

QUANTIFYING COMMUNITY VULNERABILITY TO NATURAL HAZARDS AND HYDROMETEOROLOGICAL HAZARDS: APPLICATION OF THE SOCIAL VULNERABILITY INDEX IN KAJANG AREA

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<http://doi.org/10.46754/jssm.2025.05.003>

Submitted: 5 June 2024

Revised: 22 August 2024

Accepted: 21 November 2024

Published: 15 May 2025

Abstract: The increasing phenomenon of landslide events in Malaysia, especially in urbanised areas has led to studies aiming to identify vulnerability factors to understand the weaknesses of communities when exposed to disasters. Hence, this study seeks to develop a Social Vulnerability Index (SoVI) for the Kajang community and identify the most prominent factor influencing community vulnerability. Therefore, 17 variables are identified as characterising social vulnerability, which is then applied to evaluate the assessment used in this study. The study uses a quantitative method in the form of a questionnaire to collect data while secondary data is used to determine the 17 variables used in the SoVI. 200 respondents living around the Kajang area were interviewed and analysis was executed using Principal Component Analysis (PCA). The results indicate that the Kajang Mewah hilly area is more vulnerable than the Kajang Utama hilly area. Consequently, the factors identified through PCA are household income, the environment of the housing area, household health, and housing composition. Overall, the study contributes to the deficient field of vulnerability studies in Malaysia. Furthermore, this study can help identify the vulnerability circumstances of communities in Kajang and contribute information and knowledge regarding disaster management in Malaysia.

Keywords: Sustainability, landslide, natural disaster, social vulnerability, Principal Component Analysis.

Introduction

The frequency of natural disaster events has increased exponentially from year to year. Universally, in the last 20 years, the phenomenon of geophysical and hydrometeorological disasters has increased significantly (Rahman *et al.*, 2017) and has affected many human lives. The frequent occurrence of geophysical hazards such as landslides, causes considerable damage to infrastructure, property, and human life (Rahman *et al.*, 2022).

A landslide is a natural, possibly dangerous phenomenon in which gravity causes rock, debris, or dirt to slide downhill (Cruden & Varnes, 1996). Moreover, hazardous phenomena combined with weather and climate can contribute to a landslide event. In addition to the natural

phenomenon of natural disasters, urbanisation can also negatively affect developing countries as landslides occur due to increases in population and development (Nurfashareena Muhamad & Shaharuddin Ahmad, 2014). The intervention of human beings in deforestation, agricultural activities, and housing areas can contribute to more intensified landslide occurrences (Rahman *et al.*, 2017; Zhou *et al.*, 2021; Li, 2022).

The complex relationship between humans and the environment increases the probability of natural disasters occurring (Yusoff *et al.*, 2018). Today's modern economic patterns have influenced climate and environmental change. Development activities related to economic progress positively affect both communities

and countries. However, the failure to build sustainable development places constraints on the environment during the modification process, resulting in effects that can collapse the economy and cause social conflict.

Urbanisation is incomplete without a large population to ensure that the built city functions as well as possible with the desired level of socioeconomic stabilisation. Thus, increasing population growth supports changes in economic patterns that go hand in hand with progress, resulting in environmental and socioeconomic conflicts due to coercion and the inability of nature to carry out sustainable modifications. Therefore, it is important to determine the vulnerability of a community positioned in a vulnerable area to understand the complex relationship between natural disasters and social vulnerability.

Landslide Occurrence in Malaysia

Malaysia is one of the countries affected by natural disasters such as landslides, almost every year. The frequency of natural disasters occurring in developing countries is more than that of natural disaster events occurring in other countries (Alcántara-Ayala, 2002). This is due to the climate being closely related to the development activities that occur in developing countries. The disasters in Malaysia usually occur due to the weather and climate, as Malaysia experiences a tropical climate, uniform temperatures, high humidity, and abundant rainfall throughout the year.

The factors of the climate and weather in Malaysia influence the types of disasters that usually occur in that country, i.e., hydrometeorology factors such as floods and storms and geophysical factors such as landslides and tsunamis [National Disaster Management Agency (NADMA), 2018]. According to the NADMA, the most frequently occurring natural disaster in Malaysia from 2014 to 2018 was floods, followed by storms, landslides, fires, and earthquakes (Figure 1).

Although landslides in Malaysia are not as frequent as other events such as floods, these incidences still profoundly impact local communities, infrastructure, and property. One of the earliest landslides in Malaysia was recorded in 1993 when one of the three Highland Tower condominiums in Ulu Kelang collapsed after 10 days of heavy and continuous rain. Landslides in that year caused 48 deaths (NADMA, 2018). In 2008, another landslide occurred close to where the Highland Tower landslide event happened, which caused four deaths, 15 injuries, and the collapse of 14 bungalows. In addition to death and injury, landslide events in Malaysia also affect the housing areas where families have to evacuate as settlement areas, including property damage to houses, cars, motorcycles, and infrastructure.

Landslides in Malaysia are caused by heavy rain, natural changes in earth material, plane misalignments, soil erosion caused by underground rainwater or running water (Ibrahim Komoo, 1985), and rapid land development

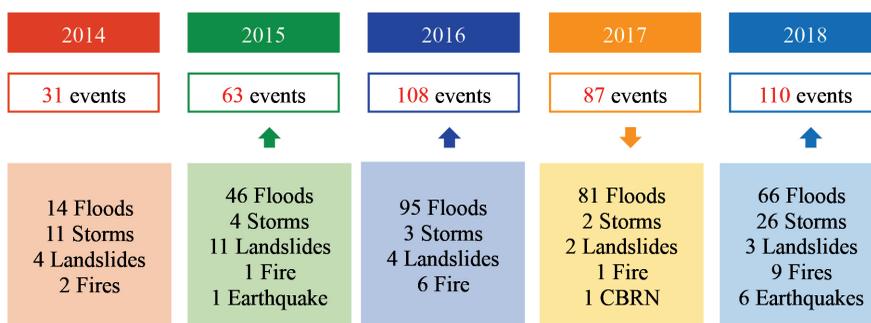


Figure 1: Natural disaster occurrences in Malaysia from 2014 to 2018
 Source: National Disaster Management Agency (2018)

(Mokhtar Jaafar *et al.*, 2011). Malaysia began to experience the process of urbanisation in the 16th century and the process has undergone certain phases (Abdul Samad Hadi, 2010). The results of this process are evident today in the urbanisation that occurs through various developments that drive the formation of a developed country. The urbanisation process is essential to ensure that the improvement from one level to another is better so that the country’s progress continues in economic and social development. However, the increasing frequency of disasters due to the unpredictable occurrence of natural phenomena has caused an increase in the level of vulnerability, especially related to the socioeconomics of groups living in involved areas (Freitas *et al.*, 2022).

Table 1 presents the series of significant landslides in Malaysia from 2000 to 2023 reported in the news. In the first 10 years (2000-2010), the landslide events were mostly focused on two states in Malaysia: Kuala Lumpur and Selangor. Kuala Lumpur and Selangor are two of the highly urbanised states in Malaysia. Over the years, major contributors to landslide events in Kuala Lumpur have been related to the overgrowth of urbanisation (Zulkaffi *et al.*, 2023). Moreover, in recent years, many casualties and fatalities have been recorded, including deaths. During the 2011 to 2020 period, Kuala Lumpur and Selangor remained the major sites for landslide events in Malaysia. In some states such as Sarawak and Pahang, the related casualties were not high, except for in Pulau Pinang in 2017 and 2018, when 11 and nine construction workers were killed, respectively, in two consecutive years. In addition, in 2011, 16 deaths were recorded in Hulu Langat, Selangor, due to landslide events. Other fatalities recorded between 2011 and 2020 include major house damage, evacuation, and roads closed to the public.

From 2021 to 2023, landslide events in Malaysia were dispersed more widely compared to the past years, with states such as Terengganu, Perak, Sabah, Negeri Sembilan, and Johor recording at least one event in those three

Table 1: Series of significant landslide occurrences in Malaysia (2000-2023)

No.	Year	Location	Consequences
1	2023	Bukit Larut, Perak	Closed area to the public.
2	2023	Gua Musang, Kelantan	1,000 indigenous people in Kampung Gawin Pos Brooke, Pos Gob, lost contact.
3	2023	Taman Chenderong Jaya, Batu Gajah, Ipoh, Perak	A total of 28 residents from six families had to be moved to the temporary transfer centre.
4	2023	Persiaran Tunku Syed Sirajuddin, Kuala Lumpur	76 individuals evacuated from the Malaysia Anti-Corruption Commission (SPRM) Academy.
5	2023	Beruas, Perak	No fatalities.
6	2023	Wisma YPR, Taman Seputeh, Kuala Lumpur	One killed.
7	2022	Batang Kali-Genting Highlang	31 people, including children were killed.
8	2022	Selangor and Negeri Sembilan	Seven incidents of landslide events, six areas in Selangor, and one in Negeri Sembilan.
9	2022	Negeri Sembilan	A total of 13 routes involving five districts in Negeri Sembilan were closed to all vehicles.
10	2022	Tongod Police Station, Sabah	No fatalities.

11	2022	Kuala Lumpur	Road closed 1/27, Taman Gembira and Jalan Hang Tuah 4, Salak Selatan, and in Section 6, Wangsa Maju.
12	2022	Taman Bukit Permai 2, Ampang	Four were killed, one was injured, 15 houses were damaged, and affected 10 vehicles were affected.
13	2022	Jalan Simpang Pulai-Cameron Highlands	Two women were killed.
14	2022	Jalan Tun Dr. Ismail and Taman Bukit Sentosa, Negeri Sembilan	Road damage in Jalan Tun Dr. Ismail and Taman Bukit Sentosa, Negeri Sembilan, and Tenaga Nasional Berhad substation.
15	2022	Kota Tinggi, Johor	No fatalities.
16	2022	Taman Elok, Jalan Bukit Nenas, Kota Kinabalu, Sabah	Two children died while two adults were injured.
17	2022	Batang Benar, Nilai, Negeri Sembilan	Six houses cracked and collapsed.
18	2022	Tenor Pangi Hydro Dam, Tenom, Sabah	No fatalities.
19	2022	Taman Halaman, Ampang, Kuala Lumpur	No fatalities.
20	2022	Kampung Kerawat, Simpang Pulai Ipoh, Perak	No casualties.
21	2021	Gombak, Selangor	No casualties.
22	2021	Jalan Pelimmbayan Indah, Sungai Penchala	94 houses were affected, and 24 of them were destroyed.
23	2021	Kampung Sungai Merab, Putrajaya	Affected two houses. No casualties.
24	2021	Kuala Terengganu	Killed a man who was buried while mining for gold.
25	2021	FT 185, KM 27.10 Jalan Simpang Pulai-Blue Valley, Ipoh, Perak	Killed two men.
26	2021	Tanah Rata, Cameron Highland	No fatalities.
27	2021	Lengkok Halia, Tanjung Bungah, George Town, Pulau Pinang	No fatalities.
28	2020	Jalan Gombak to Genting Highland	The road was closed to the public.
29	2020	Ulu Beram, Jalan Lapok	Road damage.
30	2020	Tapah to Ringlet	Closed the road to the public.
31	2020	Tapah to Cameron Highland	Closed the road to the public.
32	2019	Taman Batu Permai	No record.

33	2019	Jalan Lee Woon, Ampang, Selangor	No casualties.
34	2019	Jalan Genting-Amber Court Genting Highland, Pahang	Closed road to the public.
35	2018	Jalan Bukit Kukus, Georgetown, Penang Island	Killed nine construction workers.
36	2017	Tanjung Bungah, Penang Island	Killed 11 construction workers.
37	2016	Karak Highway	Four vehicles were trapped in the landslide and all lanes were blocked in both directions.
38	2016	Bau-Puncak Borneo, Sarawak	Comprising mainly Bidayuh settlements and Padawan Ring Road critically affected.
39	2015	KM 52.4 of the Kuala Lumpur-Karak Expressway between Lentang and Bukit Tinggi, Pahang, and Gombak-Bentong old roads	The expressway was closed to traffic.
40	2013	Putra Heights, Subang Jaya, Selangor	Several vehicles were submerged in mud.
41	2012	Taman Desa Sentosa, Hulu Langat, Selangor	Exposed four occupants of the Perkid Welfare Home for girls to danger.
42	2012	Taman Mulia Jaya, Ampang, Selangor	Water seeping through the sewerage system.
43	2011	Puncak Setiawangsa, Kuala Lumpur	88 residents of bungalows, shophouses, and double-story terrace houses were ordered to move out.
44	2011	Jalan Semantan, Kuala Lumpur	Six cars were buried and five vehicles were damaged.
45	2011	Pekan Batu 14 Hulu Langat, Selangor	16 deaths.
46	2011	Kampung Tengah, Puchong, Selangor	Five houses affected.
47	2010	Ukay Perdana, Ampang, Selangor	No fatalities.
48	2010	Taman Bukit Mulia, Ampang, Selangor	No fatalities.
49	2009	Taman Cheras Awana, Cheras, Selangor	Destroyed three cars and a motorcycle, 10 families evacuated.
50	2008	Taman Bukit Mewah, Ampang, Selangor	Four deaths.
51	2008	Ulu Kelang, Selangor	Four deaths and 15 injuries.
52	2008	Kuala Kubu Bharu, Batang Kali, Selangor	Two siblings were buried alive when a landslide hit a bungalow.
53	2008	Kemensah Heights, Ampang, Selangor	No fatalities.
54	2008	Bukit Ceylon, Kuala Lumpur	One worker died.
55	2008	Pantai Dalam, Kuala Lumpur	One was killed, four injured, and 19 families evacuated.

56	2006	Taman Esplanad, Kuala Lumpur	Two houses were damaged.
57	2006	Taman Zooview, Ampang, Selangor	Four deaths.
58	2006	Taman Bukit Serdang, Seri Kembangan, Selangor	The damaged section of the road measured 50 m by 25 m.
59	2006	Bukit Tunku, Kuala Lumpur	No record.
60	2004	Jalan Seri Penchala 1, Kuala Lumpur	24 houses were evacuated.
61	2004	Taman Melati, Gombak, Selangor	One death.
62	2003	Taman Bukit Jaya, Ampang, Selangor	No fatalities.
63	2002	Jalan Ipoh, Kuala Lumpur	Covering a three-lane road leading to Rawang from Selayang.
64	2002	Taman Hillview, Ampang, Selangor	Eight deaths and five injuries.
65	2001	Kampung Sungai Chinchin, Gombak, Selangor	A house partly destroyed.
66	2000	Jalan Bukit Antarabangsa, Ampang, Selangor	No record.

Source: Ahmad Hasbi (2022), Asliza Musa (2023), Bemama (2022a, 2022b, 2022c, 2022d, 2022e, 2023a, 2023b), Haliza Abdul Rahman and Jabil Mapjabil (2017), Juwan Riduan (2022), Majid *et al.* (2020), Nader Saadatkah *et al.* (2014), and Nor Diana *et al.* (2021)

years. Furthermore, in those three years, many casualties and fatalities were recorded such as deaths and injuries. The worst landslide event occurred in Batang Kali-Genting Highland in 2022, where a landslide that hit campsites located along a road near Father’s Organic Farm at Genting Highland caused at least 31 deaths, including children (Table 1). Figure 2 illustrates a chart of landslide occurrences in Malaysia from 2000 to 2023, highlighting that in the period from 2000 to 2023, the most landslide events in Malaysia occurred in 2022 (14 events), followed by 2021 (seven events), 2023 (six events), 2008 (six events), 2020 (four events), 2011 (four events), and 2006 (four events). Other years recorded no more than three events of landslides per year. The increasing phenomenon of landslide events in Malaysia led to the current study, aiming to identify vulnerability factors to further understand the weaknesses of communities when exposed to such disasters.

Literature Review

The Concept of Vulnerability

The concept of vulnerability is used as an analytical tool to understand and define situations of susceptibility related to the harm, powerlessness, and marginalisation of both physical and social systems. Note that it has been used as guidance for actions that can reduce the risk of harm and enhance the well-being of humans (Adger, 2006). The increasing number of natural disaster events has led to more research on vulnerability in environmental studies and economics, anthropology, psychology, as well as engineering. Vulnerability is currently a popular term used to describe societal situations that can help further understand a certain group’s inability to function well in a vulnerable situation.

According to Cutter *et al.* (2003), social vulnerability is one of the inequalities produced in social situations where such factors influence the vulnerability of a group to harm and govern the group’s ability to react to that social situation.

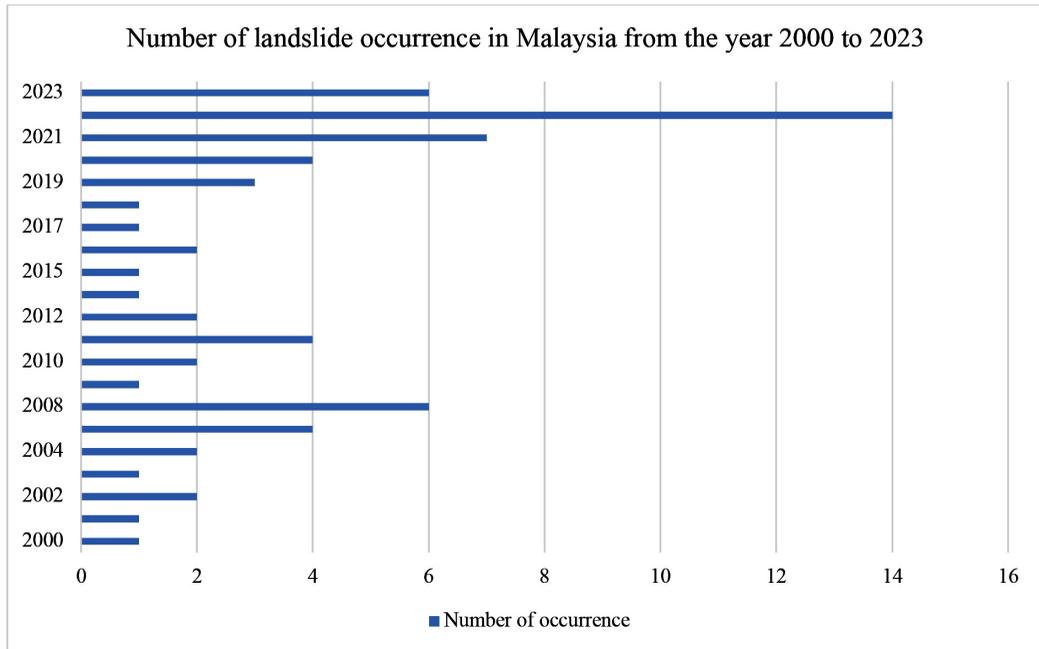


Figure 2: Number of landslide occurrences in Malaysia from 2000 to 2023

There are many factors that can influence the social vulnerability of a community (Giovene di Girasole & Cannatella, 2017). This includes socioeconomic status, gender, race and ethnicity, age, employment, rural or urban areas, residential property, infrastructure, occupation, education, population growth, medical services, social dependence, social needs of the population, and many more factors that can influence the susceptibility of individuals or communities to harm and danger (Cutter *et al.*, 2013).

The Livelihood Framework examines how hazards impact people’s assets and survival strategies (Chambers & Conway, 1992) and the study highlights the importance of various types of capital in people’s livelihood. It comprises human capital, social capital, natural capital, physical capital, and financial capital. Meanwhile, Adger (2006) explores how exposure to risk and the ability to cope and adapt are connected to risk and resilience, incorporating risk assessment and resilience. The research also delves into how communities can effectively handle and bounce back from disasters.

Therefore, to further understand the vulnerability of an individual or group, there is a need to understand the factors that influence and shape the susceptibility of that individual or group to danger and harm and the importance of vulnerability study towards one community. Thus, related studies need to consider that each individual and community has different levels of access to resources to prepare for, cope with, and recover from disasters. The potential impacts of events on groups such as the poor, single-parent households, pregnant women, those who are disabled, children, and elderly individuals are higher because they are more likely to be susceptible to harm.

Vulnerability Study

Many studies have been done to understand and determine the vulnerability of one community. Each one of the studies brings unique examples of how the vulnerabilities model and study are applied in each study and how the result impacts the community’s life. Thus, it is important to thoroughly understand each vulnerability study done in the past to understand the purpose,

techniques, methods, and applications that can be used in future studies. For example, a study by Cutter *et al.* (2003) highlighted factors that influence social vulnerability. The article highlights the lack of access to resources such as knowledge and information, power and representation, social capital and social network connection, beliefs and customs, building stock and age, the presence of physically limited and disabled people, and last, the type of infrastructure or built environment that humans live in as aspects that influence social susceptibility in human life.

Meanwhile, the Social Vulnerability Index (SVI) created by the Centers for Diseases and Prevention SVI (CDC SVI) is a vulnerability assessment using 16 United States Census variables. A value of 0 indicates that an observed area is not threatened while a value of 1 indicates an area experiencing a high level of vulnerability (ATSDR, 2022). The 16 variables include themes such as socioeconomic vulnerability [(1) those below the poverty line, (2) those who are unemployed, (3) income, (4) education], household composition and disability [(5) those aged 65 or above, (6) those aged 17 or younger, (7) those who are disabled, (8) single-parent household], minority status, and language, [(9) those who are minorities, (10) noncitizens, and (11) non-English speakers] and housing and transportation, [(12) multiunit structures, (13) mobile homes, (14) crowding, (15) no vehicles, and (16) group quarters] (Flanagan *et al.*, 2011; Cumberbatch *et al.*, 2020; Almond *et al.*, 2023).

A study by Paphoma-Köhle *et al.* (2019) represents a significant advancement in vulnerability assessment, which combines quantitative and qualitative techniques in one study. The study introduces new methods for selecting and weighing vulnerability indicators, including statistical techniques, expert input, and a participatory approach. This hybrid approach helps to capture a broad range of vulnerability dimensions and improve the robustness of the results. In Malaysia, studies on social vulnerability or social vulnerability indices are lacking and not as expandable as in other parts of

the world. The study of vulnerability is important to recognise and detect the areas or communities that are vulnerable and susceptible to risk and to help guide mitigation efforts. In a systematic review study by Nor Diana *et al.* (2021) of the social vulnerability assessment of landslide hazards in Malaysia, a total of 15 indicators were found to influence the vulnerability factors of landslides. Nonetheless, only five factors were determined to influence the life of a community: Age, ethnicity, education, disability, and health. These listed factors are more prominent in a community's vulnerability to landslide hazards.

Research by M. I. Nor Diana and Nurul Atikah (2023) determined community-level adaptation strategies using the Livelihood Vulnerability Index in a flood-prone area using indicators such as natural disaster and climate change, sociodemographic profile, livelihood strategies, social network, access to health, access to water, access to food, housing, land, finance, and income. In addition, the study also mentions the importance of adaptive capacity in increasing resilience and sustaining the community's livelihoods. The study by Nurul Ashikin *et al.* (2021) is a study on livelihood vulnerability assessment that aims to determine vulnerability areas in a flood-prone area in the state of Pahang. The study also incorporates LVI-IPCC contributing factors that use three dimensions of sensitivity, adaptive capacity, exposure, and the Sustainable Livelihood Approach (SLA) to better understand vulnerable populations.

Next, the study on social vulnerability by Kamarudin *et al.* (2022) focuses on the urban community of Bukit Antarabangsa in Kuala Lumpur, which is vulnerable to landslide-related events. The study analyses social vulnerability, as well as spatial mapping, to represent and identify socially vulnerable groups. The components used to identify vulnerability in the study are sociodemographic, socioeconomic status, community awareness and preparedness, and perception of vulnerability variables, which differ from those used in other studies on social vulnerability. In past studies, the most

common social vulnerability factors examined were socioeconomic status, age, gender, and race. Hence, adding factors such as language proficiency, education, disability, vehicle ownership, and housing area represents another way to examine social vulnerability (Cutter *et al.*, 2003).

Meanwhile, a study by Sim *et al.* (2023) sought to analyse the perception of landslide risk by local communities and experts in Malaysia. Comprehending these beliefs is essential for enhancing disaster risk management and communication tactics. Hence, the study is able to inform policymakers and disaster risk management professionals about the need for more tailored communication strategies that align community perception with experts' assessment. Unlike Jafar *et al.* (2022), the study discusses an important topic concerning the relationship between natural disasters and tourism, especially in areas like Sabah, where ecotourism is a key driver of the economy. The study also offers a comprehensive perspective on the effect of geohazards on river systems and ecotourism, considering both environmental and economic factors.

Every vulnerability study is different according to its structure. The study aims to determine how one community is vulnerable to certain conditions or hazards. Therefore, a vulnerability study is important to determine the level of vulnerability in one community and its types of vulnerability. Thus, studies on vulnerability and its impact on socioeconomics need to be emphasised, considering that nature and society interact to produce sustainable, efficient progress. However, data on natural disasters show that the result of urbanisation places less emphasis on the impact on nature, which eventually turns back on the social life of communities and countries that, in turn, must bear the socioeconomic outcomes. Nevertheless, urban communities must continue to behave rationally when faced with natural disaster situations that conflict with their survival and the restabilisation of their social life.

Therefore, this study focuses on areas experiencing urbanisation around Kajang to understand and identify the factors related to vulnerability among the Kajang community. Landslide hazards present complex challenges that require a multifaceted approach to management. By addressing issues related to hazard and risk assessment, vulnerabilities, and management strategies, the stakeholders can better mitigate the impact of landslides. Continued research and technological advancement are essential to improve understanding and response to natural hazards. Hence, this study seeks to develop the SoVI of the community of Kajang, Malaysia and identify the most prominent factors influencing its vulnerability. Therefore, 17 variables were chosen for this study to characterise the SoVI, which was used to assess them in this study. These 17 variables include variables drawn from past studies that are adapted and used to determine the SoVI of the community of Kajang, Malaysia. Table 2 presents the variables used for this study.

Methodology

Study Design

The process of constructing a SoVI consists of seven steps: Identifying variables, collecting data, standardisation and normalisation, Principal Component Analysis (PCA), constructing the SoVI, classifying the SoVI, and finally, identifying vulnerability factors.

Figure 3 illustrates a flow chart of the entire process of developing the SoVI used in this study. The first step in constructing a SoVI is identifying variables based on past research and the suitability of the study area. In the current study, this step was performed by collecting and reviewing past research on vulnerability studies. Through this process, 17 variables were identified and chosen for the current study (Table 2). Note that the quantitative method was chosen as the main method for this study because this approach uses statistical and mathematical methods to analyse data. In the second step,

Table 2: Selected variables of the study area

Variables	Description	Unit	Source
Age	Household with a child younger than 15 years old	%	(Cutter <i>et al.</i> , 2003; Mavhura <i>et al.</i> , 2017; Englund <i>et al.</i> , 2023)
	Households with elderly over 65 years old or older	%	(Cutter <i>et al.</i> , 2003; Mavhura <i>et al.</i> , 2017; Englund <i>et al.</i> , 2023)
Health	Head of household with illness	%	Author
	Member of household with illness	%	(Nurul Ashikin <i>et al.</i> , 2021)
	Distance from nearby clinic or hospital	km	Author
Education	Highest educational attainment	%	(Cutter <i>et al.</i> , 2003; Mavhura <i>et al.</i> , 2017; Bucherie <i>et al.</i> , 2022; Englund <i>et al.</i> , 2023)
Single parent household	Households with single parent	%	(Englund <i>et al.</i> , 2023)
Vehicle ownership	Number of vehicle ownership	Num.	(Englund <i>et al.</i> , 2023)
Housing	House ownership	%	(Englund <i>et al.</i> , 2023)
	Housing with more than 10 units in structure (e.g., apartment)	%	Author
	Total occupied housing unit	%	Author
Income	Households with low-income standard	%	(Englund <i>et al.</i> , 2023)
	Households with income below 60% of the national median	%	(Englund <i>et al.</i> , 2023)
	Households with income 200% over the national median	%	(Englund <i>et al.</i> , 2023)
Unemployment	Head of household unemployed longer than six months	%	(Mavhura <i>et al.</i> , 2017; Englund <i>et al.</i> , 2023)
	Members of households unemployed longer than six months	%	Author
Elevation	Average elevation from above the sea level	m	Author

empirical quantitative methods based on a survey instrument were used to collect data regarding the socioeconomic vulnerabilities of the examined urban community in a disaster-risk area. Past studies on the SoVI have focused on secondary data using census data to develop the index to determine which variables affect community vulnerability (Cutter *et al.*, 2003; Mavhura *et al.*, 2017; Bucherie *et al.*, 2022; Englund *et al.*, 2023). Therefore, this study adapted the approach taken by previous studies

on social vulnerability using primary data instead of secondary data.

The data collection process included face-to-face interviews and survey questionnaires as instruments to collect the data. The survey was administered through a self-administrated face-to-face interview by trained enumerators using a set of questionnaires distributed to a random sample of residents in Kajang. The survey questions included demographics, housing and property ownership, energy and water resources,

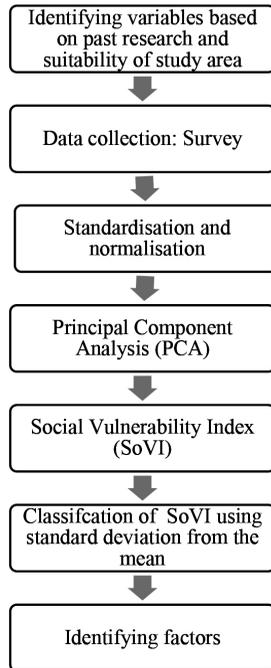


Figure 3: Flow chart of the process of developing a Social Vulnerability Index

health status, social engagement, knowledge and experience from natural disasters, disaster preparedness, infrastructure facility, and vulnerability to natural disasters. Figures 4 and 5 below display the data collection activity of the trained enumerator appointed by the researcher.

Using purposive random sampling based on area, the sample chosen is ensured to represent the different areas of Kajang, including the hilly area, a unique characteristic of Kajang’s geography. In this study, two main areas in Kajang

were chosen as the main study areas: The Kajang Mewah Hilly area and the Kajang Utama Hilly area. Next, several control measures were taken to ensure the data’s validity. First, respondents were purposive and randomly selected from the population in Kajang. Second, the survey was designed to be anonymous to encourage honest responses. Lastly, the survey was piloted among a small sample of respondents (20 respondents) to ensure the questions were clear and easy to understand. Next, for the inclusion and exclusion



Figure 4: Data collection activity in the study area



Figure 5: Face-to-face interview during data collection activity

criteria used in the study to select participants, respondents must be residents of the Kajang for at least one year. Second, respondents must be at least 18 years old and above, and lastly, respondents must be able to provide informed consent. In comparison, the exclusion criteria were respondents, who did not meet the inclusion criteria and respondents, who did not provide informed consent. All criteria are administrated during data collection to ensure the validity of the responses.

The third step in constructing and developing the SoVI was standardisation and normalisation of the data. The collected data were standardised to compare scores between different types of variables and to ensure that the data were internally consistent. Note that normalisation is a term that refers to the conversion of variable values that are measured on different scales into a unitless value on a common scale in which the value ranges from 0 to 1. After every data point was standardised and normalised, the fourth step was to use PCA to minimise the dimensionality of the index by reducing the variables or themes while preserving as much information about the data as possible. It determines which themes or variables influence the vulnerability of the examined community located in the Langat River Basin.

The fifth step was to construct a SoVI using the data obtained from the PCA by obtaining factor loadings from every data value observed

to be significant in the study. The composite index of the SoVI was then obtained by adding every value of the component or variable scores. In this study, two SoVI scores were constructed based on two study areas in Kajang: The Kajang Mewah hilly area and the Kajang Utama hilly area. The sixth step was to classify the composite index to obtain a final SoVI score using the standard deviation from the mean method, which produced a relative SoVI for the two study areas in Kajang: The Kajang Mewah and Kajang Utama hilly areas. In the last step, the most prominent factor of the SoVI was identified using the data obtained from the SoVI, in which a positive value indicates a high level of vulnerability. In contrast, a negative value indicates a low level of vulnerability.

Study Area: Kajang

This study was conducted in the business district of Kajang town, Selangor, Malaysia, one of Selangor's developed regions. Kajang is located 21 km from Kuala Lumpur and situated on the eastern bank of the Langat River Basin. The coordinates of Kajang are 2°59'0"N and 101°47'0"E. The Langat River Basin is known as the most developed and urbanised river basin in Malaysia (Nurfashareena Muhamad & Shahrudin Ahmad, 2014; Selamat *et al.*, 2023). The length of the Langat River is approximately 1,815 km. The Pangsoo, Hulu Lui, Hulu Langat, Cheras, Kajang, Putrajaya,

Hulu Semenyih, Semenyih, Batang Benar, Batang Labu, Beranang, Bangi Lama, Rinching, Teluk Datok, and Teluk Panglima Garang subbasins are the 15 subbasins that make up the Langat River Basin. The Semenyih, Lui, and Beranang Rivers are the main tributaries to the basin, which has a length of approximately 141 km. The Langat and Semenyih Reservoirs, with catchment areas of 54 km² and 41 km², respectively are two further reservoirs located in the basin. Since 1982, reservoirs have been constructed to generate power for the Langat Valley's inhabitants.

Growing urbanisation and populations correspond to the research area's rising susceptibility to environmental hazards. The total population of Kajang is 236,240 and the population density is 2,955 persons per square kilometre [Department of Statistics Malaysia (DOSM), 2023]. It has been hypothesised that this population has increased annually by 9% over the last few years. The region has a tropical environment and is located 28 m above sea level. Note that the region experiences 500 mm to 800 mm of annual rainfall and the mean annual temperature is 24°C, with the lowest and highest temperatures of 17°C and 30°C, respectively. The household income of Kajang residents is approximately RM8,127.00, with a household expenditure of RM5,434.00 and a poverty incidence rate of 0.4% in 2023. Different land resource conservation and rehabilitation initiatives have been carried out frequently in the region.

According to Nurfashareena Muhamad and Shaharuddin Ahmad (2014), Kajang has changed since the 1990s, specifically in 2005 and 2014. The area surrounding Kajang was covered by commercial agriculture and forests until the 1990s, after which the area became more urbanised, reducing the capacity of commercial agriculture and the number of forest areas, especially during changes in 2005 and 2014. One of the most prominent hazards in the Kajang area is flash floods; major flash floods occurred once each in 2002, 2008, and 2011 and thrice in 2014 (Md Azizul Bari *et al.*, 2021). Kajang remains in constant change and the rapid

changes in the built-up area will significantly increase the chances of natural disasters (Nurfashareena Muhamad & Shaharuddin Ahmad, 2014).

Rapid urbanisation and land use changes have substantially increased the frequency of hazards in the Kajang area, including landslides. As the Langat River Basin is known as a mountainous, hilly, and lowland area (Musa *et al.*, 2000; Noorazuan M. H. *et al.*, 2003), changes to this area will increase the possibility of natural hazards such as landslides occurring in the Kajang area. Therefore, this study will cover two hilly areas and nearby residential areas. The two hilly areas are known as the Bukit Mewah hilly area, with a height of 342 feet and a position of 259 2' 59" 15.51 N and 101' 47" 50.96 E (Figure 6), and the Taman Kajang Utama hilly area, with a height of 383 feet and a position of 20 58' 21.98 N and 101 48' 25.13" E (Figure 7). These areas are the hilliest and most well-known residential areas in Kajang. Respondents chosen included flat area (Pangsapuri Cemara, Pangsapuri Persona, Pangsapuri Seri Mewah, and Pangsapuri Seroja) and housing area (Mewah Court Kajang, Taman Bukit Indah, Taman Bukit Mewah, Taman Kajang Utama, and Taman Lembah Mewah).

Sampling Method and Sample Size

The sampling method used in this study was Cochran (1977), where the sample size needed by the current study was 383 respondents out of the total population of Kajang, 236,240. However, there are limitations to the number of respondents needed such as a lack of time to obtain all the data and the manpower needed to collect all the data needed. Therefore, for this study, only 200 respondents were used to obtain the data necessary for examining the vulnerability of the communities living in the study area through stratified sampling.

Principal Component Analysis (PCA)

The data obtained by the survey were analysed descriptively using the Statistical Package for Social Sciences (SPSS) computer version 26.0.



Figure 6: Kajang Mewah hilly area



Figure 7: Kajang Utama hilly area

This technique was chosen because it is known for its systematic analysis that produces detailed and accurate statistics such as percentage, frequency, mean, minimum, maximum, standard deviation, correlation, and factor analysis. The

values displayed can be used to understand and analyse the phenomena that occur between natural events and everyday life involving socioeconomic. In the current study, the analysis focused on social vulnerability through PCA.

PCA is a dimensionality-reduction technique that reduces the dimensionality of a large dataset by changing the large set of variables into a smaller dataset that still contains the same information (Jolliffe, 2002). The PCA technique converts an initial set of correlated variables into a new set of variables that seek to explain most of the overall observed variability of the set variables with the fewest number of components possible (Avila-Vera *et al.*, 2012; Arunachalam *et al.*, 2023). Meanwhile, uncorrelated variables are classified as factors or primary components and ranked according to the overall variability and linear transformation. The information size is decreased by selecting from among primary factors that collectively explain the highest level of variance. The PCA technique ensures that the first principal component is the one that describes the maximum percentage of variance in the data (Cutter *et al.*, 2003; Chen *et al.*, 2013; Maiti *et al.*, 2017).

The 17 indicators that comprise the SoVI have already been described above (Table 2). Before PCA was used, the data were standardised and normalised accordingly to ensure that the data were consistent and to obtain a mean of 0 and a standard deviation of 1 (Bucherie *et al.*, 2022). The minimum number of principal components can be determined using the eigenvalue size. Consequently, the largest eigenvalue will be retained using the Kaiser-Meyer-Olkin (KMO) criterion and only those components with eigenvalues greater than one will remain the principal components (Cutter *et al.*, 2003; Chen *et al.*, 2013). The KMO criterion was then used to test the sampling adequacy of each variable in the SoVI further (Mavhura *et al.*, 2017). The KMO criterion measures range between 0 and 1, where the value of $p > 0.6$ indicates sampling adequacy. Subsequently, Bartlett's test of sphericity was used to test the null hypothesis that the correlation matrix is an identity matrix. Bartlett's test is significant when $p < 0.05$.

After the PCA, the SoVI was formed using the values obtained from the PCA factor loadings. The components (factor loadings) were then added to form the SoVI. After the values of

the SoVI were obtained, the score was classified using the standard deviation from the mean method, demonstrating the relative community vulnerability (Bucherie *et al.*, 2022). The factors were classified throughout the screening of the factor loadings, where positive values indicate high levels of vulnerability. Meanwhile, negative values indicate low levels of vulnerability (Cutter *et al.*, 2003; Solangaarachchi *et al.*, 2012; Putiamini *et al.*, 2022).

Results

Results from PCA

Communalities from the selected variable introduced were extracted and are presented in Table 3. These communalities describe the outcomes of the PCA of the proportion of each variable's variance (Mavhura *et al.*, 2017). Note that the extracted communalities are more than 0.5, indicating that each component adequately reflected the chosen variable (Siagian *et al.*, 2014). In this study, all the variables are represented thoroughly. A KMO statistical test was calculated once the communalities were extracted (Mavhura *et al.*, 2017). The KMO test was designed to assess the sample adequacy and full and partial correlations to determine whether the data were likely to coalesce on components (i.e., whether certain items were highly connected while others were not). KMO measurements range from 0 to 1, with values closer to 1 being the most suitable. A figure of 0.5 is suggested as the minimum required value (Fekete, 2012). For example, KMO values should be greater than or equal to 0.6. In this study, the KMO value was 0.661, above the recommended minimum. This showed that the variables used were appropriate for the PCA. Furthermore, Bartlett's test of sphericity indicated a significant value ($p = 0.000$), as it is desired that $p < 0.05$ (Table 3).

Table 4 presents the total variance of the 17 variables selected for this case study. After the KMO and Bartlett's tests were conducted, PCA was used to extract six components out of 17 variables used in the analysis. These six components showed a total cumulative

Table 3: KMO and Bartlett's test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.661
	Approx. Chi-Square
	1717.090
Bartlett's Test of Sphericity	df
	136
	Sig.
	.000

Table 4: Total variance explained by the 17 selected variables

Component	Initial Eigenvalues			Extraction Sum of Squared Loading		
	Total	Percentage of Variance (%)	Cumulative (%)	Total	Percentage of Variance (%)	Cumulative (%)
1	3.616	21.271	21.271	3.616	21.271	21.271
2	2.746	16.154	37.425	2.746	16.154	37.425
3	2.089	12.290	49.714	2.089	12.290	49.714
4	1.487	8.746	58.460	1.487	8.746	58.460
5	1.189	6.996	65.456	1.189	6.996	65.456
6	1.083	6.368	71.825	1.083	6.368	71.825
7	0.912	5.364	77.189			
8	0.700	4.118	81.307			
9	0.653	3.843	85.149			
10	0.587	3.453	88.603			
11	0.557	3.279	91.882			
12	0.425	2.501	94.382			
13	0.383	2.251	96.633			
14	0.306	1.797	98.431			
15	0.152	0.892	99.323			
16	0.064	0.377	99.700			
17	0.051	0.300	100.000			

value of 71.83% of the total variance in social vulnerability (Table 5). The first column in Table 5 displays the initial eigenvalues while the second column shows the extraction sum of squared loadings. The first component in the study has the highest eigenvalue and the highest level of variance. In this study, PCA was used to reduce the dimensions of the seventeen variables most correlated with each other. The PCA results show that six variables were the most adequate for representing the SoVI used in this study. In addition, Figure 8 illustrates the scree plot used to determine the number of components and

the eigenvalues that sufficiently represented the relationships between the variables.

Next, to obtain the SoVI, the scores from all six component scores (factor loading) for each area were added. This process formed an absolute value of the SoVI, such that the classification of the SoVI score could be obtained using the standard deviation from the mean method. As seen in the results presented in Table 5, a positive number signifies an increased potential for social vulnerability. Meanwhile, a negative number represents a decrease in social vulnerability (Cutter *et al.*, 2003). The results

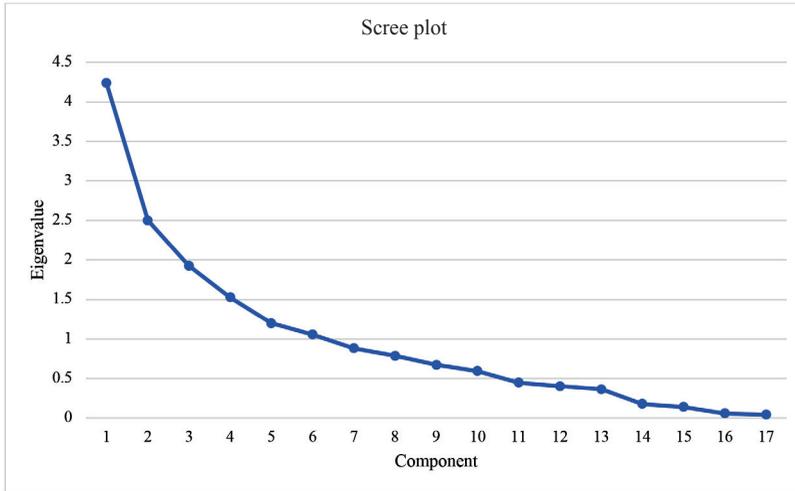


Figure 8: Scree plot of the 17 component variables

Table 5: Composite SoVI scores for two areas of Kajang

Area	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	SoVI Score
Kajang Mewah Hilly	0.01753	0.28076	0.07071	0.05653	0.07935	0.03512	0.54000
Kajang Utama Hilly	0.30235	0.01459	0.01859	0.03318	0.03282	0.13459	0.53612

Source: Author analysis (2023)

show that all the factor loadings are positive, highlighting an increase in vulnerability. The SoVI scores were then categorised based on the standard deviation from the mean into four categories: A mean of 0 and a deviation of 1 were obtained (Bucherie *et al.*, 2022). The values of 0 to 1 were then classified into four vulnerability categories (Table 6). Based on the results of the composite index of the SoVI, both the Kajang Mewah hilly area (0.54000) and the Kajang Utama hilly area (0.53612) were classified as moderately vulnerable areas. In comparison,

the Kajang Mewah hilly area is more vulnerable than the Kajang Utama hilly area, with a slight value of 0.00388.

Factor Analysis Loading from PCA

Table 7 presents the factor analysis loadings that identify the factors that are important to the study. Based on the results of the PCA, six factors were extracted from the 17 variables. The factors were classified throughout the screening of the factor loadings, in which positive values (blue) indicate those factors that are the most

Table 6: SoVI scores of the categories of vulnerability

Category	SoVI Score
Highly vulnerable	0.7501-1.0000
Moderately vulnerable	0.5001-0.7500
Low vulnerable	0.2501-0.5000
Not vulnerable	0.0000-0.2500

vulnerable or vulnerable and negative values (pink) indicate those factors with a low level of vulnerability. Five factors were extracted from the analysis. Four-factor labels were produced: Factors 1 and 2 were low-income households, Factor 3 was the environment of the housing area, Factor 4 was household health, and Factor 5 was the presence of elderly and unemployed individuals (Table 7).

Discussion

PCA was used to identify the SoVI of the urbanised area in Kajang. The results show that the Kajang Mewah hilly area is more vulnerable than the Kajang Utama hilly area in terms of vulnerability values. Overall, the results show that the Kajang community in these two areas is

vulnerable to natural hazards such as landslides. Hence, further analysis is needed to identify and determine the factors influencing the SoVI using the PCA result. Four factors have been identified: Household income, the environment of the housing area, household health, and household composition.

Household Income

The first factor is household income, which includes variables related to households with low-income standards, households with income below 60.0% of the national median, and households with income over 200.0% of the national median. One of the vulnerability factors found in this study is low-income households, which can negatively affect households living

Table 7: Factor analysis loadings

Factor Label	Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factors 1 and 2: Households' income	Households with low-income standard	0.769	0.505	0.057	-0.147	-0.607	0.016
	Households with income below 60% national median	0.708	0.554	0.126	-0.230	-0.116	0.000
	Households with income 200% over the national median	0.759	0.543	0.113	-0.208	-0.081	-0.028
Factor 3: Environment of the housing area	Housing with more than 10 units in structure	0.101	-0.10	0.531	0.162	0.447	-0.329
	Distance from a nearby clinic	0.069	-0.093	0.511	0.127	0.008	0.683
	Elevation	-0.158	0.244	0.556	-0.156	0.328	0.417
Factor 4: Household health	Head of household with illness	-0.169	0.470	.010	0.607	0.097	0.108
Factor 5: Elderly and unemployed household	Households with elderly over 65 years old	-0.107	0.395	-0.274	-0.514	0.497	-0.022
	Head of households unemployed longer than six months	-0.049	-0.045	0.061	0.375	0.458	-0.217

*Note:



Sources: Author analysis (2023)

in urban areas and make them susceptible to natural hazards. According to the census report for Ulu Langat, there was an increase in median income from 2019 (RM8,361.00) to 2022 (RM11,210.00) and a decrease in the incidence of absolute (0.5%) and relative (7.0%) poverty from 2019 to 2022 [Department of Statistic Malaysia (DOSM), 2022]. The report shows that Kajang is classified as a nonpoverty area. However, based on this study, there is poverty present in Kajang, with more than 29.5% of the respondents reporting an income less than RM2,208.00, which indicates that they are below the Malaysian Poverty Line Index (PLI).

The finding that the examined urban communities experience poverty suggests that they have a high level of socioeconomic vulnerability. Furthermore, natural disasters affect the urban poor and cause limitations with regard to action. Natural phenomena place this group in a more conflicted situation because of the current economic situation of each household involved (Rosyida *et al.*, 2019). Consequently, natural disasters can cause significant loss of life, physical and mental injuries, and severe damage to the socioeconomics of the community such as ownership of houses and cars (Yusoff *et al.*, 2018). Therefore, the underprivileged will face social pressure such as repair costs, when restabilising their social life during the post-disaster period.

Environment of the Housing Area

The second factor is the environment of the housing area, which includes variables related to housing with more than 10 units per structure (multilevel units), distance from nearby clinics, and the last elevation of the housing area. A location's environment is important because it can directly and indirectly affect households living in natural disaster-prone areas. Using high-rise buildings and housing with more than 10 units per structure is popular in urbanised areas as it can help increase the density of residences, which is ideal in urban areas (Saatcioglu, 2013). However, according to Saatcioglu, in risk disaster situations, the damage to high-rise buildings is more severe

than that to low-rise buildings. The distance from nearby clinics is important, especially after disaster events. After a disaster event, there is a very high need for post-disaster treatment such as injury triage and rehabilitation, which means that the infrastructure around the housing area plays an important role in decreasing the vulnerability of the community living there. The next variable is elevation, which suggests that a location's height determines its experienced severity of a landslide disaster. Communities living in the highest areas are more at risk than communities living on land, as high elevations tend to experience an increase in the frequency of landslide events (Dou *et al.*, 2015). Hence, the environmental factor of a housing area is valid, especially in increasing the susceptibility of communities living in disaster-prone areas.

Household Health

The third factor of household health consists of variables related to the head of household having an illness. Illness is one factor that needs to be highlighted, as individuals with health problems are regarded as the most vulnerable and sensitive to natural hazard events. There are four main type of Noncommunicable Diseases (NCDs): Cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases. According to the WHO (2023), NCDs are chronic conditions in which individuals require constant care for a long period of time, eventually creating a dependent relationship between the individual and medicine or medical technology that will eventually affect and limit the individual's activities and life expectancy.

The National Health and Morbidity Survey (NHMS) by the Ministry of Health Malaysia (MOH) (2011) has reported that 15.2% of Malaysians. For example, approximately 2.6 million adults above 18 years of age suffer from diabetes, 32.7% (5.8 million) have hypertension, and 35.1% (6.2 million) have been diagnosed with hypercholesterolemia. Therefore, household health needs to be one of the priority factors under consideration, as individuals with illness are more exposed to natural disasters.

Household Composition

The last factor is household composition, including variables related to households containing elderly individuals over 65 years of age and heads of household, who have been unemployed for more than six months. Similar to individuals with an illness, elderly individuals over the age of 65 are more likely to be susceptible to natural hazards. Hence, increasing numbers of elderly individuals in one community can increase the community's risk of becoming vulnerable.

In this study, 14.5% of the population was above 65 years of age, which signifies a higher dependency on the working group. In such cases, disaster situations can increase the susceptibility of this group to natural hazards, as elderly people naturally decline in health and require health care, socioeconomic, information, communication, and cultural resources during times of urban disaster response (Phraknoi *et al.*, 2023). In addition, households with unemployed individuals can also increase the overall vulnerability risk. A total of 23.0% of respondents in this study were found to be unemployed. In risk situations, unemployed individuals significantly affect disaster outcomes (Tasri *et al.*, 2022). Therefore, factors such as this need to be monitored by the local agency to identify individuals with more tendencies to be vulnerable during disaster events. Thus, helping local agencies stay one step ahead by monitoring such information can help reduce the impact of disaster events on the local community.

Contribution and Suggestions

Overall, the current study contributes to vulnerability studies in Malaysia, which are lacking in a focus on social vulnerability. Furthermore, this study can help identify vulnerable communities in the Kajang area and contribute information and knowledge regarding vulnerability and susceptibility to hazards, especially landslide disasters. Quantifying community vulnerability to both natural disasters and hydrometeorological hazards by identifying social vulnerability factors is vital to

disaster management at the multilevel stage of stakeholders. Even though vulnerability studies can help local communities and governments identify vulnerability in a community, the results for each community will differ depending on the community's exposure, sensitivity, and adaptability (Hahn *et al.*, 2009).

In addition, even when everyone in a community goes through the same experience, it does not mean that the process for everyone in the community will be the same (Nor Diana *et al.*, 2021). The destruction, recovery, and evaluation process can be different according to the degree of each individual's vulnerabilities. A higher level of vulnerability means that the individual is more susceptible to being a victim of natural disaster events. Therefore, every characteristic and factor needs to be evaluated accordingly so that the responsible party can distribute proper help and guidance. Further studies are needed to increase the studies of social vulnerability in Malaysia, which will help in terms of the livelihood of Malaysian households. Thus, further studies can use census data from the Malaysian government to identify and analyse the vulnerability of Malaysian households. In addition, future analyses can be more comprehensive using census data than in the current paper.

Besides, the study on vulnerability assessment is not limited to Malaysia only. Nonetheless, it can be used in countries, places, or communities with a higher chance of being affected by natural hazards event. It will help determine the vulnerability and disaster risk management factors in the target area. The growing impact of climate change and natural disaster events on different populations of the world has impacted not only the environment but also the community that lives in the environment. By assessing vulnerability, the authorities can monitor and further assist the impact of the disasters. It will also help the community in terms of mitigation action and increase the resilience of the community.

Conclusions

In conclusion, studying social vulnerability is essential, especially for communities susceptible to hazardous events such as landslides. Even though the Langat River Basin area has never experienced a landslide event, the results show that the communities located in the Langat River Basin are still vulnerable to landslide events. Therefore, there is a need for the community and the responsible party to prepare for the safety of the communities located in that area. From the study, four factors have been identified that influence the social vulnerability of the community in Kajang that is household income, second is the environment of the housing area, third is household health, and the fourth is household composition. This study has contributed to identifying vulnerable communities in the Kajang area and contributing information and knowledge regarding vulnerability and susceptibility to hazards. Although the study is limited to the Kajang area, the study on social vulnerability assessment itself is not limited to certain areas but can be expanded and applied to other communities.

Acknowledgements

This research was supported by the Ministry of Higher Education (MOHE) of Malaysia, Dana Padanan Antarabangsa (MyPAIR), and Natural Environment Research Council (NERC) grant number NEWTON/1/2018/TK01/UKM/2.

Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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