

SPATIAL ANALYSIS OF RESIDENTIAL DEVELOPMENT IN PALU CITY

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Abstract

The earthquake, tsunami, and liquefaction that hit Palu in 2018 damaged infrastructure and settlements and resulted in 2,101 fatalities. In this context, understanding the level of vulnerability and disaster mitigation is very important, especially in providing directions for spatial use. This study aimed to map the affected areas, map the suitability of land use against spatial planning, and map settlement development in Palu City. Data analysis was carried out spatially through an overlay of spatial pattern maps with disaster-affected areas to map the disaster-affected areas. Next, an overlay was carried out on the land use with the Regional Spatial Plan (RTRW) to map the suitability of land use. Finally, an overlay of disaster-prone space zones was carried out on spatial patterns to map the classification of settlement zones. The results of the analysis show that in Palu City there are locations that are suitable for settlement and development covering an area of 5233.978 Ha or 13%; an area that can be used but conditional for settlement is 26860.36 Ha or 68%; the area that can be used but with certain conditions is 3106,714 Ha or 8%; while the land area of 4057,112 ha or 10% is a forbidden zone. This study is expected to become a consideration for the community in building settlements as well as a consideration in preparing spatial plans to suit disaster mitigation efforts. This effort is made so that the construction of post-disaster settlements is carried out in disaster-safe areas.

Keywords: Palu Disaster Mitigation, Settlement Suitability, Space Utilization

Introduction

Palu, a city located at the junction of three active plates, namely the Indo-Australian plate, the Eurasian plate, and the Philippine plate, also with an active Palu Koro fault which divides Palu City along 500 km from the Makassar Strait to the Gulf of Bone, making this city very prone to earthquakes (Bock *et al.* 2003; Kaharudin *et al.* 2011; Indonesian Disaster Risk 2016). The data showed that there was a very strong earthquake in this area caused by the Palu Koro fault activity in 1927 or known as the Donggala earthquake which triggered a tsunami with a height of 8 - 10 m, causing all villages on the west coast of Donggala to almost drown. An earthquake with a magnitude of 7.3 and a tsunami occurred again in 1968, then in 1996 an earthquake with a magnitude of 7, 4 followed by a tsunami that devastated the coast in Donggala and Toli-Toli Regencies. Another earthquake occurred in 2005 with a magnitude of 6.2 on the Richter scale, causing damage in Palu City and in Sigi Regency (ESDM 2006; Pratomo & Rudiarto 2013). Apart from the threat of earthquakes and tsunamis, this area also has liquefaction vulnerability, where at

the time of the 2018 earthquake, Balaroa District (45.03 Ha), Petobo (180.06 Ha) suffered from quite severe damage (LAPAN 2018; Hamdi 2019). Liquefaction as a phenomenon in which the soil loses a lot of strength and stiffness for a short time (Seed 1975) causes buildings / infrastructure to be swallowed up by the earth and a lot of damage, death, and economic losses.

Researchers have reviewed various studies related to earthquakes, tsunamis, and liquefaction in Palu City (Kaharuddin 2011; Widyaningrum 2012; Pratomo & Rudiarto 2013; Pakpahan 2015; Fadil *et al.* 2016; Kurniawan *et al.* 2016). Widyaningrum, a researcher at the Geological Agency of the Ministry of Energy and Mineral Resources (2012), in his study stated that most of Palu City had a liquefaction threat which caused several impacts. First, areas with potential for liquefaction are advised that the foundation used should not be placed on a layer of sand, so that it is safer against liquefaction. Second, the spatial arrangement of residential, industrial, and other vital buildings should be placed in areas that have a liquefaction potential index <5. In the study it was shown that the Petobo area that was liquefied in 2018 was one of the areas with

shallow water depth <12 m, so it has a high potential for liquefaction. Although various studies related to disaster vulnerability and mitigation directions have been studied, the development and growth of residential areas and the economy have not been in line with disaster mitigation efforts. This is proven by the fact that 1,727 people died in Palu City, 188 in Sigi, 171 in Donggala, and 15 in Parigi Mountong (Dibi 2018).

The post-disaster conditions that occurred in 2018 showed that liquefaction and earthquakes had a very fatal impact on people's lives and there were no protection engineering efforts that were able to prevent buildings and communities from the threat of this disaster. Improper land use, as happened in several areas in Palu City, has had negative impacts, including the loss and damage to infrastructure and residential areas (Iskandar, *et al.* 2016; Ake, *et al.* 2018). In this context, relocation efforts and the suitability of residential development in areas that are safe from the threat of disasters (Rumayar *et al.* 2018; Santoso *et al.* 2019; Utami 2019) is one of the right solutions so that when a similar disaster occurs, the level of risk / damage and the resulting casualties can be suppressed. Appropriate spatial planning is certainly capable of realizing environmental sustainability and the sustainability of people's lives (Beta 2017; GFDR 2010). The selection of a safe location for settlement development and economic area

development is mandatory in Palu City, given the threat of similar disasters at any time. In connection with the above problems, this study aimed to determine the conditions of the spatial pattern direction in areas affected by the disaster, whether the spatial patterns determined are in accordance with disaster mitigation and map the suitability level of land use to the Regional Spatial Plan (Spatial Pattern) and map the conditions settlement zone / settlement development area based on disaster-prone space maps.

Methods

This research was conducted in Palu City. The data used includes land use maps, disaster-prone zone maps, spatial planning maps (spatial patterns), and maps of disaster-affected areas. Data analysis was carried out through an overlay map of the affected areas with a spatial pattern map to determine the affected areas. Furthermore, to find out how the suitability of land use with spatial patterns in Palu City, an overlay of the existing land use map with a spatial pattern map was carried out. In this study, an analysis of settlement zones / direction for settlement development in Palu City was also carried out through an overlay of a map of residential area spatial patterns with a map of disaster-prone spaces in 2018. The research flow chart is presented in Figure 1 below.

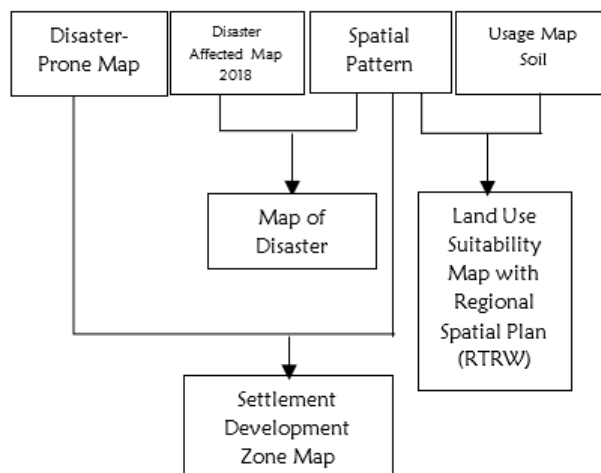


Figure 1. Research Flowchart

Results and Discussion

Suitability Analysis of Regional Spatial Plan (RTRW) for Palu City with Disaster Affected Areas

The tsunami that hit settlements around Talise Beach, Palu, and the coast in Donggala on Friday,

28/9/2018 was triggered by an earthquake with a magnitude of 7.4 SR, shaking Donggala at a depth of 10 km (shallow depth), centered at 0.18 LS and 119.85 BT or 27 km Northeast of Donggala-Central Sulawesi. The activity of the Palu-Koro fault and the fracture around the fault with horizontal movements caused damage with

a fairly severe impact and resulted in underwater landslides in Palu Bay, triggering a tsunami with a height of 0.65 - 5.3 m with the farthest distance reaching 500 m, hitting the land along the Bay of Palu and Donggala (UNDRR and UNESCO-IOC 2019).

Data analysis from Ina Geoportal's data shows that there were 1488.69 hectares of disaster-affected areas in Palu and its surroundings and 12,090 houses that were affected / suffered from damage due to the disaster. The high level of damage and casualties was caused by the energy / strength of the earthquake, which was strong enough with a shallow depth center, the lack of community preparedness, the absence of a

tsunami early warning system, and the liquefaction phenomenon that was experienced for the first time by the community in Palu City and its surroundings. In addition, these three types of disasters are disasters whose timing and duration are difficult to predict but have devastating power and deadly impacts.

In this study, researchers analyzed data on disaster-affected areas obtained from BNPB-BIG-LAPAN and BPPT data with a spatial pattern map of Palu City. Data related to the impact of damage caused by the disaster is presented in Figure 2 below.

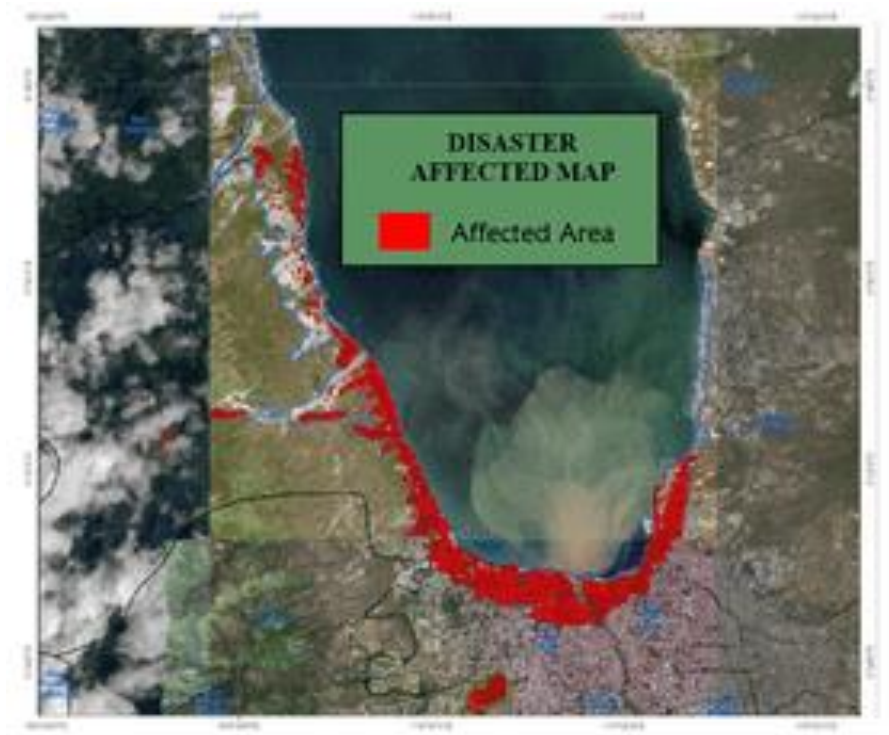


Figure 2. Disaster Affected Map (Source: Geospatial for the Country)

Figure 2 shows that the level of damage occurred mostly in the longitudinal area around the waters of Palu Bay caused by the tsunami. The density of the population and buildings and the development of the economic center in the region has implications for high levels of loss and damage. Meanwhile, the red color in the middle is the damage caused by liquefaction and earthquakes. Quick calculation data carried out by BNPB and UNDP noted that the value of damage and losses caused by the disaster reached 18.48 T (Ministry of PUPR 2019). Data related to the number of refugees and damage to

settlements due to disasters is presented in Table 1.

Apart from the death toll, the number of missing victims had also occurred in Palu City. This happened because the victim was dragged by the tsunami or buried in the liquefaction. The multi-disaster that occurred also had an impact on the high number of refugees, considering that residents' settlements were no longer usable. Some have been lost, even the morphology of the settlements has changed due to liquefaction and is difficult to rebuild.

Table 1. Data on the Impact of the Earthquake, Tsunami, and Liquefaction

No	City / District	Died	Injuries	Hi lang	Take refuge	Rmh heavily damaged
1	Palu City	11,727	1,561	1,345	52,415	65,045
2	Donggala	171	1,750	14	82,891	680
3	Sigi	188	1,112	12	76,835	897
4	Parigi Moutong	15	15	2	578	1,141

Source: DIBI (Indonesian Disaster Information Data)

This study also presents the conditions of the disaster-prone space zones in Palu City and its surroundings, where this map was signed jointly between BNPB, Ministry of PUPR, BMKG, Ministry of Energy and Mineral Resources, Ministry of PPN / BAPPENAS, and the Provincial Government of Central Sulawesi. The memorandum of understanding regarding the map of disaster space zones is expected to be a consideration and direction for the related ministries / agencies in utilizing spatial functions, so that the stipulated policies do not conflict with disaster-prone space zones. It is hoped that this

map will facilitate the coordination process, thereby accelerating the post-disaster rehabilitation and reconstruction process. One of the benefits of this map is to be used by the Ministry of ATR / BPN together with the Provincial Government of Central Sulawesi in the process of providing land for the relocation of disaster-affected communities, also as a reference for the Ministry of PUPR in building post-disaster infrastructure. The map of the disaster-prone zone for Palu City and its surroundings is presented as in Figure 3 below.

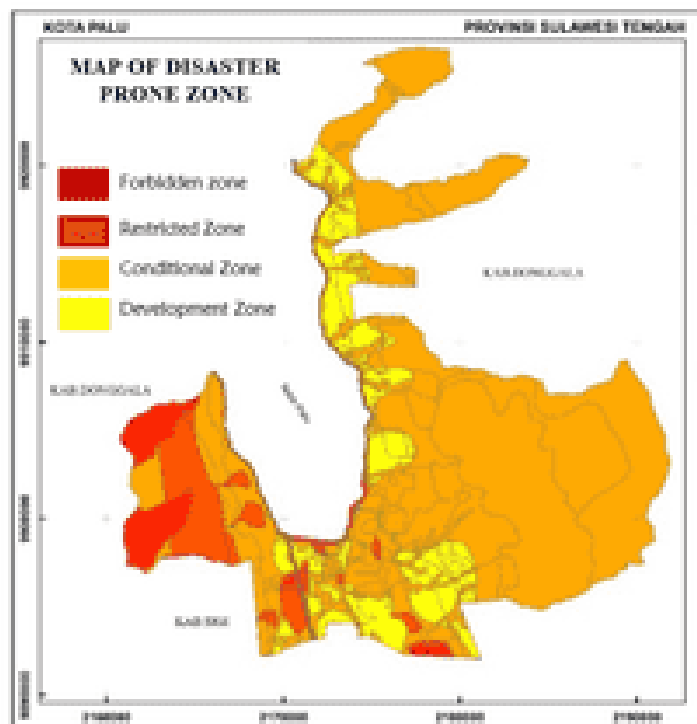


Figure 3 Map of Disaster-prone Zones (Source: Geospatial for the Country)

The disaster-prone zone map as seen in Figure 3 was determined by the post-disaster government in December 2018 by classifying the space zone into four classes, namely the forbidden zone (dark red) which includes massive liquefaction zones such as in the Petobo, Balaroa, Jono Oge, and Sibalaya areas; a tsunami prone

coastal zone that extends along the coast of Palu Bay; the active Palu-Koro fault zone (0-10 m); and high category ground motion zone. Meanwhile, the limited zone (dark yellow) is the active boundary zone of Palu Koro (10-50 m), namely the liquefaction-prone zone which is a tsunami-prone zone outside the coastal

boundary. The conditional zone (yellow) includes a liquefaction-prone zone with moderate threat and a tsunami-prone zone with a medium-level threat, flood-prone, and moderate-grade ground movement prone. Meanwhile, the development zone (light yellow) includes a disaster-prone zone with a low threat level (Humanitarian 2018). For areas with restricted zones, (dark red) as illustrated in Figure 3 above, the government should be able to

establish the right policies so that people do not resettle in the area.

In this study, an analysis of the conditions of the disaster-affected area was carried out with the designated area in the RTRW. An overlay of the disaster-affected map with a spatial pattern map produces an area per area as presented in Table 2.

Table 2. Analysis of the Areas Affected by the Earthquake, Tsunami, and Liquefaction

No.	Space Pattern Plan	Area (Ha)
1	Natural Disaster Areas	101.98
2	City Green Open Forest	1.68
3	Office Area	0.87
4	Medium Population Density	41.11
5	Other Designated Areas	3.43
6	Low Population Density	729.81
7	Natural Disaster-prone Areas	145.13
8	Tourism Area	79.35
9	High Population Density	0.61
Sigi Regency		36.53
Dongala County		65.66
The total area affected by the disaster		1488.69

The results of the overlay map of the spatial pattern of Palu City in 2010 with data on the impact of the earthquake, tsunami, and liquefaction in Palu and its surroundings show that residential areas experienced the impact of disasters, especially in low (729.81 Ha) and medium (41, 11 Ha) density areas. Apart from that, the tourism area which is located along the Talise coast was also severely damaged by the impact of the tsunami waves. This condition shows that there are still hundreds of hectares of residential areas located in disaster-prone areas, so mitigation efforts to reduce the impact of damage and prevent casualties are very necessary in Palu City. Based on this data, it can be seen that the direction of spatial patterns in Palu City, especially those designated as settlements, needs to be evaluated.

Analysis of Land Use Suitability with the Regional Spatial Plan (RTRW) of Palu City

Soil suitability, that is the suitability level of a plot of land for a particular use, can be assessed in the current condition (actual land suitability) or after improvement (potential land suitability). Meanwhile, soil evaluation is a process of assessing land resources for a specific purpose using a proven approach or method. The results of this evaluation will provide information and/or directions for land use as needed. The actual soil suitability can be determined based on data on biophysical properties (soil and climatic

characteristics related to plant growth requirements) or land resources. Potential soil suitability describes the soil suitability that will be achieved if improvements are made. The land evaluated can be in the form of conversion forest, abandoned or unproductive land, or agricultural land whose productivity is less than satisfactory but which is still possible to increase if the commodity is replaced with more suitable crops. In this study, the determination of land use suitability is based on a predetermined RTRW. The determination of this RTRW must have been preceded by studies related to actual and potential land suitability that are aligned with community needs and development interests.

Palu City Regional Spatial Plan (RTRW) 2010-2030 as a guideline that must be adhered to contains objectives, policies, spatial planning strategies, regional spatial structure plans, regional spatial pattern plans, strategic area designation, direction for spatial use, and spatial use control provisions. The plan includes spatial plans for protection and cultivation functions. Protected areas are areas defined with the main function of protecting environmental sustainability, including natural resources, man-made resources, and historical and cultural values for the sake of sustainable development. Meanwhile, the cultivation area is an area that is used in a planned and directed manner, so that it can be efficient and effective for human life. This area consists of agricultural cultivation areas and

non-agricultural cultivation areas. In this context, an area that meets the requirements for use as a cultivation area must meet the criteria of being efficient and effective. Areas that when used by the community actually cause losses or casualties are certainly not appropriate to be designated as cultivation areas. Meanwhile, what is meant by a protected forest area is an area that is ecologically an ecosystem located in a city area, a protected area that provides protection for its subordinate areas located in the city area, and other protected areas which are according to the provisions of laws and regulations managed by the city government.

Based on the results of the analysis, the suitability of land use in Palu City in 2017 with the RTRW for Palu City can be used to determine the area and location with suitable and unsuitable land uses. The results of the analysis of the suitability of land use with the RTRW can be used as a basis for policy making, especially related to land use efforts and efforts to control land. The distribution of the spatial pattern direction set in Palu City can be presented as in Table 3 below.

Table 3 Direction of Palu City Regional Spatial Pattern 2010-2030

No.	Space Pattern Direction	Area (Ha)	%
1	Protected forest	7889.84	19.97
2	Limited production forest	4236.91	10.72
3	City Green Open Forest	1614.42	4.09
4	Natural Disaster Areas	990.44	2.51
5	Industrial area	1589.75	4.02
6	Tourism Area	195.39	0.49
7	Local Protected Areas	244.64	0.62
8	Office area	279.07	0.71
9	Other Designated Areas	5211.95	13.19
10	Natural Disaster-prone Areas	1421.19	3.60
11	Nature Reserve and Cultural Conservation Areas	5565.97	14.08
12	Low Population Density	9091.14	23.01
13	Medium Population Density	848.79	2.15
14	High Population Density	338.19	0.86

Source: Data Analysis 2020

The direction of the spatial pattern in Palu City shows that the use of space as an effort to protect areas in the form of disaster-prone areas, protected forests, and limited production forests and urban green open forests, nature reserves, cultural preserves, and local protected areas have been allocated with a total area of 5,565.97 Ha or reached 55.59%. On the other hand, the spatial pattern direction that can be used as a residential area (high-medium-low density) is allocated as much as 26.02% of the total area. This data shows that the percentage allocated for residential areas is only less than half of the areas designated as forest / local protection areas / disaster-prone areas. Palu as a city with a center of economic growth which is dominated by industrial and trading activities, hotels,

restaurants, and services contributed more than 55.96% to GRDP. In the spatial pattern, efforts to fulfill the development of this sector have been allocated an area of 4% or 1,589.75 Ha. This increasing growth of economic activity has significantly transformed some of the open land in Palu City into developed land (Muamar *et al.* 2017).

This economic activity of course also has implications for the expansion of settlement development by the community. The distribution of land use in Palu City is presented in Figure 4 below.

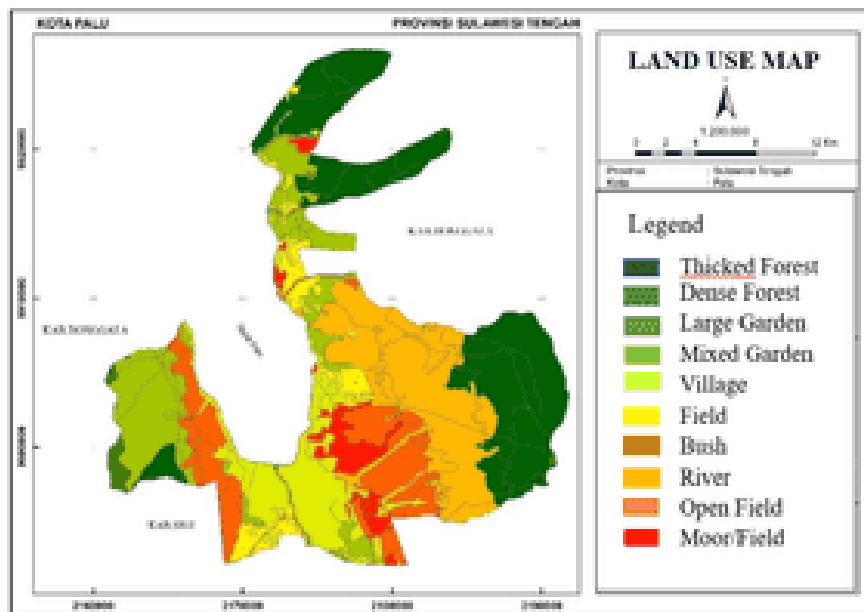


Figure 4. Palu City Land Use Map (Source: Palu City BPN Regional Office 2017)

The topography of Palu City with flat conditions in the form of a valley reaches 74.9% which affects the use of the existing land. Most of which are in the form of built land with the use of villages / settlements, industry, and trade. In Palu City, housing development is very fast, considering that this area is the capital of the province of Central Sulawesi. Based on the study conducted by Prayitno *et al.* (2019), there are 86 housing estates in this city where the most housing is in Mantikulore District and in South Palu District. The high growth of housing and settlement development in Palu City should pay attention to disaster-prone aspects. Meanwhile, the topographical conditions are wavy, steep, and very steep (25.1%), which the population uses as moor, gardens, and forests (RPJMD 2016-2021).

In this study, an analysis of the existing land use conditions against the RTRW (spatial pattern) was carried out to determine the suitability of land use conditions. Regional spatial plan as a benchmark or guideline for alignment of land use that has been approved by regional regulations should be complied with and used as a reference in development activities, so that land use

between designation and land potential can be appropriate. However, in practice, some irregularities and inaccuracies in land use often occur. In this study, the analysis of land use conditions on the RTRW is classified into two classes, namely suitable (S) and unsuitable (US). The level of conformity is determined based on the following suitability categories.

1. The suitable category (S) is when the actual land use matches the planned land use. Examples are the use of land that is planned as residential land and the actual use of land that is used as residential land.
2. The unsuitable category (US) is when the actual land use differs from the planned land use. An example of improper use of land is when the land that was previously planned is in the form of rice fields, in fact is used as a settlement.

The results of the analysis of land use suitability evaluation with the RTRW in Palu City are presented in Table 4, while the analysis map of the suitability level of land use against the RTRW is presented in Figure 5.

Table 4. Suitability of Land Use with Regional Spatial Plan (RTRW)

No.	Conformity	Area (Ha)	%
1	Suitability	24670.52	63
2	It is not in accordance with	14587.65	37
Total		39258.16	100

Source: Data Analysis 2020

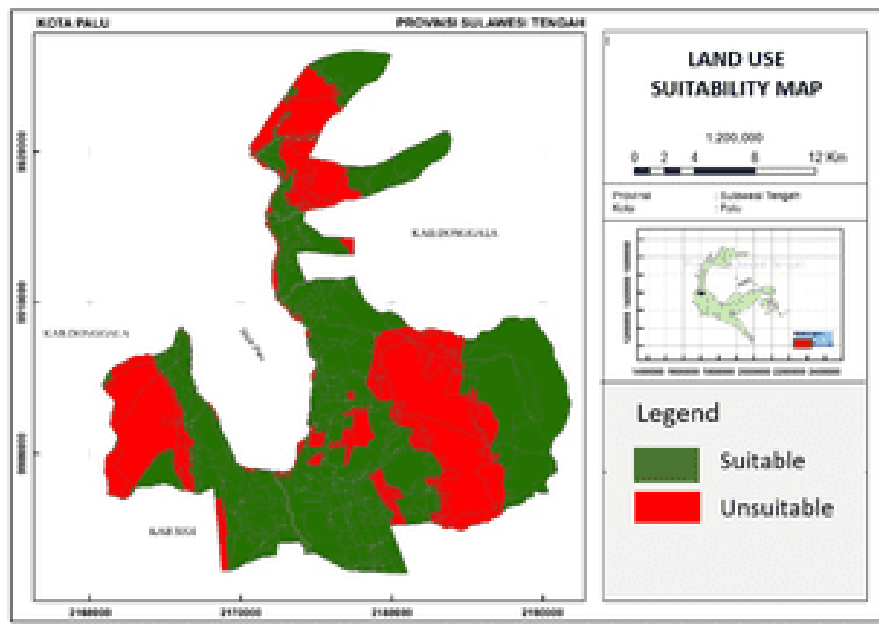


Figure 5. Land Use Suitability Map of Palu City (Source: Data Analysis 2020)

Based on the analysis of land use evaluation data in Palu City, the results of the evaluation show that there is still an Unsuitable area (US) with an area of 14,587.65 Ha or 37%, while the Suitable area (S) is 24,670.52 Ha or 63%. The mismatch of land use in Palu City will certainly have an impact on environmental degradation. Even if the mismatch occurs in disaster-prone areas, it will have implications for the high risk that is felt when a disaster occurs.

Land Suitability Analysis for Settlements

The condition of Palu City with the threat of a tsunami in the coastal area, the threat of an earthquake in the area along the Palu Koro fault, the threat of liquefaction in areas with a high liquefaction potential index (>5), the threat of landslides in steep sloping areas, and the threat of

flooding in the valley / lowland areas shows the need for spatial analysis to determine the area of community settlement development. Analysis of the disaster-prone space zones established after the 2018 disaster is at least able to become a reference for the government and the community in selecting locations for safe residential development. In this study, an analysis of the conditions of settlement direction stipulated in the RTRW is needed, given that when the tsunami disaster and liquefaction occurred in 2018, the number of settlements and communities who became victims was very high. In this study, settlement conditions are determined by overlaying a spatial pattern map with a disaster-prone area map. The settlement zone analysis is presented in Table 5.

Table 5. Analysis of Settlement Zones in Palu City

No.	Zone	Area (Ha)	%
1	Development Zone	5,233,978	13%
2	Conditional Zone	26,860.36	68%
3	Restricted Zone	3,106,714	8%
3	Forbidden Zone	4,057,112	10%
Total		39258.16	100%

Source: Data Analysis 2020

Table 5 shows that, in Palu City, only a small part of the area or 13% can be said to be safe to use as a residence, so that 68% of the area can be used as a settlement with a conditional zone, that is, the area can / may be used as a residential place with certain conditions. The percentage of

settlements with this conditional condition is affected by the vulnerability of disasters that are scattered in various regions. The analysis also shows that there are 8% of the restricted zone area and 10% of the city of Palu as a forbidden zone. Regarding the spatial pattern direction for

settlements in this forbidden zone, of course a revision of the RTRW is needed, so that the function of the forbidden zone can be converted into a local protected area, or it can also be an urban forest or green open space.

The results of this analysis show that Palu City, as an area with a multi-disaster threat, requires very extra disaster mitigation efforts. In this context, the involvement of stakeholders and the active involvement of the community is needed so that the formulated mitigation efforts can be sustainable. Efforts to build public awareness not to build settlements in restricted zone areas must be made, while the government should have an obligation to provide land with development zones or conditional settlement zones for settlement fulfillment. Relocation of people living in the forbidden zone is very necessary, considering that the impacts and risks that will be borne by the community are very high if the community continues to live in the area. To realize a spatial function that is able to support the sustainability of people's lives, the revision of the RTRW in Palu City by considering the disaster-prone space zone is very necessary so that the spatial direction set is able to reduce risks in the event of a similar disaster. Constructive disaster mitigation, namely the adjustment of buildings that are friendly to earthquakes, tsunamis, and liquefaction is urgently needed (GFDRR 2010) so that damage to settlements and infrastructure can be prevented.

Conclusion

Palu City, as a multi-disaster area with a type of disaster that has a very strong destructive force and the power to cause casualties, requires comprehensive mitigation to reduce the risk of damage / loss. The results of the study based on the disaster-prone space zone map on the spatial pattern map show that only 13% of the area in Palu City is safe to be used as a residence / settlement (suitable as a development zone). Meanwhile, most of the area, namely 68% of the area, can be used as conditional settlement. Given the densely populated condition of Palu City and the center of economic growth in Central Sulawesi, this conditional residential area zone requires special mitigation so that a disaster does not cause damage / casualties.

The results of the study show that the land-use violations and mismatches against the RTRW in this City reach 14,587.65 Ha (375). The results of this study are expected to be able to formulate policies so that land use and utilization in disaster-prone areas can be carried out appropriately. For areas that are prohibited / very prone to disasters,

restrictions on settlement development can be determined through regional regulations. Meanwhile, for settlements that are already in disaster-prone areas, education and adaptation efforts need to be made, or for areas that are very vulnerable and not in accordance with the designation of space, for example, that in coastal areas and fault zone boundaries can be directed for relocation.

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