Suitability of Post-Disaster Coastal Land Cover with Spatial Pattern Plan of Palu City

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Abstract. The population growth in Palu City has implications for increasing the need for developed land, especially after complex natural disasters in 2018. After these disasters, another impact was the need for the construction of temporary and permanent housing. Therefore, it is essential to adjust the land use with disaster-prone zones. This study aims to analyze the distribution of land cover in the Disaster-Prone Zone and the suitability of the Spatial Plan with the Disaster-Prone Zone. The method used is quantitative through spatial analysis using ArcGIS 10.5 software. The results showed that Disaster Prone Zone 2 is the most dominating zone in both the type of built-up land cover and vegetation so that it still had development opportunities. However, the suitability of the Spatial Planning with Disaster Prone Zone shows that Disaster Prone Zone 4 is still included in the spatial plan as a developed area.

1. Introduction

Indonesia is a country that often experiences natural disasters; based on Indonesian disaster information data (DIBI), the BNPB in 2019 stated that as many as 3,885 natural disasters occurred in Indonesia from 2018 to 2019. These disasters caused many fatalities, namely the number of people who died and disappeared due to natural disasters from 2018 to 2019 were 4814 people [1]. Various kinds of natural disasters ranging from tsunamis, earthquakes, floods, and others, cause various impacts on the environment and human. Based on DIBI, Indonesia was hit by two tsunamis from 2018 to 2019 and 2 earthquakes and tsunamis, with different impacts in each city. If calculated from 2000 to 2019, Indonesia was hit by natural earthquakes 213 times and seven times followed by tsunami natural disasters. Currently, no districts/cities are free from the threat of disasters, and more than 254 million people are also threatened in medium and high disaster risk [1].

Palu City is the capital city of Central Sulawesi province. Based on data from the Indonesian Disaster Risk Index (IRBI) by BNPB, it is included in Indonesia's cities with high disaster risk. It is 162.70% with the type of disasters: floods, earthquakes, forest and land fires, landslides, flash floods, and tsunamis [2]. The complexity of the disaster in of Palu City is caused by its position at the confluence of three plates, namely Indo-Australia, Eurasia, and the Philippines, making it a disaster-prone area in Indonesia [3]. In addition, other factor is also because it is located on the Palu Koro fault which is a fault in the earth's crust (fault) of which dimensions are pretty large and the earthquake activity cluster is relatively high [4]. It caused Palu City in 2018 experiencing a natural disaster that was able to turn off the activities of its people for months.

Palu City in 2018 had experienced complex natural disasters, namely earthquakes, liquefaction, and
tsunamis. This natural disaster caused 2673 dead and missing victims as well as destroyed tens of thousands buildings [1]. Based on data from BNPB (2018), the tsunami and earthquake that hit the city of Palu caused 18,107 buildings to be heavily damaged, including public facilities. Even though these natural disasters took many lives, based on data from the BPS Palu City, it was stated that in the last 20 years, the population growth in Palu City continued to increase, previously 269,083 people in 2000, increasing to 336,532 people in 2010, and in 2020 increasing as many as 373,218 people. It is, of course, a consideration in structuring the built-up area in Palu City so that it is not in a disaster-prone area.

Population growth that continues to increase will be in line with the need for land. Especially after the 2018 disaster, the need for land to build temporary houses, permanent houses, public facilities, and social facilities damaged after the disaster also increased. Thus, the following planning needs to pay attention to the suitability of development with disaster-prone areas. Several previous studies, it can be concluded that looking at the change and suitability of post-disaster land. There are land changes in Palu City, primarily related to the decline in the quality of agricultural land after the disaster; there is even a condition of heavily damaged agricultural land. Then, there is a mismatch of land, especially settlements with disaster-prone areas, even in areas where it is recommended that there are no development activities [6]. Thus, the debate is still centered on the impact that the 2018 disaster had on land conditions on a small scale. This study will discuss the comprehensive suitability of post-disaster land in Palu City, especially with the development plans for the Palu City in the future. Therefore, the purpose of this study is to analyze the distribution of existing land cover with disaster-prone areas and the suitability of spatial patterns with disaster-prone areas. In the future, it can increase the resilience of Palu City.

2. Method
This study uses a qualitative method, with an implementation time of one month, including data collection to analyze. The research method includes an explanation about research location, data collection, and data analysis.

2.1. Study Area
The location of the study was on the coast of Palu City, Central Sulawesi (Figure 1). Palu City is located between the Palu valley and Palu Bay, located at a position of 0°.36" - 0°.56" South Latitude and 119°.45" - 121°.1" East Longitude. The location is determined through the villages in Palu City, located on the coast of Palu Bay. The villages located on the coast of Palu City are Watusapu Village, Buluri Village, Tipo Village, Silae Village, Lere Village, West Besusu Village, Talise Village, Tondo Village, Layana Indah Village, Mamboro Village, Taipa Village, Kayumalue Village, Panau Village, Baiya Village, and Pantoloan Village.

2.2. Data Collection and Analysis
Data collection is done by collecting secondary data. The data used in this study are Landsat 7 ETM+ satellite imagery in 2000 and 2010, Sentinel-2 satellite imagery in 2020, and the Spatial Planning Map of Palu City from 2011-2030 (Figure 2). The data is used for the analysis of the suitability of existing land cover with disaster-prone areas and the spatial plan of Palu City, especially in coastal areas. Palu Disaster-Prone Zone Map published by Geoportal Central Sulawesi (2018) is used for the Disaster-Prone Zone (ZRB), that consisting of 4 ZRB, ZRB 1 (Development Zone), ZRB 2 (Conditional Zone), ZRB 3 (Restricted Zone), and ZRB 4 (Forbidden zone).

2.3. Spatial analysis method
The spatial analysis method is used in this study to calculate land cover in Palu City in the last 20 years and see land suitability with disaster-prone zones (ZRB). Based on the results of the mapping of the Palu ZRB, there are four zones based on the level of disaster vulnerability, starting from the Disaster-Prone Zone (ZRB) 4, which is a prohibited zone to ZRB 1 or the development zone. This zoning division
covers various type of disasters that occurred in Palu City in 2018, namely the large border (S), tsunami (T), liquefaction (L), ground movement (G), and flooding (B) [7]. With this ZRB, the future spatial planning of Palu city must be considered, especially in looking at disaster-prone areas. Figure 1 shows the research location, coastal village in Palu City.

For existing land cover conditions with disaster-prone areas, overlapping is done. The same thing was also done to see the suitability of the Palu city spatial pattern plan in the last 30 years with disaster-prone areas. Spatial analysis was carried out using ArcGIS 10.5 software, with the tools used were intersect. Calculation of land cover in 2000, 2005, 2010, 2015, and 2020 was carried out using the Supervised classification method by classifying land cover into two classes, namely built-up land, and undeveloped land. Development land is all land carried out, such as housing and general development areas, trade and service areas, social facilities, industrial areas, and others. While vegetation or non-building lands, such as forests, gardens, and others. Meanwhile, to find out the Palu City Spatial Planning by overlaying the Palu City Disaster-Prone Zone analysis, by overlapping Palu City Coastal Spatial Planning with Palu City Disaster-Prone Zone Map.

3. Results and discussion

3.1. Distribution of land cover at Palu City Disaster-Prone Zone
Palu City Disaster Prone Zone is divided into four zones that can be used to develop Palu City after the tsunami. Palu City Disaster Prone Zone typology consists of Palu City Disaster Prone Zone 4 as a restricted zone directed as a protected area, Palu City Disaster Prone Zone 3 as a restricted zone, Palu City Disaster Prone Zone 2 as a conditional zone, and Palu City Disaster Prone Zone 1 as a development zone. The division of these zones will be the basis for knowing the current condition of Palu City's development, especially the type of land cover. Land cover in this analysis is classified into two types, built and non-built land or vegetation.

Figure 2 shows Palu City Spatial Planning Map from 2011-2030, that will be used to overlay with Palu City land cover and Disaster Prone Zone. Based on the overlapping analysis results of land cover types with ZRB, it is known that ZRB 2 is the most dominating zone in both built-up land cover and vegetation (Figure 3). The area in the ZRB 2 distribution is 26210.04 Ha and is the most comprehensive zone among others. It is still possible to build land in the disaster area as a zone designated for
conditional development. However, considering the disaster conditions in the zone, liquefaction disasters are still relatively high, including floods, while tsunamis and ground movements are quite low.

Figure 2. Palu City Spatial Planning Map from 2011-2030

The results of the analysis show that Palu City still has a high opportunity in regional development. The distribution of land cover in the disaster-prone zones, as illustrated in Figure 4, shows that the highest type of vegetation land cover in ZRB 4 is in the West region. As for the built-up land in ZRB 2 is dominated by coastal areas, precisely in Palu Bay. Although the built-up land cover is still in the low disaster-prone zone, it should be noted that in ZRB 4, a zone with high disaster vulnerability, it has also been used as built-up land and is even broader than vegetation. Therefore, in future development, it is necessary to pay attention to the correct type of land cover combined with disaster vulnerability.

Figure 3. Types of land cover in Palu City Disaster-Prone Zone

Although the built-up land cover is still in the mild ZRB, it should be noted that in ZRB 4, a zone with high disaster vulnerability, it has also been used as built-up land and is even more comprehensive than vegetation. Therefore, it is necessary to pay attention to the correct type of land cover combined with disaster vulnerability in future development. Currently, based on the results of an analysis using Landsat 7 ETM+ satellite imagery, it is known that Palu City continues to experience changes in land
cover from non-built land to built. Even the analysis results show that every five years in the last 20 years the land cover of built-up land in Palu City continues to increase (Figure 5) until 2020, which is 4360.38 hectares and non-built land cover which continues to decrease to 14135.5 hectares.

Figure 4. Distribution of land cover in disaster-prone zones

The increase in the growth of built-up land cover in Palu from time to time can be seen by the expansion of built-up land, which is illustrated in orange. Over the past 20 years, built-up land cities have continued to grow, especially around coastal areas. This increase needs to be considered because considering the condition of Palu City, which is vulnerable to natural disasters, it is crucial to maintain open land as a form of mitigation. As a coastal city, the reduction in the impact of natural disasters such as tsunamis can depend on vegetation species and their nature (tree height, diameter, and density), forest area and arrangement (coastal length and beach width), and tsunami conditions [8]. Another study also stated that the coastal areas of Palu City, especially in Palu Bay, have a high vulnerability to tsunami and earthquake disasters [9]. In addition to coastal disasters, liquefaction also needs to be considered in the distribution of built-up land, especially the concentration of heavy metals resulted from the disaster [10]. Thus, the activity of land conversion from non-built to built needs to be a concern, considering the importance of coastal ecosystems such as mangroves and coastal border areas in reducing disaster risk.

3.2. Suitability of Palu City Disaster Prone-Zones and Spatial Planning from 2011-2030

The overlay technique carried out the analysis of suitability disaster-prone zones with the Palu City Spatial Planning. The analysis shows the built-up land cover in disaster-prone zones 4 (Figure 6), which should be a free zone for development activities, especially those that are not designated for residential areas or trade and services. However, the analysis results show that the residential area in disaster-prone zones 4 is 260,119 Ha, then the office and service trade area is 17,19754 Ha. Whereas based on the typology of the Palu City disaster-prone zone, zone 4 has a high level of disaster risk. It is even categorized as a bright zone with the criteria being a massive post-earthquake liquefaction zone, prone to tsunamis, prone to active Palu-Koro faults, and prone to landslides—post-earthquake height. Even residential areas in some areas cannot be developed for housing, such as in West Palu and Ulujadi [6]. Thus, in the future, it is necessary to renew the spatial plan of Palu City, especially by taking into account the vulnerability of the disasters zone.
Based on the analysis, the result shows that in disaster-prone-zone 4, a protected forest area of 1542.86 Ha remains. This protected area needs to be maintained to increase the resilience of Palu City. Palu City is a disaster-prone city because activities of the Palu-Koro fault can affect other disasters, so maintaining the existence of protected areas is crucial.

In 2018, natural disasters that hit Palu City, especially the tsunami, had a significant impact. Palu city must become a resilient city to disasters because it is located in a disaster-prone zone. Several studies have stated that the high impact caused by the disaster in 2018 was felt not only physically but also socio-economically, such as farmers whose land was heavily damaged so that it impacted on their lives [5], [11]. Protected areas, such as coastal borders and mangrove forests, should be maintained because these two elements are natural fortresses which capable in reducing the risk of coastal disasters [12], [13], [14].

Disaster risk reduction efforts in Palu City can also be carried out by disaster mitigation based on spatial planning. The Hyogo Framework for Action (HFA), agreed at the World Disaster Risk Reduction Conference in Kobe in 2005, mandates spatial planning as a tool for disaster risk reduction [15]. Regional Spatial Plan is categorized as a passive disaster mitigation tool [16]. Maintaining coastal
protected areas in spatial planning can increase resilience to disasters both socio-economically and environmentally.

Figure 6. Overlapping disaster prone-zone and Palu City Spatial Plan

4. Conclusion
The distribution of land cover in disaster-prone zones in Palu City is the developed region, especially for Disaster-Prone Zones 1 development and Disaster-Prone Zones 2 conditional development. The suitability of land in the spatial plan that has been prepared needs to be considered because there is a mismatch between the designated area of the development plan and the disaster-prone zone. An area of 260,119 hectares Disaster-Prone Zones 4 is planned to become a residential area in Palu City. Palu City needs to pay attention to between area typology and the development zone to create a disaster-resilient city that can manage the disaster risk. Thus, it is crucial for future spatial planning to understand these areas with their disaster typology. This research is still limited to the focus of analysis that looks at land suitability and spatial pattern plans with disaster-prone areas. In the future, more research is needed related to the impact of land use mismatches in disaster-prone areas, including an evaluation of the spatial planning of Palu City in looking at disaster aspects.

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