Design of Muster Area as Earthquake Evacuation Area in North Lombok Regency, West Nusa Tenggara

B D H Amni¹ A A Hadi² and Perdinan³
¹Student, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia
²Lecturer, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia
³Lecturer, Department of Geophysics and Metrology, Faculty of Mathematics and Natural Sciences, IPB University (Bogor Agricultural University), Bogor, Indonesia

E-mail: ¹baiq_eci17@apps.ipb.ac.id; ²arifin_hadi@apps.ipb.ac.id; ³perdinan@gmail.com

Abstract. Mitigation of disaster is an effort to decrease the impact of damage caused by natural disasters i.e. earthquakes. West Nusa Tenggara Barat Province (NTB) Indonesia was hit by 7.0 earthquakes in July 2018. Earthquake disaster affects the community to become a traumatic feeling and disease because of the lack of supporting facilities in the mitigation area. The local government of Lombok is preparing reconstruction and rehabilitation including mitigation area. The Green open spaces of the city can be utilized as an evacuation area or muster area in the incident of a natural disaster. Muster areas as disaster mitigation are still rarely found in Indonesia, particularly in North Lombok Regency. The muster area should be placed on the area of potentially occurring natural disasters in the Regency. Infrastructure and network utilities of muster areas must have several sectors, such as the provision of drinking water, electricity, telecommunications panel, accessibility, drainage, sewer system, parking area, and a toilet. However, green open space in North Lombok Regency, particularly in natural disaster-prone areas, is not yet utilized as a muster area. The muster area was designed according to people's needs. The questionnaire method was used to obtain input from North Lombok People who experienced the disaster.

Keywords: Disaster, earthquake, mitigation, muster area, green open space

1. Introduction
Disasters are events or sequences of events that threaten and disrupt the lives of people caused by natural or unnatural factors that lead to death, environmental destruction, loss of property, and psychological impacts [1]. BNPB explains the earthquakes are vibrations or shocks occurring on the surface of the Earth. Earthquakes are usually caused by the movement of the Earth's crust (earth plate) [2]. According to Paramesti [3], Indonesia is one of the very active areas of the earthquake, because Indonesia is located at the confluence of three main tectonic plates and one small tectonic plate. The three tectonic plates in question are Indo-Australian tectonic plates, Eurasian plates, and Pacific plates and small Philippine plates.

On 29 July 2018 Lombok Island was hit by 6.4 Mj, the earthquake shock perceived to Sumbawa and Bali. The earthquake was followed by 213 times aftershock, the largest aftershock force is 5.7 Mj. The earthquake was known as foreshock of the main earthquake on August 5 with 7.0 Mj and it comes with 121 times of aftershock. On 19 August 2018, the earthquake was returned with the point of origin in the east of the island, starting with 6.3 Mj than followed by an apparent of 6.9 Mj and followed by 484 times of aftershock until 31 August
2018. The National Disaster Management Agency (BNPB) records 560 people died, 396,032 people displaced, and 83,392 houses were damaged caused by this shock [4].

Most of the earthquake points occurred on 29 July 2018 until 31 August 2018 located in the northern part of Lombok Island. North Lombok and North part of East Lombok Regencies are the most affected areas. The most affected district after the Lombok earthquake in North Lombok regency. Until 1 October 2018 the number of casualties in the North Lombok district was 467, than 829 people suffered injuries, and the damage to the house recorded 38,497 units [8]. After the earthquake occurred, an emergency response was required to address disasters involving rapid and precise assessment of location, damage, and resources. There is also a determination of the status of disaster emergencies, rescue, and evacuation of communities affected by disasters, the fulfilment of basic needs, protection of vulnerable groups, and the restoration of infrastructures and vital means immediately. The magnitude of the earthquake that struck North Lombok Regency became a trigger to develop a mitigation system. The mitigation System can be disaster-response education to students and the community, disaster evacuation routes, and the means of gathering points.

According to Joga [5] the arrangement of the city affected by natural disasters should be rebuilt by allocating more green open space, accommodating the importance of protection, evacuation, or life defense of disasters. Disaster evacuation areas are usually located in dense residential areas, government headquarters, central district businesses, hospitals, and schools. The evacuation area is usually selected green open space with a field that is quite spacious as a gathering place (muster area), so the muster can be used as a disaster mitigation area. The standard planning for the muster area is still rare in Indonesia and there are no standard set as reference planning. Urgency will need evacuation area will increase, especially in North Lombok Regency, West Nusa Tenggara Province.

The objective of this research is to identify the area of green open space suitable to serve as the muster area as a mitigation of the earthquake disaster for the people of North Lombok Regency and design the muster of areas that correspond to the standard functional, aesthetic, comfortable, and safe disaster mitigation. The expected benefit are become a reference for planning a suitable muster area to the needs of the community.

2. Methods

The method used in this research is spatial analysis to select a green open space area suitable as a muster area, as well as a data questionnaire as a consideration in designing. Spatial analysis used thematic maps overlay technique. During analysis activities with overlay techniques required criteria in designing the area muster taken from the example of the area muster in Indonesia and abroad.

This study applied the approach proposed by Booth [6] related to the design process which consist of four stages, i.e. project acceptance, research and analysis, concept, and construction drawing. Project acceptance stages intend to planning the time and place, method, secondary data, and stakeholders that could support in gathering data and information. Research and analysis stage instead to analysis and synthesis the data to resulting the muster area. Construction drawing instead to informing the design of muster area that have appropriate the standards.

3. Results

3.1 General Conditions

North Lombok Regency is located in West Nusa Tenggara Province, based on the law of the Republic Indonesia number 26 the year 2008 about the establishment of regency, North Lombok Regency is expansion of the West Lombok Regency. Administratively North Lombok Regency bordered by Java sea in the north side, East Lombok Regency in the east side, West Lombok Regency in the south side, and Lombok Strait in the west side. The total area of North Lombok Regency reached 809,53 km². Based on the division of administration, North Lombok
Regency consist of 5 subdistrict i.e. Pemenang, Tanjung, Gangga, Kayangan, and Bayan. Subdistrict with the widest area is Bayan Subdistrict covering an area of 329,10 km², while the subdistrict with the smallest area is Pemenang Subdistrict with an area of 81,09 km². More details are presented in the Table 1.

Table 1. Total area by subdistrict in lombok utara regency, 2017 [7]

| Subdistrict | Area (km²) | Percentage (%) |
|-------------|------------|----------------|
| Pemenang    | 81.09      | 10.02          |
| Tanjung     | 115.64     | 14.28          |
| Gangga      | 157.35     | 19.44          |
| Kayangan    | 126.35     | 15.61          |
| Bayan       | 329.10     | 40.65          |
| Total       | 809.53     | 100.00         |

3.2 Topography

The topography of the North Lombok Regency has a mountainous cluster that extends from Bayan subdistrict to Pemenang subdistrict. Mount Rinjani is located in south side of North Lombok Regency with an elevation of 3,726 meter from sea level. The presence of Mount Rinjani makes the area have sources of water and rivers flowing to land and sea along the coast. Throughout the coastal area, there are only low and limited plains. Most of the topography in North Lombok Regency has hilly slope (15-30%) of 31,103.75 hectare or about 38.42% of the entire Regency. In general, the southern part of North Lombok Regency has relatively hilly and montane slope. Land slope 8-15% (wavy slope) reached 17,888.52 hectare or about 22.09% of the Regency, on this slope still found some communities scattered in the group. More details are presented in the Table 2.

Table 2. Classification of slope in North Lombok Regency

| Subdistrict | 0-3% (Ha) | 3-8% (Ha) | 8-15% (Ha) | 15-30% (Ha) | >30% (Ha) | Total (Ha) |
|-------------|-----------|-----------|------------|-------------|-----------|------------|
| Pemenang    | 343.28    | 1,007.41  | 965.64     | 2,840.28    | 3,004.87  | 8,109      |
| Tanjung     | 462.11    | 1,307.20  | 1,719.80   | 5,597.85    | 2,939.15  | 11,564     |
| Gangga      | 662.60    | 2,185.42  | 3,838.61   | 7,337.49    | 2,373.48  | 15,735     |
| Kayangan    | 482.98    | 2,420.47  | 3,451.37   | 4,328.79    | 2,434.37  | 12,635     |
| Bayan       | 1,911.49  | 6,677.57  | 7,913.10   | 10,999.34   | 7,320.29  | 32,910     |
| Total       | 3,862.46  | 13,888.57 | 17,888.52  | 31,103.75   | 18,072.16 | 80,953     |

3.3 Hydrology

North Lombok Regency has two lakes namely Lake Segare Anak and Lake Gili Meno, besides there are ± 47 springs that can be utilized for the daily needs of the surrounding communities. Some of the springs found in North Lombok Regency are Jongplanka Spring, Sangga, Batubara, Castela, Tiukelep, Bangjet Bayan, and so on. Also, 29 rivers are flowing in North Lombok Regency as in the following Table 3.
| Subdistrict | Amount of rivers | Name of rivers                          |
|------------|-----------------|----------------------------------------|
| Pemenang   | 2               | Karang Montong, Manggala               |
| Tanjung    | 3               | Segara, Sokong, Cupek                 |
| Gangga     | 3               | Jugi, Penggolong, Luk                 |
| Kayangan   | 8               | Mumbul, Padek, Tampos, Amor-amor, Aik Beri, Lebah Perbali, Bararingan, Sidutang |
| Bayan      | 13              | Bintang, Nawan, Gereneng, Segoar, Roat, Bat, Koangan, Kandang, Persani, Embar-embar, Menangen, Lebak, Mumbul |

3.4 Total population and density
The population of North Lombok district continues to grow from 2010 to 2017 for 15,785 people with a growth rate of 7.86%. In 2017, the population of North Lombok subdistrict was 216,515 people. The distribution of population in the North Lombok district is spread unevenly. The most residents are domiciled in Bayan Subdistrict with a percentage of people reaching 22.55%, while the population is least domiciled in the Pemenang Subdistrict with a percent of 16.81% of the total population of North Lombok Regency in 2017 according to BPS 2017[7]. More details are presented in the Table 4.

Population density can be calculated based on the number of people to the km². The Regency with the most number of inhabitants does not necessarily mean the regency with the highest density, it can be influenced by the area. The most populous population is in the Pemenang Subdistrict of 448.74 inhabitants per km², while Bayan Subdistrict is the lowest population density area of 148.35 inhabitants per km². More details are presented in the Table 5.

A high-density district generally has better economic development and vice versa. Empirically, people will be found in areas that have high economic activity, availability of social
facilities and infrastructure, adequate transportation, and better socio-economic conditions. Pemenang subdistrict with the highest population density has the highest level of economic activity, it is in the subdistrict of Pemenang has the tourist destinations Gili Meno, Gili Trawangan, and Gili Air which is often visited by local tourists and internationally. There are many hotels, inns, restaurants, shops, and transportation services. In the meantime, Bayan subdistrict has the lowest population of residents because most of the area in Bayan subdistrict is a mountain of mountains with slope > 40% high, it makes access to build the facilities and infrastructure is harder to develop.

3.5 Climate
The average of air temperature in North Lombok Regency is 26.57°C with the average of max temperature is 31.66°C, the average of min temperature is 22.47°C and the humidity average 83.33%. More details are presented in the Table 6.

| Month   | Maximum | Minimum | Average | Humidity on average (%) |
|---------|---------|---------|---------|-------------------------|
| January | 31.4    | 23.7    | 27.1    | 84                      |
| February| 31.2    | 22.6    | 26.6    | 85                      |
| March   | 32.2    | 23.0    | 27.0    | 83                      |
| April   | 32.4    | 22.8    | 27.1    | 83                      |
| May     | 32.2    | 21.9    | 26.6    | 83                      |
| June    | 31.1    | 21.0    | 25.8    | 86                      |
| July    | 30.5    | 20.5    | 25.2    | 84                      |
| August  | 30.8    | 20.1    | 25.3    | 81                      |
| September| 32.0   | 22.5    | 26.4    | 79                      |
| October | 32.6    | 23.3    | 27.4    | 82                      |
| November| 32.3    | 23.9    | 27.2    | 86                      |
| December| 31.2    | 24.4    | 27.2    | 84                      |

Precipitation and rainy day in 2017 data show that in December-April is rainy season and June-October is summer season, May is transition from rainy to summer and November is transition from summer to rainy. More details are presented in the Table 7 and 8.

| Month   | Pemenang | Tanjung | Gangga | Kayangan | Bayan |
|---------|----------|---------|--------|----------|-------|
| January | 248      | 306     | 260    | 388      | 502   |
| February| 351      | 248     | 308    | 548      | 388   |
| March   | 214      | 173     | 207    | 430      | 162   |
| April   | 249      | 313     | 310    | 384      | 175   |
| May     | 142      | 83      | 152    | 140      | 10    |
| June    | 88       | 39      | 58     | 93       | 59    |
| July    | -        | 0       | -      | 22       | 3     |
| August  | -        | 0       | -      | 0        | -     |
| September| 2      | 6       | -      | 41       | 0     |
| October | 39       | 51      | 42     | 92       | 2     |
| November| 141      | 116     | 120    | 296      | 54    |
| December| 158      | 228     | 332    | 361      | 226   |
Table 8. Rainy day in North Lombok Regency [7]

| Month  | Pemenang | Tanjung | Gangga | Kayangan | Bayan |
|--------|----------|---------|--------|----------|-------|
| January| 19       | 17      | 5      | 19       | 20    |
| February| 17     | 19      | 8      | 21       | 20    |
| March  | 13       | 20      | 10     | 20       | 18    |
| April  | 19       | 19      | 13     | 24       | 11    |
| May    | 12       | 7       | 5      | 12       | 7     |
| June   | 10       | 12      | 6      | 11       | 8     |
| July   | -        | 7       | -      | 6        | 3     |
| August | -        | 1       | -      | 2        | -     |
| September | 1    | 8      | -      | 3        | 6     |
| October| 8        | 15      | 7      | 17       | 5     |
| November| 17     | 22      | 13     | 26       | 20    |
| December| 20     | 23      | 14     | 22       | 12    |

3.6 Land Cover
North Lombok Regency has a quite varied land cover. There are ten land cover types, i.e. forests, lakes, plantations, open land, coastal, settlements, savanna, paddy fields, shrubs, and moor. The most dominant land cover is forest, and farm area. More details are presented in the Table 9.

Table 9. Land cover of North Lombok Regency

| Land cover | Total area (Ha) | Percentage (%) |
|------------|-----------------|----------------|
| Lake       | 110,22          | 0,13           |
| Forest     | 28,814,30       | 35,60          |
| Open field | 3,131,25        | 3,87           |
| Sand beach | 44,26           | 0,05           |
| Plantation | 21,251,14       | 26,25          |
| Settlement | 2,522,70        | 2,77           |
| Savana     | 30,79           | 11,48          |
| Rice field | 13,519,19       | 16,70          |
| Thicket    | 9,292,28        | 0,04           |
| Moor       | 2,236,88        | 3,11           |
| Total      | 80,953          | 100            |

4. Analysis and Synthesis
4.1 Suitable area for muster area
As mention in method, spatial analysis is using thematic overlay technique in ArcGIS. The thematic maps required i.e administration map, land cover map, slope map, open space map which closes to settlements, a buffer of the beach area map, and an earthquake distribution map from July to December 2018. Muster area is selected from open space in North Lombok regency. Category of selection area is an open space with a total area of at least 250 m² that is in the area of earthquake density which is high damage potential, close to the settlement, has road access, the slope between 0% to 8%, and land cover of a farm, savanna, and moor. The overlay technique is resulting suitable muster area in Figure 1. The suitable area are located in Genggelang village in the Gangga subdistrict, Kayangan village and Dangiang village in the Kayangan subdistrict.
In muster area facilities is vital in first respond to emergency situation. The facilities in muster area is based on the results of the questionnaire to 30 respondents. The questionnaire head to showing how people respond to earthquake. The result are 50% of North Lombok Regency people evacuating themselves less than 100 meters at the time of the earthquake occurred, 27% as far as 100-500 meters, and 23% 500-1000 meters, it's mean the community prefer a closer place for evacuation site. Difficult facility to obtain in the evacuation area, 50% of respondents answered the tent, therefore 30% answered electricity and 20% answered the toilet. The complaints during the evacuation site, 40% answered less broadly, 40% answered the location of evacuation away from home, 17% answered the location of the evacuation was difficult to access the vehicle, and 3% responded to the fracture trees around the evacuation site. Drinking water supply during the evacuation area, 60% answered from bottled water, 27% answered from the cooking water of TAPS, 13% answered from the springs around the evacuation site. More details are presented in Figure 2, 3, 4, 5, 6 and 7.

Figure 2. Self rescue action
Figure 3. Distance of running for self rescue
4.2 Synthesis
Planning concepts for the design of the area muster should be concerned with human safety. The muster area should be supporting human life needed also cooperate with the government, community, healthcare personnel, and disaster-handling organization, and communication media. The facilities that can be applied i.e. include parking facilities, clean water supply, public toilet facilities, Tent plaza, and the provision of solar panels for the provision of emergency electricity. Other facilities needed are presented in the table 10 and figure 8 and 9.

| No | Facilities               | Normal                  | Emergencies                          |
|----|--------------------------|-------------------------|--------------------------------------|
| 1  | Signage                  | Signage and siren       |                                      |
| 2  | Public toilets and bathroom | Emergency toilets and bathroom |                                      |
| 3  | Cafetaria                | Soup kitchen             |                                      |
| 4  | Football field           | Tent                    |                                      |
| 5  | Football pitel           | Hospitality tent        |                                      |
| 6  | Musholla                 | Musholla and emergency announcement |                                      |
| 7  | Parking                  | Parking for emergency car |                                      |
5. Conclusion
The disaster prone areas were identified based on the result of study on the Gangga Subdistrict and Kayangan Subdistrict. In the prone area, suitable muster was discovered at Genggelang village in Gangga Subdistrict, Kayangan Village and Dangiang Village in Kayangan subdistrict. The muster area needs a spatial design for maximum space utilization. The design should consider human needs. The facilities of muster area should be multifunctional in normal situation as well as during the emergencies situation.

Reference
[1] Undang-Undang RI No. 24 Tahun 2007 Tentang Penanggulangan Bencana.
[2] [BNPB] Badan Nasional Penanggulangan Bencana. 2007. Pengertian Mitigasi Bencana Bencana. Jakarta (ID): Badan Nasional Penanggulangan Bencana.
[3] Paramesti, C. A. 2011. Kesiapsiagaan Masyarakat Kawasan Teluk Pelabuhan Ratu Terhadap Bencana Gempa Bumi dan Tsunami, 22(2), 113–128.
[4] Pusat Studi Gempa Nasional. 2018. Kajian Bencana Gempa Lombok Provinsi Nusa Tenggara Barat. Jakarta (ID): Pusat Penelitian dan Pengembangan Perumahan dan Permukiman
[5] Joga N. 2010. Perencanaan Cerdas Mewujudkan Kota hijau. [diakses pada 5 Oktober 2018]
[6] Booth, N. K. 1989. Basic Elements of Landscape Architectural Design. Waveland press.
[7] [BPS] Badan Pusat Statistik. 2018. Kabupaten Lombok Utara dalam Angka. Mataram (ID): Badan Pusat Statistik Kabupaten Lombok Utara.
[8] [CERDAS IPB] Center of Disaster Studies. 2018. Pengembangan dan Implementasi Alat Ukur Kebutuhan Pascabencana. Jakarta (ID): Pusat Kajian Strategis Badan Amil Zakat Nasional.