INTEGRATION OF PARTICIPATORY MAPPING, CROWDSOURCING AND GEOGRAPHIC INFORMATION SYSTEM IN FLOOD DISASTER MANAGEMENT (CASE STUDY CILEDUG LOR, CIREBON)

M Dede[1], M A Widiawaty[2], G P Pramulatsih[2], A Ismail[2], H Murtianto[2], A Ati[3]

[1]*Master Program on Environmental Science, Graduate School, Universitas Padjadjaran, Indonesia*
[2]*Department of Geography Education, FPIPS, Universitas Pendidikan Indonesia, Indonesia*
[3]*Geography Education Program, FKIP, Universitas Halu Oleo, Indonesia*
m.dede.geo@gmail.com

***Abstract*-- Ciledug Lor is a flood-prone area in Cirebon Regency. Flood disaster management can empower the community through participatory mapping and crowdsourcing activities. This study aims to analyze the level of floods, threats, vulnerabilities, capacities, risks and refuge locations in Ciledug Lor Village based on participatory mapping, crowdsourcing, and GIS. Various indicators of threat, vulnerability, and flood capacity are obtained from field surveys, open data and official data that have been given a value and weight which are then processed using overlay analysis to obtain flood risk parameters. Determination of refuge locations used network analysis to find out the route, distance, and effective time. The results analysis and modeling showed the average flood level in Ciledug Lor reached 2.27 meters. The refugee location for *Dusun* Pamosongan and *Dusun* Kampung Baru are to the north close to the railway tracks. Meanwhile, *Dusun* Karanganyar and *Dusun* Genggong are in the Ciledug Bus Terminal. In the future, participatory mapping, crowdsourcing, and GIS are expected to build awareness and resilience of disaster.**

***Keywords*: Crowdsourcing; Flood disaster management; GIS; Participatory mapping**

I. INTRODUCTION

Disasters are natural phenomena that cause and have potential harm to humans. Lack of preparedness in handling and mitigating contributes to the potential economic loss after a disaster [1]. The top-bottom perspective of disaster management triggers an apathetic community, even though the increasing trend of potential disasters by anthropogenic activities that require sustainable environmental management. Disasters are learning tools for the community and related parties to shape awareness and resilience by involving available resources and technology [2].

Productive human resources need to be empowered in participatory disaster management efforts. Today, the productive age group has the provision of knowledge and responsiveness to the development of mobile smartphone-based information technology in the community [3]. Mobile smartphone ownership has become a basic need of the productive age group and will continue to increase every year [4]. Many government agencies such as BNPB, BPBD, and BMKG provide disaster information through social media networks in a short time because supported by telecommunications networks, and able to strengthen resilience for the community forward in a positive direction [5] [6]. This phenomenon indicates that disaster communication and community empowerment to respond to disasters have bright prospects for development by following the development of digital technology.

As an archipelago country located in the equatorial zone and a meeting between the world's tectonic plates, Indonesia has high disaster potential and requires the active role of the community as the main agent of mitigation. Disaster locality was better identified through crowdsourcing between the local government community and stakeholders as driving agents [7] [8]. Smartphone has many sensors such as the Global Navigation Satellite System (GNSS), gyro-compass, motion sensors, geo-tagging cameras, and clinometer can be used to collect disaster data as part of decision making [9] [10]. Smartphone utilization produces spatial data and its attributes have better results when combined with open data from credible agencies [11]-[13]. State agencies in Indonesia namely BNPB, KLHK, KemenPUPR, LAPAN, and BMKG providing online spatial and free used to support disaster analysis [14]. If needed foreign agencies such as USGS (US), NOAA (US), and ESA (European Union) have open data with similar mechanisms of Indonesian agencies.

Requirements geospatial data through The Indonesian Law 04/2011of Geospatial Information causing several open data is unable to use – the detailed spatial analysis a village, *dusun*, or hamlet (RW) units need the spatial resolution of 8 to 30 square meters. Besides that, data procurement solutions through terrestrial surveys and aerial photographs based on UAV require skilled resources and costly, so participatory mapping and crowdsourcing are the best choices according to local needs and characteristics [15]. Participatory mapping is an interactive method of documenting spatial information by the community to regional development [16].

Participatory mapping needs support crowdsourcing because the affected community has resources, experiences and mental maps as valuable information [17] [18]. To keep quality data for disaster analysis, participatory mapping and crowdsourcing require assistance-supervision from other parties. The participatory and crowdsourcing are efficient methods for flood disaster analysis because the observation is limited by meteorological factors. This condition common happens in the Cirebon Regency which has high annual rainfall and located downstream of several watersheds [19]. As a flood-prone area, spatial flood monitoring is limited to synthetic aperture radar (SAR) data. In terms of size and processing time, SAR data utilization requires large resources and unable to analyze flood disasters on a detailed scale.

As a flood-affected area in the Cirebon Regency, Ciledug Lor Village can conduct participatory and post-disaster mapping. The experience, space control, and community resources need to be empowered through local disaster management programs. Scientific collaborations between local governments, communities, NGOs, research institutions, and universities are able to produce data and information based smartphone technology to flood mitigation [20]. This activity can increase disaster understanding, sharing knowledge and strengthen public awareness of the environment while providing valuable data for policymaking and disaster management. Participatory mapping and crowdsourcing in flood disaster management are a collaboration between the Ciledug Lor community, NGOs, and UPI-UNY students (KKN Posdaya Program) in 2019. This activity produced geospatial data and information for flood prevention efforts after processing by the geographic information system (GIS). Therefore, this study aims to analyze flood level, disaster risk and refuge locations in Ciledug Lor Village.

II. Methods

The research held in Ciledug Lor Village, Ciledug District, Cirebon Regency, West Java, Indonesia. Ciledug Lor known as a flood-prone area and located on the banks of Cisanggarung River. In the latest rainy season, flood disaster entire of the village and this study covered all blocks -four *dusun* and one area of Tanah Bengkok (Figure 1).

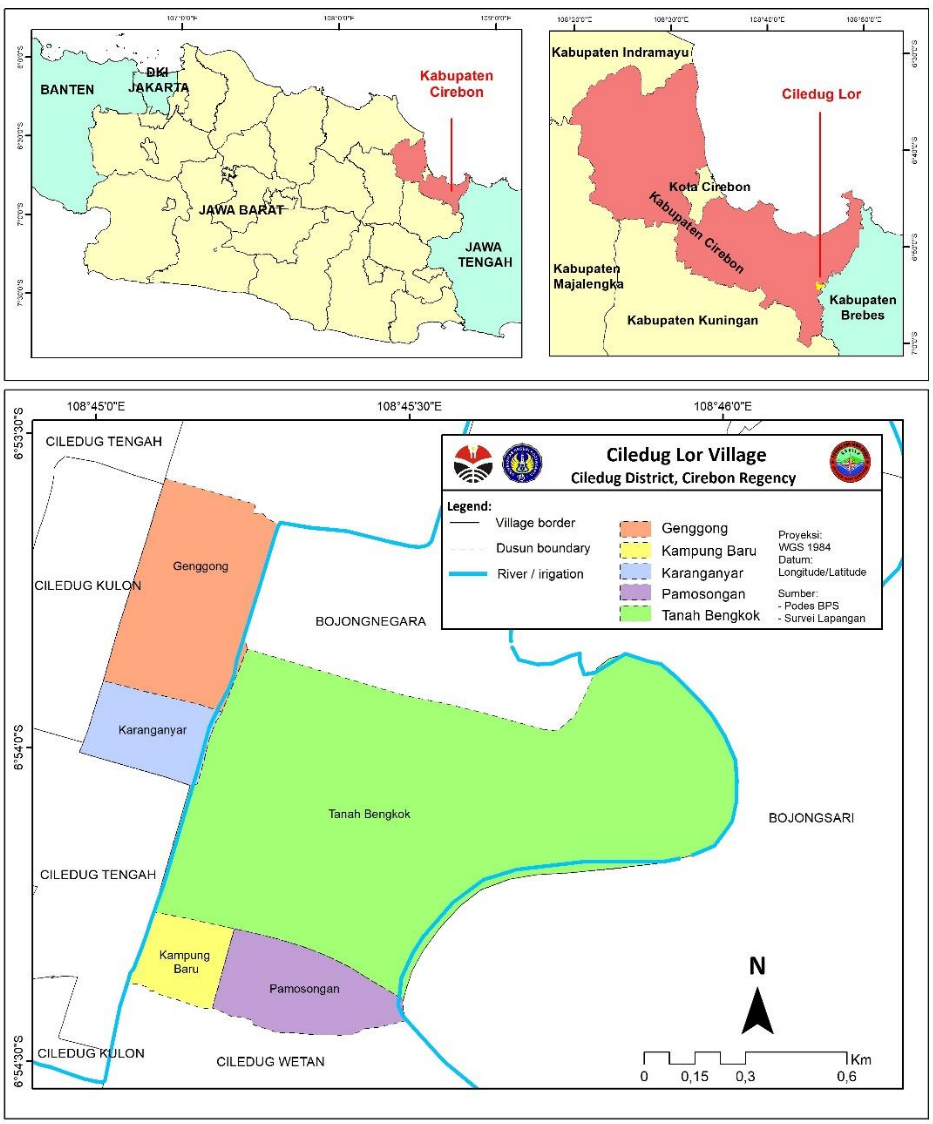

Fig. 1. Research location.

TABLE I
Data acquisition.

Data	Sources		Information
Flood level	1. Participatory mapping 2. Crowdsourcing		Using 44 points (purposive sampling) in Ciledug Lor
Flood risk	Threat	The distance of river/irrigation	*Multiple – buffering*
		Runoff coefficient	Land use map
		Land elevation	BIG DEMNas
		Land slope	*Slope analysis*
		Flood level	Kriging interpolation
	Vulnerability	Number of population and woman	Village monograph
		Road length	HOT OSM and CSRT CNES-Airbus
		Land use	*On-screen digitizing* CSRT
	Capacity	Jumlah sekolah	Village monograph
		Health facilities and workers	Field survey
		Preparedness	Structural interviews
Refuge locations	Participatory mapping		Addition to flood threat map data and structural interviews

A. Tool and Materials

Participatory and crowdsourcing requires several tools and materials such as smartphones, meters, bamboo sticks, instrument sheets, and stationery, whereas spatial analysis needed computers with GIS software (QGIS or ArcGIS) and an internet connection to access open data. Specifically for smartphones device must have a camera and GNNS sensor with an accuracy (spatial distortion) of six meters. Thus, a smartphone capable to capture a minimum of two navigation satellite systems signal namely GPS, GLONASS, Beidou, Galileo, QZSS or others [14]. Checking and calibration for a smartphone can use free software such as Polaris Navigator, Mobile Topographer or GPS Test for Android OS and GPS Maps for Apple IOS.

Data about the flood in Ciledug Lor was obtained through a structured interview. The data collection team consisted of elements of KKN Posdaya UPI-UNY, local community, disaster volunteer, and the village government. Participatory mapping begins with created *dusun* and hamlet boundaries based on the community's spatial knowledge and perceptions through digitizing high-resolution satellite imagery, while crowdsourcing is carried out information about the flood to determine disaster parameters. In addition, flood disaster management efforts also utilize several secondary data from CNES-Airbus high-resolution satellite imagery, Sentinel-1 SAR images, National DEM (BIG DEMNas), annual village monographs, OSM transportation networks, hydrographic chart, and PODES (see Table I). The various data were analyzed using GIS to produce geospatial information.

B. Analysis Methods

Flood level data is obtained through participatory mapping on 44 observation points. The measurement sets 10 points for each *dusun* and four points in crooked land block. Latest flood level data equipped with disaster photos from the community. The flood level data were interpolated using Kriging's geostatistical method because relatively better than others according to mean error (ME), root mean square error (RMSE), and r^2 [21]. The interpolation results set a pixel size of 0.5 x 0.5 meters. Flood level data is the main information to flood risk analysis.

Flood risk analysis using several aspects included threat, vulnerability, and disaster capacity (see Table II). The flood threat was obtained from several indicators such as elevation, slope, distance to river or irrigation, and run-off [22]. In this study, indicators of rainfall and soil texture (infiltration) are considered constant. For flood vulnerability, several indicators are anthropocentric and refer to human activities [23] [24]. Flood capacity analysis in used indicators of school number, health facilities or workers, and flood disaster preparedness, so the indicators can be adjusted to locality [25]. After that, flood disaster risk generated by a union and intersect overlay analysis based on Equation 1.

$$FR = \frac{T \times V}{C} \tag{1}$$

where FR is flood risk, T is a threat, V is vulnerability and C is capacity.

Meanwhile, the determination of refuge locations in Ciledug Lor considering the flood threat and evacuation route efficiency. Evacuation route determination utilizes network analysis based on disaster hazard criteria, road length and travel time [26]. This analysis also determines several temporary assembling points in each *dusun* to facilitate the community conducting the rescue.

III. RESULT AND DISCUSSION

A. Flood Level

Participatory flood level measurements are verified with photo data (geotagging) and SAR imageries to find out the footprint. Internal (*dusun* and RW) boundary of Ciledug Lor results of participatory mapping were used to facilitate flood disaster analysis. The food level average of the village reached 2.27 meters with a maximum level of up to 6.96 meters. Kriging interpolation has ME -2.67 cm, RMSE 20.58 cm, and r^2 0.95. The error value of the model was relatively lower than the IDW and Spline interpolation. The Kriging model also has a very high correlation between measured flood level and spatial estimation result.

TABLE II
Score and weight in flood disaster management of Ciledug Lor.

Flood risk aspect	Indicators	Information	Score	Weight
Threat	Distance of river / irrigation	0 – 50 m, > 50 – 100 m, > 100 – 250 m, > 250 – 500 m and > 500 m	1 – 5	25
	Runoff coefficient	0.10 – 0.30, 0.15 – 0.25; 0.20 – 0.40, 0.30 – 0.5 and 0.50 – 0.75	1 – 5	20
	Land elevation	0 – 2 m, > 2 – 6 m, > 6 – 11 m, > 11 – 13 m and > 13 m	1 – 5	15
	Land slope	0 – 8 %, > 8 – 15 %, > 15 – 25 %, > 25 – 40 % and > 40 %	1 – 5	10
	Flood level	0 - 25 cm, > 25 - 100 cm, > 100 - 200 cm, > 200 - 500 cm and > 500 cm	1 – 5	30
Vulnerability	Number of population	< 400, > 400 – 600, > 600 – 800, > 800 – 1000 and > 1000 persons	1 – 5	35
	Number of woman	< 200, > 200 – 300, > 300 – 400, > 400 – 500 and > 500 persons	1 – 5	30
	Road length each *dusun*	0 – 1500 m, > 1500 – 2000 m, > 2000 – 2500 m, > 2500 – 3000 m and > 3000 - 4500 m	1 – 5	15
	Land use	Water bodies, brushland, plantations, polyculture, cornland, onion land, paddy field, and built-up area	1 – 5	20
Capacity	Number of school	Not yet, 1 – 2 units, 3 – 4 units, 5 – 6 units and > 6 units	1 – 5	20
	Health facilities and workers	Not yet, 1 person, 2 – 3 persons, 4 – 5 persons and > 5 persons	1 – 5	30
	Preparedness	0 – 39 %, 40 – 54 %, 55 – 64 %, 65 – 79 % and 80 – 100 %	1 – 5	50

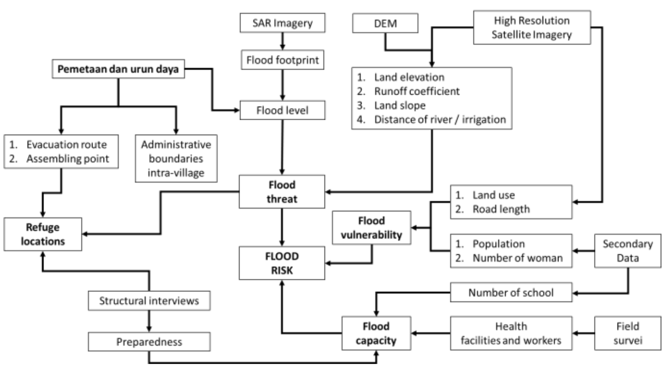

Fig. 2. Research schema.

In terms of distribution, the flood level of the village has a higher pattern in eastward approaching Cisanggarung River. The higher flood level located in *Dusun* Pamosongan and entirely inundated, although this area is known as settlement concentration. The different condition happens in *Dusun* Genggong dan *Dusun* Karanganyar got a benefit form railway. Thus, the elevations of these areas are relatively higher than the surrounding. Variations of floods exist in Tanah Bengkok with an average level of more than one meter. Referring data and information of flood (see Figure 3), *dusun* in the southern and eastern of Ciledug Lor have higher flood levels causing geographically conditions.

B. Flood Risk

Biophysical indicators of flood hazard adjusted by these characteristics, where land elevation and slope can strengthen the results of the flood analysis level which been obtained previously [19]. Land elevation from DEMNas reclassifies into five classes, DEMNas also used to determine the slope value (flood parameters can be accessed on https://bit.ly/2zwOWTg). The analysis showed that *Dusun* Kampung Baru and *Dusun* Pamosongan had the highest level of flood risk (Figure 4e). A Different condition happens in *Dusun* Genggong, it has the lowest risk because located in the northern of Ciledug Lor –Tanah Bengok is uninhabited.

Fig. 3. Data collection and flood footprint.

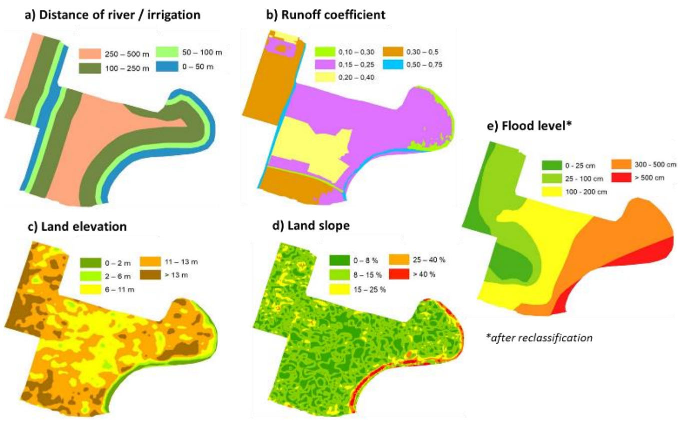

Fig. 4. Flood threat indicators.

In the flood risk parameters, vulnerability as conditions that determine hazard potentials for the community. In Ciledug Lor, it is composed of the total population, women number, road length, and land use, these indicators combined using overlay analysis to produce a flood vulnerability map (Figure 5b). The highest flood vulnerability occurred in *Dusun* Genggong and *Dusun* Pamosongan. Flood vulnerability has a centralized pattern following anthropocentric indicators, thus Tanah Bengkok has the lowest vulnerability to flooding. In addition, threat and vulnerability are directly proportional to disaster risk, capacity is an aspect to reduce the disaster risk levels [27]. Flood disaster capacity compiled on indicators of the number of schools, health facilities or workers, and community preparedness. The selection of indicators is based on consideration of its potential to reduce disaster risk (see Figure 5c).

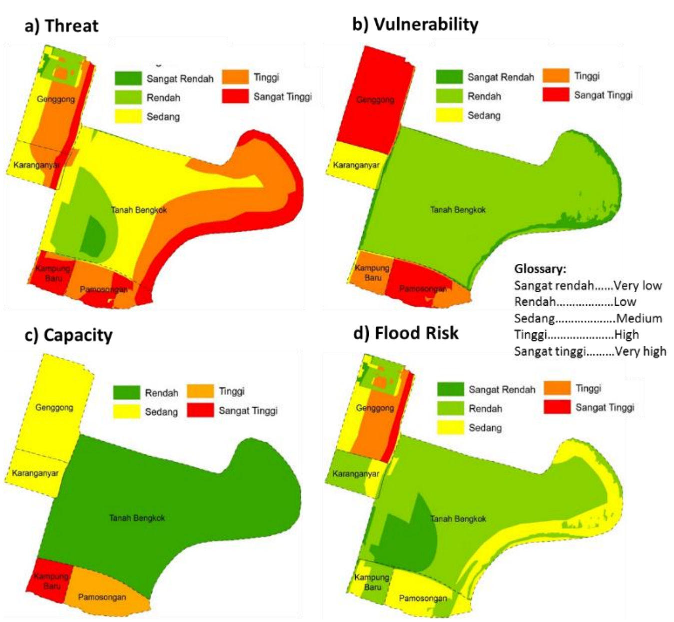

Fig. 5. Flood risk in Ciledug Lor.

Dusun Kampung Baru has the highest flood capacity in Ciledug Lor. High preparedness of them is caused by the learning from disaster experience [28]. This condition appeal related to the presence of formal educational institutions and access to health facilities or workers. If all aspects of the risk have been fulfilled, the flood disaster risk analysis results theoretically can be done. The highest risk of flood disaster occurred in *Dusun* Genggong (Figure 5d). Although located close to *Dusun* Genggong, *Dusun* Karanganyar has a different condition because of the area mostly safe from flood disaster risks. When considering land ratio, Tanah Bengkok relatively safer area than other areas because the threat and vulnerability are lower.

C. Refuge Locations

Participatory mapping and crowdsourcing also produced information about flood refuges in Ciledug Lor based on existing flood levels, land elevation, area capacities, and knowledge of the affected communities. The locations are safe and able to accommodate many refugees. Suitable locations at the north of *Dusun* Pamosongan and *Dusun* Karang Baru, precisely close to the railway. For *Dusun* Karang Anyar and *Dusun* Genggong, refuges location located in Ciledug Bus Terminal. Besides that, many temporary assembling points have been established at the houses of the hamlet (RW) leader, thus easily the community to move together towards the refugee locations (Figure 6).

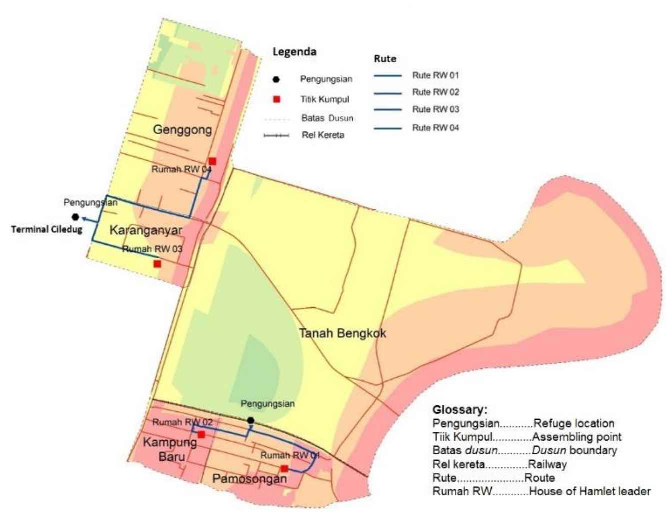

Fig. 6. Refuge locations and evacuation routes.

If assembling points and evacuation routes have been established, an evacuation route takes based on effective distance and time. The network analysis using GIS shows the effective route from *Dusun* Pamosongan to the refugee location is 387.48 m which can be taken in 48.43 seconds. Meanwhile, accessed from *Dusun* Kampung Baru reach 270.29 m and 33.78 seconds. Differences in refugee locations for the community in each *dusun* cause the route length and travel time varies. For *Dusun* Karanganyar designated refugee location has a distance of 296 m and takes 37 seconds from the assembling point, while for *Dusun* Genggong has a distance of 597.97 meters and travel time 74 seconds.

Ciledug Lor is strengthening resilience through the dissemination of disaster information resulting from participatory mapping and crowdsourcing. Disaster information which includes flood levels, threats, vulnerability, capacity, risk, and refuge location in each *dusun* and hamlet is needed (Figure 7). In addition, six pieces of water level observation instruments (TMA) were also placed to carry out better data and information collection about floods through crowdsourcing. Participatory mapping and crowdsourcing are practical learning from disaster utilizing smartphone technology as an effort to form awareness and active participation because flood triggers large potential losses, especially socio-economic.

Fig. 7. Dissemination of disaster information with TMA installation as part of flood disaster management in Ciledug Lor.

IV. Conclusion

Participatory and crowdsourcing in Ciledug Lor produced many useful data and information for flood disaster management. These activities generate information about flood level, threats, vulnerability, capacities, risks, and refuge locations that involve active participation. Utilize smartphone technology and geographic information system (GIS) produces the latest data and information to decision making. Participatory mapping and crowdsourcing have to be developed as an alternative in flood management efforts in Indonesia. Widespread smartphone ownership in the community which supported by telecommunications networks (Kominfo RI) and adequate education is a resource to strengthen disaster resilience.

V. Acknowledgment

This research was supported by the Ciledug Lor community, the local government, POTSAR Gurila, and KKN Posdaya UPI-UNY for actively participation, ideas, and financial contributions. Many meaningful things to succeed in the program and can not be expressed by words.

VI. References

[1] P. Wallemacq and R. *House*, *Economic Losses, Poverty & Disasters: 1998-2017*. Geneva: UNDRR & CRED, 2018.

[2] R. Choularton. (2001). Complex learning: organizational learning from disasters. *Safety Science 21*, pp. 61–70.

[3] APJII, *Penetrasi dan Profil Perilaku Pengguna Internet Indonesia.* Jakarta: APJII & Polling Indonesia, 2019.

[4] M. Airlangga, *Indonesia Digital Landscape 2018*. Jakarta: GDP Venture, 2018.

[5] BNPB, Laporan Kinerja Badan Nasional Penanggulangan Bencana. Jakarta: Pusdatin BNPB, 2017.

[6] P. Lestari, B. Ramadhaniyanto and D, Waryaningrum. (2018). Pemberitaan di media online untuk pengurangan risiko bencana Gunung Sinabung. *Jurnal Kajian Komunikasi*, pp. 106–120.

[7] N. Rizqihandari, R. C. Restuti and F. Hashilah. (2016). Strategi dan koordinasi kebijakan penguatan kapasitas masyarakat dalam pengurangan risiko bencana. Presented at Pertemuan Ilmiah Tahunan Riset Kebencanaan III, Bandung.

[8] C. Orchiston, E H. Doyle, D. Johnston, J. Becker, K. Crowley, E. Lambie and D. Neely, *Citizen Science in Disaster Risk Management Workshop*. Wellington: Wellington Regional Emergency Management, 2016.

[9] N. Sonck and H. Fernee, *Using Smartphones in Survey Research: a Multifunctional Tool.* Den Haag: The Netherlands Institute for Social Research, 2013.

[10] A. M. Al-Hamd, "Mobile Mapping Using Smartphones," Master Thesis, Graduate Program in Geomatics Engineering, University of Calgary, 2014.

[11] C. Schwegmann, *Open Data in Developing Countries*. Brussel: ePSI Platform, 2012.

[12] R. Fisher, S. Hobgen, N. R. Kaho and I. Mandaya, *Satellite Image Analysis and Terrain Modelling: Buku Panduan Geospasial Gratis untuk Pengelolaan Sumber Daya Alam, Risiko Bencana, dan Perencanaan Pembangunan dengan SAGA GIS*. Darwin: Charles Darwin University, 2017.

[13] J. D. Paul, W. Buytaert, S. Allen, J. A. Ballesteros-Cavonas, J. Bhusal, K. Cieslik, J. Clark, S. Dugar, D. M. Hannah, M. Stoffel, A. Dewulf, M. R. Dhital, W. Liu, J. L. Nayaval, B. Neupane, A. Schiller, P. J. Smith and R. Supper. (2017). Citizen science for hydrological risk reduction and resilience building. *WIREs Water* 5, pp. e1262.

[14] M. A. Widiawaty, *Mari Mengenal Sains Informasi Geografis*. Bandung: Aria Mandiri Group, 2019.

[15] M. M. Ar-Rahiem, M. M. (2019, August). Urun Daya dalam Sains. [Online]. Available: http://malikarrahiem.com/urun-daya-dalam-sains.

[16] A. Ismail, A. R. Afriani, S. Himayah and Y. Malik. (2019). Partcipatory mapping for community-based watershed management, lesson learn from Central Java and West Nusa Tenggara. *IOP Conference Series: Earth and Environmental Science* 286, pp. 012024.

[17] L. See, P. Mooney, G. Foody, L. Bastin, A. Comber, J. Estima, S. Fritz, N. Kerle, B. Jiang, M. Laakso, H. Liu, G. Milcinski, M. Niksic, M. Painho, A. Podor, A. Olteanu-Raimond and M. Rutzinger. (2016). Crowdsourcing, citizen science or volunteered geographic information? the current state of crowdsourced. *ISPRS Int. J. Geo-Inf.* 5(55).

[18] Sudaryatno, D. Awanda and S. E. Pratiwi. (2017). Participatory mapping for flood disaster zoning based on World View-2 data in Long Beluah, North Kalimantan Province. *IOP Conference Series: Earth and Environmental Science* 98, pp. 012011.

[19] M. A. Widiawaty and M. Dede. (2018). Pemodelan spasial bahaya dan kerentanan bencana banjir di wilayah timur Kabupaten Cirebon. *Jurnal Dialog Penanggulangan Bencana* 9(2), pp. 142–153.

[20] WMO, *Crisis Mapping and Crowdsourcing in Flood Management*. Geneva: World Meteorological Organization, 2017.

[21] M. A. Widiawaty, M. Dede and I. Ismail. (2018). Comparative study modeling of ground water using geographic information system in Kayuambon Village, Bandung Barat Regency. *Jurnal Geografi Gea* 18(1), pp. 63–71.

[22] A. Haghizadeh, S. Siahkamari, A. H. Haghiabi and O. Rahmati. (2017). Forecasting flood-prone area using Shannon's entropy model. *J. Earth Syst. Sci.*, pp. 26–39.

[23] IPCC, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption*. Cambridge: Cambridge University Press, 2012.

[24] J. Twigg, *Disaster Risk Reduction: Mitigation Preparedness in Development and Emergency Programming*. London: ODI, 2004.

[25] M. D. Mauro. (2014). Quantifying risk before disaster occur: hazard information for probabilistic risk assesment. *WMO Bulletin* 63(2).

[26] T. Athan, R. Blazek and G. C. O. Dassau, *QGIS User Guide / Manual*. Boston: Free Software Foundation, 2014.

[27] LPBPI-NU, *Penyusunan Peta Risiko*. Jakarta: LPBPI-NU, HOT OSM, dan BMInovation, 2017.

[28] H. V. Voort and H. de Bruijn. (2009). Learning from disasters: competing perspective tragedy. *IEEE Technology and Society Magz.*, pp. 28–26.