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LANDSAT 8 IMAGERY UTILIZATION TO SPATIAL ANALYSIS OF REHABILITATION AND RECONSTRUCTION OF PALU DISASTER IN 2018

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Abstract: Rehabilitation and reconstruction as a post-disaster stage becomes an important part in the disaster management cycle. Post-disaster as a moment that can be used to rebuild a better life order must be optimized in its implementation. This study was conducted using a spatial approach through the use of multitemporal remote sensing satellite imagery in Palu region. The data used in this study are Landsat 8 images in March 2018, Landsat 8 in November 2018 and Landsat 8 in March 2019. The research method is carried out through spatial analysis by supervised classification which is the maximum likelihood algorithm for classifying land use. The analysis was conducted by supervising classification to classify the existing conditions of land use. The research indicates that the locations of residential development are determined by the Government which are located in the urban village of Tondo, sub-district of Mantkulore and urban village of Duyu, sub-district of West Palu, Palu City district; and they have considered the aspect of disaster vulnerability and land availability. The analysis of Landsat imagery shows that in this area, the rehabilitation and reconstruction process is ongoing. By the analysis, it is discovered that there are changes in land-use before and after the disaster. In November 2018, there was a decrease of 56.4 hectares of built land in the village of Tondo and 17.76 hectares in village of Duyu. While, the results of the Landsat 8 image study in March 2019 shows that there are increases in these two regions.
Keywords: Land-use, Rehabilitation, Reconstruction, Remote sensing.

A. Introduction

After the disaster left a lot of work, not only the completion of the physical aspects of the construction of settlements and infrastructures but also the need for psychological recovery of the community, economic, social, cultural and the need for efforts to increase the capacity of community (Comerio 2014; BNPB 2019; Law/ UU No. 24 of 2007). Rehabilitation and reconstruction is a process to rebuild community civilization to be better (Mahapatra, Tewari, Babbo 2015). A rehabilitation and reconstruction process can be successful if the government can prepare for the future (Comerio 2014). In this context, rehabilitation and reconstruction become a way to restructure settlements, infrastructure, and people's lives so that recovery is in harmony with disaster aspects. In this connection, land use and spatial planning are important in post-disaster rehabilitation and reconstruction (Burby et al 2000; Wang 2014). Structuring of settlement and infrastructure should be done in the safe areas which mean not in the areas that have a level of disaster vulnerability (Utami, Wibowo, Afiq 2019b). Likewise, the structuring and restoration of land use and utilization arrangements should be aligned with

the directions of the disaster vulnerable map as far as possible (Utami and Wibowo 2019a).

Appropriate rehabilitation and reconstruction and also the quick process can help the community to regain life normally (Jha, et al 2010). When the community can carry out their life normally, of course, the community can run the economic, education, social and cultural fast; then, people's life gradually recovers as it was before. The scheme for completing rehabilitation and reconstruction is not always the same between one region and another. This relates to the type of disaster, the condition of the government, available budget for rehabilitation and reconstruction, community vulnerability, the stakeholders and social conditions or communities culture (Jordan, Will, Tierney 2016; Bronen 2015). Post-disaster handling of floods will be different from the handling of liquefaction disasters or tsunami disasters. After the flood disaster, the community can return to their settlement, but after the liquidation disaster, it is impossible to rebuild the settlement in the area that has been affected by the disaster; as in the geomorphological theory states that disaster and geomorphological activities that have occurred will re-occur in the same area depending on the disaster period with different frequencies and magnitudes (Smith and Petley 2008). Besides, if the post-liquefaction location will be reused for settlement, it will require very high effort and funding because the land is already flat and there is building debris that requires a process for cleaning again.

This research aims to determine the spatial conditions before and after the liquidation disaster in Palu. In this study, the researcher periodically monitored the post-disaster rehabilitation and reconstruction process by using Landsat imagery data that is presented free of charge at USGS. Image data used in this research are the form of Landsat 8 imagery before the disaster and result of recording in April 2018; and for the post-disaster use Landsat 8 imagery in October 2018 and Landsat imagery in March 2019. The data are used to find out the spatial patterns such as clustering and the development of rehabilitation and reconstruction. Imagery analysis done by supervising to classify land-use types in post-disaster areas.

B. Post Disaster of Palu

Palu is one of the areas that has a high level of disaster threat of earthquake, liquefaction and tsunami disasters. Because Palu is located on the ring of fire and the meeting point of Indo Australia-Pacific and Eurasian plates (Pramumijoyo 2018). At this location, there is also an active fault dividing the island, the Koro Palu Fault with a movement of 45 millimeters per year. This fault is a fault that was noted to have enormous strength in addition to the Great Sumatra Fault, Sorong Fault, Molucca Fault (Irsyam 2013).

The earthquake, liquefaction and tsunami disasters in Palu took a high number of fatalities and missing victims, reaching 4,402 (BNPB 2019), because these three types of disasters are quite deadly and work very quickly. The number of losses caused by the disaster on the Palu is estimated up to 23.14 trillion, while to rebuild the rehabilitation and reconstruction activities require funds up to 36 trillion (BNPB 2019). This condition illustrates that the costs and efforts needed to rebuild post-disaster are higher when compared to preventive efforts towards disaster risk reduction (GFDRR 2010; Jordan, Will, Tierney 2016). From this disaster, the government and the community should be aware not to rebuild settlements or infrastructure in areas that have been affected by disasters or in areas that are likely to occur similar disasters by considering the risk map.

Based on the experience of disasters, BNPB directs the implementation of settlements and post-disaster public facilities/social facilities rebuilding in Palu is not permitted to be built in red zone areas (zones that have very high levels of disaster vulnerability). This action was taken to prevent many casualties and damages caused by disasters that could reoccur in Palu. Some areas that need to be specifically watched in Palu are areas that have vulnerability to liquefaction disaster, the threat of earthquake disaster by avoid-

ing Palu Koro fault line[1] and areas that are vulnerable to tsunami disaster threat. The area at the tip of the Palu bay is the area that has the highest vulnerability: this is because the geomorphological condition of Palu is in the form of a bay that can cause the magnitude and strength of tsunami to be greater which has implications for higher waves and more energy pushed towards the mainland. This was proven when the tsunami occurred at the tip of the Palu bay, the height of tsunami reached 6 meters and with a run-up distance up to 500 m. Disaster risk reduction, the management and land use regulations should be re-arranged through spatial regulations, zoning arrangements (Peacock, et al. 2008; Tiepolo, Pezzoli & Tarchiani 2017).

The Presidential Instruction No. 10/2018 on the Acceleration of Rehabilitation and Reconstruction of Central Sulawesi targets the recovery period after the disaster to last until 31 December 2020. In this regulation, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency has involvement in: first, recommendations for post disaster direction; second, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency has the task of revising the Spatial planning and territory on disaster mitigation aspects and synchronizing with post-disaster rehabilitation and reconstruction action plans; third, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency has involvement in the provision of land for relocation that is safe from the threat of disaster; fourth, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency has to facilitate the procurement and management of land for relocation and post-disaster reconstruction (Presidential Instructions number 10 of 2018). The permanent housing is planned for 3000 units in which 2000 units will be built in Palu city and 1000 units will be built in Sigi district. Construction of permanent housing from the government will be carried out in urban village of Tondo, sub-district of Mantkulore and urban village of Duyu, district of West Palu, Palu city. In the implementation phase of this permanent residential development, the government will not build the residence if the land is not in a clear and clean condition (BNPB, 2019); in this context, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency together with the Regional Government has a significant role in the procurement of land for the construction of permanent housing for the disaster victims.

C. Landsat Imagery

Landsat imagery as a satellite with medium-level spatial resolution, up to 30 meters (infrared channels up to 120 meters), has the advantage of high temporal resolution and can be accessed freely (Kennedy, et al 2014; Himayah, Hartono, Danoedoro 2017). This temporal resolution can be used for monitoring land-use change activities (Zhou, Li, Chen 2011). (Arsanjani and Fonte 2016). Data of land use is the data that present and explain human activities on land such as settlement, agriculture, and forestry (Ellis 2007; Wästfelt & Arnberg 2013), while land cover presents the physical cover of land (De Sherbinin 2002).

Landsat Image 8 also known as LCDM (Landsat Data Continuity Mission) is one of the sub synchronous satellites with 16-day return period. This imagery carries an OLI (Operational Land Imager) sensor which there are spectral channels resembling ETM + (Enhanced Thermal Mapper Plus). This Landsat 8 imagery has 1 near-infrared channel and 7 visible reflective channels (Sitanggang 2010). The analysis of the imagery data in this study was done through supervised/guided classification. The method in this classification is by sampling. First of all, the user determines the number of classifications of land-use and then the user sampled the land use object that chosen (Danoedoro 1997; Danoedoro 2012). In this study, the imagery used is Landsat 8 image, recorded before the disaster in March 2018, in November 2018 and Landsat imagery in March

[1] A study conducted by the National Earthquake Center (2018) shows that the safe distance used by some countries for active faults is 100 to 200 meters.

2019. The selection of this imagery was chosen by considering the results of Landsat 8 coverage that is free of clouds, considering that one of the weaknesses of Landsat imagery is that this image has a disturbance of clouds that cannot be penetrated resulting in the earth's surface cover information being unable to be recorded.

D. Analisys of Land Use for Monitoring Rehabilitation and Reconstruction

1. Before and After the Disaster in Palu

The series of earthquake disasters with the strength of M 7.4, tsunami and liquefaction that occurred at 18:02 WITA on 28 September 2018 caused damages in the districts of Palu city, Sigi, Donggala, Parigi Mountong, and Pasang Kayu, West Sulawesi (National Epicenter, 2018). The interpretation of Landsat 8 images taken on April 2018 before the tsunami and Landsat 8 images taken in October 2018 are presented as shown below:

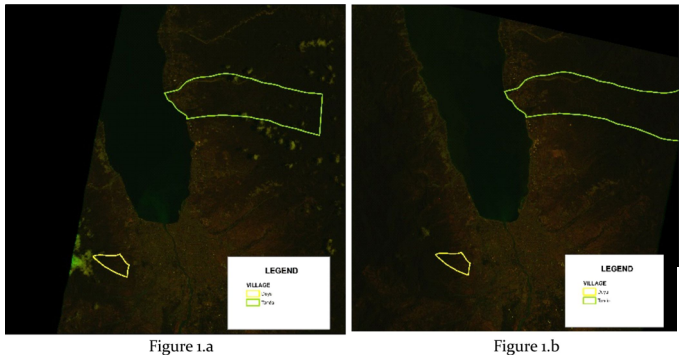

Figure 1.a Figure 1.b

Figure 1 a. Photo map of March 2018 before the tsunami and Figure 1 b. November 2019 post-tsunami photo map

Figure 1 shows the location of the study and the position of Palu which is in a bay with a very protruding bay to the mainland. While on the face of the bay based on Figure 1, there is a fairly densely populated settlement.

2. Spatial Analysis of Land Use Change

This study focused more on the location of rehabilitation and reconstruction of permanent residential areas determined by the government which is located in the urban village of Tondo, sub-district of Mantkulore and urban village of Duyu, sub-district of West Palu, district of Palu city. This location is considered to have a fairly low level of vulnerability when compared to other locations. The two locations are not on the face of the Palu bay and far enough from the coastline so they are relatively safe from the threat of tsunami. Also, it is located quite far from Palu Koro fault line so that it is relatively safe from the threat of damages due to the earthquake.

The results of the Landsat 8 image analysis through supervised classification (maximum likelihood algorithm) are presented in the figure below:

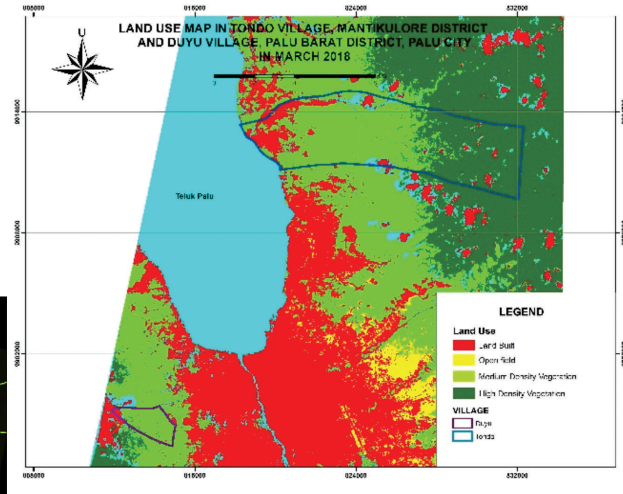

Figure 2a. Pre-disaster land use map (April 2018).

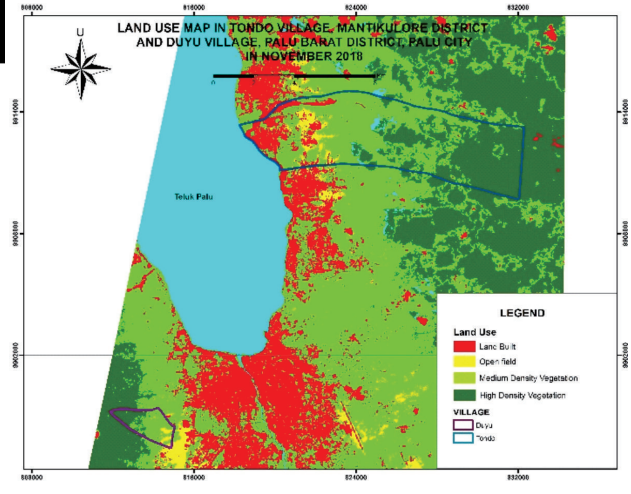

Figure 2 b. Map of post-tsunami land-use in November 2018

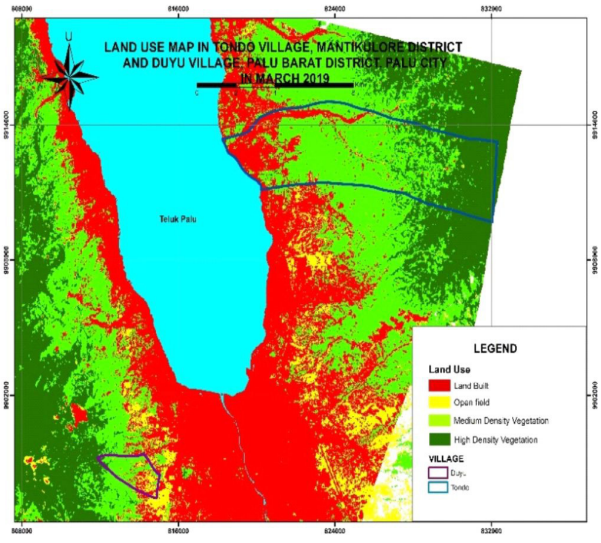

Figure 2 c. Map of post-tsunami land use in March 2019. Figure 2. a, 2.b, 2.c. Map of Land Use in Palu Sourch : Interpretation of Landsat Imagery

Based on the results of Landsat 8 imagery analysis supervised shows that on the face of the Palu bay there is a very densely populated settlement that is marked in red. The light green color indicates that around the residential area, there is low-density vegetation, while high-density vegetation indicates the area as a forest area or an area designated as a protected/conservation area. The results of image analysis as presented in figures 2.a and 2.b show that in the images before and after the disaster, there was a significant change in the appearance of the built land. Very significant changes have occurred in settlements along the face of the Palu bay and along the right and left sides of Palu bay after the tsunami which devastated along the coast.

A month after the disaster, it was clear that massive damages to the developed land occurred along the coastal area; while in the middle of the coast, the damages to the built area occurred due to the impacts of the earthquake. Besides massive damages to the developed land that occurred in the Petobo area and Balaroa due to liquefaction, the results of image interpretation show that the area turned into open land marked in yellow.

Spatial data analysis and analysis of land-use change data towards areas designated as permanent residential development areas, in the villages of Duyu and Tondo are presented in Figure 2 and Figure 3. Based on Figure 3, it shows that in Duyu urban village, the condition of the land before the disaster developed; then, a month after disaster appears to be a drastic change in which the built land has turned into open land. While, when the results of the post-disaster land-use change, analysis the image of November 2018, juxtaposed with the image of March 2019, they show surge and fast increase in built land, especially in the Tondo urban-village. The graph of changes in the use of built and open land in both residential construction sites is presented in figure 3 below:

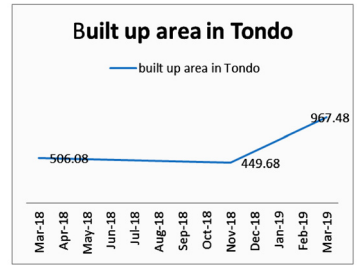

Figure 3a. Change in land use built-in Tondo urban village

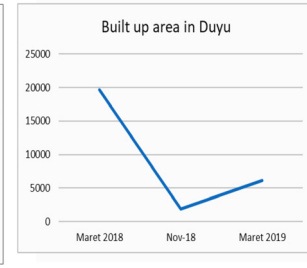

Figure 3b. Changes in land use built-in Duyu urban village

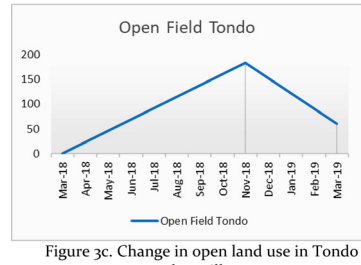

Figure 3c. Change in open land use in Tondo urban village

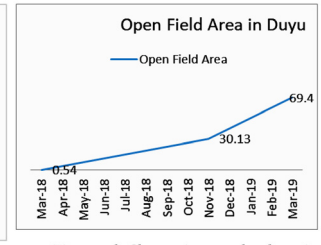

Figure 3d. Change in open land use in Duyu urban village

The observations of Figure 2.b and Figure 2.c can be used to observe how the rehabilitation and reconstruction processes are carried out in Palu. During 4 months, the change in land use from open land to developed land was quite significant. This indicates that the rehabilitation and reconstruction processes are said to be quite fast carried out by the government and the community assisted by other stakeholders. The results of the analysis of land-use changes in the urban villages of Duyu and Tondo are presented in Table 1 below:

Table 1. Changes in land use in the urban villages of Duyu and Tondo

Land Use	Village	AREAS (Ha)		
		Mar-18	Nov-18	Mar-19
Built Up Area	TONDO	506.08	449.68	967.48
	DUYU	19.657	1.891	67.68
Open Field	TONDO	0.54	182.9256	61.03
	DUYU	0.54	30.134	69.417
Medium Density Vegetation	TONDO	2111	2047.5802	2367.2
	DUYU	300.73	196.855	189.27
High Density Vegetation	TONDO	1560.9	1629.2482	1208.8
	DUYU	7.6266	112.064	14.353

Source: Data Analysis 2019

E. Acknowledgement

This study was used as a preliminary interpretation of land cover and post-disaster land-use in Palu. In this study, it is necessary to conduct surveys directly on the locations to do some ground check of the result of land-use interpretation. A comprehensive study of the implementation of post-disaster rehabilitation and reconstruction in Palu needs to be carried out so that in the future it can be used as material and lessons in developing rehabilitation and reconstruction policies in other regions.

F. Conclusion

Rehabilitation and reconstruction are important events in rearranging land use and utilization and also spatial planning in disaster areas. The efforts to reduce disaster risk through this mechanism are considered more effective so that in the future when a similar disaster occurs, the number of losses and victims can be reduced. In this study, the use of Landsat imagery with spatial resolution of 30 meters and temporal resolution can be utilized for monitoring land-use change. The results of the Landsat image analysis in November 2018 show that the land developed after the disaster experienced a significant decline in the urban village of Tondo and Duyu.

The two regions have been designated by the government as relocation sites and permanent housing developments. Based on a study of March 2019 imagery analysis, it shows that changes in land built in the two locations have increased and are higher when compared to the area of land built before the disaster. This shows that the location of rehabilitation and reconstruction as well as the development of land built at this location is quite rapid. From the study conducted an increase in built-up land in urban village of Tondo reached 517, 8 Ha while in the urban village of Duyu achieved an increase in built-up area of 65.79 Ha. The appropriate and fast development of settlements and infrastructure in the rehabilitation and reconstruction stages certainly helps accelerate the post-disaster recovery.

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