Analysis of tsunami disaster map by Geographic Information System (GIS): Aceh Singkil-Indonesia

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Abstract. Tsunami risk map is used by stakeholder as a base to decide evacuation plan and evaluates from disaster. Aceh Singkil district of Aceh-Indonesia's disaster maps have been developed and analyzed by using GIS tool. Overlay methods through algorithms are used to produce hazard map, vulnerability, capacity and finally created disaster risk map. Spatial maps are used topographic maps, administrative map, SRTM. The parameters are social, economic, physical environmental vulnerability, a level of exposed people, parameters of houses, public building, critical facilities, productive land, population density, sex ratio, poor ratio, disability ratio, age group ratio, the protected forest, natural forest, and mangrove forest. The results show high-risk tsunami disaster at nine villages; moderate levels are seventeen villages, and other villages are shown in the low level of tsunami risk disaster.

1. Introduction

Aceh Province-Indonesia is one of an area that has a high level of tsunami hazard, according to history great tsunami affected on December 26, 2004. A tsunami map should be done with multi-criteria approach corresponds with the assessment site. Geographic information systems (GIS) are a tool that would be used for analyzing and visualize the level of the tsunami risk. The Indonesian government through BNPB (Indonesian National Disaster Bureau) has regulations to standardize the maps through Perka No.2 in 2012. The regulations discussed the concept of how to develop hazard, vulnerability, capacity, risk or disaster maps in Indonesia [1].

Identify impact tsunami disaster in Tohoku 2011 and reconstruction to build tsunami-resilient community. Tsunami inundation zone recognized and measurement by satellite remote-sensing processing and field measurement [2]. Tsunami inundation numerical models have been an interpretation by using open source GIS and databases to assessment for two coastal areas of Oman. Simple software is used to estimate tsunami run-up to carry out tsunami inundation numerical models by a deterministic and probabilistic approach. Worst-case scenarios are applied a tsunami risk assessment by a deterministic and probabilistic approach [3]. A method for tsunami inundation and
impact assessment is used by integrating GIS applications, and multi-criteria investigation through Analytical Hierarchy Process (AHP) has been studied in Ofunato City, Iwate Prefecture, Japan. The parameters were used Digital Elevation Model (DEM), satellite imagery for remote-sensing analysis and field data collected. The GIS analysis consisted coastline distance created from a coastline vector map. The remote-sensing analysis has consisted of slope and elevation created from Aster GDEM version 2, vegetation density generated from ALOS ANVIR-2 image. AHP processed by weighting the parameter using a pair-wise and comparing with five iterations of a normalized matrix. Five classes of tsunami inundation map and the weighted overlay have been used to produce the tsunami vulnerability map. The final tsunami map has good agreement with the observation and historical data. It is useful for disaster mitigation, evacuation, strategy and management of preliminary disaster information [4].

Smart phone application is introduced as D-Aid app has been developed to visualize the information of victim amount, necessities, and dangerous after the disaster. This application allowed communities to order the complexity of differentiation, integration, and collaboration data [5]. Developing a system of spatial information to support tsunami evacuation action planning by using geo-information technology is discussed. GIS applications are presented through a GIS model builder as a tool in this system, and it used to minimize damages by Tsunami and developed run-up plans [6]. Tsunami thematic maps with GIS layer for the area Indonesia derived from analyzing several key parameters of the tsunami risk for the southern region of Sumatra, Java and Bali have been made by Strunz, et al, 2011 [7]. Detection of ground motion that resulting to earthquake locally by using remote sensing and GIS tools has been investigated [8]. It conducted by evaluating satellite imagery, topography, Digital Elevation Model (DEM) for extracting parameters geomorphometric, SRTM (Shuttle Radar Topography Mission) and ASTER-data.

The purpose of this work is to analyze the tsunami disaster at Seaboard area in Aceh Singkil district Aceh province Indonesia using the GIS tools. The tsunami risk-disaster map is needed by the government and the public people to understand about their region on the status of the tsunami-vulnerable or risk disaster. The government of Aceh Singkil through BPBD (regional disaster management bureau) would decide evacuation plan and evaluated the physical and infrastructure development in a safe area, especially for the risk zone according to the results in tsunami risk map. Government and stakeholders of Aceh Singkil required this tsunami disaster map that will be used as a reference to mitigating greater damage and more victims. Furthermore, tsunami map is used as a reference for region development planning area that can minimize the victim, physical and economic destruction. Many investigations and analysis about disaster maps have been done, but in this paper discussed about creating the tsunami maps refer to the Perka BNPB No.2 at 2012 (Indonesia laws from National Disaster Bureau) as the basis for the analysis of these maps.

2. Methods
Aceh Singkil is one of a district in Aceh Province of Indonesia and located on the Western Coast (Fig.1). Disaster risk map is a function of three interrelated aspects, such as hazard, vulnerability, and capacity. Data required to produce the tsunami risk map consists of administrative maps of the study area, digital Rupa Bumi Indonesia Map (Topographic map) with scale 1:50.000 from BIG (geospatial information bureau), SRTM (The Shuttle Radar Topography Mission) Aceh Singkil, shapefile of tsunami area that affected on December 24, 2005. The GPS, digital camera, computer with GIS software is used for visualization and reports. Data collection during implementation is obtained from the field survey with supported by FGD (Focus disaster group, involving local government and stakeholder). Secondary data related tsunami histories, seismic, climate, demographic are collected by the FGD.
Figure 1. Potential Indian Ocean tsunamigenic sources, red indicates subduction zones, green partly strike-slip faults, and orange volcanic centers [3].

The tsunami hazard map is obtained by analyzing the SRTM elevation data and overlay with tsunami shapefile. Vulnerability map developed from some parameters, which are social, economic, physical environmental vulnerability, and level of exposed people. Capacity maps obtained from the field assessment result. Disaster-risk map was derived by analyzing the hazard maps, vulnerability, and capacity with the disaster algorithms. All levels of hazard, vulnerability, capacity and disaster risk-map can be seen in three classes, the scoring starting from zero to one index (0-0.3333 indicate for low, 0.3334-0.6666 for medium, and 0.6667-0.9999 for high levels of hazard).

2.1. Social vulnerability
Social vulnerability is obtained from analysis Eq.1 with parameters is population density, sex ratio, poor-ratio, disability ratio and age group ratio [1]. The data obtained from the center of Indonesia’s statistics (BPS) and cross-checked with existing data at the sub-district institutions [9].

Social Vulnerability

\[
\text{Social Vulnerability} = \left( 0.6 \times \log \left( \frac{\text{Population Density}}{0.01} \right) \right) + (0.1 \times \text{Sex Ratio}) + (0.1 \times \text{Disability Ratio}) + (0.1 \times \text{Poor Ratio}) + (0.1 \times \text{Poor Ratio})
\]  

(1)

| Table 1. Parameter for analysis social vulnerability [1]. |
|----------------------------------------------------------|
| Parameter                  | Percentage (%) | Class          | Score          |
|----------------------------|----------------|----------------|----------------|
| Population density         | 60             | <500 people/km²| 500-1000 people/km² | >1000 people/km² | Class/ Max. index of classes |
| Sex ratio (10%)            |                |                |                |                |                           |
| Poor ratio (10%)           |                |                |                |                |                           |
| Disability ratio (10%)     | 40             | < 20 %         | 20-40 %        | >40%           |                           |
| Group ages ratio (10%)     |                |                |                |                |                           |
2.2. Economic vulnerability
The economic vulnerability data is analyzed Eq.2 by scoring productive land with PDRB (gross regional domestic product) [1,9].

\[
\text{Economic Vulnerability} = (0.6 \times \text{Productive Land Score}) + (0.4 \times \text{PDRB Score}) \tag{2}
\]

| Parameter                  | Percentage (%) | Low (IRD) | Medium (IRD) | High (IRD) | Score                                      |
|----------------------------|----------------|-----------|--------------|------------|--------------------------------------------|
| Productive land            | 60             | < 50 M    | 50-200 M     | > 200 M    | Class/ Max. index of classes               |
| PDRB (gross domestic income)| 60             | < 50 M    | 50-200 M     | > 200 M    |                                            |

2.3. Physical vulnerability
The physical vulnerability is analyzed by using Eq.3, which is parameters of houses, public building and critical facilities in that area [1,9].

\[
\text{Physical vulnerability} = (0.4 \times \text{house score}) + (0.3 \times \text{public facility score}) + (0.3 \times \text{critical facility score}) \tag{3}
\]

| Parameter                  | Percentage (%) | Low (IRD) | Medium (IRD) | High (IRD) | Score                                      |
|----------------------------|----------------|-----------|--------------|------------|--------------------------------------------|
| House                      | 40             | < 400 M   | 400-800 M    | > 800 M    | Class/ Max. index of classes               |
| Public facilities          | 30             | < 500 M   | 500 M-1 B    | > 1 B      |                                            |
| Critical facilities        | 30             | < 500 M   | 500 M-1 B    | > 1 B      |                                            |

2.4. Environment vulnerability
Environmental vulnerability map could be analyzed by using Eq.4. The parameters used are the protected forest, natural forest, and mangrove forest [1,9].

\[
\text{Environment vulnerability} = (0.3 \times \text{main forest score}) + (0.3 \times \text{buffering forest score}) + (0.4 \times \text{mangrove score}) \tag{4}
\]

| Parameter                  | Percentage (%) | Low (IRD) | Medium (IRD) | High (IRD) | Score                                      |
|----------------------------|----------------|-----------|--------------|------------|--------------------------------------------|
| Main forest                | 30             | < 20 ha   | 20-50 ha     | > 50 ha    | Class/ Max. index of classes               |
| Buffering forest           | 30             | < 25 ha   | 25-75 ha     | > 75 ha    |                                            |
| Mangrove                   | 40             | < 10 ha   | 10-30 ha     | > 30 ha    |                                            |
Finally, every vulnerability maps overlay using tsunami vulnerability algorithms, as shown in Eq.5 [1].

\[ Tsunami\ Vulnerability \]
\[ = (0.4 \times Social\ Score) + (0.25 \times Economic\ Score) + (0.25 \times Physical\ Score) \]
\[ + (0.1 \times Environment\ Score) \]  \hspace{1cm}  (5)

Data from field assessment used to produce the capacity map. Parameters are reviewed from the availability of local rules and society for disaster management, availability of early warning systems, the study of disaster risk, availability of disaster education, and a factor of essential risk reduction, development of preparedness funding, logistical and social networks.

The disaster risk map obtained from the overlay of those maps such as hazard, vulnerability and capacity using Eq.6 [1].

\[ Risk = \sqrt[2]{Hazard \times Vulnerability \times (1 - Capacity)} \]  \hspace{1cm}  (6)

3. Results

Aceh Singkil district consists of 11 sub-district and 120 villages. As mention before that disaster risk can be seen as the interaction of hazard (H), vulnerability (V) and capacity (C). Disaster risk map is a function of hazard map and vulnerability map then divided by capacity map.

3.1. Hazard Map

Analysis hazard map derived from the weighted overlay spatial method that obtained the hazard map for Aceh Singkil district as presented in Figure 2-5 and Table 5 shows data attribute of the hazard map.

| No. | Villages         | Sub-district    | Level Hazard |
|-----|------------------|-----------------|--------------|
| 1   | Kampung Baru     | Singkil Utara   | Medium       |
| 2   | Teluk Rumbia     | Singkil         | Medium       |
| 3   | Suka Makmur      | Singkil         | High         |
| 4   | Selok Aceh       | Singkil         | Medium       |
| 5   | Rantau Gedang    | Singkil         | Medium       |
| 6   | Pulau Sarok      | Singkil         | High         |
| 7   | Pasar Singkil    | Singkil         | High         |
| 8   | Kuta Simboling   | Singkil         | High         |
| 9   | Kilangan         | Singkil         | High         |
| 10  | Kampung Ujung    | Singkil         | High         |
| 11  | Ujung Sialit     | Pulau Banyak Barat | High       |
| 12  | Suka Makmur      | Pulau Banyak Barat | High       |
| 13  | Haloban          | Pulau Banyak Barat | High       |
| 14  | Asan Tola        | Pulau Banyak Barat | High       |
| 15  | Teluk Nibung     | Pulau Banyak Barat | High       |
| 16  | Pulau Balai      | Pulau Banyak Barat | High       |
| 17  | Pulau Baguk      | Pulau Banyak Barat | High       |
| 18  | Kuala Baru Sungai| Kuala Baru      | High         |
| 19  | Kuala Baru Laut  | Kuala Baru      | High         |
### Figure 2.
(a) The number exposures people, and (b) the number loss of property in Indonesia rupiah (IRD) by the tsunami in Aceh Singkil District.

| Location          | Exposures People | Loss of Property (IRD) |
|-------------------|------------------|------------------------|
| Kampung Baru      | 1434             | 79,073,719,062         |
| Teluk Rumbia      | 819              | 81,501,880,042         |
| Suka Makmur       | 754              | 108,031,249,784        |
| Selok Aceh        | 576              | 100,335,862,680        |
| Rantau Gedang     | 662              | 82,457,882,863         |
| Pulau Sarok       | 1968             | 124,317,603,821        |
| Pasar Singkil     | 312              | 16,095,875,588         |
| Kuta Simboling    | 1677             | 191,595,256,707        |
| Kilangan          | 2366             | 151,906,791,251        |
| Kampung Ujung     | 1336             | 8,879,517,757          |
| Ujung Sialit      | 191              | 46,594,797,866         |
| Suka Makmur       | 905              | 14,226,067,426         |
| Haloban           | 573              | 53,909,068,044         |
| Asan Tola         | 1135             | 78,539,395,350         |
| Teluk Nibung      | 1733             | 41,431,515,331         |
| Pulau Balai       | 1452             | 34,355,586,646         |
| Pulau Baguk       | 825              | 39,800,344,870         |
| Kuala Baru Sungai | 931              | 24,914,604,374         |

### Figure 4.
The number environmental damages (in hectares) by tsunami in Aceh Singkil District.

| Location          | Environmental Damages (in hectares) |
|-------------------|--------------------------------------|
| Kampung Baru      | 4546                                 |
| Teluk Rumbia      | 3617                                 |
| Suka Makmur       | 1312                                 |
| Selok Aceh        | 2087                                 |
| Rantau Gedang     | 3000                                 |
| Pulau Sarok       | 3112                                 |
| Pasar Singkil     | 1347                                 |
| Kuta Simboling    | 2705                                 |
| Kilangan          | 3100                                 |
| Kampung Ujung     | 1200                                 |
| Ujung Sialit      | 13                                   |
| Suka Makmur       | 10                                   |
| Haloban           | 10                                   |
| Asan Tola         | 5                                    |
| Teluk Nibung      | 2944                                 |
| Pulau Balai       | 2710                                 |
| Pulau Baguk       | 2678                                 |
| Kuala Baru Sungai | 10                                   |
| Kuala Baru Laut   | 10                                   |
| Kayu menang       | 25                                   |
Figure 5. Tsunami hazard map of Aceh Singkil district.

3.2. Vulnerability Map
Vulnerability map obtained from the analysis of Eq.5, which is the function of social, economic, physical environmental vulnerability maps.

Figure 5. Tsunami vulnerability map of Aceh Singkil district.
Table 6. Tsunami vulnerability analysis of Aceh Singki district.

| No. | Village               | District     | Score of Vulnerability |
|-----|-----------------------|--------------|------------------------|
| 1   | Biskang               | Danau Paris  | 0.535495701            |
| 2   | Danau Pinang          | Danau Paris  | 0.461265483            |
| 3   | Lae Balno             | Danau Paris  | 0.586344095            |
| 4   | Napa Galuh            | Danau Paris  | 0.546612169            |
| 5   | Sikoran               | Danau Paris  | 0.541781929            |
| 6   | Sikoran               | Danau Paris  | 0.541360338            |
| 7   | Sintuban Makmur       | Danau Paris  | 0.477901334            |
| 8   | Situbuh-tubuh         | Danau Paris  | 0.48832011             |
| 9   | Blok 15               | Gunung Meriah| 0.570432587            |
| 10  | Blok 31               | Gunung Meriah| 0.565524608            |
| 11  | Blok VI Baru          | Gunung Meriah| 0.56602279             |
| 12  | Blok-18               | Gunung Meriah| 0.4776248              |
| 13  | Bukit Harapan         | Gunung Meriah| 0.600208703            |
| 14  | Cingkam               | Gunung Meriah| 0.582186825            |
| 15  | Gunung Lagan          | Gunung Meriah| 0.616451945            |
| 16  | Labuhan Kera          | Gunung Meriah| 0.866676384            |
| 17  | Lae Butar             | Gunung Meriah| 0.568397106            |
| 18  | Pandan Sari           | Gunung Meriah| 0.52978637             |
| 19  | Panjahitan            | Gunung Meriah| 0.844867753            |
| 20  | Parangusan            | Gunung Meriah| 0.580782128            |
| 21  | Pertampakan           | Gunung Meriah| 0.553414103            |
| 22  | Rimo                  | Gunung Meriah| 0.581953473            |
| 23  | Sangga Beru Selulusan| Gunung Meriah| 0.54326786             |
| 24  | Sebatang              | Gunung Meriah| 0.578144281            |
| 25  | Seping Baru           | Gunung Meriah| 0.594345651            |
| 26  | Sianjo Anjo Mariah    | Gunung Meriah| 0.545775538            |
| 27  | Sidorejo              | Gunung Meriah| 0.565676981            |
| 28  | Suka Makmur           | Gunung Meriah| 0.565840334            |
| 29  | Tanah Bara            | Gunung Meriah| 0.569982995            |
| 30  | Tanah Merah           | Gunung Meriah| 0.610487654            |
| 31  | Tanjung Betik         | Gunung Meriah| 0.735914427            |
| 32  | Tulaan                | Gunung Meriah| 0.570796653            |
| 33  | Tunas Harapan         | Gunung Meriah| 0.559873303            |
| 34  | Butar                 | Kota Baharu  | 0.582758115            |
| 35  | Danau Bungara         | Kota Baharu  | 0.577525485            |
| 36  | Ladang Bisik          | Kota Baharu  | 0.575509359            |
| 37  | Lapahan Buaya         | Kota Baharu  | 0.53258096             |
| 38  | Lentong               | Kota Baharu  | 0.58642335             |
| 39  | Muara Pea             | Kota Baharu  | 0.578505403            |
| 40  | Mukti Lincir          | Kota Baharu  | 0.593910628            |
| 41  | Samardua              | Kota Baharu  | 0.591318392            |
| 42  | Selakar Udang         | Kota Baharu  | 0.498659883            |
| 43  | Sumber Muki           | Kota Baharu  | 0.680789344            |
| 44  | Kayu menang           | Kuala Baru   | 0.545247721            |
| 45  | Kuala Baru Laut       | Kuala Baru   | 0.485089986            |
| 46  | Kuala Baru Sungai     | Kuala Baru   | 0.500595827            |
| 47  | Suka Jaya             | Kuala Baru   | 0.492308018            |
| 48  | Pulau Baguk           | Pulau Banyak | 0.592257278            |
| 49  | Pulau Balai           | Pulau Banyak | 0.59116185             |
| 50  | Teluk Nibung          | Pulau Banyak | 0.590309904            |
| No. | Village              | District                  | Score of Vulnerability |
|-----|----------------------|---------------------------|------------------------|
| 51  | Asan Tola            | Pulau Banyak Barat        | 0.456958104            |
| 52  | Haloban              | Pulau Banyak Barat        | 0.508909934            |
| 53  | Suka Makmur          | Pulau Banyak Barat        | 0.454336341            |
| 54  | Ujung Sialit         | Pulau Banyak Barat        | 0.431392243            |
| 55  | Cibubukan             | Simpang Kanan             | 0.504398997            |
| 56  | Guha                 | Simpang Kanan             | 0.50111879             |
| 57  | Kain Golong          | Simpang Kanan             | 0.526618017            |
| 58  | Kuta Batu            | Simpang Kanan             | 0.516278185            |
| 59  | Kuta Kerangan        | Simpang Kanan             | 0.558259101            |
| 60  | Kuta Tinggi          | Simpang Kanan             | 0.507004074            |
| 61  | Lae Gambir           | Simpang Kanan             | 0.498543318            |
| 62  | Lae Gecih            | Simpang Kanan             | 0.486677509            |
| 63  | Lae Nipe             | Simpang Kanan             | 0.449025086            |
| 64  | Lae Riman            | Simpang Kanan             | 0.501566912            |
| 65  | Lipat Kajang Atas    | Simpang Kanan             | 0.505769515            |
| 66  | Lipat Kajang Bawah   | Simpang Kanan             | 0.503993469            |
| 67  | Pakiraman            | Simpang Kanan             | 0.479452431            |
| 68  | Pandan Sari          | Simpang Kanan             | 0.490480513            |
| 69  | Pangi                | Simpang Kanan             | 0.481259507            |
| 70  | Pertabas             | Simpang Kanan             | 0.478078867            |
| 71  | Serasah              | Simpang Kanan             | 0.500619462            |
| 72  | Siantas              | Simpang Kanan             | 0.621277369            |
| 73  | Sidodadi             | Simpang Kanan             | 0.49079077             |
| 74  | Sidorejo             | Simpang Kanan             | 0.534967596            |
| 75  | Silatong             | Simpang Kanan             | 0.517212023            |
| 76  | Tanjung Mas          | Simpang Kanan             | 0.490916299            |
| 77  | Tugan                | Simpang Kanan             | 0.510911153            |
| 78  | Tuh-Tuhan            | Simpang Kanan             | 0.470977567            |
| 79  | Ujung Limus          | Simpang Kanan             | 0.509004261            |
| 80  | Kampung Ujung        | Singkil                  | 0.606505959            |
| 81  | Kilangan             | Singkil                  | 0.546755182            |
| 82  | Kuta Simboling       | Singkil                  | 0.553028432            |
| 83  | Pasar Singkil        | Singkil                  | 0.56073654             |
| 84  | Paya Bumbung         | Singkil                  | 0.575881339            |
| 85  | Pemuka               | Singkil                  | 0.624308996            |
| 86  | Pulau Sarok          | Singkil                  | 0.585589132            |
| 87  | Rantau Gedang        | Singkil                  | 0.551363639            |
| 88  | Selok Aceh           | Singkil                  | 0.566720326            |
| 89  | Siti Ambia           | Singkil                  | 0.631526966            |
| 90  | Suka Damai           | Singkil                  | 0.588602634            |
| 91  | Suka Makmur          | Singkil                  | 0.543270359            |
| 92  | Takal Pasir          | Singkil                  | 0.4232003              |
| 93  | Teluk Ambon          | Singkil                  | 0.581406981            |
| 94  | Teluk Rumbia         | Singkil                  | 0.553646977            |
| 95  | Ujung Bawang         | Singkil                  | 0.59655226             |
| 96  | Gosong Telaga Barat  | Singkil Utara            | 0.565797866            |
| 97  | Gosong Telaga Selatan| Singkil Utara            | 0.653946101            |
| 98  | Gosong Telaga Timur  | Singkil Utara            | 0.621074894            |
| 99  | Gosong Telaga Utara  | Singkil Utara            | 0.634045763            |
| 100 | Kampung Baru         | Singkil Utara            | 0.663399385            |
| 101 | Ketapang Indah       | Singkil Utara            | 0.64978343             |
3.3. Capacity Map

The capacity index is calculated based on the indicator from the Hyogo Framework for Actions (HFA). It is obtained by carrying out FGD for some actors in disaster management in an area. Based on the evaluation of achievement indicators of resilience area that would divide it into five levels (Table 7), there are:

**Level 1** is the area had small achievements in disaster risk reduction by implementing some advanced actions in plans or policies.

**Level 2** is the area has implemented several actions in disaster risk-reduction achievements with still sporadic from lack of institutional commitment and systematic policy.

**Level 3** is the government's commitment and related to some community disaster risk-reduction in an area has been reached and supported by a systematic policy, but the achievements obtained by the commitment, and the policy have not been comprehensive still not sufficiently to reduce the risk of disaster.

**Level 4** is supported by full commitment and overall policy on disaster risk reduction in the area has success to gain the achievements. However, it recognized there are still limitations in commitment, financial resources or operational capacity in the implementation of disaster risk-reduction efforts within the region.

**Level 5** is the overall achievement has been the success with the full commitment and capacity to all community and government levels.

| No. | Village         | District     | Score of Vulnerability |
|-----|----------------|--------------|------------------------|
| 102 | Telaga Bakti   | Singkil Utara | 0.646259117           |
| 103 | Lae Pinang     | Singkohor    | 0.560919767           |
| 104 | Lae Sipola     | Singkohor    | 0.624787686           |
| 105 | Mukti Jaya     | Singkohor    | 0.595385918           |
| 106 | Pea Jambu      | Singkohor    | 0.425526898           |
| 107 | Singkohor      | Singkohor    | 0.661189349           |
| 108 | Sri Kayu       | Singkohor    | 0.598723174           |
| 109 | Alur Linci     | Suro Makmur  | 0.464752781           |
| 110 | Bulu Ara       | Suro Makmur  | 0.499503722           |
| 111 | Bulu Sema      | Suro Makmur  | 0.614149945           |
| 112 | Keras          | Suro Makmur  | 0.514232565           |
| 113 | Ketangkuhan    | Suro Makmur  | 0.517698735           |
| 114 | Lae Bangun     | Suro Makmur  | 0.544607071           |
| 115 | Mandumpang     | Suro Makmur  | 0.519536902           |
| 116 | Pangkalan Sulampi | Suro Makmur | 0.49291591           |
| 117 | Siompin        | Suro Makmur  | 0.541958043           |
| 118 | Sirimo Mungkur | Suro Makmur  | 0.475702412           |
| 119 | Suro Baru      | Suro Makmur  | 0.508986688           |

Table 7. Capacity index components [1].

| No. | Indicator                                      | Index | Data source                                                                 |
|-----|-----------------------------------------------|-------|----------------------------------------------------------------------------|
| 1   | Local institutional rules and disaster management |       | Forum Discussion Group (National government, National-International non-government, Stakeholder, University) |
| 2   | Early Warning and Study of Disaster Risk Reduction |       |                                                                            |
| 3   | Education of disaster                         |       |                                                                            |
| 4   | Basic factor of risk reduction                |       |                                                                            |
| 5   | Preparedness development on the all sector    |       |                                                                            |
3.4. Tsunami risk disaster map

Disaster risk map based on hazard, vulnerability and capacity map could be seen as a function of interaction from those maps. They are used to obtain the level of an area disaster risk by calculating the potential of people exposures, loss-property, and environment damage area. Hazard map analyzed by SRTM and tsunami affected maps, vulnerability map analyzed by the overlay of social, economic, physic and environmental damage and capacity map analyzed by evaluation of achievement indicators. The result from the analysis by the weighted overlay obtained tsunami level risk map for Aceh Singkil district as shown in Fig.7 and Table 8.

Figure 6. Tsunami capacity map of Aceh Singkil district.
Figure 7. Tsunami risk disaster map of Aceh Singkil district.

Table 8. Tsunami risk disaster analysis of Aceh Singki district.

| No. | Villages       | Sub-district     | Level of Risk |
|-----|----------------|------------------|---------------|
| 1   | Kayu menang    | Kuala Baru       | Medium        |
| 2   | Suka Jaya      | Kuala Baru       | Medium        |
| 3   | Kuala Baru Sungai | Kuala Baru   | Medium        |
| 4   | Pulau Baguk   | Pulau Banyak     | Medium        |
| 5   | Teluk Nibung  | Pulau Banyak     | High          |
| 6   | Ujung Sialit  | Pulau Banyak Barat | Medium    |
| 7   | Suka Makmur   | Pulau Banyak Barat | High    |
| 8   | Haloban       | Pulau Banyak Barat | Medium    |
| 9   | Asan Tola     | Pulau Banyak Barat | Medium    |
| 10  | Teluk Rumbia  | Singkil          | Medium        |
| 11  | Pulau Sarok   | Singkil          | Medium        |
| 12  | Pasar Singkil | Singkil          | Medium        |
| 13  | Kilangan      | Singkil          | Medium        |
| 14  | Paya Bumbung  | Singkil          | Medium        |
| 15  | Siti Ambia    | Singkil          | Medium        |
| 16  | Pemuka        | Singkil          | Medium        |
| 17  | Rantau Gedang | Singkil          | High          |
| 18  | Kampung Ujung | Singkil          | High          |
| 19  | Ujung Bawang  | Singkil          | High          |
| 20  | Kampung Baru  | Singkil Utara    | High          |
| 21  | Ketapang Indah| Singkil Utara    | Medium        |
| 22  | Telaga Bakti  | Singkil Utara    | Medium        |
| 23  | Gosong Telaga Barat | Singkil Utara | Medium        |
| 24  | Gosong Telaga Timur | Singkil Utara | High          |
| 25  | Gosong Telaga Utara | Singkil Utara | High          |
| 26  | Gosong Telaga Selatan | Singkil Utara | High          |
4. Conclusion

Study of tsunami hazard, vulnerability, capacity, and disaster maps for Aceh Singkil district with three levels risk (high, medium and low) is analyzed in this paper based on Perka No.2. The results show sixteen villages have high and four villages have the medium level of hazard. The tsunami vulnerability analysis of Aceh Singkil district can be concluded that the largest number exposure people (4,428 people) and loss property (IDR 631,361,435,495) at Pulau Sarok, and the highest number of environmental damages showed at Kampung Baru village (4,546 ha).

High tsunami risk-disaster shows at Teluk Nibung, Suka Makmur, Rantau Gedang, Kampung Ujung, Ujung Bawang, Kampung Baru, Gosong Telaga Timur, Gosong Telaga Utara, and Gosong Telaga Selatan villages. Some villages in moderate level are Kayu menang, Suka Jaya, Kuala Baru Sungai, Pulau Baguk, Ujung Sialit, Haloban, Asan Tola, Teluk Rumbia, Pulau Sarok, Pasar Singkil, Kilangan, Paya Bumbung, Siti Ambia, Pemuka, Ketapang Indah, Telaga Bakti, and Gosong Telaga Barat. The low level of tsunami risk shows for other remaining villages in Aceh Singkil District.

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