# HUMAN-LANDSCAPE INTERACTION IN THE MERAPI VOLCANIC REGION DURING THE CLASSICAL JAVANESE ERA

*Interaksi Manusia dan Landskap di Kawasan Gunung Merapi Semasa Era Jawa Klasik*

GRACE HELENA AMRANTHOIS KAPISAN[1]

[1]Department of Geography Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

*Corresponding author: Grace Helena Amaranthois Kapisan.
Email: gracehelena.2022@student.uny.ac.id

Received: 20 Mac 2025 ; Revised: 20 May 2025; Accepted:25 May 2025 ; Published: 1 Jun 2025

To cite this article: Grace Helena Amranthois , K. (2025). Human-landscape interaction in the merapi volcanic region during the classical javanese era. *GEOGRAFI*, *13*(1), 149-167. https://doi.org/10.37134/geografi.vol13.1.10.2025

ABSTRACT *Java, Indonesia, is one of the regions in the world that has shown human-environment interaction in volcanic landscapes since the classical era in medieval times. This paper presents the results of an investigation into the history of human-landscape interaction in Hindu-Buddhist Java 14 centuries ago. This study combines geography and history approaches. The data collected includes secondary and primary data through various data collection activities, namely literature study, document analysis, and observation. Data were analyzed using Geographic Information Systems, namely buffering and overlay techniques, supported by descriptive and historical analysis. Temples were used as a proxy to identify past settlements. There are two significant findings from this study. First, humans utilize the potential of natural resources as a form of human-landscape interaction. The utilization of natural resources is indicated by temples built close to rivers and springs and flat land in the volcanic plain. Secondly, the lives of ancient people were not free from natural disasters. This is indicated by temples that were damaged and buried by volcanic materials from the Merapi eruption. In summary, this study provides alternative information about human-landscape interaction in ancient Javanese society in the active volcanic environment of Merapi. Also, this research contributes new insights that communities living close to the main river channels are at greater risk of being affected by the dangers of the Merapi eruption. Reflection of these findings contributes to current disaster research, especially in the Merapi volcano area.*

***Keywords**: Human-landscape interaction, Merapi volcano, Javanese society, Temples*

## 1. Introduction

Human life since ancient times has never been separated from interactions with the landscapes where they live. Landscapes provide space for human life along with the various natural resources needed. Humans, with their ability to think, adapt to the

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

landscape conditions by utilizing the multiple opportunities available while avoiding adverse conditions. Human-landscape interaction is very diverse, among others related to selecting residential locations, livelihoods, and other aspects of life. Human-landscape interaction is as old as human civilization itself, including in volcanic landscapes (Cashman & Giordano, 2008). Evidence has been found around the world of human-landscape interaction on volcanic landscapes since ancient times, including in Costa Rica (Ruiz et al., 2018), Arabia (Groucutt, 2020), and Papua New Guinea (Boyd et al., 2005; Neall et al., 2008). It is undisputed that volcanic landscapes have long been a determinant of the progress and decline of human civilization (Riede, 2019).

Southeast Asia has extensive volcanic landscapes due to its position on the southwestern flank of the Pacific Ring of Fire. In this area, human-landscape interaction that has been going on since ancient times is found in the Javanese community in Indonesia. The Javanese community, the largest ethnic group in Indonesia, has built a civilization since the classical period of the Hindu-Buddhist era in medieval times. The volcanic landscape in Central Java is said to be the cradle of the Javanese civilization. Evidence of ancient life from the medieval era is found in this area as archaeological remains in temples built in the 8th to mid-10th centuries, associated with the Sanjaya and Syailendra Dynasties of the Ancient Mataram Kingdom. No less than 280 temples are scattered in this area, which indicates the development of an advanced civilization at that time (Degroot, 2009). The development of ancient Javanese civilization in volcanic landscapes since 14 centuries ago cannot be separated from economic and belief factors. Economic factors encourage people to choose landscapes with high natural resource potential (Ashari, 2014; Prijono, 2011). Meanwhile, belief factors at that time, especially Hinduism, directed people to live near the foot of mountains, rivers, springs, and gardens, with abundant water sources, gurgling rivers, lakes, and sufficient sunlight (Kramrisch, 1946). These conditions indicate that human-landscape interaction has also been ongoing since ancient times. However, the problem is that studies reviewing human-landscape interaction in ancient Javanese society in medieval times are still scarce. Information related to this topic is still relatively less discussed in the previous literature. This indicates a gap in our knowledge that needs to be filled with further studies. Moreover, despite abundant archaeological evidence, systematic spatial studies of settlement choices in ancient volcanic landscapes remain limited. Among Central Java, the southern and western sides of Merapi Volcano are the best places to see human-landscape interaction in ancient Javanese society during the Hindu-Buddhist period. Merapi is an active volcano that stores many natural resources, including land, water, biological, and mineral resources (Sutikno et al., 2007). The availability of these abundant resources was a determining factor for the large number of people living in this region during the Hindu-Buddhist period. The south and west sides of Merapi Volcano have the highest density of temples in Central Java, which was thought to be the centre of government in the past. As many as 36% of the 8th to 10th-century temples in Central Java are

concentrated in this area (Degroot, 2009). On the other hand, eruptions have also affected this area from time to time (Andreastuti et al., 2000; Gertisser et al., 2012; Newhall et al., 2000). Moreover, the move of the centre of the ancient Mataram Kingdom to East Java around the 12th century is also thought to be related to the disaster caused by the Merapi eruption (Andreastuti et al., 2006).

In this regard, studying human-landscape interaction on the south and west sides of Merapi Volcano is very interesting to conduct. This study can reveal the past relationship between humans and landscapes, both positive relationships in utilizing natural resources and negative relationships due to natural disasters. This paper analyses human-landscape interaction in the southern and western flanks of the Merapi volcanic landscape. There are two specific objectives in this study. First, to analyze the relationship between the selection of past habitation sites and the availability of natural resources. Second, to investigate the impact of natural disasters on people's lives in the classical era, namely the Hindu-Buddhist period in medieval times. The temple, as an indicator of sedentary life in the past, is used as a proxy to analyze the extent to which the temple site was built near the location of water sources, productive land, and river valleys where andesite rocks as the primary material can be obtained. In summary, this study provides alternative information on the life history of ancient Javanese society, especially concerning human-landscape interaction.

## 2. Research Area

This research was conducted on the southern and western flank of Merapi Volcano (Fig 1). This area is mapped on a 1:150,000. Geomorphologically, the south and western flanks comprise the volcanic cone, volcanic slope, volcanic foot, volcanic plain, and volcanic footplain landforms (Ashari, 2017; Setyawati & Ashari, 2017). This study focuses on the volcanic foot and volcanic plain landform units, which have the most archaeological remains in the form of temples. Geologically, this area is dominated by young Merapi volcanic material and a little from Old Merapi. Volcanic foot and volcanic plain landforms have experienced a lot of pyroclastic and lava deposition over time, even in the era before human civilization was affected by a gigantic avalanche that collapsed the cone morphology of Old Merapi (Andreastuti et al., 2000; Bronto et al., 2014; Gertisser et al., 2012; Mulyaningsih et al., 2006).

Until the modern era, namely in the last few decades, the southern and western flank of Merapi Volcano is an area that is mainly affected by eruptions in the form of pyroclastic material deposition and lahars (Lavigne et al., 2000; Lavigne & Thouret, 2002). The 2010 eruption with VEI-4 scale, which is said to be the largest eruption in the last century, also affected the southern and western flank of Merapi Volcano the most. On the other hand, this volcanic material forms a high-productivity aquifer system with excellent water resource potential (Sutikno et al., 2007). The characteristics of materials with high infiltration capacity drive the

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

amount of water infiltrated as groundwater (Purwantara et al., 2020).

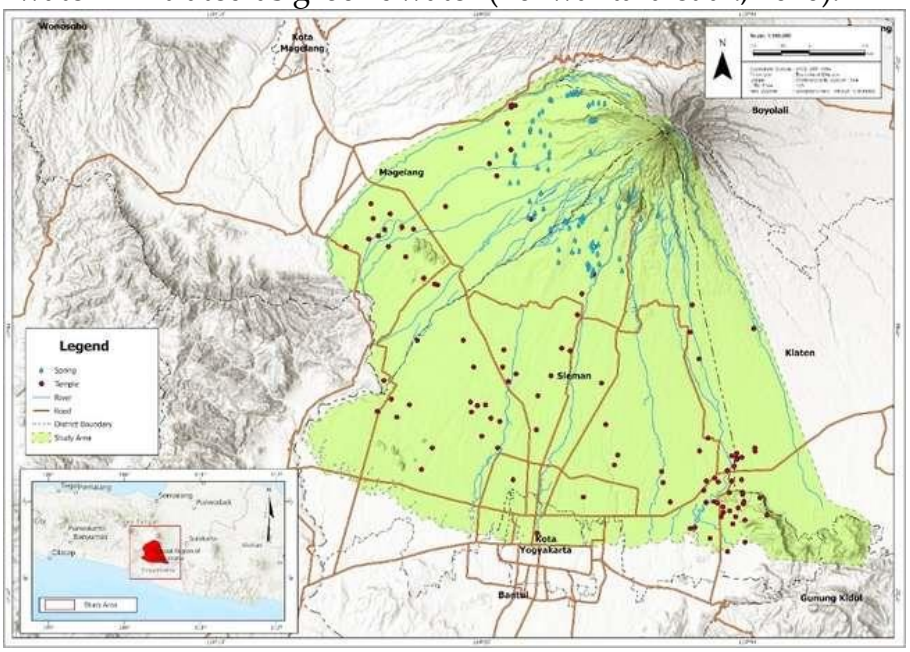


**Figure 1.** *The Study Area*
*Source:* Data Analysis

The high water resource potential of the southern and western flank of Merapi Volcano is indicated by the large number of springs, especially in the volcanic foot landform (Aurita & Purwantara, 2017; Ratih et al., 2018, 2019). In addition to springs, potential water resources in this area also come from perennial rivers throughout the year. These rivers still have flow even during the dry season, although the amount is much reduced (Ashari, Wardoyo, et al., 2021; Kharisma et al., 2021). These natural resources support the lives of the population. The southern and western flanks of Merapi Volcano have large populations because of the city of Yogyakarta. The population's activities are also very diverse, as indicated by land use, consisting of built-up and agricultural land.

## 3. Research Methodology

This study uses a geographical approach to reveal human-landscape interaction in the past, namely the ecological approach. This approach provides a means to discuss the relationship between humans and their environment. The historical approach supports the geographic approach, providing comprehensive information about past life. The subject of this study is the entire southern and western flank of Merapi Volcano. The object of this study is the human-landscape interaction during the classical period in the area. The object of this study is reconstructed by using temples as a proxy to determine past life activities. Using temples as a proxy for past settlements still contains limitations and potential bias. This is because it cannot be ascertained that temples were always built together with settlements. To overcome this possible bias, evidence of traces of settlements around the temple was provided

either by observation to find artifacts or by literature studies.

The study used primary and secondary data. Primary data included the location of the springs and the impact of natural disasters on past life. This data was obtained from observation. Meanwhile, secondary data consists of the location of temples, landforms, and river valleys, the history of life during the Hindu-Buddhist period, and the history of Merapi volcanic activity. These data were collected through literature study and document analysis. Some of the spring data was also obtained from the literature, namely a previous study by Ratih et al. (2018, 2019). Literature study and document analysis are essential data collection techniques in this study. Data from these two collection methods are primarily related to archaeology and history. The relationship between data types, data collection methods and data sources is shown in more detail in Table 1. The data obtained was validated first before further analysis. The data obtained was validated first before further analysis. Validation is carried out by comparing field measurement data and secondary data from the literature. Instruments used in field measurements, including GPS, are calibrated before use by comparing their level of accuracy with several similar instruments.

**Table 1.**
*Types of data, data collection, and instrument/data sources*

| Data | Data collection | Instrument/Data Sources |
|---|---|---|
| Temple location | Literature study | Degroot (2009) |
| | Document analysis | Culture Preservation Center Region 10 of the Republic of Indonesia |
| Landform | Document analysis | Indonesian Topographical Maps, Section Kaliurang, Sleman, dan Pakem |
| | | The data of the National Digital Elevation Model of the Republic of Indonesia |
| River Valley | Document analysis | Indonesian Topographical Maps, Section Kaliurang, Sleman, dan Pakem |
| Spring location | Observation | GPS, Digital Camera, Geological Compass, Observasi Sheet |
| | Literature Study | Ratih et al. (2018, 2019) |
| History of life during the Hindu-Buddhist period | Literature Study | Tanudirdjo et al. (2011) |
| History of Merapi volcanic activity | Literature Study | Newhall et al. (2000) (2000); Andreastuti et al. (2000); Gertisser et al. (2012) |
| Natural disasters in the past | Observation | GPS, Digital Camera, Geological Compass, Observasi Sheet |

*Source:* Research design

The data that has been obtained is then analyzed using GIS analysis, descriptive analysis, and historical analysis methods. GIS analysis with buffering and overlay techniques was used to answer the objectives regarding the relationship between the

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

selection of past residential locations and the availability of natural resources. The buffering technique was used to see the distance between the temples, representing past life, with springs and rivers as water sources. Overlay was used to determine the temple's location in terms of landforms and geology. Furthermore, descriptive analysis supported by historical analysis was used to answer the problem of the impact of natural disasters on people's lives in the classical era. This analysis described the history of ancient life and natural disasters identified in the temple.

## 4. Findings and Discussion

### *4.1 Temple as an indicator of human civilization in the southern and western flank of Merapi Volcano*

Since the classical period in medieval times, human-landscape interaction has taken place in Javanese society in Indonesia. Human-landscape interaction in this ancient period is reflected in the selection of residential locations that tend to be located near the presence of natural resources, especially water resources and fertile land resources. The temple, as a heritage site of medieval civilization, is an indicator of the existence of ancient settlements in the past. The existence of a temple as a cult building in a location indicates the existence of a settled community, either building a centre of civilization or simply managing and maintaining the temple building. In other words, temples are a proxy to determine past settlements' existence, as Ashari (2022) conducted in the Borobudur Basin, Central Java.

According to Degroot (2009), in the southern to western flank of Merapi Volcano, there are 109 temples. These south and western flank areas are administratively included in Magelang and Klaten Regencies, Central Java Province, and Sleman Regency, Yogyakarta Special Region. Concerning this administrative area, it turns out that most of the temples are located in the Sleman Regency area, which is 69%. Meanwhile, in Magelang Regency, 23% of temples are temples, and in Klaten Regency, 7% are temples. Physiographically, the southern flank of Merapi Volcano has 79% of the temples, while the western flank only has 21% of the temples. This is also influenced by the broader coverage of the southern flank, as the western flank is adjacent to another sizeable volcanic structure, Merbabu Volcano (Fig 1).

At present, these temples are not entirely intact. Among these temples, only 27% still have building structures, another 20% are just temple remains, and the rest are no visible remains whose existence is only known based on history. Most temples still have structures with only the base, base, and foot. There are relatively few temples in this study area that are intact up to the superstructure. Meanwhile, the remains of the temples in question are scattered stones, mounds, and unfinished sculptures. Table 2 shows the list of temples that still have structures.

**Table 2.**
*List of Temples with Structures in the Study Area*

| No | Temple Name | Location (UTM Zone 49S) | | Building structure | Area |
|---|---|---|---|---|---|
| | | X | Y | | |
| 1 | Asu | 428472 | 9167887 | Base and foot | Western flank |
| 2 | Gunung Sari | 420935 | 9159605 | Base only | Western flank |
| 3 | Gunung Wukir | 422445 | 9156066 | Base only | Western flank |
| 4 | Lumbung (Magelang) | 428206 | 9167794 | Base and foot | Western flank |
| 5 | Ngawen | 419746 | 9159409 | Base and temple body | Western flank |
| 6 | Pendem | 428500 | 9168071 | Base and foot | Western flank |
| 7 | Bubrah | 444446 | 9143684 | Base and foot | Southern flank |
| 8 | Gana | 444100 | 9143684 | Base only | Southern flank |
| 9 | Lumbung (Klaten) | 444097 | 9143515 | Base only | Southern flank |
| 10 | Plaosan Lor | 445355 | 9144342 | Base and foot | Southern flank |
| 11 | Sewu | 444103 | 9143979 | Base and temple body | Southern flank |
| 12 | Arca Ganesa | 444523 | 9141114 | Up to the superstructure | Southern flank |
| 13 | Banyunibo | 444208 | 9140189 | Up to the superstructure | Southern flank |
| 14 | Barong | 444560 | 9140472 | Up to the superstructure | Southern flank |
| 15 | Dawangsari | 444600 | 9140632 | Base only | Southern flank |
| 16 | Gebang | 435644 | 9143139 | Up to the superstructure | Southern flank |
| 17 | Kadisoka | 438912 | 9142698 | Base only | Southern flank |
| 18 | Kalasan | 441839 | 9141393 | Up to the superstructure | Southern flank |
| 19 | Kedulan | 441526 | 9144126 | Base and temple body | Southern flank |
| 20 | Lengkong | 422023 | 9151754 | Up to the superstructure | Southern flank |
| 21 | Loro Jonggrang | 443923 | 9143079 | Up to the superstructure | Southern flank |
| 22 | Miri | 445714 | 9140888 | Base only | Southern flank |
| 23 | Morangan | 441479 | 9150501 | Base and foot | Southern flank |
| 24 | Plaosan | 427730 | 9146149 | Up to the superstructure | Southern flank |
| 25 | Ratu Boko | 443601 | 9141236 | Base only | Southern flank |
| 26 | Sambisari | 439018 | 9141924 | Up to the superstructure | Southern flank |
| 27 | Sari | 442007 | 9142038 | Up to the superstructure | Southern flank |
| 28 | Sentono | 441735 | 9136332 | Up to the superstructure | Southern flank |
| 29 | Watugudig | 442762 | 9140528 | Base only | Southern flank |

*Source:* Degroot (2009)

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

According to Table 2, only 40% of all temples in the study area still have structures with intact structures up to the superstructure. Temples with structures up to the superstructure are all found on the southern flank of Merapi Volcano. The western flank has only a few temples with structures that still exist. This region only has 21% of temples; even then, they only have a base or base and foot. The only temple with a body is found in Ngawen Temple. The temples in the research area are no longer structurally complete for various reasons, including natural disasters and socio-political factors, including warfare.

### *4.2 The relationship between the selection of ancient residential locations and the availability of natural resources*

The temples in the southern and western flank of Merapi Volcano are mostly scattered on the volcanic footplain landform, and some are scattered on the volcanic foot. Referring to Degroot (2009), the temples' distribution still extends to the fluvio-volcanic plain, although the number is not significant. However, this study is only limited to the volcanic foot and volcanic footplain, as human interaction with volcanic landscapes is more intensive in this area. The fluvio-volcanic plain is located far away from the active volcanic cone, so the influence of volcanic activity is not too significant; instead, other factors, such as fluvial processes, have also been influential. The fluvio-volcanic plain is genetically a terrain formed from volcanic activity, but from the aspect of human-landscape interaction, it does not strongly show the influence of active volcanism.

The total number of temples identified in the study area is 109. 15% are located on the volcanic foot and 75% on the volcanic footplain. The GIS analysis results of the temples' location towards the central river valley show that 37% are located less than 500 meters from the main river valley. In the study area, there are 12 major river valleys, from the southern flank to the western flank, namely Woro, Gendol, Opak, Kuning, Boyong, Bedog, Krasak, Batang, Putih, Blongkeng, Lamat and Pabelan. Nine of these rivers, except Opak, Bedog, and Lamat, are river channels that actively flow lava from the summit of Merapi Volcano (Lavigne et al., 2000). When viewed in more detail on a larger scale, most temples are 100-300 meters from large river valleys, reaching 21%. The remaining 12% are located at a distance of 300-500 meters, and only 4% are located at a distance of less than 100 meters.

The findings show interesting results. Firstly, it was found that ancient medieval societies also considered choosing to live close to large rivers. This is because large rivers provide water to fulfil their daily needs. The belief factor also encouraged people to live near rivers (Kramrisch, 1946). Another interesting fact is that large rivers that flow lava can provide abundant andesite rocks from eruptions. This makes it easier for people to get good stones as materials for temples, statues, relief sculptures, and inscriptions (Saputra & Azmi, 2024). Despite living close to the river valley, people do not place settlements too close to the valley. The most temples are found at a distance of 100-300 meters. Meanwhile, the nearest distance, less than

100 meters, has the fewest temples because residents also need to consider the hazard of living too close to the river valley. These large river channels have been the transportation route for eruption materials for centuries (Gertisser et al., 2012; Mulyaningsih et al., 2006). Residents seem to understand the dangers of this volcanic material transportation.

In addition to temples located at a distance of fewer than 500 meters from a large river valley, in the study area, 63% of temples are situated at a distance of more than 500 meters from a large river valley (Fig 2). Even though they are located farther from a large river valley, this does not mean people do not consider water resources when selecting settlement locations. Temples situated more than 500 meters from a large river were built near smaller rivers, not the main rivers upstream from the peak of Merapi. Another possibility is that these temples were also built in the past near large rivers at a distance of less than 500 meters. Still, due to geomorphologic dynamics, these rivers have experienced valley displacement. In their studies, Ashari et al. (2021) and Maruyama (1993) found that river valleys on the southern to western flank of Merapi Volcano repeatedly experienced valley shifts. Temples once located near the river are likely farther away because the river has shifted its flow. As an indicator, the temples are located close to the palaeochannel, as Ashari (2022) found in the Borobudur Basin.

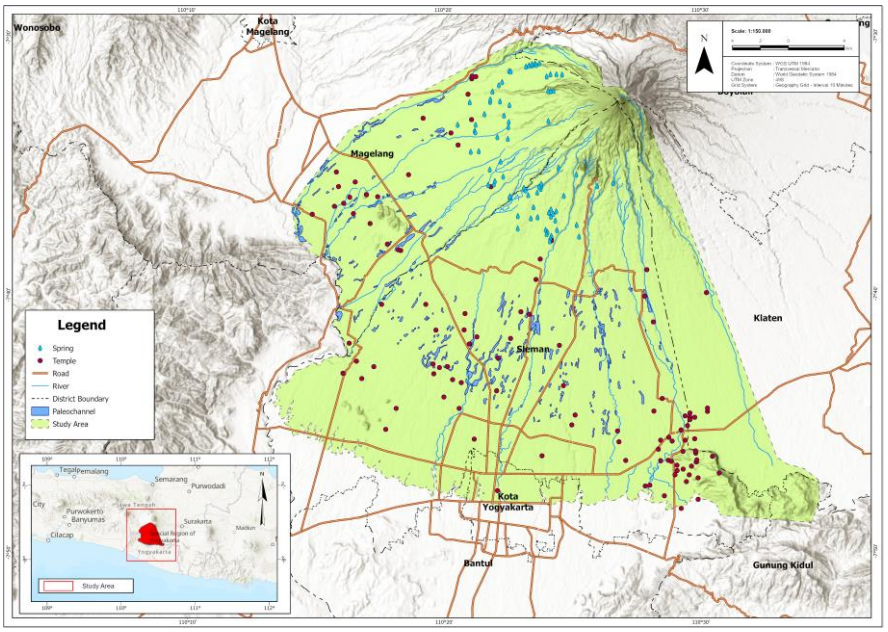


**Figure 2.** *Temple location in relation to paleochannel and springs.*
*Source:* Data Analysis

The construction of temples near springs also shows the human-landscape interaction concerning the availability of natural resources. In the volcanic foot, there are many springs. On the other hand, there are also 18 temples in this area. The analysis shows that 45% of the temples on the volcanic foot landform are less than 500 meters from the springs. This again indicates that settlement development in the

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

past was close to natural resources, in this case, water resources. The spring is one of the water sources considered for constructing settlements and worship as taught in Hinduism (Kramrisch, 1946). The location of the temple construction near the spring is similar to Ashari's (2014) findings on the eastern flank of Sundoro Volcano, Central Java. Hindu-Buddhist temples in Central Java tend to be built near springs whenever possible (Fig 2).

Land resources were also considered in the construction of settlements in the past. Most of the temples, 75% in the study area, were built on volcanic footplain landforms. In contrast, only 15% were built on volcanic foot landforms. This is also related to the potential of land resources. Volcanic footplains have better land potential than volcanic foot. Land in volcanic footplain has a flat to gentle relief with a slope of 2%-7%, while in the volcanic foot, it is more sloping, sometimes even steeper. Flat-sloping land on the volcanic footplain landform will tend to be more likely to be cultivated for agricultural purposes than steep land. In addition, flat land also facilitates the construction of buildings and supports broader population mobility due to easy accessibility. With such land characteristics, past settlement development was mainly carried out on the volcanic footplain, as indicated by the many temples in this region.

Meanwhile, geologically, there is no difference in lithology between the volcanic foot and volcanic footplain areas. Almost all temples in the study area were built on the Young Merapi volcanic deposits. As one of the parameters of land resources, lithology is not a factor that determines the selection of settlement locations. The type of lithology, namely Young Merapi volcanic deposits, is the same throughout the research area. The materials composing the Younger Merapi volcanic deposits are pyroclastics and lahars. Some temples are also built on hills that are not Young Merapi material. It is suspected that the choice of this location was more influenced by considerations of hill relief following the beliefs of the people at that time rather than lithological factors.

### *4.3 The impact of natural disasters on people's lives in the classical era.*

In addition to utilizing natural resources, human-landscape interaction is evident from human interaction with potential natural disasters in the surrounding environment. People living on the southern and western flanks of Merapi Volcano are also repeatedly affected by natural disasters caused by eruptions. Merapi Volcano, throughout history, has erupted more than 80 times (Andreastuti et al., 2000; Ashari & Purwantara, 2022; Badan Geologi, 2014; Newhall et al., 2000). During the classical Hindu-Buddhist era, Merapi experienced at least eight eruptions, some of which reached the VEI-3 or VEI-4 scale (Andreastuti et al., 2000). These significant eruptions had wide-scale impacts on the southern and western flanks of Merapi Volcano. Newhall et al. (2000) explained that explosive Merapi eruptions occurred before, during, and after temple construction. Some temples experienced destruction and or backfilling after their construction. As a result of this event, the civilization that developed on the southern and western flank of Merapi Volcano even regressed

and moved to eastern Java.

Past eruption disasters that impacted people's lives in the Hindu-Buddhist period can be traced from the condition of the temples in the study area. The analysis shows that four of the 29 temples in the study area still have building structures on volcanic foot landforms, namely Asu, Lumbung (Magelang), Pendem, and Morangan. Interestingly, the four temples' structures are only base and foot. None of the remaining temples on the volcanic foot has a temple body, let alone up to the superstructure. In a volcano structure, the volcanic foot is closer to the eruption centre than the volcanic plain, which is more affected by the eruption. Although it is possible that the damage to temples in this area was also caused by factors other than volcanic eruptions, the structure of temples in the volcanic foot is proven to be related to the high potential for eruption disasters.

In contrast, temples in the volcanic plain have more diverse structures, not only the base and foot but also the temple body and superstructure. Among the 25 temples in the volcanic plain, 11 temples only have a base or base-and-foot structure, three have a temple body, and the other 11 are still intact up to the superstructure. This condition shows the eruption's impact is also found in the volcanic foot. However, due to its greater distance from the eruption centre, the effect of eruptions in this area is minor. The eruption's impact caused damage to some temples, but others are still intact up to the superstructure.

When comparing the southern flank and western flank of Merapi Volcano, the eruption's impact is more visible on the western flank. All temples in the western flank, whether in the volcanic foot or volcanic plain, only have a base and foot, except Ngawen Temple, which still has a temple body. Moreover, none of the temples in this area is up to superstructure. Meanwhile, in the Southern flank, nine temples only have base and foot, two temples have temple bodies, and 11 temples have up to superstructure, among a total of 22 temples that still have building structures in the volcanic plain of this region. This shows that the number of undamaged temples is quite large. When associated with eruption disasters, Merapi's eruption history has indeed directed more material to the western flank than the southern flank (Andreastuti et al., 2000; Gertisser et al., 2012; Newhall et al., 2000).

The alleged influence of the eruption on temple damage is evidenced by temples buried by volcanic material from Merapi's explosive eruption. At the volcanic foot on the western flank of Merapi Volcano is Candi Pendem, which is buried by volcanic material with a thickness of up to three meters (Fig 3A). The temple was discovered after excavation and is about three meters lower than the surrounding land. Pendem Temple, derived from the Javanese 'pendem' meaning buried, is located very close to the Pabelan River Valley at a distance of less than 100 meters. This temple was buried by pyroclastic material and lava from the repeated eruptions of the Merapi Volcano, which were found in rock outcrops on the Pabelan River cliff (Ashari, 2013). Asu Temple and Lumbung Temple, two temples from the same complex located a little further from the river valley, are not buried too deeply. Still, the buildings are only left with the base and foot, possibly because volcanic

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

materials hit them. Asu Temple is only one meter lower than the surrounding land.

Far to the south of the Asu Temple Complex is the Ngawen Temple, which is located on the volcanic plain. This temple is located about 500 meters from the Blongkeng River Valley. Although located in the volcanic plain, this temple indicates the eruption's impact in the form of lava material deposition that reached this area through the Blongkeng River. Ngawen Temple is two meters lower than the surrounding land (Fig 3B). Ngawen Temple still has a temple body, but its feet are buried several meters in volcanic material. Other temple parts have also been damaged, leaving only the base and foot.

On the southern flank of Merapi Volcano, there is Sambisari Temple, which shows symptoms of being buried by volcanic material. The temple is located about 300 meters from the Yellow River valley. Even though it is located in the volcanic plain far from the eruption centre, the reach of lava material through the Yellow River caused damage to this temple, so it was buried in volcanic material. Currently, Sambisari Temple is lower than the surrounding land (Fig 3C). Some publications mention that this temple was buried by lava from Merapi Volcano, up to six meters thick (Masyhudi, 2005; Newhall et al., 2000). All these buried temples indicate that in the past, the lives of residents were also not free from the impact of eruptions. Temples as a proxy for settlements damaged and filled in by volcanic materials indicate the same effect on past civilizations in this region due to disasters from Merapi Volcano.

A B C

**Figure 3.** *Temples buried by volcanic materials. (A) Pendem Temple at the Volcanic Foot of the Western Flank of Merapi Volcano. (B) Ngawen Temple, on the Volcanic Plain of the Western Flank of Merapi Volcano. (C) Sambisari Temple, on the Southern Flank of Merapi Volcano.*
*Source:* Google Earth.

### *4.4 Discussion*

Human-landscape interaction in volcanic landscapes has been going on for a long time. This study found that in Javanese society in Indonesia, human-landscape interaction has been going on since the classical Hindu-Buddhist era in medieval times. Human-landscape interaction, among others, occurs in the form of natural resource utilization and the impact of natural disasters on life. Here, it is found that

by utilizing natural resources, humans build settlements near water sources, such as large rivers and springs. In addition, settlement development also considers good land conditions on the flat volcanic plain. On the other hand, people also received a lot of impacts from eruption disasters that caused the decline of this ancient civilization.

The findings in the southern and western flanks of Merapi Volcano have similarities and differences with human-landscape interaction in other volcanic landscapes around the world. In Central Java, another area that shows human-landscape interaction since the classical Hindu-Buddhist period is on the eastern flank of Sundoro Volcano. Here, Ashari (2014) shows that temple construction was built close to springs to indicate ancient settlements. However, the distribution of temples following a large river valley, as found in Merapi, is not found here. The findings at Merapi, which show a connection between river valleys and temples, provide new insights because the same phenomenon is not found at Sundoro Volcano, although both are located in the Central Java Region.

On the other hand, the eruption's impact on life also occurred on the eastern flank of Sundoro Volcano, as happened at the Liyangan Site. The study shows that Liyangan is an ancient settlement site, which is reflected in the diversity of data, including stone structures and buildings, artifacts, organics, and geological and environmental data. Liyangan site is a settlement of Ancient Mataram from the 6th to 10th century AD. The site includes residential areas, worship areas, and agricultural areas. Just like in Merapi, Liyangan provides evidence that the lives of ancient people are not free from eruption disasters. The pyroclastic flows of Mount Sundoro destroyed the ancient village of Liyangan. The eruption of Mount Sindoro itself occurred many times. About 34,000 years ago, there were at least 12 eruptions, causing this area to be buried by pyroclastic flows mixed with lava, followed by lava flows. Not only buried by volcanic materials, the buildings at the Liangan site, which were initially one unit, were then separated by the lava flow that formed Kali Langit (Riyanto, 2015, 2017; Tanudirjo et al., 2019).

Human-landscape interaction in volcanic landscapes in Indonesia also occurs at Samalas Volcano. This volcano sustained the lives of ancient people. However, its eruptions caused massive disruption to life. Samalas Volcano, in the past, experienced eruptions on a scale of VEI-7. As a result of Samas' volcanic activity, a manuscript called Babad Suwung was written, which describes the story of volcanic events. Babad Suwung manuscripts were written relatively recently in the last three centuries. They record the oral and folk traditions of earlier times. According to the manuscripts, the most severe eruption of Mount Samalas that affected human life occurred in 1257. Human-landscape interaction with the volcanic environment occurred in this eruption event, namely community response, emergency response, and recovery strategies carried out by residents in the midst of a devastating eruption (Lavigne et al., 2013; Malawani et al., 2022; Mutaqin et al., 2019).

In Arabia, human-landscape interaction also occurred in ancient civilizations and coloured the history of the development of these societies. Based on

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

ethnographic records of oral traditions about volcanism, it is known that humans have responded to volcanic activity in various forms of local knowledge since ancient times. One example of local knowledge is establishing familiarity with volcanic activity after a community has lived in an area for some time. These oral traditions reflect communities learning how best to inhabit volcanically active regions. Volcanism is part of the process behind creating environments that are particularly suitable for hominin habitation (Groucutt, 2020). This finding is the same as in Merapi: selecting temple construction locations to indicate settlement is also a form of implementation of indigenous knowledge. Even in Merapi, this indigenous knowledge is still preserved until the modern era (Septiana et al., 2019; Setyawati et al., 2015). However, this indigenous knowledge is increasingly being abandoned along with modernization and globalization (Jamaludin et al., 2021).

In Central and South America, human-landscape interaction in volcanic environments is found in the Andean Volcano in the Andes Mountains, Bolivia and Costa Rica. Again, as in Merapi, human landscape interaction is also established through resource utilization and the impact of eruption disasters. In the Andes Mountains, a significant eruption impacted the Tiwanaku civilization in the Lake Titicaca Basin, Bolivia. Widespread tephra layers indicate the eruption occurred between 400-720 AD. The ash covered farmlands and pastures, disrupting the food production and grazing systems on which the local people depended. This ecological disruption likely forced the population to migrate to more stable areas, one of which was the thriving city of Tiwanaku at the time. The eruption also triggered significant social changes, such as increased cooperation between communities in the face of crisis and the adaptation of agricultural technology to cope with the eruption's effects. Although volcanic eruptions are often regarded as disasters, in some cases, such as in the Andes, these events have been the driving force behind social change and the development of civilizations (Marsh et al., 2024).

In Costa Rica, communities have lived near volcanic centres for thousands of years and learned to utilize natural resources. The study conducted in Costa Rica shows the same results as in Merapi, where settlements near the volcano are more vulnerable to the impacts of volcanic hazards than those further away. This study validates that the effects of an eruption are more significant for settlements located within the eruption centre, e.g. volcanic foot, compared to more distant areas, e.g. volcanic plain (Ruiz et al., 2018). Ancient settlement life provides essential benefits as a reference in contemporary land use planning, because it shows how humans shaped their living space adaptively and in harmony with the natural conditions around them. Especially in disaster-prone areas such as the slopes of Mount Merapi, past communities-built settlements with a deep understanding of environmental potential and risks, choosing strategic locations close to water sources and fertile land, but maintaining a safe distance from centers of volcanic activity. These settlement patterns also reflect the integration of social, cultural, and belief system aspects, contributing to community cohesion and resilience in the face of disasters. These principles can be used as a reference in modern spatial planning to create

settlements that are adaptive to disaster risks, sustainable in resource utilization, and responsive to the local characteristics of an area.

## 5. Conclusion

Human-landscape interaction has been ongoing throughout the history of human life itself, including in volcanic environments. Here, we found human-landscape interaction in ancient Javanese communities from medieval times in the southern and western flank of Merapi Volcano. Human-landscape interaction took two forms. First, in the utilization of natural resources. Second, in facing the threat of natural disasters. The utilization of natural resources is indicated by temples built close to water sources and fertile land resources. This study complements previous studies that successfully demonstrated the impact of eruption disasters on the progress and decline of ancient cultures. Moreover, this study provides new insights into how ancient communities attempted to live close to natural resources by the teachings and beliefs of the time.

This study is not free from limitations. The main limitation of this study is that the study area is still limited to the volcanic foot and volcanic plain, the two landforms of the most ancient civilizations. Due to this limitation, it is recommended that future studies should cover a wider area, upwards to the volcanic slope and downwards to the fluvio-volcanic plain. Thus, the information presented will be more comprehensive.

## 6. Acknowledment

The authors would like to thank Muhammad Yuanda Zara, Ph.D. and Nanang Setiawan, MA. from the Department of History, Universitas Negeri Yogyakarta, for providing guidance and direction for this writing. Special thanks go to Assist. Prof. Arif Ashari from the Department of Geography Education, Universitas Negeri Yogyakarta, has inspired in writing, methodology development, data acquisition, supporting data on spring locations, and constructive discussions in interpreting the study findings and preparing this paper.

**Author contribution:**
**Grace Helena Amaranthois Kapisan:** Conceptualization, Methodology, Investigation, Data curation, Writing original draft, Visualization, Reviewing and editing

**Conflicts of Interest:** The authors declare no conflict of interest.

**Data Availability Statement:**
The author's confirm that the data supporting the findings of this study are availability within the article.

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

## 8. REFERENCES

Andreastuti, S. D., Alloway, B. V., & Smith, I. E. M. (2000). A detailed tephrostratigraphic framework at Merapi Volcano, Central Java, Indonesia: implications for eruption predictions and hazard assessment. *Journal of Volcanology and Geothermal Research*, *100*, 51–67.

Andreastuti, S. D., Newhall, C., & Dwiyatno, J. (2006). Menelusuri kebenaran letusan Gunung Merapi 1006. *Jurnal Geologi Indonesia*, *1*(4), 201–207. http://ijog.bgl.esdm.go.id

Ashari, A. (2013). Kajian Fasies Gunungapi di Kompleks Candi Asu untuk Pendugaan Bencana Erupsi Merapi. *Socia*, *10*(2), 129–138.

Ashari, A. (2014). Distribusi Spasial Mataair Kaitannya dengan Keberadaan Situs Arkeologi di Kaki Lereng Timur Gunungapi Sindoro antara Parakan dan Ngadirejo Kabupaten Temanggung. In D. R. S. Sumunar & N. Khotimah (Eds.), *Mega Seminar: Geografi Untukmu Negeri* (pp. 169–179). Jurusan Pendidikan Geografi, Fakultas Ilmu Sosial, Universitas Negeri Yogyakarta.

Ashari, A. (2017). Geomorphology of the Southern Flank of Merapi Volcano in Relation to the Potential Hazards and Natural Resources: A Review. *Geomedia*, *15*(2), 183–192.

Ashari, A. (2022). The Role of Late Holocene Landscape Evolution in Affecting Settlement Distribution in Borobudur Basin, Central Java, Indonesia. *Geography, Environment, Sustainability*, *15*(2), 13–22. https://doi.org/10.24057/2071-9388-2020-013

Ashari, A., Purwantara, S., Arif, N., & Widodo, E. (2021). Spatial Evolution of the River Valleys under the Influence of Active Volcano: A Case of Merapi Volcanic Plain. *Quaestiones Geographicae*, *40*(3), 45–64. https://doi.org/10.2478/quageo-2021-0023

Ashari, A., Wardoyo, M. A. I., Jamaludin, S., Kharisma, K., & Rosa, A. F. (2021). Potensi Air Sungai di Sebagian Bentuklahan Kaki Vulkan Merapi pada Mangsa Karo Tahun 2020. *JURNAL GEOGRAFI Geografi Dan Pengajarannya*, *19*(1), 35. https://doi.org/10.26740/jggp.v19n1.p35-48

Ashari, A., & Purwantara, S. (2022). *Bentanglahan Vulkanik Indonesia: Aspek Fisikal dan Kultural*. UNY Press.

Aurita, R. P., & Purwantara, S. (2017). Karakteristik Mataair Kaki Lereng Gunung Merapi dan Pemanfaatannya di Kecamatan Dukun Kabupaten Magelang. *Geomedia*, *15*(1), 75–85.

Badan Geologi. (2014). *G. Merapi - Sejarah Letusan*. Data Dasar Gunungapi. http://www.vsi.esdm.go.id/index.php/gunungapi/data-dasar-gunungapi/542-g-merapi?start=1

Boyd, W. E., Lentfer, C. J., & Parr, J. (2005). Interactions Between Human Activity, Volcanic Eruptions and Vegetation During the Holocene at Garua and

Numundo, West New Britain, PNG. *Quaternary Research*, *64*(3), 384–398. https://doi.org/10.1016/j.yqres.2005.08.017

Bronto, S., Ratdomopurbo, A., Asmoro, P., & Adityarani, M. (2014). Longsoran Raksasa Gunung Api Merapi Yogyakarta - Jawa Tengah. *J.G.S.M.*, *15*(4), 165–183.

Cashman, K. V, & Giordano, G. (2008). Volcanoes and human history. *Journal of Volcanology and Geothermal Research*, *176*, 325–329. https://doi.org/10.1016/j.jvolgeores.2008.01.036

Degroot, V. (2009). *Candi, Space and Landscape: A Study on the Distribution, Orientation and Spatial Organization of Central Javanese Temple Remains*. Sidestone Press. https://books.google.com/books?id=u2HzduME8OcC&pgis=1

Gertisser, R., Charbonnier, S. J., Keller, J., & Quidelleur, X. (2012). The geological evolution of Merapi volcano, Central Java, Indonesia. *Bulletin of Volcanology*, *74*, 1213–1233. https://doi.org/10.1007/s00445-012-0591-3

Groucutt, H. S. (2020). Volcanism and human prehistory in Arabia. *Journal of Volcanology and Geothermal Research*, *402*. https://doi.org/10.1016/j.jvolgeores.2020.107003

Jamaludin, S., Ashari, A., & Saputro, E. P. N. (2021). Rethinking local genius of the Merapi's community in eruption disaster risk reduction. Does it still work? *IOP Conference Series: Earth and Environmental Science*, *884*(1). https://doi.org/10.1088/1755-1315/884/1/012011

Kharisma, Prasetyo, M., Rosa, A., Fitrianingrum, I., Wardoyo, M., & Ashari, A. (2021). The potential of river discharge at the peak of the dry season in some disaster-prone area of Merapi Volcano. *IOP Conference Series: Earth and Environmental Science*, *884*(1), 012005. https://doi.org/10.1088/1755-1315/884/1/012005

Kramrisch, S. (1946). *The Hindu Temple Vol I*. University of Calcuta.

Lavigne, F., Thouret, J. C., Voight, B., Suwa, H., & Sumaryono, A. (2000). Lahars at Merapi volcano , Central Java : an overview. *Journal of Volcanology and Geothermal Research*, *100*, 423–456.

Lavigne, F., & Thouret, J.-C. (2002). Sediment transportation and deposition by rain-triggered lahars at Merapi Volcano, Central Java , Indonesia. *Geomorphology*, *45–69*. https://doi.org/10.1016/S0169-555X(02)00160-5

Lavigne, F., Degeai, J. P., Komorowski, J. C., Guillet, S., Robert, V., Lahitte, P., Oppenheimer, C., Stoffel, M., Vidal, C. M., Suronoh, Pratomo, I., Wassmer, P., Hajdas, I., Hadmoko, D. S., & De Belizal, E. (2013). Source of the great A.D. 1257 mystery eruption unveiled, Samalas volcano, Rinjani Volcanic Complex, Indonesia. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(42), 16742–16747. https://doi.org/10.1073/pnas.1307520110

Malawani, M. N., Lavigne, F., Sastrawan, W. J., Jamaluddin, Sirulhaq, A., & Hadmoko, D. S. (2022). The 1257 CE cataclysmic eruption of Samalas volcano (Indonesia) revealed by indigenous written sources: Forgotten kingdoms, emergency response, and societal recovery. *Journal of Volcanology and*

*Geografi Vol.13 (1), 149-167*
*ISSN 2289-4470 /eISSN 2462-2400*

*Geothermal Research*, *432*, 107688. https://doi.org/10.1016/j.jvolgeores.2022.107688

Marsh, E. J., Harpel, C. J., & Damby, D. E. (2024). The Khonkho tephra: A large-magnitude volcanic eruption coincided with the rise of Tiwanaku in the Andes. *The Holocene*, *34*(12), 1865–1874. https://doi.org/10.1177/09596836241275000

Maruyama, Y. (1993). Influence of Rapid Geomorphological Change by Volcanic Activity on Flood and Inundation in the Mt. Merapi Area, Central Java, Indonesia. *GeoJournal*, *34*(4), 340–342.

Masyhudi, Nfn. (2005). Situs Candi Sambisari Yang Pernah Terpendam. *Berkala Arkeologi*, *25*(1), 31–45. https://doi.org/10.30883/jba.v25i1.908

Mulyaningsih, S., Sampurno, Zaim, Y., Puradimaja, D. J., Bronto, S., & Siregar, D. A. (2006). Perkembangan Geologi pada Kuarter Awal sampai Masa Sejarah di Dataran Yogyakarta. *Jurnal Geologi Indonesia*, *1*(2), 103–113.

Mutaqin, B. W., Lavigne, F., Sudrajat, Y., Handayani, L., Lahitte, P., Virmoux, C., Hiden, Hadmoko, D. S., Komorowski, J. C., Hananto, N. D., Wassmer, P., Hartono, & Boillot-Airaksinen, K. (2019). Landscape evolution on the eastern part of Lombok (Indonesia) related to the 1257 CE eruption of the Samalas Volcano. *Geomorphology*, *327*, 338–350. https://doi.org/10.1016/j.geomorph.2018.11.010

Neall, V. E., Wallace, R. C., & Torrence, R. (2008). The volcanic environment for 40,000 years of human occupation on the Willaumez Isthmus, West New Britain, Papua New Guinea. *Journal of Volcanology and Geothermal Research*, *176*(3), 330–343. https://doi.org/10.1016/j.jvolgeores.2008.01.037

Newhall, C. G., Bronto, S., Alloway, B., Banks, N. G., Bahar, I., Del Marmol, M. A., Hadisantono, R. D., Holcomb, R. T., McGeehin, J., Miksic, J. N., Rubin, M., Sayudi, S. D., Sukhyar, R., Andreastuti, S., Tilling, R. I., Torley, R., Trimble, D., & Wirakusumah, A. D. (2000). 10,000 Years of explosive eruptions of Merapi Volcano, Central Java: Archaeological and modern implications. *Journal of Volcanology and Geothermal Research*, *100*(1–4), 9–50. https://doi.org/10.1016/S0377-0273(00)00132-3

Prijono, S. (2011). *Arkeologi Pola Permukiman dan Lingkungan Hidup*. Alqaprint.

Purwantara, S., Ashari, A., & Ibrahim, M. H. Bin. (2020). The characteristics of infiltration on the southern flank of Merapi Volcanic Plain, Yogyakarta, Indonesia. *International Journal of GEOMATE*, *19*(74), 201–209. https://doi.org/10.21660/2020.74.52941

Ratih, S., Awanda, H. N., Saputra, A. C., & Ashari, A. (2018). Hidrogeomorfologi mataair kaki Vulkan Merapi bagian selatan. *Geomedia, Majalah Ilmiah Dan Informasi Kegeografian*, *16*(1), 25–36.

Ratih, S., Awanda, H. N., Saputra, A. C., & Ashari, A. (2019). Volcanic Springs, An Alternative Emergency Water Resource to Support Sustainable Disaster Management in Southern Flank of Merapi Volcano. *IOP Conference Series: Earth and Environmental Science 271 (2019) 012012*, 1–19.

https://doi.org/10.1088/1755-1315/271/1/012012

Riede, F. (2019). Doing palaeo-social volcanology: Developing a framework for systematically investigating the impacts of past volcanic eruptions on human societies using archaeological datasets. *Quaternary International*, *499*, 266–277. https://doi.org/10.1016/j.quaint.2018.01.027

Riyanto, S. (2015). Situs Liangan: Ragam Data, Kronologi, dan Aspek Keruangan. *Berkala Arkeologi*, *31*(1), 33–58.

Riyanto, S. (2017). Situs Liangan Dalam Bingkai Sejarah Matarām Kuno. *Berkala Arkeologi*, *37*(2), 141–158. https://doi.org/10.30883/jba.v37i2.177

Ruiz, P., Mana, S., Gutiérrez, A., Alarcón, G., Garro, J., & Soto, G. J. (2018). Geomorphological insights on human-volcano interactions and use of volcanic materials in pre-hispanic cultures of Costa Rica through the holocene. *Frontiers in Earth Science*, *6*(February), 1–22. https://doi.org/10.3389/feart.2018.00013

Septiana, M. E., Wardoyo, M. A. I., Praptiwi, N. Y., Ashari, A. N. S., Ashari, A., Susanti, N. I., Jainudin, Latifah, F., & Nugrahagung, P. P. (2019). Disaster Education Through Local Knowledge in Some Area of Merapi Volcano. *IOP Conference Series: Earth and Environmental Science 271 (2019) 012011*, 1–15. https://doi.org/10.1088/1755-1315/271/1/012011

Setyawati, S., & Ashari, A. (2017). Geomorfologi Lereng Baratdaya Gunungapi Merapi Kaitannya dengan Upaya Pengelolaan Lingkungan dan Kebencanaan. *Geomedia*, *15*(1), 45–60.

Setyawati, S., Pramono, H., & Ashari, A. (2015). Kecerdasan Tradisional dalam Mitigasi Bencana Erupsi pada Masyarakat Lereng Baratdaya Gunungapi Merapi. *Socia*, *12*(2), 100–110.

Sutikno, Santosa, L. W., Widiyanto, Kurniawan, A., & Purwanto, T. H. (2007). *"The Merapi Kingdom": Natural resources and carrying capacity ("Kerajaan Merapi": Sumberdaya alam dan daya dukungnya)*. BPFG UGM.

Tanudirjo, D. A., Zaim, Y., Prasetyo, B., Aziz, F., Ardika, I. W., & Sulistyanto, B. (2011). *Indonesia dalam Arus Sejarah, Jilid 1: Prasejarah*. Ichtiar Baru van Hoeve.

Tanudirjo, D. A., Yuwono, J. S. E., & Adi, A. M. W. (2019). Lanskap Spiritual Situs Liyangan. *Berkala Arkeologi*, *39*(2), 97–120. https://doi.org/10.30883/jba.v39i2.474

Widya Saputra, Y., & Azmi, M. (2024). The Use of Andesite Rocks in the Hindu-Buddhist Kingdoms in Indonesia. *Yupa: Historical Studies Journal*, *8*(2), 250–262. http://jurnal.fkip.unmul.ac.id/index.php/yupa