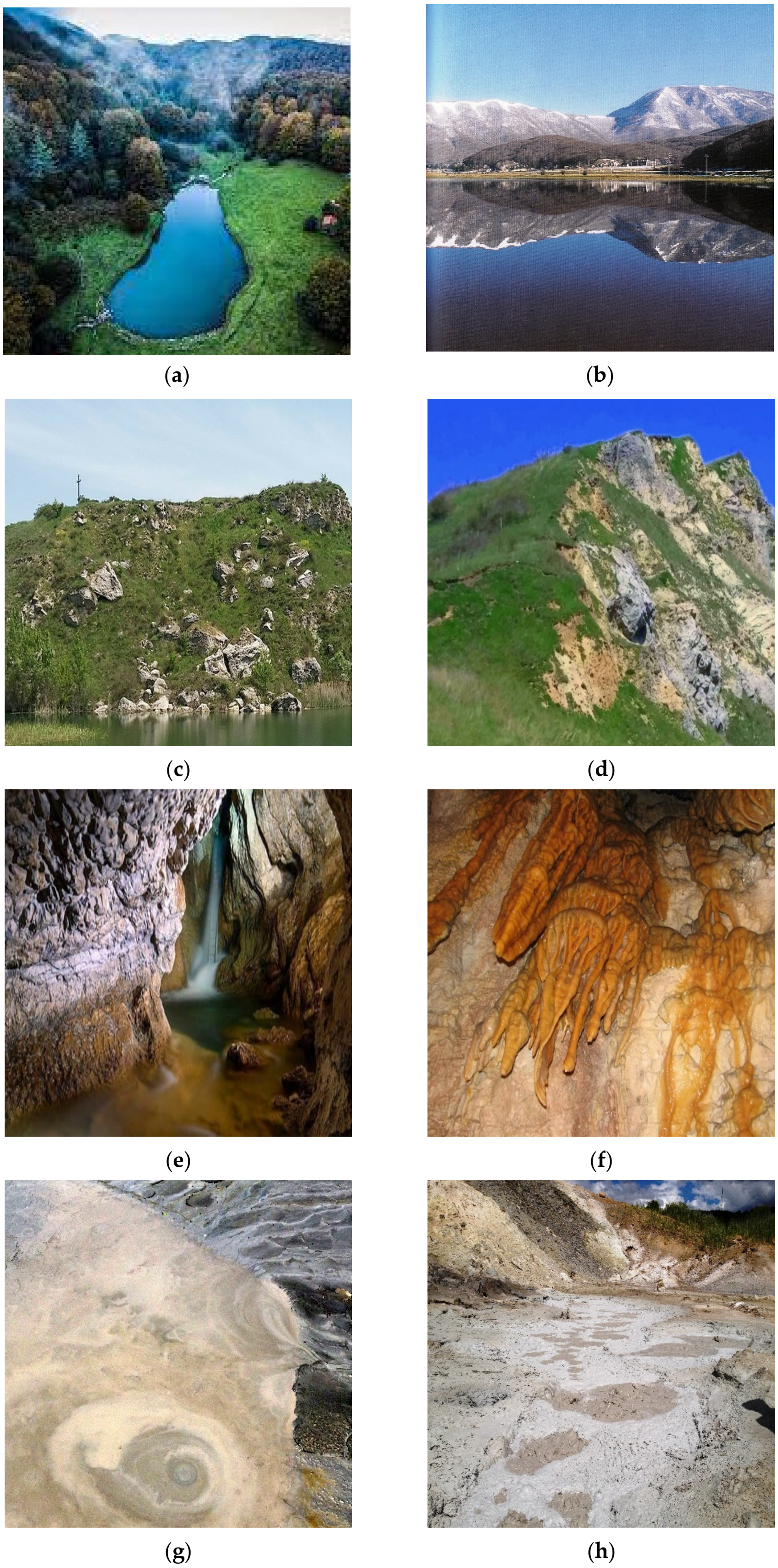


Figure 5. Some images related to the 8 geosites evaluated in this study: (**a**) Verteglia Polje; (**b**) Laceno Polje; (**c**) La Starza; (**d**) Mount Castello; (**e**) Caliendo Cave; (**f**) Profunnata Cave; (**g**) Malvizza Bubbles); (**h**) Mefite in Ansanto Valley. Ph: (**a**) http://www.paesaggiirpini.it, (accessed on 11 October 2022); (**b**,**c**,**g**,**h**) M. Sisto; (**d**,**e**) https://it.wikipedia.org; f: www.tripadvisor.it, (accessed on 11 October 2022).

The 8 geosites are all registered with CAREGEO [15] and are on the lists suggested by our working group [16,17].

Having chosen the eight geosites [32], we chose the methods for quantitative evaluation from an analysis of the numerous geotouristic-assessment methods reported in the literature (Mucivuna et al., 2019 [32]); the eight methods—that will be detailed here—were selected, each representative of one or more peculiarities (scientific, additional, protection, educational values, hotel facilities, etc.) that are quantitatively valid and representative of their geotouristic purposes [33–44].

3.1. The Method of Pereira et al., 2007

The first method applied in our research for defining the value of the geological site (VG) is the one proposed by Pereira et al. [33]. We applied this method in our previous research, and it provided interesting results, especially in evaluating scientific and touristic values in the context of the management of protected areas, as noted in our comparative studies of methodologies [32].

3.2. The GAM Method

The second method applied is the so-called GAM (Geosite Assessment Model) proposed by Vujičić et al., 2011 [34], which has been used particularly in the Serbian spatial context by other authors [35,36]. In a nutshell, GAM consists of two key indicators: main values (MV) and additional values (AV). These are further divided into 12 and 15 subindicators, respectively, each individually marked from 0.00 to 1.00.

GAM as a simple equation:

$$\text{GAM} = \text{AV} + \text{MV}$$

where AV is expressed by the following equation: AV = VFn (functional value) + Vtr (touristic values). MV is expressed by the following equation: MV = VSE (scientific/educational value) + VSA (scenic/aesthetic value) + VPr (protection value).

3.3. The Method of Coratza et al., 2011

The third method used is the one proposed by Coratza et al., 2011 [37]. This method is applied by the authors for the definition of the value of geomorphosites (see Panizza, 2001 [31]), but we have verified that, without any modification, it can be generally applied to all geosites (see Wimbledon, 1996 [6] and Reynard, 2004 [38]). The method enables the Q value (quantitative assessment of scientific value) to be obtained by adding the following three indicators: scientific value (SV), additional value (AV—understood as the sum of cultural, aesthetic, and ecological values) and use value (UV). Each of these parameters is obtained by the sum of 17 sub-indicators/criteria (4 for SV, 9 for AV, and 4 for UV), giving a total maximum value of 10: scientific value = maximum 4; additional value = maximum 3; use value = maximum 3).

According to Mucivuna et al., 2019 [32], this method very effectively illustrates the relationships between scientific, use, and protection values.

3.4. The Method of Fassoulas et al., 2012

The fourth methodology applied is the one proposed by Fassoulas et al., 2012 [39]. As is known, the proposed method is based on the results of the scores of the various groups of criteria, articulated on three indices that refer to the educational (Vedu), the tourist value (Vtour), and the protection need value (Vprot) of each geosite.

To estimate the educational value index (Vedu), it is necessary to add the score assigned to the scientific, ecological, cultural, and aesthetic criteria, using the following formula:

$$\text{Vedu} = 0.4 \text{ scientific score} + 0.2 \text{ cultural score} + 0.2 \text{ aesthetic score} + 0.2 \text{ ecological score}$$

Similarly, the same formula must be used to obtain the Vtour index for calculating the tourism value of the geosite:

$$\text{Vtour} = 0.4 \text{ aesthetic score} + 0.2 \text{ cultural score} + 0.2 \text{ potential of use Score} + 0.2 \text{ economic score}$$

Finally, the quantification of the protection value (Vprot) is preceded by the calculation of the ecological risk factor (Fecol = ecological impact score/protection status score). As soon as Fecol is defined, the protection value can be calculated with the following formula:

$$\text{Vprot} = [\text{Scientific Score} + \text{Fecol} + (11\text{-Integrity})]/3$$

The interesting values provided by this method also concern cultural, ecological, and aesthetic aspects, which are assigned considerable weight.

3.5. The Method of Pica, 2014

The method proposed by Pica (2004) [40] and tested by Pica et al., 2015 [41], was applied to the 8 selected geosites. The GVS (geotouristic value of the site) was appropriately determined by assigning values to the following indicators:

- RP (representativeness value), an indicator assessing correspondence to the idea's model, distinctiveness, typicality, and plurality of interests, the sum of which varies between 0 and 20 points; the final RP score is then entered into classes, which assign the RP value.
- RR (rarity value), which depends on the geographical scope and rarity in context (rarity classes vary between 0 and 5).
- SCE (aesthetic scenic value), which is composed of visibility, color contrast, and shape singularity, with final values ranging from 0 to 5.
- SAC (historical–archaeological–cultural value), which takes constraints, protection laws, connection with history and traditions, and toponymy into account (again, classes varying between 0 and 5).
- AC (accessibility value), which evaluates how to reach the site, difficulties, and services present (score 0–5).

The method correlates the scientific and use values.

3.6. The Method of Brilha, 2017

The method proposed by Brilha (2017) [42] was also applied to deduce the geotouristic value (GV) of our 8 selected geosites. The method is based on the definition and quantitative evaluation of four distinct indicators: SV (scientific value), PEU (potential educational use), PTU (potential tourist use, which uses some elements already reported in Table 2), and DR (degradation risk). Each of the four indicators, defined through a variable number of sub-indicators, is refined through a system of percentage weights (weight%) that correct the various sub-indicators.

3.7. The Method of Suzuki and Takagi, 2018

The method proposed and tested by Suzuki and Takagi, 2018 [43] is based on the measurement of 18 parameters grouped into 6 sub-indicators, as follows: Ved—educational value; Vsc—scientific value; Vtr—tourism value; Vsa—safety and accessibility; Vcs—conservation value and site sustainability; Vti—tourist information. A variable score from 1 to 4 on a matrix basis is assigned to each of the parameters and indicators.

As will be explained in detail in Section 4.7, the following are emphasized: the educational usefulness for all generations, aspects of natural heritage, convenience of access, and attraction for geotourism.

3.8. The Method Kubalíková et al., 2021

Finally, a very special method of evaluation proposed and tested by Kubalikovà et al. (2021) [44] was also applied to our 8 selected geosites. Using a semiquantitative approach, the method emphasizes the intrinsic value and attractiveness of a geosite (e.g., hill, rock spur, mountain, rim, etc.) from the point of view or perspective of Earth Sciences. This method is particularly appropriate for our case studies as all 8 selected Irpinia geosites are immersed in spectacular landscapes which are rich in geodiversity, even if among them there are underground karst cavities. Based on this visibility analysis, the results obtained with the application of this method to our 8 selected geosites will be explained and discussed below in Section 4.9. They provide interesting insights that reinforce the principle that the evaluation of the geotouristic and geoeducational potential of geosites can help balance geotourism/education needs with nature conservation [45].

4. Results and Discussion

The concept of geodiversity, intuited since the late twentieth century, has quickly gained the approval of scientists around the world [1,46–52].

However, while there is still no shared, unambiguous method for assessing geodiversity (three of the most effective proposals are those of [53–55]), many steps have been taken to progress the assessment of individual geosites. This can serve on a local scale, as in our case study, to give an indirect assessment of the potential landscape richness of an area, given that geosites represent the intersection between geodiversity and geoheritage [56,57] and are the fulcrum of geoconservation [58].

In the following paragraphs, in order to define the value of the eight selected geosites—representative of the Irpinia geoheritage—in a qualitative and quantitative way, the results obtained using various evaluation methods are reported; the methods used are well-known in the literature and have been successfully tested in other geographical areas of the world.

To estimate the values of the individual indicators that contribute to the final value of a geosite (VG—geosite value), we gathered data from the following: interviews and surveys with residents and users of the analyzed premises; the opinions expressed by the managing bodies, administrators, and local managers; the authors' own experience and knowledge of the places and socioeconomic policies [3–19]. While excluding a certain amount of subjectivity, the results obtained by testing the selected geosites with various methods were to be considered very encouraging and invite incentives for geoconservation and enhancement policies in the geoheritage of Irpinia.

In quantitative terms, the results obtained from the application of the various methods make it possible to state that the eight selected geosites all have their own geotouristic value commensurate with the peculiarities analyzed. This obligates that attention be turned toward geoconservation issues (protection, preservation, and promotion of sites) from the perspective of sustainable development with its relevance in socioeconomic terms.

4.1. The Method of Pereira et al., 2007

The first method applied in our research, proposed by Pereira et al. [33], is illustrated in Table 2.

Table 2. Results of the application of the geosite value (VG) evaluation method proposed by Pereira et al., 2007 [33].

ID	Name of Geosite	VGm (Geological Value)		VGt (Use Value)		VG
		SV (Max = 6)	AV (Max = 4)	UV (Max = 7)	PV (Max = 3)	
1	Verteglia	4.75	3.0	6.0	3	16.75
2	Laceno	4.75	3.0	6.0	3	16.75
3	La Starza	3.67	0.75	2.72	0.75	7.90
4	Monte Castello	3.67	0.75	2.72	0.75	7.90
5	Caliendo	4.75	1.75	1.87	2.5	10.90
6	Profunnata	4.75	2.75	1.87	2.5	10.90
7	Malvizza	5.0	3.75	5.58	1.5	15.83
8	Mefite	5.75	4.0	5.75	2	17.50

GV (value of a geological/geomorphological site) = VGm + VGt (the maximum value the method assigns to a geosite is 20), given by:

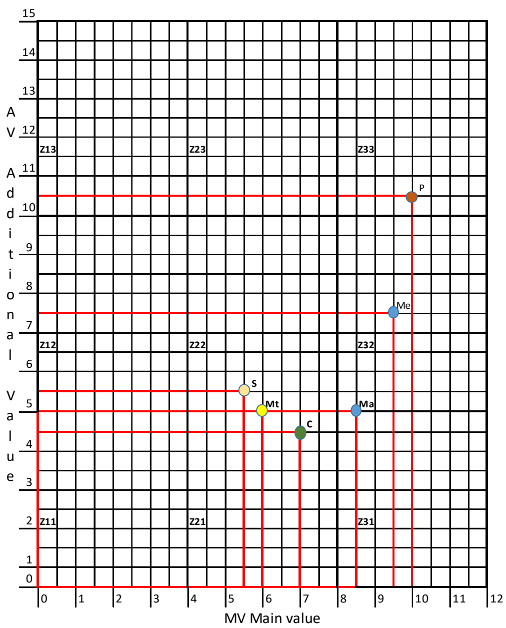
- SV (scientific value): the indicator results from the summation SV = Ar (rareness in the study area) + De (deterioration) + R (representativeness of processes and pedagogical interest) + Di (number of interesting geomorphological features or diversity) + G (other geological features with heritage value) + K (scientific knowledge on geological issues) + An (rareness at a national level): maximum value = 6.
- AV (additional value): the indicator is given by the sum of cultural value + aesthetic value + geologic value: maximum value = 4.
- UV (use value): given by the sum of Ac (accessibility) + V (visibility) + Ug (present use of the geological/geomorphological interest) + U (other interests) + P (legal protection and use limitations) + E (equipment and support service): maximum value = 7.
- PV (protection value): given by the sum of deterioration and vulnerability to visitors use: maximum value = 3.

4.2. The GAM Method

The results of second method applied, GAM [34], are shown in Table 3; here, the Zfields where these geosites are placed in the AV–MV comparison can also be noted.

Table 3. GAM values for the 8 selected geosites.

Indicators	V	L	S	Mc	C	P	Ma	Me
MV	10.0	10.0	5.5	6.0	7.0	7.0	8.5	**9.5**
AV	10.5	10.5	5.5	5.0	4.5	4.5	5.0	**7.5**
GAM	20.5	20.5	11.0	11.0	11.5	11.5	13.5	**17.0**
Zfield	Z33	Z33	Z22	Z22	Z21	Z21	Z32	**Z32**



Verteglia (V) and Laceno (L) Poljes; La Starza (S); Mt. Castello (Mc); Caliendo (C) and Profunnata (P) Caves; Malvizza (Ma); Mefite (Me).

To give an example, the Mephitis geoarchaeosite is located in the Z32 field (GAM = 17; Table 3), which corresponds to areas with high scientific, aesthetic, and protective value. Interesting comparisons are evident from the data as a whole; for example, the geoarchaeological site of the Mefite, which appears in Table 3, also appears resized in Table 4, which sees it as low in development for tourism and functionality.

Table 4. Application of GAM method to Mefite geoarchaeosite.

MV	Mark (0.00–1.00)					Additional Values—AV	Mark (0.00–1.00)				
Scientific/educational value—VSE	0.00	0.25	0.5	0.75	1.00	Functional values—VFn	0.00	0.25	0.5	0.75	1.00
Rarity—SIMV1			x			Accessibility—SIAV1			x		
Representativity—SIMV2					x	Additional natural values—SIAV2			x		
Exploration of the site—SIMV3					x	Additional anthropogenic values—SIAV3					x
The level of interpretation—SIMV4					x	The proximity to the emitting centers—SIAV4	x				
Landscape/aesthetic value—VSA	0.00	0.25	0.5	0.75	1.00	The proximity to the main roads—SIAV5				x	
Lookouts—SIMV5					x	Additional functional values—SIAV6		x			
Surface area—SIMV6			x			Touristic values—VTr	0.00	0.25	0.5	0.75	1.00
Landscape and nature around it—SIMV7					x	Promotion—SIAV7			x		
Incorporation of the locality in the surroundings—SIMV8			x			Organized visits—SIAV8				x	
Protection—VPr	0.00	0.25	0.5	0.75	1.00	The proximity to the visitor centers—SIV9					
Current state—SIMV9					x	Interpretation boards—SIAV10				x	
The level of protection—SIMV10		x				The number of visitors—SIAV11		x			
Sensitivity—SIMV11				x		Tourist infrastructure—SIAV12	x				
Bearing capacity—SIMV12					x	Guide service—SIAV13		x			
VSE	3.50					The accommodation services—SIAV14					x
VSA	3.00					Restaurant services—SIAV15					x
VPr	3.00					VFn	3.00				
MV = VSE + VSA + VPr	9.50					VTr	4.50				
						AV= VFn + VTr	7.50				

4.3. The Method of Coratza et al., 2011

The third method used is the one proposed by Coratza et al., 2011 [37]. The results obtained from applying this method to our eight selected geosites are shown in Table 5.

Table 5. Q values for the 8 selected Irpinia geosites according to the method proposed by Coratza et al., 2011 [37].

Values	Criteria		V	L	S	MC	C	P	Ma	Me
Scientific value (max 4)	Paleo-geomorphological model		0.5	0.5	0.25	0.5	0.5	0.5	0.5	0.5
	Rareness		0.75	0.75	0.25	0.5	0.5	0.5	1	1
	Representativeness		1	1	0.5	0.5	0.5	0.5	1	1
	Integrity		1	1	0.5	0.5	1	1	1	1
Additional values (max 3)	Ecological value (max 1)	Ecologic support role	0.5	0.5	0	0	0	0	0	0.5
		Protected site	0.5	0.5	0	0	0.5	0.5	0	0.5
	Aesthetic value (max 1)	Panoramic quality	0.25	0.25	0.25	0.25	0	0	0.25	0.25
		Colour diversity	0.25	0.25	0	0.25	0	0	0.25	0.25
		Vertical development	0.25	0.25	0	0.25	0	0	0	0.25
		Naturalness	0.25	0.25	0	0	0.25	0.25	0.25	0.5
	Cultural value (max 1)	Religious importance	0	0.33	0	0	0	0	0.33	0.33
		Historical importance	0	0.33	0	0	0	0	0.33	0.33
		Artistic importance	0	0.33	0	0	0	0	0	0.33
Use value (max 3)	Accessibility		0.75	0.75	0.5	0	0	0	0.75	0.75
	Visibility		0.75	0.75	0.75	0.75	0	0	0.75	0.75
	Services		0.75	0.75	0	0	0	0	0.25	0.25
	Importance for education		0.75	0.75	0.5	0.5	0.5	0.5	0.5	0.75
Q = SV + AV + UV			**8.3**	**9.2**	**3.5**	**4.0**	**3.8**	**3.8**	**7.2**	**9.2**

Verteglia (V) and Laceno (L) Poljes; La Starza (S); Mt. Castello (MC); Caliendo (C) and Profunnata (P) Caves; Malvizza (Ma); Mefite (Me).

We propose a relationship between total scientific value and total additional and use value, defined as the *tourism rating* [59]. By plotting the data in a specific diagram, we successfully determined this parameter for the geomorphosites of the Island of Gozo (Malta). Following this example, Figure 6 proposes an analogue diagram of SV vs. AV + UV, showing the potential tourism rating of the eight selected geosites.

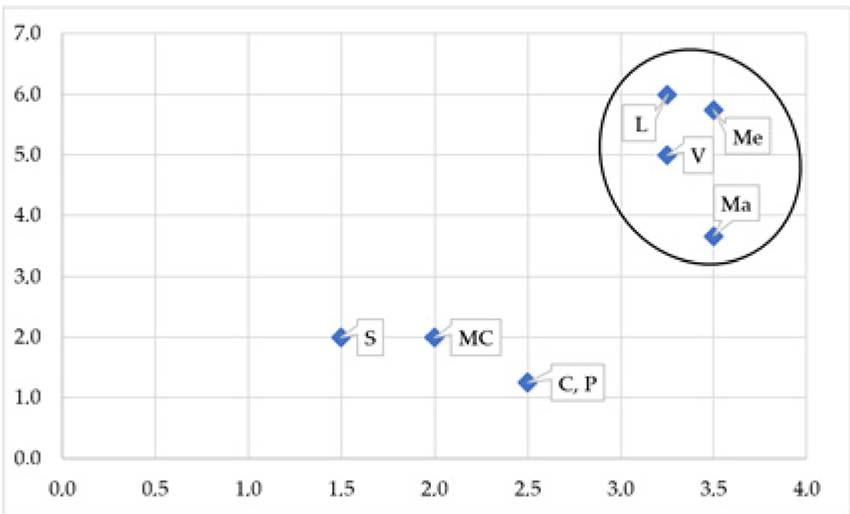


Figure 6. Diagram SV (in abscissa) vs. AV + UV (in ordinate) showing the potential tourism rating of the 8 selected geosites. The top-rated geosites are shown in the circled area.

4.4. *The Method of Fassoulas et al., 2012*

The fourth methodology applied is the one proposed by Fassoulas et al., 2012 [39]. The results of applying this method, already tested by other authors [36], to our eight selected geosites are illustrated in Table 6 and shown in graphical form in Figure 7.

Table 6. Results of the quantitative evaluation of the 8 selected geosites obtained by applying the method of Fassoulas et al., 2012 [39].

Geosites/Indicators	Scientific Score	Ecology Score	Cultural Score	Aesthetic Score	Economic Score	Potential Use Score	F_{ecol}	V_{edu}	V_{prot}	V_{tour}
Verteglia Polje	5.5	7.5	5.6	8.8	5.8	3.7	2	6.6	3.7	6.5
Laceno Polje	5.5	7.5	5.6	8.8	5.8	3.7	2	6.6	3.7	6.5
La Starza	5	3.8	6.3	8.8	2.3	6	2	5.8	4.3	6.4
Mount Castello	5	3.8	1	8.8	2.3	5.5	2	4.7	4.3	5.3
Caliendo Cave	6.5	7.5	1	1	2.3	7.7	2	4.5	3.2	2.6
Profunnata Cave	6.5	7.5	1	1	2.3	7.7	2	4.5	3.2	2.6
Malvizza	6.5	2.5	6.3	8.8	4.2	7	2.5	6.1	3.3	7.0
Mefite	8	7.5	10	8.8	4.2	7	2	8.5	3.7	7.7

Scientific score: geologic history, representativeness, geodiversity, rarity, integrity	Potential use score: intensity of use, impacts, fragility, accessibility, acceptable changes
Ecology score: ecological impact, protection status	Aesthetic score: viewpoints, landscape difference
Cultural score: ethics, history, religion, art, and culture	Economic score: visitors, attraction, official protection

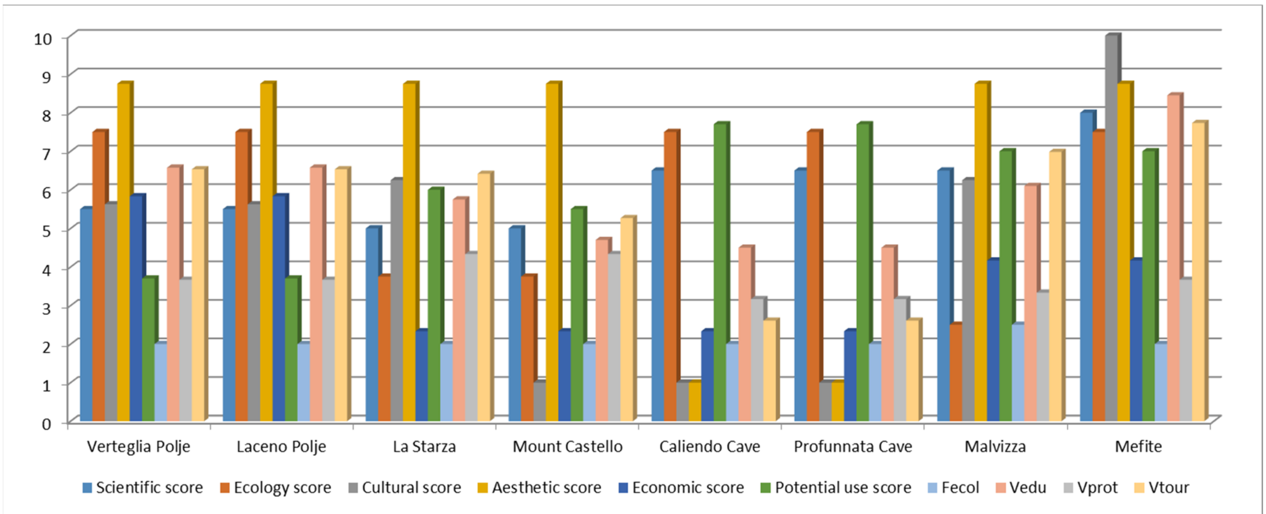


Figure 7. Graphical representation of the value of the indicators associated with the 8 selected geosites obtained with the method of Fassoulas et al., 2012 [39].

4.5. The Method of Pica, 2014

The method proposed by Pica (2004) [40] that was tested by Pica et al., 2015 [41] was also applied to our eight selected geosites.

Table 7 shows the values of the indicators in detail; the sum of the indicators gives the GVSs of our geosites as the final results.

Table 7. Values of the indicators of the method proposed by Pica, 2004 [40], assigned to each of our 8 selected geosites. The sum of the indicators gives the GVS for each geosites.

Geosites/Indicators	RP	RR	SCE	SAC	AC	GVS
1. Verteglia	5	3	5	5	5	**23**
2. Laceno	5	3	5	5	5	**23**
3. La Starza	4	4	4	4	3	**19**
4. Monte Castello	4	4	4	3	3	**18**
5. Caliendo	4	3	4	4	1	**16**
6. Profunnata	4	3	4	4	1	**16**
7. Malvizza	5	3	4	3	5	**19**
8. Mefite	5	4	5	5	4	**23**

GVS = RP + RR + SCE + SAC + AC (the maximum value of each indicator is 5, for a theoretical total of 25).

4.6. The Method of Brilha, 2017

The method proposed by Brilha, 2017 [42], with the calculation of geotouristic value (GV), was used in two distinct ways. For the sake of brevity, Table 8 shows only the data relating to the various indicators proposed by Brilha, 2017, which contribute to defining the geotourism value of the Mefite (Me) geoarchaeosite.

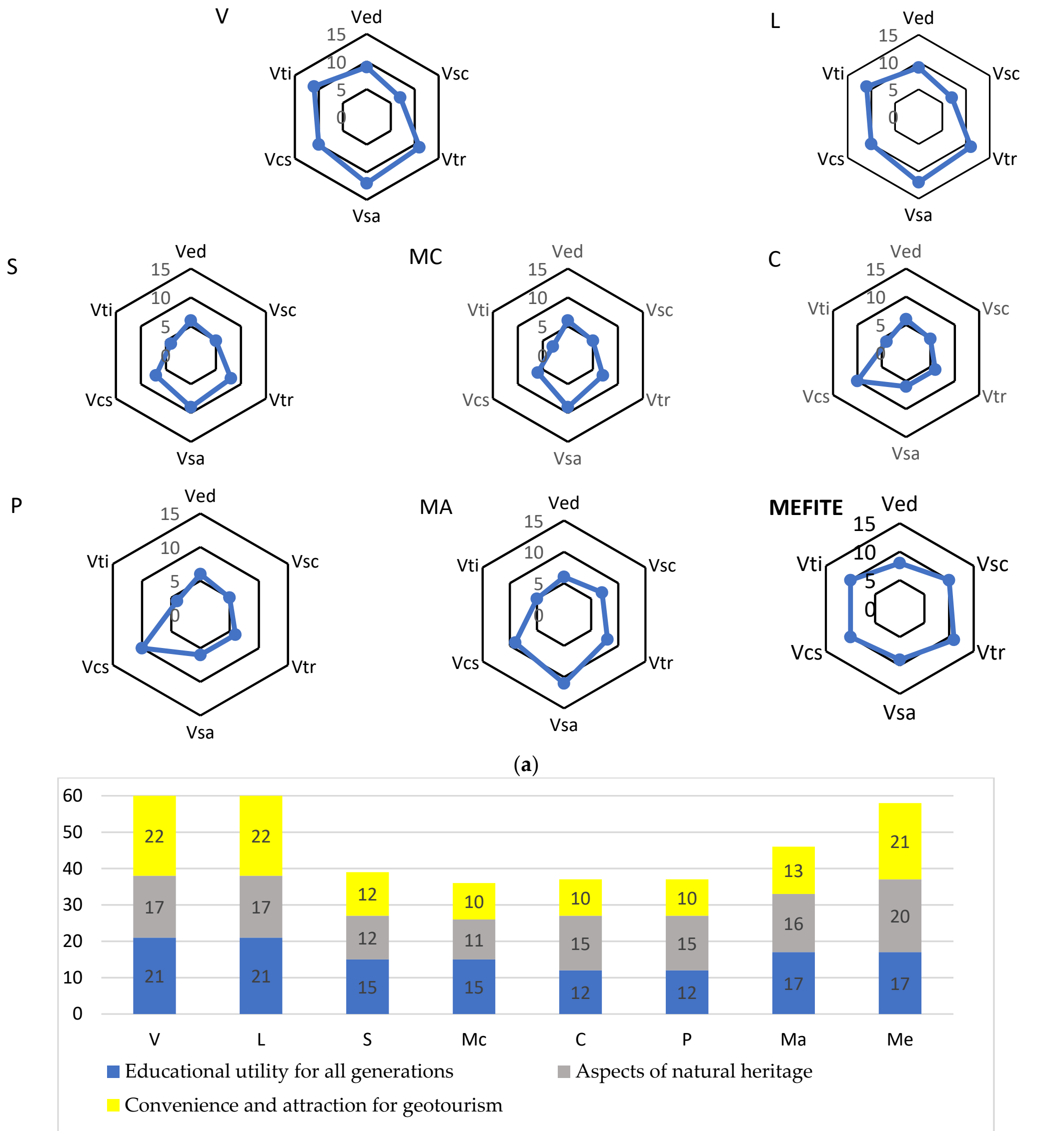
Table 8. Results of the quantitative evaluation of the indicators of the geotouristic value of the geoarchaeosite of Mefite (Me), obtained by applying the method proposed by Brilha, 2017 [42].

SV	Score	W%	PEU	Score	W%	PTU	Score	W%	DR	Score	W%
A. Representativeness	4	30	A. Vulnerability	3	10	A. Vulnerability	3	10	A. Deterioration of geological elements	2	35
B. Key locality	4	20	B. Accessibility	3	10	B. Accessibility	3	10	B. Proximity to areas/activities with potential to cause degradation	3	20
C. Scientific knowledge	4	5	C. Use limitations	4	5	C. Use limitations	4	5	C. Legal protection	2	20
D. Integrity	4	15	D. Safety	3	10	D. Safety	3	10	D. Accessibility	3	15
E. Geological diversity	4	5	E. Logistics	4	5	E. Logistics	4	5	E. Density of population	1	10
F. Rarity	4	15	F. Density of population	3	5	F. Density of population	3	5			
G. Use limitations	2	10	G. Association with other values	4	5	G. Association with other values	4	5	SV + PEU + PTU + DR = 13.10		
			H. Scenery	4	5	H. Scenery	4	15			
			I. Uniqueness	3	5	I. Uniqueness	4	10			
			J. Observation conditions	4	10	J. Observation conditions	4	5			
			K. Didactic potential	4	20	K. Interpretative potential	4	10			
			L. Geological diversity	4	10	L. Economic level	1	5			
						M. Proximity of recreational areas	5	5			
Total SV	3.80		Total PEU	3.65		Total PTU	3.40		Total DR	2.25	

The summary data relating to the other seven selected geosites will be explained and discussed below in Section 4.9.

4.7. The Method of Suzuki and Takagi, 2018

The results of applying the method proposed by Suzuki and Takagi [43] to our wight selected geosites are reported in Figure 8a using hexagonal radar graphs; here, the vertices correspond to the six sub-indicators mentioned. The method also allows the recombination of the six sub-indicators into at least three groups of primary indicators: educational usefulness for all generations (Ved and Vsa); aspects of natural heritage (Vsc and Vcs); convenience and attraction for geotourism (Vtr and Vti). These three primary indicators make it possible to obtain an evaluation of geosites from a different political and socioeconomic perspective. Figure 8b graphically shows the results of the evaluation of the eight selected geosites obtained by recombining the scores according to the primary indicators—Ved and Vsa; Vsc and Vcs; Vtr and Vti—introduced by the method.



(**a**)

(**b**)

Figure 8. (**a**) The results of applying the method of Suzuki and Takagi, 2018 [43] to our 8 selected geosites are expressed by hexagonal radar graphs; here, the vertices correspond to the 6 sub-indicators (see text). (**b**) Differences in the evaluation results between selected geosites in a combined scores graph—Ved and Vsa; Vsc and Vcs; Vtr and Vti.

4.8. The Method of Kubalíková et al., 2021

The results of applying the method proposed by Kubalíková et al. [44] are shown in Table 9.

Table 9. Results obtained with the application of the method proposed by Kubalikovà et al., 2021 [44], to our 8 selected geosites.

Viewpoint Geosites	V	L	S	MC	C	P	Ma	Me
1. Panoramic view: up to 90° (1 point), 90–180° (2 points), 180–270° (3 points), 270–360° (4 points)								
1. Values	4	4	3	4	1	1	4	4
2. Diversity or number of Earth Science elements visible from viewpoint (1 point for each element, max 5 for each sub-criterion)								
2a. Geology (lithology, tectonics, stratigraphy, etc.)	4	4	3	3	4	4	3	4
2b. Geomorphology (cryogenic landforms, glacial landforms, karst, fluvial landforms, etc.)	5	5	2	2	5	5	3	3
2c. Hydrological components (water bodies, rivers, soils, etc.)	5	5	2	2	3	3	3	3
3. Geocultural features: anthropogenic landforms incorporated in landscape, buildings from local material, small sacral objects (1 point for each feature, max. 3 points)								
3. Values	2	3	3	1	1	1	2	3
4. Overall landscape aesthetic (contrasts and structuration): 1 point—low; 3 points—average; 5 points—high								
4. Values	5	5	1	3	1	1	3	5
5. Disturbing elements: 0 points—elements affecting or obscuring the view (large constructions, industrial plants); 2 points—several disturbing elements not obscuring the view; 4 points—no disturbance								
5. Values	4	4	4	4	4	4	4	4
6. Tourist and educational characteristics (use characteristics)								
6a. Overall visibility: 1 point—low (view obscured by trees or other elements); 2 points—average (some obstacles); 3 points—very good visibility)	3	3	2	3	1	1	3	3
6b. Readability of Earth Science elements: 1 point—low (a need for explication or information provided on site); 2 points—average (possible to read and recognize, usually with brief information); 3 points—high (easy to read and recognize)	3	3	1	1	1	1	2	3
6c. Safety: 1 point—access at own risk; 2 points—access with specific issues that may affect the safety (e.g., lack of the fences, poor paths); 3 points—no safety issues	3	3	1	1	1	1	3	1
6d. Accessibility: 1 point—accessible by walk; 2 points—accessible by car (parking near the viewpoint); 3 points—accessible by public transport	2	2	1	1	1	1	2	2
6e. Infrastructure: 1 point—no infrastructure, only a path leading to the site; 2 points—marked paths, information available, e.g., on websites; 3 points—well-equipped site, tourist-marked paths leading to it, information panels onsite	2	3	1	1	1	1	1	3
7. Current status: 1 point—site not very attractive (damaged, overused); 3 points—some disturbances (vandalism, destruction of tourist infrastructure); 5 points—site managed well, even if visited frequently								
7. Values	5	5	1	1	1	1	3	5
TOTAL SCORE	**47**	**49**	**25**	**27**	**25**	**25**	**36**	**43**

4.9. Comparative Assessment

The assessments of the geotouristic potential carried out with various methods have demonstrated the high scientific, patrimonial, and educational value of the eight Irpinia geosites selected for analyses in this research. The overall data in comparative form are summarized in Table 10. The result of the sites possessing high scientific, patrimonial, and educational value was expected; the eight geosites analyzed are already appreciated by a considerable number of people, ranging from non-specialists (occasional tourists, simply curious, students, etc.) to bio-geoscience scholars. We agree with Štrba et al. [60] in that we consider the evaluation methods to be important but—above all—we value the opinions expressed by tourists, without whom geotourism would not be possible. For this, we reviewed the results of several dissertations and previous articles [3] which referred to questionnaires submitted to geotourists (where the authors have acted as guides for groups and students), with the aim of overall monitoring and improvement of management activities.

Table 10. Final results of the evaluation of the geotouristic potential of the 8 selected geosites obtained with various methods.

Methods	V	L	S	MC	C	P	Ma	Me
VG according to the method of Pereira et al., 2007 [33]	16.75	16.75	7.90	7.90	10.90	10.90	15.83	**17.50**
GAM according to the method of Vujičić et al., 2011 [34]	**20.5**	**20.5**	11.0	11.0	11.5	11.5	13.5	17.0
SV, AV, and UV according to the method of Coratza et al., 2011, and Fassoulas [37]	8.3	**9.2**	3.5	4.0	3.8	3.8	7.2	**9.2**
$V_{edu} + V_{prot} + V_{tour}$ according to the method of Fassoulas et al., 2012. [39]	16.8	16.8	16.5	14.3	10.3	10.3	16.4	**19.9**
VSG according to the method of Pica et al., 2014 [40]	**23**	**23**	19	18	16	16	19	**23**
SV, PEU, PTU, and DR according to the method of Brilha et al., 2016 [42]	12.3	12.3	11.9	11.7	9.3	9.3	12.3	**13.1**
Ved, Vsc, Vtr, Vsa, Vcs, and Vti according to the method of Suzuki and Takagi et al., 2017 [43]	**60**	**60**	39	36	37	37	46	58
Landscaping viewpoint according to the method of Kubalíková et al., 2022 [44]	47	**49**	25	27	25	25	36	43

The best values obtained for each geosite with each method used are shown in bold.

Without prejudice in interpreting these considerations, we believe that the results of the quantitative assessments of geosites must be usefully displayed to inform visitors, and should not be only used in academic research.

5. Conclusions

Landscape geodiversity, similarly to biodiversity, is increasingly perceived as an essential resource for the wellbeing of local communities and the progress of human societies. This perception has emerged in recent years especially, following the COVID-19 pandemic, the global energy crisis triggered by the Russia–Ukraine conflict, and, finally, the natural disasters caused by climate change.

For this reason, more and more experts and institutions are working to promote geoethical values and geoenvironmental education in order to preserve the existence of geodiversity. However, it is always difficult to understand and evaluate—especially in a quantitative way—geodiversity and the elements that characterize it. Among these, an important role is played by geosites, which were—in this study—evaluated in terms of all of the most representative elements of landscape geodiversity. Furthermore, they are also posited as fundamental parts of geoheritage, because they are closely linked to intangible cultural heritage (myths, traditions, etc.), history, and biodiversity.

With this research, we have highlighted that many authors—even when starting from different assumptions and points of view—have worked to offer quantitative evaluations in this field; these evaluations are not entirely devoid of a certain amount of subjectivity, but they are capable of demonstrating the scientific value and use of geosites. The evaluation methods proposed and tested by these authors have been successfully applied to eight selected geosites, which are representative of the geodiversity and geoheritage of the Irpinia landscape.

The results obtained, summarized in Table 10—beyond a simple comparison in terms of the importance of the various indicators that characterize each geosite—confirm the high qualitative and quantitative value of the geotouristic potential of the eight selected geosites and, therefore, indirectly attest to the value of Irpinia's geodiversity. Our findings could be further enhanced through the emotional participation of people through art or social forms (as is already the case, for example, at Mefite, with its gatherings of painters and poets from many nations—not only European), which are certainly very effective in conveying both scientific and cultural issues [61].

The results obtained from the application of the various methods used, relative to the indicators for which they were proposed, show that the eight selected geosites assessed in this study all have high geotouristic value. From the perspective of geodiversity conservation, our findings imply that they have relevant socioeconomic roles, including in terms of sustainable development.

In conclusion, the data obtained encouraged us to undertake design policies of usability, protection, and promotion [2] for the eight geosites selected, using these examples as a driving force for the enhancement of the entire Irpinia territory.

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