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The Estimation of Tsunami Vulnerable Areas and the Mitigation Effort in Banten West Coast - Indonesia

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Abstract
Western coast of Banten Province is one of vulnerable area of tsunami.Under water volcanic eruption of Krakatau volcano is one of Tsunami source possibility. The second one source is caused by the shifting Asian and Australian tectonic plates in Indian ocean. Extra ordinary impact of Tsunami are: devastating people, animal, cultivate, destroyed building, industrial area, agriculture land and others. Tsunami vulnerable areas can be known by using the primary and secondary data such as Thematic data and maps, existing remote sensing image and Topographical Map. The objective of this study is to determine the spatial distribution of tsunami vulnerable areas and its mitigation. Coastal management assessment can be prepared by zonation (zonal) based on the most vulnerable level, importance Land use and physical condition of the impacted area. The methods used are Shuttle Radar Topographic Mapping (SRTM) image classification on slope and elevation to be slope map and Elevation map. The main analysis are maps overlay on Geographic Information System (GIS) application. To compose of Zonal Map using visual lines at the main land use boundaries especially perpendicular line at the coastal line of Tsunami vulnerable map. Research activities started from data and spatial information collection, analysis and distribution of depictions of areas vulnerable to tsunami disaster preparation description. Result of this study is a map of the spatial distribution of tsunami vulnerable areas and zonation map for Tsunami mitigation and coastal management for the study area. Based on the result map, its can contribute to the policy recommendation for local Government on coastal management especially Tsunami mitigation.

1. Introduction

Disaster may be occurred at any time and any where in a sudden without any signal before. What researcher should know is how to minimize risks and losses from any disaster. Indonesia that lies in the dynamics and active plate so researcher should examine and make some mitigation or prevention to the disaster vulnerable areas. Tsunami as one of danger and horrifying disaster to most of people lives near the coast that close to volcanoes or lies between two different plates (Tanioka, Y., Latief H. etc., 2012). Based on Webster's Dictionary, Tsunami is defined as a great sea wave produced by submarine earth movement or volcanic eruption. The Indonesian sains dictionary explained Tsunami as : " The large ocean waves usually caused by earthquakes or

volcanic eruptions in the sea. Can also be caused by a large mud slip under the water . These waves reach a height of 10 meters spreads in concentric circles from the epicenter, often run reached 700 km/h. Tsunami can be very destructive when it reaches the coast. Despite it is rarely happened, tsunami was extremely dangerous and damaging the environment, habitat and various aspects of human's life (Anneliseb, Hagan et.al., 2006). Local research in Indonesia on tsunami - prone areas that can occur in the southern regions of Sukabumi district in West Java is the result of tectonic earthquake in the sea (Oktariadi 0., 2009).

Experience of the devastating earthquake and the impact of the shift plate collision in west of Sumatera island in 2004 is possible to be occurred in the south of Java island. Beside that, Krakatau eruption in August 27, 1883 was unpredictable and likely to be occurred in the future. Research on the area distribution of human settlement, industrial buildings, particularly chemical and food storage industries become indispensable to mitigate tsunami disaster (Kertapati, E., 2006). Multy-risk of Tsunami hit in chemical industry area may incident in the study area. Mitigation action must be prepared and high priority to be conserved.

The tsunami that devastating very rare but interspersed with some small tsunami , making very different opinions between the opinion that the tsunami disaster is very important and less important, especially to measure the impact of its loss (Triatmadja R, 2010). Furthermore, in its research report stated that Indonesia, Japan, Portugal, Chile and Peru have the highest number of victims of the tsunami disaster among other countries. The amount of losses and social impacts of humanitarian, economic, physical and environmental effects caused by multi tsunami depends on the disasters ampleness (Prabowo, onny, 2007). Further it is stated that Mount Krakatau eruption in August 27, 1883 had brought a terrible catastrophic impact to global climate change (BMKG, 2004). Various post-eruption impacts include physical damage to residential areas, agriculture, other human activities and a variety of living biota(NREA – Indonesia,2006).

Data Tsunami height in some places, that in southern Java Sea is only about 3 - 5 meters, in Japan 15-24 m or even more. in Chile 20 m, in the west coast of Sumatra including Aceh 5-25 m, in the Pacific Hawaii 20-35 m and in the Sunda strait by the eruption of Krakatau in 1883 very powerful but no data recorded (Dewi R. S., and Dulbahri, 2015). Based on the mention above so this study will take an estimation that possibilities' of Tsunami disaster

The first one objective of the study is to determine the spatial location and distribution of tsunami vulnerable areas. The second one is to make zonation on the Tsunami vulnerable map based on land use and physical condition on most vulnerable areas. Based on the reason that impact of Tsunami's wave is a huge sweeping seashore areas especially in the slightly sloping and seashore areas. Impacted areas usually consist of residential areas, important building, industrial areas, paddy field, fisheries, high economic areas such as markets, shops, offices, and tourism areas. Many impacts occurred: social, economic, physical and multi effect that maybe exist are environment destruction directly by tsunami hit and indirectly by any chemical substance that may infect the surroundings. There are so many chemical industries scattered around Anyer region, West of Cilegon to the end of Pulomerak. The results will be found are Tsunami vulnerable map and Tsunami management zones map and also their sort description.

2. Materials and Methods

Topographic map (RBI) Digital 1:25.000 scale map, BAKOSURTANAL production. Shuttle Radar Topography Mission (SRTM) imagery. Imagery @digital Globe – Google Geo-reference processed, Administrative boundary map scale 1:25.000, Elevation Map scale 1 : 25.000 and Slope map scale 1:25.000 Classified and interpreted from SRTM imagery as mentioned above.

The method used are maps overlay technique on GIS analysis and Tsunami mitigation zones mapping. The first step is preparation, the second step is making elevation and slope map from SRTM imagery. The thirds stepis to make a criteria key and classification of vulnerable levels. The fourth step is to do overlay the maps activities using criteria key. Result of the overlay processing is to find a final vulnerable classification namely: extremely or most vulnerable, high vulnerable, low vulnerable and not vulnerable areas. The result of the study are width of vulnerable areas for each subdistrict is shown in the map and also perform on the table form. The fifth step is to do field check and field survey for primary data collection and also take field photographs.The sixth step is to make zone map using visual lines at the main land use boundaries especially perpendicular line at the coastal line. The last step is to compiled their description and mitigation of tsunami vulnerable at the study area.

Table 1. *Scoring of Altitude and Slope Level.*

No.	Altitude Class(meter)	Altitude Score	Slope Class(%)	Slope Score
1	0-5	15	0 - 2	5
2	5 - 10	10	2 - 8	4
3	10 - 25	5	8 - 15	3
4	25 - 50	0	15 - 25	2
5	50 - 100	0	25 - 40	1
6	100 - 250	0	40 - 100	0
7	250 - 500	0	> 100	0
8	500 - 1000	0		
9	1000 - 1500	0		
10	1500	0		

2.1. Vulnerability Classification

Determination of vulnerability class is a combination of the score of altitude or elevation class and score of slope classes in Table 1. Altitude level is the main aspect so the score is three times slope levels. After doing "Tray and error" test, its can find the slope score and altitude score affected by

Tsunami vulnerability. This table score is also determined susceptibility classes ranging from the highest, high and low level of vulnerability until not vulnerable region. (See Table 2).

2.2. Formula for Tsunami Vulnerability Levels (TVL)

TVL = Total score of (elevation + Slope) as Table 2.

Table 2. *Criteria Key for Tsunami Vulnerability levels (TVL).*

Total Score of Elevation and slope	Vulnerability Level
0 - 5	Not Vulnerable
6 - 10	Low Vulnerable
11 - 15	High Vulnerable
16 - 20	extremely or most Vulnerable

Result of overlay technique are Tsunami Vulnerable levels Map (see Figure 1.)

3. Results and Discussion

The area affected by the tsunami disaster (tsunami assumptions) as follows:

1. Middle Class Tsunami, assuming 5 meters from sea level, flow speed is very fast by the first possibility is the eruption of Krakatau and the possibility devastating caused by the shifting Asian and Australian tectonic plates.
2. The condition of coastal is flat to gently sloping, it possible to be swept far away from the shore relative to the upstream.
3. If the slope of shoreline is steep, the power glide to land will decrease, and if it is more steep, the pace of the tsunami will be stuck, and quickly turned the water mass corresponding to gravitational force.
4. If Flatness Level of coastal area is very flat, the altitude is less than 5 meters, will be affected most. Instead higher with steep slope places will be safe from tsunami disaster.
5. The roughness surface variations and the amount of obstacles in the topographic conditions and land, crops and building density, the tsunami upstream pace become hampered.
6. The farther the distance from the coastline tsunami upstream will weakened the power of the masses wane and discharged at a place.

From these assumptions, risk criterion and vulnerable level can be predicted and estimated by determining the score of each altitude level and slope mountain level. Tsunami vulnerable level in this study can be classified into four level such as : Extremely high or very high vulnerable, high vulnerable, low vulnerable, and not vulnerable. Tsunami disaster threats depend on the position of beach and coastline, altitude, steepness of slope, distance and roughness of surface, vegetation barrier, size of building and the ampleness of tsunami. Coastal areas affected by the tsunami disaster is generally sloping coast. Studies in the region there are 14 districts.

Therefore it covers 14 districts that lies from the north, namely : Pulomerak, Grogol, Citangkil, Ciwandan, Anyar, Cinangka, Carita, Labuan, Pagelaran, Sukaresmi, Patia, Panimbang, Sobang, and Angsana (Bakosurtanal, 2007).

The result map of the study area can be seen at Figure 1 it's at next page below. The width area each *kecamatan* Tsunami vulnerable area can be seen at Table 3.

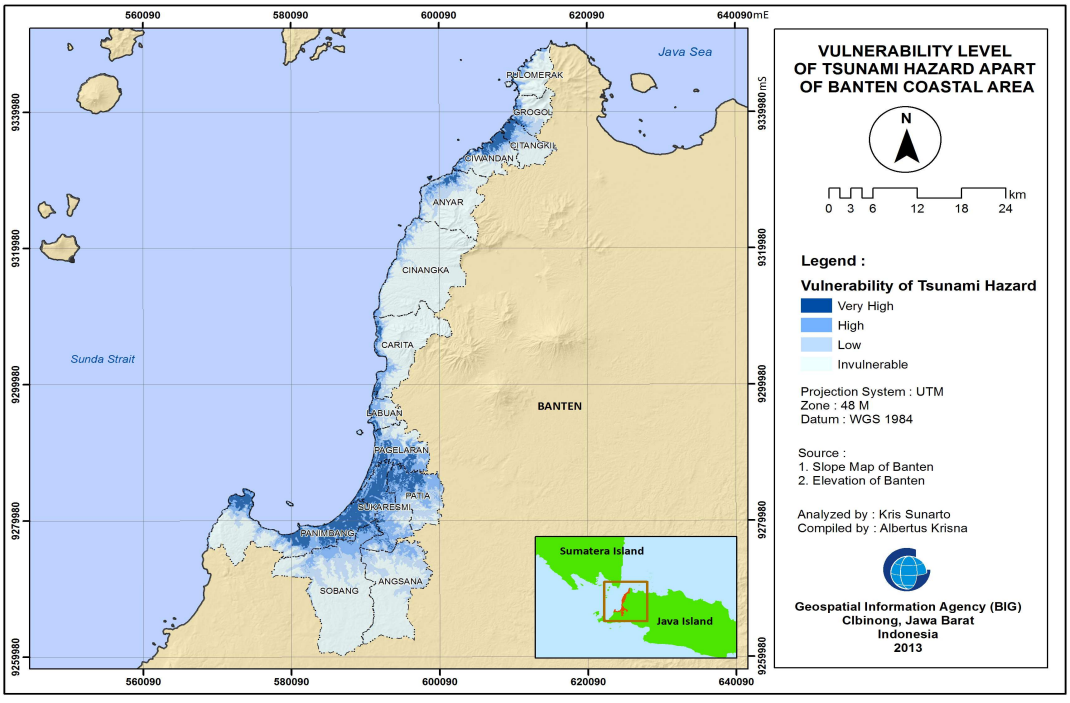

Figure 1. *Vulnerable Level of Tsunami HazardMap.*

Table 3. *Tsunami Vulnerable Areas by sub district in Banten Coastal zone (m^2).*

Sub-District	Not Vulnerable	Low	High	Extremely High	Grand Total
Angsana	59749501	25139384	4960255	0	89849140
Anyar	39270141	13705618	5868692	2625069	61469520
Carita	55988381	6917980	5388127	2660535	70955023
Cinangka	108157161	7701471	4699752	579161	121137545
Citangkil	12050634	7345720	2449568	3492656	25338578
Ciwandan	13306086	7179400	4743687	6618696	31847869
Grogol	13744243	5814041	3554840	1592058	24705183
Labuan	4207332	6195941	3773716	1823824	16000813
Pagelaran	7737463	7103159	16547341	10611871	41999834
Panimbang	34523636	13755053	18825080	32929052	100032821
Patia	5891184	15575184	16179255	10793406	48439030
Pulomerak	19469209	2764428	2427706	1014028	25675371
Sobang	90551935	25905920	16432540	2638669	135529064
Sukaresmi	2365379	8915857	23251264	15455952	49988452
Grand Total	467012282,7	154019159,2	129101825	92834976,05	842968242,9

Source: Sunarto K., 2013.

3.1. Zonation (Zonal) of the Area

Based on tsunami vulnerable area was known above,so many action can be planned for the future. Especially for the coastal zone management of West Banten coastal area. Zonation of the area was estimated in 12 zones (Fig. 2 Management zone of west coast area of Banten Province). One of the application of study result is zoning vulnerable areas on the map result for coastal mitigation management. According khusrizal that different types of soil, rocks and mud in coastal areas require different management efforts. By the time constraints of this study did not arrive at that much detail about it, including the slope of the seabed as an important factor on the speed of tsunami waves of water future. According khusrizal that different types of soil, rocks and mud in coastal areas require different management efforts. By the time constraints of this study did not arrive at that much detail about it, including the slope of the seabed as an important factor on the speed of tsunami waves of water future (Khusrizal M. P.,2014).

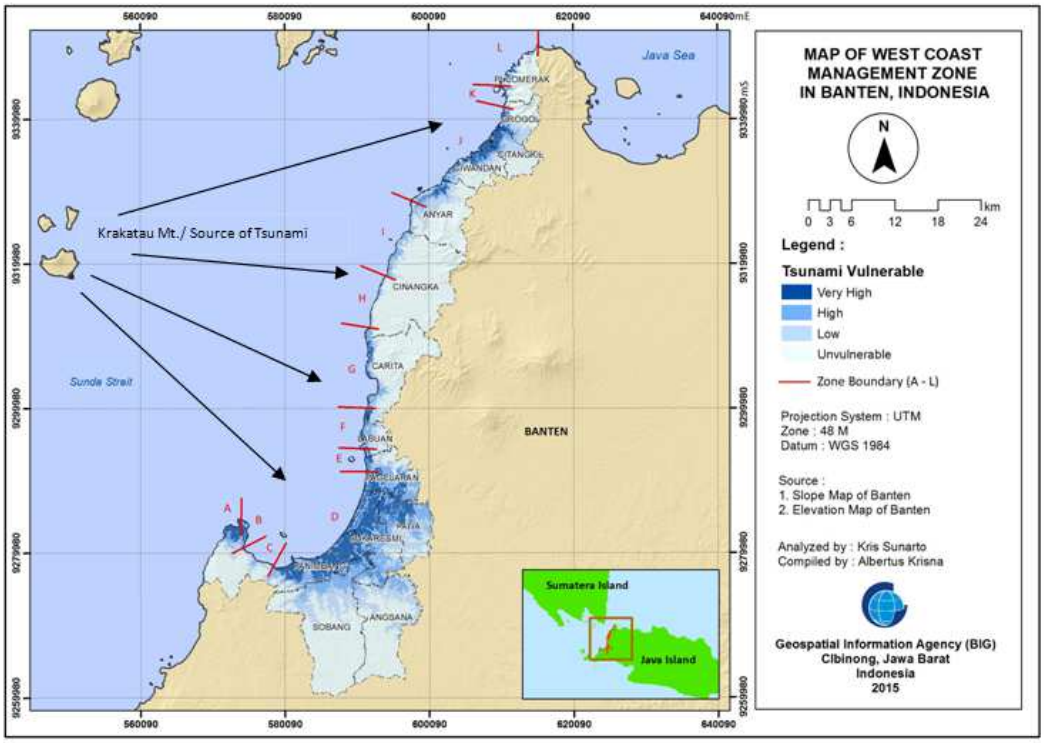

Figure 2. *Management Zone for Mitigation of the study area.*

The eruption of Mount Krakatau is the source of tsunami with wave propagation direction as in the map or figure 2. This condition is very important to consider in coastal management arrangement and zoning of the main lad use on coastal areas of western Banten .As has been revealed by Darmawan that for management arrangement at the most

vulnerable area needed many kind of data such as Data base, meta data geospatial and physical land data (Darmawan M., 2011). Researcher agree that so many data detailed its very important such as: field data, land use data, geographic reference data, administrative boundary data, social data on population, agriculture, animal husbandry and land ownership of data.

3.2. Description of Each Zones

Zone A up to Zone L can be descripted for landscape, land cover and their land use. Mitigation of the area can be done by degree start from the most urgent and need a priority task. The other hand sustainable development must be give them attention (See Table 4). Related management issues of coastal areas, In geomorphological procces, Banten coastal areas develop normally, in contrast to local conditions in Aceh are often affected by the tsunami as expressed by Meilianda (Meilianda E.,2009).Along the coast of study area each land use type has Tsnunami vulnerability lavel. There is no beach shaped cliff so in a safe condition as revealed by Lopez (Lopez G. I.,2012). Therefore, in the following description of almost all the necessary mitigation and the need expressed different levels of priority.

Table 4. *Description of each zone.*

Zone		Description
A	:	a part of the area hilly land covered by forest, bush and scrub. The tsunami mitigation on this area is not high priority level.
B	:	Tanjung Lesung Resort area, tsunami mitigation on this area is very high priority level and many part of them was built safety dyke.
C	:	mixed cultivation such as upland crop and paddy rice combine with bush and scrub. tsunami mitigation on this area is not high priority level.
D	:	Lada bay located in this zone, so tsunami mitigation on this area is very high priority level. Geographical landscape consist of very large flood plain and covered by rice field. So the area called as a Large rice barn.
E	:	Fishpond (*Tambak ikan*), only a small part of the coast applied for fishpond. Bandeng and prawn cultivated in that area, is not high priority level.
F	:	Vary rarely dense settlement on the up position to the coast line. The tsunami mitigation on this area is not high priority level.
G	:	Carita resort area and public vacation area, the tsunami mitigation on this area is very high priority level. The great fence is the best way for vulnerable tsunami risk especially for important building and dense settlement.
H	:	Upland crop and rarely settlement on sloping area,the tsunami mitigation on this area is not so high priority level.
I	:	Anyer resort and dense settlement, cadastral mapping is the most important and high priority. the Tsunami mitigation on this area is very high priority level.
J	:	Industrial area, many kind of industrial building, material stock, tools and also their product must be safely. The impact Tsunami not only physically but also chemically.the tsunami mitigation on this area is very high priority level.
K	:	Merak Harbor, especial of Harbor authority was built and manage perfectly
L	:	Industry area, located in hilly land coast, so the area is the best and safety area. Tsunami mitigation on this area is not high priority level

4. Conclusions

The conclusion from this study are: SRTM image has a big contribution as a data source to make an accurate altitude map and slope map. The dispersions and dimensions of Tsunami vulnerable areas can be known exactly by scoring analysis process, and be compiled on the map and table. By knowing the vulnerable areas, it can make some suggestions to make several tsunami mitigation plan and action at the most vulnerable areas. By using zonation visual technique on the Tsunami vulnerable map, mitigation priority area can be known. Many impacts occurred: social, economic, physical and multi effect that maybe exist are environment destruction directly by tsunami hit and indirectly by any chemical substance that may infect the surroundings. There are so many chemical industries scattered around Anyer region, West of Cilegon to the edge of Pulomerak. Protection for industrial areas and tsunami preventive is needed.

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