

EXPLORING THE HIDDEN DEPTHS: IDENTIFYING AND MAPPING CAVES IN SOUTH MALANG'S KARST AREA FOR SPECIAL INTEREST TOURIST ATTRACTIONS

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Abstract: The aim of this research is exploring through identifying the cave landscape and mapping around the Coban Perawan Cave for special interest tourism object. The method used in this research was field survey by plotting the entrance area which was used to determine the location and coordinate control during cave mapping. The results of the cave mapping were then processed using survex software and geographic information systems. The cave passage landscape was portrayed in the form of a cave map and presented with a geographic information system to show the connection between the cave passages. Mathematical calculations of the cave passage were also used to determine the size of the cave passage, these include cave passage's length, depth, width and volume. Cave dimensions were used as a comparison of the width and height of the cave passage to see the spatial conditions and shape of the cave passage. Furthermore, the results of the analysis on special interest tourism objects by looking at the condition of the cave surface, cave passages, the accessibility, the level of difficulty of the cave and the facilities are presented in a descriptive table. The results of the research show that there is a single passage that is not connected to other caves, except the Pramuka Cave which is possible to connect with other caves. The mapping results showed that there are vertical passages in the study area and also single horizontal passages. Besides, there is also a combination of vertical and horizontal passages. The dimensions of the caves in the cave passage segment show that the cave passage has a tendency to having circular dimensions or forming a chamber, but there are also narrow passages. In Pramuka Cave Block, there is tendency of having a connection between the cave passages and the Coban Perawan Cave Block due to the existence of the connection of its hydrological system to other caves. The existence of these caves in the study area certainly has educational value and its uniqueness that can be utilized in special interest tourism attraction.

Keywords: cave passage, cave mapping, cave tourism, specified tourism destination

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INTRODUCTION

The southern part of Malang Regency has a karst landscape with many caves, springs, and other karst morphological features. The landscape is located in the Southern Mountains which were uplifted during the Miocene period, southward with a slope of approximately 10° (Suyanto et al., 1992). The landscape creates seasonal surface rivers, dry valleys and developing karst hills. There are caves that also develop passages to the south (Suprianto and Labib, 2019), with varying slopes of passages. The survey results on the existence of caves in southern Malang are in several segments such as Sendang Biru Block (Astina et al., 2021; Salaka, 2018; Suprianto et al., 2017), Donomulyo Block (Impala, 2012; Labib et al., 2019), some parts in Bantur Block (Fauzi et al., 2015) and Gedangan Block (Rosyida et al., 2023; Sahrina et al., 2022). However, the distribution of these caves has not all been traced or mapped, so it is still difficult to identify the potential inside the cave.

The identification of unmapped cave appears to be in Gedangan segment, which has been studied previously. Only Jenggot Cave and Coban Perawan Cave that had been mapped previously, but there are still many caves that have not been

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explored and mapped (Rosyida et al., 2023). The existence of these caves can certainly be carried out in further research and can be seen their utilization in the future. Currently, there are many caves that are exploited for special interest tourism destinations and used as geo-sites in geo-parks such as Pindul Cave, Gong Cave, Cokro Cave, which have become special interest tourism destinations. The appearance of karst formations in South Malang can certainly be objects of geo-tourism (Susilo, 2017), especially caves in Gedangan area. to make it one of geo-tourism objects, it is necessary to observe the condition of the cave by tracing and mapping the cave. Coban Perawan Cave and its surroundings have educational value that can be used as a tourist attraction. he educational aspects of the cave include the diversity of ornaments, the existence of subterranean rivers, karst morphology, and cave biota (Rosyida et al., 2023). The existing caves certainly have different characteristics, such differences in shape conditions in the cave passage segment, the presence of vertical and horizontal passages, the overall shape of the passage, the presence of streams, and the educational value that exists in the cave passage. Due to these reasons, the purpose of this research is to conduct deeper exploration through identifying the appearance and mapping the caves around Coban Perawan Cave for special interest tourism object.

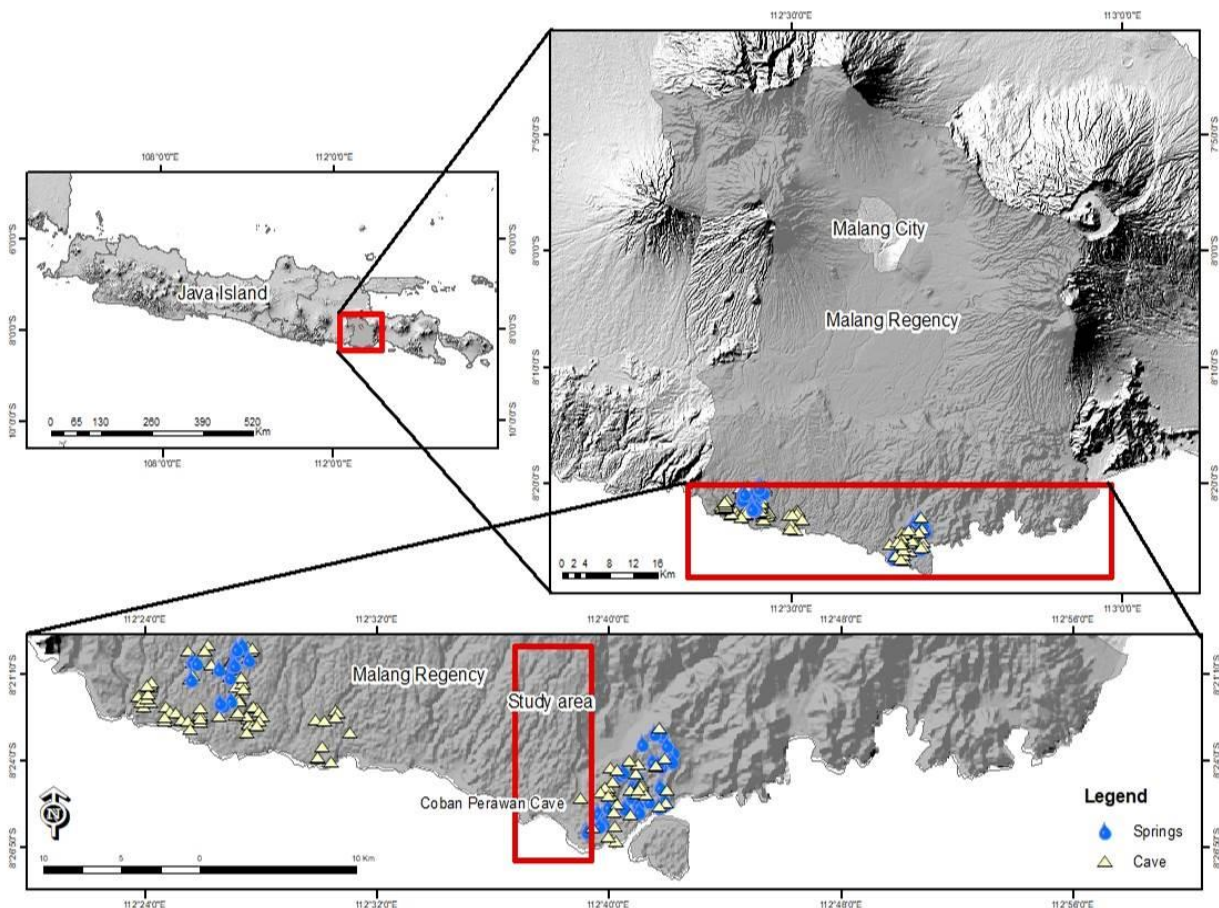


Figure 1. Cave Entrance and Spring Distributions Malang Regency
 (Source: Fauzi et al., 2015; Impala, 2012; Labib, 2016; Rosyida et al., 2023; Salaka, 2018; Suprianto et al., 2017)

MATERIALS AND METHODS

This research was conducted in the Southern part of Malang Regency through a field survey. Plotting the entrance area was used to determine the location and coordinate control during cave mapping. The tools used were clinometer, laser meter, worksheet and compass to determine the width height and direction of the cave passage. The results of cave mapping were then processed using Survex Software and Geographic Information Systems (GIS). The appearance of the cave passage formation was portrayed in the form of planview and extended cave map or cave profile. Documentation was used to figure out the landscape of the cave. The shape of the cave passage was presented with a Geographic Information Systems to show the relationship between the cave passages. Mathematical calculations of the cave passage were also used to determine the size of the cave passage, calculations in the form of the overall length and the depth of the cave passage the result of cave mapping (Klimchouk, 2006), the width and the length of the cave passage used the results of processing from survey (Labib et al., 2019), the area of the cave passage the area of the cave passage by multiplying the width and the length of the cave passage area, the volume of the cave passage area by multiplying the depth of the cave passage (Dora et al., 2023; Klimchouk, 2006; Labib et al., 2019), for the cave passage area were using polygon calculations from GIS processing (Labib et al., 2019). Cave dimensions were used as a comparison of the width and height of the cave passage to see the spatial condition and the shape of the cave (Pardo-Iguzquiza et al., 2011). The analysis of special interest tourism attraction was done by observing the condition of the cave surface, the condition of the cave passage, the accessibility, the level of difficulty of the cave, and the facilities were presented in the descriptive table. The research design is presented in Figure 2.

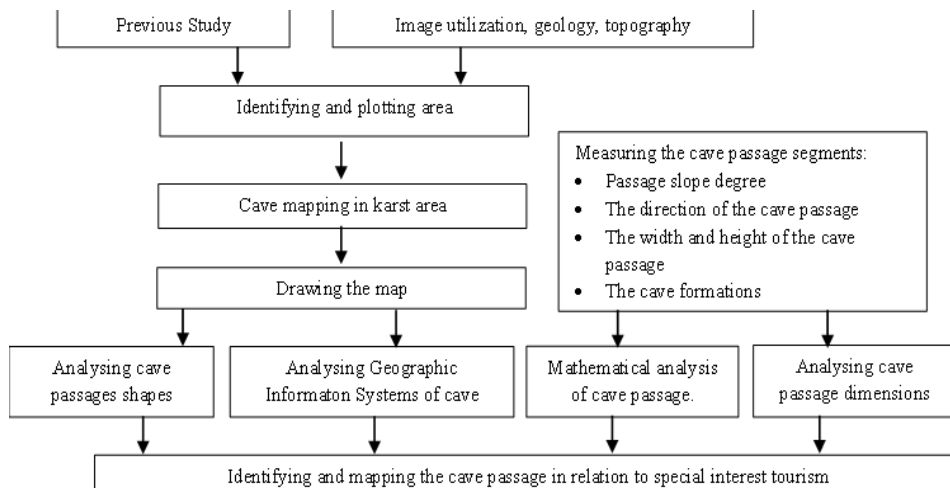


Figure 2. Research Design

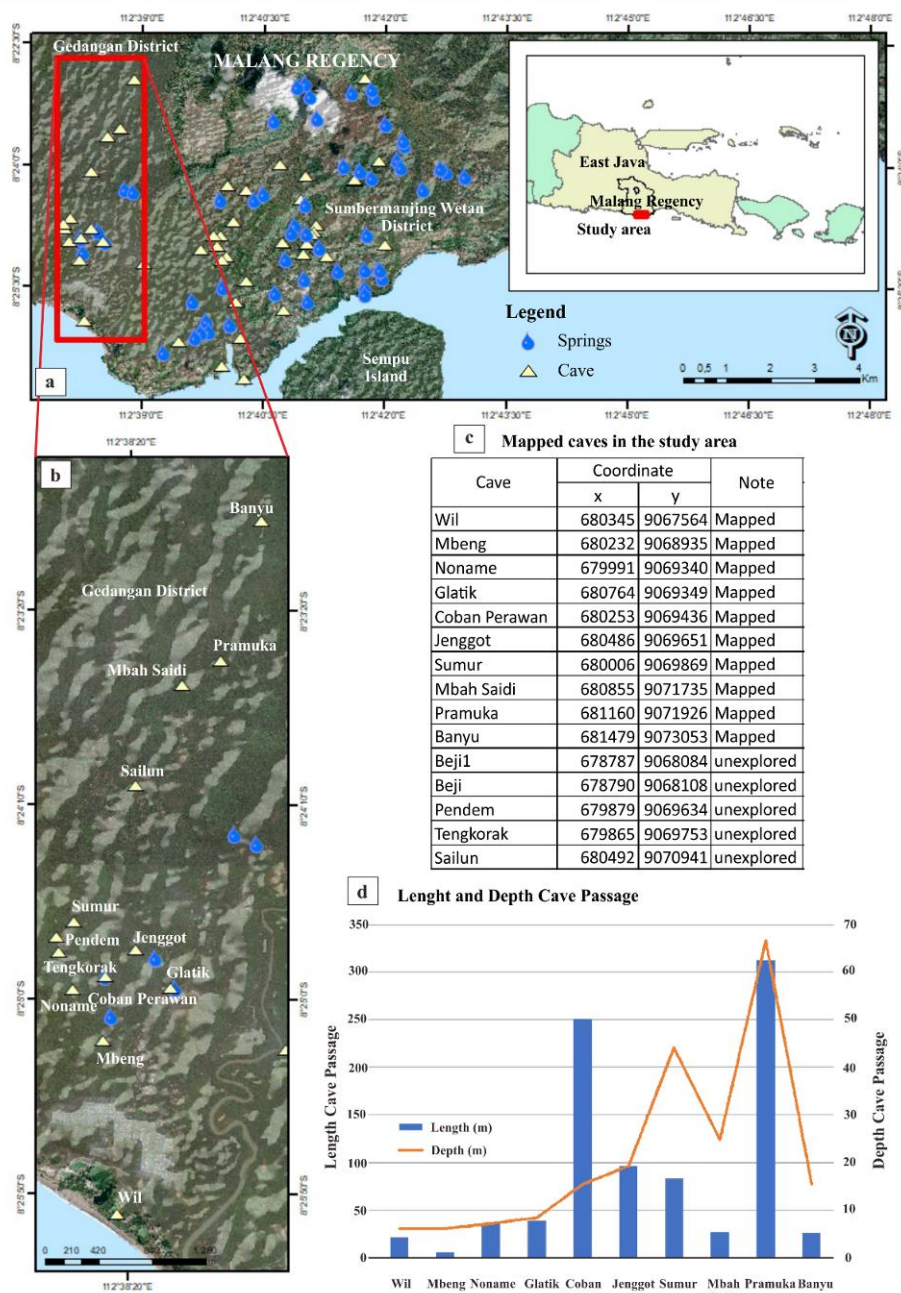


Figure 3. Distribution of cave entrances around the study area (a) and distribution in the study area (b), mapped caves (c) length and depth of cave passages (Source: Rosyida et al., 2023; Salaka, 2018, and data collected by author, 2024)

RESULTS AND DISCUSSION

The Distribution and Mapped Cave Areas

The exploration of the cave passages entrance was done to determine the current condition of the mapped caves. Figure 3a shows the distribution of caves that have been identified around the study area in Sumbermanjing Wetan District, while Figure 3b shows the distribution of caves that have been identified in the study area. As the results of identifying and exploring the cave passageway, 10 caves were mapped (Figure 3c). The Pendem Cave and Tengkorak Cave haven't been mapped because they had been blocked by rocks, the Sailun Cave has thin oxygen level, meanwhile Beji 1 and Beji Cave are far from the study area. Morphologically, the landscape in South Malang is characterized by the existence of caves and springs (Impala, 2012; Labib, 2016; Salaka, 2018), this can also be seen in Sumbermanjing Wetan Sub-district where many caves and springs are also found. The exploration of the existing cave and springs required observing and collecting data (Withuda et al., 2023). This area can support the existence of special interest tourism especially in cave exploration. There are caves that have long passages such as Pramuka Cave which can be explored more, because the map hasn't been completed yet. Meanwhile there are also caves which formed into alcoves such as Wi Cave around Ungapan Beach. Pramuka Cave also considered to be the cave that has deep cave passage compared to others, this is due to the accumulation of each segment in the cave passage, while the deepest vertical passage in the study area are in Sumur Cave and Mbah Saidi Cave. This can be seen in Figure 3d which shows the length and depth of the cave passages, caves with complexity such as Pramuka Cave have high passage lengths and depths.

The Condition and the Distribution of Cave Passages

The cave passage has various shapes, the condition of the cave passageways influenced by various processes occurred in the past. The formation of the cave passage can be seen in Figure 4, the narrowing passage generally happened at the end of the passage that can not be traced, such as in no-named cave (Figure 4a and 4), Banyu Cave also has narrow passage.

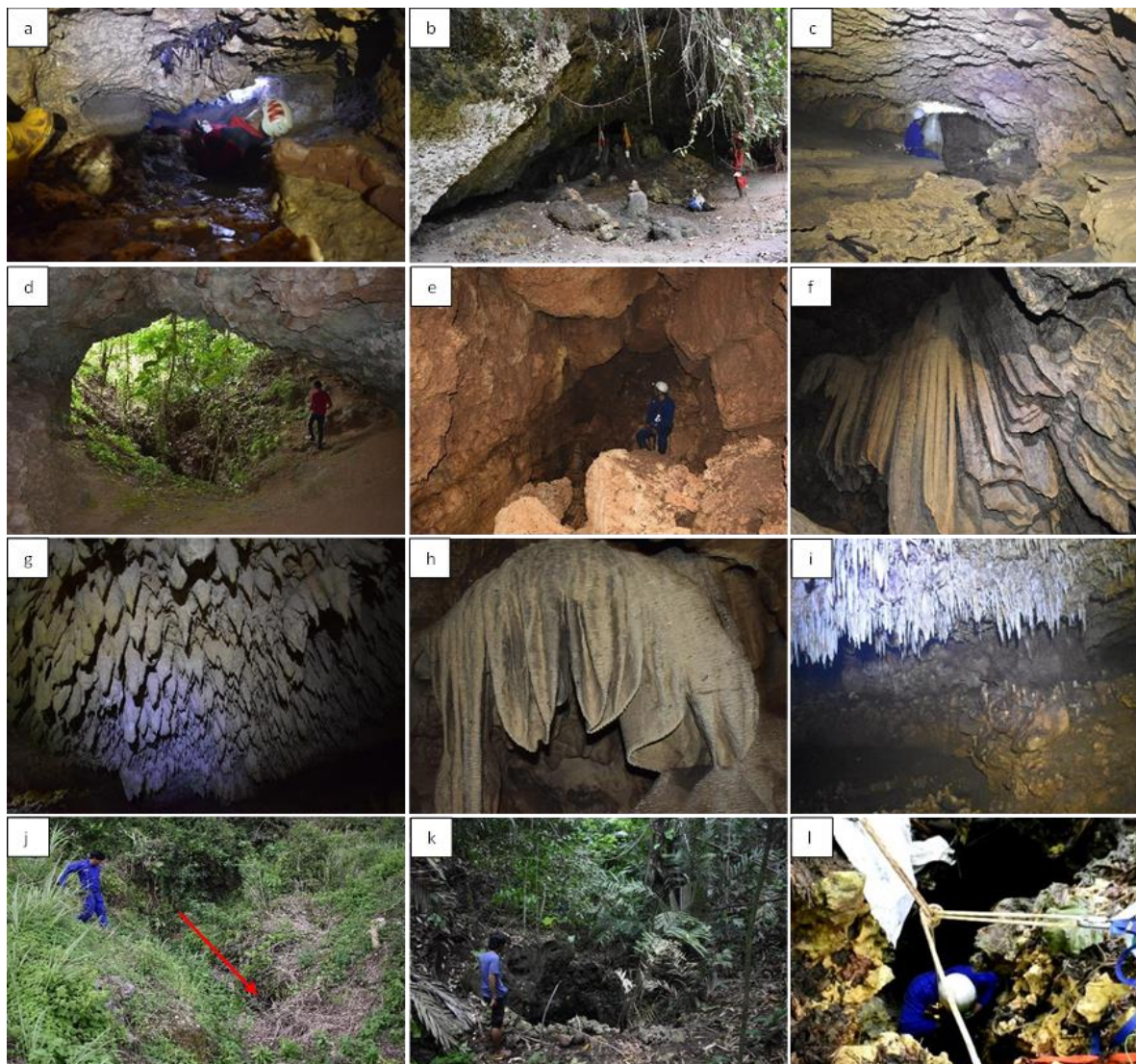


Figure 4. Small passage in No-name Cave (a), entrance in Wil Cave (b), keyhole in Pramuka Cave (c), vertical entrance in Sumur Cave (d), rock breakdown in Sumur Cave (e), flowstone in Sumur Cave (f and h), stalactite in No-name Cave (g), soda straw in Pramuka Cave (i), Banyu cave entrance (j), vertical entrance in Mbah Saidi Cave (k), and vertical passage at the entrance in Mbeng Cave (l). Photos will be taken in June-July 2023 (Source: Data collected by author, 2024)

The existence of a cave in the form of an alcove is seen in Wil Cave, which is near the coast (Figure 4b). This chamber-type cave passage also exists in several cave segments. Cave passages with circular formations are seen in Pramuka Cave in various passage segments. In addition, there are keyhole formations as shown in Figure 4c. There are also many pits in this cave area in Sumur Cave (Figure 4d, 4f and 4h), entrance formations located on valley such as in Figure 4j in Banyu Cave Mbah Saidi Cave which is in the form of a vertical passage with large entrance dimensions (Figure 4k), and Mbeng Cave entrance that has narrow vertical passage shown in Figure 4l. The cave conditions are also dominated by the existence of rocks, these rocks can come from the roof and walls of the caves that are unstable and tumbled. The appearance of these rocks can be seen in Figure 4e in Sumur Cave. The presence of cave ornaments also affects the shape of the cave passage configuration, develops the roof, walls and floor of the cave passages. Various kinds of these cave ornaments develop in study area such as stalagmite, stalactite, flowstone, rhimestone, soda straw and pillar. Cave that has these kind of ornaments found in Jenggot Cave (Rosyida et al., 2023).

The condition of the cave planview (Figure 5) shows that the cave has a single passage that cannot be traced further such as in Mbeng Cave, No-named Cave, Glatik Cave, Jenggot Cave, Banyu Cave, Wellur Cave, Wil Cave, and Coban Perawan Cave. While Pramuka Cave still has an unmapped passage and Mbah Saidi Cave according to information from people who have entered the cave has a long passage, but because it is blocked by sediment, it cannot be traced. Narrow passages are also seen in Banyu Cave and no-named Cave, where this passage becomes a water flow to enter the subterranean river system. The condition of the cave floor contains a lot of sediment in the Glatik Cave and Jenggot Cave, while the domination of rock chunks is found in no-named cave, Banyu Cave, Mbah Saidi Cave, and Sumur Cave.

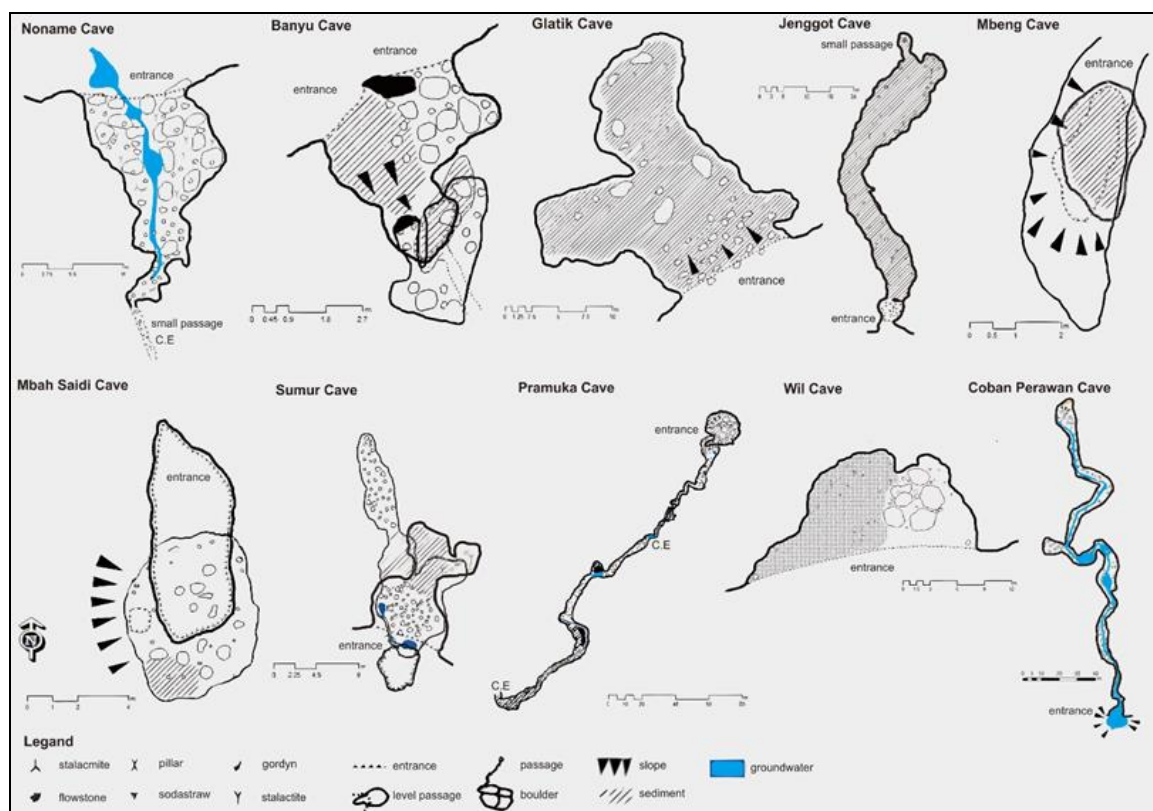


Figure 5. Planview of Coban Cave and its surroundings (Source: data collected by author, 2024)

The mapping results also show the existence of horizontal, vertical, and a combination of vertical and horizontal passages (Figure 6). These vertical, horizontal and combined passages form the morphological appearance of the caves in the study area. Caves that have vertical passages are located in Mbah Saidi Cave, Mbeng Cave, Wellur Cave, Banyu Cave, Pramuka Cave, and Coban Perawan Cave. While horizontal passages are in the caves of Gua Jenggot, Gua Glatik, Gua Wil, and Gua No-named. In addition, there is also a combination of vertical and horizontal passages such as in Pramuka Cave and Coban Perawan Cave. There is a single closed cave passage with varying depths such as wells, namely Mbah Saidi Cave, Sumur Cave, and Mbeng Cave. The appearance of the cave planview map can be used as an indication of the connection between one cave and another. Figure 7 shows the existence of a cave passage with surface conditions and the appearance of another cave entrance. One of them, Pramuka Cave passage leads to Mbah Saidi Cave in a Southwest direction. This is because the Pramuka Cave passage is still long and based on the information from local people that the cave passage is connected. However the current condition shows that Mbah Saidi Cave has been blocked by sediment, so it cannot be traced. Besides that, in Coban Perawan Cave area there are several caves that are close one to another, for example Sumur Cave, Jenggot Cave, Tengkorak Cave, Pendem Cave, No-named Cave, and Glatik Cave. Coban Perawan Cave is not connected to other cave passages because the caves around it are the caves which have got single passage such as shown in mapping results which are in Sumur Cave Jenggot Cave, No-named Cave, and Glatik Cave. Therefore,

Tengkorak Cave and Pendem Cave have been blocked by rocks, so it is not possible to trace and find the connections between passages. However, the connection of hydrological systems can appear by looking for other other karst features. Such as the possibility of the connection between subterranean river flow in No-named Cave to Kedung Biru Spring or the connection of the flow system from Tengkorak Cave, Sumur Cave, Pendem Cave to the flo in Coban Perawan Perawan.

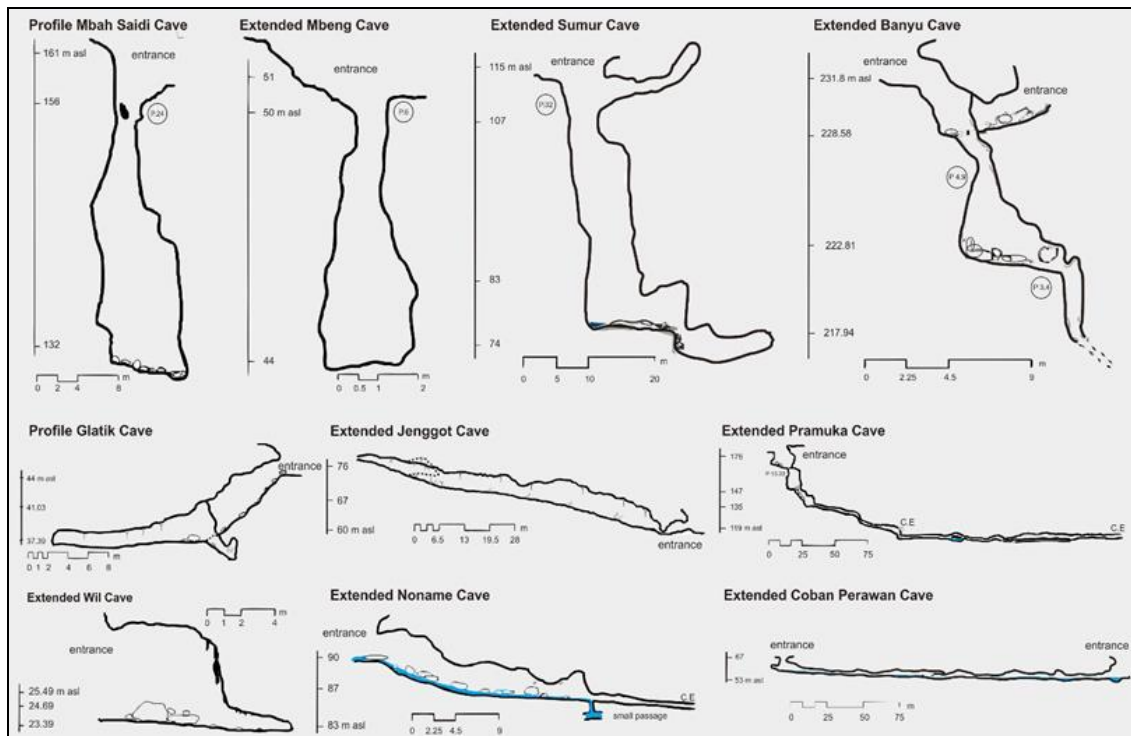


Figure 6. Profile and extended caves located in Coban Perawan area and surroundings (Source: data collected by author, 2024)

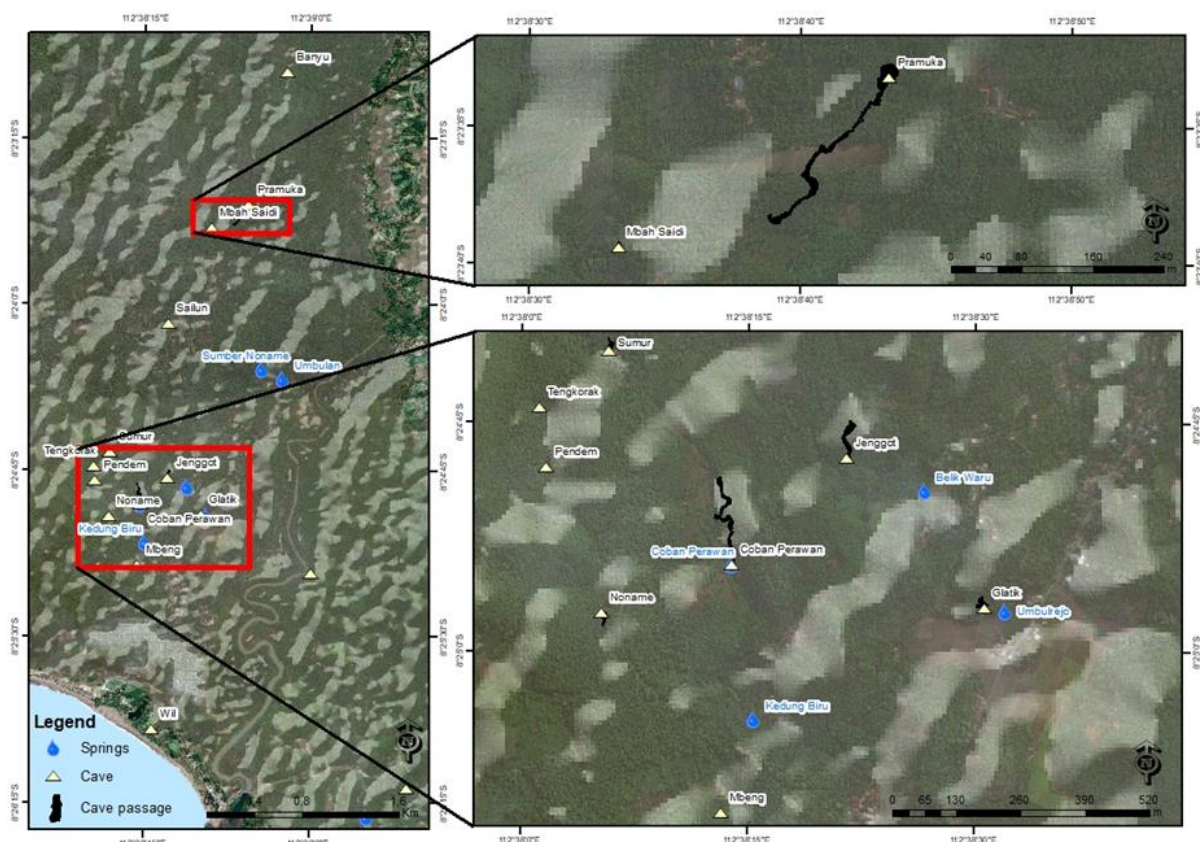


Figure 7. Passage Landscape and Surface Condition around Coban Perawan Cave (Source: data collected by author, 2024)

Cave Passage Dimensions and Sizes

The measurements were taken in the field will provide mathematical values for the measured cave passages. The

measurements of the width, height and direction of the cave passage will give an idea of the shape of the passage and show different dimensions. The measurements of the length, depth and width of the cave area were assessed using the survex software, while the area of the cave passage was measured using the ArcGis application. To calculate the overall area of the cave and the volume of the cave area, mathematical calculations were carried out (Table 1).

The results of mathematical carving showed that the highest values were found in caves that have long passages such as Pramuka Cave and Coban Perawan Cave, while caves that have short passages such as Mbeng Cave, Mbah Saidi Cave, and Banyu Cave have small mathematical values.

Table 1. Mathematical Size of Cave Passages in the Study Area (Source: data collected by author, 2024)

Cave	Elevation (m asl)	Length (m)	Depth (m)	length of the cave area (m)	Width of the cave area (m)	Area coverage of the cave (m ²)	Area of the cave passage (m ²)	Volume of cave area (m ³)
Wil	24	22.05	6.21	14.73	25.33	373	199.75	2,317
Mbeng	50	6.54	6.29	5.3	2.7	14	4.28	90
No-named	90	36.66	7.29	29.15	14	408	185.12	2,975
Glatik	44	39.6	8.45	22.25	16.15	359	274.39	3,036
Coban Perawan	53	251.08	15.53	171.46	42.85	7,347	1,277.72	114,100
Jenggot	59	96.44	19.42	76.85	26.23	2,016	640.93	39,146
Sumur	112	84.22	44.19	29.3	12.49	366	126.98	16,172
Mbah Saidi	156	27.48	24.96	11	4.99	55	36.79	1,370
Pramuka	175	312.82	66.54	177.29	145.12	25,728	1,430.13	1,711,963
Banyu	232	26.51	15.58	6.47	5.14	33	14.94	518

Another mathematical aspect also related to the cave passage dimensions. These cave passage dimensions are based on the ratio of passage segments to the width and height of the cave passage. Cave passage dimensions will show caves that tend to have oval, circular or flat dimensions. This can be seen by looking at the comparison when measuring the cave segments. Figure 8 shows the results of the calculation of the ratio of the segment to the height of the cave segment. A comparison value smaller than 1 shows that the passage tends to develop upwards, while a comparison value greater than 1 shows that the passage develops broadly. This is certainly related to the condition of the cave passage that can be occupied by cave explorers. Wil Cave, Jenggot Cave, and Glatik Cave have a dominance of wide passages that can be entered by several people and in other caves there are still variations of narrow, wide, and high cave passages as shown in Figure 8.

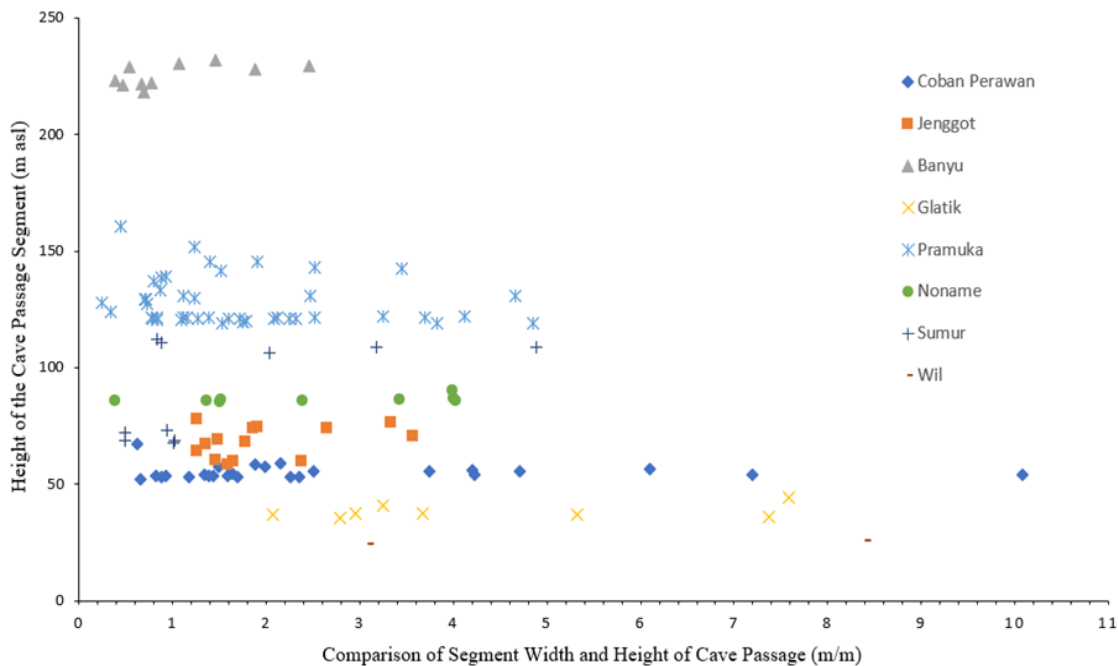


Figure 8. Cave Passage Dimension (Source: data collected by author, 2024)

Tourism Education Aspects of Caves in the Study Area

The appearance of caves in the southern Malang Regency is unique from other landscape. The existence of caves can be used as an educational aspect regarding the development and condition of the cave passage. Coban Perawan Cave, which is a special interest tourism attraction, is used as a cave exploration area that can provide education about cave ornaments, the existence of subterranean rivers, and the appearance of vertical passages at the end of the passage. The educational aspect can provide new knowledge for visitors who come to the Coban Perawan Cave tourism attraction. In addition, the existence of other caves can certainly provide new knowledge about the overall condition of the caves around the Coban Perawan Cave. The condition and educational value of the caves in the study area can be seen in Table 2.

Table 2. Caves conditions in study area (Source: Data collected by author, 2024)

Cave	Surface Condition	Passage characterization			Level of Difficulty	Accessibility	Facility
		Passage Condition	Cave Ornament	Hydrology			
Wil	located in about 20m from Ungapan Beach area, under the cliff	in the form of single chamber sandy passage	stalactite, stalagmite and flowstone	no water flow, only water dripping from cave ornaments	short and horizontal passage	can be reached/passed by motorcycle	campsite in Coban Perawan Cave management
Mbeng	located in rice field area and have sloping topography	approximately 6m deep single muddy vertical passage	none	become the place of water entering the cave in rainy season	short and vertical passage	can be reached/passed by motorcycle	campsite in Coban Perawan Cave management
No-named	located in the valley and has a steep slope, there are many trees around the cave	in the form of chamber and narrowing passage which have got many ornament and rocks	stalactite, micro gourdam, and stalagmite	become the place of water entering the cave in rainy season because it takes place in the valley	horizontal and narrow passage	can be reached/passed by motorcycle and continued walking to the cave entrance	campsite in Coban Perawan Cave management
Glatik	located near the umbulan source The entrance is on hillside	in the form of chambers which have got clay sediment and rocks on its floor	stalactite and flowstone	no water flow, only water dripping from cave ornaments	short and horizontal passage	can be reached/passed by car	campsite in Coban Perawan Cave management
Coban Perawan	The vertical passage entrances on the valley and the common entrance passed by the tourists is in the form of a lake that comes from the water flow of Coban Perawan Cave.	deep static pool, watery and rocky inside the cave, in the form of various passages and chambers	stalactite, micro gourdam, flowstone, pillar, and stalagmite	water goes in the cave and out from the mouth of the cave as river	horizontal and vertical passages and various dimensions	can be reached/passed by car	restroom, prayer room, caving equipment, rest area
Jenggot	The vegetation in the cave area is dense. It is located on a hillside. There is no stream entering the cave.	narrow passage near the entrance, wider and can be entered by several people in the next passage, the floor is dominated by clay sediment	stalactite, micro gourdam, flowstone drape, sodastraw, pillar, and stalagmite ornaments	no water flow, only water dripping from cave ornaments	horizontal and short passages	located near Coban Perawan Cave, can be reached by walking near the area of Coban Perawan Cave	campsite in Coban Perawan Cave management
Sumur	located in a valley, creating water recharge from the surface, steep slope conditions	consists of some levels, many ornaments in the first level, approximately 32m depth of vertical passage, rocks in the second level	stalactite, micro gourdam, flowstone, and drape ornaments	water puddle inside the cave, water dripping from cave ornaments	first level is horizontal, the second is vertical ad short passage	can be reached/passed by motorcycle and continued walking to the cave entrance	campsite in Coban Perawan Cave management
Mbah Saidi	located in a valley, creating water recharge from the surface, steep slope conditions	dominated by 24m depth vertical passage with clay sediment and rocks on the bottom, the passage is blocked by clay sediment and cannot be explored more.	stalactite on cave wall	water entering this cave because it takes place in valley and sunken area, water dripping from the cave ornament	vertical passage tat cannot be further explored, because had been blocked by sediment	can be reached/passed by motorcycle and continued walking to the cave entrance	campsite in Coban Perawan Cave management
Pramuka	located in a valley, the entrances covered by vegetation is in the form of vertical passage, can be reached by walking in cave wall	has various dimension of passages, a 15m depth vertical passage was found after passing the debris of cave entrance, there is clay sediment and rocks inside the cave, can be further explored	stalactite, flowstone, and stalagmite ornament	seepage on the cave passage, lot of static pool in some cave segment, water dripping from cave ornament	horizontal and vertical passages and various dimensions	can be reached/passed by motorcycle/car and continued walking to the cave entrance	campsite in Coban Perawan Cave management
Banyu	located in 232m asl, blocked mouth cave entrance, dominated by sediment and rocks around the entrance	narrow passage can be entered by 1 person only, 4.9m and 3.4m depth vertical passages, chunks of rocks and sediment of the surface	none	no water flow but become the place of water entering the cave in rainy season	vertical and narrow passage	can be reached/passed by motorcycle and continued walking to the cave entrance	campsite in Coban Perawan Cave management

DISCUSSION

Caves in Southern Malang stretch from Sumbermanjing Wetan to Donomulyo. The landscape is an integral part of the southern mountains of Java Island. This can also be seen from the appearance of caves in the southern mountains in the Gunungsewu Karst (Efriyanto, 2022; Rahayu, 2015), Karangbolong Karst (Haryono et al., 2017; Kholid, 2020), Blambangan Peninsula Karst (Suputra et al., 2007). The existence of caves in the karst area can be used as special interest tourism attraction. In Gunungsewu karst area there are Gong Cave, Luweng Jomblang, Kali Suci Cave, Cokro Cave and others which are used as geosites of karst landscapes (Parno, 2018).

In Karangbolong karst there are caves such as Gua Barat, Gua Jatijajar, and Gua Petruk which are the attraction of special interest tourism objects in the area (Ansori, 2018). The karst landscape conditions that exist in various locations can be an attraction for tourists to visit the area. The caves in the study area are not only used for cave tours, but are also used for rituals, as is the case in Wil Cave. There are traces of incense used for rituals at the entrance of the cave. Wil Cave, which is an alcove and located near the beach, is certainly more accessible to visitors.

Cave passages that have various shapes and dimensional variations become the basis for exploring the cave. The existence of caves in Southern Malang can be used as a special interest tourism attraction, as has been developed in other areas (Ansori, 2018; Parno, 2018). The existence of chambers in the cave passage also provides a large space for visitors to enter the cave together, as found in No-named Cave, Jenggot Cave, Coban Perawan Cave, and Glatik Cave. However, at the end of the passage there is a narrow passage, that making it difficult for tourists to enter.

In addition, the caves also have vertical passages with formations such as luwung/ wells, namely in Sumur Cave, Mbah Saidi Cave, and Mbeng Cave. To search for caves that have vertical passages requires special skills and techniques in searching such as installation, rigging, rappelling/descending, ascending, and other techniques in cave searches (Marbach and Tourte, 2002). This is also seen in other caves in Malang Regency that have vertical passages and chambers (Labib et al., 2020). Human resources play an important role in cave management, in addition to other aspects. There are many vertical cave passages in the study area. Thus, it is necessary to have activities that support human resources so that they are able to enter and mitigate if there are problems in the caves, such as a case of lost explorer or case of falling inside the cave and drowning in subterranean river.

The planview passage segment of the cave can also be used as information related to the condition of the cave passage. Maps are the result of scientific studies that can be used as educational media to the public or tourists who will visit the cave. The existence of cave conditions also exists in various cave tourism locations as information media, such as in Cokro Cave (Hamidah et al., 2024). The information aspect in the cave can also be presented in a map that can show the real conditions in the field. The existence of cave ornaments is an attraction that can be seen by cave visitors, as seen in Jenggot Cave, where there are many cave ornaments (Rosyida et al., 2023). Cave passage areas that present the appearance of cave ornaments can be seen in Gong Cave and Tabuhan Cave in Gunungsewu Karst (Fandeli and Adji, 2005). The existence of subterranean rivers that can be used as water tourism can be seen in Coban Perawan Cave.

The existence of water tourism in caves also occurs in other karst landscapes such as Kalisuci Cave in Gunungsewu Karst area and Pindul Cave in the Wonosari Basin. The aspect of interconnection between cave passages and water flow systems in special interest tourism areas is also interesting information for tourists. This is the case at Pindul Cave where there is an underground flow system that leads to Pindul Cave (Agniy et al., 2017).

In addition, at Coban Perawan Cave it is also possible that there is a connection with other flow systems. Furthermore, Pramuka Cave may also be connected to other flow systems. Meanwhile, in Pramuka Cave it is possible to connect the caves due to the proximity of the caves passages to the entrance of Mbah Saidi Cave.

The coverage area and catchment area of the water entering the cave are of concern in looking at the condition of the cave passage. Cave area coverage and catchment area entering the cave will cause changes in water level fluctuations in the cave. These changes in water level can also make tourists trapped in the cave and accidents can occur, especially during floods when surface flow enters the cave passage (Noname, 2013), and other accidents such as getting lost, falling, and drowning (<https://caves.or.id/basis-data-kecelakaan>). This becomes a particular concern regarding the catchment area and coverage area of the cave passage. Coban Perawan Cave, No-named Cave and Pramuka Cave have a large coverage area. In addition, the three caves are also located on a slope, so that the flow of water coming from the surface will be collected and enter the cave as input from the surface. Due to these conditions, it is necessary to pay attention to the weather around the cave when visiting and exploring the cave to avoid flooding in the cave.

The existence of caves in the study area has an important educational value in providing information to visitors or tourists who are doing tourism activities, such as geodiversity in the form of karst features and cultural diversity, such as that found in the Gunungsewu karst and the Sangkulirang-Mangkalihat karst (Haryono et al., 2022; Parno, 2018). However, management of cave tourism is not only limited to the educational value, but also involves various aspects. Cigna and Pani (2013) provided index in cave management such as previous studies, access and pathways, visitors, surface, cave environment. These categories are still lacking for caves in the study area.

In the previous study category, of course, access to some caves is difficult to reach, and limited facilities, but there are other tourist attractions. The access and pathways category is still natural and there are no tourist paths, no materials or lighting in the cave. The visitors category still has no supporting material or capacity in entering the cave, only limited to tours for nature activists and visitors who explore the cave passage. The surface category is an ecosystem that is still natural and has not been modified. The cave environment category is in the form of management that is still minimal in the study area and there is no monitoring of the cave environment. By looking at these conditions, of course, improvements are needed to support special interest tourism in cave exploration.

CONCLUSION

Caves become special interest tourism attraction in karst landscapes. The existence of caves in Southern Malang indicates that caves develop with the presence of ornaments and subterranean rivers. Cave tourism objects have various forms of passages and varying dimensions. The existence of cave passages has a size and shape that certainly affects the conditions in the utilization of cave tourism. The condition of the space in the cave is also an education for tourists that can be presented on a map as a medium of information to visitors to cave tourism, with various appearances of ornaments, subterranean rivers, and cave passage conditions. The existence of the cave also has a drainage system or hydrological system which of course becomes an educational value in special interest tourism.

Cave management requires various aspects, and of course the existing conditions in the study area are still limited related to aspects of cave management. Suggestions for future researchers, need to look at the distribution and appearance of cave formations to find out the cave and hydrological systems that exist below the surface. In addition, it is necessary to have human resources who have special skills in conducting cave searches.

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REFERENCES

- Agniy, R. F., Cahyadi, A., & Nurkholis, A. (2017). Analisis Karakteristik Akuifer Karst dengan Uji Peruntan dan Pemetaan Gua [Analysis of Karst Aquifer Characteristics by Tracing Tests and Cave Mapping]. *Proceeding, Kongres Dan Pertemuan Ilmiah, September*, 13–15.
- Ansori, C. (2018). Geosite identification in Karangbolong High to support the development of Karangsembung-Karangbolong Geopark candidate, Central Java. *IOP Conference Series: Earth and Environmental Science*, 118(1), 0–12. <https://doi.org/10.1088/1755-1315/118/1/012014>
- Astina, I. K., Sumarmi, & Kurniawati, E. (2021). Tourism in coastal areas: Its implication to improve economic and culture acculturation (Case study in Goa China Beach, Malang). *Geojournal of Tourism and Geosites*, 37(3), 740–746. <https://doi.org/10.30892/GTG.37302-704>
- Cigna, A. A., & Pani, D. (2013). Quality Assessment of Show Caves: the Management Evaluation Index (Mei). *16th International Congress of Speleology, July 2013*, 219–222. <https://www.researchgate.net/publication/320532327>
- Dora, D., Lazaridis, G., Vouvalidis, K., Tokmakidis, K., & Veni, G. (2023). Morphometric Analyses of Greek Caves: How Morphology Predicts Cave Origin. *Bulletin Geological Society of Greece*, 60(2), 14–26. <https://doi.org/http://dx.doi.org/10.12681/bgsg.34887>
- Efriyanto, O. (2022). *Strategi Pengembangan Objek Wisata Geosite Ngingrong Di Kabupaten Gunungkidul* [Universitas Pembangunan Nasional Veteran Yogyakarta]. [http://eprints.upnyk.ac.id/30384/3/ABSTRAK - OKI EFRIYANTO.pdf](http://eprints.upnyk.ac.id/30384/3/ABSTRAK%20OKI%20EFRIYANTO.pdf) [http://eprints.upnyk.ac.id/30384/2/SKRIPSI FULL - OKI EFRIYANTO.pdf](http://eprints.upnyk.ac.id/30384/2/SKRIPSI%20FULL%20OKI%20EFRIYANTO.pdf)
- Fandeli, C., & Adji, T. N. (2005). Analisis Daya Dukung Gua untuk Pengembangan Ekowisata (Studi Kasus: Gua Gong dan Gua Tabuhan, Kabupaten Pacitan) [Analysis of Cave Supportability for Ecotourism Development (Case Study: Gong Cave and Tabuhan Cave, Pacitan Regency)]. *Masyarakat, Kebudayaan Dan Politik*, 18(4), 2005.
- Fauzi, I., Baihaqi, M. R. K. T. D. M., & Eko, A. (2015). *Laporan Pendataan Gua, Mata Air dan Telaga di Karst Malang Selatan Desa Bandung Rejo dan Desa Sumber Bening Kecamatan Bantur Kabupaten Malang* [Report on Data Collection of Caves, Springs and Ponds in Karst South of Malang Bandung Rejo Village and Sumber B. <https://caves.or.id/wp-content/uploads/2015/12/Laporan-Pendataan-Bandungrejo-18-20092015.pdf>
- Hamidah, A. N., Sari, U., Azzahra, Z. F., Ridho, M. R., & Widiatmoko, W. (2024). Potensi Gua Cokro Sebagai Objek Wisata Gua Karst Di Kelurahan Umbulrejo, Kapanewon Ponjong Kabupaten Gunungkidul [The potential of Cokro Cave as a Karst Cave Tourism Object in Umbulrejo Village, Kapanewon Ponjong, Gunungkidul Regency]. *Jurnal Swarnabhumi*, 9, 64–73.
- Haryono, E., Reinhart, H., Hakim, A. A., Sunkar, A., & Setiawan, P. (2022). Linking Geodiversity and Cultural Diversity in Geoheritage Management: Practice From Karst of Sangkulirang-Mangkalihat, Indonesia. *Geojournal of Tourism and Geosites*, 42(2), 671–682. <https://doi.org/10.30892/gtg.422sp105-876>
- Haryono, E., Trijuni Putro, S., Suratman, & Sutikno. (2017). Polygonal karst morphology of Karangbolong area, Java-Indonesia. *Acta Carsologica*, 46(1), 63–72. <https://doi.org/10.3986/ac.v46i1.3589>

- Impala. (2012). *Studi Potensi Kawasan Karst Inventarisasi dan Pendataan Ponor, Mata Air, dan Telaga/Danau Karst Serta Pemetaan Fauna Gua Dan Studi Masyarakat Di Desa Kedungsalam, Kecamatan Donomulyo, Kabupaten Malang [The Study of the Potential of Karst Areas Inventory a.*
- Kholid, N. (2020). *Kajian Geografis Daya Tarik Wisata Alam Gua Dan Strategi Pengembangan Objek Wisata Di Kecamatan Ayah Kabuapten Kebumen [Geographical Study of Cave Natural Tourism Attraction and Tourism Object Development Strategy in Ayah District, Kebumen Regency].* Universitas Negeri Semarang. <https://talenta.usu.ac.id/politeia/article/view/3955>
- Klimchouk, A. (2006). Unconfined versus confined speleogenetic settings: variations of solution porosity. *International Journal of Speleology*, 35(1), 19–24. <https://doi.org/10.5038/1827-806x.35.1.3>
- Labib, M. A. (2016). *Speleogeomorfologi Karst di Kecamatan Donomulyo Kabupaten Malang [Karst Speleogeomorphology in Donomulyo District, Malang Regency].* Universitas Gadjah Mada Yogyakarta.
- Labib, M. A., Fitriani, D., Suprianto, A., Sahrina, A., Effendi, S., Hidayat, K., Irianto, P.A., Aulya, A., Romadhoni, A., & Triyono, J.A., (2020). Karakteristik Lorong Vertikal Dan Chambers Gua Karst Kabupaten Malang [Characteristics of Vertical Passages and Chambers of Karst Caves in Malang Regency]. *Jurnal Geografi, Edukasi Dan Lingkungan (JGEL)*, 4(2), 50–60. <https://doi.org/10.29405/jgel.v4i2.4808>
- Labib, M. A., Haryono, E., & Sunarto. (2019). The development of cave passage in Donomulyo, Malang-Indonesia. *E3S Web of Conferences*, 76, 1–7. <https://doi.org/10.1051/e3sconf/20197604010>
- Marbach, G., & Tourte, B. (2002). *Alpine Caving Techniques* (M. Alpaugh (ed.)). Urs Wildmer.
- Noname. (2013). *Laporan Investigasi Kecelakaan Luweng Serpeng 2* (Issue April).
- Pardo-Iguzquiza, E., Durán-Valsero, J. J., & Rodríguez-Galiano, V. (2011). Morphometric analysis of three-dimensional networks of karst conduits. *Geomorphology*, 132(1–2), 17–28. <https://doi.org/10.1016/j.geomorph.2011.04.030>
- Parno. (2018). *Gunung Sewu: UNESCO Global Geopark [Gunung Sewu: UNESCO Global Geopark].* Badan Pengembangan dan Pembinaan Bahasa, Kementerian Pendidikan dan Kebudayaan.
- Rahayu, E. (2015). *Potensi dan Strategi Pengembangan Pariwisata Minat Khusus Gua Paesan Di Desa Tambakromo Kecamatan Ponjong Kabupaten Gunungkidul [Potential and Development Strategy of Paesan Cave Special Interest Tourism in Tambakromo Village, Ponjong District, Gunungkidu].* Universitas Negeri Yogyakarta.
- Rosyida, F., Sahrina, A., Wirahayu, Y. A., Wiguna, A., Sukoco, G. F., Chabib, M. F., & Labib, M. A. (2023). Potensi Gua Coban Perawan Dan Sekitarnya Untuk Menunjang Wisata Minat Khusus Di Kecamatan Gedangan Kabupaten Malang-Indonesia [Potential of Coban Perawan Cave and Its Surroundings to Support Special Interest Tourism in Gedangan District, Malang Regency-In. *Jurnal Geografi, Edukasi Dan Lingkungan (JGEL)*, 7(1), 18–28. <https://doi.org/10.22236/jgel.v7i1.10020>
- Sahrina, A., Fadlan, M. S., Withuda, F. A., Labib, M. A., Fitriani, D., & Ma'Asika, N. M. (2022). Elaborative Analysis of Caves As Specified Tourism Destination in Malang Regency – Indonesia. *Geojournal of Tourism and Geosites*, 41(2), 368–375. <https://doi.org/10.30892/gtg.41205-839>
- Salaka, M. J. (2018). *Eksplorasi Kawasan Karst Sendang Biru Kabupaten Malang*. CV, Komojoyo Press.
- Suprianto, A., & Labib, M. A. (2019). Estimasi Penentuan Tingkatan dan Pola Lorong Gua Banyu dan Sekitarnya dengan Menggunakan GIS [Estimation of Level Determination and Passage Pattern of Banyu Cave and Its Surroundings by Using GIS]. *JPIG (Jurnal Pendidikan Dan Ilmu Geografi)*, 4(1), 1–8. <https://doi.org/10.21067/jpig.v4i1.3086>
- Suprianto, A., Prasetyono, D., Hardianto, A. S., Labib, M. A., Efendi, S., Hidayat, K., Triyono, J. A., & Ahmad, A. A. (2017). Identifikasi Hubungan Kelurusan dan Pola Lorong Gua Karst di Kecamatan Sumbermanjing Weta Kabupaten Malang [Identification of Straightness Relationship and Passage Pattern of Karst Cave in Sumbermanjing Wetan District, Malang Regency]. *Prosiding Seminar Nasional Geotik*, 20–30.
- Suputra, R., Suryatmojo, H., & Srijono. (2007). Geopotency Prospect of Blambangan Peninsula As Supporter for Conservation Development in Alas Purwo National Park, East Java. *Proceedings Joint Convention Bali*, 1196–1208.
- Susilo, A. (2017). Geo-tourism Potential of Karst and Coastal Areas at South of Malang District, East Java, Indonesia. *Joint Convention Malang*. https://www.iagi.or.id/web/digital/5/2017_IAGI_Malang_Geo-tourism-Potential.pdf
- Suyanto, Hadisantono, R., Kusnama, Chaniago, R., & Bahruddin, R. (1992). *Geologi Lembar Turen, Jawa [Geology of the Sheet Turen, Java].* Bandung : Pusat Penelitian dan Pengembangan Geologi
- Withuda, F. A., Sahrina, A., Sukoco, G. F., Gabriele, M. T., Ma'asika, N. M., & Fitriani, D. (2023). Eksplorasi Sumberdaya Air Di Kawasan Karst Desa Tambakrejo Kabupaten Malang [Exploration of Water Resources in the Karst Area of Tambakrejo Village, Malang Regency.]. *Geography: Jurnal Kajian, Penelitian Dan Pengembangan Pendidikan*, 11(2), 310–321.