Settlement Suitability Analysis Based on the Catastrophic Eruption of Sinabung

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Abstract. Mount Sinabung is an active volcano after being 'dormant' for a long time since the 1600s. Sinabung has begun to show its activities from 2010 to 2020, so that it has a long impact on community activities, damage to settlements, agricultural and threats to the lives of residents around Sinabung. This study aims to determine the conditions of land use in disaster-prone areas in relation to spatial patterns and levels of disaster prone. The research method is carried out through spatial analysis by overlaying the land use map with the spatial planning map to produce a land use suitability map. The spatial pattern suitability map is overlaid with a disaster hazard map to determine the level of security in settlements. The results showed that 5 affected Districts, namely in the Districts of Naman Teran, Payung, Simpang Empat, Tiganderket, Munte, the safe zone was 145.66 hectares, the less safe zone was 0.98 hectares, the unsafe zone was 36.91 hectares and the very insecure zone was 1.25 hectares. It is hoped that the spatial analysis regarding the distribution of safe locations for settlements is expected to become a policy material for the government to formulate arrangements for the use and utilization of space so that the spatial planning policies that are established are in line with efforts to reduce the risk of the eruption of Mount Sinabung disaster.

1. Introduction
Mount Sinabung is one of the active volcanoes in Indonesia [1], it was recorded that it had never erupted since 1600 (Strato volcano type B) [2], but this volcano showed eruptive activity on August 27, 2010 (changed to GA Strato Type A), November 2013, June 2015, May 2016, February - April 2018 and until now 2020 [3], [4]. This prolonged disaster began with an eruption in 2010 which activated a shallow active hydrothermal system [5]. The eruption then triggers and activates the deep hydrothermal system so that the eruption occurs in a prolonged manner [6]. The prolonged eruption with a very strong eruption force that produced lava and pyroclastic deposits from 2010 to 2015 amounting to approximately 2.89108 m³ impacted damage in several areas including 5 (five) districts, namely Naman Teran, Payung, Tiganderket, Simpang Empat, and Munte in Karo, North Sumatra Province [7], [8], [9]. The extent of the impact of damage and losses caused by the eruption is due to the fact that the community considers Mount Sinabung to be inactive, so that residents live and depend on the agricultural sector with a radius very close to the peak of Sinabung [3]. As the most active mountain, the eruption has an impact on the area up to a radius of ± 7 kilometers from the peak causing residents to lose their homes and infrastructure, damage and disappearance of agricultural land and livestock, damage to plantation crops [10], [11], [12], decreased income in the tourism sector [13], health problems due to volcanic ash [14] and loss of other assets, which required residents to evacuate and be relocated to a safer place [15], [16].
The main livelihood condition of the majority of the community as farmers where land and agricultural crops are damaged has implications for decreasing farmer income levels [17], [18].

The threat of the Sinabung eruption always threatens all the time, but the current condition is that there are still some residents who have not moved from their homes and their cultivated land, one of which is in part of the Guru Kinayan Village area. Socio-economic reasons make the community persist in the red zone radius so that there are still exposed people who are likely to be at risk if an eruption occurs [16]. As a disaster mitigation effort, the government has designated a radius of 3 km, 4 km to 5 km (red zone) Sinabung as the zone that must be vacated considering the threat of the impact of pyroclastic flows due to eruptions is very high [19], [20]. This relocation effort by the government was carried out through several stages, Phase I (residents of Sukameriah, Beekerah, Simacem Villages) with a total of 370 households for houses and 457 households in the form of farming land in Siosar Village [21], independent relocation Stage II (residents of Gurukinayan, Berastepu, Gamber, Kuta Tonggal Villages) with a total of 1,679 families and agricultural land have also been completed, while relocation Phase III (Sukanalu, Sigarang-garang, Mardinding, Lau Kawar) until 2019 is still incomplete for 892 residents or ± 3,500 people [22]. The difficulty of obtaining the availability of land that is safe from eruptions, land with clear and clean conditions for relocation is one of the obstacles to resettlement for victims of eruptions. In addition, high land prices and the unavailability of basic infrastructure for settlements make it difficult for residents to carry out independent relocation [16]. This condition results in the presence of people living in refugee camps and people who are still carrying out economic activities in the red zone [19].

The vulnerability of people living or farming in locations close to the center of the eruption requires the right solution [23], considering the number of victims due to hot cloud attacks that occurred in 2010 as many as 4 people died and 405 were injured, while in 2014 the number of victims increased to 17 people due to pyroclastic flows, and than in 2016 the Sinabung eruption caused 9 fatalities [24]. Regulating the functions and utilization of space through the determination of Spatial Planning Regulation (RTRW/RDTR) and proper zoning arrangements in disaster-prone areas is certainly one of the right solutions so that losses and casualties can be prevented [25], [26], [27]. In addition, monitoring efforts on the suitability of land use against predetermined spatial patterns and control of land use and utilization, especially in disaster-prone areas are the key so that the available space is able to support and create sustainable life [28], [29], [30]. The study aims to present a spatial analysis of the conditions of settlements around Mount Sinabung, to determine the level of suitability of settlements with spatial patterns, and to determine the level of security of settlements from disaster threats.

2. Method

This research was conducted through a spatial approach with an overlay technique to place one map graphic on top of another map graph and display the results in a new map. This method is able to combine digital data and its attributes so that it can produce a combined map of the two by having attribute information from the two maps. Some of the maps used in this study include land use maps, spatial planning maps and Mount Sinabung eruption hazard maps. The existing land use map is obtained through interpretation of satellite images from the SAS Planet providing. In this study, the land use classification is adjusted to the needs of the analysis so that land use is classified into residential and non-residential. Meanwhile, the spatial map was obtained from GISTARU data/information system about spatial planning from the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency. This map provides spatial information regarding the distribution of directions for the use and utilization of space in the area around Mount Sinabung, especially directions for settlement locations. In order to provide direction for safe settlements from disasters in this study, a disaster-prone map determined by the Karo District Disaster Management Agency is used. The determination of safe areas is also based on several literature reviews by researchers related to the direction and impact of the Sinabung eruption that occurred from 2010 to 2021. The flow chart in this study is presented as follows:
Based on the flow chart above, the overlay method is carried out between the land use map and the spatial plan map. From this overlay, it is obtained empty land that is still available for settlements where the location in the RTRW directions is used as a settlement. Furthermore, the overlay result in the form of a map of land availability for settlements is overlaid with a disaster-prone map to map the spatial distribution of the availability of settlements with the level of disaster security. From the results of this overlay, it is obtained the spatial distribution of settlement directions in accordance with the spatial layout and safe from the disaster location. And the final result of this analysis produces 4 criteria settlement security level, namely: Criteria 1) the location is available and safe from disasters; 2) The location is available but less safe; 3) the location is unsafe; 4) the location is very unsafe.

3. Result and Discussion

3.1. Mount Sinabung Eruption Prone Areas

Karo Regency has 16 (sixteen) sub-districts in total and there are 5 (five) sub-districts included in the eruption-prone area of Sinabung. We can observe this based on the map of the eruption-prone areas of Mount Sinabung which is overlaid with the administrative boundaries of Karo Regency as presented in Figure 2.
The following districts are included in the Disaster Prone Area (DPA) to the eruption of Mount Sinabung:

**Table 1. Area of Sinabung Eruption Prone District**

| No | Sub-district          | DPA I (M²) | DPA II (M²) | DPA III (M²) | Non DPA (M²) | Total (M²) |
|----|-----------------------|------------|-------------|--------------|--------------|------------|
| 1  | Munte                 | 185.99     | -           | -            | 13494.36     | 13680.35   |
| 2  | Naman Teran           | -          | 1124.47     | 2383.29      | 4469.58      | 7977.34    |
| 3  | Payung                | 388.41     | 779.61      | 1185.61      | 737.55       | 3091.17    |
| 4  | Simpang Empat         | -          | 1239.41     | 662.47       | 5393.87      | 7295.75    |
| 5  | Tiganderket           | 383.00     | 663.25      | 1742.71      | 9536.71      | 12325.67   |
|    | **Total**             | **957.40** | **3806.73** | **5974.08**  | **33632.07** | **44370.28** |

Source: Data Analysis 2020

As the most active volcano since 2010, the eruption that occurred has characteristics with different destructive forces and impacts. The characteristics and impacts of the Sinabung eruption can be presented as in table 2 below:

**Table 2. Characteristics of Eruption and the Impact of the Sinabung Eruption**

| Year | Eruption Characteristics                                                                 | Casualties and displacement | Damage                                                      |
|------|-----------------------------------------------------------------------------------------|------------------------------|------------------------------------------------------------|
| 2010 | Freactive eruptions, followed by magma activity in the form of explosive materials: ash/dust, bombs, lava flows to the east-southeast reaching a radius of up to 2 km. Affected areas (Sukameriah, Gungpitu, Sigarang-garang, Sukodebi and Susuk villages) | 1 died ± 28.756 people evacuated | Damage to agricultural land and people’s settlements         |
| 2013 | Volcanic type magmatic eruption, by throwing volcanic material as high as 10,000 m, followed by hot clouds with a sliding distance of up to 1500 m, ash rain spreads up to 5 km | ± 19.286 people evacuated | Damage to agricultural land (33,586.6 Ha) in 7 districts & damage to houses up to 5000 buildings. |
| 2014 | Magmatic eruptions of volcanic and merapi types, volcanic material as high as 5000 m, glide of hot clouds reaching 2 - 4 km to the south. | 17 people died, 33.210 people evacuated | Damaged settlements, agriculture in 7 districts, loss of food and horticultural crops covering an area of 2,959 hectares, singed a forest out to at least 3.9 Km |
| 2016 | Radius of hot clouds reaches up to 4 km                                                  | 9 people died (activities in the red zone), 11.113 Evacuated | Damage to agricultural land                                 |
| 2017 | Hot clouds bursting up to a radius of 4.6 km                                             | ± 7.255 people. Evacuated | Damage to community agricultural land                        |
| 2018 | Bursts of volcanic material as high as 5.000 m, rain of rocks to Kec. Munte              | ± 100 people Evacuated | Damage to community agricultural land                        |
The biggest eruption with volcanic material bursts as high as 7 km, hot cloud radius of up to 3.5 km. Areas affected by volcanic ash Mardingding, Naman Teran, Merdeka and Brastagi - 7,256 people displaced. Damage to agricultural land is widespread because it is covered in ash.

The height of the ash column is ± 5000 m, the areas affected by the volcanic ash of Naman Teran, Berastagi, Simpang Empat and Merdeka District - ± 1.483 Ha of crop failure in Namanteran, Merdeka, Berastagi and Dolat Raya.

Source: Kusumayudha (2018), Indonesia Disaster Information Data (2020), Pallister (2019), Yulianto (2016)

Based on figure 2 shows that pyroclastic flow are the result of volcanic eruptions which are very dangerous and result in high casualties [32]. The Sinabung eruption that occurs quite often and it is not known when it will stop has had a wide impact on the villages around the dome of Mount Sinabung, the worst damage was in villages on the south, east and southeast sides which were influenced by the shape of the dome on the open side [33]. Data on villages that were affected by the Sinabung Eruption were quite severe, where some or even all areas were covered by volcanic material including:

| No | District   | Village                        | Village with the worst impact & relocated          |
|----|------------|--------------------------------|---------------------------------------------------|
| 1  | Naman Teran| Bekerah, Simacem, Kuta Tonggal, Sigarang-garang, Lau Kawar, Sukanalu, Kutarakyat, Kebayaken, Kutambulelin, Kutagugung. | Bekerah, Simacem, Kuta Tonggal, Sigarang-garang, Lau Kawar, Sukanalu |
| 2  | Simpang Empat | Berastepu, Gamber, Kuta Tengah, Sibintun | Berastepu, Gamber, Sibintun |
| 3  | Payung      | Sukameriah, Guru Kinayan, Berastepu, Selandi, | Sukameriah, Guru Kinayan, Selandi, |
| 4  | Tigan Derket | Mardinding, Perbaji, | Mardinding |
| 5  | Munte       | Kutambaru, Muntehe | |

Sources: Several Online Media, Karo Regency Website, Interpretation of Google Earth Imagery (2020).

Naman Teran is an area that is experiencing the most severe conditions on the south, east and southeast side of the mountain, where the direction of the dome and pyroclastic flow directly leads to this area. Several villages that were severely damaged in this sub-district had been relocated in stage 1 and stage 2 considering that the residential conditions were already covered in very thick volcanic material and were always affected by the attack of pyroclastic flows. While the sub-district that experienced the least impact of damage was in Munte District, where this location is not directly facing Mount Sinabung and this location is in a fairly far radius from the peak of Sinabung, but in Kutambaru Village it is passed by a river that carries erupted pyroclastic material. Sinabung so that this village is quite vulnerable. In a large eruption with volcanic material bursts as high as 5000 m in 2018, rain of rocks and gravel reached up to Kutambaru and Kutarakyat villages, this shows that the impact of the Sinabung eruption was fluctuating.

3.2 Land Use in the Mount Sinabung Eruption Prone District

Land use has an influence on the high level of vulnerability and risk that can be caused by disasters. The more land use mismatches in disaster-prone areas, especially the red zone, the higher the level of vulnerability and risk that will be borne by the community. As happened in Sinabung, the improper use of land (settlements and agricultural/plantation land) in the red zone resulted in a high number of casualties, losses and damage as well as many people who had to flee due to the eruption. In this study, land use is determined based on the land cover obtained from the interpretation of the downloaded
satellite images using the SAS Planet application with the selection of image sources from Bing Satellite. Based on image interpretation, land use classification is divided into two types, namely land use for residential and non-residential areas, land use maps are presented in Figure 3 below.

![Figure 3. Land Use Map in Affected Districts. (Source: Data analysis 2020)](image)

Based on image observations, it shows that land use for settlements in these five districts is still low, this is influenced by the level of population density in this area only in the range of 172.36/Km² to 266.89/Km², this figure is much lower when compared to The population density in Kabanjahe District reached 1725.69 Km² [34].

Table 4. Land Use

| No | District         | Land Use               |
|----|------------------|------------------------|
|    |                  | Resettlement (Ha) (%) | Non Resettlement (Ha) (%) |
| 1  | Munte            | 177.68 1.30            | 13502.67 98.70            |
| 2  | Naman Teran      | 74.96 0.94             | 7902.38 99.06             |
| 3  | Payung           | 74.68 2.42             | 3016.49 97.58             |
| 4  | Simpang Empat    | 131.76 1.81            | 7163.98 98.19             |
| 5  | Tiganderket      | 94.11 0.76             | 12231.56 99.24            |
|    | **Total**        | **553.20 1.44**        | **43817.08 98.56**        |

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3.3 Suitability of Land Use in Districts Affected by Mount Sinabung Eruption

Land use suitability analysis is an effort made to see the suitability of a land use with the spatial pattern plan determined by the Regional Government. This spatial pattern map functions to regulate the use and utilization of space including activities on it. Spatial data related to spatial patterns in these 5 districts is presented in the following figure:
Figure 4. Karo Regency Spatial Plan Map  
(Source: Karo District Government)

In the Karo Regency spatial pattern plan, it has been regulated that an area with a radius close enough to Sinabung is designated as Disaster-prone areas/DPA III, where this area has vulnerability and vulnerability to pyroclastic hazards. However, in this area there are still uses of land in the form of settlements or agricultural land cultivated by the community as a supplier of food/horticultural needs for Karo Regency. The spatial pattern as shown in Figure 4 shows that in the DPA III and DPA II areas the RTRW directions are designated as protected areas with the function of providing local protection against the impact of eruptions, while for residential areas, dry land agricultural land and wetlands the spatial pattern is set at a fairly far and safe from the impact of the eruption. This study of land use analysis focuses on settlements, by dividing the level of suitability of land use into 3 (three) categories, namely appropriate, unsuitable, and others. The explanation of the three categories is as follows:

(a). Appropriate means that the use of the land is the same as the spatial pattern plan (especially for settlements).

(b). Unsuitable means that the use of the land is not the same as the spatial pattern plan (especially for settlements).

(c). Miscellaneous means that land use is not assessed in this study, it may or may not be appropriate. This condition is because this research is limited/focused on the study of the suitability of land use in the form of settlements only.
Based on the analysis of the suitability level of land use, the level of suitability of residential land use is obtained as follows:

**Table 5. Suitability of Settlements with Spatial Patterns in Karo District**

| No | District      | Suitable (Ha) | (%) | Unsuitable (Ha) | (%) |
|----|---------------|---------------|-----|-----------------|-----|
| 1  | Munte         | 34.96         | 18.3| 190.94          | 84.5|
| 2  | Naman Teran   | 26.67         | 33.5| 79.44           | 74.8|
| 3  | Payung        | 33.82         | 49.8| 67.83           | 66.7|
| 4  | Simpang Empat | 62.36         | 28.6| 217.35          | 77.7|
| 5  | Tiganderket   | 26.98         | 28.06| 96.12           | 78.1|
|    | **Total**     | **184.80**    | **22 %**| **651.68**    | **77.9 %**|

(Source: Data Analysis 2020)

The table above shows that more land uses for settlements are not in accordance with the predetermined spatial pattern. As in Naman Teran, Simpang Empat, and Payung Subdistrict as areas very prone to settlement mismatches reached 77.7%. This condition has resulted in the post-eruption of the community having to do relocation because residents' settlements were destroyed by the eruption. The quite high mismatch of residential land use in this area can occur due to a lack of socialization in land use regulation or it can also occur due to low control and monitoring of spatial functions.

### 3.4 Safe Zone for Settlements in Affected Districts Prone to Eruption of Mount Sinabung

It should be noted that any land use for settlements that is in accordance with the spatial pattern plan is not necessarily safe for areas prone to eruption of Mount Sinabung. This condition could occur due to the preparation of the RTRW which probably paid less attention to disaster mitigation aspects or could also be caused by the impact of the damage caused by the Sinabung eruption that was expanding, resulting in changes in the level of disaster hazard. Therefore, in determining a safe and sustainable
settlement in previous studies, the variable that must be considered is the security aspect of the threat of disaster [35]. As happened in Karo District, the Map of Disaster Prone Areas (DPA) issued by the National Disaster Management Agency (BNPB) was updated in 2015.

Based on the nature of the eruption and the condition of Mount Sinabung, the potential dangers of an eruption that may occur include: pyroclastic flows (hot clouds), pyroclastic falls (throwing incandescent rocks and ash rain), lava flows and lava. Based on the potential hazards that may occur, the disaster-prone areas of Mount Sinabung can be divided into three levels of vulnerability from low to high, namely: Disaster Prone Area I, Disaster Prone Area II and Disaster Prone Area III.

a. Disaster-prone area III (DPA III) is an area that has the potential to be affected by hot clouds, lava flows and avalanches, throwing rocks (incandescent), heavy ash rain and poisonous gases. The disaster-prone area III (DPA III) of Mount Sinabung is located at a radius of ± 1.5 Km consisting of two parts, namely:
   1) Areas prone to disasters from mass flows (hot clouds, lava flows and avalanches), and poisonous gases.
   2) Areas prone to disasters due to rock throwing materials (incandescent) and heavy ash rain.

b. Disaster prone area II (DPA II) is an area that has the potential to be affected by hot clouds, lava flows, lava avalanches, throwing rocks (incandescent) and heavy ash rain, this area is located at a radius of about 5 km from the eruption center. This area is divided into two parts:
   1) Areas prone to mass flows (hot clouds, lava flows and avalanches).
   2) Areas prone to disasters due to throwing stones (incandescent) and heavy ash rain.

c. Disaster-prone area I (DPA I), is an area that has the potential to be affected by lava flow / flooding and may be exposed to expansion of lava / hot clouds. DPA I to flow is located along the river or valley. In DPA I there is still the possibility of pyroclastic falls ejecting incandescent stones or falling fragments < 2 cm [36].

To map the level of the safe zone for settlements, it is carried out through an overlay of land use maps for settlements that are in accordance with the spatial pattern plan against the map of the eruption-prone areas of Mount Sinabung. The zone classification of residential security levels in accordance with the spatial pattern plan is divided into 4 (four) categories, namely Safe, Less Safe, Unsafe, and Very Unsafe. The following is the classification of the four categories:

a. The safe category is obtained if the use of land for settlements that is in accordance with the spatial pattern plan does not overlap with the area prone to eruption of Mount Sinabung, be it DPA I, II, or III.

b. The less safe category is obtained if the use of land for settlements is in accordance with the spatial pattern plan that overlaps with the eruption-prone area of Mount Sinabung DPA I.

c. The unsafe category is obtained if the use of land for settlements is in accordance with the spatial pattern plan that overlaps with the eruption-prone area of Mount Sinabung DPA II.

d. The very unsafe category is obtained if the use of land for settlements is in accordance with the spatial pattern plan that overlaps with the eruption-prone area of Mount Sinabung DPA III.

The results of the mapping of settlement security levels against the threat of the Sinabung eruption based on the DPA map are presented as shown in map 6 below.
Based on Figure 6 above, it shows that the distribution of settlements that are in accordance with the spatial plan but still in the DPA III and DPA II zones is still there, while the detailed data on the distribution of settlement security levels from disaster threats is presented in Table 6.

**Table 6. Settlement Security Levels in Five Districts**

| No | District       | Safe (Ha) | Safe (%) | Less Safe (Ha) | Less Safe (%) | Not Safe (Ha) | Not Safe (%) | Very Not Safe (Ha) | Very Not Safe (%) |
|----|----------------|-----------|----------|----------------|---------------|---------------|--------------|-------------------|------------------|
| 1  | Tiganderket    | 8,94      | 33,12    | 0,00          | 0,01          | 17,69         | 65,58        | 0,35              | 1,29             |
| 2  | Simpang Empat  | 58,05     | 93,10    | 0,00          | 0,00          | 3,40          | 5,45         | 0,90              | 1,45             |
| 3  | Payung         | 25,10     | 74,23    | 0,56          | 1,64          | 8,16          | 24,13        | 0,00              | 0,00             |
| 4  | Naman Teran    | 19,02     | 71,30    | 0,00          | 0,00          | 7,66          | 28,70        | 0,00              | 0,00             |
| 5  | Munte          | 34,54     | 98,79    | 0,42          | 1,21          | 0,00          | 0,00         | 0,00              | 0,00             |
|    | **Jumlah**     | **145,66**| **74,11**| **0,98**      | **0,57**      | **36,91**     | **24,77**    | **1,25**          | **0,55**         |

(Source: Data Analysis 2020)

The results of the analysis of the existing conditions in these 5 districts, there are still settlements that are currently in very unsafe condition, namely in the Simpang Empat and Tigan Derket Districts, although in small percentages. Meanwhile, the existence of people living in unsafe conditions, namely in the DPA II area, is also still found in 4 Districts, namely in Tiganderket, Naman Teran, Payung and Simpang Empat where the four Districts have previously carried out relocation of their residents. It is hoped that the distribution of security levels for residential settlements in 5 districts is expected to become a database to formulate appropriate disaster mitigation policies so that the level of disaster risk...
can be reduced. The relocation of the community in DPA III and DPA II which are likely to be affected by the pyroclastic threat is very necessary, considering that there is no other mechanism besides relocation to avoid the threat of this deadly disaster. Relocation of people who are in locations prone to eruptions are also carried out in communities around Mount Merapi Volcano and communities around Mount Manyon, Philippines [37], [38]. Based on the results of this study and resettlement studies on cases in Merapi, San Vicente Volcano El Salvador and Manyon Volcano the Philippines, relocation efforts emphasize the importance of community involvement, security from disaster threats, sustainable livelihoods and availability of public facilities [37], [38], [39].

Adaptation patterns and public awareness not to build resettlement areas that have been affected by the eruption need to be encouraged by enforcement of regulations through detailed spatial plans and zoning which function the disaster prone area as a non-residential zone and as a protection zone for the local area. Relocation efforts by providing land that is safe from disasters, clear and clean as well as efforts to restore community life by providing agricultural land that is in accordance with the capacity of the land as well as various assistance and assistance for the affected communities are needed so that the community is able to realize a safe and sustainable life.

4. Conclusion

The phenomenon of Sinabung as a 'sleeping' volcano for ± 400 years has implications for the community to live and cultivate agricultural land with a radius very close to the eruption center. This has resulted in a very high number of casualties, losses and damage due to the eruption from 2010 to 2020. This study shows that in 5 (five) districts affected by land use in the form of settlements, it reaches 553.20 Ha. Meanwhile, from this area, the mismatch level of settlements with spatial patterns reached up to 77.9 %, where this condition mostly occurs because people live in areas that are very prone to disasters/DPA III. Based on the data on the suitability level of settlements with the spatial plans overlayed with the DPA map, it shows that there are still settlements (0.5%) in very vulnerable areas, namely in Tiganderket and Simpang Empat Districts. Settlements that are in unsafe conditions (at DPA II) also still exist, covering an area of 36.91 hectares in 4 districts, namely in Tiganderket, Namateran, Simpang Empat and Payung. Disaster mitigation efforts through relocation of people who are in very unsafe zones are the best alternative considering the ability of any technology has not been able to overcome the impact caused by eruptions in the form of pyroclastic flows, one of which is a hot cloud. In this context, disaster mitigation as outlined in the spatial plans regulation is very necessary so that the available space is able to support the security and sustainability of people's lives. Research development related to ideal spatial planning to support disaster mitigation efforts needs to be done so that the spatial plan that is prepared is capable of realizing sustainable development.

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