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Survey-based Mapping of Households' Vulnerability Towards A Comprehensive Evacuation Plan in Karang Kendal, Mt. Merapi

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Abstract: *To enhance resilience, a comprehensive evacuation map that considers the residents' social vulnerability is critical. This paper aims to discuss this concern based on community service at Karang Kendal permanent housing in Mt. Merapi's hazard zone level II, an area to which the Pelemsari community relocated and resided after the violent eruption in 2010. The planning methods used to create such a map are questionnaire surveys and field observations. The results indicate the highly vulnerable populations of the sub-village where 67% of the total 81 houses are occupied by 2-3 vulnerable residents and 68% of these populations are women. These findings then served as a basis for the making of an evacuation map that was not only integrated with the information on the distribution of vulnerable households but also capable of developing the residents' awareness of disasters concerning their socio-demographic conditions.*

Keywords: *social vulnerability, disaster awareness, vulnerable populations, interactive evacuation map, socio-demographic conditions*

Introduction

The position of Indonesia which lies at the intersection of three tectonic plates: Indo-Australia, Pacific, and Eurasia, makes this country prone specifically to eruptions, earthquakes, and tsunamis.[1] World Bank (2005) even listed Indonesia as one of 60 countries with the highest level of risk to multiple hazards[2], the majority of which had forced people in prone areas to leave their origins. In the last ten decades (2010-2021), about 6.5 million displacements have occurred throughout the country as an effect of at least 1,845 disaster events. Eruptions contributed to about 13% of these, preceded by floods (63%) and earthquakes (21%).[3] In Yogyakarta, the Regional Agency of Disaster Prevention (BPBD) recorded that from December 2022 to January 2023, about 244

[1] Asian Development Bank and Internal Displacement Monitoring Centre, *Disaster Displacement: Indonesia Country Briefing*, 2023; KESDM, "MAGMA Dan Resistensi Indonesia Dalam Ring of Fire," *Kementerian Energi Dan Sumber Daya Mineral Republik Indonesia*.

[2] Maxx Dilley et al., *Natural Disaster Hotspots : A Global Risk Analysis* (World Bank, 2005).

[3] ADB and IDMC, *Disaster Displacement in Asia and the Pacific: A Business Case for Investment in Prevention and Solutions* (Geneva: The Internal Displacement Monitoring Centre, 2022), accessed December 30, 2022, https://www.adb.org/sites/default/files/publication/823176/disaster-displacement-asia-pacific.pdf.

natural disasters occurred, among which were landslides (109 events), earthquakes (99 events), and wind storms (14 events).[4] Although the frequency of eruptions is relatively lower than that of landslides, the impacts of the former can be more catastrophic. Mt. Merapi's three-month series of eruptions and violent blasts on October 26, 2010, and November 5, 2010, for example, had claimed about 346 lives and forced about 150,000 people to relocate.[5] From November 2020 to March 2023, the volcano erupted again, emitting a pyroclastic flow that could move about four kilometers to the southwest. As a response, The Investigative and Technological Development Office of Geological Disaster (BPPTKG) increased the volcano's alert status from advisory level (Level II) to watch level (Level III).[6] Despite its aim at reducing disaster risks, the increased alert level had negatively impacted the local economy that relied on the forest. Grass is a forest product upon which villagers depend for fodder, particularly those in the Cangkringan District who farmed about 3,060 dairy cows in 2017.[7]

Cangkringan District comprises five villages: Wukirsari, Argomulyo, Glagaharjo, Kepuharjo, and Umbulharjo.[8] Among these, Umbulharjo is an area with the highest risks of eruptions, particularly of pyroclastic flow. The village lies about 17.5 kilometers to the southeast of the capital of Sleman Regency and is located about 475-1,300 meters above sea level. On average, the annual rainfall amounts to 600-900 mm per month and the temperature is 19-30 degree Celsius.[9] Its territory is bordered by Mount Merapi National Park in the north, Hargobinangun Village in the west, Wukirsari Village in the South, and Kepuharjo Village in the east and consists of nine sub-villages: Pelemsari, Pangukrejo, Gondang, Gambretan, Balong, Plosorejo, Karanggeneng, Plosokerep, and Pentingsari. Historically, Umbulharjo originated from the terms "umbul" and "harjo". The former refers to a large water source that buttresses the local's basic needs while the latter refers to prosperity and peace.[10] After the eruption in 2010, the government collaborated with the Regional Agency of Disaster Prevention to mobilize the residents in high-risk zones to permanently live at the designated relocation sites. In addition, the Ministry of Public

[4] BPBD, *Infografis Data Kebencanaan Daerah Istimewa Yogyakarta* (Yogyakarta, 2023), accessed April 10, 2023, http://www.bpbd.jogjaprov.go.id/assets/uploads/INFOGRAFIS_JANUARI_2023.pdf.

[5] BPBD, *Tanggap Darurat Erupsi Merapi 2010* (Sleman, 2011), accessed April 10, 2023, https://bpbd.slemankab.go.id/wp-content/uploads/2017/11/Tanggap-Darurat-Merapi-2010.pdf; CNN, "Warga Sleman Yang Menetap Di Kawasan Gunungberapi Merapi Masih Berhadapan Dengan Potensi Erupsi Yang Memaksa," *CNN Indonesia*, 2023, accessed April 10, 2023, https://www.cnnindonesia.com/nasional/20230311192740-20-923831/status-gunung-merapi-masih-siaga-usai-rangkaian-erupsi-hari-ini.

[6] CNN, "Warga Sleman Yang Menetap Di Kawasan Gunungberapi Merapi Masih Berhadapan Dengan Potensi Erupsi Yang Memaksa."

[7] BPS, *Badan Pusat Statistik* (Jakarta, 2023), accessed March 5, 2023, https://www.bps.go.id/.

[8] BPS, *Kecamatan Cangkringan Dalam Angka 2022* (Badan Pusat Statistik Kabupaten Sleman, 2022).

[9] Umbulharjo, "Masalah & Isu Strategis Kalurahan," *Karanggeneng Umbulharjo Cangkringan Sleman*.

[10] Umbulharjo, "Website Resmi Kelurahan Umbulharjo Kecamatan Cangkringan Sleman," last modified 2022, https://umbulharjo.smartvillage.id/first/wilayah.

Works through the REKOMPAK Program facilitated the planning and construction of permanent houses by engaging the impacted community.[11] Since 2011, nearly 2,682 houses for eruption victims and 341 houses for the victims of cold lahars have been successfully established throughout Umbulharjo, Wukirsari, Argomulyo, Kepuharjo, and Sindumartani.[12] Despite this, of 3,612 households eligible for the program, around 1,059 households refused to relocate permanently.[13]

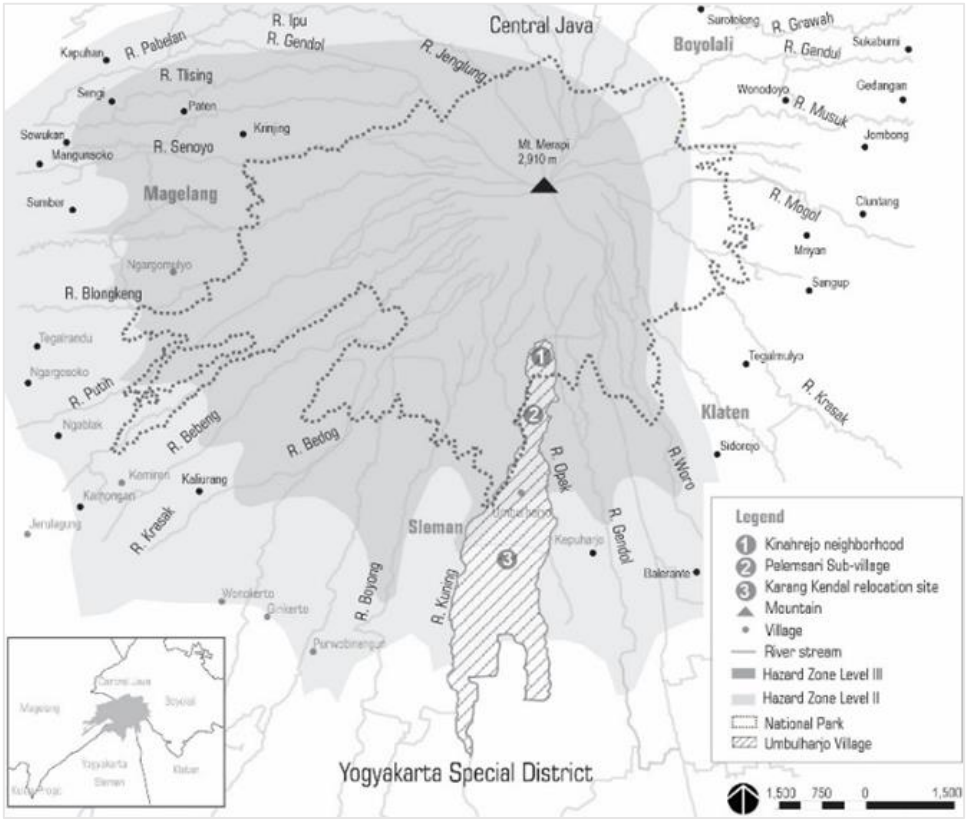

Figure 1. The location of the Pelemsari before the 2010 eruption (number 2) and after the event (number 3). The image was redrawn by the author in 2022.

Different from the residents of other sub-villages, those of Pelemsari accepted relocation particularly after the eruption claimed 37 lives of its members. The survivors then mobilized by collectively purchasing land in Karang Kendal, Balong sub-village, situated about three kilometers from their former settlement (Fig.1). To compensate for their voluntary relocation, the government provided rehabilitation aid in the form of 30

[11] Kanako Iuchi and John Mutter, "Governing Community Relocation after Major Disasters: An Analysis of Three Different Approaches and Its Outcomes in Asia," *Progress in Disaster Science* 6 (2020): 100071, https://doi.org/10.1016/j.pdisas.2020.100071.

[12] DIY, "Awali Pembangunan Huntap Korban Merapi,Sultan Letakkan Batu Pertama," *Pemerintah Provinsi Daerah Istimewa Yogyakarta*, last modified 2012, accessed April 10, 2023, https://jogjaprov.go.id/berita/awali-pembangunan-huntap-korban-merapisultan-letakkan-batu-pertama-.

[13] Ratnawati Yuni Suryandari, Endi Haryono, and Abdullah Sumrahadi, "Merapi Pasca Letusan 2010: Polisi Penempatan Semula Penduduk," *Malaysian Journal of Society and Space* IX, no. 1 (2013): 138–149, accessed February 26, 2023, https://www.proquest.com/docview/2488753350.

million cash per household and reconstruction assistance to build an earthquake-resistant house with a minimum dimension of 36 m2 on land not more than 100 m2 in 2011.[14] In the same year, the Pelemsari residents finally obtained the legal certificates of their former homes but were prohibited from re-occupying these for residentials. In the everyday context, they must routinely move from their current homes in Karang Kendal to the forest to collect grass for fodder.

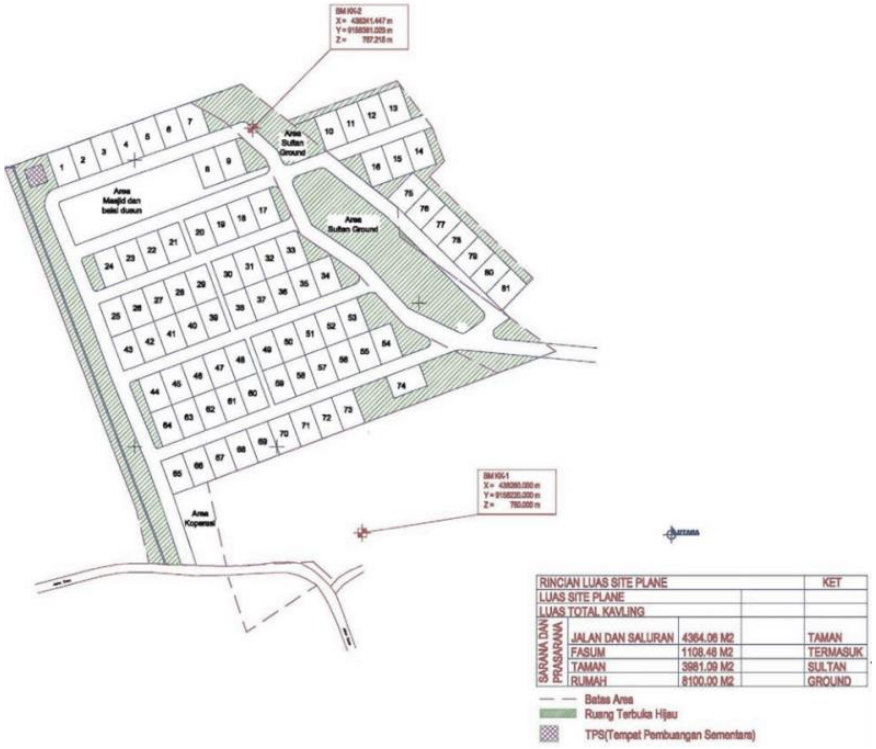

Figure 2. The Karang Kendal's site plan.[15]

The Karang Kendal relocation site has a total area of about 13,365 m2 and comprises 81 houses(Fig.2). Administratively, it contains four neighborhood units consisting of Kinahrejo, Pelemsari, Ngrangkah Lor, and Ngrangkah Kidul. The infrastructure built therein includes drainage, lightning detectors, green areas, paved streets, retaining walls, and public facilities such as a Mosque, playground, community hall, garbage area, communal cowshed, communal dumping ground, and electricity. Despite this, the site, which lies within Mt. Merapi's hazard zone level II, has not yet been equipped with a comprehensive disaster-evacuation map, which is important to inform and assist a relief team in assisting the residents during an emergency.

[14] BNPB, *Rencana Aksi Rehabilitasi Dan Rekonstruksi Wilayah Pasca Bencana Merapi Di Provinsi D.I. Yogyakarta Dan Jawa Tengah Tahun 2011-2013*, 2011, https://bnpb.go.id/uploads/migration/pubs/448.pdf.

[15] REKOMPAK, *Profil Huntap Karang Kendal, Pagerjurang, Dan Batur* (Sleman: Satuan Kerja Rehabilitasi dan Rekonstruksi Rumah Pascagempa bumi DIY dan Jateng, 2013), 3.

Figure 3. The housing conditions and infrastructure of Karang Kendal.

Evacuation is the preparedness phase of emergency management that relates to life-saving efforts and disaster risk reductions[16] and refers to a quick movement from a high-risk zone to a safe zone as a response to disasters. As a process, planning a disaster evacuation system must consist the following: 1) compiling the population census in a high-risk area and updating it at least once every five years or during the increasing eruption activities; 2) gathering data about livestock so the evacuation can be performed efficiently; 3) identifying the vital facilities (e.g., electricity, transmission radio, water supply, food storage) and the damages that can exacerbate the disaster impacts; 4) identifying the nearest areas as the first-level evacuation center supported by facilities like telecommunication radio, and 5) identifying evacuation route that is safe from physical barriers. Regarding evacuation transportation, planners must: 1) identify the number of people who possess private vehicles; 2) calculate the number and the location of the population requiring transportation; 3) determine the evacuation center and pick-up areas using public transportation, and 4) organize the process of obtaining gasoline for evacuation modes.[17]

Nevertheless, the effectiveness of an evacuation map in reducing risks would be much improved only if it considers the socio-demographic vulnerabilities of the households.[18] The risk map of the Sumber sub-village in Klakah, Magelang, for example, does not only display the evacuation route and assembly points but is also complemented with information on its population vulnerability.[19] It is expected that integrating an

[16] Michael K. Lindell and Ronald W. Perry, *Behavioral Foundations of Community Emergency Planning* (Hemisphere Publication, 1992); IOM, *Evacuations and Disaster Risk Reductions in the Carribean* (San Jose, 2021), www.rosanjose.iom.int.

[17] UN, *Volcanic Emergency Management* (United Nations Disaster Relief Coordinator, 1985), accessed April 10, 2023, https://unesdoc.unesco.org/search/N-EXPLORE-55a3612a-3872-4b73-8ad6-1d5b25309bff.

[18] E Fucile-Sanchez and M Davlasheridze, "Adjustments of Socially Vulnerable Populations in Galveston County, Texas USA Following Hurricane Ike," *Sustainability (Switzerland)* 12, no. 17 (2020), https://www.scopus.com/inward/record.uri?eid=2-s2.0-85090407528&doi=10.3390%2fsu12177097&partnerID=40&md5=b435d62f6be44b620ca17c1285a71fd0.

[19] Andreastuti, Budianto, and Paripurno, "Integrating Social and Physical Perspectives of Mitigation Policy and Practice in Indonesia."

evacuation map with information about households' vulnerability would benefit the disaster agencies in distributing aid or providing evacuation assistance to vulnerable households[20].

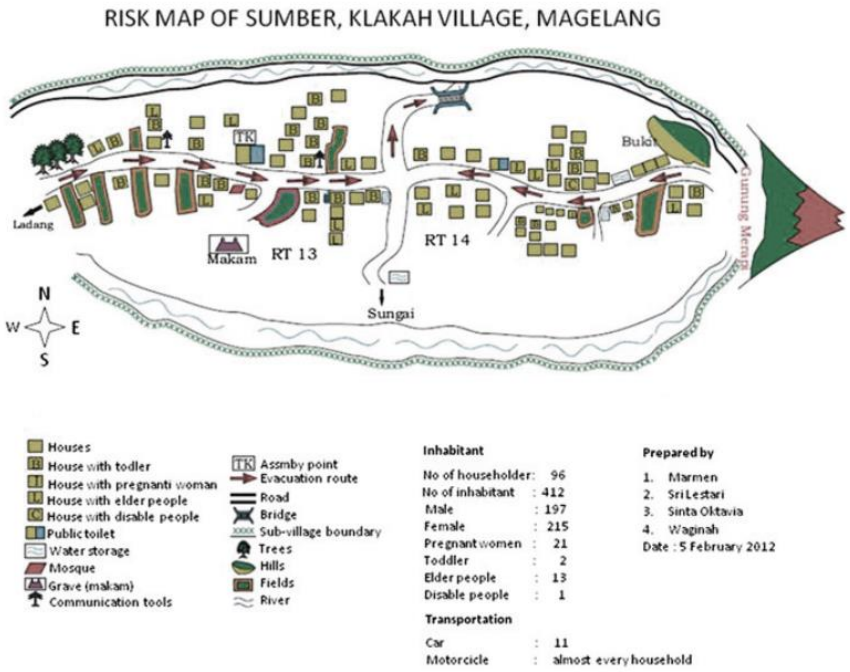

Figure 4. Krakah's evacuation map incorporates data on vulnerable populations.[21]

Hazard vulnerability is a phenomenon within a social system that exists before a disaster occurs. Additionally, the impacts of a disaster can be amplified by the existing social conditions of the residents, implying the presence of vulnerable groups and social vulnerability. A vulnerable group is a homogenized population without regard for the intersecting traits and continual factors that result in unequal disaster and environmental outcomes.[22] Social vulnerability refers to negative social conditions (e.g., residents' lack of access to resources, political power, and social capital) that contribute to the amplification of disaster impacts.[23] Indeed, the level of one's exposure to hazards is

[20] Fucile-Sanchez and Davlasheridze, "Adjustments of Socially Vulnerable Populations in Galveston County, Texas USA Following Hurricane Ike"; Andreastuti, Budianto, and Paripurno, "Integrating Social and Physical Perspectives of Mitigation Policy and Practice in Indonesia."

[21] Ibid.

[22] Jamie Vickery, "Using an Intersectional Approach to Advance Understanding of Homeless Persons' Vulnerability to Disaster," *Environmental Sociology* 4, no. 1 (2018): 136–147.

[23] James R. Elliott and Jeremy Pais, "Race, Class, and Hurricane Katrina: Social Differences in Human Responses to Disaster," Social Science Research 35, no. 2 (June 1, 2006): 295–321; Hans G. Bohle, Thomas E. Downing, and Michael J. Watts, "Climate Change and Social Vulnerability: Toward a Sociology and Geography of Food Insecurity," Global Environmental Change 4, no. 1 (March 1, 1994): 37–48; Barry Smit and Olga Pilifosova, "From Adaptation to Adaptive Capacity and Vulnerability Reduction," Climate Change, Adaptive Capacity and Development (2003): 9–28; Barry E. Flanagan et al., "A Social Vulnerability Index for Disaster Management," Journal of Homeland Security and Emergency Management 8, no. 1 (2011); W. Neil Adger, "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam," World Development 27, no. 2 (February 1, 1999): 249–269.

dependent upon many factors such as gender, age, and physical capacity, and can be exacerbated by the social and economic conditions, norms, task distributions, and the dynamics of one's political relationships with other community members and the government.[24] Given the complexity of these factors, a consensus about the fixed attributes of a vulnerable population is difficult to reach. However, a wealth of studies consistently describe elderly people, women, children, and people with physical and mental disabilities as what make up a vulnerable population.[25] As such, this community service used these as indicators for identifying vulnerable households in Karang Kendal.

Since 2011, the Pelemsari residents have been living in Karang Kendal. Of 241 residents in 2021, 28 people are elderly, 9 are infants, and 28 are kids aged between 5 and 19. In terms of gender, 144 are females and 97 are males. As such, about 25% of the population was prone to disaster. The relatively large population vulnerable to disasters coupled with the fact that Karang Kendal is within the second-level hazard zone indicates the urgent need for an informative evacuation map that is integrated with local vulnerability information. The objective of this community service is, thus, to enhance Pelemsari's awareness of disasters by developing an interactive evacuation map that is integrated with information about the local households' vulnerability to disasters and that motivates them to periodically update their social-demographic data. For the government, the map would help assist the disaster agency in prioritizing aid distribution and evacuation assistance to households with moderate-to-high vulnerability.

Methods

The target of this community service is the Pelemsari residents who after the 2010 eruption, resided in the Karang Kendal relocation site in Balong sub-village, Umbulharjo Village, Cangkringan District. In general, there are five phases of the community service that we conducted: 1) the data collecting phase; 2) the analysis phase; 3) the design phase; 4) the socialization phase, and 5) the construction phase (Fig.5). The community service was conducted in six months, from May through October 2023. The data collection took about two-thirds of the program's time duration. In general, respondents were met at around 3 P.M. or above at their homes, that is after they collected grass and took care of their dairy cows. In this program, the information on vulnerable populations

[24] IOM, *Evacuations and Disaster Risk Reductions in the Carribean*.

[25] Lindsey van der Meer et al., "Social Determinants of Vulnerability in the Population of Reproductive Age: A Systematic Review," *BMC Public Health* 22, no. 1 (December 1, 2022); Xenia. Scheil-Adlung, Catharina. Kuhl, and Bureau international du travail. Département de la sécurité sociale., *Addressing Inequities in Access to Health Care for Vulnerable Groups in Countries of Europe and Central Asia* (International Labour Office, Social Security Department, 2011); Christian Henrik Alexander Kuran et al., "Vulnerability and Vulnerable Groups from an Intersectionality Perspective," *International Journal of Disaster Risk Reduction* 50 (November 1, 2020): 101826; Vickery, "Using an Intersectional Approach to Advance Understanding of Homeless Persons' Vulnerability to Disaster"; Flanagan et al., "A Social Vulnerability Index for Disaster Management"; Neil Adger, "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam."

relied mainly on the local responses gathered through the questionnaire surveys.

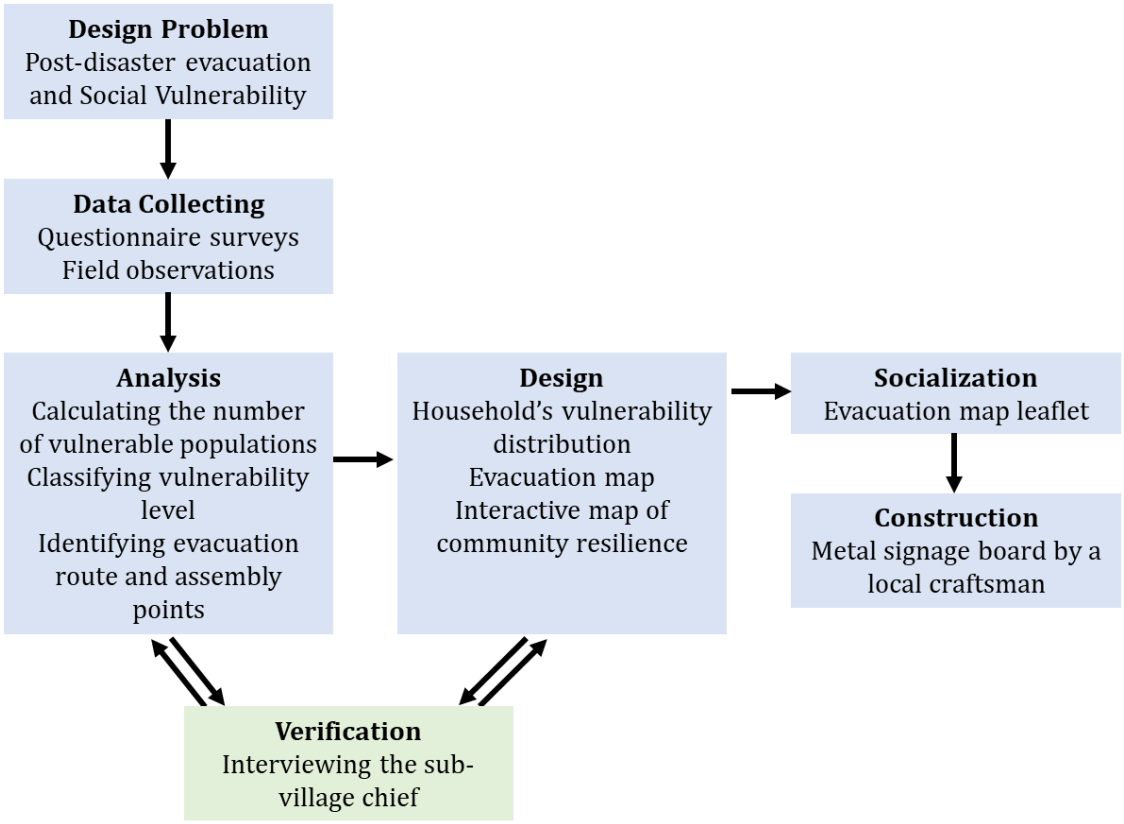

Figure 5. The community service process in Karang Kendal.

Data Collecting Phase

The methods used to collect data for the community service are questionnaire surveys and field observations. The former was specifically aimed to collect data about the total number of vulnerable households based on gender, age, and physical and mental disabilities and was carried out from May through June 2023. The population groups categorized as vulnerable are women, children (aged equal to or less than 12 years old), elderly (aged equal to or above 65 years old), and people with physical and mental disabilities/impairments (Table 1).

Tabel 1. **Variables of vulnerable population based on demographic attributes**

Attributes	Variables	Indicators
Age	Children	Aged equal to or less than 12
	Elderly	Aged equal to or above 65 years old
Gender	Women	-
	Pregnant women	-
Disability	Physical disability	Suffered from blindness, deafness, limps, and other physical impairments alike.
	Mental disability	Suffered from autism, bipolar disorder, schizophrenia, mental retardation, or alike.

The latter was carried out to map out the distributions of the identified vulnerable households as well as the local streets and open spaces that have the potential to serve as evacuation routes and evacuation centers. A series of field observations were conducted in July 2023. In addition, to produce a comprehensive evacuation map, we used the recent Karang Kendal map obtained from the sub-village chief and then made some adjustments based on field observations (Fig.6). Finally, the already-modified map was transferred into a digital map by using Sketchup and AutoCAD.

Figure 6. The field observations on the local conditions for maps' adjustment.

Analysis Phase

In this phase, the data from the questionnaire surveys were calculated in the Microsoft Excel spreadsheet. The total number of members determined the household's vulnerability level to disasters. The vulnerability levels were then categorized into three classes: "low" if the number of vulnerable people living in a house is between 0 and 1; "moderate" if the number of vulnerable people living in a house is between 2 and 3; and "high" if the number of vulnerable people living in a house is more than 3. In the evacuation map, each level was then labeled using different colors. The yellow label indicates a low vulnerability, the orange indicates a moderate vulnerability, and the red indicates a high vulnerability to disasters.

Figure 7. The potential sites for the location of the map around the Karang Kendal's entrance gate: the security post (left) and the *joglo*-style community hall (right)

To determine the evacuation route and center, we considered the street's capacity for an evacuation, the street's clarity and connectivity to the surroundings, the residents' familiarity with the streets and public facilities, the physical barriers of streets and public facilities, and the public facilities' capacity and their locations. We recommended the local streets connecting all neighborhoods and communal cowshed to the main street as the evacuation route and the *joglo*-style community hall around the entrance gate as the evacuation center. These recommendations were then transferred onto an evacuation map in which "red arrows" indicate the potential evacuation route and "a red dot" indicates the potential assembly point in Karang Kendal (Fig.11).

Design Phase

The design phase includes the activity of transferring the findings into a comprehensive evacuation map. The software used for this are SketchUp, CorelDraw, AutoCAD, and Adobe Photoshop. Besides the map, this phase also includes designing the construction details of the metal signboard based on a signage design standard (Fig. 8).

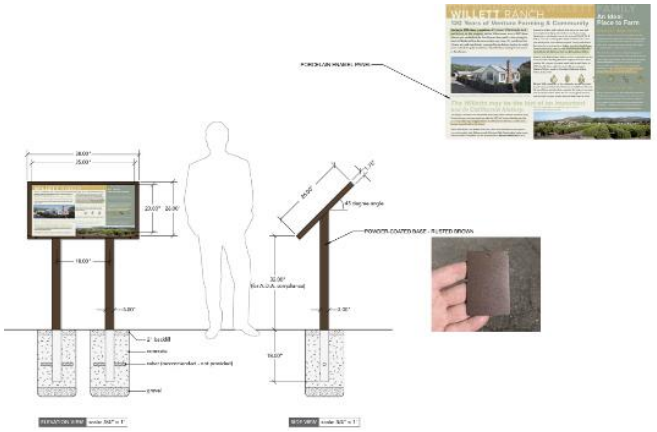

Figure 8. A signage design standard by the Preservation Committee of Ventura City.[26]

[26] Dan Bruechert, *Montgomery County Historic Preservation Commission Staff Report*, 2019,

Construction Phase

After obtaining the sub-village chief's verification of the local vulnerability data, the completed evacuation map was presented to the community through a meeting. Here, leaflets were also distributed to inform them about their potential evacuation system and disaster risk level. Besides socialization, this phase also entails the metal board's construction which involved a local metalsmith.

Result

The outcome of our community service is a local-level evacuation map that is not only well-integrated with the information on the households' vulnerability to disasters but also considers the need for creating an interactive map that allows the residents to make modifications based on their social-demographic condition.

Comprehensive Evacuation Map

Of 81 households in Karang Kendal, 23 are categorized as having a low vulnerability level, 54 are categorized as having a moderate vulnerability level, and two are categorized as having a high vulnerability level. The level of a household's vulnerability to disasters is determined by the number of vulnerable members living in the same house (Table 2).

Tabel. 2 Households' vulnerability level based on residences

Category	Level	Vulnerable households
Unidentified	-	2
Low	0-1	23
Moderate	2-3	54
High	>3	2
Total		81

In percentage, about 67% of the total households are categorized as having a moderate vulnerability level (2-3 vulnerable people per household), about 28% are grouped as having a low vulnerability level (0-2 vulnerable people per household), and only about 2% are grouped as having a high vulnerability level (more than 3 vulnerable people per household) (Fig.9).

accessed October 28, 2023, https://montgomeryplanning.org/wp-content/uploads/2019/08/I.D-4101-Muncaster-Mill-Road-Rockville.pdf; Ventura, *Historic Preservation Committee: City of Ventura*, 2020, accessed October 28, 2023, https://www.cityofventura.ca.gov/DocumentCenter/View/21767/2020-06-17_Item-2_PROJ-12828_WillettRanch.

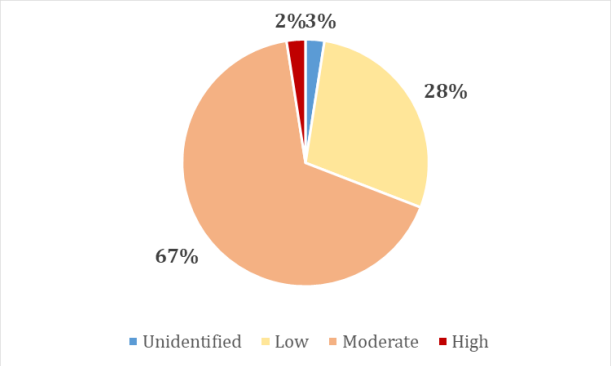

Figure 9. The composition of disaster-vulnerability level.

Further, of 164 vulnerable people we identified, 112 are women, 24 are elderly people, and 28 are children (Table 3). We found no physically or mentally impaired residents in our surveys. It is worth mentioning that we include either an elderly woman or an infant/child when calculating the total number of women. In other words, the women category considers a person who is also grouped as a child or an elderly woman, implying that the women category includes an individual with two identities.

Tabel. 3 **Households' vulnerability based on demographic attributes**

Demographic attributes	Vulnerable households (people)
Women (inc. pregnant women, elderly, children)	112
Elderly people (inc. women)	24
Infants to children (inc. women)	28
Physically and mentally impaired people	0
Total	164

In percentage, of 164 vulnerable people in Karang Kendal, 68% are women, 17% are children (aged equal to or less than 12 years old), and 15% are elderly people (Fig.10). This percentage indicates a relatively high number of vulnerable households that is dominated by women in Karang Kendal.

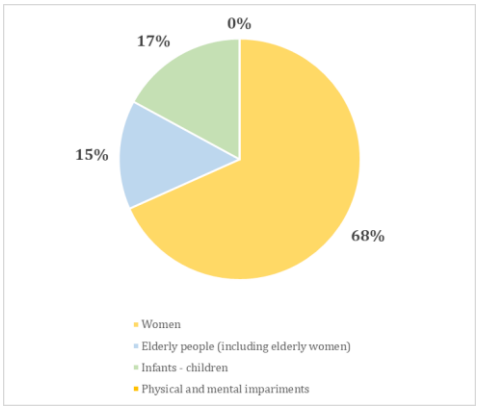

Figure 10. The composition of demography-based vulnerable households.

An Interactive Evacuation Map

Using these data, an evacuation map that considers the vulnerability level of each household was developed (Fig.11). Assisted by two students of the Department of Architecture, the map was created by using graphic software. The household was represented by its residence and the vulnerability level was grouped into three types: low, moderate, and high with an addition of "unidentified" which refers to vacant houses as they were no longer inhabited. These types of categorization were labeled on the map as follows: low in yellow color to indicate a household with 0-1 vulnerable residents, moderate in orange color to indicate that with 2-3 vulnerable residents, and high in red color to indicate that with more than 3 vulnerable residents.

Besides the household's vulnerability level, we also identified public facilities such as the reading house (RB), the mosque (M), the public toilet (MCK), the village hall (B), the communal cowshed (K), the park (T), and *joglo*-style community hall (J). An assembly point typically takes the form of a local landmark that can accommodate a large number of evacuees and has accessible transportation, parking, and an indoor sheltering area.[27] Taking these into consideration, we then recommended the community hall (J) as the potential assembly point at the local level.

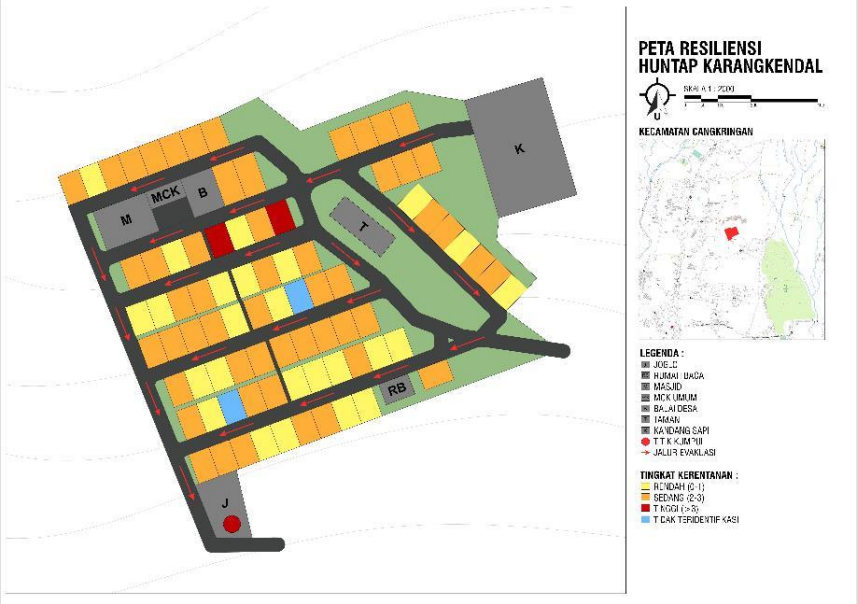

Figure 11. The evacuation route map is embedded with information on the households' vulnerability level and local infrastructures.

[27] Alberta, *Community Evacuation Framework and Planning Considerations*, 2018, accessed October 29, 2023, https://open.alberta.ca/dataset/2613f44a-2639-4195-a281-265fbbea37ff/resource/87364f53-45d4-4594-bed5-9fe0640ae8fe/download/community-evacuation-guidelines-planning-considerations-may-2018.pdf; Us Department of Homeland Security and Federal Emergency Management Agency, *Planning Considerations: Evacuation and Shelter-in-Place - Guidance for State, Local, Tribal and Territorial Partners*, 2019.

When designing the evacuation map, we considered the user-friendly and interaction capacities of users with the media for a memorable learning experience. As such, the evacuation map we proposed in this program is a creative product, which is beyond a conventional map that is simply printed and hung on the wall. The evacuation map should be able to motivate the community to consistently update its social-demographic conditions. In the long run, this would help develop local awareness of disasters, which correspond with their social conditions. The evacuation map would also assist the disaster agencies in providing immediate assistance during an emergency by prioritizing vulnerable households.

To create an interactive evacuation map, we used a 2-mm iron plate which was then coated with paint for durability and aesthetics, acrylic for indicating the different labeled households/houses, a 3M double tape magnetic strip (1 mm x 2.5 cm x 1 m) for sticking the acrylic blocks to the coated-iron plate, stickers for the map legend, and reverse stickers for the colorful labels. Regarding the acrylic blocks, we used a service from a shop specialized in laser cutting. In completing this map, we were assisted by two student assistants (Fig.12).

Figure 12. The making of the interactive map, clockwise from top-left: internal

discussion for making the map; cutting the 3 M magnetic strip into squares based on the house pattern; coating the iron plate with paint; the materials for making the map; the acrylic blocks with a peeled up sticker; the reverse colorful stickers on the blocks; the backside of a 3 M magnetic strip; the front-side (yellow reverse sticker) and the back-side (black magnetic sticker) of the acrylic block.

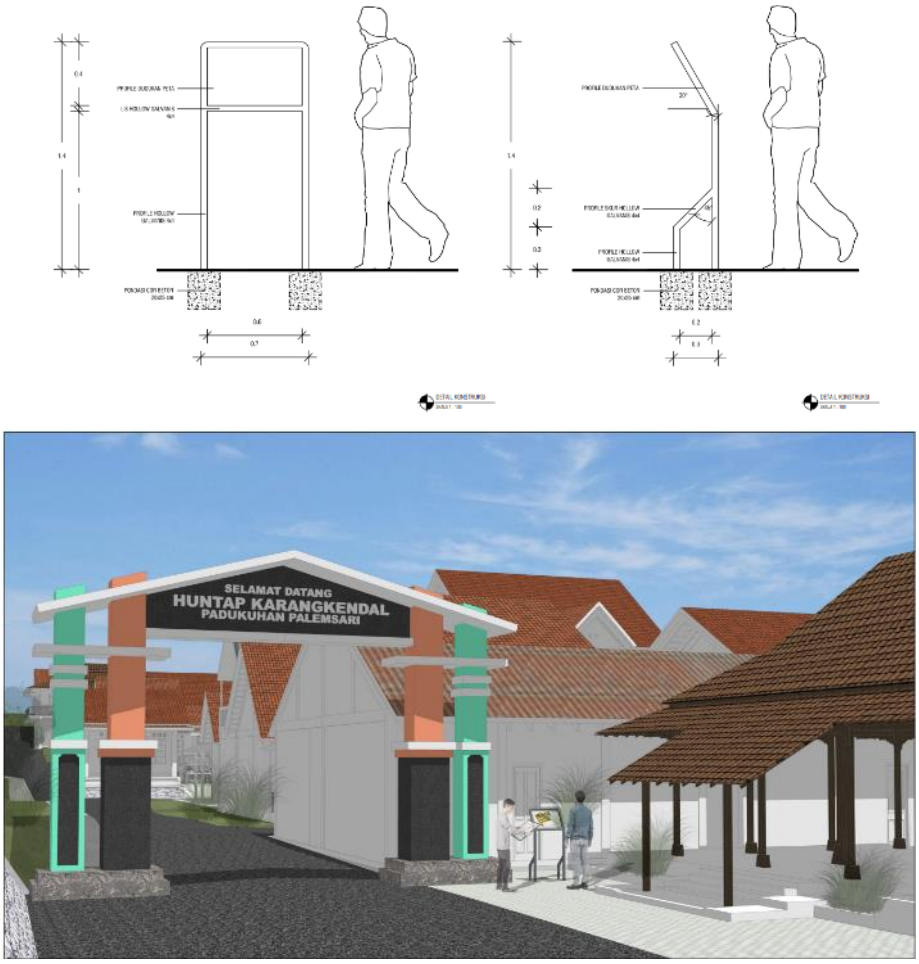

Figure 13. The construction details of the installed metal board (top) and an architectural perspective that shows the evacuation map's site (bottom).

Further, the signage board's construction details must follow the architectural design standards and were drawn using AutoCAD (Fig. 13). The drawings were then communicated to a local metalsmith who was appointed by the sub-village chief to help construct the map's metal board.

Community Engagement

Engaging the community in the making of evacuation maps has been carried out in many cases. For example, Hizbaron et al. (2015) and Wiwaha et al. (2016) conducted a

participatory evacuation map-making in disaster risk areas in Yogyakarta.[28] Nevertheless, programs that integrate an evacuation map with households' vulnerability are very few. Our community service attempts to fill in the gap by involving the community in data gathering through face-to-face questionnaire surveys (Fig.14), engaging a local metalsmith in the construction of the map's metal board (Fig.15), and involving the community in determining the site of its construction (Fig.16).

Figure 14. Interviewing the community about their social vulnerability to risks.

Figure 15. Clockwise from top-left: consulting the design to a local metal smith, the finishing process of the metal board, installing the acrylic blocks onto the metal board, the completed map and metal board, the metal board's construction, and the view to the

[28] Dyah R Hizbaron et al., "A Participatory Evacuation Map Making Towards Sustainable Urban Heritage Kotagede, Yogyakarta," *A Participatory Evacuation ... (Hizbaron, et al) Forum Geografi* 29, no. 1 (2015): 11–22, accessed October 29, 2023, https://journals.ums.ac.id/index.php/fg/article/view/787; Adam Abraham Wiwaha et al., "Perencanaan Partisipatif Jalur Evakuasi Dan Titik Kumpul Desa Ngargomulyo Dalam Upaya Pengurangan Resiko Bencana Gunungapi Merapi," *Journal of Regional and City Planning)* 27, no. 1 (2016): 34–48.

standing metal board of the interactive evacuation map around the entrance gate.

On November 11, 2023, planners socialized the evacuation map and its process to the community in a local meeting (Fig.16). The occasion was held in a local preschool facility after *maghrib*, that is around 7:30 A.M. and ended at around 9:30 A.M. Here, the metal board along with the installed acrylic map was presented to the community to allow them to interact directly with the media. This occasion was also intended to obtain the community's input about the exact site of the map's construction. Respectively, the construction site would be around the entrance gate and the *joglo*-style community hall. The considerations they stressed were the visual accessibility of the public to the map while maintaining public movement and parking activities around the *joglo*.

Figure 16. Planners socialized the comprehensive evacuation map using the metal board and leaflet (top), and the community representatives read the presentation materials and discussed the future site of the metal board's construction (bottom).

Discussion

The Karang Kendal's formal layout, small-sized compound, attached homes, and clear street system would benefit the local future evacuation as these enable the identification of evacuation routes and assembly points that meet the minimum requirements for an effective evacuation system. In addition, the compactness of the housing may also enhance the residents' familiarity with its elements, such as streets and public buildings. In this community service, we recommended the local main streets that connect all neighborhoods as the evacuation route and the *joglo*-style community hall as the local assembly point.

The planning team considered the importance of motivating the residents to responsibly update their demographic conditions and modify the evacuation map accordingly. This led us as planners to create an interactive map. Interactive mapping is a technique of displaying a spatial map that lets users identify specific features, query the underlying data, or visualize select information in the map. This technique typically adopts the GIS (Global Information System) to show spatial data [29] and has been widely used by many agencies worldwide.[30] The benefits of this map are increasing engagement with users, improving data visualization and communication, enhancing user experience and navigation, creating content tailored to local needs, increasing accessibility and inclusivity, providing real-time data, improving the quality of decision-making, saving cost for information sharing, and providing learning opportunities.[31] In our community service, the degree of "user-map interactions" is limited when compared to, for example, web-based GIS maps. Despite this, we recognized the community's enthusiasm toward our comprehensive and interactive evacuation map during the community meeting (Fig.16). This signals the capacity of the map to provide a unique experience of representing, reading, and communicating data which in the long run, would contribute to the enhancement of their disaster awareness and willingness to periodically update their social-demographic conditions.

Conclusion

Rather than only focusing on demographic attributes, the making of a comprehensive resilience map should also consider other factors like poverty level and the mean of household income. Many scholars have introduced the Social Vulnerability Index (SVI) to measure the vulnerability of a community before, during, and after disasters.[32] This approach is a good alternative for enhancing the comprehensiveness of an evacuation map in the future. Nevertheless, this would require the local apparatus to consistently update their community profiles, which at the sub-village level is usually reported through Dusun's monograph. It is worth noting that the outdated data of the sub-village had made this community service quite challenging and forced us to allocate a considerable amount of time to run a series of survey questionnaires.

[29] GEI, "Interactive Mapping," *Interactive Mapping*, last modified 2023, accessed October 29, 2023, https://www.betterevaluation.org/methods-approaches/methods/interactive-mapping#:~:text=Interactive%20mapping%20involves%20using%20maps,select%20information%20in%20the%20map.; Whitney Taylor and Brandon Plewe, "The Effectiveness of Interactive Maps in Secondary Historical Geography Education," *Cartographic Perspectives*, no. 55 (2006): 16–33.

[30] GEI, "Interactive Mapping"; Colombia, "Interactive Map of Evacuation Alerts and Orders"; UNESCO, "World Heritage Interactive Map," *World Heritage Convention*, last modified 2023, accessed October 29, 2023, https://whc.unesco.org/en/interactive-map/.

[31] AI, "The Benefits of Creating Interactive Maps for Improved Reach," last modified 2023, accessed October 29, 2023, https://aicontentfy.com/en/blog/benefits-of-creating-interactive-maps-for-improved-reach.

[32] Flanagan et al., "A Social Vulnerability Index for Disaster Management."

The interactive evacuation map can serve as an example for other community service programs to produce outcomes beyond the conventional ones. When updating the data and the map, we recommend local youths to be engaged. This undoubtedly would increase the map's sustainability, enhance their awareness of disasters at an early stage, and motivate a creative learning process about the community's disaster resilience and vulnerability.

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References

ADB, and IDMC. *Disaster Displacement in Asia and the Pacific: A Business Case for Investment in Prevention and Solutions*. Geneva: The Internal Displacement Monitoring Centre, 2022. Accessed December 30, 2022. https://www.adb.org/sites/default/files/publication/823176/disaster-displacement-asia-pacific.pdf.

AI. "The Benefits of Creating Interactive Maps for Improved Reach." Last modified 2023. Accessed October 29, 2023. https://aicontentfy.com/en/blog/benefits-of-creating-interactive-maps-for-improved-reach.

Alberta. *Community Evacuation Framework and Planning Considerations*, 2018. Accessed October 29, 2023. https://open.alberta.ca/dataset/2613f44a-2639-4195-a281-265fbbea37ff/resource/87364f53-45d4-4594-bed5-9fe0640ae8fe/download/community-evacuation-guidelines-planning-considerations-may-2018.pdf.

Andreastuti, Supriyati, Agus Budianto, and Eko Teguh Paripurno. "Integrating Social and Physical Perspectives of Mitigation Policy and Practice in Indonesia." In *Advances in Volcanology*, 307–320. Springer Science and Business Media Deutschland GmbH, 2018.

BNPB. *Rencana Aksi Rehabilitasi Dan Rekonstruksi Wilayah Pasca Bencana Merapi Di Provinsi D.I. Yogyakarta Dan Jawa Tengah Tahun 2011-2013*, 2011. https://bnpb.go.id/uploads/migration/pubs/448.pdf.

Bohle, Hans G., Thomas E. Downing, and Michael J. Watts. "Climate Change and Social Vulnerability: Toward a Sociology and Geography of Food Insecurity." *Global Environmental Change* 4, no. 1 (March 1, 1994): 37–48.

BPBD. *Infografis Data Kebencanaan Daerah Istimewa Yogyakarta*. Yogyakarta, 2023. Accessed April 10, 2023. http://www.bpbd.jogjaprov.go.id/assets/uploads/INFOGRAFIS_JANUARI_2023.pdf

.

———. *Tanggap Darurat Erupsi Merapi 2010*. Sleman, 2011. Accessed April 10, 2023. https://bpbd.slemankab.go.id/wp-content/uploads/2017/11/Tanggap-Darurat-Merapi-2010.pdf.

BPS. *Badan Pusat Statistik*. Jakarta, 2023. Accessed March 5, 2023. https://www.bps.go.id/.

———. *Kecamatan Cangkringan Dalam Angka 2022*. Badan Pusat Statistik Kabupaten Sleman, 2022.

Bruechert, Dan. *Montgomery County Historic Preservation Commission Staff Report*, 2019. Accessed October 28, 2023. https://montgomeryplanning.org/wp-content/uploads/2019/08/I.D-4101-Muncaster-Mill-Road-Rockville.pdf.

CNN. "Warga Sleman Yang Menetap Di Kawasan Gunungberapi Merapi Masih Berhadapan Dengan Potensi Erupsi Yang Memaksa." *CNN Indonesia*, 2023. Accessed April 10, 2023. https://www.cnnindonesia.com/nasional/20230311192740-20-923831/status-gunung-merapi-masih-siaga-usai-rangkaian-erupsi-hari-ini.

Colombia. "Interactive Map of Evacuation Alerts and Orders."

Department of Homeland Security, Us, and Federal Emergency Management Agency. *Planning Considerations: Evacuation and Shelter-in-Place - Guidance for State, Local, Tribal and Territorial Partners*, 2019.

Development Bank, Asian, and Internal Displacement Monitoring Centre. *Disaster Displacement: Indonesia Country Briefing*, 2023.

Dilley, Maxx, Robert S. Chen, Margaret Arnold, Jonathan Agwe, Piet Buys, Oddvar Kjekstad, Bradfield Lyon, and Gregory Yetman. *Natural Disaster Hotspots : A Global Risk Analysis*. World Bank, 2005.

DIY. "Awali Pembangunan Huntap Korban Merapi,Sultan Letakkan Batu Pertama." *Pemerintah Provinsi Daerah Istimewa Yogyakarta*. Last modified 2012. Accessed April 10, 2023. https://jogjaprov.go.id/berita/awali-pembangunan-huntap-korban-merapisultan-letakkan-batu-pertama-.

Elliott, James R., and Jeremy Pais. "Race, Class, and Hurricane Katrina: Social Differences in Human Responses to Disaster." *Social Science Research* 35, no. 2 (June 1, 2006): 295–321.

Flanagan, Barry E., Edward W Gregory, Elaine J Hallisey, Janet L. Heitgerd, and Brian Lewis. "A Social Vulnerability Index for Disaster Management." *Journal of Homeland Security and Emergency Management* 8, no. 1 (2011).

Fucile-Sanchez, E, and M Davlasheridze. "Adjustments of Socially Vulnerable Populations in Galveston County, Texas USA Following Hurricane Ike." *Sustainability (Switzerland)* 12, no. 17 (2020). https://www.scopus.com/inward/record.uri?eid=2-s2.0-85090407528&doi=10.3390%2fsu12177097&partnerID=40&md5=b435d62f6be44b620ca17c1285a71fd0.

GEI. "Interactive Mapping." *Interactive Mapping*. Last modified 2023. Accessed October

29, 2023. https://www.betterevaluation.org/methods-approaches/methods/interactive-mapping#:~:text=Interactive%20mapping%20involves%20using%20maps,select%20information%20in%20the%20map.

Hizbaron, Dyah R, Raditya Jati, Hidehiko Kanegae, and Yusuke Toyoda. "A Participatory Evacuation Map Making Towards Sustainable Urban Heritage Kotagede, Yogyakarta." *A Participatory Evacuation ... (Hizbaron, et al) Forum Geografi* 29, no. 1 (2015): 11–22. Accessed October 29, 2023. https://journals.ums.ac.id/index.php/fg/article/view/787.

IOM. *Evacuations and Disaster Risk Reductions in the Carribean*. San Jose, 2021. www.rosanjose.iom.int.

Iuchi, Kanako, and John Mutter. "Governing Community Relocation after Major Disasters: An Analysis of Three Different Approaches and Its Outcomes in Asia." *Progress in Disaster Science* 6 (2020): 100071. https://doi.org/10.1016/j.pdisas.2020.100071.

KESDM. "MAGMA Dan Resistensi Indonesia Dalam Ring of Fire." *Kementerian Energi Dan Sumber Daya Mineral Republik Indonesia*.

Kuran, Christian Henrik Alexander, Claudia Morsut, Bjørn Ivar Kruke, Marco Krüger, Lisa Segnestam, Kati Orru, Tor Olav Nævestad, et al. "Vulnerability and Vulnerable Groups from an Intersectionality Perspective." *International Journal of Disaster Risk Reduction* 50 (November 1, 2020): 101826.

Lindell, Michael K., and Ronald W. Perry. *Behavioral Foundations of Community Emergency Planning*. Hemisphere Publication, 1992.

van der Meer, Lindsey, Lisa S. Barsties, Leonie A. Daalderop, Adja J.M. Waelput, Eric A.P. Steegers, and Loes C.M. Bertens. "Social Determinants of Vulnerability in the Population of Reproductive Age: A Systematic Review." *BMC Public Health* 22, no. 1 (December 1, 2022).

Neil Adger, W. "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." *World Development* 27, no. 2 (February 1, 1999): 249–269.

REKOMPAK. *Profil Huntap Karang Kendal, Pagerjurang, Dan Batur*. Sleman: Satuan Kerja Rehabilitasi dan Rekonstruksi Rumah Pascagempa bumi DIY dan Jateng, 2013.

Scheil-Adlung, Xenia., Catharina. Kuhl, and Bureau international du travail. Département de la sécurité sociale. *Addressing Inequities in Access to Health Care for Vulnerable Groups in Countries of Europe and Central Asia*. International Labour Office, Social Security Department, 2011.

Sleman. "Pembangunan Huntap Karangkendal Dimulai." *Kabupaten Sleman*. Last modified 2022. http://www.slemankab.go.id/2841/pembangunan-huntap-karangkendal-dimulai.slm.

Smit, Barry, and Olga Pilifosova. "From Adaptation to Adaptive Capacity and Vulnerability Reduction." *Climate Change, Adaptive Capacity and Development* (2003): 9–28.

Suryandari, Ratnawati Yuni, Endi Haryono, and Abdullah Sumrahadi. "Merapi Pasca Letusan 2010: Polisi Penempatan Semula Penduduk." *Malaysian Journal of Society and Space* IX, no. 1 (2013): 138–149. Accessed February 26, 2023.

https://www.proquest.com/docview/2488753350.

Taylor, Whitney, and Brandon Plewe. "The Effectiveness of Interactive Maps in Secondary Historical Geography Education." *Cartographic Perspectives*, no. 55 (2006): 16–33.

Umbulharjo. "Masalah & Isu Strategis Kalurahan." *Karanggeneng Umbulharjo Cangkringan Sleman*.

———. "Website Resmi Kelurahan Umbulharjo Kecamatan Cangkringan Sleman." Last modified 2022. https://umbulharjo.smartvillage.id/first/wilayah.

UN. *Volcanic Emergency Management*. United Nations Disaster Relief Coordinator, 1985. Accessed April 10, 2023. https://unesdoc.unesco.org/search/N-EXPLORE-55a3612a-3872-4b73-8ad6-1d5b25309bff.

UNESCO. "World Heritage Interactive Map." *World Heritage Convention*. Last modified 2023. Accessed October 29, 2023. https://whc.unesco.org/en/interactive-map/.

Ventura. *Historic Preservation Committee: City of Ventura*, 2020. Accessed October 28, 2023. https://www.cityofventura.ca.gov/DocumentCenter/View/21767/2020-06-17_Item-2_PROJ-12828_WillettRanch.

Vickery, Jamie. "Using an Intersectional Approach to Advance Understanding of Homeless Persons' Vulnerability to Disaster." *Environmental Sociology* 4, no. 1 (2018): 136–147.

Wiwaha, Adam Abraham, Estuning Tyas, Wulan Mei, and Dan Rini Rachmawati. "Perencanaan Partisipatif Jalur Evakuasi Dan Titik Kumpul Desa Ngargomulyo Dalam Upaya Pengurangan Resiko Bencana Gunungapi Merapi." *Journal of Regional and City Planning)* 27, no. 1 (2016): 34–48.