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**Research Article**

# Suitability of the Former Mamut Copper Mine for Nature-based Tourism: A Preliminary Visual Assessment of Site Conditions

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## ABSTRACT

The Former Mamut Copper Mine (MCM) is a historical landmark rich in both aesthetic and cultural values, but from a scientific perspective, its potential for nature-based tourism remains unexplored. A visual rapid assessment was conducted at MCM, to examine its suitability for nature-based tourism, focusing on site accessibility, hazard levels, scenic visibility, and scenic beauty. Twenty locations with high aesthetic and/or historical values were visually investigated, based on the four specified criteria, utilizing a three-point rating score system. The assessment emphasized a moderate suitability level for nature-based tourism at MCM (Score = 2.337), with significant variations in suitability level observed between the 20 locations ($\chi^2$ = 32.36, p = 0.021). Twelve locations showing higher scores in site accessibility, hazard level, and scenic visibility were determined to be more suitable for nature-based tourism, when compared to the other eight locations. Both the Principal Component Analysis and Spearman's Correlation test highlighted the significant influences of hazard level ($\rho = 0.685$, $p < 0.001$), accessibility ($\rho = 0.652$, $p = 0.002$), and scenic visibility ($\rho = 0.685$, $p < 0.001$) on the suitability of MCM for nature-based tourism, in comparison to site scenic beauty ($\rho = 0.203$, $p = 0.381$). These findings provide new insights highlighting the high suitability of MCM for nature-based tourism. Additionally, this research uncovers safety concerns, rendering public access and the carrying out of recreational activities at MCM, currently infeasible. Management authorities are urged to prioritize efforts that reduce hazard levels and enhance the quality and accessibility of local attractions in future.

**Keywords:** Former Mamut Copper Mine; nature-based tourism; site suitability; tourism potential; visual assessment.

## INTRODUCTION

Sabah in Malaysian Borneo, known as the "Land Below the Wind", is renowned for its diverse landscapes and natural resources, and also its rich historical and cultural heritages (Tay & Chan, 2014; Augustine & Dolinting, 2016). These tangible and intangible resources are introduced as core tourism products by local communities, attracting a significant influx of international and domestic tourists to Sabah, thus fuelling the growth of the local tourism sector since 2010 (Danting et al., 2018). Presently, different alternative tourism practices are available throughout the state, yet nature-based tourism remains a focal point for tourists, because it offers tourists the opportunity to access diverse local landscapes and natural resources in natural settings (Zain et al., 2015; Talib, 2020). This trend has led to a surge in the promotion of nature-based tourism attractions, both domestically and internationally, resulting in the establishment of numerous

new tourist destinations throughout Sabah in recent years (Augustine & Dolinting, 2016; Halim et al., 2018; Lim et al., 2022).

The suitability of a location for nature-based tourism is dictated by various aspects that significantly impact a tourist's satisfaction, including the quality of available tourism products or services, as well as the existing site's cultural and aesthetic values, scenic visibility, hazard level, and accessibility (Feng et al., 2010; Tay & Chan, 2014; Lim et al., 2019; Hasmat et al., 2020). These aspects can collectively dictate tourists' perception of a destination during their visit and, subsequently, its suitability for tourism (Zain et al., 2015). However, previous research has mostly focused on the mere presence or absence of specific elements, rather than their existing conditions, which consequently determines the suitability of a location for nature-based tourism (Zulhazman et al., 2004; Hasmat et al., 2020; Fiffy et al., 2021). This study intended to address this gap, focusing on the Former Mamut Copper Mine (MCM) as the chosen experimental site. Presently, this abandoned mine is a historical landmark that holds significant aesthetic and cultural values, yet its potential for nature-based tourism remains unexplored from the scientific standpoint. Transforming former copper mines into tourist destinations can help in funding the long-term conservation and restoration efforts of local landscapes and biodiversity, plus benefit the surrounding communities (Buonincontri et al., 2021; Gillette & Boyd, 2024). This initiative can help create job opportunities, such as work as tour guides or rangers for the sites, and offer accommodations and dining options for tourists, thereby fostering economic growth in the region (Rudd & Davis, 1998; Dimitrovski & Senić, 2019).

Consequently, many former copper mines across the globe are being marketed as tourist attractions, including the Bor Copper Mine in Serbia, the Kennecott Copper Mine in the United States of America, and the Falun Copper Mine in Sweden (Rudd & Davis, 1998; Pashkevich, 2017; Dimitrovski & Senić, 2019). These continual efforts are geared towards delivering lasting ecological, social, and economic benefits to nearby communities, while assisting management authorities in the long-term sustainable management, restoration, and conservation of the given areas (Armis & Kanegae, 2021; Buonincontri et al., 2021; Gillette & Boyd, 2024). This suggests that promoting MCM as a new nature-based tourism destination in Sabah can bring benefits to both site management authorities and neighbouring communities, underscoring the importance of determining its potential for nature-based tourism. However, there is limited understanding on how accessibility, scenic beauty, scenic visibility, and hazard level impact its suitability for nature-based tourism, and information on these subjects is currently limited (Musta et al., 2019; Adnan, 2021). In order to address these research gaps, a preliminary visual assessment was carried out at MCM. This research intended not only to investigate its suitability, but also to validate the factors that distinctly influenced its suitability, for nature-based tourism. The anticipated outcome of this research was to provide scientific insights to assist management authorities in making decisions regarding the long-term sustainable utilization and management of this old abandoned mine.

**Study site**

Covering about 2,112 ha of rugged montane terrain, MCM is characterized by numerous steep-sided valleys. This abandoned mine is located on the southeastern slope of Kinabalu Park in Ranau, Sabah, with an elevation ranging from 1,300 m to 1,600 m above sea level. Operating for 24 years from 1975 to 1999, the mining activities have left this area largely barren, occupied by patches of grasses and shrubs, while some sections host either native lower montane forest species or pioneer montane plant species (Saibeh et al., 2016). The former large open-pit quarry is inundated with water throughout the year, forming a large pit lake covering an area of approximately 50.0 ha and measuring over 100.0 m deep. The water in this lake is highly acidic,

with a pH ranging from 3.6 to 3.9. The study site experiences a sub-tropical climate, with annual precipitation sometimes exceeding 4500.0 mm (monthly precipitation: 250.0 mm to 400.0 mm), and local annual temperature ranges from 15°C to 28°C (Saibeh et al., 2016; Cleophas et al., 2022). Around the large pit lake (Mamut Lake), a total of 20 locations were identified for their high aesthetic and/or historical values, and each of these locations were given a name reflecting their core attraction (Figure 1).

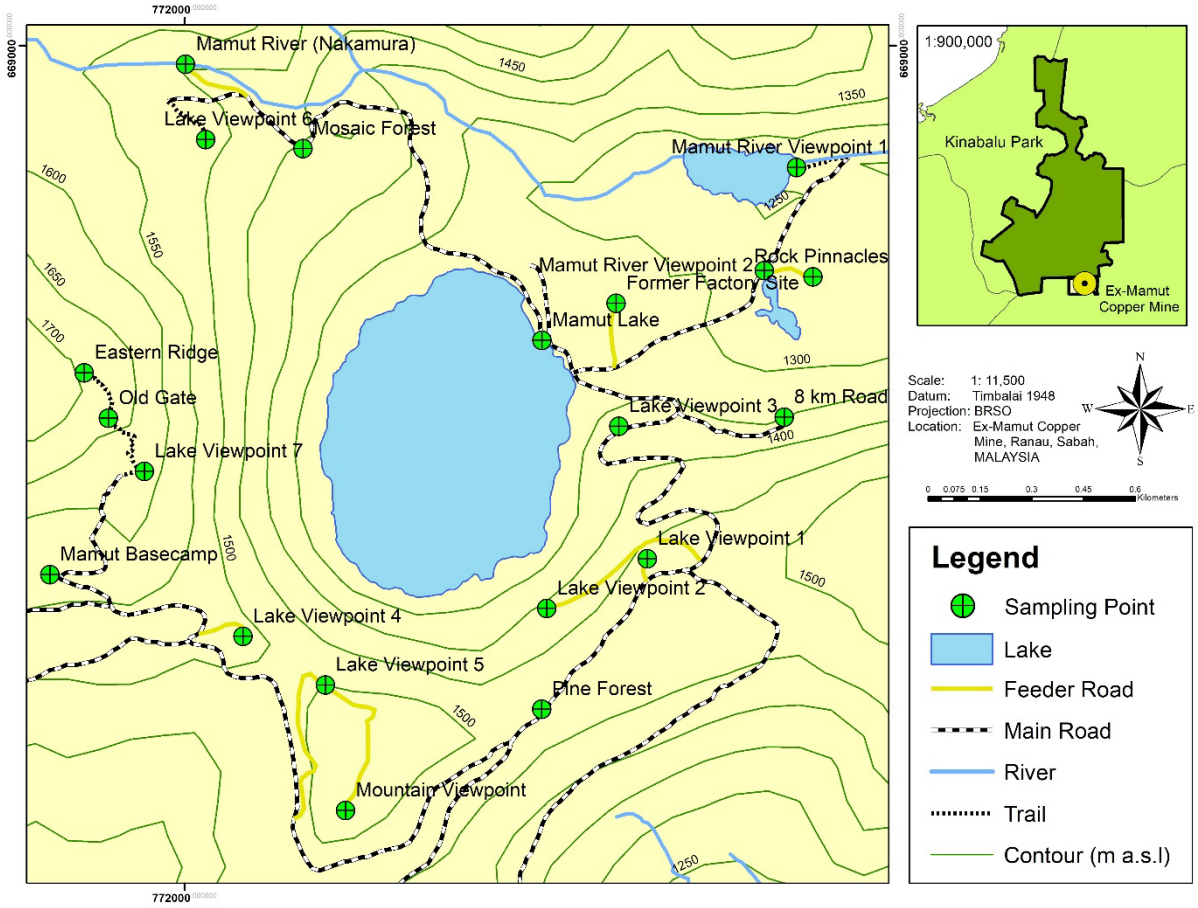


**Figure 1:** Locations of the 20 sampling points established across the Former Mamut Copper Mine in Ranau, Sabah, Malaysia Borneo

## METHODOLOGY

This study was conducted at MCM over a five-day period, from 20th September till 24th September 2022, during the Mamut Scientific Expedition 2022, organized by Sabah Parks. A Garmin GPSMAPS 64s handheld global navigation satellite system receiver was used to record the coordinates of each of the 20 sampling points. The collected coordinates were then compiled and presented in two distinct coordinate systems, which were the World Geodetic System 1984 (WGS84) and Borneo Rectified Skew Orthomorphic (BRSO) (Table 1). The site conditions at each of the 20 sampling points were visually examined at field, focusing on factors such as 1) scenic visibility; 2) scenic beauty; 3) accessibility, and; 4) hazard level, which shaped the site suitability level for nature-based tourism, as suggested by the findings of several relevant past research (e.g., Zulhazman et al., 2004; Feng et al., 2010; Tay & Chan, 2014; Musta et al., 2019; Lim et al., 2022). Given that the only infrastructure remaining at MCM comprised pathways

established prior to the mine closure (before 1999), this research exclusively assessed the conditions of the vehicle or human pathways that led to the respective sampling points.

**Table 1:** Coordinates and designated names of the 20 sampling points with high aesthetic and/or historical value, at the Former Mamut Copper Mine in Ranau, Sabah, Malaysia Borneo.

| Sampling Point | BRSO[1] | | WGS84[2] | |
|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude |
| Pine Forest | 667069.6 m | 773045.7 m | N 6 01.196 | E 116 39.497 |
| Lake Viewpoint 1 | 667510.2 m | 773341.8 m | N 6 01.431 | E 116 39.664 |
| Lake Viewpoint 2 | 667365.7 m | 773052.7 m | N 6 01.354 | E 116 39.505 |
| Lake Viewpoint 3 | 667894.4 m | 773264.2 m | N 6 01.640 | E 116 39.620 |
| Former Factory Site | 668250.4 m | 773250.1 m | N 6 01.833 | E 116 39.617 |
| Mamut River Viewpoint 1 | 668645.2 m | 773778.8 m | N 6 02.045 | E 116 39.902 |
| Rock Pinnacles | 668335.0 m | 773828.2 m | N 6 01.873 | E 116 39.927 |
| Mamut River Viewpoint 2 | 668349.1 m | 773680.1 m | N 6 01.883 | E 116 39.850 |
| Lake Viewpoint 4 | 667291.7 m | 772171.6 m | N 6 01.313 | E 116 39.028 |
| Mamut Basecamp | 667460.9 m | 771618.2 m | N 6 01.411 | E 116 38.726 |
| Mountain Viewpoint | 666780.6 m | 772467.6 m | N 6 01.038 | E 116 39.188 |
| Lake Viewpoint 5 | 667147.2 m | 772407.7 m | N 6 01.235 | E 116 39.157 |
| Mosaic Forest | 668701.6 m | 772340.7 m | N 6 02.079 | E 116 39.127 |
| Lake Viewpoint 6 | 668729.8 m | 772065.8 m | N 6 02.094 | E 116 38.974 |
| Mamut River (Nakamura) | 668941.3 m | 772005.9 m | N 6 02.213 | E 116 38.943 |
| Mamut Lake | 668144.7 m | 773042.2 m | N 6 01.776 | E 116 39.500 |
| 8 km Road | 667922.6 m | 773740.1 m | N 6 01.653 | E 116 39.880 |
| Lake Viewpoint 7 | 667763.1 m | 771889.6 m | N 6 01.573 | E 116 38.875 |
| Old Gate | 667922.6 m | 771776.8 m | N 6 01.657 | E 116 38.819 |
| Eastern Ridge | 668053.0 m | 771706.3 m | N 6 01.728 | E 116 38.782 |

*Note: [1]BRSO=Borneo Rectified Skew Orthomorphic (m=meter).
[2]WGS84=World Geodetic System 1984 (N=North, and; E=East).

In this study, the four assessment criteria were analysed quantitatively by using a three-point rating score system (Table 2). The accessibility of each sampling point was determined by averaging the rating scores for 1) its proximity to the nearest road/trail; 2) the condition of the nearest road/trail surface, and; 3) the steepness of the nearest road/ trail (Zulhazman et al., 2004; Lim et al., 2019, 2022). Additionally, the scenic beauty surrounding each sampling point was verified by averaging the rating scores for seven scenic features, such as: 1) water body; 2) atmospheric phenomenon; 3) vegetation; 4) mountain massif; 5) tourist environment; 6) folk culture, and; 7) fauna. These seven scenic features were rated through the system applied by Feng et al. (2010). Henceforth, the suitability level of each sampling point for nature-based tourism was represented by the mean value of rating scores for accessibility, hazard level, scenic visibility, and scenic beauty with the ratings as followed: A) 1 = Low suitability; B) 2 = Medium suitability, and; C) 3 = High suitability (Lim et al. 2022).

**Table 2:** The assessment criteria applied in examining the suitability levels of the 20 sampling points for nature-based tourism at Former Mamut Copper Mine in Ranau, Sabah, Malaysia Borneo.

| Assessment Criterion | Description | Rating System |
|---|---|---|
| Scenic Visibility | Visibility of the scenery presented at the surrounding of a sampling point to the visitors. | 1=Low (0–33%); 2=Moderate (33–67%); 3=High (67–100%) |
| Scenic Beauty | Qualities of the scenic features that are viewable to visitors, namely the vegetation (VE), water body (WB), fauna (FA), folk culture (FC), tourist environment (TE), mountain massif (MM), and atmospheric phenomenon (AP), presented at the surrounding of a sampling point.<br>The quality of each scenic feature is rated by utilizing the rating system proposed by Feng et al. (2010) | 1=Low; 2=Moderate; 3=High<br>(Calculated as the mean value of the rating scores for seven scenic features that define the site scenic beauty) |
| Accessibility | Accessibility of a sampling point to visitors, which is dictated by its proximity to the nearest road/ trail, as well as the surface condition and the steepness of the nearest road/trail. | 1=Low (0–33%); 2=Moderate (33–67%); 3=High (67–100%)<br>(Calculated as the mean value of the rating scores for three factors that define the site accessibility) |
| | Proximity to the nearest road/trail (PR) | 1=Far (>300m); 2=Moderate (150–300m); 3=Near (<150m) |
| | Surface condition of the nearest road/trail (SC) | 1=Poor; 2=Moderate; 3=Good<br>(Dependent to the type of ground cover and surface smoothness of the road/trail-in-question) |
| | Steepness of the nearest road/ trail (ST) | 1=Steep (>30$^{o}$); 2=Moderate (15 –30$^{o}$); 3=Gentle (<15$^{o}$) |
| Hazard Level | Level of risk posted to the visitors at a sampling point. | 1=High risk; 2=Moderate risk; 3=Low risk<br>(Dependent to the diversity and severity of hazard presented at the site-in-question) |

This study utilized the statistical software PAST ver. 3.25 (Hammer et al., 2001) for all descriptive and inferential analyses, using a 95.0% confidence interval ($p = 0.05$). The gathered data was examined for normal distribution, and the outcome indicated that it was non-normally distributed (Shapiro-Wilk test: $p<0.05$). Therefore, the non-parametric Kruskal-Wallis test was applied to evaluate the variability in suitability levels among the 20 established sampling points. The clustering pattern of the given sampling points, based on site suitability level, was validated through Principal Component Analysis (PCA). Additionally, the non-parametric Spearman's Correlation test was utilized to examine the correlations between site hazard level, accessibility, scenic visibility, scenic beauty, and the suitability level for nature-based tourism at each point in this research.

## RESULTS

The 20 sampling points were found to be highly accessible to visitors (Score>2.0), with five areas receiving the highest rating scores for accessibility in this research (Lake Viewpoint 1,

Lake Viewpoint 4, Lake Viewpoint 7, Mamut Lake, and Pine Forest; Score = 3.0) (Table 3). These areas were positioned close to pathways (<100m) constructed along gentle slopes (<15$^{o}$) with smooth surfaces covered in gravel, rocks, or moss. Contrarily, the remaining 15 locations were verified to either having moderate or good accessibility, based on the three defining factors (Table 2). The hiking trail leading Mamut River Viewpoint 1 to the vehicle road was inundated with algae-filled water. Parts of the vehicle roads leading to Lake Viewpoint 2, Lake Viewpoint 6, 8 km Road, and Mosaic Forest were severely eroded and very rough, and the routes to Lake Viewpoint 3 and Eastern Ridge were notably steep (>30$^{o}$) and lengthy (>300m), respectively. In other words, the pathways connecting these seven areas to the vehicle road were considered poor in various aspects (Score = 1.0), designating Lake Viewpoint 2, Lake Viewpoint 3, Lake Viewpoint 6, and Mamut River Viewpoint 1 as the least accessible locations to visitors in this research (Score = 2.0) (Table 3).

The scenery visibility at the Old Gate and Eastern Ridge were validated to be the lowest (<33.3%; Score = 1.0) (Table 3). Subsequently, four locations were verified to possess moderate scenery visibility (Lake Viewpoint 7, Mamut River (Nakamura), 8 km Road, and Mamut River Viewpoint 1; 33.3%<Scenic Visibility<66.7%; Score = 2.0), whereas the remaining 14 locations offered high scenery visibility to visitors (>66.7%; Score = 3.0) (Table 3). The scenic beauty ratings across the 20 sampling points were generally moderate, with the Old Gate and Eastern Ridge receiving the lowest rating scores (1.714), whereas eight sampling points ascertained the highest rating scores (2.286) (Table 3). This result stemmed from the similarity in rating scores across the seven scenic features defining scenic beauty between these 20 sampling points (Table 4). A majority of these sampling points provided good scenic views of Mount Kinabalu and the surrounding mountain massif, which were frequently accompanied by lenticular clouds, mist, and expanse of cloud cover (MM and AP: Score = 3.0). At Mamut River (Nakamura) and Lake Viewpoint 7, visitors could observe the highly aesthetic-looking mountain ranges veiled in mist and enveloped by expanse of clouds, contrasting with the Old Gate and Eastern Ridge offering restricted views of local atmospheric phenomena and mountain massif to visitors (MM and AP: Score = 1.0). Furthermore, these 20 sampling points hosted limited diversity and density of local vegetation and were rarely visited by local wildlife, thus resulting in generally low to moderate scenic views of local fauna and vegetation across these 20 sampling points (Table 4).

**Table 3:** Mean rating scores computed for the four assessment criteria and suitability level that aim to represent the overall conditions of various aspects of the Former Mamut Copper Mine in Ranau, Sabah, for nature-based tourism.

| Sampling Point | Rating Score | | | | |
|---|---|---|---|---|---|
| | Scenic Visibility | Scenic Beauty | Accessibility | Hazard Level | Suitability Level |
| Pine Forest | 3.000 | 2.000 | 3.000 | 3.000 | 2.750 |
| Lake Viewpoint 1 | 3.000 | 2.286 | 3.000 | 3.000 | 2.822 |
| Lake Viewpoint 2 | 3.000 | 2.000 | 2.000 | 1.000 | 2.000 |
| Lake Viewpoint 3 | 3.000 | 2.286 | 2.000 | 2.000 | 2.322 |
| Former Factory Site | 3.000 | 2.286 | 2.667 | 1.000 | 2.238 |
| Mamut River Viewpoint 1 | 2.000 | 2.143 | 2.000 | 1.000 | 1.786 |
| Rock Pinnacles | 3.000 | 1.857 | 2.667 | 2.000 | 2.381 |
| Mamut River Viewpoint 2 | 3.000 | 2.286 | 2.667 | 2.000 | 2.488 |
| Lake Viewpoint 4 | 3.000 | 2.286 | 3.000 | 2.000 | 2.572 |
| Mamut Basecamp | 3.000 | 2.000 | 2.667 | 3.000 | 2.667 |
| Mountain Viewpoint | 3.000 | 2.000 | 2.667 | 3.000 | 2.667 |

| | | | | | |
|---|---|---|---|---|---|
| Lake Viewpoint 5 | 3.000 | 2.000 | 2.667 | 2.000 | 2.417 |
| Mosaic Forest | 3.000 | 2.286 | 2.333 | 2.000 | 2.405 |
| Lake Viewpoint 6 | 3.000 | 2.000 | 2.000 | 2.000 | 2.286 |
| Mamut River (Nakamura) | 2.000 | 2.000 | 2.333 | 3.000 | 2.333 |
| Mamut Lake | 3.000 | 2.286 | 3.000 | 2.000 | 2.572 |
| 8 km Road | 2.000 | 2.143 | 2.333 | 2.000 | 2.119 |
| Lake Viewpoint 7 | 2.000 | 2.286 | 3.000 | 2.000 | 2.322 |
| Old Gate | 1.000 | 1.714 | 2.667 | 2.000 | 1.845 |
| Eastern Ridge | 1.000 | 1.714 | 2.333 | 2.000 | 1.762 |
| **Overall Condition** | 2.600 (Good) | 2.100 (Moderate) | 2.550 (Good) | 2.100 (Moderate) | 2.337 (Moderate) |

Mamut River (Nakamura), Lake Viewpoint 7, and Eastern Ridge were the only regions providing good scenic views of the pristine highland forest (Score = 3.0) (Table 4). However, sighting of wildlife was scarce at Mamut River (Nakamura) (Score = 1.0), unlike the other two locations with higher probability of sighting local wildlife, especially the Pig-tailed Macaque (*Macaca nemestrina*) (Score = 2.0). Numerous bird species could be easily observed at Mountain Viewpoint and Lake Viewpoint 7, where moderate scenic views of the local vegetation (grassy and bushy, with several trees in the vicinity) were present at these two locations (Score = 2.0).

**Table 4:** Rating scores of the seven scenic features and three factors used to represent site scenic beauty and accessibility, respectively, at the Former Mamut Copper Mine in Ranau, Sabah.

| **Sampling Point** | **Scenic Beauty[1]** | | | | | | | **Accessibility[2]** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **WB** | **MM** | **TE** | **VE** | **FA** | **FC** | **AP** | **SC** | **PR** | **ST** |
| Pine Forest | 1 | 3 | 3 | 2 | 1 | 1 | 3 | 3 | 3 | 3 |
| Lake Viewpoint 1 | 2 | 3 | 3 | 2 | 1 | 2 | 3 | 3 | 3 | 3 |
| Lake Viewpoint 2 | 2 | 3 | 1 | 1 | 1 | 3 | 3 | 1 | 3 | 2 |
| Lake Viewpoint 3 | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 1 |
| Former Factory Site | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 3 |
| Mamut River Viewpoint 1 | 2 | 3 | 2 | 2 | 1 | 2 | 3 | 1 | 2 | 3 |
| Rock Pinnacles | 1 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | 3 | 3 |
| Mamut River Viewpoint 2 | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | 3 |
| Lake Viewpoint 4 | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 |
| Mamut Basecamp | 1 | 3 | 2 | 2 | 1 | 2 | 3 | 2 | 3 | 3 |
| Mountain Viewpoint | 1 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 3 |
| Lake Viewpoint 5 | 2 | 3 | 1 | 1 | 1 | 3 | 3 | 2 | 3 | 3 |
| Mosaic Forest | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 3 | 3 |
| Lake Viewpoint 6 | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 2 | 3 |
| Mamut River (Nakamura) | 3 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 3 |
| Mamut Lake | 2 | 3 | 2 | 2 | 1 | 3 | 3 | 3 | 3 | 3 |
| 8 km Road | 1 | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 3 | 3 |
| Lake Viewpoint 7 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 3 |
| Old Gate | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 3 |
| Eastern Ridge | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 3 | 1 | 3 |

*Note: [1]Scenic Beauty: WB=Water Body; MM=Mountain Massif; TE=Tourist Environment; VE=Vegetation; FA=Fauna; FC=Folk Culture, and; AP=Atmospheric Phenomenon.
[2]Accessibility: SC=Surface Condition of the Nearest Road/Trail; PR=Proximity to the Nearest Road/Trail, and; ST=Steepness of the Nearest Road/Trail.

The large pit lake of MCM could be observed from over half of the 20 sampling points, whether from a distance or up close. However, the scenic qualities of the lake visible from these locations were reduced by its contaminated water (Score = 2.0). Conversely, the upstream of the Mamut River retained its cleanliness and was surrounded by dense native vegetation, providing visitors at the Mamut River (Nakamura) a good scenic view (Score = 3.0) (Table 4). Water bodies were hardly visible at the remaining seven sampling points (Score = 1.0), although water puddles were evident in the vicinity of Mountain Viewpoint. Over half of the 20 sampling points offered visitors good scenic views of local folk cultural elements (Score = 3.0), along with moderately attractive tourist environments (Score = 2.0) (Table 4). The folk cultural elements showcased at MCM included waste rock dumpsites, abandoned mining infrastructure, and a large pit lake. Therefore, the remaining nine areas offered visitors either moderate or poor scenic views of these elements. Lake Viewpoint 2 and Lake Viewpoint 5 were found to have poor tourist environments (Score = 1.0), whereas the remaining four sites, including Pine Forest, Lake Viewpoint 1, Old Gate, and Eastern Ridge, were validated to provide good tourist environments (Score = 3.0) (Table 4).

Various hazards were identified across the 20 sampling points examined in this research. Specifically, hazards identified at the Mamut River Viewpoint 1, Former Factory Site, and Lake Viewpoint 2, include the potential for landslides, flash floods, rugged rocky pathways, falling rocks, sulphuric scents, slippery surfaces, wildlife attacks, contaminated water, and erosion were verified to pose high risks to visitors (Score = 1.0) (Table 3). Visitors at Mamut Basecamp, Pine Forest, Mountain Viewpoint, Lake Viewpoint 1, and Mamut River (Nakamura) were likely to face comparable hazards, albeit with low hazard levels (Score = 3.0) (Table 3). Regarding the remaining 12 areas with moderate hazard levels (Score = 2.0), the risks of falling deadwood and tree branches were only observed at Old Gate and Eastern Ridge (low risks). Moreover, similar hazards like rocky pathways, sulphuric scents, erosion, and landslides could potentially happen at these 12 areas (low risks). Essentially, MCM was verified with high accessibility (Score = 2.55) and scenic visibility (Score = 2.6), along with moderate scenic beauty and hazard level (Score= 2.1), resulting in its moderate suitability for nature-based tourism (Score = 2.337) (Table 3).

According to the data presented in Table 3, Mamut Lake, Mamut Basecamp, Mountain Viewpoint, Lake Viewpoint 1, Lake Viewpoint 5, and Pine Forest exhibited significantly higher levels of suitability (Score>2.5) compared to some other locations (1.5<Score<2.5), particularly Old Gate (Score = 1.845), Eastern Ridge (Score = 1.762), and Mamut River Viewpoint 1 (Score = 1.786; $\chi^2 = 32.36$, $p = 0.021$). The outcomes of the PCA analysis revealed that 89.01% of the total variance was explained by the first two principal components (PC), indicating the existence of two distinct clusters, as depicted in a scatter plot (Figure 2). Within one of the two clusters, 12 locations were validated with high rating scores for accessibility, hazard level, scenic visibility, and suitability level, all exhibiting positive values for PC1. On the contrary, the other eight sites comprising the other cluster displayed contrasting characteristics. The results from Spearman's Correlation test further indicated a significant positive correlation between the suitability level of a sampling point and accessibility ($\rho = 0.652$, $p = 0.002$), scenic visibility ($\rho = 0.685$, $p<0.001$), and hazard level ($\rho = 0.685$, $p<0.001$). Nonetheless, there was no significant correlation between the suitability level of a sampling point and scenic beauty ($\rho = 0.203$, $p = 0.381$), thereby aligning with the results of the PCA analysis. In summary, these three factors predominantly shaped the suitability level of a sampling point at MCM for nature-based tourism.

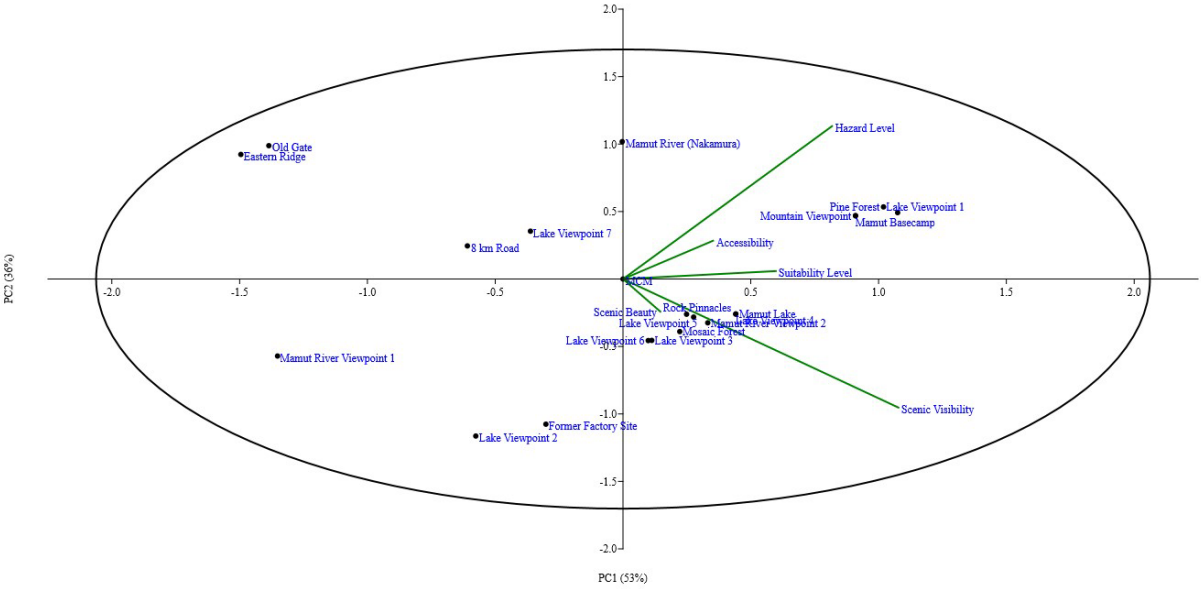


**Figure 2:** A scatter plot depicting the scenic visibility, scenic beauty, accessibility, hazard level, and suitability levels of the 20 established sampling points across the Former Mamut Copper Mine.

## DISCUSSION

The results of this study indicated notable differences in the suitability levels for nature-based tourism among the 20 established sampling points. Owning to their high aesthetic and/or historical values, the qualities of the seven scenic features visible at these 20 locations exhibited a general similarity. Consequently, the scenic beauty among these 20 locations also exhibited a general similarity, falling within a moderate range (1.5<Score<2.5). The environments at these 20 locations had undergone changes from their original state, due to habitat degradation caused by past mining operations. Furthermore, these areas ceased to be affected by human disturbance following the decommissioning of the local mining operation in 1999 (Low et al., 2020; Adnan, 2021). Hence, the scenic views focusing on the atmospheric phenomenon and mountain massif, namely the lenticular cloud that regularly formed around the peaks of Mount Kinabalu, maintained high qualities at the majority of the 20 established sampling points. Conversely, the waste rock dumpsites, abandoned mining infrastructure, and large pit lake were visible only at certain areas, offering unfavourable tourist environments and limited scenic views of the local vegetation and fauna. This is because Mount Kinabalu being situated at a distance and at a higher elevation than the whole MCM area, unlike the tourist environments, vegetation, water bodies, fauna, and folk cultures found within the vicinity of this abandoned mine (Saibeh et al., 2016; van der Ent & Edraki, 2016; Cleophas et al., 2022).

Previous research emphasized diverse landscapes and distinctive natural features, which were rare and authentic to a particular area, and highly suitable for promotion as local flagship attractions (Zulhazman et al., 2004; Hasmat et al., 2020; Fiffy et al., 2021). The highly aesthetic Mount Kinabalu and lenticular cloud were readily viewable to visitors from various sites within MCM. Moreover, the abandoned mining infrastructure, waste rock dumpsites, and large pit lake were inherent to MCM's identity. Henceforth, these unique and authentic natural and manmade features were well-suited to be introduced as local flagship attractions. All of the sampling points were located within the post-mining environment of MCM, hence emphasizing the absence of significant differences in surrounding environmental conditions throughout these areas. This scenario could contribute to similarities in the scenic beauty qualities of the different

accessible scenic features observed by visitors across these 20 locations (Feng et al., 2010; Zain et al., 2015; Talib, 2020). On the other hand, there were generally diverse levels of accessibility, scenic visibility, and hazard levels among these locations. The differences in these three factors and the similarity in scenic beauty qualities between these 20 locations would ultimately result in the insignificant influence of scenic beauty on the suitability of a sampling point within MCM for nature-based tourism, as emphasized by the results of both the PCA analysis and Spearman's Correlation test conducted in this research (Li et al., 2018; Alsaqr, 2021; Wang et al., 2021).

The site accessibilities and scenic visibilities were generally high (Score>2.5), while the site hazard levels were predominantly moderate (Score = 2.0), resulting in the identification of 14 locations as moderately suitable and 6 locations as highly suitable, for nature-based tourism. The visibility of the scenery surrounding an area to visitors is dictated by the characteristics of the local vegetation (size, structure, density, and composition) and topography (slope steepness, aspect, and position) (Lang et al., 2021; Courbin et al., 2022). The perceived scenic quality by visitors may differ when viewing a particular scenery from different locations with different topographic and vegetation conditions (Lim et al., 2019, 2022). A change in the visible scenic beauty can impact the satisfaction experienced by visitors when engaging in recreational activities at the location (Feng et al., 2010; Zain et al., 2015). As a result, a dense forest situated along a slope area is likely to provide visitors with lower scenic visibility, visible scenic beauty, and satisfaction, while an open area located on a plateau, valley, or ridge region is likely to offer the opposite experience to visitors (Bayliss et al., 2014; Talib, 2020; Lang et al., 2021; Courbin et al., 2022). This phenomenon helps in clarifying the significantly positive correlation between site scenic visibilities and suitability levels across the 20 sampling points evaluated in this study.

Since 1999, environmental degradation and pollution resulting from the past mining activities have not been properly addressed, and the maintenance of the hiking trails and vehicle roads leading to the 20 sampling points have been neglected (van der Ent & Edraki, 2016; Musta et al., 2019; Low et al., 2020; Adnan, 2021). The combined factors of pathway length, gradient, and surface condition determine the difficulty level in accessing an area, thereby impacting the motivation for visitors to visit the given location for recreational purposes (Bayliss et al., 2014; Lim et al., 2019, 2022). Moreover, this research validated a wide variety of hazards, with each posing varying risks to visitors across the 20 established sampling points. Among these hazards, the sulphuric scent and contaminated water were verified as the major local hazards, contrasting with the other hazards categorized as minor local concerns. These two hazards can have adverse effects on human health, with the severity of their impact dictated by both the proximities and the duration of exposure of visitors to their sources (Barbusiński et al., 2021). The presence of the hydrogen sulphide ($H_2S$), which is a toxic gas mostly originating from the large pit lake at MCM, was indicated by the smell of sulphur. Different sources of contaminated water, such as the large pit lake, puddles, and several smaller pit lakes within the MCM, were identified in this study. Past results denoted that these waters contained elevated levels of copper and sulphur minerals, and also a variety of bacterial species and trace elements (van der Ent & Edraki, 2016; Low et al., 2020). In summary, visitors are at risk of encountering both major and minor hazards, which may detrimentally impact their sense of security and overall satisfaction, both physically and mentally, when engaging in recreational activities within the MCM area (Tay & Chan, 2014; Augustine & Dolinting, 2016).

The results of PCA indicated that a cluster of twelve sampling points, characterized by moderate to high site accessibility, scenic beauty, and scenic visibility, and also low to moderate site hazard levels, exhibited positive values for the PC1. Six of these 12 locations (Mamut Lake, Pine Forest, Mountain Viewpoint, Lake Viewpoint 1, Lake Viewpoint 4, and Mamut Basecamp)

were validated as highly suitable candidates for promotion as the main attraction sites at MCM (Score>2.5), despite their moderate site scenic beauty (1.5<Score<2.5). The results of this study highlight that the visitors' perceptions of security and convenience while accessing a particular feature in its entirety, either physically or scenically, could serve as primary motivations for engaging in recreational activities, in contrast over the importance of scenic beauty (Zulhazman et al., 2004; Hasmat et al., 2020; Fiffy et al., 2021). Furthermore, visitors typically show strong preference for safe environments that offer convenient access to flagship attractions, regardless of the area's scenic beauty being of low quality, and vice versa (Feng et al., 2010; Bayliss et al., 2014; Talib, 2020; Lim et al., 2022). Consequently, these twelve sampling points, distinguished by their high aesthetic and/or historical significance, were instrumental in shaping the moderate suitability level of MCM for nature-based tourism, thereby contributing to the existing body of tourism research at this abandoned mine.

The establishment of a successful nature-based tourism destination greatly relies on the engagement of multiple stakeholders, comprising local communities, government agencies, site managers, private organizations, environmental groups, and potential destination visitors (Tay & Chan, 2014; Danting et al., 2018). This trend is evident in the renowned Falun Copper Mine, Bor Copper Mine, and Kennecott Copper Mine, all of which have been successfully introduced as tourism destinations in recent years (Rudd & Davis, 1998; Pashkevich, 2017; Dimitrovski & Senić, 2019). Their achievement in establishing long-term sustainable management as tourism destinations is the result of ongoing environmental remediation efforts that prioritize restoring site ecosystems, mitigating site environmental impacts, and ensuring the safety of visitors and neighbouring communities, with support from involved stakeholders (Armis & Kanegae, 2021; Buonincontri et al., 2021; Gillette & Boyd, 2024). As for nearby communities, this tourist activity could significantly influence their livelihoods, either positively or negatively, contingent towards the long-term sustainability of local site management (Rudd & Davis, 1998; Buonincontri et al., 2021; Gillette & Boyd, 2024). Consequently, specific adjacent communities may oppose the conversion of MCM into a recreational site, out of concern about exacerbating the local environment's ongoing recovery from past mining activities, and its potential adverse impacts on their long-term livelihoods (Pashkevich, 2017; Musta et al., 2019). Since researchers have yet to thoroughly investigate the perception of local communities regarding the promotion of MCM for nature-based tourism, further research should be conducted to address this subject, before proceeding with its promotion for nature-based tourism in the future.

The findings of this research simply aid management authorities in validating the existing availabilities and qualities of tourism attractions (supplies) in the vicinity of MCM. As this area remains closed to public access at present, this research did not investigate the expectations (demands) of visitors who may visit this abandoned mine. The expectations and preferences of visitors seeking first hand experiences with certain attractions at a destination are referred to as visitors' demands, and these highly-anticipated attractions may not always be the local flagship attractions (Arbieu et al., 2017; Lim et al., 2022). The failure to meet expectations and preferences of visitors can negatively influence their levels of satisfaction and subsequently, the perceived image of the given destination (Zain et al., 2015; Kubo et al., 2019). This emphasizes that the true feasibility of MCM for nature-based tourism is determined by the compatibility between local tourism supplies and visitors' demands (Arbieu et al., 2017; Kubo et al., 2019). Particular stakeholders may also envision alternative uses for MCM, such as fully preserving this abandoned mine for restoring the local environment and biodiversity. This could potentially impact public access to this area for recreational purposes in the future (Pashkevich, 2017). However, neither of these subjects have been thoroughly evaluated in previous or the present study, underscoring the necessity for additional research on these topics at MCM.

The absence of basic facilities like signboards, restaurants/cafés, trash bins, and resting areas, along with poorly maintained pathways leading to the attraction sites, continue to be the shortcomings that have prevented MCM from being ready to be promoted as a nature-based tourism destination at this moment. The given facilities and infrastructures are essential for the operation of a tourist destination site (Augustine & Dolinting, 2016; Halim et al., 2018). It is crucial for the management authority to ensure the proper establishment of these amenities, not only at the 12 sampling points with high levels of suitability for nature-based tourism, but also across the entirety of MCM. Additionally, numerous hazards were presented throughout MCM, with some posing prominent risks to visitors. This may undermine their sense of security when engaging in recreational activities at local attraction sites (Zulhazman et al., 2004; Hasmat et al., 2020; Fiffy et al., 2021). Therefore, it is crucial for the management authority to effectively manage and mitigate local hazards, particularly the sulphuric scent and contaminated water, to reduce local hazard levels and elevate visitor satisfaction in this region (Lim et al., 2019, 2022). In other words, further initiatives are required to improve local basic infrastructure and facilities, grasp the perceptions of all involved stakeholders regarding the possibility of promoting MCM as a nature-based tourism destination, restore the local ecosystem, and mitigate local hazards, prior to permitting public access for recreational purposes in future at this abandoned mine. Most importantly, these endeavours should be underpinned by scientific evaluations and robust evidence before suggesting feasible recreational activities to be promote at MCM, stressing the significance of safety measures for its potential as a future nature-based tourism destination.

## CONCLUSION

The findings of this study affirms that MCM holds moderate suitability for nature-based tourism. Among the 20 established sampling points, 12 locations were identified as suitable for promotion as local core attraction sites, attributed to the moderate to high site accessibility and scenic visibility, along with moderate to low site hazard level. This abandoned mine boasts both natural (Mount Kinabalu and lenticular cloud) and manmade (large pit lake, waste rock dumpsites, and abandoned mining infrastructure) features, all of which are suitable to be promoted as local flagship attractions. However, the accessibility of these potential attractions to visitors, whether in terms of physical access or scenic views, differs from one site to another. Moreover, the suitability of each established sampling point for nature-based tourism is determined to be majorly defined by accessibility, hazard level, and scenic visibility, instead of scenic beauty. This highlights the significance of these three aspects in determining the potential of MCM for promotion as a nature-based tourism destination. However, the findings of this research merely validate the existing availabilities and qualities of features in the vicinity of MCM with potential to be marketed as local tourism attractions. Moreover, the present study neglects to address stakeholder perceptions on the potential of MCM for nature-based tourism, plus the alignment of visitor demand with local tourism supplies, which are acknowledged as crucial determinants in determining the feasibility of marketing a location as a nature-based tourism destination. The limitations of this study, along with inadequate essential infrastructures and facilities, ongoing ecosystem recovery from past mining activities, and the presence of numerous hazards posing risks to visitor safety, render the opening of MCM for public recreational use unviable at present time. Additional research is needed to overcome the limitations of this study and address the shortcomings at MCM. This will help establish robust scientific evidence that can support management authorities and other stakeholders in decision-making regarding the planning and management of MCM. Consequently, this will enhance its suitability for nature-based tourism, thereby increasing the feasibility of opening it to public recreational access in the future.

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