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# Spatial Characteristics of Permanent Relocation Housing in Disaster-Prone Areas of Cangkringan

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ABSTRACT

The Merapi relocation permanent residential settlements (huntap) are spread across 2 sub-districts, Cangkringan and Minggir. The relocation located in Disaster Prone Area (KRB) 2, an area with a high level of vulnerability. The settlements are in rural areas contoured by mountain slopes. This study aims to describe and identify the condition of the spatial character of huntap settlements from an accessibility perspective. Aspects that influence regional emergencies in the mitigation stage are the complexity of shelters, shelter buildings, land morphology, settlement accessibility and preservation facilities. This research was carried out qualitatively deductively with 18 objects of observation in the Merapi relocation huntap settlements. Data were collected from contour data (GIS-Google Earth), primary & secondary literature studies, observations and interviews. This classification is then analyzed based on physical characteristics in the form of buildings, land and preservation facilities. The character of the building will influence the shape of the road pattern and the level of visibility. The morphological characteristics of the land will influence the ease of mobility based on the shape of the road and human movement. The nature of preservation facilities will affect the level of wayfinding which residents can recognise their environment.. So to support the optimization of the success of the evacuation process, the main road is in a position parallel to the contour line, minimizing the potential for density accumulation. There is an open area between the grid so that the level of visibility is wider. Minimizing the number of intersections in areas that are segregated/separated from other areas. Adding access gates to the entrance and exit to prevent bottlenecks, accumulation in the gate area.. It is hoped that this study can be used as a reference, recommendation and basis for the government, architects, urban designers or planners in designing relocation shelters at other points.



## 1. Introduction

The permanent relocation of residents (known as "*huntap*") is a form of housing assistance provided by the government to communities affected by the Mount Merapi eruptions. These eruptions occur periodically. Historical data from the 20th century indicates that Mount Merapi can erupt 4 to 6 times in a single year, producing magma and forming lava domes [1]. During the 2010 Merapi eruption, 400,000 internally displaced individuals were evacuated to refugee camps [2]. Settlements located in Disaster Prone Area (KRB) 2 continue to face a high level of vulnerability to eruption disasters. Consequently, it remains likely that new relocation sites will need to be established to accommodate future victims of such disasters.

The relocation shelter was constructed using a participatory approach through *REKOMPAK* program, actively involving the community in both the building and distribution of housing. Long-term community involvement in this process can foster the achievement of sustainable resilience [3]. The *REKOMPAK* program is a national pilot project for Community-based housing reconstruction program [4]. Experience in dealing with disasters also makes the community ready to participate in anticipating the impact of the Merapi eruption [5]. Relocation in Merapi often faces challenges in adapting to the new environment, which affects accessibility and mobility of residents [6]. The housing units have a standardized design, featuring a building area of 36 m² on a 100 m² plot of land. Each unit comprises three rooms: a bedroom, a living room, a family room, and a bathroom.

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The houses are arranged in pairs, with each pair consisting of two housing units [7]

There are 18 Merapi relocation hunting points spread across Cangkringan and Minggir sub-districts (Table 1) [8]. Each housing complex exhibits diversity in terms of unit numbers, capacity, and land area. One distinctive aspect of the Merapi relocation *huntap* is the contoured land due to its location in rural areas on the mountain slopes. The physical and spatial diversity of these shelters is substantiated by data concerning their vulnerability and future development potential. Hence, there is a pressing need for studies aimed at identifying the spatial characteristics of relocation *huntap* settlements.

**Table 1**. Register for Observational Relocation *Huntap*

| Huntap | Huntap |
|---|---|
| Pagerjurang | Gading |
| Dongkelsari | Cancangan |
| Batur | Jetis Sumur |
| Banjarsari | Gondang 3 |
| Kuwang | Jelapan |
| Randusari | Bulaksusukan |
| Plosokerep | Kisik |
| Gondang 2 | Koripan |
| Karangkendal | Gambretan |

Settlement studies related to spatial character studies will depend on the locus of observation. Differences in geographic location will influence the spatial character of a settlement [9]. conducts a study of spatial characteristics in coastal villages. Focuses on areas with coastal morphological conditions using a morphological and behavioral approach [10]. Identifying physical characteristics in Bunaken settlements with a focus on observing physical, social and economic conditions. Whereas [11] study is related to the spatial patterns of settlements on the banks of the Pemulung River [12]. The study investigated the physical and spatial transformation in Kembangsari village, Semarang, focusing on the spatial characteristics of Merapi relocation *huntap* settlements situated in contoured rural and disaster-prone areas. Based on this, there has been no study related to the spatial characteristics of settlements on volcanic slopes. The condition of settlements on the slopes of mountains that have a contour has a direct impact on the movement of residents. Meanwhile, there is a vulnerability to volcanic eruptions, where the disaster mitigation process in the form of evacuation becomes crucial.

The objective was to describe the spatial conditions of these settlements. Understanding the spatial characteristics of Mount Merapi's settlements aims to establish optimal evacuation route schemes and systems. The importance of integration between spatial design of settlements and accessibility to improve sustainability. [13]. This study's findings are anticipated to serve as a scholarly resource through literature reviews for researchers, architects, urban designers, planners, and relevant agencies. They may also provide recommendations to the government for designing shelter settlements in other relocation sites.

## 2. Methods

Research on the spatial characteristics of residential areas was conducted qualitatively using rationalistic deductive methods. Data collection involved literature reviews, cloud data from both primary and secondary sources, and field observations. Land morphology data was sourced from Google Earth data points, including numerical data related to longitude, altitude, and latitude coordinates. These coordinate data points were then processed using the QGIS application to visualise them into a contour map, with base map data sourced from OpenStreetMap. The use of Geographic Information System (GIS) can identify optimal land use patterns [14]. The study focused on 18 Merapi relocation *huntap* settlements. The objects of observation were the populations of these relocation shelters, located in Cangkringan District, Sleman. Each *huntap* displayed a variety of spatial conditions, allowing for the identification of recurring patterns. The classification of certain patterns in the relocation shelters was based on settlement accessibility.

The method employed in this study is descriptive qualitative with a rationalistic deductive approach. Qualitative research focuses on comprehensive exploration efforts in complex environmental conditions, emphasising the correlation between cause and effect. This approach seeks to identify relationships between variables that can form specific recurring patterns [15]. The rationalistic approach is through abstract rational reasoning. It is based on valid logical thinking in the form of accuracy in the researcher's reasoning.[16] Of the 18 housing complexes, they were then classified based on land area and number of units showing a higher level of complexity. The characteristics of relocation shelters are influenced by residential spatial variables as in Table 2.

The spatial characteristics variables of settlements derived from the research literature are listed in Table 2. These variables were then synthesised based on their relation to the accessibility of residential routes, resulting in the variables presented in Table 3.

**Table 2**. Settlement Spatial Character Variables

| Category | Variable | Source |
|---|---|---|
| Building | Building condition, building pattern, building orientation, building density, building distribution | [10][12] [11][9][17] [18][19] |
| Environment | Land use, use, zoning, physical morphology, land form, physical accessibility, circulation | [10][9][18] |
| Infrastructure | Road network, utilities, road patterns | [10][11][12] [20] |

**Table 3**. Spatial Characteristic Variables

| Spatial Characteristics | Variable |
|---|---|
| Building character | Settlement patterns |
| | Building orientation |
| | Building density |
| Land character | Land morphology |
| Accessibility character | Road pattern |
| | Road function |
| | Road visibility |
| Character of preservation facilities | Mitigation facilities |

Settlement patterns, orientation, and building density define the character of residential buildings. The morphology and contour shape reveal the diversity of topographic conditions. The pattern, function, and road visibility influence the accessibility of *huntap* settlements. Mitigation facilities determine the character of supporting infrastructure necessary for planning and responding to disaster situations.

## 3. Results and Discussion

The resettlement settlements are distributed across two sub-districts: Cangkringan and Minggir. The majority of these settlements are located in the Cangkringan sub-district, situated in disaster-prone area 2. This area is highly vulnerable to hazards such as hot clouds, eruptive lava, and heavy ashfall, as depicted in Figure 1. The regions classified as KRB 2 are marked in pink.

The distribution of shelters is illustrated in Figure 2. The KRB (Disaster Prone Areas) map delineates three zones: KRB 3 (red), KRB 2 (pink), and KRB 1 (yellow). KRB 3 represents the zone with the highest vulnerability, encompassing areas at risk of exposure to hot clouds, lava flows, hot rock falls, and poisonous gas. The primary distinction between KRB 3, 2, and 1 lies in their proximity to the volcano's peak and the paths of hot and cold lava.

The majority of *huntap* are situated in the KRB 2 area, as shown on the map. The relocation huntaps are positioned near the original homes of the residents. This proximity is intentional, aimed at ensuring that people feel comfortable by remaining in a familiar environment and allowing them to continue their previous livelihoods. However, this also means that the relocation *huntap* are located in areas with a high level of vulnerability to volcanic eruption disasters.

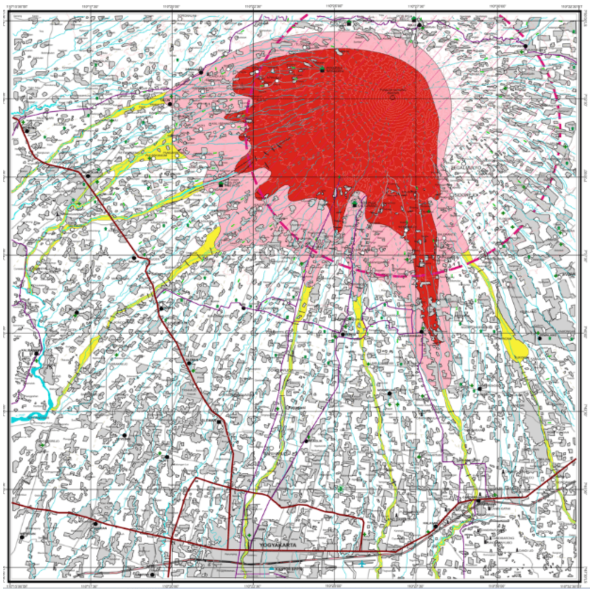

**Figure 1**. Map of Merapi Disaster Prone Areas

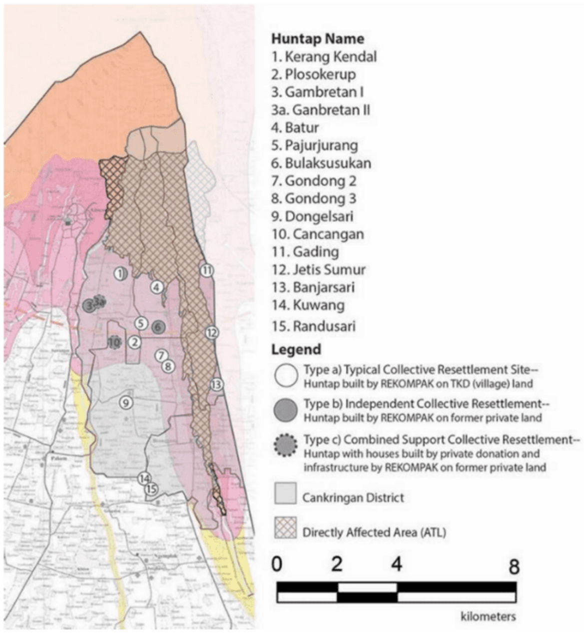


**Figure 2.** Distribution Map of Merapi Relocation Huntap

The relocation shelter house is a type 36 house, covering an area of 36 m² on a 100 m² plot of land. These houses are semi-detached with gable roofs, with every two houses positioned adjacent to each other. The basic model of each residential house includes 2 bedrooms, 1 family room, an outdoor kitchen, and a bathroom as Figure 3. Over time, it has been observed that many of these *huntap* houses transform, including the addition of extra rooms, decorative elements, and different flooring options.

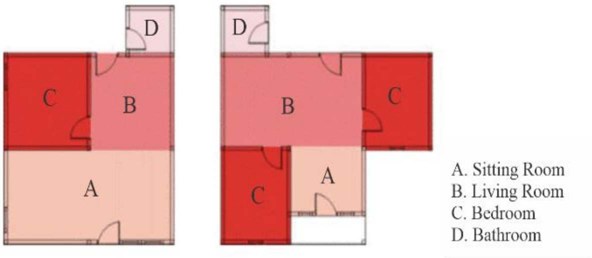


**Figure 3.** Huntap House Plan. 1 bedroom floor plan (left), 2 bedroom floor plan (right)

Residential housing in the relocation areas is designed to meet the basic needs of residents. These houses are built with fundamental specifications, allowing residents to make independent additions as needed. The construction process follows a participatory approach, involving the local community in decision-making. Over 5-10 years, many residents have made additions or renovations to their homes to accommodate their growing space requaritmen

**Figure 4.** Coupling House (Base Model) for Merapi Relocation Huntap

Relocation shelter buildings were observed from settlement patterns, building orientation and density. The size and the settlement pattern of the *huntap* can be observed in Table 4.

**Table 4**. Amount of Relocation Observation

| Huntap | Quantity Data |
|---|---|
| Pagerjurang | Area 66,000 $m^2$; 301 families; distance 9.7 km |
| Dongkelsari | Area 30,050 $m^2$; 207 families; distance 12.3 km |
| Batur | Area 48,900 $m^2$; 204 families; distance 8.4 km |
| Banjarsari | Area 31,350 $m^2$; 177 families; distance 11.9 km |
| Kuwang | Area 23,100 $m^2$; 154 families; distance 14.9 km |
| Randusari | Area 21,866 $m^2$; 110 families; distance 15.1 km |
| Plosokerep | Area 30,300 $m^2$; 89 families; distance 10.5 km |
| Gondang 2 | Area 22,650 $m^2$; 89 families; distance 10.9 km |
| Karangkendal | Area 10,050 $m^2$; 81 families; distance 8.2 km |
| Gading | Area 77,700 $m^2$; 62 families; distance 8.7 km |
| Cancangan | Area 6,895 $m^2$; 58 families; distance 10.5 km |
| Jetis Sumur | Area 12,600 $m^2$; 54 families; distance 10.3 km |
| Gondang 3 | Area 6,000 $m^2$; 36 families; distance 11.2 km |
| Jelapan | Area 39,000 $m^2$; 26 families; distance 15 km |
| Bulaksusukan | Area 2,850 $m^2$; 19 families; distance 10.3 km |
| Kisik | Area 33,000 $m^2$; 14 families; distance 10.6 km |
| Koripan | Area 33,000 $m^2$; 14 families; distance 10.5 km |
| Gambretan | Area 1,200 $m^2$; 8 families; distance 9.3 km |

The building orientation of the residential units faces the road as Figure 4, with each unit having a single facade. This design aims to maximise land use and enhance accessibility efficiency. The next aspect to consider is building density, as detailed in Table 5. Building density is determined by comparing the number of building units to the total residential land area available within the complex. According to indicators from the Ministry of Public Works and Housing (PUPR), a high-density residential area is characterised by a density level of over 200-250 units per hectare. The current density of the huntap settlements falls significantly below this high-density indicator.

**Table 5**. Relocation Density

| Huntap | Density Level (unit/Ha) |
|---|---|
| Pagerjurang | 45.6 units/Ha |
| Dongkelsari | 69 units/Ha |
| Batur | 41.7 units/Ha |
| Banjarsari | 56.5 units/Ha |
| Kuwang | 66.6 units/Ha |
| Randusari | 50.4 units/Ha |
| Plosokerep | 29.6 units/Ha |
| Gondang 2 | 39.4 units/Ha |
| Karangkendal | 81 units/Ha |
| Gading | 8 units/Ha |
| Cancangan | 85 units/Ha |
| Jetis Sumur | 42.8 units/Ha |
| Gondang 3 | 60 units/Ha |
| Jelapan | 6.6 units/Ha |
| Bulaksusukan | 67.8 units/Ha |
| Kisik | 4.2 units/Ha |
| Koripan | 4.2 units/Ha |
| Gambretan | 66.6 units/Ha |

Results of observations and data collection on hunting land morphology. Based on BPBD, it can be seen from the topographic conditions. The highest and closest huntap locations to Mount Merapi are the Karangkendal, Batur and Gading *huntaps*. Meanwhile, the lowest and furthest *huntap* from Mount Merapi are the poinsettia and koripan. In Table 5, it can be seen that each shelter is located on contoured land with elevation differences from north to south. Typical settlements on mountain slopes with densely contoured elevation differences. Contour elevations are taken based on data points from Google Earth which are then processed using QGIS. So we get the contour map results for each relocation *huntap* in the image below.

The relocation resident contour map was made with an elevation difference of 1 meter, the contour conditions of each *huntap* have diversity. If grouped based on contour lines relative to road position. So there are 2 types, namely contour lines perpendicular to the main road and contour lines parallel to the main road. This will affect the level of road steepness. The position of the contour perpendicular to the road makes the road condition steep so that human movement tends to slow down compared to sloping roads.

**Figure 5.** *Huntap* in Pagerjurang Contour Map

**Figure 6.** *Huntap* in Dongkelsari Contour Map

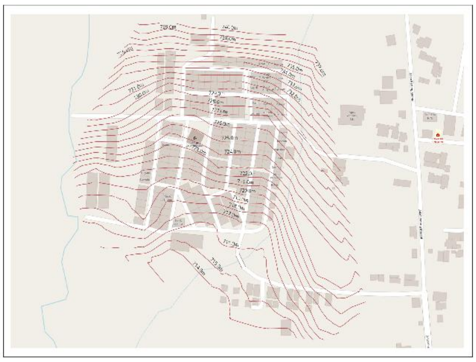

**Figure 7**. *Huntap* in Batur Contour Map

**Figure 8.** *Huntap* in Banjarsari Contour Map

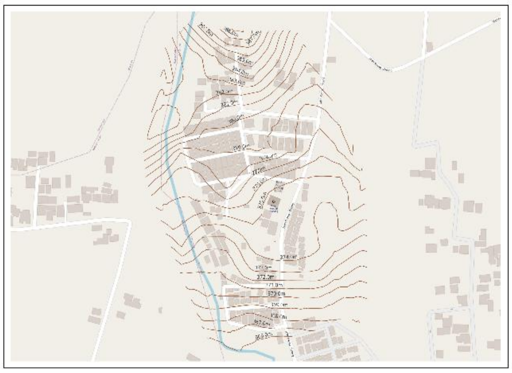

**Figure 9**. *Huntap* in Kuwang Contour Map

**Figure 10.** *Huntap* in Randusari Contour Map

**Figure 11.** *Huntap* in Plosokerep Contour Map

**Figure 12**. *Huntap* in Gondang 2 Contour Map

**Figure 13.** *Huntap* in Karangkendal Contour Map

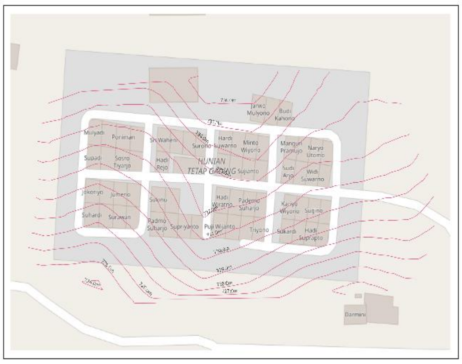


**Figure 14**. *Huntap* in Gading Contour Map

**Figure 15.** *Huntap* in Cancangan Contour Map

**Figure 16.** *Huntap* in Jetisumur Contour Map

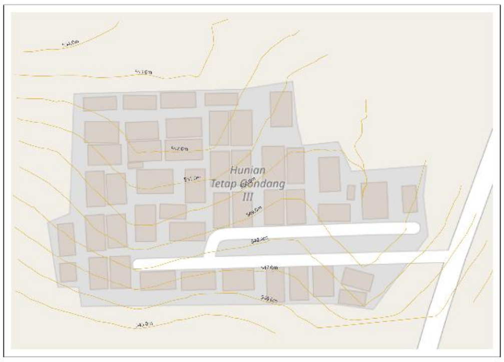


**Figure 17.** *Huntap* in Gondang 3 Contour Map

**Figure 18.** *Huntap* in Jelapan Contour Map

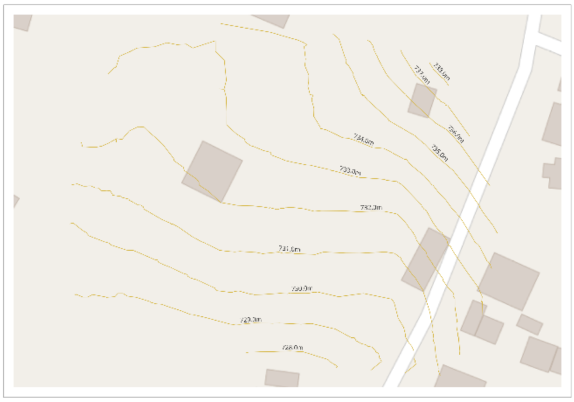

**Figure 19.** *Huntap* in Gambretan Contour Map

The condition of the contours at Huntap Pager Jurang shows that the contour lines are perpendicular to the main road. Huntap with lustre grid pattern. The main road is located on the right edge (can be seen in Figure 5). The main road connects each cluster road. Main road infrastructure is a vital route for the movement of shelter residents [22]. Judging from the contour conditions, the main road is perpendicular to the contour.

The contour of the Dongkelsari *huntap* is quite similar to that of the Pagerjurang *huntap*, with contour lines running perpendicular to the main road, as depicted in Figure 6. However, the building pattern of Huntap Dongkelsari is elongated linearly and divided into two zones, similar to the Plosokerep *huntap* (Figure 11). This elongated shape places a significant load on the main road in terms of accommodation capacity.

Moving to Huntap Batur (Figure 7)ts contour conditions also appear perpendicular to the road, with closely spaced contour lines indicating relatively steep topography. The main road here serves as a crucial evacuation route during volcanic eruptions, highlighting the importance of its condition. Compared to other *huntap*, it exhibits a higher contour line density, which can pose challenges for residents.

The Banjarsari *huntap* (Figure 8) features contour lines perpendicular to the road and follows a grid pattern. Each grid accommodates approximately 12-16 *huntap* units, connected directly to a single-lane main road leading to entry and exit gates on the north-south sides. Similar to Huntap Batur, the steep conditions of the main road impact accessibility.

Moving to Kuwang *Huntap* (Figure 9) and Randusari (Figure 10), sparse contour lines indicate sloping topography, affecting road gradients. Conversely, in *huntap* such as Gondang 2 (Figure 12), Karangkendal (Figure 13), Gading (Figure 14), Cancangan (Figure 15), and Jetisumur (Figure 16), contour lines run parallel to the main road with relatively sparse density, indicating manageable slopes. Despite contoured terrain, these areas offer comfortable movement for residents without significant disturbances.

Huntaps can be classified into two groups based on contour orientation: those perpendicular and those parallel to contour lines. The orientation of contour lines significantly influences the comfort and safety of activities, particularly mobility. Perpendicular contour lines indicate steeper terrain and consequently steeper roads, affecting resident movement and potentially increasing vulnerability during evacuations.

Regarding road patterns in *huntap* areas, the dominant grid pattern is found in housing complexes with square-shaped land nearing maximum capacity. Linear patterns are observed where residential capacity is not fully utilised, while network patterns are seen in elongated, flat complexes nearing maximum capacity.

Roads in huntaps serve dual functions: daily use and evacuation routes. Evacuation routes are crucial during emergencies, designed with single-access direction per shelter to facilitate efficient evacuation.

In terms of road visibility, DK Ching categorises it into frontal, indirect, and spiral. Frontal visibility allows direct viewing of exits without obstructions, indirect visibility allows viewing without direct obstruction, and spiral visibility requires rotation of the line of sight towards exits.

Mitigation facilities at *huntap* shelters include gathering points (Figure 20), evacuation signs (Figure 21), evacuation routes (Figure 22), and patrol posts serving as early warning infrastructure for residents. These facilities enhance disaster preparedness and response capabilities within the *huntap* communities.

Supporting infrastructure at the relocation shelters includes essential amenities such as a mosque, community hall, food stalls, playground, multi-purpose building, cow pen, and reservoir. These facilities are strategically spread across the open areas of the *huntap* settlements. Known as public facilities (fasum), they serve crucial roles in supporting community activities, especially communal gatherings and disaster preparedness efforts.


**Figure 20.** Huntap Assembly Point

**Figure 21.** Evacuation Sign

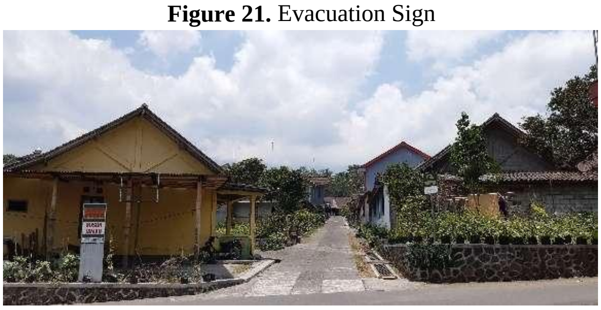

**Figure 22.** Evacuation Route

In housing complexes like those in Cangkringan, public facilities such as communal cow pens are particularly significant due to the prevalence of livestock ownership among residents. During disasters, these facilities play integral roles in mitigation processes, serving as patrol posts, gathering points, aid distribution centres, and safe zones. They are strategically located within the *huntap* complexes, typically in central and accessible areas, facilitating their use by the entire population.

The effectiveness of these public facilities during disasters, such as eruptions from Mount Merapi, underscores their importance in community resilience. The distribution and availability of fasum vary depending on the size of the land area and the number of housing units in each complex. Larger complexes with more units generally have more comprehensive fasum offerings, ensuring adequate support for residents' daily activities and emergency response needs. Detailed distribution maps of these public facilities across different housing complexes can be referenced in Figures 23 - Figure 30, illustrating their strategic placement and role in enhancing community resilience and disaster management capabilities.

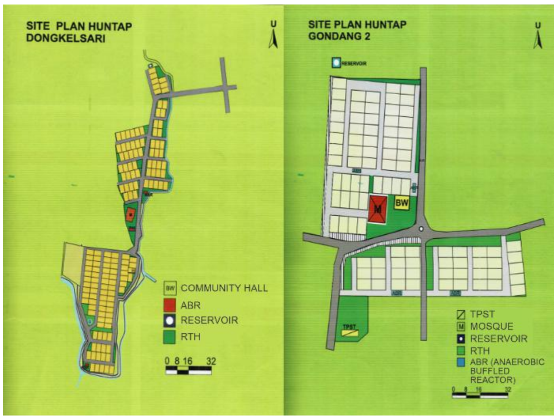


**Figure 23.** Masterplan of Dongkelsari and Gondang 2.


**Figure 24.** Masterplan of Gondang 3 and Batur.

The diversity of the spatial character of the huntap will depend on the level of complexity of the huntap. Based on the analysis results, it was found that the level of complexity will depend on the land area and level of building density. The larger the land area and the higher the density of buildings, the more complex the spatial conditions of housing settlements will be as seen in the form of settlement patterns that emerge, road accessibility and supporting infrastructure. So this study of the spatial characteristics of residential housing complexes looks at the variables that determine the complexity of the residential housing complex. In this way, a spatial character classification was obtained, including housing complexes with low to high levels of complexity. From this explanation, the housing group can be classified as shown in Table 6:


**Figure 25.** Masterplan of Pagerjurang and Kuwang.


**Figure 26.** Masterplan of Plosokerep and Karangkendal.

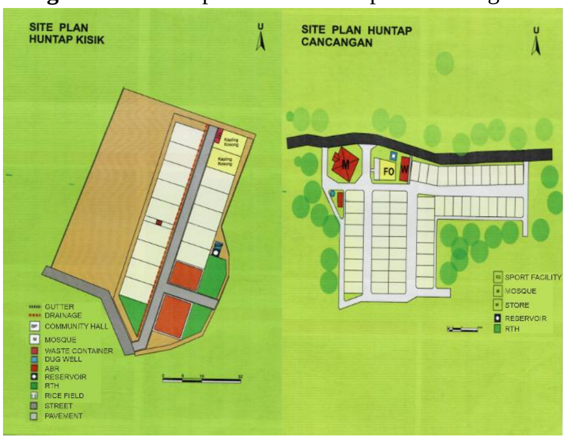


**Figure 27.** Masterplan of *Huntap* in Kisik and Cancangan.

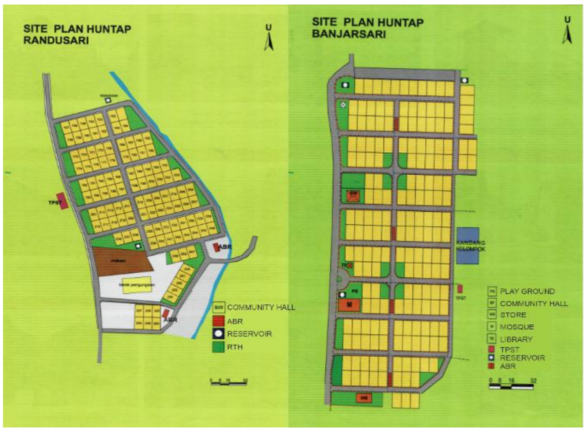


**Figure 28.** Masterplan of Randusari and Banjarsari.


**Figure 29**. Masterplan of Jetis Sumur and Gading.

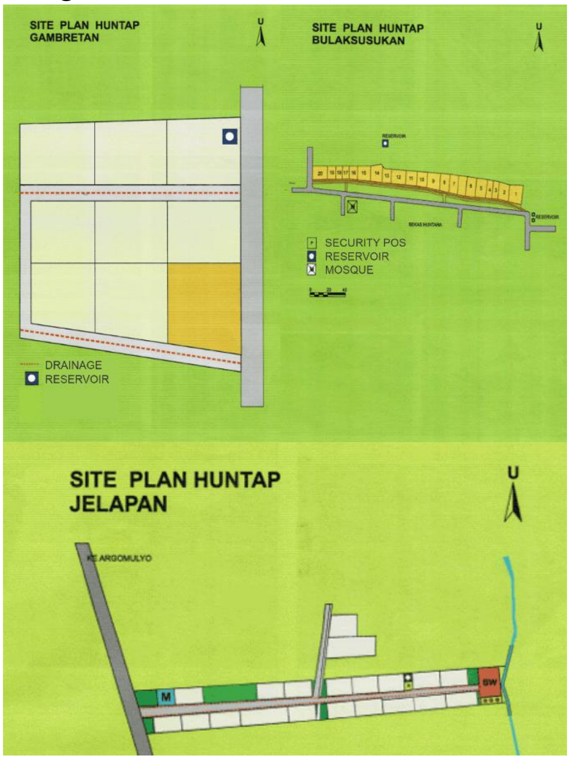


**Figure 30.** Gambretan-Bulaksusukan-Jelapan Masterplan.

**Table 6**. Relocation Huntap Classification

| Huntap Group | Category | Huntap |
|---|---|---|
| Group 1 | Large land, high density | Kuwang, Dongkelsari, Batur, Pagerjurang, Banjarsari, Karangkendal, Gondang 3, Randusari |
| Group 2 | Large land, low density | Gondang 2, jetis sumur, plosokerep, gading, kisik , jelapan |
| Group 3 | Small land, high density | Cancangan, gambretan, bulaksusukan |

### 3.1 Spatial Characteristics of Buildings on Accessibility

One important aspect of resilient settlements is physical resources. Resilient settlements are settlements that are able to face and adapt when a disaster occurs before, during and after [23]. The resilience capability of a settlement is a must. The government through PUPR encourages regions to be resilient. Physical resources are residential resources in physical form. In the context of this study, it is a housing unit building. Identify the spatial character of the shelter building aspect. Aspects of the huntap building consist of building patterns, orientation and building density. The character of the huntap building is then grouped into 3 according to the accessibility of the lanes formed. The accessibility aspect is seen from road patterns and road visibility according to Table 7.

**Table 7**. Spatial Characteristics of Buildings on Accessibility

| | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Building pattern | Grid | Grid | Grid & linear |
| Orientation | The building faces the access road | | |
| Density | Tall | Low | Tall |
| Road Pattern | grids & networks | grids | Grid & linear |
| Visibility Level | low | currently | tall |

Judging from the *huntap* settlement block plan in Figure 5 - Figure 19, there is a tendency for settlement patterns to take the form of grid and linear clusters. The building pattern in a grid shape is arranged as in Figure 31. 1 grid generally consists of 8 to 16 housing units. The grid collection will be connected to the main road as connecting access between the cluster zone and the entry and exit gate to the *huntap* complex. The grid building pattern is the pattern that is considered the most efficient in utilizing residential land.

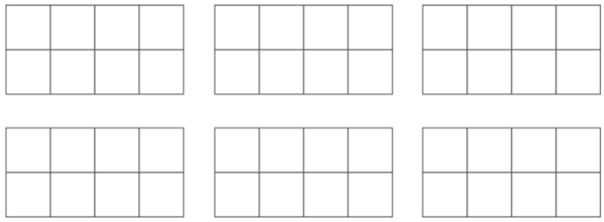

**Figure 31.** Grid Building Pattern

The cluster grid pattern was found in housing units that were already full of unit capacity. tend to be housing complexes with large unit capacities and large land areas. Because the unit capacity is large, housing complexes with a cluster grid pattern have a higher level of complexity. With a grid building pattern, the road pattern is also arranged in a grid form. Grid road patterns have more intersections than linear roads. The more intersections/turns/turning points there are, the potential for population accumulation during the evacuation process. The number of intersections is also directly proportional to the mean of depth huntap. mean of depth is the depth of a point in the huntap complex area leading to the entry and exit gates. The deeper the mean depth, the more segregated the area is, a greater distance is needed to get to the entry and exit gates. The roads on each grid are connected to the main road. So the main road becomes the estuary for every road of housing units. So the main road is one of the keys to determining the success of the evacuation process. When an evacuation occurs, residents will head to the main road before heading to the entrance and exit. Linear patterns are found in housing units that are still developing or not yet at full capacity. Prepared for the next shelter development in the event of population relocation during an eruption disaster. Linear building pattern as in Figure 32.

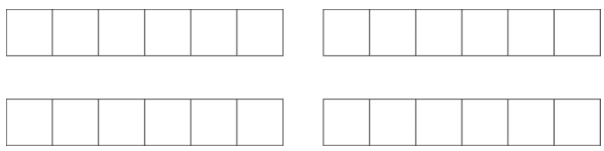

**Figure 32.**Linear Building Pattern

Next is the network-building pattern. The network building pattern is a variation development of the linear pattern. What differentiates it from the linear building pattern is that the network building pattern is linear and divided into 2 central groups of housing units. So there are 2 areas connected by main road access. The network building pattern looks like in Figure 33.

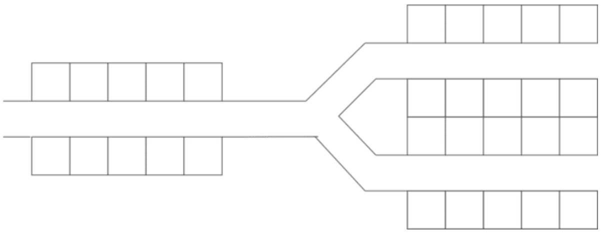

**Figure 33.** Network Building Patterns

The network building pattern will also form a road pattern with a network shape. As seen in image X, the network road pattern is divided into 2 areas. Connecting road intersections are crucial points for the potential accumulation of population density.

Huntap in groups 1 and 2 have a grid settlement pattern. The cluster grid pattern is considered the most optimal pattern to maximize the number of unit capacities. With a grid pattern and high density, the road lines also follow a grid shape. Grid road patterns in dense settlements will create blocks of roads. So the grid pattern will produce many turns/bends in *huntap* settlements. Many turns/bends will create low human visibility because they are blocked by house buildings. Apart from the grid road pattern, in group 1 there are also shelters with a network pattern. This is because the *huntap* flowers are divided into large areas. The network road pattern is composed of linear main roads which are then connected by a grid road pattern between each house. Network road patterns tend to have fewer turns/bends because the building patterns are arranged lengthwise. This results in a higher level of visibility compared to a grid road pattern.

In group 2, stage 1 development starts from a linear pattern first. Filling units on the main road. Then in the next development, they are arranged to form a grid pattern. Low density and large area, grid-shaped road pattern. A grid pattern at low density has better visibility compared to a grid pattern at high density because the house blocks formed and the turns/bends are not as many as in group 1. The group 3 pattern is found in grid and linear form. Grid patterns are found in landforms that tend to be square/equilateral. The linear shape is found on elongated flat land. With the linear shape of the shelter, the visibility of residents is much wider than in the grid form of the shelter. This adapts to existing land availability and forms a grid and linear road pattern. Street patterns, settlement distribution, and evacuation facilities play a key role in designing resilient settlements[24]. So the spatial character of buildings on accessibility will influence the shape of road patterns and the level of visibility in shelter settlements.

### 3.2 Spatial Characteristics of Land Morphology on Accessibility

Spatial morphology that is connected and integrated with a good road network and infrastructure encourages the achievement of resilience[25]. Land topography and accessibility conditions support risk mitigation and emergency evacuation [26]. Based on the results of the study, it can be seen that the entire residential area is in a contoured condition. It can be seen in Figure 5 - Figure 19. There is a diversity of contour shapes in the form of the position of the contour lines relative to the road (perpendicular and parallel) and the density of the contour lines (steep and sloping). It can be seen in Table 8. Topographic contours influence residential building patterns and road patterns. These 2 things also affect the performance of shelters in dealing with disasters. Land morphology is seen from the shape of the land and land contour. The shape of the land is elongated and equal-sided. This landform usually adapts to existing land availability. The contour of the sloping land will depend on the position of the slope to the layout of the buildings and roads. Accessibility is seen from the shape of the road and human movement. The land is elongated or equilateral. Accessibility is an important aspect that can influence the spatial characteristics of a shelter settlement.

**Table 8**. Land Morphology Characteristics on Accessibility

| | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Landform | Elongated | Elongated | Flat/equilateral |
| Contour with the road | Perpendicular | Parallel | Parallel |
| Road shape | Steep | Sloping | Sloping |
| Movement | Slow down | Normal | Normal |

Huntap is on the slopes of Mount Merapi. Groups 1 and 2 tend elongated landforms with elevation contours from north to south. Square/equilateral land shapes tend to be found in 3. The availability of large-sized land is easier to find in elongated land shapes, while small-sized land can still be found in square/equilateral land. The size of the *huntap* land depends on the availability of land found. Huntap land comes from land owned by village/government land or purchased from private land.

Group 1 (Figure 34) has an elongated shape and a road position perpendicular to the contour. Roads that are perpendicular to the contour make the road look steep and make the evacuation process difficult. This road makes the uphill position long, with a long stretch of uphill road making vehicle and pedestrian traffic slower compared to sloping roads. Slow movement creates the potential for congestion to build up at that point.

**Figure 34.** The road of *Huntap* Group 1

**Figure 35.** The road of *Huntap* Group 2

**Figure 36.** The road of *Huntap* Group 3

Group 2 (Figure 35) is a housing complex with an elongated landform and road position parallel to the contour. By positioning the road parallel to the contour, the road becomes sloping. in the context of comfort and safety, it is considered more ideal than group 1 roads. Sloping roads will make it easier for residents to carry out their activities. Population mobility, either by vehicle or on foot, is easier because you don't need to be careful of slipping. With a faster moving speed than steep roads, it can minimize accumulation at certain points when congestion occurs. In group 3 (Figure 36), a housing complex with a square/equilateral land shape, the position of the main road is parallel to the contour and the road is sloping. Roads parallel to the contour of the mountain slope are more effective in reducing evacuation time [27]. So the morphological characteristics of the land influence the accessibility of residential areas in the ease of mobility based on the shape of the road and human movement.

### 3.3 Spatial Characteristics of Preservation Facilities on Accessibility

Roads in relocation shelters serve dual functions: as daily routes and as evacuation routes during emergencies. Each shelter is equipped with an evacuation route within its residential complex, specifically designated for primary mobility during emergencies. These routes facilitate one-way traffic towards the exit gate and are strategically located to ensure easy accessibility for all residents. Typically, evacuation routes are positioned along main roads, centrally or along the sides of the complex.

Three main road patterns are observed in relocation shelters: linear, grid, and network. Linear patterns feature straight or elongated main roads, correlating with a linear settlement layout, often found in simpler Group 3 huntaps. Grid patterns consist of intersecting longitudinal and transverse roads, creating block-shaped areas, commonly seen in Group 1 and 2 huntaps with larger land areas and more units. Network patterns involve a spreading pathway arrangement, typically found in larger huntaps with elongated landforms divided into two large areas.

Preservation facilities, crucial for disaster management, include gathering points, evacuation signs, community halls, and designated evacuation routes. Gathering points are strategically located in open areas with wide visibility along roads leading to exit gates. Their prominent visibility aids residents in easily locating them, facilitating effective wayfinding and mobilisation during emergencies. These points serve as initial meeting places during disasters to coordinate evacuation efforts.

Evacuation signs are strategically placed along evacuation routes within huntaps, guiding residents towards exit gates. These signs play a critical role in directing residents safely out of the area during emergencies, ensuring clear and efficient evacuation procedures.

## 4. Conclusion

The spatial characteristics of *huntap* settlements are influenced by three key factors: *huntap* buildings, land morphology, and preservation facilities, which collectively affect the accessibility of *huntap* settlement roads. These factors interact and vary depending on the complexity level of the *huntap*. The first factor determining the spatial characteristics is the capacity to accommodate residential units. Second, the availability of suitable land influences the building pattern and accessibility within the huntap settlement. For instance, housing complexes in Group 1 exhibit characteristics such as cluster grid building patterns, elongated landforms, high density, large plots of land, and perpendicular contour lines. These tend to have grid-network road patterns with steep gradients and limited visibility due to the grid layout.

In contrast, Group 2 of *huntap* feature grid-building patterns, larger plots of land, lower density, elongated land shapes, and parallel contour lines. These complexes typically adopt grid road patterns with sloping roads and moderate visibility. Group 3 *huntap*, characterized by grid-linear building patterns, smaller plots of land, low density, and contour lines parallel to roads, favour grid-linear road patterns with high visibility and sloping roads.

The importance of main road accessibility and the suitability of housing design to support the sustainability of relocation settlements [28]. To optimise the evacuation process, it is ideal for the main evacuation route to run parallel to contour lines, ensuring a sloping terrain that minimises congestion risks. The building patterns, whether cluster grid or linear, should incorporate open areas between grids to enhance visibility. Minimising intersections in segregated areas and strategically adding entry and exit gates can prevent bottlenecks and congestion during evacuations. These measures aim to enhance the success of evacuation efforts by ensuring efficient and safe movement within *huntap* settlements.

By conducting a study related to the spatial characteristics of the Merapi relocation housing settlement, it can be used as a guideline and recommendation in planning future relocation housing in order to achieve resilient settlements based on the accessibility aspect in responding to emergency mitigation of the Mount Merapi eruption disaster. In practice, it can identify the spatial characteristics of the relocation housing settlement through vulnerability mapping. So that certain treatments or engineering can be carried out to minimize the potential risks when designing new relocation housing. Scientifically, it can add to the scientific treasury in the field of architecture, especially regarding the housing and settlement study group in the form of studies related to the spatial characteristics of settlements.

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