

Review

Where Does Sustainability Stand in Underground Tourism? A Literature Review

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Abstract: Underground sites have become an attractive tourist destination for an increasing number of visitors. This flow of visitors has made sustainability a major issue, that is, the way in which tourism development ensures economic benefits for host communities and respects local identity without compromising the environmental resources. Many studies have explored sustainable tourism in the Underground Built Heritage (UBH), but privilege the analysis of a single perspective, that is, economic sustainability, e.g., potentialities of cultural routes, or environmental sustainability, such as the impact of visitors on the cave climate. However, some attention has been paid to the social implications of tourism in the UBH, that is, the impacts of tourism development on improving the quality of life of the local community and the enhancement of their sense of community while respecting cultural authenticity. Our aim is to reconcile these perspectives and obtain, through a semi-systematic review, a clear picture of the sustainability of tourism in UBH sites. The aggregation of existing knowledge around the three pillars of sustainability has highlighted the importance of community involvement and collaboration among UBH stakeholders to ensure a balance between the protection and valorisation of UBH, which can also be achieved through networking strategies.

Keywords: sustainability; sustainable tourism; tourism development; underground sites; systematic review; heritage; mine; cave; review



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1. Introduction

Sustainability, including environmentalism, social equity and economic development, has become a priority on a global level. Institutions are attempting to build a consensus around the importance of not compromising future generations and to thereby trigger a change in collective values, beliefs and behaviours through regulations, laws, and initiatives to raise community awareness about sustainability issues.

All industries are undergoing changes in processes and products with sustainable goals, with related investments in infrastructure and equipment to support these organizational changes. The tourism industry is no exception [1]. In the 1970s, tourism organisations were already concerned with balancing the environmental, economic, and socio-cultural impacts in tourism development [2]. More recently, the World Tourism Organization (UNWTO) designated 2017 as the International Year of Sustainable Tourism for Development [3].

Sustainable tourism entails optimizing the exploitation of environmental resources to preserve natural heritage and biodiversity (i.e., environmental pillar of sustainability), to respect the identity and cultural authenticity of the host community (i.e., social pillar of sustainability) and ensure long term socio-economic benefits (i.e., economic pillar of sustainability) [4]. Its objectives include improving the living standards of the host population

in the short and long term; satisfying the tourists' demands and safeguarding the natural environment [5].

Conflicting visions of sustainable tourism exist [2,3,5–8]. Some researchers believe that sustainability is not always appropriate in tourism as there are too many competing interests and trade-off decisions that undoubtedly create a priority for certain interests over others [8,9]. The volume of tourists, i.e., people who can be successfully accommodated, remains a key issue for the negative implications of excess tourism on the destination sustainability [9]. Furthermore, they point out that even small-scale tourism, located in sensitive and vulnerable environments, can be seriously detrimental [9]. These authors advise that sustainable tourism may become a marketing label adopted by destinations to attract a growing proportion of visitors who are conscientious about sustainability issues [2,6,7,9].

A great number of scholars, while acknowledging the challenges, argue that sustainable tourism is achievable in all destinations, for mass and small-scale tourism, because sustainability—regardless of scale—is a long-term aim [2]. To achieve this aim, destinations need to revise the purposes of tourism, moving away from those that are selfish, individualistic and hedonistic, and instead, allowing tourism to act as a facilitator of education, cross-cultural engagement, ecological appreciation, and spiritual development [1,5,6]. Sustainability becomes a hard-to-copy competitive factor that creates value for the visitors in a strategic process of destination repositioning [1]. This includes a dynamic vision of sustainability, achieved through a continuous process of trade-off decisions performed day-by-day to enhance the resilience to disturbance in a complex system [5,7]. Continuous challenges are faced, that differ from destination to destination because sustainable tourism is an adaptive paradigm: several development pathways may be legitimised according to demand, supply and the host communities' desires and needs [7]. An essential condition is a cultural change implicit in values, beliefs and behaviours of all actors [5]. Sustainability should be embedded in the tourism organizations' goals, and as opposed to making superficial changes, the related changes should contribute to part of a future-oriented vision to position themselves as sustainable organizations [1]. Likewise, tourists should be aware of sustainability issues, while hosting communities should aim at preserving culture integrity, biological diversity and ecological processes [1,8].

Sustainable tourism is particularly interesting when examined in sites of the Underground Built Heritage (from now UBH) [10,11]. The term UBH is used here to refer to caves, for which the main body is located under the geographical zero level, which are an expression of local material and immaterial cultural heritage [12,13]. It encompasses natural and artificial caves centered on artistic features, such as the paintings in the prehistoric caves; religious elements, e.g., catacombs or temples; places used by the local community as burial places, cellars (for e.g., wine or storehouses); shelters (e.g., for military purposes); water collecting places (e.g., cisterns) and for extracting raw materials (i.e., mines) [13].

UBH sites have an intrinsic scientific (e.g., geological record), cultural (e.g., superstitious rituals, archaeological artifacts) and recreational value (e.g., exploring inner caves) [14], leveraged for “cave tourism” including, among other forms of tourism, geo-tourism, mining tourism, adventure-tourism [14–16]. Geo-tourism focuses on geology and promotes the conservation of geodiversity and learning of earth sciences in caves [17,18]. Mining tourism refers to the recovery of old mines to attract visitors interested in mine heritage [16,18,19]. It combines elements of geo-tourism with visits to industrial sites in the caves (e.g., machinery, warehouses) and their surrounding areas (e.g., buildings, factories). Most importantly, mining tourism allows visitors, via on-site visits to mines, museums, and cultural-historical monuments related to mining activity and life of miners, to feel an affinity with one of the oldest human activities, developed mostly underground over centuries. Finally, adventure tourism relates to challenging activities such as boating in caves [18].

The flow of visitors entering UBH sites leads to a negotiation in terms of sustainability, i.e., how to ensure a balance between “protection” of their tangible and symbolic value and

tourism promotion [7,12,15]. Despite the relevance of this issue, a number of studies do not explicitly mention sustainability assumptions, instead privileging the analysis of a single pillar of sustainability. In this respect, several studies have so far focused on environmental sustainability, i.e., on the preservation and conservation of natural resources [5,6] by analysing, factors such as the impact of visitors on the climate and water temperatures of quarries [20,21]. Other authors have investigated economic implications [2,6], e.g., potentialities of mining cultural routes [17]. The social implications have been overlooked in such studies [2,6] neglecting that without the involvement of residents, the journey leading to sustainable tourism may not be realised [2,9]. The aim of this paper is to reconcile these different perspectives and obtain, through a semi-systematic review, a clear picture of the sustainability of tourism in the UBH sites.

In the following sections, we first describe the method followed for the semi-systematic review of existing studies that have investigated the sustainability tourism issues in UBH sites. Then, based on a deductive coding process, we aggregate existing knowledge according to the three pillars of sustainability, that is, economic, environmental, and social dimensions. The last sections reflect on this aggregated knowledge and offer conclusive remarks.

2. Method

A semi-systematic review has been undertaken to obtain a clear picture of the sustainability of tourism in UBH sites, that is, we have mapped the literature on this theme, synthesised the current state of knowledge, and created an agenda for further research.

A semi-systematic review is a method for identifying and evaluating the key scientific contributions on a specific theme that have been explored by researchers within diverse disciplines [22]. It plays a key role in highlighting the relative strengths and limitations of the different research approaches. It is regarded as a fundamental scientific activity, able to provide a rigorous and transparent process based on three main stages (Table 1) [23].

Table 1. Stages of a semi-systematic review.

Stages	Actions
First stage: Planning the review	Definition of the topic Identification of keywords and search terms
Second stage: Conducting a review	Selection of studies Extraction of information
Third stage: Analysing	Descriptive and conceptual information
Fourth stage: Reporting and dissemination	Development of a report

Source: Adapted by Sneider, 2019.

The initial stage of a semi-systematic review is aimed at defining the subject area, in order to identify and clarify the relevance and size of the literature. The databases and search terms are identified too. Not all the papers collected through this process are relevant for the review, and some are excluded by following inclusion and exclusion criteria.

The second stage is conducting the review. Information about the most relevant literature is extracted from the selected sources, following the above-mentioned inclusion/exclusion criteria. A search protocol is developed to ensure reliability and transparency of the review process, specifying the relevant features of studies included in the review (e.g., year, authors, affiliation, journal, context of the study, main purpose, methodology, main findings, future research, emergent themes, etc.).

The third stage is an analysis of the papers collected. Data extracted from the papers can be in the form of descriptive information, in the form of effects and findings, or in the form of conceptualizations of a certain idea or theoretical perspective [24].

The final stage provides a report so as to allow the readers to understand the developments in the discipline, by synthesizing the extensive primary research papers. The report provides information on the evolution of research over time, the main authors, the methodologies adopted, the core contributions, the recurrent issues and the key emerging themes.

In conducting this semi-systematic review, we have followed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines, conceptualised in the health care research domain, and often used in social science due to its reliability [25]. This has further improved the transparency of the review process, since the flow of information obtained through the different phases has been evaluated, through a detailed checklist regarding the following factors: form of review; summary; rationale; aim of the study; protocol; inclusion and exclusion criteria; identification of sources; search; study selection; data collection process; data items; method of analysis; measures; study characteristics; results; summary of evidences; limitations and conclusions. The authors have followed all these items, to be sure to make the review process clear and repeatable.

The first stage of the study is focused on planning the review. In this phase, the search terms useful to achieve the study aim have been identified, and the databases from which the papers were extracted have been selected. Since the use of ‘Underground built heritage’ did not procure results, and in order to ensure the inclusion of all useful studies for the review, the search terms used to select the papers were:

“Underground heritage” AND “Sustainable tourism”

“Underground” AND “sustainable tourism”

“Underground” AND “tourism”

“Cave tourism”

“Cave” AND “Tourism”

“Geo-tourism” AND “underground”

“Mining tourism”

“Subterranean Tourism”

The term ‘tourism’ has been included in all the strings, with the aim to collect all the available studies in this field. The decision to refer to a large number of search terms is related to the aim of collecting all the possible typologies of sustainable tourism in UBH sites. These include underground heritage tourism, cave tourism, mining tourism, underground geo-tourism, and subterranean tourism. Terms not strictly related to sustainable tourism have also been identified. This is due to the fact that the UBH sites, both human made and natural, are so fragile that it is always necessary to consider forms of tourism aimed at protecting the sites rather than at only exploiting them. For this reason, authors often consider a sustainable form of tourism for these sites, even if they do not use the word ‘sustainable’ in their studies. A search for papers, only focusing on ‘sustainable tourism’ or by using the string ‘tourism sustainability’, would not obtain all the possible studies on the investigated topic.

The following databases were chosen for the search: Scopus, Google Scholar, Web of Science Core Collection (from now WOS-CC), and ScienceDirect. The combination of these databases has allowed us to locate the appropriate academic literature, because they contain studies published in journals, conferences and workshops which are seen to present acceptable rigour within the research community. The search terms were used for search on the title, abstract, and keywords of the studies in the above-mentioned databases.

Then, the inclusion and exclusion criteria were identified with the aim to select the relevant literature that has addressed sustainable tourism in UBH sites.

According to the inclusion criteria, only peer reviewed studies in the English language were considered for the review. Furthermore, the focus of the search was on articles, chapters and conference proceedings published during the period 2005–2021, since 2005 marks the year in which the development of tourism in underground sites began to be seriously considered within the tourism sector debate, as an example, the Scopus database revealed that 1 paper was published in 2004 on the topic of underground tourism. The next year, 5 articles were published, and 11 in 2007. Despite the importance of updated findings provided by the grey literature, the conventional approach of including only studies published

in scientific journals, conference proceedings, or volumes was followed [26]. As for the exclusion criteria, working papers and conference abstracts were excluded. Likewise, studies that are not accessible online were excluded, as well as contributions not directly related to the tourism sector, its management, and the business. The inclusion and exclusion criteria have been applied using the databases search options, and by reading the main elements of potentially relevant studies, including the source title, abstract, and introduction of each contribution.

The data extraction form was then developed based on our research aim to obtain descriptive information of the reviewed studies, as well as to ensure the information useful for classifying and comparing all contributions was recorded (Table 2).

Table 2. Data extraction form.

Data	Information
Source	Databases from which the study is extracted
Study identification	Authors Title Year Publication details
Study features and specific information	Keywords Purpose Gap that the paper wants to fill Originality/value Main topic addressed by the study Geographical context
Role of sustainable tourism for the tourism development of the UBH site	Typology of sustainability
Methodology	Method and technique used in the paper Study design Data collection
Results	Key results Future research Theoretical and managerial implications
General impressions	Subjective conclusions after studying the paper and most relevant aspects of the paper.

Source: Our elaboration.

The second stage of the semi-systematic review relates to data collection, that is, the selection of studies and the extraction of information. The selection of studies is developed by applying the chosen databases the search terms, taking into account the above-mentioned inclusion and exclusion criteria. The execution of the systematic literature review took place in June and July 2021.

In the third phase of the review process, we develop an analysis. In this phase, references were listed and alphabetically ordered to exclude duplicates. Lastly, the full papers were downloaded (fourth and fifth phases).

Table 3 specifies stages for each selected database: Scopus, Google Scholar, WOS-CC, and ScienceDirect.

Table 3. Phases and databases used in the data collection.

Stages	Search Engine			
	Scopus	WOS-CC	Science Direct	Google Scholar
First phase	The strings were searched in the title, abstract, or keywords. The period of time was 2005–2021			The strings were searched in the title. The period of time was 2005–2021.

Table 3. Cont.

Stages	Search Engine			
	Scopus	WOS-CC	Science Direct	Google Scholar
Second phase	Selection of paper and conference proceedings (excluding working paper, conference abstract) in journal, book, book series (excluding trade journals) Language: English Selected areas: Social science, business management and accounting	Selection of review articles, research articles, book chapters, and conference proceedings Language: English Selected areas: Social science, Management, Economics, Hospitality and leisure	Selection of review articles, research articles, book chapters, and conference proceedings Language: English Selected areas: Social science, business management and accounting	Patents and citations were excluded. All languages were selected
Third phase	The results were compared in order to eliminate the duplicates since some papers were in more databases			
Fourth phase	The abstracts of the papers were read and, according to the research aim, only the studies totally fitting with the sustainable tourism in UBH from a managerial perspective were selected and, consequently, the related full papers were collected			
Fifth phase	Exclusion of studies when the full text of paper was not available Reading of full text of papers			

Source: our elaboration.

In the Google Scholar database, it was not possible to search only papers in the English language, therefore the ‘all the languages’ option was selected, although the authors have limited the collection to the studies in English language.

Table 4 shows the number of papers collected in the first and second phases in the four databases.

Table 4. Number of papers collected in the first two phases.

	Scopus		WOS-CC		Science Direct		Google Scholar	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
“Underground heritage” AND “Sustainable tourism”	0	0	0	0	0	0	11	8
“Underground” and “sustainable tourism”	8	4	10	3	1	1	1	1
“Underground” and “tourism”	72	9	18	8	5	2	19	6
“Cave tourism”	21	7	16	10	1	1	70	19
“Cave” AND “Tourism”	58	9	92	10	18	11	45	6
“Geotourism” and “underground”	16	1	34	8	2	2	10	3
“Mining tourism”	30	8	16	8	2	0	152	24
“Subterranean Tourism”	1	1	1	1	0	0	6	0
Total	206	39	187	49	29	17	314	67
Total after removing duplicated papers in each database		35		45		16		62

Source: our elaboration.

As a result of the first phase of data collection in the databases, a total of 736 papers were collected. Once the inclusion/exclusion criteria were applied, the number of papers was reduced to 172. Subsequently, duplications were deleted. After removing papers resulting from different research strings in the same database, there were a total of 158 papers. Additionally, duplications among the four databases were considered and a further 25 papers were excluded. To elaborate, there were 4 duplicates among the Science Direct and the WOS databases; 9 duplicates among the WOS and Scopus databases, 1 among

the Science Direct and Scopus databases, 11 among Google Scholar and Scopus databases; 1 among the Science Direct and Google Scholar databases, and 4 among the Google Scholar and WOS databases.

As a result, a total of the 133 studies were collected, as reported in Table 5, distinguishing the final number of studies for each database.

Table 5. Total of studies collected for each database.

	Scopus	WOS-CC	Science Direct	Google Scholar	Total
Total	26	36	15	56	133

Source: our elaboration.

In order to conduct the review, the main subjects explored in the studies, found in the abstracts, were read to exclude all studies not directly related with our research aim. A total of 81 papers were included in the fourth phase. These articles were thoroughly read for the final selection of studies that addressed sustainable tourism in UBH sites that were to be included in this semi-systematic review. In this fifth stage, the authors reviewed the studies by reading the full texts in order to exclude irrelevant papers. If there was not a full text available for a study, it was also excluded, along with studies published in unreputed outlets, and those not focused on the sustainable tourism in UBH sites from a managerial point of view. Some studies on sustainable tourism in UBH sites, in fact, addressed carrying capacity, technical issues strictly related to the conservation of the caves, or implications of lighting systems.

As a result, 58 papers have been considered in this semi-systematic review, for which the main elements have been reported in the data extraction form. It is important to note, however, that, according to other systematic review studies, the findings of this work do not refer to all the reviewed studies, because some reported negligible findings [27].

2.1. Descriptive Analysis

In this section, we present a descriptive analysis of the 58 reviewed studies to understand how the research on sustainable tourism in the UBH has evolved over time. In this regard, the majority of reviewed studies have been published between 2016 and 2021 (i.e., the 55% of the total sample), following the “Expert Meeting on the Mainstreaming of the Methodological approach related to the Recommendation on the Historic Urban Landscape in the Operational Guidelines”, held in 2013 in Río de Janeiro (see the following Figure 1). The increasing number of studies may be a result of the complex concepts presented at the meeting, as well as the increasing awareness about the underground heritage as another layer of the territory connected to the rest of the surface elements, and therefore, as an indispensable part of the cultural landscape of any area.

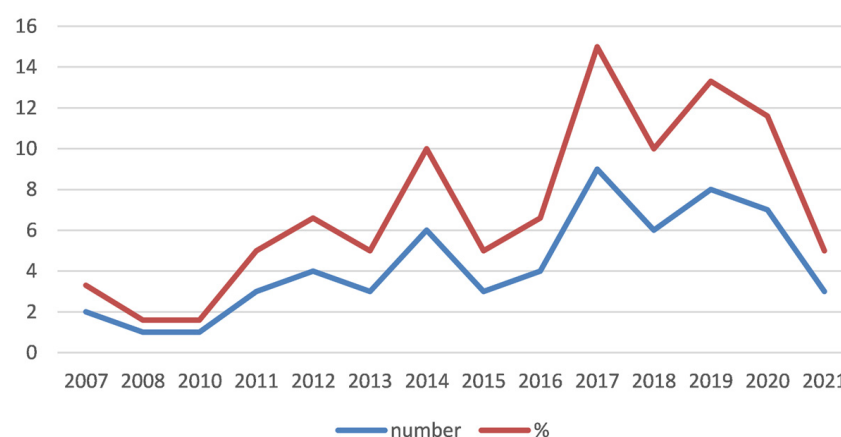


Figure 1. Publication by year.

As for the type of publication, the majority of studies are papers published in scientific journals, while the remaining contributions are book chapters and conference proceedings, which constitute twenty percent of the total sample (see the following Figure 2). In addition, more than half of these papers have been published in open access journals. This reflects a development that is also being experienced in other areas of research, which is the “democratization” of information through the use of quality open access journals. In this sense, it is worth highlighting journals such as “Tourism Management Perspectives”, which is an open access journal indexed in 4 international databases, achieving an impact factor of 7, which places it in the 50th position out of 226 in Management.

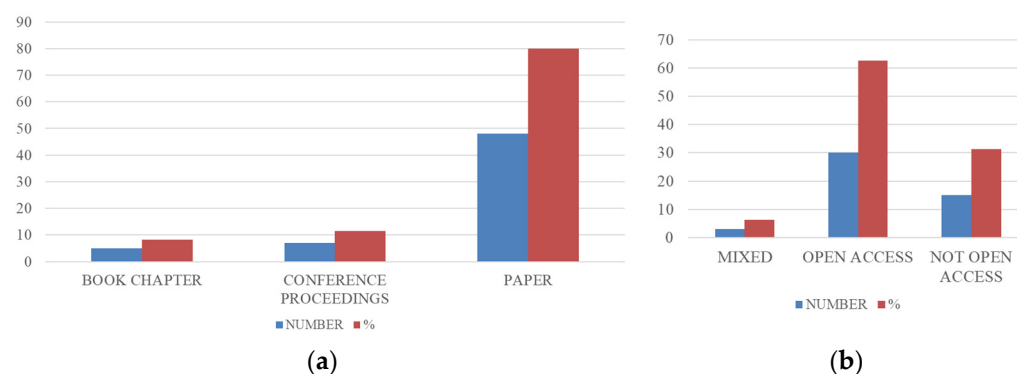


Figure 2. (a) Type of publication. (b) Open access option for paper.

Interestingly, journals in which reviewed studies have been published can be traced to four thematic areas: tourism management, general science (which includes the area of engineering, geography and geology), cultural heritage and social sciences. Furthermore, 51% of the reviewed papers have been published on tourism management (see Figure 3).

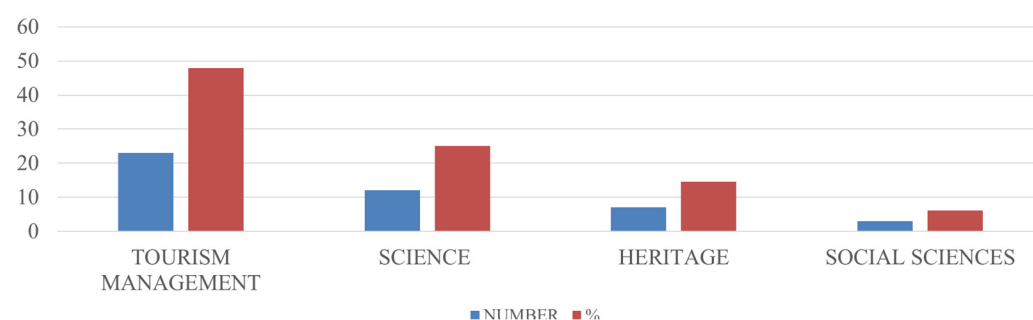


Figure 3. Thematic area of paper journals.

In terms of the methodology, the analysed sample includes five theoretical and conceptual studies, while more than 90% of the documents are empirical studies (n. 55), with most of them using qualitative methodologies (almost 62%) as indicated in Figure 4. In detail, the authors in the sample have generally conducted case studies to empirically explore sustainable tourism in the UBH, rather than exploring the theoretical foundations.

It is evident that, in conducting case studies, researchers have privileged the analysis of the supply perspective rather than the demand perspective (e.g., local community) with the objective to highlight the possibilities offered by these underground sites for sustainable development (see Figure 5). This knowledge could be beneficial for subsequent conceptualisation from the cases already worked on in practice.

Finally, as indicated in Figure 6, Europe and Asia represent the main geographical areas where case studies have been conducted (jointly 85%). Continents such as America, Africa and Australia still require a lot of research in this respect. This may be related to the fact that the main international recommendations concerning sustainable tourism in the UBH have been declared in Europe and Asia due to the high number of heritage sites,

over ground and underground, that must be protected from uncontrolled tourism, with guidelines to ensure economic, environmental and social sustainability.

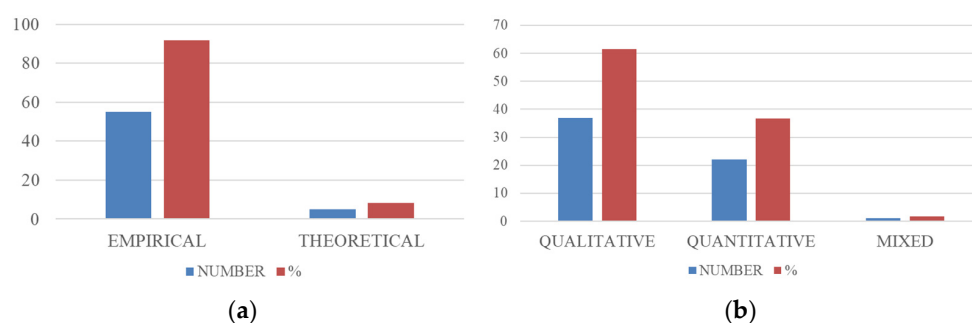


Figure 4. (a) Theoretical/Empirical. (b) Methodology of the sample analysed.

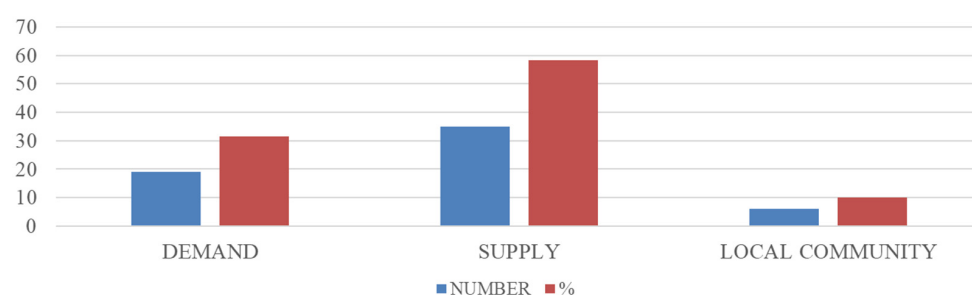


Figure 5. Perspective of the publications.

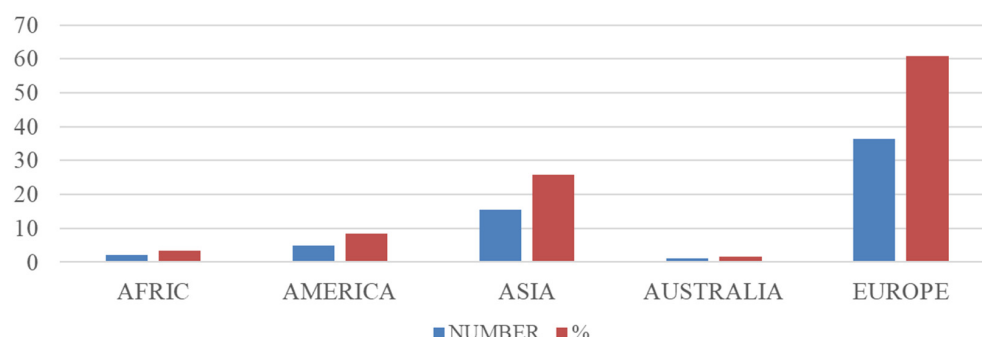


Figure 6. Geographic area of the cases published.

3. Findings

In the following sections, we have aggregated knowledge from studies included in this semi-systematic review and organised the review around the three pillars of sustainability, that is, economic, environmental and social sustainability as reported in the following Table 6 [28,29].

Table 6. Main features of selected references.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Agustriani et al. (2020)	Social	Analyze the extent of how to utilize the unused surface-mined lands in the Balibe Hill, Bonder Village, Central Lombok.	The results show that the alternative use of the unused surface-mined lands can be beneficial if they are designed to become tourism destinations, in which, in addition to services and tourism infrastructure design, it also considered the participation of resident communities in the development process of the area.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Akca et al. (2016)	Social	Analyze the determinants of the expenditure of same-day visitors on cave tourism.	Findings show that distance, age, level of education and gender were important determinants of expenditure on cave tourism. Oftentimes, frequency or pattern of visits to natural attractions are influenced by quality of the experience, taking into account the appeal and component facilities offered by a natural attraction.
Akkar et al. (2021)	Economic	Analyze Karaya as a place of opportunity for development alternatives to mass-tourism	The research shows that territories with quarries can seize the opportunity of cave tourism and its economic effects. However, it is important that these sites become the object of specific projects able to keep alive the memory and the identity of the places.
Amorfini et al. (2015)	Environmental	Illustrate the main actions taken by the Apuan Alps Geopark Authority to enhance knowledge and understanding of the Park's geoheritage	The main outcome of the inventory is that the classified geosites are considered as "structural invariants", that is to say, they are physical objects characterised by invariance
Antić (2020)	Economic	Explore the potential of anchorite sacred caves in Serbia for religious tourism development	The research highlights the potential of cave tourism in an area that is still underdeveloped and the importance of considering the use of these resources as a priority for economic development.
Araujo et al. (2017)		Describe the general panorama of Portugal speleotourism, through the search of tourist grottos in the country and characterize how administration oversees public use	In areas where there are tourist caves, the formation of co-operation networks is encouraged in order to increase the competitiveness and sustainability of tourist caves. The positioning of these various caves on almost identical themes will not allow for the emergence of new dynamics and the evolution of the commercial offer. The fact that managing bodies act in different sectors of society (public, private and third sector), is also beneficial for stimulating innovation, professional growth, partnerships and the development of cave tourism overall.
Artal-Tur et al. (2019)	Social	Investigate how linkages between personal values and tourism development can modulate the perception of tourism impacts by local residents	The results show that linkages between personal values and tourism development are stronger when focusing on environmental issues and socio-cultural impacts rather than economic impacts. The measure of product identity mainly includes attributes of continuity and self-esteem for local inhabitants, with tourism able to maintain, preserve and valuing local mining history and heritage.
Bashit et al. (2007)	Economic	Conducts an economic assessment of the area of Kreo Cave that has been developed	The economic value of the area is assessed based on the value of benefits from the benefits of existence, the benefits of knowledge providers and the benefits of beauty and the economic value of the region based on the function of the tour provider.
Berendse and Roessingh (2007)		Explore ideas on tourism development and image building, with a focus on authenticity and sustainability	The search for authenticity is not always in agreement with sustainability goals. Sometimes an overly recognizable authentic tourism product can attract mass tourism. In such a case, it is important to monitor the process of touristic flows and the carrying capacity of sites.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Camaño-Franco and Suárez (2020)	Social	Address the complexities of integrating this cultural landscape into a tourism development strategy and analyze the support and impacts perceived by the local	The results show that bureaucratic-administrative barriers related to cultural site management can often hinder geo-tourism sustainable development. These barriers prevent the creation of a unique, holistic, integral, and coordinated planning and management system that encourages participation in this natural and cultural space, based on a sustainable balance between visitors, residents, organizations, businesses, and the environment.
Cañizares Ruiz (2011)	Social	Analyze how mining and industrial heritage has represented a pivotal force in the socio-economic recovery of certain territories.	Oftentimes mining sites have visitor centres, museums, themed centres, access to the mines, mineral processing facilities, mine trains and other interesting activities, which given their large scale makes it a necessary to create more or less organised tours, thus turning the territory into a museum
Cetin (2015)	Environmental	Evaluate the potential for the caretakers of the ancient city of Pompeipolis within Kastamonu to establish modern conservation approaches, balance its conservation and use this within the framework of cultural tourism, and determine problem areas and opportunities	In this context, the slope of the ancient city and its surroundings was obtained via a height and visibility analysis. The resulting route for sightseeing in the area was revealed by this height and slope analysis; an alternative point of view was presented through a visibility analysis.
Chami (2018)	Social	Propose strategies for sustainable tourism development in the Amboni Limestone Caves	The results of the research show that the development of geotourism can be restrained in the presence of low quality infrastructure and accommodation, poor marketing and lack of a site management plan, and also due to the lack of involvement from the local community.
Conesa (2010)	Social	Understand tourism development projects in the mining town of La Unión (Spain)	The research shows that mining tourism has great potential both economically and socially. However, with regard to the objective of the protection of identity, it is essential to make greater efforts.
Dans and González (2018)	Economic	Explore an effective tourism management program for the Altamira Complex	The research results show how a territory that possesses mines can attract visitors and tourists and moreover, if adequately equipped and organised, how it can generate direct and indirect economic effects.
Dimitrovski and Senic (2019)	Social	Examine the role of the local community for the sustainable mining tourism.	Sustainable development in the context of mining does not question the long-term economic justification of resource extraction; however, it focuses attention on measures against negative social and environmental consequences. The research findings show that the local population views its support for sustainable development of mining tourism exclusively in the context of economic development, and not through perceived benefits linked to ecological and social development.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Emeka et al. (2017)	Environmental	Understand opportunities and risks from geotourism development in Agu-Owuru cave in Ezeagu (Nigeria).	From an environmental point of view, one of the major environmental challenges facing the site is littering of waste products by tourists. Erosion has also caused damage to the pathways leading to the cave. The paper underlines the importance of a tourism development plan that starts from the synergy between tourism professionals, government and host community in order to achieve the sustainable development of cave tourism.
Farsani et al. (2019)	Economic	(1) assess the motivation of domestic tourists for participating in geo-mining tours; (2) examine the importance of geotourism activities for tourists; and (3) investigate the satisfaction of tourists during organised geo-mining tours to the Nakhla and Muteh mines.	The results clearly illustrates that discovering new tourist destinations is the motivation of the majority of tourists who participated in geo-mining tours. Promoting mining tourism can improve the local economy indirectly, since tourists buy local products and food, and stay in local accommodation.
Ferreira et al. (2019)	Economic	This aims wants to inventory and quantify the Geosites in the State Tourist Park of Alto Ribeira, in order to focus on the geoconservation strategies.	Regarding the tourist usage value, the characterization of geosites showed great geotourist potential for educative purposes concerning a heterogeneous touristic public, from tourists without an advanced level of education to tourists with university degrees. However, due to lack of infrastructure and accessibility in the nuclei where they are presented, tourist usage values are not compatible with their potential visitation. These are factors that highly restrict tourism, and it is actions such as improving the access roads and the creating more infrastructure to receive visitors, i.e., lodging and restaurants are recommended.
Garofano and Govoni (2012)	Economic	Explore underground geotourism in Italy, along with its economic role in the tourism industry business.	The organisations of the tourist caves in Italy varies and range from small associations of volunteers to well-established private companies. By comparing show cave tourism and show mine tourism different typologies of visitors appear, and it has been found that in mining tourism, the majority of visitors are students. The comparison of caves is managed by private organisations, by public administrations and by volunteers groups.
Gessert et al. (2018)	Economic	Investigate the tourism visit rate incidence through an Attractiveness Index concerning 12 caves in Slovakia.	The results of research show that the most important factor affecting visitor numbers is the attractiveness of the location in terms of the presence of other cultural and natural facilities, quality and amount of services and the overall economic and political situation of the country.
Giblin et al. (2017)	Environmental	Describes the impact of Rwanda's heritage tourism industry on archaeological resources.	A balance between leisure and environmental activities and heritage activities can be achieved by promoting and developing cave tourism. In detail, archaeological narratives should be included in the cave tourism experience and archaeological values should be carefully considered before construction is extended to other caves. Competing heritage values may be better managed in Rwanda if economic experts responsible for these developments enter into consultations and collaborative relationships with heritage experts.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Gregorova et al. (2020)	Economic	Analyzes the issue of mining brownfields in terms of their secondary use after revitalization as potential new sites of mining tourism.	The authors' research confirms that the unmapped mining underground and its manifestations on the surface and lousy statistics on the preserved surface and underground objects, whether construction or relief, are often hidden dangers.
Huges et al. (2021)	Environmental	Explores the potential of replicas to address the negative impacts associated with over-tourism by examining tourists' reactions to four replica cave sites in Europe.	Results show that reactions to the four replica sites ranged from full acceptance and willingness to immerse in the experience to the comprehensive rejection of replica experiences as commercialised and inauthentic. Some visitors note the presence of reproductions and appreciate the opportunity to experience something akin to the original; some immerse themselves in the experience to the point that they forget about the surroundings being replicas; others are unable to look past the fact that the site and paintings are reproductions. Reactions were predominantly positive, but a small portion of visitors did not enjoy the replica experience; consequently, such sites may have limited appeal to certain sections of the population.
Jalani (2012)	Social	Determine the local people's perception on the importance of natural resource to the tourism industry according to their type of livelihood (ecotourism or non-ecotourism job) and according to their length of stay in Sabang Palawan.	Residents of Sabang have a high level of awareness and involvement in the protection of the environment. However, due to overdependence on tourism, most of the respondents were unaware that as tourism in the Subterranean River is a form of ecotourism and the environment is therefore the key tourism resource, and instead were more interested in the economic aspects of tourism.
Kim et al. (2008)	Economic	Investigate tourists' motivations to visit caves	There are four motivational factors related to visiting caves for tourism purposes: "escape", "knowledge", "socialization" and "novelty". Cave tourists tend to list the main purpose of their visit as socialization or escape from their workplace or every-day routines.
Knežević et al. (2011)	Economic	Investigate cave heritage and cave tourism promotion.	Caves represent a complex resource in the tourist trade of Primorsko-Goranska County, to which little importance has been attached to date. There are promising opportunities for tourism development in the area. Visitor numbers and revenue can be increased by repositioning the cave-tourism product and enhancing the offering with new facilities and services.
Kršák et al. (2016)	Social	Understand the role of online open data resources on Slovakia's mining heritage and tourism.	The local tourism industry in the analysed towns has not reached a significant position regarding creating jobs yet. A valid strategy to implement sustainable mining tourism in the area, is the creation of a DMO able to support the tourism development and the collaboration among the near towns.
Kubalikova et al. (2016)	Environmental Social	Understand the environmental suitability and social implications of geo-tourism and geo-educational activities in the different anthropogenic landforms within Brno city (Czech Republic).	The most attractive landforms from the geo-touristic and geo-educational point of view are the mining (quarries, pits), urban (underground, artificial caves) and communication landforms (road or railway cuttings).

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Kubalikova et al. (2017)	Environmental Social	Provide with a description of a number of underground sites within Brno city (Czech Republic) to understand tourism development in the area.	Findings evidence that these underground sites are valuable and unique. However, their potential for tourism development is not fully recognised and thus exploited for geo-tourism and geo-educational activities.
Kumar (2014)	Social	Understand the prospect of tourism development in Meghalaya caves.	The study evidences the potential to create adventure paths in the Meghalaya region to revitalize the underground heritage. However, this is hampered by a number of factors i.e., political instability, violence, immigration flows.
Lewkowicz (2011)	Social	Explore the historical touristic evolution of Polish-Slovak cross-border area	Findings indicate importance of raising ecological awareness of visitors through educational programs and media campaigns, conducted by institutions and associations.
Le (2014)	Social	Explore the destination identity-negotiation nexus regarding the Cu Chi tunnels in Vietnam	The incorporation of these underground sites in the local community's identity is inhibited by their original use during the during the Vietnamese War
Lobo et al. (2013)	Environmental	Investigate a non-deterministic method to define tourist carrying capacity in Brazilian Diabo caves.	In defining the tourist carrying capacity, authors suggest a) to find a balance between environmental conservation and tourism promotion to ensure economic-environmental sustainability; b) consider the interest of all involved stakeholders to ensure community support.
Lobo et al. (2015)	Environmental	Explore the process underlying the definition of tourist carrying capacity in Santana cave.	The exploitation of caves for tourism purposes must involve both managers and researchers and be based on scientifically environmental knowledge
Maksimović et al. (2016)	Economic Social	Identification of actions supporting the development of mining tourism in Stara planina (Eastern Serbia).	Authors identify three relevant actions supporting the development of mining tourism, namely: (1) training human resources for mines and tourism; (2) adoptting an effective marketing plan to promote mining tourism in the destination; (3) create tourism-related infrastructures.
Main Rindam (2014)	Economic Environmental	Investigate the potential of Asar Cave as natural tourism asset at Lenggong Valley (Perak).	The study underlines the uniqueness of the Asar case which can be exploited for speolotourism and ecotourism. This tourist asset could be leverage to improve local economy and the standard of living of the local community.
Margiotta and Sansò (2017)	Economic	Investigate the opportunities from tourism promotion in abandoned quarries in Salento (Italy).	A possible tourism valorisation strategy for a group of abandoned caves of high geological interest is to define them as "geo-attractors", i.e., potential nodes of a regional geo-touristic network. To this end, the authors point out the importance of involving local stakeholders, i.e., local institutions, universities and environmental associations should collaborate to make these underground sites attractive.
Melo Zurita (2019)	Environmental	Analyze the contribution of carving explorations to the social and physical construct of Yucatan Peninsula's subterranean (Mexico).	The study underlines the establishment the connection between the touristic boom in the area and the narratives of divine permission linked to rituals.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Mossa et al. (2018)	Economic	To map mining sites allocated to tourist use.	Findings underline the relevance of industrial heritage in the recognition of underground sites, geosite and geoparks, from economic perspective and, as a result from UNESCO perspective.
Musadad (2018)	Social	Explore community participations (and barriers) to tourism activities in Pindul Cave (Yogyakarta, Indonesia).	Community participation is crucial to empower the local people living in the area around Pindul Cave. However, they face barriers to participate in cave tourism-related business mainly due to the lack of language skills, along with management and tourism-related competences.
Novas et al. (2017)	Environmental	Discuss the definition of carrying capacity of touristic caves.	Findings underline that the definition of the maximum number of visitors accessing the caves (i.e., carrying capacity) should be intended as a dynamic activities based on a real-time monitoring of environmental parameters.
Pace (2021)	Economic	Introduction to the European Project Cost Action CA18110 Underground4value	The chapter addresses the participatory processes to involve local community in the successful valorisation of the Underground Built Heritage (UBH).
Parga-Dans et al. (2020)	Social	Investigate the dichotomy between underground site protection and tourism promotion from the point of view of citizens and visitors.	The study identifies factors determining the “social value” attributed to Altamira Prehistoric Caves (Spain) by citizens and visitors. The recognition of high social value of these caves means that people (mainly the most educated) are more willing to accept their closure as they recognise the importance of protecting the cultural value they contain.
Pingbin et al. (2012)	Economic	Develop a scientific system for optimizing the exploitation of cave tourism and tourism development in the Zhejiang Province.	The study proposes a hierarchical and sequential exploitation of cave tourism to create a pole-path-network process, i.e., interregional tourism routes connecting karst caves located in the province.
Rachmawati et al. (2020)	Economic	Identify the motivations for cave tourism in West Java of Indonesia.	Motivations of visitors of caves in West Java fall into three categories: (a) recreational (i.e., who see cave tourism as a way to stay in natural and scenic surroundings), cultural (i.e., mainly families who visit the quarries for their historical value) and adventure seeker cave visitors (i.e., young to adult people looking for challenging activities and adrenaline boosting in the cave).
Rahmawati and Sunkar (2013)	Economic	Understand the tourists’ intention to return visits the Cave Bentar (Yogyakarta)	Findings evidence the importance to improve the experience inside (e.g., security and professional guides) and outside (e.g., cultural attractions and tourism services) the caves in order to increase visitors’ satisfaction so that they return to visit the sites.
Rindam (2014)	Economic Social	Investigate the economic and social potential of tourism exploitation of Asar Quarries in Malaysia.	The author proposes a SWOT analysis to discuss opportunities and threats of tourism exploitation in these caves. Interestingly, he points to the importance of a pro-active role of institutions for successful tourism promotion.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Różycki and Dryglas (2017)	Economic	Examines tourists' perceptions about visiting mines and other geological locations.	Mining tourism encompasses different types of tourism such as cultural tourism (e.g., trips to mines to attend cultural events); active/adventure tourism (i.e., for challenging activities); industrial tourism (e.g., workshops exploring various industries); therapeutic tourism (e.g., for therapeutic treatments); business tourism (e.g., corporate events) and religious tourism (e.g., pilgrimage).
Ruiz Ballesteros and Hernández Ramírez (2007)	Social	Understand the relationship between community identities affect mining tourism.	Heritagisation refers to the crystallization process among identity, community and tourism. Findings show that when local communities deny mining industry, they divorce themselves from mines as far as possible. Neither investment, nor institutions and associations can succeed due to this cultural barrier. Without a community identity based on mining, there is no collective mining heritage to be exploited as a touristic resource.
Sebela and Turk (2014 a)	Environmental	Assess the impact of tourist visits on the air and groundwater temperature in Postojna Caves (Poland).	Cave air and water temperature are sensitive to climate dynamics. Natural phenomena influence the cave-air temperature more than anthropogenic factors in the long term. In contrast, the visitor's influence on groundwater temperature (i.e., body temperature is transmitted to the rocks and then to the water). For this reason, authors highlight the importance of defining the maximum number of visitors that can enter annually to not compromise internal conditions and thus ensure the conservation of spaces.
Sebela and Turk (2014 b)	Environmental	Investigate the impact of tourism on micro-climate of the Predjama Cave in Slovenia.	Climate fluctuations may compromise the fauna and flora. For this reason, the authors, while recognising tourism opportunities, advise setting a maximum number of visitors and the adoption of a regulatory framework that allows cave exploitation without compromising the environment.
Shavanddasht et al. (2017)	Economic	Examine the motivations of cave tourists and destination satisfaction in Alisadr Cave, Iran.	Intrinsic and extrinsic motivations are both important for cave tourists' destination satisfaction. However, intrinsic motivation—particularly the opportunity to enjoy inside the caves—has a stronger relationship with tourist satisfaction, i.e., the greater the individual desire to visit a place and the opportunity to enjoy, the more positively this will influence satisfaction.
Shavanddasht and Schanzel (2019)	Economic	Investigate factors affecting adolescents' satisfaction in tourism in Ali Sadr cave in Iran.	Adolescent satisfaction is influenced by the way in which they approach the location and by parental style. Regarding this second dimension, an authoritative style makes the adolescents more satisfied, thus contributing to a satisfactory holiday experience where all family members' desires and needs are met and intra-conflict are reduced. On the contrary, the most dissatisfied are the adolescents who have parents who have an authoritarian style that leaves no room for negotiation and imposes travel decisions, without the involvement of the children. These teenagers are the ones who report a negative mood and feel dissatisfied, thus compromising the satisfaction of the whole family.

Table 6. Cont.

Author(s)	Contribution to Pillar(s) of Sustainability	Goals and Scope	Main Findings/Highlights
Sidor et al. (2017)	Environmental Social	Investigate the use of Open Street Map in mining heritage.	Findings suggests that mining heritage should be associated with natural heritage. They also demonstrate the suitability of the Open Street Map for creating spatial data on mining heritage to identify points of interests within bounded destinations.
Torabi Farsani et al. (2020)	Economic	Identify factors that allow for the successful implementation of mining tourism routes in the Yazd province (Iran).	Financial support and tourism expertise and knowledge represent some of the most important factors for the successful implementation of mining tourism routes in the Yazd province. Authors also point at the importance to prepare travel packages for promotion nationally and worldwide through professional tour operators and travel agencies.
Tseane-Gumbi and Ani (2018)	Social	Investigate the economic opportunities in South Africa arising from mining tourism.	Despite recognising the opportunities of tourist exploitation of the many former mining sites, findings show that the lack of support from local institutions hinders successful private investment in mining tourism in South-Africa. Indeed, institutions play a key role and should provide local people with training to allow them to run a tourism business profitably.
Ulloa and Goicoechea (2013)	Social	Investigate the social potentialities of geo-tourism in Costa Rica	Descriptive analysis of tourism in the main mines of Costa Rica. Authors focus on the involvement of local community as tour guides inside the caves, as well as in the tourism services established around the mines (e.g., hotels and camping, bars and restaurants, horseback riding)

Source: our elaboration.

3.1. Economic Sustainability

The reviewed papers that focus on the economic aspects of sustainability recognized the importance of protecting UBH but also emphasised the opportunities to leverage underground sites as tourist attractions for its positive implications on the local economy [30]. For example, Margiotta and Sansò (2017) [31] have found that some abandoned mines in Salento (Southern Italy) have a unique geological value that could be exploited and may function as “geo-attractors” i.e., sites characterised by valuable geological features, a favourable geographical location and sufficient area for geo-tourism activities. This would have positive economic implications and, at the same time, would avoid a number of environmental issues produced by abandoned mines such as groundwater contamination [32]. In order to make this project successful, the commitment of decision makers and tourism managers is fundamental, and they should be involved in the strategic planning regarding the site itself (e.g., trained staff to guide visitors along the geo-trails and viewpoints, information panels to illustrate geological features) and the surrounding area (e.g., parking and reception points, walking and cycling routes, sports facilities such as climbing, picnic areas and resting places) [33].

On one hand, studies framed within “economic sustainability” have focused on management dynamics and, on the other hand, on the relevant characteristics of visitors to implement effective marketing strategies.

For the former, researchers have mainly focused on network strategies and marketing policies to be implemented to enhance the attractiveness of these underground sites and thus generate economic benefits in the surrounding areas [16,34–38]. In this regard, Gessert et al., 2018 [35] have found that the most significant factors that influence the attractiveness of a cave are the abundance of cave decorations along with the position of the caves i.e., its

proximity to other points of cultural, recreational or tourism interest. Their study, in fact, revealed that oftentimes, cave tourism is not the main motivation for tourists, but that their visits to underground sites are linked to other tourism attractions.

At the level of the single underground site, Maksimović et al., 2016 [37] proposes the implementation of the following strategies for the successful development of mining tourism: (a) training human resources for competence in the field of mining tourism; (b) using aggressive marketing and advertising to increase the attractiveness of mines as tourism destination and (c) creating tourism infrastructure that support tourism experiences around the mines. At the network level, Torabi Farsani et al., 2020 [16] suggested the creation of “mining tourism routes” that connect the many ancient over ground and underground mines in the province of Yazd (Iran) promoted through travel packages that exploit successful experiences with geo-tourism and ecotourism already existent in the area. In the same vein, Pingbin et al., 2012 [39] propose a hierarchical and sequential exploitation of caves to create a “pole-path-network process” for the development of karst cave tourism, with the possibility of creating interregional tourism routes. In particular, the study proposes to (1) systematise the caves in the different areas so that less developed areas can benefit from the tourism resources in other more developed areas (i.e., promote multi-grade growth poles); (2) create interregional tourist routes, i.e., strengthen cooperation between the different caves and create routes to exploit the potential of karstic cave tourism and integrate resources; (3) optimize the exploitation network by creating a thematic karstic tourism cluster. Bashit et al., 2007 also pointed to the importance of combining this network strategy with the creation of a “territorial image” that stresses the importance of authenticity and the attention paid to sustainability [40].

Numerous scientific studies have been developed to accommodate for the demand side of tourism in the UBH sites. In particular, Różycki and Dryglas (2017) have found different typologies of tourism demand depending on the target tourists. This encompasses geo-tourism (i.e., visit caves for their geological features); cultural tourism (i.e., trips to caves to attend cultural events); active/adventure tourism i.e., travelling underground for challenging activities and/or in difficult climatic conditions; industrial tourism (e.g., workshops exploring various industries); therapeutic tourism (i.e., a place with scientifically proven conditions for therapeutic treatment based on natural healing fossil, marine or climatic resources); business tourism (e.g., corporate events and workshops) and religious tourism (e.g., for pilgrimage) [19].

Beginning with the assumption that geo-sites show a great tourism potential due to a heterogeneous interest among tourists [41], Farsani et al., 2019 have investigated the satisfaction of mining tourists and found that they can contribute to the improvement of the local economy indirectly, because tourists enjoy the “geo-experience”, including staying in geo-accommodation such as stone villages, visiting underground and surface mining eco-museums, buying local products related to the mining heritage, and participating in geo-sports such as cycling and hiking in mines [16]. Rachmawati and Sunkar (2013) [17] sought to identify the motivations underlying people’s decision to visit mines (i.e., preferences, travel pattern, perceptions and attitudes), thereby providing indispensable information for the promotion and marketing of cave tourism because motivation is the driving force behind all behaviours that reflect in a person’s travel choices and expectations. Motivation also contributes to defining the level of satisfaction of a visit. Rahatmawati et al. (2020), in a follow-up study, identify factors that determine the intention to visit Cav Bentar in Indonesia again. Based on a questionnaire administered to 103 visitors, the study demonstrates that the tourist’s purpose in visiting the cave (i.e., need that drives someone or act in a certain way to achieve the desired satisfaction) influences their experience, which is related to seeing, learning, enjoying and living a different lifestyle [42].

Shavanddasht et al., 2017 [14] explore the motivations for visiting quarries and the relationship of these motivations with the degree of satisfaction of visitors. To this end, they use the self-determination theory which is a meta-theory of motivation that assumes human beings are active organisms driven by competence, autonomy and relatedness.

The study shows that both intrinsic motivations (i.e., enjoy, relax, novelty seeking, escape, socialisation, knowledge) and extrinsic motivations (i.e., identifies, introjected, external regulation) have a positive impact on tourist destination satisfaction with regard to available infrastructures; environmental factors, i.e., the beauty of the place; its scale, i.e., number of visitors; management service, i.e., hospitality and friendliness of the staff; catering, i.e., convenience. The same approach is adopted in another study, in which Różycki and Dryglas (2017) investigate the relationship between adolescents' mood (i.e., how they feel during the holidays, which may be influenced by the fact that they have been forced to go to a place by their parents) and perceived parenting style (i.e., authoritative, permissive, authoritarian) and adolescent tourism needs satisfaction [19].

Finally, some authors have also investigated the role and the perception of residents regarding the development of these tourist sites [10,43–47]. Resident communities determine the identity of these places and therefore increase the experiential potential of the visitor experience. Artal-Tur et al., 2019 and Mossa (2019) emphasise the impact of personal values and tourism development on the perception of tourism impacts by local residents [45,46]. This aspect also influences the place identity, which in the case of caves and mines, mainly includes the attributes of continuity and self-esteem for local residents, with tourism allowing them to maintain, preserve and enhance local history and heritage.

3.2. Environmental Sustainability

Another fundamental factor of sustainable tourism is the interest that decision makers, tourism managers, and practitioners should divert to the environmental aspects of tourism development. It is, in fact, clear that the development of sustainable tourism should also be based on the appropriate usage of natural resources, the protection of local flora and fauna, the respect of biodiversity and the careful enhancement of ecological and natural processes of the places.

Many papers listed in this systematic review have dedicated attention to the environmental aspects of the development of sustainable tourism in underground sites. More precisely, the studies have addressed two important aspects:

1. The drivers that guide the development of tourism aimed at enhancing and protecting the environment (economic advantages, educational purposes, etc.)
2. The instruments that allow for a balance between the enhancement and protection of sites (collaboration among actors, combination among different forms of tourism, managerial and technological tools, etc.).

The first aspect is related to the drivers that can guide the development of tourism, aimed at enhancing and protecting the environment of UBH sites. Giblin et al., 2017 [48] investigate the economic convenience of more sustainable forms of tourism; they confirm that the interest in obtaining rapid financial returns has prompted the management to promote some cave sites in Rwanda as nature-based tourism attractions, that are able to balance tourism with the protection of the natural resources. A similar mode of sustainable tourism, in fact, supports the protection of natural resources, and can have a positive impact on the tourism market, by informing and educating the tourists via a more protective form of tourism.

Another driver is identified by Kubalikova et al., 2017 [49], who consider the caves in Brno's city to be viable places for the education of visitors on the geological aspects of underground sites. It directly implies the protection and conservation of the environment, since the unique natural aspects of the underground sites become the object of study. Through educational activities, tourists learn more about the natural resources of the caves and their conservation, ensuring the protection of the sites. The importance of preserving a Malaysian cave and of transforming it into an educational point of reference is the focus of the study by Rindam (2014) [34]. The author considers the cave a natural source of tourism that is able to enhance environmental conservation and to increase awareness of environmental education. This can be made possible by planning a form of tourism entirely devoted to the protection and enhancement of the natural environment of the

caves, through the presence of an information centre about natural caves, the study of artistic lighting to demonstrate to the tourists the peculiarities of stalactites and stalagmites, and the enhancement of the scientific value of the place.

Amorfini et al. (2015) use the Apuan Alps Geopark to describe how a site can have a tourism development through environmental education and partnerships with universities and agencies for research and environmental protection. The Geopark owes most of its fame to the beauty of its large caves [50]. The awareness of managing and enhancing these caves has encouraged the Park Authority to integrate its actions regarding research, conservation and the enhancement of sites as tourist attractions. In order to ensure tourism activities invested in the dissemination of new and updated knowledge about the site and its unique characteristics, the Geopark has developed cooperation agreements with universities and other research institutions. Furthermore, it offers educational courses for local primary and secondary schools, promoting the understanding and knowledge of caves and its environments, and initiatives on the tradition and culture of the Apuan territory.

In their work, aimed at inventorying and quantifying the geosites in the State Tourist Park of Alto Ribeira, Ferreira et al. (2019) focus their attention on the need to identify and characterize all the elements present in underground sites, that can have a valuable impact at the cultural and social level, and are representative of the place [41]. These can be of scientific, educational, and recreational interest, and should be enhanced and protected through the implementation of geoconservation strategies, which also allows for the meaningful development of sustainable tourism. The study reveals that sustainable tourism development has to provide to visitors with materials for interpretation and dissemination of a geosites' value, in order to instil an awareness about the cultural, scientific and educational value of each geosite among tourists.

The focus on the environmental aspects of the sustainable development of tourism in underground sites has also helped to identify that many papers in this systematic review have explored instruments that achieve a balance between enhancement and the protection of natural resources.

The main instrument, considered by numerous other studies, is the role of collaboration for developing a sustainable mode of tourism that is able to enhance and protect the environmental features of the places.

Giblin et al., 2017 [48] consider the importance of developing successful tourism in the caves of Rwanda, by combining the natural aspects of caves with their historical and cultural value. Similar achievements are possible through a strong collaboration between the subjects interested in the sustainable development of the underground sites, so as to ensure the protection of natural resources, the enhancement of local heritage, and the satisfaction of tourists. The need for further collaboration between the actors to better enhance the environmental aspects of tourism in underground sites is the focus of the study by Emeka et al., 2017 [51]. The authors examine the implications of developing geo-tourism in a cave and consider the site a place of environmental conservation, able to attract specific forms of tourists and to enrich the local economy. In this sense, caves are very important to tourism if their potential is properly harnessed, as they are able to improve the social and economic well-being of the host community, as is the need to consider the conservation of biodiversity and the environment. To this end, collaboration between tourism professionals, cave managers, and locals is necessary.

The collaboration between scientists and quarry managers is also considered fundamental for the preservation of the caves and for their sustainable exploitation by Sebela & Turk (2014a) [20] and Amorfini et al., 2015 [50].

According to Kubalikova et al., 2016 [52], the collaboration of specialists of different branches (scientists, teachers, local authorities, owners, etc.), is a focal starting point, otherwise the geo-educational and geo-touristic potential of Brno's city's underground sites may not be fully and sensibly exploited. The authors consider the underground sites of the city as valid places for geo-tourism, specially devoted to educational purposes, due to the diversity of the natural environment, that can be protected and used for tourism at the

same time. Cooperation among all the stakeholders is necessary in order to recognize the potential of the natural resources, sensibly make use of the places, improve the protection of the environment, and properly promote the sites.

Another instrument that is useful to guide a balanced promotion of the natural resources in UBH sites is the tourist carrying capacity of caves. This theme is addressed by Sebela and Turk (2014a, b) [20,21]. By exploring tourism and its impacts on a Poland cave, the authors [20] found that artificial lighting causes degradation of cave rock, and that the water temperature in the cave is influenced to a greater extent by human presence than by natural phenomena. For these reasons, the authors identify the need for a constant monitoring system and the definition *ex ante* of the maximum number of visitors that can enter annually and during the various seasons in the caves. These solutions are able to protect the internal conditions and to ensure the conservation of spaces.

Sebela and Turk (2014b) [21] also investigate the impact of tourism in Slovenian caves. The constant monitoring of the climate inside and outside the caves reveals that the climate is influenced by the visitors, and that tourism can potentially compromise the fauna and flora inside. For this reason, the authors, while recognising the opportunities in terms of tourism given the exceptional nature of the places, call for institutional monitoring and the adoption of a regulatory framework that allow the caves to be exploited for tourism, without compromising the environment.

Lobo et al. (2013, 2015) begin with the consideration that the management of tourist related activities in caves requires a solid and scientifically based understanding of the environment, since subterranean habitats are among the most fragile environments in the world [53,54]. The environmental fragility of caves can be protected through an understanding of the concept of the potential use of carrying capacity as a tool for the improvement of the use of natural attractions for tourism purposes that are compatible with environmental conservation. Lobo et al. (2013, 2015) propose a planning tool designed to open further avenues that consider the needs of several actors, such as inhabitants, scientists, decision makers, and tourism professionals [53,54]. According to their instrument, the carrying capacity is based on a flexible model, by aligning an analysis of situations of environmental conservation with the needs of the management and the maintenance of tourism. A constant monitoring, through the use of technologies, and future developments of the instrument are essential, in order to adapt to any alteration of the environment.

The use of technologies to facilitate a more sustainable development of tourism in UBH sites is at the centre of the study also by Novas et al. (2017) [55]. They present a real-time monitoring system to be used for environmental parameters measurement in tourist caves. The technological tool can be employed for protecting the natural environment of caves during its tourism development, since it allows for the registration of vast levels of metadata (temperature, relative humidity, wind speed and direction, CO₂, atmospheric pressure, rain, presence and visitor count), which is useful to define the microclimate modification that occurs in relation to the number of visitors. The authors found that the influence of tourist visits on the cave's microclimate appears significant because there is an over-riding influence from surface climate conditions in the parts of the cave used for tourism. The continuous monitoring facilitates the development of a flexible plan for regulating potential visitors and an understanding of the environment, thereby allowing for the development of tourism based on a sustainable preservation program.

3.3. Social Sustainability

Social sustainability embraces an anthropocentric perspective to assess the socio-cultural consequences of tourism development [2]. In this sense, sustainability attaches importance to the contribution of people to tourism development and to the transformation of the underground sites to achieve the growth of the local economy and ensure the satisfaction of the aesthetic needs of tourists [56]. It also refers to the impacts of tourism development on improving the quality of life of the local community in the short and long

term [57] and enhancing their sense of community while respecting community identity and cultural authenticity [58].

Among the reviewed studies, we have found that a number of authors have investigated the socio-cultural implications of tourism development in the UBH sites. More specifically, the studies in this group have mainly focused on:

1. evidencing the opportunities of tourism development for social equity;
2. exploring the process of the formation of community identity linked to the existing UBH sites;
3. understanding community participation in the decision-making process related to tourism development.

As for the first point, a number of studies have pointed at the potentialities of the UBH sites in playing a pivotal role in the socio-economic recovery of otherwise unattractive territories [59], by leveraging eco-tourism [34,60], adventure tourism [61] and geo-tourism [49,52].

Regardless of their type, the reviewed studies have shown that tourism development improves the life quality of hosting communities and ensures social equity i.e., a fair distribution of benefits among different stakeholders [34,49,52,61–63]. In this regard, Ulloa and Goicoechea (2013) have elucidated the social benefits from geo-tourism in Costa Rica, which is a country characterised by geological diversity with karstic and volcanic quarries and, above all, tunnels for mining activities due to its historically extensive mining activity for gold, silver and other minerals [64]. For example, a cooperative set up in Olla Quemada has initiated a comprehensive touristic plan around the existing mines including a museum with an exhibition of machineries used in the extraction and transport of materials, lodging options, hostels, food services and a number of activities in the surrounding areas (e.g., horse ridings). Likewise, the development of eco-tourism in the subterranean site in Sabang in the Philippines has created job opportunities for local people in tourism-related activities [60]. From another perspective, Maksimović et al., 2016 [37] have underlined the potential of the recovery of three former uranium mines in Stara Planina (Eastern Serbia, Europe) to limit the emigration of young people via successful tourism attractions, thus providing local people with the economic conditions and, most importantly, interest, borne of tourism, to remain in the country.

Another group of studies has described social sustainability as improving the quality of life through an increase of local entrepreneurship [34,56,59,64]. Indeed, reviewed studies have underlined that the tourism services and activities that take place in (e.g., tour guides) and around (e.g., coffee shops) the underground sites are generally run by local entrepreneurs or comprise small-sized family businesses (e.g., [59]). However, while tourism development is likely to increase the level of entrepreneurship of local people, it can also be risky and unsuccessful if they are not adequately supported by local institutions with ad hoc investments aimed at training future entrepreneurs and aiding their business in strategic and operational aspects. The importance of entrepreneurial competencies and skills, including those emphasizing independence and self-reliance (internal factors), combined with a supportive institutional environment (external factors) in the tourism promotion of underground sites clearly emerges from the case studies presented by Tseane-Gumbi and Ani (2018) [56] related to the projects of tourism valorisation of the many former mining industrial sites in South-Africa, which, in 2013, was the fifth largest and most important mining industry in the world.

Tourism development around the underground sites has been demonstrated to also be a powerful tool to enhance the sense of community in the host destination [58], shaped by community pride, shared values, and closer social bonds that lead to harmonious relationships between different individuals and groups so that each person feels responsible for their community as integral members, generating greater care for UBHs and for their community image [65]. In order to accomplish this, it is essential that the host community is made aware of the intrinsic social value of these underground sites. In this regard, the recent study of Parga et al., 2020 [15] explored the “social value” attached by local

community to the Altamira Caves, which are Spanish caves famous worldwide for their Upper Palaeolithic wall paintings, in the following dimensions: (a) aesthetic value, intended as the sensory perceptions of a heritage site i.e., perceptions about arts, architecture and craftsmanship in the past era; (b) heritage value, i.e., understanding of the historical significance and cultural value of a certain site; (c) economic value referred to the economic potentialities in the surrounding territory; (d) legacy value that implies the preservation of this cultural heritage for future generation.

Several studies have focused on the process of the construction of community identities around UBH, for which it is important to understand context and to address heritage tourism in a way that is coherent with the local identity. Indeed, community identity has a symbolic nature with the function of representing reality, but also a performative dimension because it does not only describe social subjects, it also creates them and helps them come into being [66]. These studies have highlighted two distinct patterns [44,63,66–68]. On the one hand, there are studies that have shown that some local communities strongly believe in the importance of including UBH in their identity to preserve their history and traditional values [63,68]. However, this process of incorporating underground sites into the community's identity is sometimes hampered by the original use of these UBH. Indeed, when these underground sites evoke “negative memories” and are thus perceived as negative heritage, it is fundamental to create a narrative that includes the traumatic event itself in its discourse [69–71]. An example is the Cu Chi tunnels, a vast underground military system near Saigon used by VietCong against South Korea and the US during the Vietnam War in the 1960s and 1970s. Only recently has there been a progressive reconciliation of the perceptions of Vietnamese communities around the world, and second generation Vietnamese living in the USA have started to recognize that this UBH is part of the local identity [44].

On the other hand, Ruiz Ballesteros and Hernández Ramírez (2007) have evidenced that, despite the long mining tradition in Andalusia (Spain) and the existence of tangible symbols (remains and landscapes related to the mining activity) and intangible symbols (rituals, memory about the mining activity etc.), discursive patterns of local communities often do not include and do not recall the mining activity [66]. This happens because the local community does not recognise their heritage value and does not feel a strong connection with mining activities, which therefore cannot be expressed and transferred in the community identity. They reject the importance of mines and try to divorce their community and town from the history of the mines as far as possible.

Lastly, a group of scholars have focused on the community cooperation and the way in which they act collectively to achieve sustainable tourism in the underground sites. These studies agree on the importance of local community engagement and thus participation in the decision-making process related to tourism development in the UBH [67,72–74]. However, they have pointed out that this engagement process in the management, conservation and tourism development of the sites is sometimes inhibited by a lack of skills related to language and managerial skills of the local people [73,74].

4. Discussion and Conclusions

Assuming that sustainable tourism development at the destination level can be achieved by focusing on the three pillars of sustainability (economic, environmental and social dimensions) and then enhancing its role as a facilitator of education, intercultural engagement, ecological appreciation, and spiritual development [1,5,6], this paper focuses on the so-called Underground Built Heritage (UBH).

UBHs are caves for which the main body is located under the geographical zero level and expression of local material and immaterial cultural heritage [12,13]. For these sites, the issue of sustainable development is highly topical.

The scientific literature highlights that UBH sites have an intrinsic scientific, cultural and recreational value [14], leveraged for “cave tourism” including, among other forms, geo-tourism, mining tourism and adventure-tourism [14–16]. Many UBH sites are also

UNESCO sites in which the guiding principle is to protect assets considered unique and universal in order to enjoy them and to ensure that this privilege is passed on to future generations. The sustainability criterion is inherent in the philosophy behind each site. It follows that these territories, these assets, these cultures, should convey social equity, environmental integrity and economic efficiency in the long period through their operations and visibility [75]. At the same time, UBH sites are often close to other cultural, natural or landscape attractions. This emphasizes the need to design systems in which all these resources are integrated, making the territories ideal tourist destinations.

The semi-systematic review has captured a clear picture of the sustainable development of tourism in UBH sites, specifically related to the three pillars of sustainability, that is, the economic, environmental, and social dimensions.

Many studies on sustainable tourism in Underground Built Heritage sites have favoured the analysis of a single perspective. None have provided an integrated approach and for this reason, our paper attempts to integrate the three perspectives.

The literature review shows that studies related to economic sustainability, divided into demand and supply side studies, emphasize the need to ensure that caves (considered geo-attractors) could act as a strategic touristic resource to invest in services, infrastructure and marketing actions. In this way, it will be possible to generate economic effects on the territories in which these resources are located. Moreover, from a demand point of view, there are multiple targets related to cave tourism activities, including cultural tourism, geo-tourism, active/adventure tourism, trekking, industrial tourism, wellness tourism, business tourism, religious tourism [19].

The papers focused on environmental sustainability, emphasizing that tourism development must be based on the acceptable use of natural resources, the protection of local flora and fauna, respect for biodiversity, and the careful enhancement of ecological and natural processes of the places. This is possible by planning a form of tourism that is concerned with the protection, preservation, but also the enhancement of the natural environment of the caves, through an informative and educational engagement with tourists. In this way, it is possible to implement a geo-preservation strategy in which scientific educational and recreational interests are integrated.

Finally, research about the social sustainability of UBHs shows that these sites play a strategic role in territorial socio-economic recovery. In particular, tourism development could improve citizen's quality of life, ensure greater social equity, stimulate entrepreneurship among populations, and even increase the sense of community, shaped by community pride, shared values and identity, closer social ties, and positive changes that lead to harmonious relationships among diverse individuals [58].

In addition, the literature review reveals the following common factors in the three dimensions of sustainability in UBH sites:

- the focus on human resources and the need to design training and educational initiatives for both operators and tourists that support the process of sustainable development in its triple meanings;
- community participation in the decision-making process relating to UBH tourism development;
- the need to start collaboration paths among UBH tourism stakeholders (in particular tourism professionals, cave managers, local population), in order to ensure an effective trade-off between protection and valorisation.
- the promotion of a network of strategies and marketing policies aimed at increasing the attractiveness of these destinations, while respecting the carrying capacity of the sites.

In Figure 7 we summarise the common factors of the three dimensions of sustainability. In addition to being the result of the UBH management process, these dimensions represent inputs for this same process.

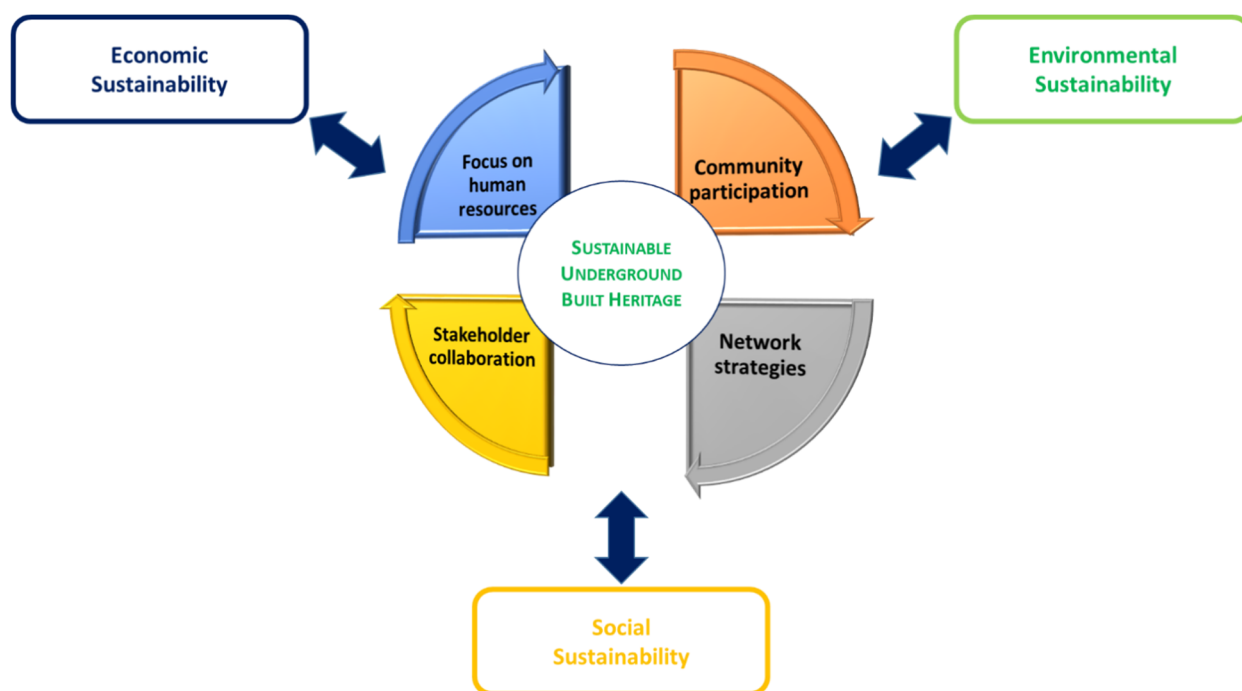


Figure 7. The main factors for the sustainable development of UBH. Source: Our elaboration.

At the theoretical level, the paper underlines the need for further in-depth social analyses, but it also adopts an integrated perspective to analyse the UBH phenomenon, which is better aligned with a “holistic approach” that considers the site as an indispensable node for increasing the attractiveness of a wider territory and, at the same time, considers the participation of all stakeholders in the development process as a *conditio sine qua non* for sustainability. In addition to its contribution to the literature on Underground Built Heritage, the paper intends to provide support to professionals, managers and policy makers involved in the valorisation of these significant touristic and cultural value sites. In fact, the review is a starting point to elaborate a possible new decision-making framework. In this context, the work provides a few points of reference through which the specific issues can be addressed and the variables to be considered in the decision-making choices of destination managers and key stakeholders in all the phases necessary for the valorisation of specific sites.

As for future directions of research, this review has evidenced that existing studies have mainly focused on the environmental implications of tourism development in caves. It would be important to further study sustainable tourism in the different types of UBH sites as identified by Varriale (2021) [13] and to propose a comparative study (cross-case analysis) in order to identify similarities and differences. In particular, it would be valuable to investigate the potential environmental opportunities from mining tourism. Mining activity has negative impacts on the environment. It contributes to the destruction of an ecosystem, negatively influences biodiversity, releases heavy metals, toxic substances, and acids that can damage waters and air. These strongly influence agriculture and other aspects of the economy and life of local communities. Because mine closures tend to be less monitored, the environmental impacts can be particularly damaging, leaving a legacy of environmental degradation. It is important that future studies investigate experiences where the abandoned mines have been valorised in a form of sustainable tourism. Furthermore, it would be valuable to expand on, via empirical research, the analysis of sustainable tourism in cultural routes (e.g., at European level) in which regions that have, e.g., mines, similar industrial activities are linked [18]. Another research avenue concerns stakeholder engagement, aiming at the development of sustainable tourism [2] considering global pressures in the tourism business, as well as in the society, that can guarantee the

environmental commitment of local and tourism managers, to influence the design and management of forms of underground tourism better aimed at protecting natural resources. The role of tourism managers and local operators in influencing tourists' behaviour towards a more respectful and careful form of visiting underground sites should be investigated too. Finally, more attention should be also directed to the role of innovation and of new technologies for developing tourism that, through the use of real time information and of virtual and augmented reality, can better protect the environment, by enhancing the tourism experience of visitors.

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