Assessing Hutan Simpan Ampang using GIS-based Potential Surface Analysis approach

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Abstract. This paper aims to determine potential spaces for sustainable future development at Hutan Simpan Ampang, Ulu Klang, Malaysia. The site is highly valuable due to strategic location and high availability of spaces. However, due to several landslide incidents happened in Ulu Klang over the past decades, the site is categorised as a landslide-prone area. Therefore, Potential Surface Analysis (PSA) is conducted to determine the potential areas within the site that are safe and suitable for future development. All the factors were processed in Geographic Information System (GIS) through the overlay mapping technique, combining spatial and attribute data to obtain the suitability map. The result found that the majority coverage of the site is not suitable for any future development. There are only a few coverage areas that are suitable for small scale development. However, a combination of the very high suitability area and the high suitability area expanded the opportunity for sustainable future development.

Keywords: Potential Surface Analysis, Suitability mapping, Hutan Simpan Ampang, Highland Tower, Environmental disaster

1. Introduction
Disasters are unavoidable and they have been seen repeatedly in Malaysia and around the world. Landslide is a common type of disaster. Most landslides incidents occurred due to heavy rainfall in hot and humid countries like Malaysia [1]. A huge number of hillslopes have been classified by the Malaysian Public Works Department (PWD) as dangerous hillslopes that can bring landslides. Among these hillslopes are Genting Highlands, Gunung Raya (Langkawi), Paya Terubung Valley (Penang), the mountain around Ulu Klang and Cameron Highlands and Frazer Hill, Penang [2, 3, 4, 5, 6, 7, 8]. Landslides cause terrible threats to the surrounding buildings and transportations infrastructures. From an economic perspective, it would affect the residents, tourism, and natural resources.

Since 1993, many landslides happened in Ulu Klang such as the collapse of Highland Towers which caused 48 deaths in 1993 [9], a landslide at Taman Hillview in 2002, landslides at Taman Hamorni, Taman Zoo View, Kampung Pasir in 2006 and the most recent was at Taman Bukit Mewah in 2008 [1, 10, 11, 12]. These tragedies have claimed lives and economic losses [1]. According to the experts, the reasons for the landslides were the improper soil testing, the soil’s bearing test, and the pre-construction site visit at the pre-design phase and the failure to identify the peripheral condition.
The soil erosion caused by the heavy rains was a main contributing factor, which destroyed the retaining wall and causing the Highland Tower building’s collapse. Now it is planners and designers that can positively change the lives of people hit by disasters [13]. However, these interventions by the planners and designers can sometimes affect the population negatively if the interventions are not coordinated well and are not designed according to the needs and desires of people [14]. Thus, this paper aims to determine potential spaces for future development in Hutan Simpan Ampang, Ulu Klang, Malaysia to inject life into the unused green forest and green space into a community lively space that could enhance the living quality of the community and natural environment.

With the introduction and advancement of technologies like GIS, it is now easy to evaluate the potentials of the surface with ease [15]. Similarly, the Analytic Hierarchy Process (AHP) is available in the simplest form online. AHP can weigh the involved factors and provides raw scores for GIS analysis. Thus, these two tools are required for running Potential Surface Analysis (PSA).

2. Method

2.1. Study area
The study area is located at Hutan Simpan Ampang, Ulu Klang, Malaysia. The contextual map in Figure 1 shows its boundary and surrounding areas. The hotspots surrounding the study area are also pointed out.

![Figure 1. Contextual map](image)

2.2. Potential Surface Analysis (PSA)
Potential Surface Analysis (PSA) technique is widely used for suitability analysis. This technique was developed from the overlay mapping technique and that combined the spatial data and the attribute data in GIS [16]. At the beginning stage, an appropriate ranking technique is required for weighting the PSA’s factors based on the physical factors of the study area. This includes the usage of a variety of parameters for the calculation. To create the physical database in the current study, the parameters of the potential spaces for future development were considered: (P1) slope sustainable demonstration; (P2) infrastructure and activities; (P3) resonance and awareness; (P4) wildlife habitat and flora preservation. In the end, all the physical factors were run through overlay mapping in GIS by the identification method: \( \text{PSA} = \text{P1} + \text{P2} + \text{P3} - \text{P4} \) to obtain the suitability map (see Figure 2).
2.3. Analytic Hierarchy Process (AHP)

To weight the PSA’s factors based on the physical data of the studying area, Analytic Hierarchy Process (AHP) will first be conducted. This is one of the multi-criteria decision-making methods that was originally developed by Prof. Thomas L. Saaty in 1980 [16]. This method derives ratio scales from paired comparisons. The input can be obtained from actual measurement, otherwise through human judgement. However, AHP allows minute inconsistency in judgment because human is not always consistent. Pairwise comparison judgements are applied to pairs of homogenous criteria, eventually generating the overall priorities for ranking the alternatives. In the process of pairwise comparisons, a scale of numbers that indicates how many times a more important or dominant element over another element is required. Each factor ranges from 1 to 9 according to the importance of factors at the site. Within parameter, every criterion will run through normalization calculation to determine the weightage of each criterion by the formula, weightage normalization = Cw/MaxCwx5. The result indicates how important each criterion is when running the suitability analysis. In the current study, the above process was run smoothly and data was obtained to be used in GIS.

2.4. Geographical Information System (GIS) mapping

Geographic Information System (GIS) plays an important role in analysing and increasing the accuracy of the weight of parameters in a PSA approach. After obtaining weightage for the PSA’s factors, all the factors were then processed in GIS through the overlay mapping technique. This technique combined the spatial and attribute data in GIS software such as ArcGIS. Secondary data including research papers and other documents were also used in this study and transformed to attribute data in ArcGIS 10.5. The other data related to the physical characteristics from the biological, economic, and social agencies were applied to understand the study area and use of the data analysis. Subsequently running through analysis for every factor, the suitability map can be generated through the identification method, PSA = P1+P2+P3-P4; P1 = Primary Physical Factor, P2 = Secondary Physical Factor, P3 = Tertiary Physical Factor, P4 = Disturbance Factor.
3. Results and Discussion

Pairwise comparisons between the physical factors are rated range from 1 to 9 according to the importance of factor for future site development (see Table 1). The result shows P1, slope sustainable demonstration, as the most influential factor at 52.6% (see Figure 3). This is because the site is known as a landslide-prone area. More research on the dynamic and viability of slope at the site is necessary to ensure the area is safe for development. The most concerning factors followed up with P2 (see Figure 4), infrastructures and activities, and P3 (see Figure 5), resonance, and awareness, both at 20.6%. The factors ensured the functionality of the area and as well as instil awareness of the possible landslide occurrence by providing appropriate infrastructure and activities for the people. P4, Wildlife habitat and flora preservation, has the lowest score at 6.2% (see Figure 6). Preservation of flora and fauna is very important to secure the biodiversity at a particular area and keep people in touch with nature [17]. Therefore, it was categorised as the disturbance factors where these areas will be excluded from development.

Table 1. Factors listed based on the importance.

| Objectives                                      | AHP       | Final weightage |
|-------------------------------------------------|-----------|-----------------|
| P1 Slope sustainable demonstration              | 52.6% = 0.5 | 5               |
| P2 Infrastructures & activities                 | 20.6 = 0.2 | 2               |
| P3 Resonance & awareness                        | 20.6 = 0.2 | 2               |
| P4 Wildlife habitat & flora preservation        | 6.2 = 0.1  | 1               |

**Primary Physical Factor (P1)**

**Criteria and Sub-criteria for Primary Physical Factor: Slope Sustainable Demonstration**

| Criteria   | AHP   | Weightage Normalization | Final Weightage |
|------------|-------|--------------------------|-----------------|
| 1. Slope   |       |                          |                 |
| 2. Hydrology|       |                          |                 |
| 3. Landform|       |                          |                 |
| 4. Vegetation|       |                          |                 |

**AHP Analysis (P1)**

| OBJECTIVE 1 - Slope Sustainable Demonstration | AHP | Weightage Normalization | Final Weightage |
|-----------------------------------------------|-----|-------------------------|-----------------|
| C1  - Slope                                    | 52.9% = 0.5 | 0.5/0.5 X 5 = 5 | 5 |
| C2  - Hydrology                                | 26.8% = 0.3 | 0.3/0.5 X 5 = 3 | 3 |
| C3  - Landform                                 | 13.4% = 0.1 | 0.1/0.5 X 5 = 1 | 1 |
| C4  - Vegetation                              | 6.8% = 0.1 | 0.1/0.5 X 5 = 1 | 1 |

**Figure 3. AHP analysis of P1.**
The result of the AHP Analysis of P1 comprises 4 criteria: slope, hydrology, landform, and vegetation. Slope ranked first at 52.9% as a directly relatable criterion that identifies the gradient of an area. The sub-criteria of the slope are assigned into class range 1 to 4, indicating 4 as the safest class with a gentle slope. Class 4, therefore, holds the highest score among all. Water as one of the main causes of the Highland Tower incident brings hydrology to rank second at 26.8% [12]. The results followed up with landform at 13.4% and vegetation comes last at 6.8%. Landform indicates the contour pattern which can affect the slope properties. Vegetation such as shrub, tree, and groundcover is responsible for holding the land with roots.

**Secondary Physical Factor (P2)**

| Criterias and Sub-criteria for Secondary Physical Factor: | Infrastructures & Activities |
|----------------------------------------------------------|-------------------------------|
| **P2 - Infrastructure & Activities**                     |                               |
| 1. Visual & View                                         |                               |
| 2. Hydrology                                             |                               |
| 3. Space & Senses                                        |                               |
| 4. Slope                                                 |                               |

**CRITERIA**

| Sub-Criteria | Weightage Normalization = $C_i/\text{Max}C_i \times X$ |
|--------------|--------------------------------------------------------|
| C1 - Slope   | 1. Class 1 (≤ 15° Slope Gradient)                     |
|              | 2. Class 2 (15° to 25° Slope Gradient)                |
|              | 3. Class 3 (25° to 35° Slope Gradient)                |
|              | 4. Class 4 (> 35° Slope Gradient)                     |
| C2 - Hydrology | 1. No water flow                                       |
|              | 2. Gentle water flow                                   |
|              | 3. Rapid water flow                                    |
| C3-Visual & View | 1. Weak View                                           |
|              | 2. Moderate View                                       |
|              | 3. Good View                                           |
| C4-Space & Sense | 1. Public space                                        |
|              | 2. Semi-public space                                   |
|              | 3. Private space                                       |

**AHP Analysis P2**

| Objective 2 - Infrastructure & Activities |
|--------------------------------------------|
| CRITERIA                                    | AHP | WEIGHTAGE NORMALIZATION | FINAL WEIGHTAGE |
|--------------------------------------------|-----|-------------------------|-----------------|
| C1 - Slope                                 | 51.4% = 0.5 | 0.5/0.5 X 5 = 5 | 5               |
| C2 - Hydrology                             | 21.0% = 0.2 | 0.2/0.5 X 5 = 2 | 2               |
| C3 - Visual & View                         | 21.0% = 0.2 | 0.2/0.5 X 5 = 2 | 2               |
| C4 - Space & Senses                        | 6.7% = 0.1  | 0.1/0.5 X 5 = 1 | 1               |

**Figure 4. AHP analysis of P2.**

The result of AHP Analysis of P2 comprises 4 criteria: slope, hydrology, visual and view, and spaces and senses. Slope scored first at 51.4% with the sub-criteria assigned into class range 1 to 4, indicating 4 as the safest class with a gentle slope. Selecting a flatter area to build infrastructure is always the most ideal decision. This can not only mitigate the cost required for cut and fill operation, but the land is also safer to withhold the infrastructure that could safeguard the area from a landslide. The result follows up with hydrology and visual and view, both at 21%. Water as one of the main causes of the Highland Tower incident should come to concern when designing the drainage around the infrastructure. On the other hand, the criterion of visual and view is important in selecting an area with the best view for the user. Finally, space and senses scored last at 6.7%.
The result of the AHP Analysis of P3 comprises 3 criteria: landslide location, slope, and landform. Landslide location ranked first at 62.5%. These locations in which landslide incidents happened can create a sense of resonance and awareness for the people. This is followed by the slope at 23.8% with its sub-criteria assigned into class range 1 to 4, indicating 1 as the dangerous class with slant slope. Class 1, therefore, holds the highest score among all to warn and prevent the developer and others not to build any man-made structures on it. It requires cut and fill on the slanting slope area as well which costs more and brings a negative impact to the hill slope area. Finally, the landform scored last at 13.7%.
The result of the AHP Analysis of P4 comprises 3 criteria: Wildlife, vegetation, and hydrology. Both criteria are correlated to each other because the site is mostly covered by a high density of green. Therefore, it has a high potential habitat area for different species of wildlife, flora, and fauna. This is why the score for both wildlife and vegetation are the highest and equally important. Lastly, the hydrology scored last at 20%. Most of the areas have moderate water source which provides water for wildlife and plants.

The results of AHP analysis for all four factors were brought into GIS. Using Model Builder in the GIS environment (see Figure 7, 8, 9, and 10), relevant maps were created (see Figure 11). Later, the four maps were overlaid and the final suitability map was created (see Figure 12).

Figure 6. AHP analysis of P4.
Figure 9. Data mapping diagram for P3.

Figure 10. Data mapping diagram for P4.

Figure 11. Overlay mapping result of P1, P2, P3 and P4.
Based on the suitability map, there are very few coverage areas that indicate very high suitability for future development. However, when combining with high suitability area, development at the site appear to be possible. The site may require a more detailed study to minimise the usage of high suitability area. Developers should consider the safety of the area especially areas with a steep slope. This is to reduce any risk of an undesirable natural disaster such as landslide and flooding. There are small areas that are suitable for small scale development such as commercial shop lot development or recreational function in the forest or green space. The findings also confirmed that there a minor coverage of area which is suitable for infrastructures and activities. Other than that, there is only a small spot of coverage on the Highland Tower which possesses a strong sense of resonance and awareness towards landslide tragedy. It brings out a lesson and censure to remind us to appreciate the existing beauty of habitats and Mother Nature. Furthermore, the coverage of the wildlife habitat and flora preservation on the site is extremely high. The area with a high presence of endangered flora and fauna should be excluded. This will help to preserve biodiversity.

4. Conclusion
This study concludes that the majority coverage of the site is not suitable for any future development. There is a limited area that is suitable for small scale development. However, the combination of a very high suitability area and high suitability area expanded the feasibility for more opportunity and variety of development. Planners and developers should conduct further research to minimise the usage of high or moderate suitability areas. This is to ensure the safety of users, as well as to mitigate disruption toward the habitat of endangered flora and fauna species.

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