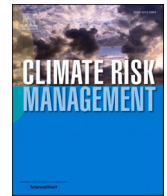




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Household external vulnerability due to climate change in Selangor coast of Malaysia

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ABSTRACT

Coastal areas are already facing various risks due to increasing climate-related hazards that are likely to amplify with changing climate and make the households living in these areas even more vulnerable in terms of livelihoods and living conditions. This study attempted to evaluate vulnerability mapping of the coastal areas due to climate change using an integrative external and internal framework from three dimensions at the household level: exposure (E) to coastal hazards, sensitivity (S) due to demographic, socio-economic and structural characteristics and adaptive capacity (AC) relating to available assets and adaptive behaviour to cope with climate change impacts. Primary data on relevant indicators for assessing vulnerability were collected from ten historically eroded critical coastal areas along Selangor coastline, Malaysia. Using a pre-tested questionnaire, face-to-face interviews were conducted with 1050 randomly selected households. The collected data were used to estimate a composite vulnerability index (VI) from E, S, and AC indices. The vulnerability was classified according to four categories (low, moderate, high, very high) based on quarterly percentile distribution to evaluate the status. The results showed that about 96% of households had moderate exposure, and 4% had high exposure to climate change. All of the households exhibited moderate sensitivity. Low adaptive capacity was observed in 76% of households, moderate adaptive capacity in 17% and high adaptive capacity in 7%. Composite VI indicated that eight coastal areas (84% of households) are highly vulnerable, and two coastal areas (16%) are moderately vulnerable to climate change. The high vulnerability was attributed to increased exposure to shoreline erosion, high-risk perception, limited income, weak housing structures and lack of financial capital. The variation in exposure, socio-economic characteristics and available capitals resulted in different degrees of vulnerability in Selangor coastal areas indicating the diversified need for proactive adaptation planning at the local level. It is recommended that an appropriate mix of equitable community-based adaptations that adequately address the needs of the most vulnerable, focusing on poverty reduction, financial incentives and livelihood resilience and climate policies based on equity and justice, cultural and societal values are implemented to contribute to rural coastal households' resilience. This study is limited by the selective indicators of the external household vulnerability and subjective range of vulnerability classification.

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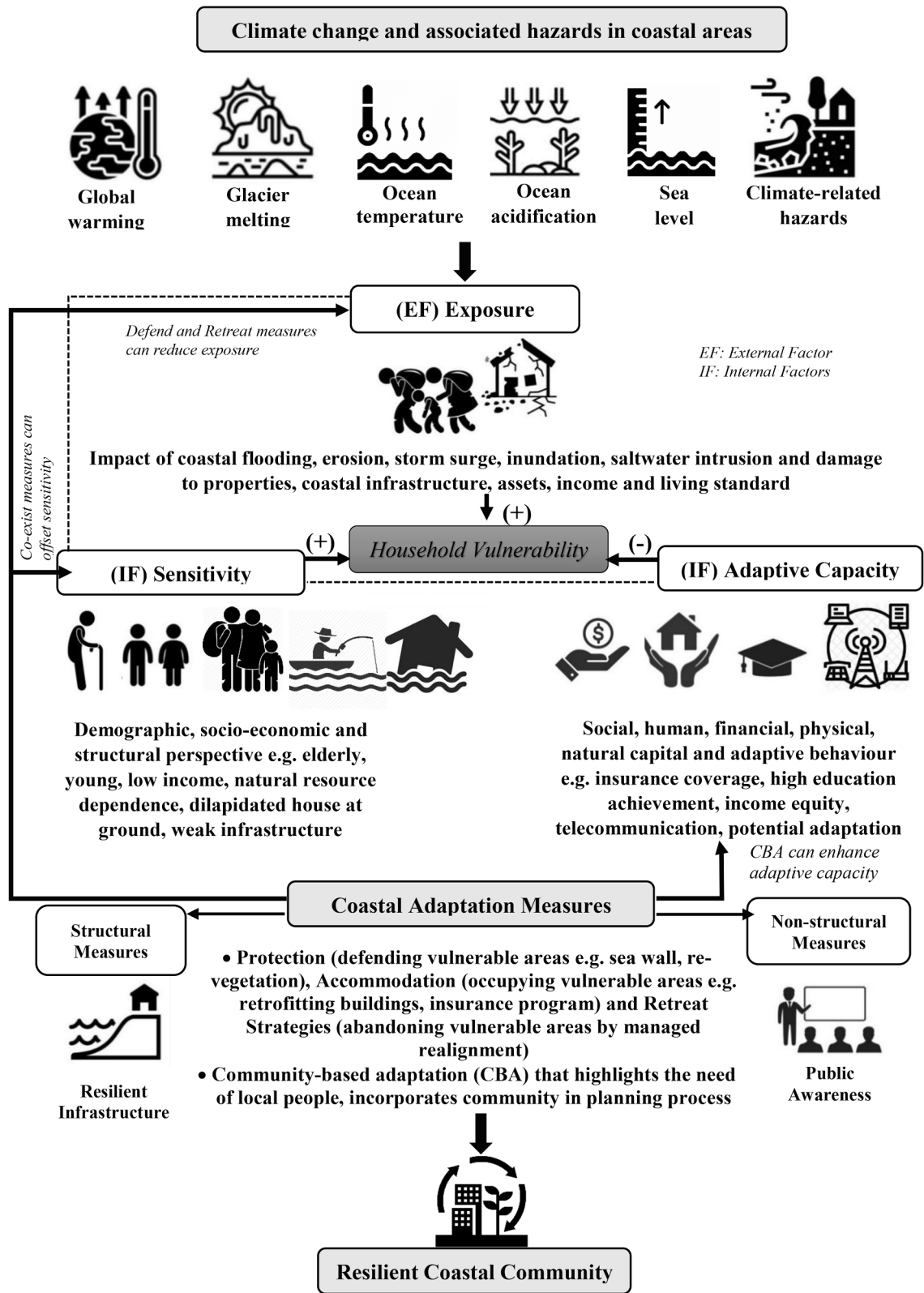


Fig. 1. Elements of household vulnerability to climate change in coastal areas.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) evidenced that the global climate is changing at rates unprecedented in recent human history, leading to a change in geophysical, biological and socio-economic systems (IPCC, 2018). Malaysia is experiencing an increasing trend in annual mean surface temperature, mean sea level, and extreme weather events (Tang, 2019). Likewise, coastal areas are constantly facing climate-related hazards; for instance, among the total coastline of 8,840 km, 1,349.3 km of coastline is continuously being eroded in Malaysia (Government of Malaysia, 2018). The adverse impacts of climate change on the natural resources of the coastal areas are documented in the form of reduced fish density in each fishing zone, reduced yearly production of marine fishes by 1.67% in 2014 (DOF, 2017), incidences of mass coral reef bleaching over recent years (NRE, 2016), and decreased agricultural productivity and profitability (Alam et al., 2014; Vaghefi et al., 2016; Alam et al., 2011). Throughout the 21st century, the climate in Malaysia is projected to observe a further increase in temperature, rise in sea level, highly variable rainfall spatially and seasonality with some drier and wetter conditions, and increased frequency of extreme weather events (NAHRIM, 2021).

The associated impacts of projected climate change in coastal areas are shoreline erosion, flooding, saltwater intrusion and inundation (Ehsan et al., 2019), which increases the susceptibility of low-lying coastal areas by impacting the coastal property and assets (Li et al., 2020), critical infrastructure such as transport network and utility infrastructure (Bove et al., 2020; Neumann et al., 2015), several mangrove functions, and aquaculture (He and Silliman, 2019; Lu et al., 2018; Froehlich et al., 2018; Williams et al., 2016; Hewitt et al., 2016), cultural resources (Dastgerdi et al., 2019; Fatorić and Seekamp, 2017), livelihood (Hoque et al., 2019; Yanda et al., 2019; Ankrah, 2018), and public health and safety (Okaka and Odhiambo, 2019) of the coastal community. These problems aggravate the potential susceptibility, risk, and hazard to developing a sustainable coastal township (Ahmad et al., 2021).

Coastal areas worldwide represent an aggregation of population and assets of growing socio-economic and ecological significance, yet climate change can cause setbacks to its functionality. Vulnerability assessments can identify the factors and the segments of the society that are incredibly susceptible to experiencing the unfavourable impacts from climate variability. Thus, to understand the process of the household should withstand climate change and associated hazards, a vulnerability assessment is critical. IPCC (2007) defines vulnerability as a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. It deems the factor of vulnerability as a function of 'internal' factors, namely, sensitivity and adaptive capacity that underlies the capacity of the system to anticipate, cope with and recover from climate impact, as well as 'external' factors such as exposure to climate change (Diana et al., 2019). According to IPCC (2014a), "exposure is the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected; sensitivity is the degree to which a system is affected either adversely or beneficially by climate-related stimuli, and adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences." Some populations have a heightened vulnerability to climate change impacts due to having lower adaptive capacity relative to specific sensitivities and an increased likelihood of exposure (Engle, 2011). Fig. 1 highlights the linkage between climate change and the elements of exposure, sensitivity, the adaptive capacity that are likely to influence the household vulnerability and associates the role of community-based adaptation to reduce the vulnerability and build resilience.

Fig. 1 represents a coastal area in which the conditions of exposure, sensitivity, and adaptive capacity determine the coastal population's vulnerability. This study explores the dynamic relationship between the elements of vulnerability, as argued by Ngarava et al. (2019). The degree of potential impact is related to the nature and degree of exposure and internal sensitive characteristics (Sharma and Ravindranath, 2019); for instance, households that live in dilapidated houses (high sensitivity) during the extreme event of coastal flooding (high exposure) may suffer more significant adverse impacts (high potential impact). Adaptive capacity helps the community to adjust to the potential impacts; for instance, the households may decrease the sensitivity by opting for climate hazard-related housing insurances. However, households' demographic, socio-economic and structural sensitivity and adaptive capacity (available assets and adaptive behaviour) can be interlinked. A household with low income (high sensitivity) is likely to be less financially capable (low adaptive capacity) to adapt to climate change (Tran et al., 2012). On the other hand, low-income groups (high sensitivity) can have substantial social capital (high adaptive capacity) that is beneficial to adapt to climate change (Malherbe et al., 2020). Coastal adaptation strategies can offset the degree of potential impacts, e.g. by building resilient infrastructure (reducing sensitivity), early warning system (reducing exposure) (Sinay and Carter, 2020), and community-based adaptation (CBA) approach that implements efficient adaptation based on local needs. Community participation can nurture the household adaptive capacity by mobilising crucial assets and motivating the latent adaptation into actual adaptation (McNamara et al., 2020).

With the increasing need to investigate the vulnerability of climate change, several impact studies at regional and local scale attempted econometric analysis such as ordinary least square, probit regression, and Ricardian modelling (Ozturk and Al-Mulali, 2019; Fahad et al., 2020; Fahad and Jing, 2018; Huong et al., 2019). Nevertheless, the vulnerability was widely measured through an indicator-based approach (Diana et al., 2019). For instance, Giri et al. (2021) used indicators from the context of natural hazards, politico-economic, and ecological resilience strands to assess the urban poor in Nepal. Das et al. (2020) evaluated the livelihood vulnerability of Gangetic plain communities from social and biophysical indicators. Sekhri et al. (2020) used a multi-hazard risk index based on the IPCC framework to assess the vulnerability of the Indian Himalayan Region. Gupta et al. (2019) explored the socio-environmental vulnerability of socio-ecological systems at different altitudes in the Indian Himalayas using the indicators based on literature lists. Omerkhil et al. (2020) evaluated the vulnerability of smallholder farmers in Afghanistan due to climate change using the IPCC framework. Likewise, several studies attempted social and livelihood vulnerability assessment to aid community preparation for local areas (Adu et al., 2018; Carvalhaes and Omिताomu, 2017; Huynh and Stringer, 2018; Martins and Gasalla, 2020; Nguyen et al., 2017; Nong et al., 2020; Ashikin et al., 2021; Wu et al., 2016; Zacarias, 2019). Most of these studies selected indicators within the

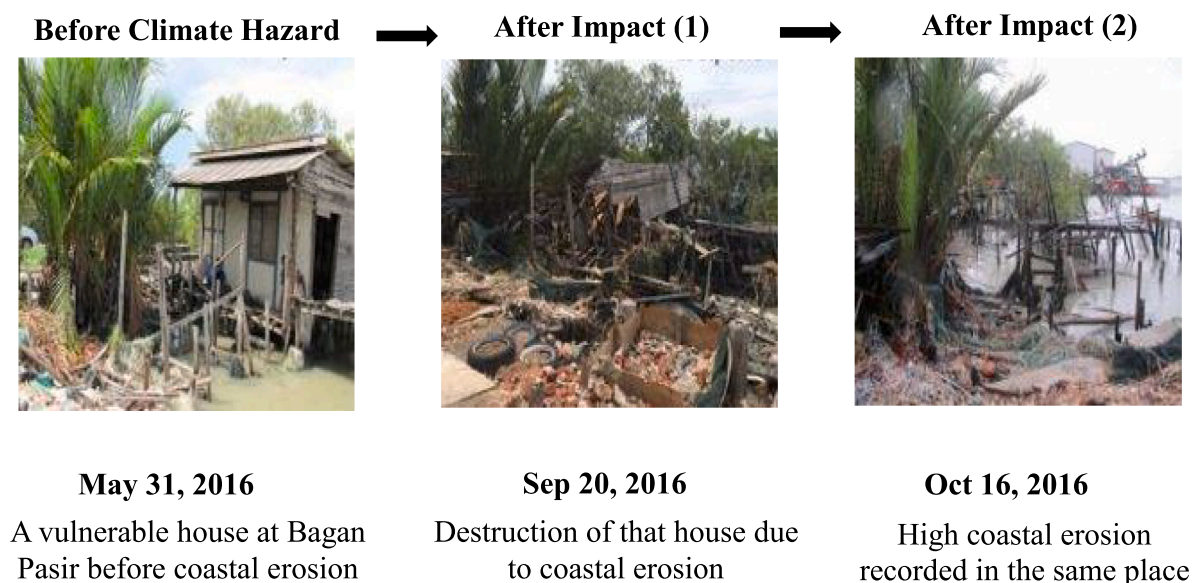


Fig. 2. Timeline presentation showcasing the degree of impact at Selangor Coast.

theoretical framework of exposure, sensitivity and adaptive capacity. However, previous studies reflect that methods of vulnerability measurement are not universal as the choice of indicators for vulnerability assessment varies due to the variability of climate change impacts within different contexts (household/livelihood functions, e.g. fishing, agriculture /social) and regions (river plain, mountain, rural, urban, coastal areas). Likewise, empirical evidence on the factors that influence individual vulnerability at the household scale remains limited, despite that households are connected to broader socio-economic processes in the community and have significant influence in making decisions about climate change adaptation (Nguyen et al., 2017). Based on a comprehensive review of vulnerability assessments, this study attempts to develop a framework for household vulnerability index due to current climate change and climate-related hazards in coastal areas, as presented in section 2.

Selangor, one of the significant states in Peninsular Malaysia, contributed the largest economy of RM344.5 billion gross domestic product (GDP) in 2019, making up 24.2% of total GDP. It has GDP per capita (RM54,995) above the national level, with good infrastructure, the largest population (6.51 million), the highest median gross monthly household income (RM8,210) and the lowest absolute poverty (1.2%) in the country (Department of Statistics Malaysia, 2019). However, 276 km of Selangor coast from Kuala Langat to Sabak Bernam is exposed to catastrophic hazards such as shoreline erosion and coastal flooding (Selamat et al., 2017), storm surge (Jamaluddin et al., 2016) and drought from increasing heat (Fung et al., 2020). According to Asmawi and Ibrahim (2013), about 144,473 people living in the vicinity of the Selangor coastline are directly threatened by climate change. Fig. 2 illustrates the visible impact of coastal erosion on residential properties within six months along the Selangor coast.

The population density, socio-economic and ecological importance, the rising sea level and the increased intensity of extreme events in the coastal areas lead directly to the questions of ‘who is vulnerable due to climate change, ‘what are the factors that lead to the vulnerability and ‘how these vulnerabilities can be managed’. Very few studies have been carried out on coastal vulnerability assessment in the Malaysian context. Existing studies attempted to assess the physical factors associated with coastal vulnerability, such as the geophysical dynamics of the coastal areas in Pahang (Mohd et al., 2018), Batu Pahat (Hassan and Rahmat, 2016) and Peninsular Malaysia (Mohamad et al., 2014). Similarly, a coastal vulnerability in East Malaysia assessed the exposure of climate variabilities such as sea-level rise, the sensitivity of bio-physical elements, the adaptive capacity of the shoreline in Tun Mustapha Park (Saleh and Jolis, 2018), Lahad Datu (Cheo et al., 2017) and Semporna Conversation Area (Jolis and Saleh, 2015). The findings indicated that the coastline in Malaysia is indeed physically vulnerable. However, these studies did not link the physical impacts with the societal aspects of climate change. At the same time, any empirical evidence on the factors that influence individual vulnerability at the household scale in the coastal regions remains limited. This remains a significant area of concern as households in the coastal areas are connected to broader socio-economic processes in their existing communities and tend to influence the decision-making procedure regarding effective climate change adaptation (Diana et al., 2019; Huynh and Stringer, 2018). Malaysia’s Third National Communication to the UNFCCC also addresses the research gap and needs to assess local vulnerabilities for adaptation to enhance resilience and protect its development gains (Government of Malaysia, 2018).

The concept of household vulnerability includes local geographical components, which intercede the climate risks and socioeconomic characteristics that provide needed insights on human capacity (Diana et al., 2019; Tate, 2012). The people in coastal areas are seemingly dependent on their intrinsic ability to tolerate the ever-changing climate. Vulnerability assessment can identify sources and forms of vulnerability specific to local areas to design context-specific resilience and adaptation measures that may help the government comprehend and handle communities’ vulnerabilities to a more considerable extent and work towards sustainable coastal townships. In turn, this aids in providing local policymakers and communities with practical tools required to understand

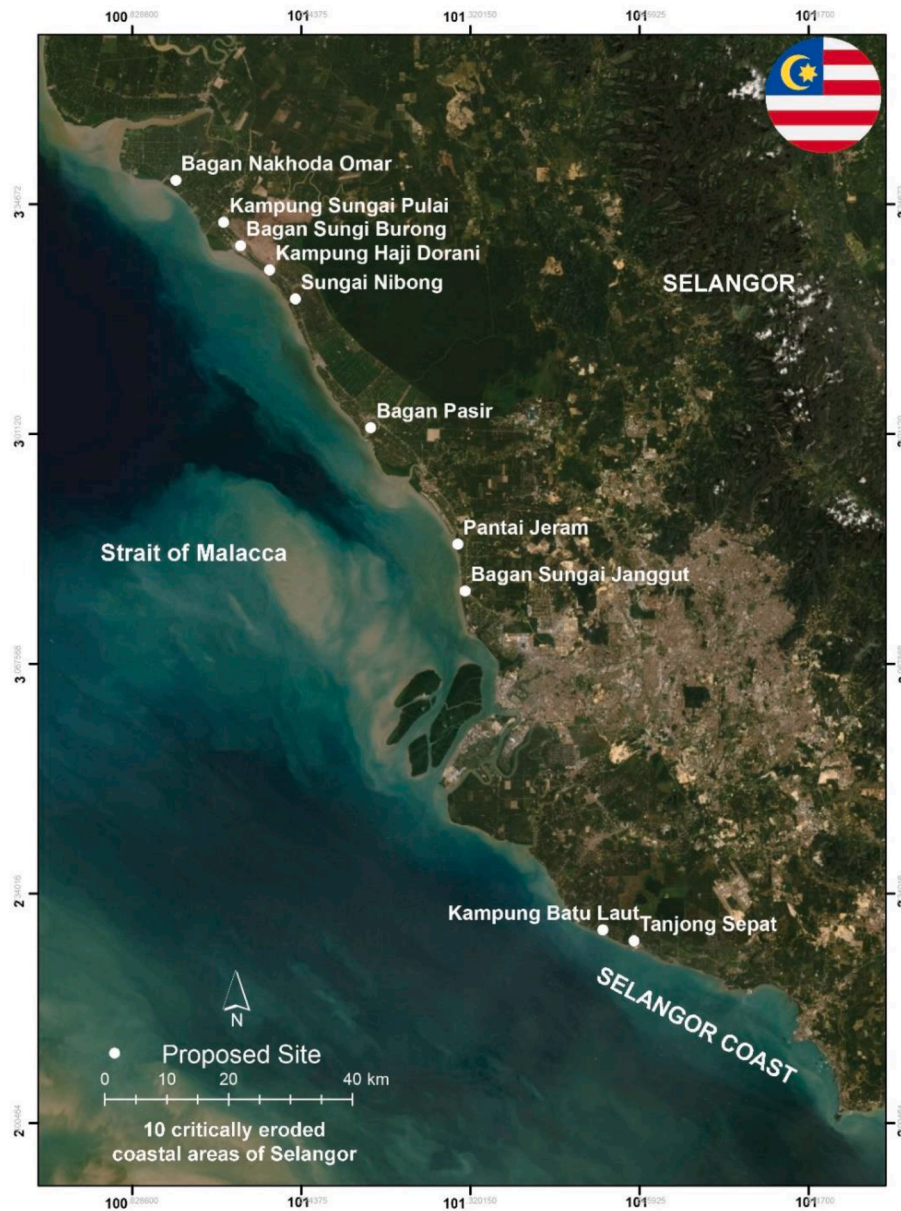


Fig. 3. Aerial map of the study area at Selangor Coast, Peninsular Malaysia.

demographic, social and other affiliated factors that play crucial roles in contributing to climate change vulnerability. Even though climate change is inevitable, the degree of impact is highly dependent on the proactive adaptation (IPCC, 2018); thus, an integrated approach that considers the physical context, socioeconomic, cognition and behavioural factors could play a significant role in moderating the adverse effects of climate change through a wide range of actions that are targeted at the vulnerable population (Aksha et al., 2020; Füssel, 2007). This study focuses on those needs above and the existing gaps through assessing external vulnerability due to climate change at the household level in critically eroded shorelines of Selangor coast, Malaysia. The specific objectives of this study are:

- To select major study areas based on the historical shoreline erosion rate and biophysical conditions of the shoreline that are susceptible to potential coastal hazards;
- To develop local context-specific indicators of exposure, sensitivity and adaptive capacity from the theoretical frameworks for coastal vulnerability assessment;
- To assess the socio-economic factors that contribute to the increasing and decreasing level of household vulnerability in the coastal areas based on indices values;

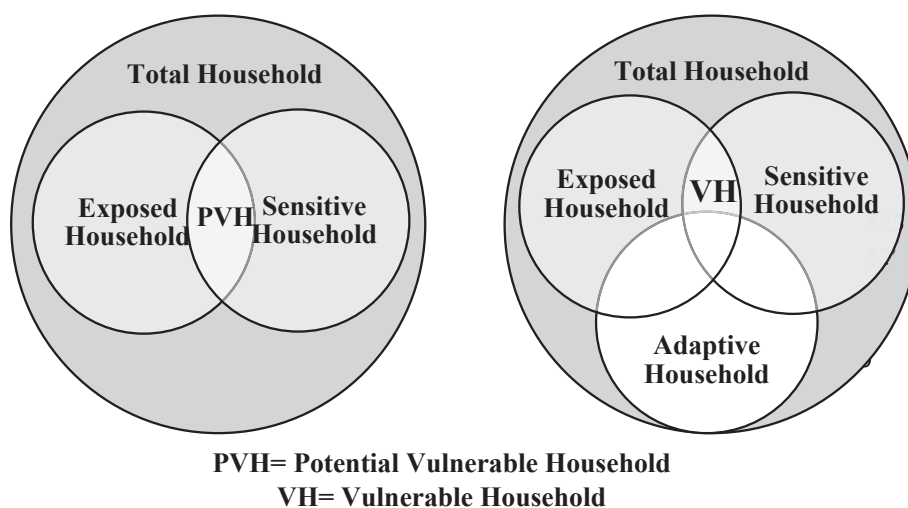


Fig. 4. Components of household vulnerability and their causal relationships.

- To explore the proactive adaptation options in climate risk management in vulnerable coastal areas.

The methodology of this study is presented in Section 2. The results and discussion of the detailed assessment of household vulnerability are provided in Section 3. The final section offers the conclusion of the study.

2. Research methodology

2.1. Study area

Selangor coastline is located at the west coast of Peninsular Malaysia, facing the Strait of Malacca. Ten coastal areas in Selangor namely Tanjung Sepat, Kampung Batu Laut, Bagan Sungai Janggut, Pantai Jeram, Bagan Pasir, Sungai Nibong, Kampung Haji Dorani, Bagan Sungai Burong, Sungai Pulai and Bagan Nakhoda Omar are among the critically eroded shorelines reported in Malaysian National Coastal Erosion Study (NCES, 2015). A recent study suggests that 2558 (Ha) areas eroded in these coastal areas between 1984 and 2013 (Ahmad et al., 2021). The shoreline of these coastal areas is vulnerable due to physical characteristics of geomorphology, shoreline change rate, maximum current speed, maximum tidal range, significant wave height and sea-level rise (Mohamad et al., 2014; Ahmad et al., 2021). The study area is limited to 1 km from the shoreline toward the land that has a tropical climate and generally experiences rainfall extremes and is at risk of severe flood due to intense rainfall in the wet period and a more prolonged drought due to lack of precipitation in the dry period (Rahman, 2018). Selangor coast mainly consists of muddy beaches (Hashim et al., 2017) and mudflats that are primarily made up of easily erodible alluvium (Ahmad et al., 2021) that are rich with diverse species of mangrove (Hashim and Noor; 2013). Land use features of these coastal areas reflected that areas are heavily composed of oil palm plantations, paddy fields, and mangrove forests (Daud et al., 2021). The basis of settlements, economic activities, and exposures from the sea were surveyed in initial field visits. The main livelihood mechanisms of the people are typically based on natural resources such as agriculture, forestry, fisheries and aquaculture industries. Proximity to the shoreline, the areas' physical features, and its dependency on natural resources make them highly vulnerable to climate change. Fig. 3 indicates the ten study areas and highlights the Selangor coast.

2.2. Core components of vulnerability and household vulnerability framework

The household vulnerability is assessed from the exposure, sensitivity and adaptive capacity components. The causal relationships between these components are adapted from Nguyen et al. (2017). Fig. 4 shows that total household denotes the total population living in the ten study areas (4065 households). Among them, the households directly affected by climate change impact and with vulnerable demographic, socio-economic and structural characteristics are exposed and sensitive households, respectively. The households that are mutually exposed and sensitive represent potentially vulnerable households. Conversely, vulnerable households (VH) are exposed, sensitive and have inadequate adaptive capacities to adjust to climate change impacts.

This study develops a conceptual framework to assess household vulnerability due to climate change and climate-related hazards in coastal areas. The methodology attempts to quantify where and how many people are vulnerable and what characteristics contribute to their vulnerability. The household vulnerability framework is demonstrated in Fig. 5. It consists of several processes to evaluate the vulnerability to current climate change and climate-related hazards (e.g. shoreline erosion, coastal flooding, storm surge, and drought) by assessing the household level's exposure, sensitivity, and adaptive capacity. The measuring indicators for components of

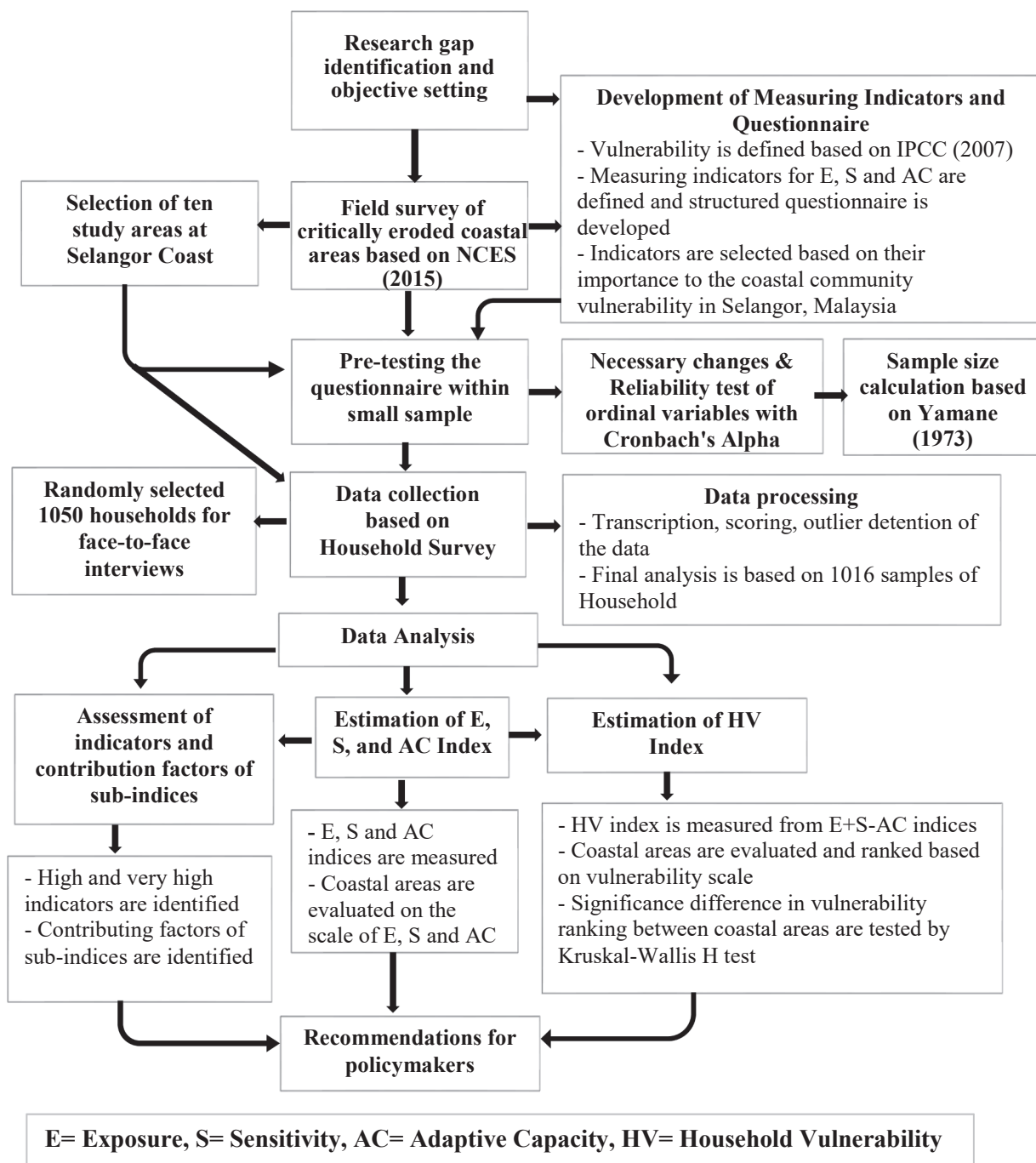


Fig. 5. Schematic diagram of household vulnerability assessment.

vulnerability are defined and developed from existing literature and expert local opinion to represent and understand the scenario specific to the coastal areas in Malaysia. The survey questionnaire was carefully constructed to include the indicators. Secondly, the data collection process comprises the sample size calculation, selection of sampling method, prior testing of the questionnaire and face-to-face interviews. The final analysis included 1016 households, and exposure, sensitivity, adaptive capacity and vulnerability index are estimated.

2.3. Theoretical framework of household vulnerability

The numerous definitions of vulnerability correspond to multiple conceptualising and quantifying it (Schneiderbauer and Ehrlich,

2004). The theoretical framework of vulnerability should be aligned with the aim and scope of the study. It addresses the needs of location and context-specific proactive adaptation primarily by classifying the coastal areas (vulnerability mapping) based on existing internal socioeconomic characteristics in the face of external climate change. Household is the focus of this study, and the scope is confined to the vulnerability assessment of climate change, including the incremental adverse impacts such as rise in sea level and coastal hazard perspective that takes into account the adverse impacts of shoreline erosion, coastal flooding, drought and storm surge that are apparent in Selangor coastal areas. Understanding the present climate variability in society will reduce the ultimate impacts of climate change on individuals and society (Adger et al., 2007; Ahsan and Warner, 2014). Theoretically, this study adopted an integrated approach for assessing vulnerability to climate change by combining the household's exposure to 'external' hazards (risk-hazard approach) and 'internal' factors such as sensitivity and adaptive capacity of household (internal social vulnerability approach) (Füssel, 2007).

Indicators for external factors are based on the theory related to the exposure of coastal hazards. In contrast, parameters for internal factors include the hazard-dependent characteristics such as proximity to the coast, quality of the housing infrastructure, adaptive behaviour that is relevant for vulnerability to extreme coastal events and hazard-independent common socio-economic factors that are relevant for vulnerability to gradual changes and any hazards such as age, income source and diversity, education, insurance, access to information etc. to cope and deal with climate change at household level (Schneiderbauer and Ehrlich, 2004). Therefore, adopting a theory-driven approach, drawing from climate change and climate-related hazards, socio-economic factors, and capacity strands of vulnerability literature, an integrated set of indicators for exposure, sensitivity and adaptive capacity components are comprised after a comprehensive review of the following studies, e.g. Abdul-Razak and Kruse, 2017; Adu et al., 2018; Brechwald et al., 2015; Brodie et al., 2006; Carvalhaes and Omitaomu, 2017; Cooley et al., 2012; Hahn et al., 2009; Huynh and Stringer, 2018; Kuhlicke et al., 2011; Madhuri et al., 2015; Majid et al., 2019; Nguyen et al., 2017; Nong et al., 2020; Diana et al., 2019; Ashikin et al., 2021; Panthi et al., 2016. After several field visits to the study area and informal experience sharing talks with the community members, indicators that are relevant to the local context, measurable, available in terms of resource and time constraints have been chosen. The detailed measuring indicators and relevant references are presented in Appendix A.

The exposure in this study is expressed as the degree to which the population of a studied area is exposed to coastal hazards. Exposure components assess the impacts of significant climate-related hazards considering the nature of exposure, impact dimensions and risk perception. The indicators, e.g., directly affected households due to drought, shoreline erosion, storms, coastal flooding, evaluate the nature of exposure. Impact dimensions assess how the households are affected by the hazards, e.g., loss of income, physical damage to property and assets, breakdown of the transportation network. Risk perception is included to assess the degree of exposure the household perceives. Several studies argued that perception of risk – the subjective judgement that people make about the characteristics and severity of a risk (IPCC, 2014b) is vital to assess the extent to which people are at risk (Rühlemann and Jordan, 2021). Thus, based on the perceived severity, it considers climate change's current and future damage to livelihood. It assumes that households that are directly affected and perceive serious risk reflect susceptibility to climate change.

Secondly, the sensitivity is the degree to which households in a studied area are susceptible to climate change due to their internal characteristics. Sensitivity components comprise demographically, socio-economically, and structurally sensitive households facing climate-related hazards. Demographic sensitivity such as elderly and young population, female as household head, household head not attaining any formal education, large family composition, new immigrants, minority race, language barriers, and having no insurance coverage increases the vulnerability of the household. Similarly, socio-economic sensitivity due to household heads being unemployed, low income, income below the poverty line, income dependent on natural resource increases the household vulnerability. Income diversification has an essential link with vulnerability (Ellis, 2000); thus, indicators, e.g. household depending on one income source, one income of a single earning member, and more than five family members depending on one income source are introduced. Low income and less income diversity increase vulnerability of climate-related hazards due to less financial resources to cope with adaptation. Thirdly, structural sensitivity relates to the house location closer to the shoreline, being renter of the house, vulnerable housing structure and lack of household facilities that increase vulnerability in household properties.

Adaptive capacity is the degree to which specific households in a studied area have the capacity, made up of a diversity of elements that evaluates the ability of the households to cope with climate change impacts using available resources that include the asset base and the adaptive behaviour. The power of a community to respond to changing climate is mainly dependent on access and control over the critical assets (Jones et al., 2010; Daze et al., 2009). Thus, it assesses the availability of critical assets such as social capital (community organisation), human capital (education, government jobs and health insurance), natural capital (productive agricultural land), financial capital (insurance coverage, income above state median, more than one income source), and physical capital (ownership of properties, telecommunication services, transportation, robust housing structures). Besides, adaptive behaviour such as availability of floodproofing materials and other temporary measures to protect the house, familiarity with community adaptation, disaster map, evacuation procedure and weather forecast assesses the latent adaptation for climate-related hazard risk reduction. Conversely, knowledge of climate change is intentionally not chosen since Adger et al. (2007) argues that due to the 'value action' or 'attitude behaviour gap', it does not necessarily lead to adaptation.

In total, there are 59 indicators grouped into three components of vulnerability, e.g., exposure with ten indicators divided into three sub-indices (nature of exposure, impact dimension and risk perception), sensitivity containing 26 indicators divided into three sub-indices (demographic, socio-economic and structural) and adaptive capacity includes 23 indicators in 6 sub-indices (social capital, natural capital, human capital, physical capital, financial capital, and adaptive behaviour).

2.4. Data collection

This study employs primary data by conducting household surveys to collect data for estimating the indices (Ahsan and Warner, 2014; Hahn et al., 2009), which helps to overcome the limitations of secondary data-driven methods such as measurement error and limited information (Nguyen et al. 2017). A survey questionnaire was designed incorporating the indicators of exposure, sensitivity and adaptive capacity to assess the household vulnerability. The questionnaire consisted of the following sections: basic demographic details of household representative/household head and other members, socio-economic and structural characteristics of the household, questions related to impact and intensity of hazards, risk perception, and adaptive behaviour. The questionnaire was verified in a series of instrument development meetings with several local experts working in the field of climate change in Malaysia. The validated question was pretested among 50 households at Selangor. The preliminary survey reflected the need for three adjustments to the questionnaire for better comprehension of the respondents - rephrasing of the scientific linguistic 'sea level rise', 'climate change' to related standard local dialect such as 'flood', 'long term changes in weather, avoidance of open-ended questions for fewer complications, limitation of Likert scale into 3 points for less confusion. After the adjustment to the questionnaire, the final phase of data were collected using the structured questionnaire through face-to-face interviews by ethnic enumerators, who were initially trained to be equipped with the necessary understanding of the climate change in coastal areas.

This study's sample size is calculated using the Yamane (1973) formula with a 97 per cent confidence interval and a ± 0.03 precision level, which is presented in Equation (1).

$$n = N / (1 + N(e)^2) \quad (1)$$

where n = sample size required, N = number of people in the population, e = allowable error (%). The calculation resulted in at least 1003 household respondents. The researcher increased the sample size to 1050 households to obtain reliable population presentations. A random sampling method was used to randomly select 1050 households within 1 km from the seashore along Selangor coastline among 4065 households living in these areas. 34 questionnaires of 1050 were not included in the analysis due to partial incompleteness. The final study included 1016 households resulting in a 97% response rate. The reliability of the questionnaire was tested using Cronbach's alpha test. Cronbach's alpha resulted in 0.716 for the variables on the ordinal scale. These indicate a high level of internal consistency for the scale as the values are higher than 0.7 (Kline, 2005).

2.5. Household vulnerability assessment

This study used a quantitative method approach for empirically assessing household vulnerability by constructing exposure, sensitivity and adaptive capacity indices. Indices help encapsulate a complex reality into simpler terms and allow comparisons (Mesfin et al., 2020). They have become prominent in studies related to climate change (Brooks et al., 2005). Vulnerability index development is done in sequential stages – selecting indicators, transcription in the questionnaire, data input, normalisation of indicators to a standard scale underlying theoretical dimension of vulnerability and the aggregation stage to estimate the index value. The data analysis followed several steps, as shown in Fig. 5. First, descriptive statistics were summarised and assessed by removing the outliers. The unit of all the indicators was percentage to ensure compatibility with future studies (Nguyen et al., 2017); each indicator was normalised to values between 0 and 1 following Eq. (1) as commonly used in many studies such as Pandey et al., 2015; Huynh and Stringer, 2018; Sujakhu et al., 2018; Menezes et al., 2018; Zacarias, 2019; Hahn et al., 2009.

$$\text{Normalised Value} = \frac{\text{Actual Value} - \text{Minimum Value}}{\text{Maximum value} - \text{Minimum Value}} \quad (1)$$

The normalised values of exposure, sensitivity and adaptive capacity indicators were averaged to yield the Exposure (E), Sensitivity (S) and Adaptive Capacity (AD) indices for each coastal area (Pandey et al., 2017; Morzaria-Luna et al., 2014; Martins and Gasalla, 2020; Hahn et al., 2009):

$$EIL1 \dots L10 = \sum_{e=1}^n ELi/n \quad (2)$$

$$SIL1 \dots L10 = \sum_{s=1}^n SLi/n \quad (3)$$

$$ACIL1 \dots L10 = \sum_{i=1}^n ACLi/n \quad (4)$$

EIL , SIL , $ACIL$ represents the exposure, sensitivity and adaptive capacity indices for coastal area L ; ELi , SLi , $ACLi$ are the normalised values indexed by indicator i and n is the number of indicators in the respective index. This study undertook a balanced weightage average approach, which adopted the view that each indicator and index is equally crucial for overall vulnerability assessment without a weight scale (Hahn et al., 2009; Morzaria-Luna et al., 2014; Ashikin et al., 2021). Weight assignment is avoided because of subjectivity and bias (Becker et al., 2017).

Mean index values were used to assess the indicators in exposure, sensitivity and adaptive capacity index:

Table 1
Ranking of the coastal areas according to the indices.

Assessment	Exposure and Sensitivity Indices			
Rank	Low	Moderate	High	Very High
Value	0.000 – 0.250	0.251 – 0.500	0.501– 0.750	0.751 – 1.00
Assessment	Adaptive Capacity Index			
Rank	Low	Moderate	High	Very High
Value	0.000 – 0.250	0.251 – 0.500	0.501– 0.750	0.751 – 1.00
Assessment	Vulnerability Index			
Rank	Low	Moderate	High	Very High
Value	0.000 – 0.250	0.251 – 0.500	0.501– 0.750	0.751 – 1.00

$$\bar{E}_i = E/n_{location} \tag{5}$$

$$\bar{S}_i = S/n_{location} \tag{6}$$

$$\bar{AC}_i = AC/n_{location} \tag{7}$$

E, S, and AC are the values indexed by indicators i and n represent coastal areas. The contributor factors of each sub-index were assessed (Ashikin et al., 2021) as follows:

$$\bar{x}Li = xLi/n_{sub-index} \tag{8}$$

where, $\bar{x}Li$ are the values indexed by indicator i for coastal area L, n represents the number of indicators of each sub-index. Indices were combined to create a composite vulnerability index by using an additive (averaging) approach as used in Sujakhu et al., 2018; Menezes et al., 2018:

$$HVIL1 \dots L10 = \sum_{i=1}^n \frac{EIL + SIL + (1 - ACIL)}{3} \tag{9}$$

where, HVI represents the household vulnerability index for coastal area L and EI, SI and ACI are exposure, sensitivity, and adaptive capacity index of the respective coastal area. The evaluation scale for household vulnerability index (HVI) ranges from 0 (least vulnerable) to 1 (most vulnerable).

The intensity scale (0 to 1) is used to evaluate and rank the coastal areas according to the indices. It is based on the distribution of the population in the coastal areas according to their index values. Using the ranking, the current status of the coastal areas can be evaluated through the household distribution reflecting exposure, sensitivity, adaptive capacity, and vulnerability characteristics, which provide insights into the community’s local needs and facilitate decision-making for context-specific proactive adaptation measures. The ranking is divided into four quartiles; each represents one-fourth of the population. Based on the value of percentile, indicators and sub-indices values correspond to less than 50% of the household are in the moderate to low category and values greater than 50% of the household are in the high to very high category. Table 1 represents the description of the ranking. Additionally, a rank-based nonparametric test such as the Kruskal-Wallis H test (Sheskin, 2011) was conducted to determine significant differences in vulnerability between coastal areas based on their response of exposure, sensitivity adaptive capacity indicators. The differences resulting in $p \leq 0.05$ were considered statistically significant.

3. Results and discussion

Household vulnerability to climate change based on exposure, sensitivity and adaptive capacity indices evaluates each indicator on average index values, explores the contributing factors of the sub-indices, and ranks the vulnerability indices according to their values. The distribution of sample households among the coastal areas indicated that most of them are from Tanjung Sepat (27.1%), followed by Kampung Batu Laut (20.8%) and Kampung Haji Dorani (12%). In addition, 65.6% are male, and the average age is 47. The majority of the households belong to the Malay race (65.8%), while only 9.9% of the household head completed their high school certificates. Most of the household heads are involved in fishing (25%), followed by private sector employment (16%), business (14%) and self-employment (10%), agriculture (7%).

The monthly gross household income is analysed based on the range set by the Department of Statistics Malaysia (2019) that categorises household income into three groups- B40 (the lowest 40%), M40 (the middle 40%) and T20 (The top 20%) while B40 is further divided into lowest B1, second-lowest B2, third-lowest B3 and fourth lowest B4 categories. The results indicated that 90% of the households in Selangor coastal areas are from the low-income group (B40), 9.4% belongs to the middle-income group (M40), and only 0.1% are in the high-income group (T20). The median monthly household income is RM2,000. In Malaysia, the median for the low-income group (B40) is RM4,850, and the income threshold for the lowest (B1) is less than RM2,499. Thus, the results indicate that

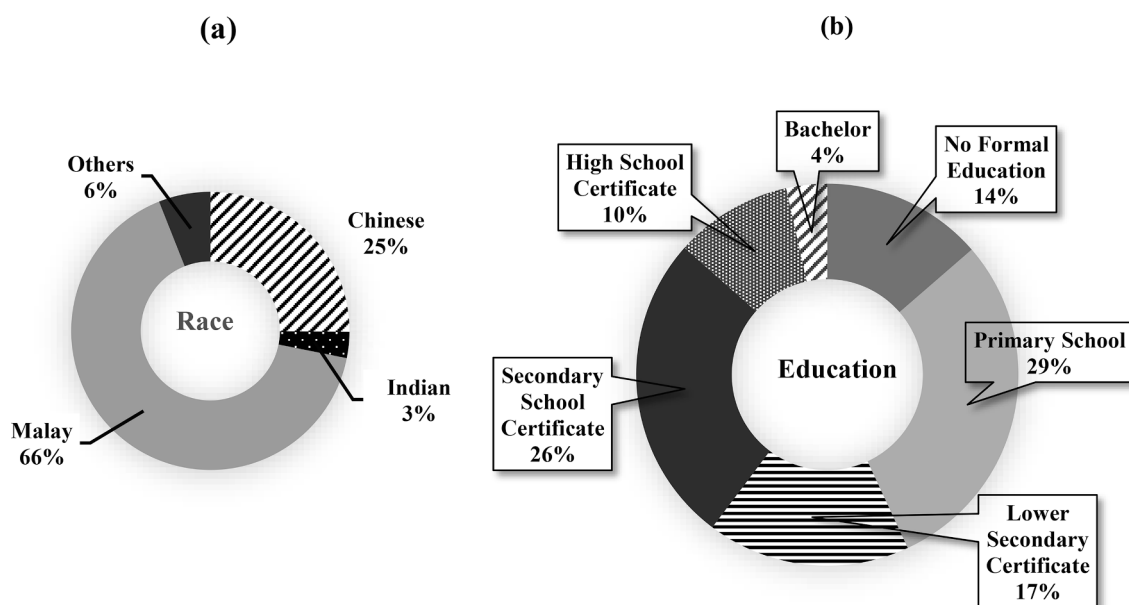


Fig. 6. Percentages of (HH) based on socio-economic characteristics of the households at Selangor coastal areas (a) Racial Distribution; (b) Educational Attainment; (c) Occupational Distribution; (d) Household Size Distribution; (e) Income Distribution.

55.3% of households in Selangor coastal areas are among the lowest income earners, 21.4% are second lowest, 6% are third lowest, and 7.8% are fourth lowest income earners in Malaysia. Fig. 6 illustrates the essential socioeconomic characteristics of the households in the coastal areas.

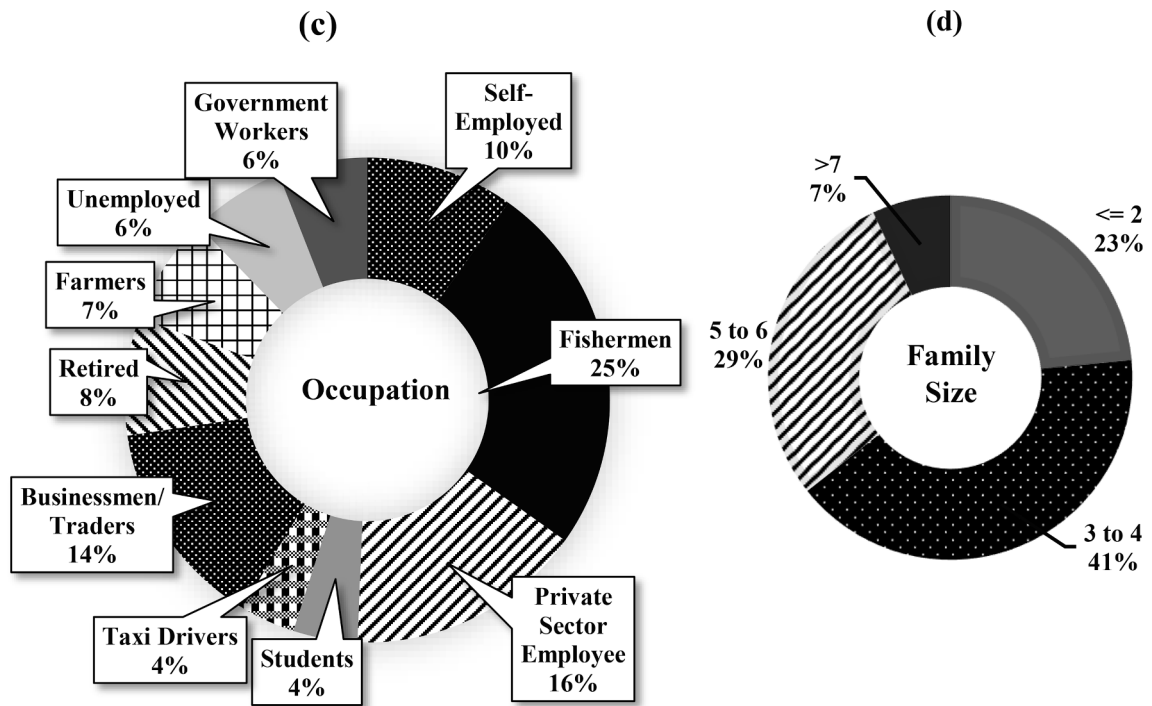
3.1. Household exposure index

According to IPCC (2018), climate change poses significant long-term impacts, and its severity depends on the vulnerability of different communities and their exposure to climate threats. For these reasons, assessing the household's nature of exposure, impact dimensions, and risk perception are significant. The results of exposure indicators are summarised in Fig. 7. It revealed that 89% of households are directly affected by shoreline erosion, and 64% are directly affected by storm surges on the Selangor coast. These high exposures to climate-related hazards directly impact the economic, social, and ecological functions of the coastal areas and livelihoods of coastal households by threatening their properties and access to the sea, the coast and the mangrove areas (Ehsan et al., 2019). Contrarily, households are moderately exposed to drought (38%) and coastal flooding (30%). Impact dimension indicators reflected that 34% of households are directly affected by income loss, and 27% are directly affected by property and asset damage due to extreme weather events induced by climate change. Rising sea levels will intensify such effects (Nicholls and Cazenave, 2010), leading to prolonged disruption of economic activities, livelihoods, and sustainable development of the coastal areas.

Risk perception is a priority of Sendai's Framework for disaster risk understanding (UNISDR, 2015). Therefore, indicators in the exposure index assessed the households' risk perception about current and future climate change. The findings show that, on average, 57% of households perceived damage caused by current climate change as severe, and 68% of households perceived future climate change will pose severe damages to their livelihood. High-risk perception has two implications on vulnerability. For instance, recognising the personal risks are essential to adapt to climate change; in other words, adaptation measures that may reduce the vulnerability require an ability to respond to these perceived risks. Diversely, from a psychological point of view, high-risk perceptions may produce mental health consequences such as anxiety and depression (Farrokhi et al., 2020).

Fig. 8 demonstrates the contributing factors of the nature of exposure, impact dimension and risk perception sub-indices. It indicates risk perception influences the exposure index ($\bar{X}=0.61$) followed by the nature of exposure ($\bar{X}=0.55$) and impact dimension ($\bar{X}=0.21$). Based on coastal area wise analysis, Bagan Sungai Burong had a distinct pattern from other regions due to the highest values of nature of exposure and impact dimension sub-indices, meaning that it is the most affected due to climate-related hazards; however, it perceived less risk of current and future damage of climate change compared to Kampung Sungai Pulai and Sungai Nibong who perceived the highest risk. Interestingly, the most exposed and impacted coastal area may not necessarily perceive the highest climate change risk. Taylor et al. (2014) reasoned about the optimism bias and the perception of low probability of experiencing adverse events that could explain this difference in risk perception.

Overall, the results show that about 96% of all sampled households have moderate exposure and 4% have high exposure. Furthermore, the exposure index (Table 2) indicates that Bagan Sungai Burong is at high exposure with a value of 0.53. Similarly, other coastal areas are at moderate exposure, with values ranging from 0.36 to 0.46. Households are highly exposed to shoreline erosion and



(e) Monthly Household Income

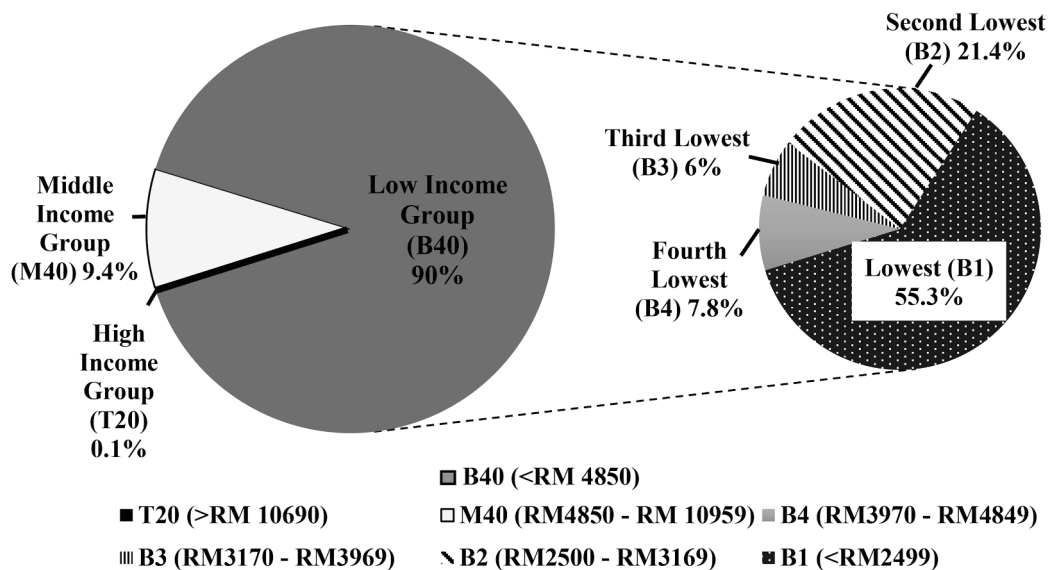


Fig. 6. (continued).

storm surge, while climate-related hazards moderately impact household income in all coastal areas. This indicates the need for protective and accommodating adaptation measures in Selangor coastal areas to reduce the economic loss due to climate-related hazards. Kampung Haji Dorani is at the lower bound of the exposure index that perceived the lowest risk of climate change, resulting in less disaster preparedness. Bollettino et al. (2020) found the association between disaster preparedness and risk perception in the Philippines as Filipinos who perceived climate change directly impacting their households reported taking more significant action to prepare for disasters. Thus, climate-related education and awareness-raising programs on climate change impacts and adaptation

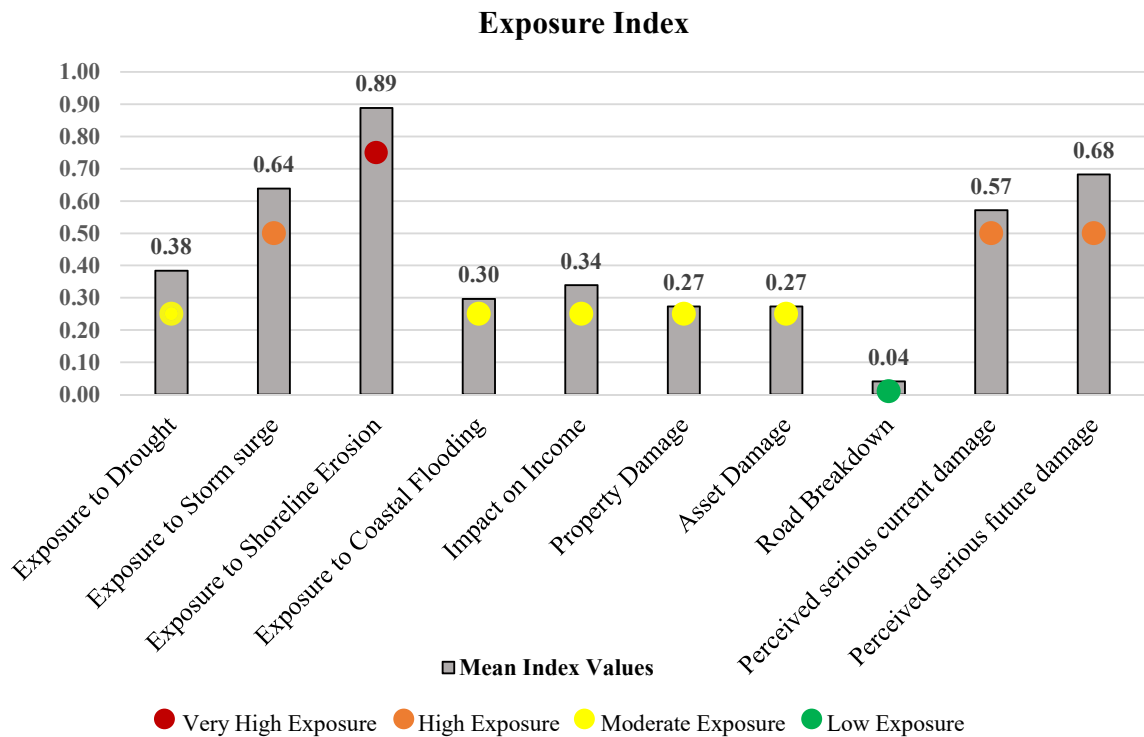


Fig. 7. Mean index values and evaluation of indicators at exposure index.

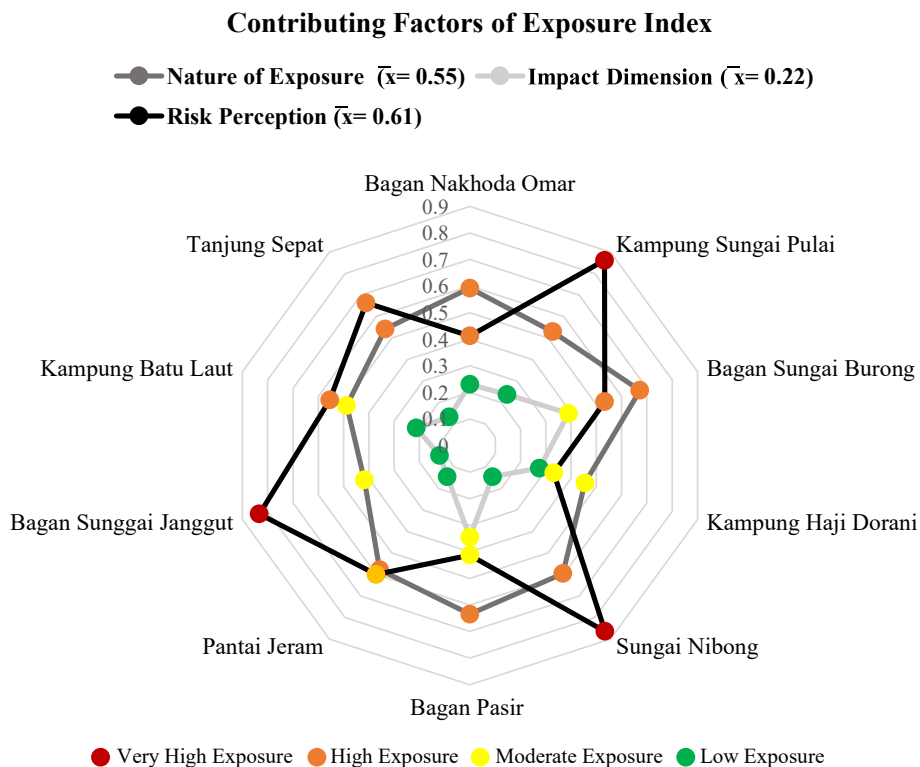


Fig. 8. Web analysis of the sub-indices and their contributing factors to exposure index at Selangor coastal area.

Table 2
Results of household exposure index for coastal areas in Selangor.

Sub-Index	Indicators	Bagan Nakhoda Omar	Kampung Sungai Pulai	Bagan Sungai Burong	Kampung Haji Dorani	Sungai Nibong	Bagan Pantai Pasir	Bagan Jeram	Kampung Sungai Janggut	Batu Laut	Tanjung Sepat
Exposure to climate-related hazards	Exposure to drought	0.56	0.38	0.53	0.27	0.49	0.37	0.35	0.32	0.30	0.27
	Exposure to storm surge	0.50	0.53	0.67	0.58	0.60	0.65	0.68	0.70	0.73	0.75
	Exposure to shoreline erosion	0.83	0.83	0.89	0.73	0.96	0.90	0.91	0.93	0.94	0.96
	Exposure to coastal flooding	0.48	0.38	0.60	0.24	0.33	0.27	0.23	0.19	0.14	0.10
Dimensions of climate-related impact	Loss of income	0.33	0.35	0.44	0.35	0.30	0.34	0.33	0.32	0.32	0.31
	Property damage	0.28	0.30	0.56	0.36	0.14	0.26	0.24	0.22	0.20	0.17
	Asset damage	0.28	0.30	0.56	0.36	0.14	0.26	0.24	0.22	0.20	0.17
	Road breakdown	0.03	0.00	0.00	0.03	0.00	0.15	0.20	0.00	0.00	0.00
Risk Perception	Serious current damage	0.38	0.72	0.53	0.23	0.73	0.58	0.60	0.62	0.65	0.67
	Serious future damage	0.45	1.00	0.53	0.43	1.00	0.48	0.48	1.00	0.68	0.77
Household Exposure Index		0.41	0.48	0.53	0.36	0.47	0.43	0.43	0.45	0.41	0.42

■ Very high exposure
■ High exposure
■ Moderate exposure
■ Low exposure

measures are crucial in the low-risk perception areas such as Kampung Haji Dorani and Bagan Nakhoda Omar.

3.2. Household sensitivity index

The assessment of sensitivity indicators points out the essential characteristics of the households that make them more susceptible to climate change exposure than others. The results of sensitivity indicators (Fig. 9) reveal that all the households have young family members, and 79% of the households do not have any health insurance coverage. These specific characteristics create very high sensitivity for the households from a demographic perspective. The demographic sensitivity reflects that the households have difficulty preparing and moving to safety, affected more by public health service interruption, disruption in school attendance, difficulty adapting to changing environment, health impacts due to low immunity, risk of malnutrition, and exhaustion sensitiveness mental health. Several climate change impacts on children in East Asia were evidenced by UNICEF (2015).

In addition, the mean index values of socio-economic sensitivity indicate that majority of the households are worse-off economically; for instance, the monthly income for 80% of households is below the poverty line set for Selangor by the Malaysian Government, 81% of households are very low-income earners, whose income are among the lowest income category (B1) in Malaysia, 95% households belong to the low-income group (bottom 40%) in Malaysia. These reflect very high socio-economic sensitivity. On the other hand, households depending on the single earning member, single income source and aqua-culture income are 43%, 38% and 36%, respectively, which reflect moderate sensitivity due to less income diversity and natural resource dependence. Thus, households would be less able to prepare for, respond to or recover from the impact, e.g. may not be able to accommodate the cost of moving or repairing their property during the disaster, limited resources to prepare or cope, fewer financial resources to address needs such as housing, healthy food, health and transportation, vulnerable health impact as low income is associated with poor health, physical health risk as limited means to practice healthy behaviour and access health care services due to low-income and mental health concerns as low-income individuals need to divert wages from daily needs to pay for immediate impacts of climate change (Hallegatte and Rozenberg, 2017). Low income is also associated with less preparedness, less disaster management resources and more loss during climate-related disasters (Mohammad-pajooch and Aziz, 2014). The analysis of structural sensitivities reflects that households in the Selangor coast live in proximity to the shoreline (48%), in the dilapidated houses (71%), made of wood/semi-wood (53%), that are not above ground to deter flooding (83%). These structural sensitivities increased the risk of climate change impacts. They are more susceptible to coastal flooding, and shoreline erosion found commonly in Malaysian coastal areas (Tran et al., 2012).

Fig. 10 illustrates the contributing factors of the sub-indices. The socio-economic perspective is the highest contributing sub-index

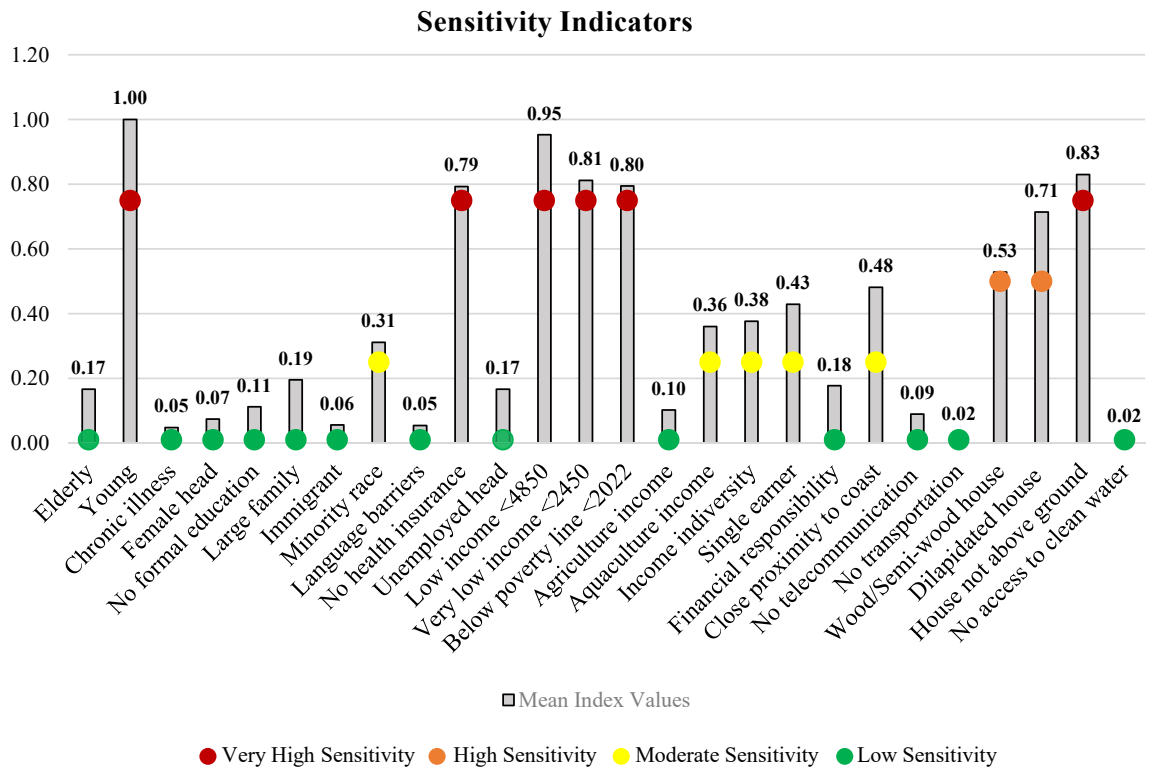


Fig. 9. Mean index values and evaluation of indicators at sensitivity index.

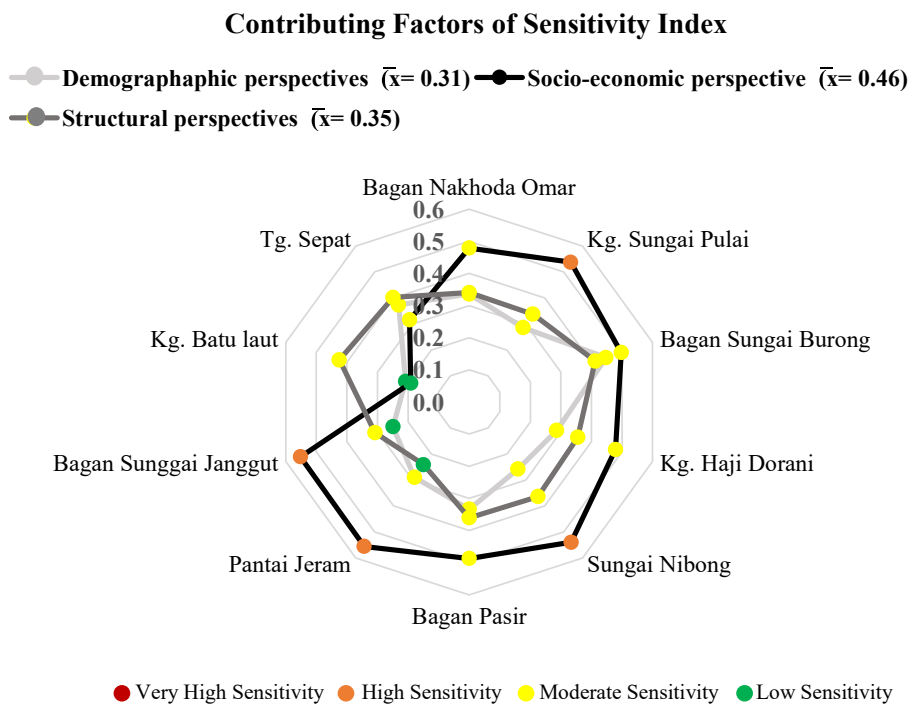


Fig. 10. Web analysis of the sub-indices and contributing factors to sensitivity index in Selangor coast.

Table 3
Results of household sensitivity index for Selangor coast.

Sub-index	Indicators	Bagan Nakhoda Omar	Kampung Sungai Pulai	Bagan Sungai Burong	Kampung Haji Dorani	Sungai Nibong	Bagan Pantai Pasir Jeram	Sungai Janggut	Kampung Batu Laut	Tanjung Sepat	
Demographic	Elderly	0.20	0.13	0.38	0.16	0.11	0.15	0.05	0.08	0.13	0.27
	Young	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female head	0.15	0.03	0.02	0.06	0.07	0.10	0.10	0.05	0.09	0.07
	No formal education	0.15	0.09	0.16	0.07	0.07	0.14	0.03	0.08	0.13	0.23
	Large family	0.28	0.12	0.29	0.25	0.20	0.30	0.15	0.13	0.09	0.15
	Immigrant	0.15	0.00	0.02	0.02	0.07	0.09	0.05	0.08	0.07	0.01
	Minority race	0.15	0.17	0.87	0.04	0.04	0.23	0.63	0.13	0.07	0.78
	Language barriers	0.05	0.08	0.29	0.00	0.00	0.03	0.03	0.03	0.00	0.04
	No health insurance	0.90	0.96	1.00	0.98	0.76	0.98	0.58	0.67	0.29	0.82
Socio-economic	Unemployed	0.10	0.09	0.04	0.14	0.09	0.14	0.23	0.13	0.27	0.44
	Low income <RM4850	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.57	0.96
	Very low income <RM2450	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.12	0.00
	Below poverty line <RM2022	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00	0.00	0.00
	Agriculture income	0.03	0.06	0.07	0.17	0.07	0.08	0.15	0.07	0.11	0.22
	Aquaculture income	0.23	0.44	0.40	0.28	0.51	0.36	0.33	0.77	0.17	0.12
	One income source	0.38	0.52	0.42	0.29	0.46	0.34	0.60	0.41	0.16	0.19
	Single earner	0.43	0.57	0.44	0.34	0.50	0.35	0.60	0.46	0.28	0.32
	>5 people on one income source	0.16	0.16	0.11	0.14	0.23	0.12	0.10	0.13	0.03	0.59
Structural	Proximity to the shoreline	0.55	0.39	0.70	0.54	0.34	0.56	0.33	0.44	0.36	0.60
	No tele-communication	0.00	0.14	0.04	0.07	0.21	0.03	0.13	0.10	0.03	0.15
	No transportation	0.05	0.02	0.02	0.02	0.01	0.05	0.00	0.00	0.00	0.06
	Wood/semi-wood house	0.45	0.66	0.89	0.62	0.43	0.68	0.18	0.31	0.80	0.28
	Dilapidated house	0.50	0.76	0.53	0.62	0.77	0.50	0.73	0.77	0.98	1.00
	Grounded House	0.88	0.69	1.00	0.86	0.94	0.89	0.53	0.54	0.99	1.00
	No access to clean water	0.03	0.00	0.04	0.02	0.03	0.01	0.03	0.03	0.01	0.00
	Renter	0.28	0.05	0.07	0.10	0.17	0.18	0.03	0.28	0.23	0.14
Household Sensitivity Index	0.29	0.29	0.36	0.28	0.28	0.30	0.26	0.27	0.25	0.34	

Very High Sensitivity High Sensitivity Moderate Sensitivity Low Sensitivity

(\bar{X} =0.46) in the sensitivity index. Pantai Jeram, Bagan Sungai Janggut, Sungai Nibong and Kampung Sungai Pulai and Bagan Sungai Burong are highly socio-economically sensitive among the coastal areas. It also demonstrates that the structural sub-index contributes to the sensitivity index (\bar{X} =0.35) following the socio-economic sub-index. Thus, the vulnerability of the built environment reasonably contributed to the sensitivity of the households in Selangor coastal areas. Housing often contributes the significant economic losses due to disasters (Lyons, 2009).

The household sensitivity index (Table 3) indicates moderately sensitive coastal areas. A study by Solaymani and Kari (2014) in coastal communities of Malaysia also revealed similar socio-economic sensitivities by reporting that young Malaysian fishers are often found multi-dimensionally poor in terms of insurance, health, and education. Nevertheless, all coastal areas are highly sensitive as they occupy the young population; thus, adaptation policies in Selangor coastal areas have to incorporate children's health, safety, protection, education, and social development to reduce the adverse impact of climate change on the young population. In addition, availing health insurance policies in Bagan Nakhoda Omar, Kampung Sungai Pulai, Bagan Sungai Burong, Kampung Haji Dorani, Sungai Nibong, Bagan Pasir and Tanjung Sepat are needed for managing climate change risks.

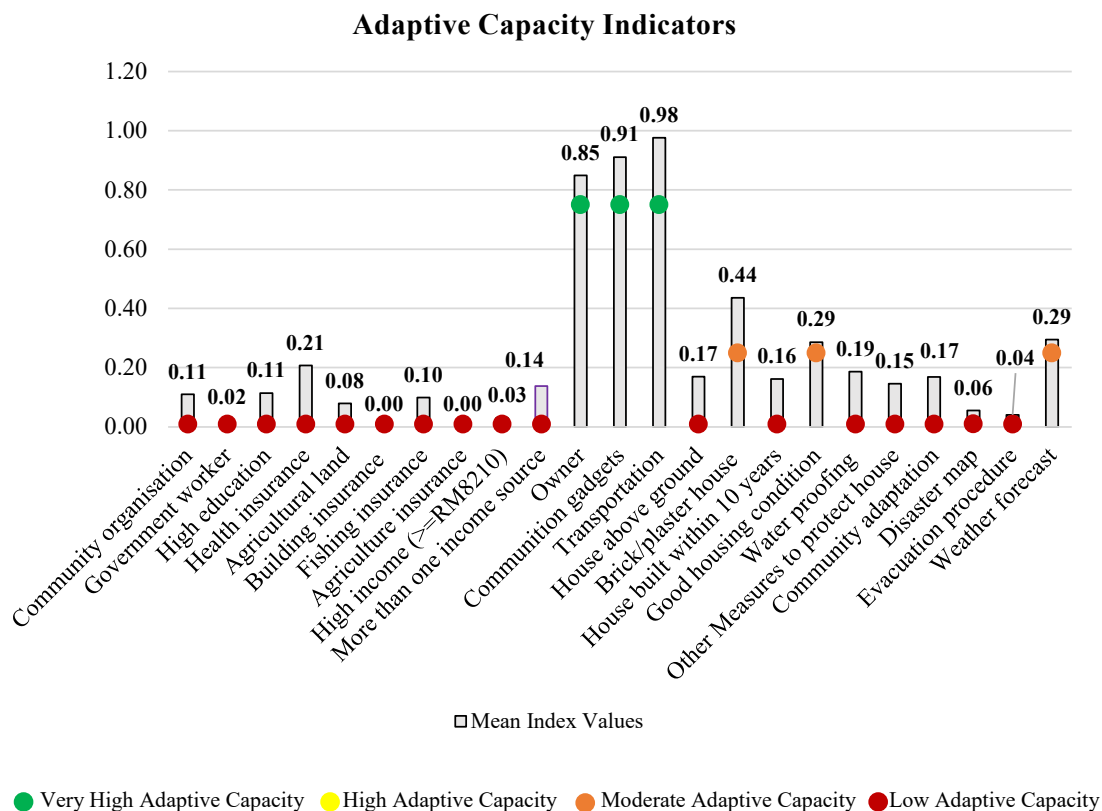


Fig. 11. Mean index values and evaluation of indicators at adaptive capacity index.

In terms of low income, all the coastal areas expect Kampung Batu Laut are highly sensitive while Bagan Nakhoda Omar, Kampung Sungai Pulai, Bagan Sungai Burong, Kampung Haji Dorani, Sungai Nibong, Bagan Pasir, Pantai Jeram, and Bagan Sungai Janggut have very high sensitivity due to income below poverty line. These economically disadvantaged households are particularly at risk due to climate change that will be intensified by 2030. Climate change is expected to be a poverty multiplier that makes poor people poorer and increases the poverty headcount (Hallegatte and Rozenberg, 2017; IPCC, 2018). Thus, financial equity and poverty eradication should be the primary concern of climate risk management policies in these coastal areas, particularly Bagan Sungai Janggut and Sungai Nibong, with a distinctive feature of high dependency on aquaculture income that is found to be highly vulnerable in terms of livelihoods due to changing climate on a global scale (Handisyde et al., 2017). Besides, the majority of the households in Bagan Sungai Burong, Tanjung Sepat and Pantai Jeram belong to a minority race that can be associated with less disaster preparedness due to historical and systematic inequity (Bethel et al., 2013), indicating the need for policy intervention. The results also suggest that Selangor coastal areas share a common attribute of vulnerable housing structures. Studies indicate that post-disaster housing reconstruction includes the highest recovery barriers (Rouhanizadeh et al., 2020). Thus, protecting and accommodating adaptation strategies for properties are necessary for the Selangor coast, specifically in Kampung Batu Laut, Bagan Sungai Burong and Tanjung Sepat.

3.3. Household adaptive capacity index

Adaptive capacity assessment recognises the assets and behaviours households can utilise to cope and identifies resource-poor households with limited ability to adapt to climate change’s adverse effects. The results of adaptive capacity indicators are summarised in Fig. 11. It shows that majority of the households have property ownership (85%), communication gadgets (91%) and access to transportation (98%). This physical capital can be utilised to adapt to climate change and reduce the household vulnerability to climate-related hazards. For instance, owners may make informed decisions on preventive and adaptive measures to protect the house from hazards and minimise economic loss to the property and assets. Mulilis et al. (2000) also found that homeowners show more responsibility to protect the home, thus being more prepared than the renters.

Similarly, the availability of communication gadgets can be utilised as an effective tool for climate-related knowledge and behaviour by enhancing the awareness and capacity building in community-based disaster management (Barua et al., 2020) that can prepare the household to disseminate information during disaster and aid subsequent recovery and reduce the impacts. Additionally,

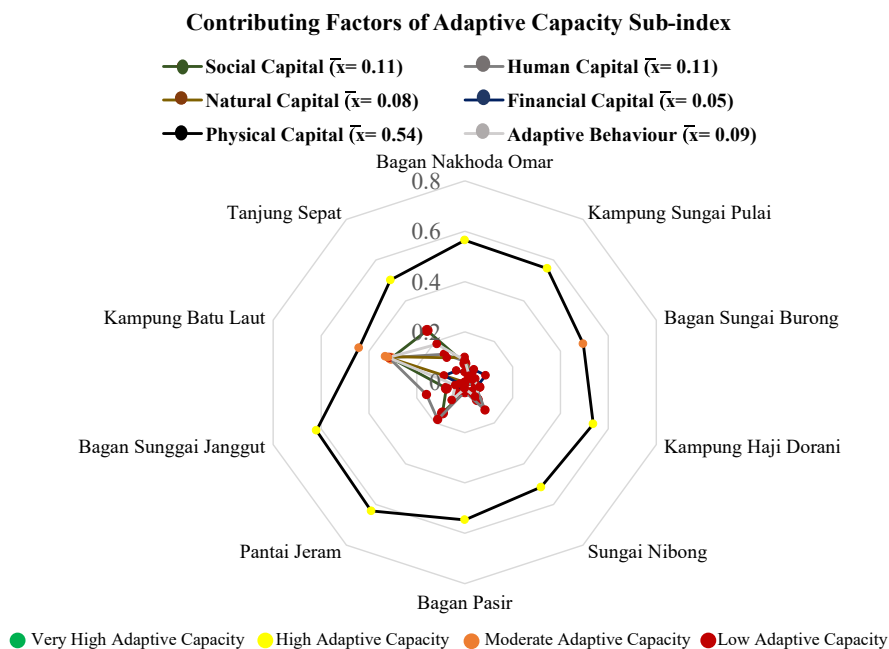


Fig. 12. Web analysis of the sub-indices and their contributing factors to adaptive capacity index at Selangor coastal area.

households with their transportation have flexibility in movements, which could be particularly important during the evacuation of climate-induced disasters (Todd, 2006). However, adequate mobilisation of these resources is essential in pursuing adaptation actions as adaptive capacity is not merely about having resources, but more importantly, about the willingness to deploy those resources (Cinner et al., 2018).

Conversely, the majority of the household have fewer resources in terms of capital (social, natural, human and financial) and adaptive behaviour, reflecting very low adaptive capacity. For instance, only 11% of households are involved in the social network of community organisations, 8% own productive agricultural land reflecting the lack of social and natural capital. Likewise, only a tiny per cent of households have government jobs, high educational attainment, insurances (health, agricultural, building and fishing), high income, and more than one income source that indicate the availability of less human and financial assets. Furthermore, 29% of households are familiar with average water levels weather forecasts and 19% have available waterproofing materials, 17% are familiar with community adaptation; however, most are not familiar with disaster maps or evacuation procedures. This lack of resources and low adaptive capacity could mean that households are less prepared in the face of changing climate, and they would be more vulnerable and prone to damage due to lack of adaptation. Thus, there is a need to allocate resources and assist these resource-poor households deserving priority consideration to reduce vulnerability.

Fig. 12 exhibits the sub-indices contributing factors, indicating that the availability of physical capital is the highest contributing sub-index ($\bar{x}=0.54$). Contrarily, financial capital is the lowest contributing sub-index ($\bar{x}=0.05$), representing the reduced adaptive capacity due to the lack of financial assets. It is more likely that households without required financial resources to draw upon when climate variability or hazards disrupt income generation cannot withstand periods of financial hardship. Less diversity of income sources indicates less choice for employment opportunities should their jobs be adversely affected by climate change (Wall and Marzall, 2006). This may lead to high vulnerability as lack of access to financial capital undermine the livelihood options and strategies available to people to cope with climate change risk (Handisyde et al., 2017). Thus, capacity building for enhancing the financial capital is necessary for Selangor coastal areas.

Overall, 76% of all sampled households exhibit low adaptive capacity. Moderate and high adaptive capacity are observed in 17% and 7% of households. Table 4 presents the household adaptive capacity index. Most coastal areas reveal low adaptive capacity except Pantai Jeram, Bagan Nakhoda Omar, and Bagan Sunggai Janggut reflect moderate adaptive capacity. Bagan Sungai Burong indicates the most insufficient adaptive capacity. The values for the social, human, natural, physical, financial capital and adaptive behaviour are homogenous for all areas studied. Thus, Selangor coastal areas are generally resource-poor in critical assets for adaptive capacities and adaptive behaviour. These have various implications on the household ability to cope with climate change. Households without solid social networks would face difficulty handling damaging impacts of hazards as it is fundamental to efforts for restoring community amenities (Wall and Marzall, 2006). Likewise, human, financial, and physical capital is paramount to managing societal vulnerability to climate change and undertaking practical adaptation actions (Nelson et al., 2010). Low education level is also a barrier that prevents households from accessing information to recognise the impact of climate and seek adaptive strategies (Le and Vo, 2020). There is also a lack of adaptive behaviour among the households. The results indicate that several capacity-building plans are desirable

Table 4
Results of the household adaptive capacity index for Selangor coast.

Sub-index	Indicators	Bagan Nakhoda Omar	Kampung Sungai Pulai	Bagan Sungai Burong	Kampung Haji Dorani	Sungai Nibong	Bagan Pantai Pasir	Sungai Jeram	Bagan Sungai Janggut	Kampung Batu Laut	Tanjung Sepat
Social Capital	Community organisation	0.08	0.03	0.02	0.06	0.09	0.04	0.15	0.08	0.31	0.26
	Government workers	0.03	0.02	0.00	0.02	0.01	0.03	0.00	0.00	0.11	0.01
Human Capital	High educational attainment	0.13	0.09	0.00	0.09	0.16	0.06	0.13	0.15	0.13	0.22
	Health insurance	0.10	0.04	0.00	0.02	0.24	0.03	0.43	0.33	0.71	0.18
Natural Capital	Agricultural land (Surplus)	0.10	0.03	0.04	0.07	0.06	0.01	0.03	0.00	0.33	0.12
	Building insurance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Financial Capital	Fishing insurance	0.10	0.14	0.33	0.11	0.00	0.13	0.05	0.00	0.09	0.05
	Agriculture insurance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	High Income \geq RM8210	0.05	0.01	0.09	0.04	0.04	0.01	0.05	0.00	0.00	0.00
	More than one income source	0.05	0.16	0.02	0.11	0.18	0.04	0.15	0.10	0.34	0.23
	Owner	0.73	0.95	0.93	0.90	0.83	0.83	0.98	0.72	0.77	0.87
	Communication gadgets	1.00	0.86	0.96	0.93	0.79	0.98	0.88	0.90	0.97	0.85
Physical Capital	Access to Transportation	0.95	0.98	0.98	0.98	0.99	0.95	1.00	1.00	1.00	0.94
	House high above 3 feet	0.13	0.31	0.00	0.14	0.06	0.11	0.48	0.46	0.01	0.00
	House-made of brick and plaster	0.55	0.31	0.11	0.30	0.55	0.33	0.70	0.59	0.20	0.72
	House less than 10 years old	0.10	0.26	0.02	0.12	0.17	0.14	0.13	0.44	0.12	0.13
	Good housing condition	0.50	0.24	0.47	0.39	0.23	0.50	0.28	0.23	0.02	0.00
	Waterproofing material	0.30	0.22	0.02	0.20	0.26	0.20	0.25	0.10	0.19	0.13
	Other measures to protect the house	0.35	0.15	0.02	0.07	0.16	0.14	0.28	0.21	0.09	0.02
	Community adaptation	0.33	0.13	0.02	0.13	0.24	0.20	0.35	0.21	0.06	0.03
Adaptive behaviour	Familiar with disaster map	0.00	0.04	0.00	0.05	0.00	0.01	0.20	0.21	0.04	0.00
	Familiar with evacuation	0.03	0.03	0.00	0.04	0.04	0.00	0.10	0.15	0.00	0.00
	Familiar with the weather forecast	0.68	0.15	0.18	0.26	0.27	0.38	0.43	0.21	0.19	0.21
	Household Adaptive Capacity Index	0.272	0.224	0.183	0.218	0.233	0.221	0.304	0.264	0.247	0.216

Very High Adaptive Capacity High Adaptive Capacity Moderate Adaptive Capacity Low Adaptive Capacity

to enhance the adaptive capacity of households in all coastal areas.

3.4. Household vulnerability index for Selangor coastal areas

According to the World Bank's report for coastal areas with low elevation, East Asian countries, including Malaysia, are the most severely impacted region in the developing world due to the rising sea level (Dasgupta et al., 2007). At the national level, it is predicted that 37 out of 344 coastal areas are at risk under the critical erosion and significant erosion categories by 2030 (NCES, 2015). The projected increase in sea level rise, surface temperature, extreme events associated with climate change in Malaysia (NAHRIM, 2021) will exaggerate the existing risk (IPCC, 2018). Households in these natural resource and bio-diversity affluent coastal areas (Hashim and Noor, 2013; Daud et al., 2021) are dependent on numerous significant economic, ecological and social functions that are on the

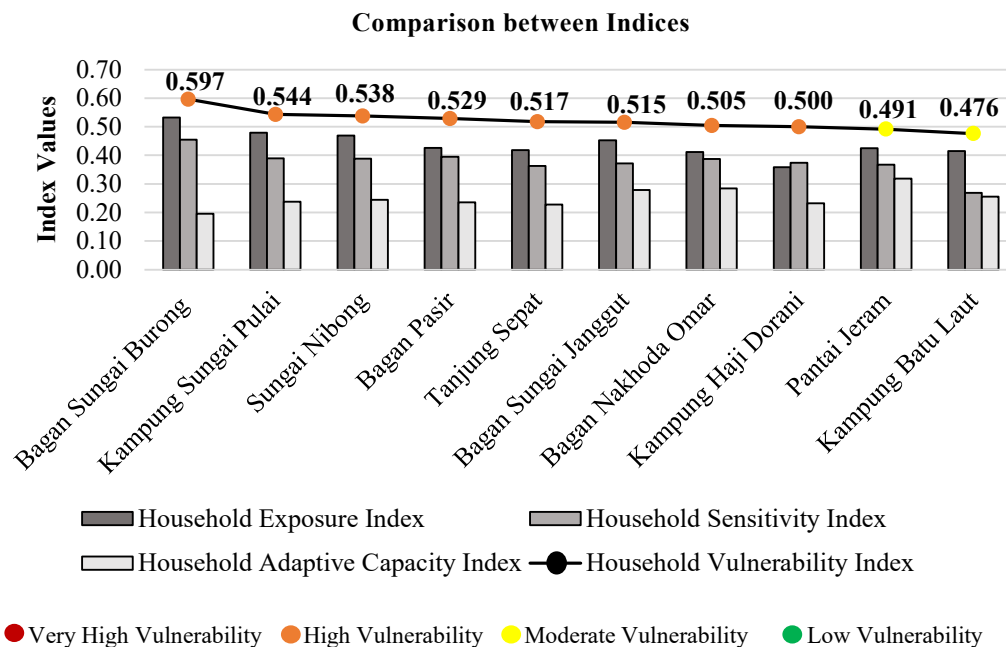


Fig. 13. Household E, S, AC, & V indices in Selangor coast.

verge of adverse effects of climate change (Shaffril et al., 2017; Mohamad et al., 2014; Ehsan et al., 2019). Even though climate change is inevitable, the adverse impacts can be remarkably reduced by implementing mitigation and adaptation programmes (IPCC, 2018). However, mitigation strategies are proactive and more emphasised in the context of Malaysia (Tang, 2019). Recently, the Government of Malaysia (2018) highlighted the need for adaptation research to bridge the current gaps. Understanding ‘who is vulnerable’ and ‘what factors contribute to vulnerability at the root level’ are the first steps to formulating local context-specific proactive adaptation strategies for managing this vulnerability through community resilience and offsetting climate change impacts. Thus, assessing household vulnerability is critical to facilitate the process of climate risk management, recognising key characteristics of exposure, sensitivity and local coping mechanisms to strengthen the adaptive capacities.

Households in Selangor coastal areas have experienced and been impacted by damaging infrastructures and loss of income by climate change such as shoreline erosion, coastal flooding, storm surge and drought. The demographic, socio-economic and structural characteristics of households showed increased susceptibility to climate change and extreme events. Household adaptive capacity in social, human, natural and financial capital and adaptive behaviour towards changing climate is proven inadequate due to the lack of social network, education attainment, agricultural land, income and less familiarity with disaster preparedness activities. The households’ exposure, sensitivity, and adaptive capacity in Selangor coastal areas reflect household vulnerability from two extents, i.e. the vulnerability during incremental adverse effects of climate change and the vulnerability of disaster preparedness and recovery from hazards. The gradual changes in the Malaysian climate (Tang, 2019; NAHRIM, 2021) impose a significant negative impact on the economic and ecological functions of coastal areas by the reduction in fish production (DOF, 2017; Kamal, 2016), aquaculture (Barange et al., 2018; Froehlich et al., 2018; Hamdan et al., 2015) and agriculture production (Solaymani, 2018; Vaghefi et al., 2016; Sarkar et al., 2020). Thus, the natural resources dependency, less income diversity and lack of financial and natural capital are likely to increase the household’s vulnerability in loss of income, food insecurity and degraded livelihood during these incremental changes at Selangor coastal areas.

On the other hand, studies have evidenced an increasing trend of coastal hazards in Malaysia, such as flood frequencies (Amin et al., 2017), shoreline erosion (Ahmad et al., 2021), storm surge and drought (Jamaluddin et al., 2016; Fung et al., 2020). Several socio-economic characteristics of households residing in Selangor coastal areas such as low income, vulnerable housing structure, low-risk perception, less adaptive behaviour, low education level and lack of insurance are expected to impact disaster preparedness and recovery from hazards. As Tran et al. (2012) argued, due to minimal financial capacity, houses of low-income households are the most vulnerable without strong structure and often built based upon experiences of local masons without technical designs and construction supervision. Low income also limits the ability to meet the expense of adaptation measures to protect the properties and assets, such as the elevation of the residences above the ground (Ashikin et al., 2021). Therefore, the lower-income household would be severely impacted during climate-induced disasters (Ibrahim and Siwar, 2017).

Climate risk insurances can provide incentives decreasing the adversative financial impacts (Prabhakar et al., 2015), but may not be the affordable option for low-income groups. Contrarily, Adger et al. (2007) argued that individuals often fail to purchase insurance against low-probability high loss events even when offered at favourable premiums due to specific human cognition. Minimal use of

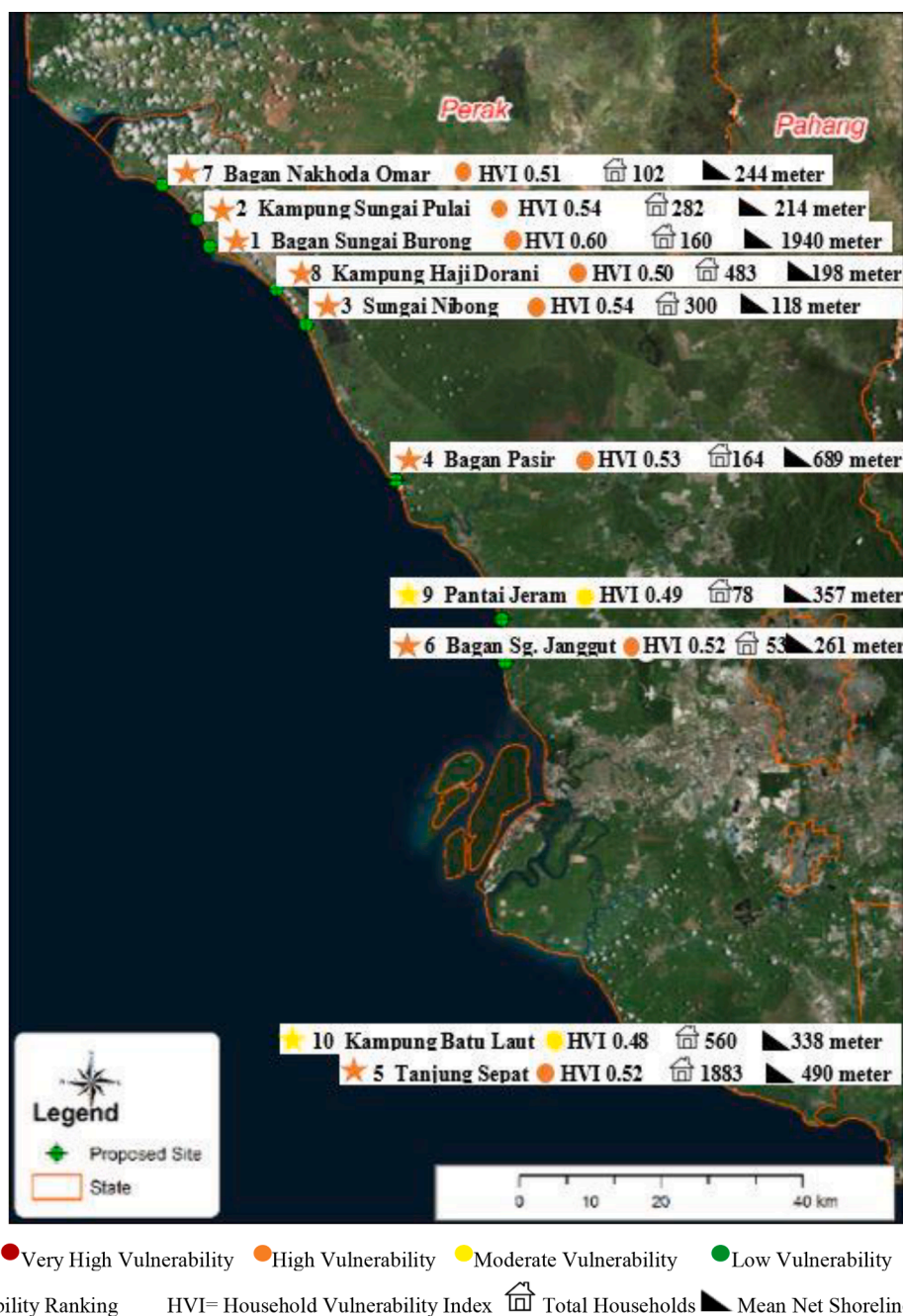


Fig. 14. Household vulnerability mapping at Selangor coastal areas.

insurance among Selangor coastal households reflects that insurance is not a standard adaptation tool to climate change. Coastal households' limited financial capacity and low-risk perception towards climate change could deter the insurance purchase. This subjective risk perception and income level are also identified in other studies in Malaysia as discriminating factors for flood insurance for properties and buildings (Aliagha et al., 2014) and agricultural insurance for disaster risk reduction (Alam et al., 2020).

Moreover, in the aftermath of the inundation due to sea-level rise, households with a lack of high educational attainment would face difficulty finding employment; a low employment rate is one of the significant barriers in post-recovery of disasters (Rouhani-zadeh et al., 2020). These features act as a vicious cycle of vulnerable households being more sensitive and less adaptive in the face of changing climate. The lack of social, human, natural and financial resources also points towards the challenges to their sustainability. By strengthening coping strategies by managing critical resources and promoting social equity, communities are less likely to be critically damaged by extreme events and increase social sustainability (Pandey et al., 2017).

Overall, about 84% of all sampled households reflected high vulnerability, and 16% reflected moderate vulnerability. The findings of the estimated indices are demonstrated in Fig. 13. Eight coastal areas in Selangor are highly vulnerable to climate change. The high vulnerability of Malaysian households to climate change in the context of fishers, farmers and flood are also reflected in earlier studies of Shaffril (2018), Alam et al. (2019) and Ashikin et al. (2021), respectively. The comparison of the indices reflects that households' adaptive capacity is far less than their exposure and sensitivity, which resulted in a higher vulnerability of the households in the Selangor coastal areas. Bagan Sungai Burong is ranked as the most vulnerable area with the highest exposure and sensitivity and least adaptive capacity index values compared to other places. This area is also experiencing the most increased mean net shoreline movement (1,940 m), as Maulud and Selamat (2018) reported. On the other hand, households in Kampung Batu Laut and Pantai Jeram are moderately vulnerable. The variation in vulnerability index values indicates the different degrees of vulnerability in Selangor coastal areas to climate change. The non-parametric Kruskal-Wallis test ($p < 0.05$) for vulnerability ranking confirms the statistically significant vulnerability differences between these coastal areas due to the local conditions, socio-economic characteristics, and capacities, as discussed in earlier sections. Fig. 14 illustrates household vulnerability mapping at Selangor coastal areas.

Vulnerability assessment, disaster risk reduction and climate change adaptation are strongly linked to a strategic planning challenge for coastal communities (Sinay and Carter, 2020). In light of the household vulnerability to climate change, proactive adaptation is an urgent priority (Tang, 2019). Bottom-up approaches such as community-based adaptation that adequately addresses the needs of vulnerable populations and involve the community in design and implementation can be a viable option to empower communities to take action on climate change and build resilience (Clarke et al., 2019). The findings of this study provide the ground research for articulating the needed local proactive adaptation measures to offset the exposure and sensitivity and enhance the adaptive capacity for the vulnerable coastal communities in Malaysia. In summary, the vulnerability assessment described here shows that the indicator set provides an intuitive view, facilitating local authority and government to easily delineate those areas with the highest vulnerability and in greatest need of investment.

In the sparsely populated rural coasts, safeguarding communities by conserving coastal ecosystems and natural morphodynamic processes, and restoring those already degraded, is the central element of an integrated strategy (Roy et al., 2018). Nature-based coastal protection strategies can be more cost-effective (Reguero et al., 2018), use up less raw materials, increase system adaptability and present opportunities to improve ecosystem functioning (Nat et al., 2016). As the households are natural resource-dependent, protection of coastal ecosystems such as mangrove, wetlands protection (Chow, 2018; Wang et al., 2016); habitat enhancement by re-vegetation of coastal dunes, assisting salt-marsh, and sea-grasses growth are necessary to increase biodiversity and maintain habitat for fish and aquaculture (NCCARF, 2016). Hard engineered structural protection measures should be used cautiously due to the adverse effects that these structures may have on morphological, hydrodynamic and ecological conditions (Schoonees et al., 2019). For instance, protecting structural adaptation measures that reduce the risk of coastal hazards by decreasing its probability of occurrences (Klein et al., 1999), such as sea wall/ storm surge barriers and artificial breakwaters/reefs to reduce wave erosion (Minano et al., 2018; Lane et al., 2017) can be reinforced only to protect the highly vulnerable areas with high erosion rates such as Bagan Sungai Burong, Bagan Pasir and Tanjung Sepat. Hard coastal protection can lead to flooding or erosion elsewhere (Roy et al., 2018). Combining nature-based design concepts on the main structures can be the most promising way to maintain high safety standards (Nat et al., 2016). Similarly, accommodating adaptation measures that increase society's ability to cope with the effects of climate change (Klein et al., 1999) for fragile housing structures in the highly vulnerable coastal areas such as house elevation/ strengthening construction; efficient drainage; use of water-resistant materials; and elevating cabinets for asset storage (Wardekker et al., 2010; Hino et al., 2017), hazard mapping and warning systems (Kelman and Glantz, 2014) can reduce the economic loss of property and asset damage.

On the other hand, retreat is worth considering now where coastal population size and density is low, risks are already high, and the economic, cultural and socio-political impacts of retreat and resettlement are carefully considered and addressed by at-risk communities and their governing authorities (Roy et al. 2018).

Improved participatory approaches are increasingly framed as integral to the successful and sustainable management of coastal resources (Mckinley et al., 2021). For instance, community education and public awareness shape the knowledge, abilities and skills that can influence risk perception and adaptive behaviour, essential for disaster preparedness and recovery (Hoffmann and Blecha, 2020). Community engagement and participation (Taylor et al., 2013) can strengthen local adaptation programs' social linkage and efficiency. In addition, national education effort, indigenous knowledge, and enhanced information sharing can build resilience and reduce maladaptation risks (Roy et al., 2018).

Climate change and climate variability worsen existing poverty and exacerbate inequalities, and the poor will continue to experience climate change severely, and climate change will exacerbate poverty (Oppenheimer et al. 2019). Professional skill enhancement and ensuring educational attainment (Garner and Keller, 2018; Bradley et al., 2015) are necessary to reduce the poverty rate, create income diversity and new opportunities. Ending poverty is often a highly effective form of climate adaptation (Hallegatte and Rozenberg, 2017) and its positive outcome as an adaptation strategy depends on whether increased household wealth is directed towards risk reduction and management strategies (Nelson et al., 2010) and whether finance for adaptation is made available (Roy et al. 2018). Therefore, insurance availability at affordable premiums and its promotion by educating about impacts can provide financial incentives during recovery (Thomas and Leichenko, 2011). In addition, financial incentives to secure properties (Sidle et al., 2017) can help low-income groups bear the expense of reconstructing vulnerable houses.

In addition to the accessibility to financial incentives and poverty reduction, low adaptive capacity can be enhanced through several other ways. For instance, the indigenous Munda community in Bangladesh, who were more vulnerable to hazard shocks and severely affected by the more significant financial, settlement, and physical damage, showed a comparatively better ability to respond to, cope with, and recover from shock than the wealthier due to their hard work and livelihood-seeking behaviours and their on-going

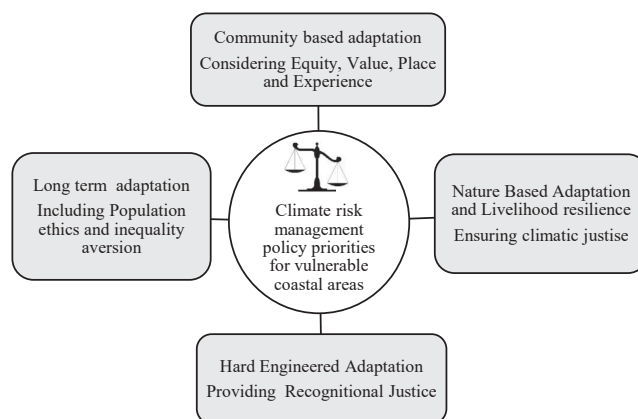


Fig. 15. Ethical considerations in designing effective climate policies for vulnerable coastal areas.

survival in the periods of before and after cyclone Alia (Roy, 2018). Therefore, mobility in livelihood resilience should also be encouraged to increase the adaptive capacity of vulnerable households.

Moreover, providing children centric incentives, involving children in the design of policy, and designing climate change policies with children's rights in mind, are essential to reduce the adverse impact of climate change on the young population (Vaghri, 2018).

Effective adaptation measures are usually selected based on their economic efficiency from quantifying the associated tangible costs and benefits of the adaptation. However, managing the climate risk in the highly vulnerable sparsely populated and underdeveloped rural coastal areas critically brings several ethical concerns. Designing climate policies to build resilience for low-income households living close to shore, heavily dependent on natural resources and inadequate adaptive capacities, can be far more complex and arguably more important than urban settlements. Contrary to the top-down approach that does not demonstrate the local interaction and adaptability, vulnerability assessment at the household level can help adaptation and community involvement based on the diversified needs of the society (Huynh et al., 2020). Based on the findings of the exposure, sensitivity and adaptive capacity indicators, which reflected the existing local socio-economic conditions, income and livelihood impacts, and critical available assets, the household vulnerability assessment poses considerations of equity and justice, cultural and societal values in the context of climate change. Fig. 15 highlights the ethical considerations in designing effective climate policies for vulnerable coastal areas.

Child-centred climate policy and long-term adaptation measures are adequately needed to manage the climate risk for the vulnerable coastal areas that reflect high sensitivity due to a large number of young population. Since climate change entails a risk of extinction of the human population, it also points to the need to discuss population ethics that assesses the value of population size for social welfare and distribution of well-being across individuals belonging to different generations in the context of climate change. Méjean et al. (2020) showed that accounting for the risk of human extinction due to climate change alters the expected cost-benefit analysis results. Putting a more significant weight on population size and low inequality aversion warrants tighter climate policy and gives more considerable importance to the welfare of future generations (Scovronick et al., 2017; Méjean et al., 2020). Therefore, findings indicate that long term climate policies and efficient adaptation planning must incorporate the issues of population ethics and inequality aversion in the context of climate change.

Study findings revealed the vicious cycle of income inequalities, dilapidated housing structures, lack of educational attainment and inadequate financial capacities of the vulnerable coastal communities. The burdens of climate change fall disproportionately on the poorest communities, who have contributed least to the problem of global warming, are affected most severely by its adverse effects, and raise serious concerns about equity and climate justice (IPCC, 2014a; Shue, 2014; Gordijn and ten Have, 2012). As poor people face a double burden of inequality — from uneven development and climate change, there is an increasing need for equitable adaptation from a moral point of view, improving economic productivity, social cohesion, health and peace. Therefore, community-based adaptation must directly meet the poorest' needs, putting them at the centre of decision-making with funding (Pelling and Garschagen, 2019). Flegal and Gupta (2018) suggested that equity should be treated as empirical matters in the cost-benefit frame, requiring scientific assessment of feasibility, risks, distributive outcomes, and optimisations. An equitable partnership between the scientists, locals and funding authorities to co-produce knowledge, such as mapping risks in informal settlements or harnessing local ecological expertise to fine-tune climate forecasts, can be a helpful tool for effective climate risk management policies in the poor-rural settings to tackle poverty and inequality (Roy et al., 2018). Prioritising adaptation financing based on equitable partnerships and inequality concerns in the climate policies is also an essential requirement to manage vulnerable in this kind of rural setting (Pelling and Garschagen, 2019; Kuruppu and Willie, 2015; Popke et al., 2016). In addition, mobilisation of climate finance, carbon taxation and environmentally motivated subsidies can reduce inequalities, advance climate mitigation and adaptation (Chancel and Picketty, 2015), and be conducive to strengthening and enabling environments for resilience building (Nhamo, 2017; Halonen et al., 2017).

The differences in the risk perception at the household level vulnerable assessment point to the need of incorporating the richness of local voices and experiences. External stressors, including environmental and climatic changes, can threaten not only a place but also the experiences, daily practices, identities, and social relationships bound up with those places, potentially resulting in stress, loss,

grief, hopelessness, and alienation, ultimately affecting health and well-being. Policy progress is measured primarily on averages and aggregates and can quickly fail to capture these needs and realities of the most vulnerable (Pelling and Garschagen, 2019). Therefore, community-based adaptation must be value, place and experience-based to ensure equity and justice. This is an emerging issue that challenges climate science and adaptation policy to engage more deeply by learning about the loss of climate change through values, place and experience perspective and a relational framing of trade-off by expanding on particular aspects of a relational theory of risk and examining more closely the dynamics underlying people's prioritisation of what they consider at stake and worth protecting (Tschakert et al. 2017). Pursuing place-specific adaptation pathways towards a warmer world has the potential for significant positive outcomes for well-being at all levels of development (Oppenheimer et al., 2019). Care-based approaches to ethics and politics that demand the ability to appreciate who people are, where they are coming from, and what they are saying about their situation and pay heed to the distribution of power and vulnerability within any network of relationships should be a central part of community-based adaptation measures (Preston and Carr, 2018).

Recognition justice is fundamental in choosing hard engineered adaptation measures to protect highly vulnerable rural areas. Suarez et al. (2018) argued a moral imperative to facilitate involving the most vulnerable in decision-making about climate engineering. For instance, Preston and Carr (2018) found that a large majority of interviewees in Kenya, the Solomon Islands, and the North American Arctic did not prefer climate engineering as an adaptation response and argued that given the existing inequities in climate change, any proposed climate engineering strategy to solve the climate problem must meet a high threshold for justice by recognising the importance of environmental heritage and community identity and by paying attention to neglected considerations such as relationships, context, power, vulnerability, narrative, and affect (amongst others).

There is also a need for a deeper assessment on the choice of nature-based adaptation measure based on its ability to offset the adverse impacts of climate change and consider the impacts of adaptation on the poorest and most vulnerable households. For instance, shrimp aquaculture, which is regarded as a technical solution to the social and ecological crisis of climate change, poses several risks exacerbating existing disparities in the communities as the benefits of commercial shrimp production are not shared among all members equally (Belton, 2016; Paprocki and Cons, 2014; Hossain et al., 2016; Paprocki and Cons, 2014). Paprocki and Huq (2018) argued that the value of possible adaptation strategies should be assessed about precisely this concern: their impact on existing socioeconomic disparities and benefits to the poorest and most vulnerable to ensure climate justice and attention to power imbalances, as opposed to technical solutions, can help provide more equitable outcomes of adaptation measures.

Therefore, designing and implementing an appropriate mix of adaptation responses for the most vulnerable rural communities is not only a technical task but also an inherently political and value-laden social choice that involves trade-offs between multiple values, goals and interests, which should be addressed through an integrated combination of well-established and emerging planning, public participation and conflict resolution practices, decision analysis methods to promote fair and just climate resilience and sustainable development (Oppenheimer et al. 2019).

4. Conclusion

Climate change impacts in coastal Malaysia are currently evidenced, and these changes are likely to intensify over time with the projected increase in sea level. This study identifies indicators influencing external vulnerability to climate change in critically eroded ten coastal areas in Selangor Coast based on household surveys. An integrative composite vulnerability index (VI) has been employed that includes theory-driven indicators of exposure index components (EI) such as households that are directly affected by coastal hazards, sensitivity index components (SI) such as demographic, socio-economic and structural characteristics of the households and adaptive capacity index components (ACI) such as the households' social, human, natural, financial, physical capital and adaptive behaviours. These indices help identify the critical features of household vulnerability in different coastal areas. Incorporating local context in several steps of the methodology such as selecting the study areas based on physical vulnerability, considering community experience in the selection of indicators, verification of questionnaire with local experts working in the field of climate change, use of solely primary data from the household survey, and vulnerability mapping of the coastal areas fill the research gap of needed regional vulnerability analysis from the household perspective. It eases the pathway for proactive adaptation planning. The approach adopted in this study ensure compatibility with future studies and can be argued that a simple integrative method by developing indices for coastal areas can be a practical option for assessing vulnerability that can be refined and applied as part of a larger-scale study. The framework of household vulnerability is highly relevant and applicable to other low-lying coastal areas within national and international settings, and the simplistic use of primary data opens up a range of possibilities to assess vulnerabilities due to climate change in scarce data regions such as in low and middle-income countries. It also provides a methodological starting point as a community-based or 'bottom-up' approach that can be embraced to address vulnerability under different scenarios such as social and livelihood vulnerability of a community through the modification of exposure, sensitivity and adaptive capacity indices.

Using the composite index, the findings indicate that eight of the ten study areas in Selangor are highly vulnerable to climate change. The households are highly exposed to shoreline erosion, demographically sensitive due to young population, minorities and unavailability of health insurance, socio-economically sensitive in terms of low income, dependency of natural resource income, structurally sensitive due to vulnerable and poor housing structure, low adaptive capacity due to lack of financial capital, natural assets, social network and low education attainment and adaptive behaviour. On the other hand, physical capital such as ownership of communication gadgets and transportation provides assets to pursue climate change adaptation. The high exposure and sensitivity and low adaptive capacity make the households vulnerable facing the changing climate. Thus, climate risk management policies in Malaysia is imperative and should develop a feasible climate-resilient local adaptation pathway of linked strategies that include cost-effective and equitable adaptation measures to accomplish the common sustainable development goals in coastal areas. Importantly,

this indicates that a combination of community-based adaptation, hard engineered and nature-based adaptation policies will be more appropriate since a particular adaptation option will not necessarily fit all coastal areas in the West Coast of Malaysia due to the differences in household's exposure, demographic, socio-economic, structural characteristics and adaptive capacities. Community-based adaptation initiatives whereby adaptation is locally-led, and communities drive their agendas based on the needs of the vulnerable population can strengthen the diverse capabilities of communities, can be helpful to achieve local objectives equitably, and effectively promote long-term adaptive capacity. In addition, ethical considerations of equity and justice, cultural and societal values in developing climate risk management policies for the sparsely populated rural coastal areas are mandatory to build community resilience against changing climate.

The findings provide decision-makers and concerned authorities with a meaningful tool to identify and prioritise certain vulnerable areas and actions to reduce the existing climate change vulnerabilities in the West Coast, Malaysia, in a methodologically defensive way. It can contribute significantly to developing the National Adaptation Policy and other programs related to sustainable coastal townships to make the communities more resilient to climate change. Findings can also be used for decision scaling by linking bottom-up vulnerability with climate projection to build domestic support for future climate treaties, empower citizens, and motivate leaders to take action. Even though climate change impacts are not evenly distributed across the regions, the findings of the high vulnerability of the sparsely populated rural coastal communities to climate change in an upper-middle-income country like Malaysia reflects the inherent susceptibilities of human-environment systems exposed to climate change and presents the arguments of equitable adaptation, which can be learning tools for different communities. Imminent studies should extend vulnerability assessment on future climate scenarios incorporating sustainable livelihood framework and institutional and governance capacity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A1
Development of Measuring Indicators for Households Vulnerability.

Exposure	Household vulnerability components	Measuring indicators of household vulnerability	Relevant Reference
	Nature of exposure to climate change consists of households that are directly affected by climate-related hazards in the coastal areas	Indicators 1: Percentage of households directly affected by drought in the last 5 years	Nguyen et al. (2017)
		Indicators 2: Percentage of households directly affected by storm surge in the last 5 years	
		Indicators 3: Percentage of households directly affected by shoreline erosion in the last 5 years	Adapted from Nguyen et al. (2017) ; Martins and Gasalla (2020)
	Impacts due to exposure to climate change consist of households that are directly impacted in various dimensions by climate-related hazards	Indicators 4: Percentage of households directly affected by coastal flooding in the last 5 years	Nguyen et al. (2017)
		Indicator 5: Percentage of households directly affected by loss of income	Adapted from Ashikin et al. (2021) ; Kuhlicke et al. (2011)
		Indicator 6: Percentage of households affected by physical damage to properties	Adapted from Ashikin et al. (2021) ; Kuhlicke et al. (2011) ; Majid et al. (2019) ; Diana et al. (2019)
		Indicator 7: Percentage of households affected by physical damage to assets	
	Risk perception includes perception of degree of damage by climate change	Indicator 8: Percentage of households impacted by breakdown of road/bridge	Adapted from Kuhlicke et al. (2011)
		Indicator 9: Percentage of households perceived current damages caused by climate change are serious	Adapted from Martins and Gasalla (2020)
		Indicator 10: Percentage of households perceived future damage by climate change as serious	
Sensitivity	Demographic perspectives include e.g. elderly, young, female as head, level of education of	Indicator 1: Percentage of households with at least 1 person over 60 years old	Nguyen et al. (2017)

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Table A1 (continued)

head, family composition, immigrant, race, language barriers, insurance coverage subcomponents	Indicator 2: Percentage of households with at least 1 person under 15 years old Indicator 3: Percentage of households with females as head	Adapted from Nguyen et al. (2017); Ashikin et al. (2021); Majid et al. (2019); Diana et al. (2019); Hahn et al. (2009); Adu et al. (2018); Madhuri et al. (2015); Panthi et al. (2016)
	Indicator 4: Percentage of households with a head of the households did not attend any formal education	Adapted from Nguyen et al (2017); Ashikin et al (2021); Majid et al (2019); Diana et al (2019); Hahn et al (2009); Adu et al (2018); Madhuri et al. (2015); Panthi et al (2016)
	Indicator 5: Percentage of households with more than 5 members	Adapted from Kuhlicke et al. (2011)
	Indicator 6: Percentage of households moved to current location from another area in the last 5 years	Nguyen et al. (2017)
	Indicator 7: Percentage of households belonging to minority	Adapted from Brechwald et al. (2015); Carvalhaes and Omitaomu (2017); Cooley et al. (2012)
	Indicator 8: Percentage of households without a member speaking the official and national language	Adapted from Brechwald et al. (2015); Carvalhaes and Omitaomu (2017); Cooley et al. (2012)
	Indicator 9: Percentage of households without a health insurance	Cooley et al. (2012)
	Indicator 10: Percentage of households with the head being unemployed	Adapted from Kuhlicke et al. (2011); Carvalhaes and Omitaomu (2017)
Socio-economic perspectives consist of non-employment, low monthly household income, natural resource dependence, less income diversity *Income range and category is defined by the Department of Statistics, Malaysia (2019)	Indicator 11: Percentage of households with low income (*monthly gross household income less than RM4,850, which is the bottom 40% income category in Malaysia known as B40)	Adapted from Nguyen et al (2017); Ashikin et al. (2021); Majid et al. (2019); Diana et al. (2019); Carvalhaes and Omitaomu (2017)
	Indicator 12: Percentage of households with very low income (*monthly gross household income less than RM2,499, which is the lowest income category in Malaysia known as B1)	This study
	Indicator 13: Percentage of households living below poverty line (*monthly gross household income less than RM2,022, which is the average poverty line income for Selangor)	Adapted from Nguyen et al. (2017); Ashikin et al. (2021); Majid et al. (2019); Diana et al. (2019); Carvalhaes and Omitaomu (2017)
	Indicator 14: Percentage of households depending on agriculture as their primary source of income	Adapted from Nguyen et al. (2017); Ashikin et al. (2021); Majid et al. (2019); Diana et al. (2019); Hahn et al. (2009); Adu et al. (2018); Madhuri et al. (2015); Nong et al. (2020)
	Indicator 15: Percentage of households depending on aquaculture as their primary source of income	Nguyen et al. (2017)
	Indicator 16: Percentage of households dependent on one income source	Adapted from Abdul-Razak and Kruse (2017)
	Indicator 17: Percentage of households dependent on single earning member	This study
	Indicator 18: Percentage of households with more than 5 family members dependent on one income of a single earning member	This study
	Indicator 19: Percentage of households living proximity to the coastline (within 500 m)	This study
Structural perspectives relate to the vulnerable location and housing structure and lack of household facilities	Indicator 20: Percentage of households that do not have access to telecommunication services	Adapted from Ashikin et al. (2021); Panthi et al. (2016)
	Indicator 21: Percentage of households without any vehicle	Adapted from Brechwald et al. (2015); Brodie et al. (2006)
	Indicator 22: Percentage of households living in houses made of vulnerable structures (wood/semi-wood)	Adapted from Ashikin et al. (2021); Diana et al. (2019); Panthi et al. (2016)
	Indicator 23: Percentage of households living in dilapidated houses	This study
	Indicator 24: Percentage of households living in houses not built above the ground to deter flooding	Adapted from Ashikin et al. (2021); Diana et al. (2019); Panthi et al. (2016)
	Indicator 25: Percentage of households without any consistent water supply	Adapted from Nguyen et al. (2017)
	Indicator 26: Percentage of households renting the house	Adapted from Kuhlicke et al. (2011); Brechwald et al. (2015); Cooley et al. (2012)

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Table A1 (continued)

Adaptive Capacity	Social capital includes social network	Indicator 1: Percentage of households involved in any climate-related community-based organisation	Adapted from Nguyen et al.(2017); Martins and Gasalla (2020); Abdul-Razak and Kruse (2017)
	Human capital includes occupation, education and health insurance	Indicator 2: Occupation: Percentage of households with at least one person working in government offices Indicator 3: Education: Percentage of households with at least one member attained high school certificate or higher Indicator 4: Percentage of households with health insurance coverage	Nguyen et al. (2017) Adapted from Nguyen et al. (2017); Brechwald et al. (2015); Huynh and Stringer (2018); Abdul-Razak and Kruse (2017) Adapted from Martins and Gasalla (2020)
	Natural capital includes natural resource stock	Indicator 5: Percentage of households with own productive agricultural land	Adapted from Huynh and Stringer (2018)
	Financial capital includes financial assets	Indicator 6: Percentage of households with building insurance coverage Indicator 7: Percentage of households with fishing insurance coverage Indicator 8: Percentage of households with agriculture insurance coverage Indicator 9: Percentage of households with high income (*monthly income equal or more than Selangor's median income RM 8,210) Indicator 10: Percentage of households with more than one income source	Adapted from Martins and Gasalla (2020) Adapted from Martins and Gasalla (2020) Adapted from Martins and Gasalla (2020); Huynh and Stringer (2018) Nguyen et al. (2017) Nguyen et al. (2017)
	Physical capital includes factors of production, e.g. machinery, building, equipment	Indicator 11: Percentage of households with own residential housing tenure Indicator 12: Percentage of households that own telecommunication services, e.g. TV/radio/ internet/ telephone Indicator 13: Percentage of households with own transportation (car/lorry/motorcycle) Indicator 14: Percentage of households living in houses high above 3 feet that can prevent water Indicator 15: Percentage of households living in houses made of solid structure (brick and plaster) Indicator 16: Percentage of households living in houses less than 10 years old Indicator 17: Percentage of households living in houses in good housing conditions	Adapted from Martins and Gasalla (2020); Huynh and Stringer (2018) Huynh and Stringer (2018) Brodie et al. (2006) Adapted from Huynh and Stringer (2018) Nguyen et al. (2017) Adapted from Huynh and Stringer (2018) Adapted from Martins and Gasalla (2020); Huynh and Stringer (2018)
	Adaptive behaviour includes potential adaptation in the context of disaster preparedness	Indicator 18: Percentage of households with available waterproofing materials Indicator 19: Percentage of households with other available measures to protect the house Indicator 20: Percentage of households familiar with community adaptation Indicator 21: Percentage of households familiar with disaster map Indicator 22: Percentage of households familiar with the evacuation procedure Indicator 23: Percentage of households familiar with normal water levels and weather forecasts	This study This study This study This study This study This study

References

- Abdul-Razak, M., Kruse, S., 2017. The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. *Clim. Risk Manag.* 17, 104–122. <https://doi.org/10.1016/j.crm.2017.06.001>.
- Adger, W.N., Agarwala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., Takahashi, K., 2007. Assessment of adaptation practices, option, constraints and capacity, in: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden P.J., Hanson C.E. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, pp. 717–743. doi:10.1007/978-1-349-02250-2_5.
- Adu, D.T., Kuwornu, J.K.M., Anim-Somuah, H., Sasaki, N., 2018. Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana. *Kasetsart J. Soc. Sci.* 39 (1), 22–32. <https://doi.org/10.1016/j.kjss.2017.06.009>.
- Ahmad, H., Abdul Maulud, K.N., Karim, O.A., Mohd, F.A., 2021. Assessment of erosion and hazard in the coastal areas of Selangor. *Malaysian J. Soc. Sp.* 17 (1) <https://doi.org/10.17576/geo-2021-1701-02>.
- Ahsan, M.N., Warner, J., 2014. The socio-economic vulnerability index: a pragmatic approach for assessing climate change led risks—a case study in the south-western coastal Bangladesh. *Int. J. Disaster Risk Reduct.* 8, 32–49. <https://doi.org/10.1016/j.ijdrr.2013.12.009>.
- Aksha, S.K., Resler, L.M., Juran, L., Carstensen, L.W., 2020. A geospatial analysis of multi-hazard risk in Dharan, Nepal. *Geomatics. Nat. Hazards Risk* 11 (1), 88–111. <https://doi.org/10.1080/19475705.2019.1710580>.
- Alam, A.S.A.F., Begum, H., Masud, M.M., Al-Amin, A.Q., Filho, W.L., 2020. Agriculture insurance for disaster risk reduction: a case study of Malaysia. *Int. J. Disaster Risk Reduct.* 47, 101626. <https://doi.org/10.1016/j.ijdrr.2020.101626>.
- Alam, M., Siwar, C., Murad, W., Toriman, M.E., 2019. Impacts of Climate Change on Agriculture and Food Security Issues in Malaysia: an Empirical Study on Farm Level. *Assessment* 14, 431–442. <https://doi.org/10.31219/osf.io/mdqpz>.

- Alam, M.M., Toriman, M.E., Siwar, C., Talib, B., 2011. Rainfall variation and changing pattern of agricultural cycle. *Am. J. Environ. Sci.* 7, 82–89. <https://doi.org/10.3844/ajessp.2011.82.89>.
- Alam, M.M., Siwar, C., Talib, B., Toriman, M.E., 2014. Impacts of climatic changes on paddy production in Malaysia: micro study on IADA at North West Selangor. *Res. J. Environ. Earth Sci.* 6, 251–258. <https://doi.org/10.19026/rjees.6.5767>.
- Aliagha, U.G., Jin, T.E., Choong, W.W., Jaafar, N.M., Ali, H.M., 2014. Factors affecting flood insurance purchase in residential properties in Johor, Malaysia. *Nat. Hazards Earth Syst. Sci.* 14, 3297–3310. <https://doi.org/10.5194/nhess-14-3297-2014>.
- Amin, M.Z.M., Shaaban, A.J., Ercan, A., Ishida, K., Kavvas, M.L., Chen, Z.Q., Jang, S., 2017. Future climate change impact assessment of watershed scale hydrologic processes in Peninsular Malaysia by a regional climate model coupled with a physically-based hydrology models. *Sci. Total Environ.* 575, 12–22. <https://doi.org/10.1016/j.scitotenv.2016.10.009>.
- Ankrah, J., 2018. Climate change impacts and coastal livelihoods; an analysis of fishers of coastal Winneba. Ghana. *Ocean Coast. Manag.* 161, 141–146. <https://doi.org/10.1016/j.ocecoaman.2018.04.029>.
- Ashikin, N.A., Diana, N.M.I., Siwar, C., Alam, M.M., Yasar, M., 2021. Community preparation and vulnerability indices for floods in the Pahang State of Malaysia. *Land* 10, 198. <https://doi.org/10.3390/land10020198>.
- Asmawi, M.Z., Ibrahim, A.N., 2013. The perception of community on coastal erosion issue in Selangor, Malaysia. *J. Clean Energy Technol.* 1, 164–168. <https://doi.org/10.7763/jocet.2013.v1.38>.
- Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., 2018. Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. *FAO Fisheries and Aquaculture Technical Paper No. 627*. Rome. 628 pp <http://www.fao.org/3/i9705en/i9705en.pdf>.
- Barua, U., Mannan, S., Islam, I., Akther, M.S., Islam, M.A., Akter, T., Ahsan, R., Ansary, M.A., 2020. People's awareness, knowledge and perception influencing earthquake vulnerability of a community: a study on Ward no. 14, Mymensingh Municipality, Bangladesh. *Nat. Hazards* 103 (1), 1121–1181. <https://doi.org/10.1007/s11069-020-04028-2>.
- Becker, W., Saisana, M., Paruolo, P., Vandecasteele, I., 2017. Weights and importance in composite indicators: closing the gap. *Ecol. Indic.* 80, 12–22. <https://doi.org/10.1016/j.ecolind.2017.03.056>.
- Belton, B., 2016. Shrimp, prawn and the political economy of social wellbeing in rural Bangladesh. *J. Rural Stud.* 45, 230–242. <https://doi.org/10.1016/j.jrurstud.2016.03.014>.
- Bethel, J.W., Burke, S.C., Britt, A.F., 2013. Disparity in disaster preparedness between racial/ ethnic groups. *Disaster Heal.* 1 (2), 110–116. <https://doi.org/10.4161/dish.27085>.
- Bollettino, V., Alcayna-Stevens, T., Sharma, M., Dy, P., Pham, P., Vinck, P., 2020. Public perception of climate change and disaster preparedness: evidence from the Philippines. *Clim. Risk Manag.* 30, 100250. <https://doi.org/10.1016/j.crm.2020.100250>.
- Bove, G., Becker, A., Sweeney, B., Voudoukas, M., Kulp, S., 2020. A method for regional estimation of climate change exposure of coastal infrastructure: case of USVI and the influence of digital elevation models on assessments. *Sci. Total Environ.* 710, 136162. <https://doi.org/10.1016/j.scitotenv.2019.136162>.
- Bradley, M., van Putten, I., Sheaves, M., 2015. The pace and progress of adaptation: marine climate change preparedness in Australia's coastal communities. *Mar. Policy* 53, 13–20. <https://doi.org/10.1016/j.marpol.2014.11.004>.
- Brechwald, D., Planner, R., Lowe, L., Planner, S., 2015. *Housing and Community Risk Multiple Hazard Risk Assessment*. Association of Bay Area Government, Oakland.
- Brodie, M., Weltzien, E., Altman, D., Blendon, R.J., Benson, J.M., 2006. Experiences of Hurricane Katrina evacuees in Houston shelters: implications for future planning. *Am. J. Public Health* 96 (8), 1402–1408. <https://doi.org/10.2105/AJPH.2005.084475>.
- Brooks, N., Neil Adger, W., Mick Kelly, P., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Glob. Environ. Chang.* 15 (2), 151–163. <https://doi.org/10.1016/j.gloenvcha.2004.12.006>.
- Carvalhoes, T., Omitaomu, O., 2017. *Developing a Climate-Induced Social Vulnerability Index for Urban Areas: A Case Study of East Tennessee*. Oak Ridge National Laboratory, Oak Ridge.
- Chancel, L., Picketty, T., 2015. *Carbon and Inequality: from Kyoto to Paris. Trends in the Global Inequality of Carbon Emissions (1998–2013) & Prospects for an Equitable Adaptation Fund*. Paris School of Economics, Paris, France, p. 50.
- Cheo, S.K., Salleh, E., Herminatalia, T., 2017. *Climate Change Vulnerability Assessment of Lahad Datu's Coastline in Sabah*. WWF-Malaysia, Petaling Jaya.
- Chow, J., 2018. Mangrove management for climate change adaptation and sustainable development in coastal zones. *J. Sustain. For.* 37 (2), 139–156. <https://doi.org/10.1080/10549811.2017.1339615>.
- Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S., Hicks, C.C., Hughes, T.P., Lau, J., Marshall, N.A., Morrison, T.H., 2018. Building adaptive capacity to climate change in tropical coastal communities. *Nat. Clim. Chang.* 8 (2), 117–123. <https://doi.org/10.1038/s41558-017-0065-x>.
- Clarke, T., McNamara, K.E., Clissold, R., Nunn, P.D., 2019. Community-based adaptation to climate change: lessons from Tanna Island, Vanuatu. *Isl. Stud. J.* 14, 59–80. <https://doi.org/10.24043/isj.80>.
- Cooley, H., Moore, E., Heberger, M., Allen, L., 2012. *Social Vulnerability to Climate Change in California*. Pacific Institute, Oakland.
- Das, M., Das, A., Momin, S., Pandey, R., 2020. Mapping the effect of climate change on community livelihood vulnerability in the riparian region of Gangetic Plain, India. *Ecol. Indic.* 119, 106815. <https://doi.org/10.1016/j.ecolind.2020.106815>.
- Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D., Yan, J., 2007. *The impact of sea-level rise on developing countries: A Comparative Analysis (No. WPS4136)*, World Bank Policy Research Working Paper. Washington, DC.
- Dastgerdi, A.S., Sargolini, M., Pierantoni, I., 2019. Climate change challenges to existing cultural heritage policy. *Sustain* 11, 5227. <https://doi.org/10.3390/su11195227>.
- Daud, S., Milow, P., Zakaria, R.M., 2021. Analysis of shoreline change trends and adaptation of Selangor Coastline, Using Landsat Satellite Data. *J. Indian Soc. Remote Sens.* 49 (8), 1869–1878.
- Daze, A., Ambrose, K., Erhart, C. *Climate Vulnerability and Capacity Analysis Handbook*. CARE International, Geneva.
- Department of Statistics Malaysia, 2019. *The Key Findings: Income, Poverty, Inequality, Expenditure, Basic Amenities*. https://www.dosm.gov.my/v1/index.php?r=column/tthemeByCat&cat=120&bul_id=U00TmRhQ1N5TUxHVWN0T2VjbXJYZz09&menu_id=amVoWU54UTI0a21NWmdhMjFMMWcyZz09 (accessed on 31 March 2021).
- Diana, N.M.I., Chamburi, S., Mohd Raihan, T., Nurul Ashikin, A., 2019. Assessing local vulnerability to climate change by using Livelihood Vulnerability Index: case study in Pahang region, Malaysia. *IOP Conf. Ser. Mater. Sci. Eng.* 506, 012059. <https://doi.org/10.1088/1757-899X/506/1/012059>.
- DOF (Department of Fisheries Malaysia), 2017. *Fishery Sector Performance and Achievements*, Putrajaya doi:10.1007/s12524-020-01218-0.
- Ehsan, S., Begum, R.A., Nor, N.G.M., Maulud, K.N.A., 2019. Current and potential impacts of sea-level rise in the coastal areas of Malaysia. *IOP Conf. Ser. Earth Environ. Sci.* 228, 012023. <https://doi.org/10.1088/1755-1315/228/1/012023>.
- Ellis, F., 2000. The determinants of rural livelihood diversification in developing countries. *J. Agric. Econ.* 51, 289–302. <https://doi.org/10.1111/j.1477-9552.2000.tb01229.x>.
- Engle, N.L., 2011. Adaptive capacity and its assessment. *Glob. Environ. Chang.* 21 (2), 647–656. <https://doi.org/10.1016/j.gloenvcha.2011.01.019>.
- Fahad, S., Jing, W., 2018. Evaluation of Pakistani farmers' willingness to pay for crop insurance using contingent valuation method: the case of Khyber Pakhtunkhwa province. *Land Use Policy* 72, 570–577. <https://doi.org/10.1016/j.landusepol.2017.12.024>.
- Fahad, S., Inayat, T., Wang, J., Dong, L.I., Hu, G., Khan, S., Khan, A., 2020. Farmers' awareness level and their perceptions of climate change: a case of Khyber Pakhtunkhwa Province, Pakistan. *Land Use Policy* 96, 104669. <https://doi.org/10.1016/j.landusepol.2020.104669>.
- Farrokhi, M., Khankeh, H.R., Amanat, N., Kamali, M., Fathi, M., 2020. Psychological aspects of climate change risk perception: A content analysis in the Iranian context. *J. Educ. Health Promot.* 9, 346. doi:10.4103/jehp.jehp.415.20.
- Fatorić, S., Seekamp, E., 2017. Are cultural heritage and resources threatened by climate change? A systematic literature review. *Clim. Change* 142 (1-2), 227–254. <https://doi.org/10.1007/s10584-017-1929-9>.

- Flegal, J.A., Gupta, A., 2018. Evoking equity as a rationale for solar geoengineering research? Scrutinizing emerging expert visions of equity. *Int. Environ. Agreements Polit. Law Econ.* 18 (1), 45–61. <https://doi.org/10.1007/s10784-017-9377-6>.
- Froehlich, H.E., Gentry, R.R., Halpern, B.S., 2018. Global change in marine aquaculture production potential under climate change. *Nat. Ecol. Evol.* 2 (11), 1745–1750. <https://doi.org/10.1038/s41559-018-0669-1>.
- Fung, K.F., Huang, Y.F., Koo, C.H., 2020. Spatiotemporal analysis of seasonal SPEI in Peninsular Malaysia. *IOP Conf. Ser. Earth Environ. Sci.* 476 (1), 012113. <https://doi.org/10.1088/1755-1315/476/1/012113>.
- Füssel, H.-M., 2007. Vulnerability: a generally applicable conceptual framework for climate change research. *Glob. Environ. Chang.* 17 (2), 155–167. <https://doi.org/10.1016/j.gloenvcha.2006.05.002>.
- Garner, G.G., Keller, K., 2018. Using direct policy search to identify robust strategies in adapting to uncertain sea-level rise and storm surge. *Environ. Model. Softw.* 107, 96–104. <https://doi.org/10.1016/j.envsoft.2018.05.006>.
- Giri, M., Bista, G., Singh, P.K., Pandey, R., 2021. Climate change vulnerability assessment of urban informal settlers in Nepal, a least developed country. *J. Clean. Prod.* 307, 127213. <https://doi.org/10.1016/j.jclepro.2021.127213>.
- Gordijn, B., ten Have, H., 2012. Ethics of mitigation, adaptation and geoengineering. *Med. Heal. Care Philos.* 15 (1), 1–2. <https://doi.org/10.1007/s11019-011-9374-4>.
- Government of Malaysia, 2018. Third National Communication and Second Biennial Update Report To the United Nations Framework Convention on Climate Change (NC3). Ministry Of Energy, Science, Technology, Environment And Climate Change, Putrajaya.
- Gupta, A.K., Negi, M., Nandy, S., Alatalo, J.M., Singh, V., Pandey, R., 2019. Assessing the vulnerability of socio-environmental systems to climate change along an altitude gradient in the Indian Himalayas. *Ecol. Indic.* 106, 105512. <https://doi.org/10.1016/j.ecolind.2019.105512>.
- Hahn, M.B., Riederer, A.M., Foster, S.O., 2009. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique. *Glob. Environ. Chang.* 19 (1), 74–88. <https://doi.org/10.1016/j.gloenvcha.2008.11.002>.
- Hallegratte, S., Rozenberg, J., 2017. Climate change through a poverty lens. *Nat. Clim. Chang.* 7 (4), 250–256. <https://doi.org/10.1038/nclimate3253>.
- Halonon, M., Julia, I., Markus, K., Henrik, S., 2017. Mobilizing climate finance flows: Nordic approaches and opportunities. *TemaNord* 2017:519, Nordic Council of Ministers, 151 pp. doi:10.6027/TN2017-519.
- Hamdan, R., Kari, F., Othman, A., 2015. Biophysical vulnerability impact assessment of climate change on aquaculture sector development in Sarawak, Malaysia. *DLSU Bus. Econ. Rev.* 24, 32–44.
- Handisyde, N., Telfer, T.C., Ross, L.G., 2017. Vulnerability of aquaculture-related livelihoods to changing climate at the global scale. *Fish Fish.* 18 (3), 466–488. <https://doi.org/10.1111/faf.12186>.
- Hashim, A.M., Noor, N.A.M., 2013. Performance evaluation of innovative concrete armor unit for coastal protection structure. *2013 IEEE Bus. Eng. Ind. Appl. Colloq.* 673–678.
- Hashim, H., Suhatri, M., Hashim, R., 2017. Assessment of liquefaction hazard along shoreline areas of Peninsular Malaysia. *Geomatics Nat. Hazards Risk* 8 (2), 1853–1868. <https://doi.org/10.1080/19475705.2017.1391882>.
- Hassan, M.I., Rahmat, N.H., 2016. The effect of coastline changes to local community's socioeconomic. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. XLII-4/W1*, 25–36. <https://doi.org/10.5194/isprs-archives-XLII-4-W1-25-2016>.
- He, Q., Silliman, B.R., 2019. Climate change, human impacts, and coastal ecosystems in the anthropocene. *Curr. Biol.* 29 (19), R1021–R1035. <https://doi.org/10.1016/j.cub.2019.08.042>.
- Hewitt, J.E., Ellis, J.I., Thrush, S.F., 2016. Multiple stressors, nonlinear effects and the implications of climate change impacts on marine coastal ecosystems. *Glob. Chang. Biol.* 22 (8), 2665–2675. <https://doi.org/10.1111/gcb.13176>.
- Hino, M., Field, C.B., Mach, K.J., 2017. Managed retreat as a response to natural hazard risk. *Nat. Clim. Chang.* 7 (5), 364–370. <https://doi.org/10.1038/nclimate3252>.
- Hoffmann, R., Blecha, D., 2020. Education and disaster vulnerability in Southeast Asia: evidence and policy implications. *Sustain.* 12, 1–17. <https://doi.org/10.3390/su12041401>.
- Hoque, M.Z., Cui, S., Xu, L., Islam, I., Tang, J., Ding, S., 2019. Assessing Agricultural Livelihood Vulnerability to Climate Change in Coastal Bangladesh. *Int. J. Environ. Res. Public Heal.* doi:10.3390/ijerph16224552.
- Hossain, M.S., Dearing, J.A., Rahman, M.M., Salehin, M., 2016. Recent changes in ecosystem services and human well-being in the Bangladesh coastal zone. *Reg. Environ. Chang.* 16 (2), 429–443. <https://doi.org/10.1007/s10113-014-0748-z>.
- Huong, N.T.L., Bo, Y.S., Fahad, S., 2019. Economic impact of climate change on agriculture using Ricardian approach: a case of northwest Vietnam. *J. Saudi Soc. Agric. Sci.* 18 (4), 449–457. <https://doi.org/10.1016/j.jssas.2018.02.006>.
- Huynh, H.L.T., Do, A.T., Dao, T.M., 2020. Climate change vulnerability assessment for Can Tho city by a set of indicators. *Int. J. Clim. Chang. Strateg. Manag.* 12 (1), 147–158. <https://doi.org/10.1108/IJCCSM-01-2018-0003>.
- Huynh, L.T.M., Stringer, L.C., 2018. Multi-scale assessment of social vulnerability to climate change: an empirical study in coastal Vietnam. *Clim. Risk Manag.* 20, 165–180. <https://doi.org/10.1016/j.crm.2018.02.003>.
- Ibrahim, A.Z., Siwar, C., 2017. *Kelestarian Penghidupan Petani Luar Bandar*. UUM Press, Sintok.
- IPCC, 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden P.J., Hanson C.E. (Eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
- IPCC (Intergovernmental Panel on Climate Change), 2014a. *Climate Change 2014: Synthesis Report*. In: Pachauri, R.K., Meyer, L.A. (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva.
- IPCC, 2014b. *Annex II: Glossary*. In: Mach, K.J., Planton, S., von Stechow, C. (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva.
- IPCC (Intergovernmental Panel on Climate Change), 2018. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. In: Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (Eds.). In Press.
- Jamaluddin, U.A., Yaakub, J., Suratman, S., Pereira, J.J., 2016. Threats faced by groundwater: a preliminary study in Kuala Selangor. *Bull. Geol. Soc. Malaysia* 62, 65–72.
- Jolis, G., Saleh, E., 2015. *Climate Change Vulnerability Assessment of Semporna Priority Conservation Area (PCA)*. WWF-Malaysia, Petaling Jaya.
- Jones, L., Ludi, E., Levine, S., 2010. *Towards a characterisation of adaptive capacity: a framework for analysing adaptive capacity at the local level*. Working paper. Overseas Dev. Inst.
- Kamal, A.H.M., 2016. A Decade in Climate Changes and Marine Fisheries: Assessing the Catchment Volume in Peninsular Malaysia, in: AGU Fall Meeting. American Geophysical Union, Washington, DC. 2016AGUFMGC11D1165K.
- Kelman, I., Glantz, M.H., 2014. Early Warning Systems Defined. *Reducing Disaster Early Warn. Syst. Clim. Chang.* 89–108. https://doi.org/10.1007/978-94-017-8598-3_5.
- Klein, R.J.T., Nicholls, R.J., Mimura, N., 1999. Coastal adaptation to climate change: can the IPCC technical guidelines be applied? *Mitig. Adapt. Strategy. Glob. Chang.* 4, 239–252. <https://doi.org/10.1023/A:1009681207419>.
- Kline, R.B., 2005. *Principles and Practice of Structural Equation Modelling*, second ed. Guilford, New York.
- Kuhlicke, C., Scolobig, A., Tapsell, S., Steinführer, A., De Marchi, B., 2011. Contextualizing social vulnerability: findings from case studies across Europe. *Nat. Hazards* 58 (2), 789–810. <https://doi.org/10.1007/s11069-011-9751-6>.
- Kuruppu, N., Willie, R., 2015. Barriers to reducing climate enhanced disaster risks in Least Developed Country-Small Islands through anticipatory adaptation. *Weather Clim. Extrem.* 7, 72–83. <https://doi.org/10.1016/j.wace.2014.06.001>.

- Lane, D., Beigzadeh, S., Moll, R., 2017. Adaptation decision support: an application of system dynamics modeling in coastal communities. *Int. J. Disaster Risk Sci.* 8 (4), 374–389. <https://doi.org/10.1007/s13753-017-0154-5>.
- Le, S.T., Vo, C.D., 2020. The livelihood adaptability of households under the impact of climate change in the Mekong Delta. *J. Agribus. Dev. Emerg. Econ.* 11, 7–26. doi:10.1108/JADEE-09-2019-0139.
- Li, M., Zhang, F., Barnes, S., Wang, X., 2020. Assessing storm surge impacts on coastal inundation due to climate change: case studies of Baltimore and Dorchester County in Maryland. *Nat. Hazards* 103 (2), 2561–2588. <https://doi.org/10.1007/s11069-020-04096-4>.
- Lu, Y., Yuan, J., Lu, X., Su, C., Zhang, Y., Wang, C., Cao, X., Li, Q., Su, J., Ittekkot, V., Garbutt, R.A., Bush, S., Fletcher, S., Wagey, T., Kachur, A., Sweijd, N., 2018. Major threats of pollution and climate change to global coastal ecosystems and enhanced management for sustainability. *Environ. Pollut.* 239, 670–680. <https://doi.org/10.1016/j.envpol.2018.04.016>.
- Lyons, M., 2009. Building back better: the large-scale impact of small-scale approaches to reconstruction. *World Dev.* 37 (2), 385–398. <https://doi.org/10.1016/j.worlddev.2008.01.006>.
- Madhuri, Tewari, H.R., Bhowmick, P.K., 2015. Livelihood vulnerability index analysis: An approach to study vulnerability in the context of Bihar. *Jamba J. Disaster Risk Stud.* 6, 1–13. doi:10.4102/jamba.v6i1.127.
- Majid, N.A., Nazi, N.M., Idris, N.D.M., Taha, M.R., 2019. GIS-based livelihood vulnerability index mapping of the socioeconomy of the Pekan community. *Sustain.* 11, 6935. <https://doi.org/10.3390/SU11246935>.
- Malherbe, W., Sauer, W., Aswani, S., 2020. Social capital reduces vulnerability in rural coastal communities of Solomon Islands. *Ocean Coast. Manag.* 191, 105186. <https://doi.org/10.1016/j.ocecoaman.2020.105186>.
- Martins, I.M., Gasalla, M.A., 2020. Adaptive capacity level shapes social vulnerability to climate change of fishing communities in the south Brazil Bight. *Front. Mar. Sci.* 7, 1–11. <https://doi.org/10.3389/fmars.2020.00481>.
- Maulud, K.N.A., Selamat, S.N., 2018. Impact on Coastal development due to the shoreline changes. National Seminar on Coastal Morphology (COSMO). National Hydraulic Research Institute of Malaysia (NAHRIM), Seri Kembangan.
- McKinley, E., Crowe, P.R., Stori, F., Ballinger, R., Brew, T.C., Blacklaw-Jones, L., Cameron-Smith, A., Crowley, S., Cocco, C., O'Mahony, C., McNally, B., Power, P., Foley, K., 2021. 'Going digital' - Lessons for future coastal community engagement and climate change adaptation. *Ocean Coast. Manag.* 208, 105629. <https://doi.org/10.1016/j.ocecoaman.2021.105629>.
- McNamara, K.E., Clissold, R., Westoby, R., Piggott-McKellar, A.E., Kumar, R., Clarke, T., Namoumou, F., Areki, F., Joseph, E., Warrick, O., Nunn, P.D., 2020. An assessment of community-based adaptation initiatives in the Pacific Islands. *Nat. Clim. Chang.* 10 (7), 628–639. <https://doi.org/10.1038/s41558-020-0813-1>.
- Méjean, A., Pottier, A., Fleurbaey, M., Zuber, S., 2020. Catastrophic climate change, population ethics and intergenerational equity. *Clim. Change* 163 (2), 873–890. <https://doi.org/10.1007/s10584-020-02899-9>.
- Menezes, J.A., Confalonieri, U., Madureira, A.P., Duval, I.D.B., Santos, R.B.D., Margonari, C., Mertens, F., 2018. Mapping human vulnerability to climate change in the Brazilian Amazon: the construction of a municipal vulnerability index. *PLoS One* 13 (2), e0190808. <https://doi.org/10.1371/journal.pone.0190808>.
- Mesfin, D., Simane, B., Belay, A., Recha, J.W., Schmiedel, U., 2020. Assessing the adaptive capacity of households to climate change in the central Rift valley of Ethiopia. *Climate.* 8, 106. <https://doi.org/10.3390/cli8100106>.
- Minano, A., Johnson, P.A., Wandel, J., 2018. Visualizing flood risk, enabling participation and supporting climate change adaptation using the Geoweb: the case of coastal communities in Nova Scotia, Canada. *GeoJournal* 83 (3), 413–425. <https://doi.org/10.1007/s10708-017-9777-8>.
- Mohamad, M.F., Lee, L.H., Samion, M.K.H., 2014. Coastal vulnerability assessment towards sustainable management of Peninsular Malaysia Coastline. *Int. J. Environ. Sci. Dev.* 5 (6), 533–538.
- Mohammad-pajooh, E., Aziz, K.A., 2014. Investigating factors for disaster preparedness among residents of Kuala Lumpur. *Nat. Hazards Earth Syst. Sci. Discuss.* 2, 3683–3709. <https://doi.org/10.5194/nhessd-2-3683-2014>.
- Mohd, F.A., Nizam Abdul Maulud, K., Karim, O.A., Ara Begum, R., Firoz Khan, M.D., Shafrina Wan Mohd Jaafar, W., Mastura Syed Abdullah, S., Ekhwan Toriman, M., Khairul Amri Kamarudin, M., Barzani Gasim, M., Abd Wahab, N., 2018. An assessment of coastal vulnerability of Pahang's coast due to sea-level rise. *Int. J. Eng. Technol.* 7 (3.14), 176. <https://doi.org/10.14419/ijet.v7i3.14.16880>.
- Morzaria-Luna, H.N., Turk-Boyer, P., Moreno-Baez, M., 2014. Social indicators of vulnerability for fishing communities in the Northern Gulf of California, Mexico: implications for climate change. *Mar. Policy* 45, 182–193. <https://doi.org/10.1016/j.marpol.2013.10.013>.
- Mullis, J.-P., Duval, T.S., Bovalino, K., 2000. Tornado preparedness of students, nonstudent renters, and nonstudent owners: issues of PrE Theory1. *J. Appl. Soc. Psychol.* 30 (6), 1310–1329. <https://doi.org/10.1111/j.1559-1816.2000.tb02522.x>.
- NAHRIM (National Water Research Institute of Malaysia), 2021. Climate Change Adaptation Framework for water sectors. Institut Penyelidikan Air Kebangsaan Malaysia, Seri Kembangan.
- Nat, V.D.A., Vellinga, P., Leemans, R., van Slobbe, E., 2016. Ranking coastal flood protection designs from engineered to nature-based. *Ecol. Eng.* 87, 80–90. <https://doi.org/10.1016/j.ecoleng.2015.11.007>.
- NCCARF, 2016. Adaptation options for coastal environments: Ecosystem management. CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.
- NCES, 2015. National Coastal Erosion Study. Department of Irrigation and Drainage Malaysia, Kuala Lumpur.
- Nelson, R., Kocik, P., Crimp, S., Meinke, H., Howden, S.M., 2010. The vulnerability of Australian rural communities to climate variability and change: Part I - Conceptualising and measuring vulnerability. *Environ. Sci. Policy* 13 (1), 8–17. <https://doi.org/10.1016/j.envsci.2009.09.006>.
- Neumann, J.E., Price, J., Chinowsky, P., Wright, L., Ludwig, L., Streeter, R., Jones, R., Smith, J.B., Perkins, W., Jantarasami, L., Martinich, J., 2015. Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage. *Clim. Change* 131 (1), 97–109. <https://doi.org/10.1007/s10584-013-1037-4>.
- Ngarava, S., Zhou, L., Monde, N., 2019. Gendered water insecurity: a structural equation approach for female-headed households in South Africa. *Water.* 11, 2491. <https://doi.org/10.3390/w11122491>.
- Nguyen, C.V., Horne, R., Fien, J., Cheong, F., 2017. Assessment of social vulnerability to climate change at the local scale: development and application of a Social Vulnerability Index. *Clim. Change* 143 (3–4), 355–370. <https://doi.org/10.1007/s10584-017-2012-2>.
- Nhamo, G., 2017. New global sustainable development agenda: a focus on Africa. *Sustain. Dev.* 25 (3), 227–241. <https://doi.org/10.1002/sd.1648>.
- Nicholls, R.J., Cazenave, A., 2010. Sea-Level Rise and Its Impact on Coastal Zones. *Science.* 328 (5985), 1517–1520.
- Nong, H.T.T., Gan, C., Hu, B., 2020. Climate change vulnerability and adaptation in Vietnam from a gender perspective: a case study of Northern Province of Vietnam. *Int. J. Soc. Econ.* 47, 953–972. doi:10.1108/IJSE-09-2019-0534.
- NRE (Ministry of Energy and Natural Resources), 2016. National policy on biological diversity 2016–2025, biodiversity and forestry management division. Ministry of Natural Resources and Environment, Malaysia.
- Okaka, F.O., Odhiambo, B.D.O., 2019. Households' perception of flood risk and health impact of exposure to flooding in flood-prone informal settlements in the coastal city of Mombasa. *Int. J. Clim. Chang. Strateg. Manag.* 11 (4), 592–606. <https://doi.org/10.1108/IJCCSM-03-2018-0026>.
- Omerkhil, N., Chand, T., Valente, D., Alatalo, J.M., Pandey, R., 2020. Climate change vulnerability and adaptation strategies for smallholder farmers in Yangi Qala District, Takhar, Afghanistan. *Ecol. Indic.* 110, 105863. <https://doi.org/10.1016/j.ecolind.2019.105863>.
- Oppenheimer, M., Glavovic, B.C., Hinkel, J., Wal, R., Magnan, A.K., Abd-Elgawad, A., Cai, R., Cifuentes-Jara, M., DeConto, R.M., Ghosh, T., Hay, J., Isla, F., Marzeion, B., Meyssignac, B., Sebessvari, Z., 2019. Sea Level Rise and implications for low-lying islands, coasts and communities, in: Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N.M. (Eds.), IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, In press.
- Ozturk, I., Al-Mulali, U., 2019. Investigating the Transboundary of Air Pollution Between the BRICS and Its Neighboring Countries: An Empirical Analysis. In: Shahbaz, M., Balsalobre, D. (Eds.), Energy and Environmental Strategies in the Era of Globalization. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-06001-5_2.

- Pandey, R., Kala, S., Pandey, V.P., 2015. Assessing climate change vulnerability of water at household level. *Mitig. Adapt. Strateg. Glob. Chang.* 20 (8), 1471–1485. <https://doi.org/10.1007/s11027-014-9556-5>.
- Pandey, R., Jha, S.K., Alatalo, J.M., Archie, K.M., Gupta, A.K., 2017. Sustainable livelihood framework-based indicators for assessing climate change vulnerability and adaptation for Himalayan communities. *Ecol. Indic.* 79, 338–346. <https://doi.org/10.1016/j.ecolind.2017.03.047>.
- Panthi, J., Aryal, S., Dahal, P., Bhandari, P., Krakauer, N.Y., Pandey, V.P., 2016. Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. *Reg. Environ. Chang.* 16 (4), 1121–1132. <https://doi.org/10.1007/s10113-015-0833-y>.
- Paprocki, K., Cons, J., 2014. Life in a shrimp zone: aqua- and other cultures of Bangladesh's coastal landscape. *J. Peasant Stud.* 41 (6), 1109–1130. <https://doi.org/10.1080/03066150.2014.937709>.
- Paprocki, K., Huq, S., 2018. Shrimp and coastal adaptation: on the politics of climate justice. *Clim. Dev.* 10 (1), 1–3. <https://doi.org/10.1080/17565529.2017.1301871>.
- Pelling, M., Garschagen, M., 2019. Put equity first in climate adaptation. *Springer Nat.* 569 (7756), 327–329.
- Popke, J., Curtis, S., Gamble, D.W., 2016. A social justice framing of climate change discourse and policy: adaptation, resilience and vulnerability in a Jamaican agricultural landscape. *Geoforum* 73, 70–80. <https://doi.org/10.1016/j.geoforum.2014.11.003>.
- Prabhakar, S.V.R.K., Arpah, A., Sobiah, B., 2015. Insurance for Disaster Risk Reduction and Climate Change Adaption — An Overview. Institute for Global Environmental Strategies, Kanagawa. <http://www.jstor.com/stable/resrep00848.11>.
- Preston, C., Carr, W., 2018. Recognition justice, climate engineering, and the care approach. *Ethics, Policy Environ.* 21 (3), 308–323. <https://doi.org/10.1080/21550085.2018.1562527>.
- Rahman, H.A., 2018. Climate change scenarios in Malaysia: engaging the public. *Int. J. Malay-Nusantara Stud.* 1, 55–77.
- Reguero, B.G., Beck, M.W., Bresch, D.N., Calil, J., Meliane, L., Anel, J.A., 2018. Comparing the cost effectiveness of nature-based and coastal adaptation: a case study from the Gulf Coast of the United States. *PLoS One* 13 (4), e0192132. <https://doi.org/10.1371/journal.pone.0192132>.
- Rouhanizadeh, B., Kermanshachi, S., Nipa, T.J., 2020. Exploratory analysis of barriers to effective post-disaster recovery. *Int. J. Disaster Risk Reduct.* 50, 101735. <https://doi.org/10.1016/j.ijdrr.2020.101735>.
- Roy, S., 2018. Livelihood resilience of the indigenous munda community in the Bangladesh Sundarbans Forest. *Handb. Clim. Chang. Resil.* 1–22. https://doi.org/10.1007/978-3-319-71025-9_10-1.
- Roy, J., Tschakert, P., Waisman, H., Abdul Halim, S., Antwi-Agyei, P., Dasgupta, P., Hayward, B., Kanninen, M., Liverman, D., Okereke, C., Pinho, P.F., Riahi, K., Rodriguez, A.G., 2018. Sustainable Development, Poverty Eradication and Reducing Inequalities, in: Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (Eds.), *Global Warming of 1.5°C*. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, In Press.
- Rühlemann, A., Jordan, J.C., 2021. Risk perception and culture: implications for vulnerability and adaptation to climate change. *Disasters.* 45 (2), 424–452.
- Saleh, E., Jolis, G., 2018. Climate change vulnerability assessment of the Tun Mustapha Park, Sabah. WWF-Malaysia, Petaling Jaya.
- Sarkar, M.S.K., Begum, R.A., Pereira, J.J., 2020. Impacts of climate change on oil palm production in Malaysia. *Environ. Sci. Pollut. Res.* 27 (9), 9760–9770. <https://doi.org/10.1007/s11356-020-07601-1>.
- Schneiderbauer, S., Ehrlich, D., 2004. Risk, hazard and people's vulnerability to natural hazards: a review of definitions, concepts and data. ISSN 1018-5593 Eur. Comm. Jt. Res. Centre. <https://op.europa.eu/s/poU2>.
- Schoonees, T., Gijón Mancheno, A., Scheres, B., Bouma, T.J., Silva, R., Schlurmann, T., Schüttrumpf, H., 2019. Hard structures for coastal protection, towards greener designs. *Estuaries Coasts* 42 (7), 1709–1729. <https://doi.org/10.1007/s12237-019-00551-z>.
- Scovronick, N., Budolfson, M.B., Dennig, F., Fleurbay, M., Siebert, A., Socolow, R.H., Spears, D., Wagner, F., 2017. Impact of population growth and population ethics on climate change mitigation policy. *Proc. Natl. Acad. Sci. U. S. A.* 114 (46), 12338–12343. <https://doi.org/10.1073/pnas.1618308114>.
- Sekhri, S., Kumar, P., Fürst, C., Pandey, R., 2020. Mountain specific multi-hazard risk management framework (MSMRMF): assessment and mitigation of multi-hazard and climate change risk in the Indian Himalayan Region. *Ecol. Indic.* 118, 106700. <https://doi.org/10.1016/j.ecolind.2020.106700>.
- Selamat, S.N., Abdul Maulud, K.N., Jaafar, O., Ahmad, H., 2017. Extraction of shoreline changes in Selangor coastal area using GIS and remote sensing techniques. *J. Phys. Conf. Ser.* 852, 012031. <https://doi.org/10.1088/1742-6596/852/1/012031>.
- Shaffril, H.A.M., Samah, A.A., D'Silva, J.L., 2017. Adapting towards climate change impacts: strategies for small-scale fishermen in Malaysia. *Mar. Policy* 81, 196–201. <https://doi.org/10.1016/j.marpol.2017.03.032>.
- Sharma, J., Ravindranath, N.H., 2019. Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change. *Environ. Res. Commun.* 1 (5), 051004. <https://doi.org/10.1088/2515-7620/ab24ed>.
- Sheskin, D.J., 2011. *Handbook of Parametric and Nonparametric Statistical Procedures*, fifth ed. Chapman & Hall/CRC Press, Florida.
- Shue, H., 2014. *Climate Justice. Vulnerability and Protection*. Oxford University Press, Oxford.
- Sidle, R.C., Gallina, J., Gomi, T., 2017. The continuum of chronic to episodic natural hazards: Implications and strategies for community and landscape planning. *Landscape Urban Plan.* 167, 189–197. <https://doi.org/10.1016/j.landurbplan.2017.05.017>.
- Sinay, L., Carter, R.W.B., 2020. Communities and local governments. *Climate* 8, 7. <https://doi.org/10.3390/cli8010007>.
- Solaymani, S., 2018. Impacts of climate change on food security and agriculture sector in Malaysia. *Environ. Dev. Sustain.* 20 (4), 1575–1596. <https://doi.org/10.1007/s10668-017-9954-4>.
- Solaymani, S., Kari, F., 2014. Poverty evaluation in the Malaysian Fishery Community. *Ocean Coast. Manag.* 95, 165–175. <https://doi.org/10.1016/j.ocecoaman.2014.04.017>.
- Sujakhu, N.M., Ranjitkar, S., Niraula, R.R., Salim, M.A., Nizami, A., Schmidt-Vogt, D., Xu, J., 2018. Determinants of livelihood vulnerability in farming communities in two sites in the Asian Highlands. *Water Int.* 43 (2), 165–182. <https://doi.org/10.1080/02508060.2017.1416445>.
- Tang, K.H.D., 2019. Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Sci. Total Environ.* 650, 1858–1871. <https://doi.org/10.1016/j.scitotenv.2018.09.316>.
- Tate, E., 2012. Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis. *Nat. Hazards* 63 (2), 325–347. <https://doi.org/10.1007/s11069-012-0152-2>.
- Taylor, A.L., Dessai, S., Bruine-de-Bruin, W., 2014. Public perception of climate risk and adaptation in the UK: a review of the literature. *Clim. Risk Manag.* 4, 1–16. <https://doi.org/10.1016/j.crm.2014.09.001>.
- Taylor, B.M., Harman, B.P., Inman, M., 2013. Scaling-up, scaling-down, and scaling-out: local planning strategies for sea-level rise in New South Wales, Australia. *Geogr. Res.* 51 (3), 292–303. <https://doi.org/10.1111/1745-5871.12011>.
- Thomas, A., Leichenko, R., 2011. Adaptation through insurance: lessons from the NFIP. *Int. J. Clim. Chang. Strateg. Manag.* 3 (3), 250–263. <https://doi.org/10.1108/17568691111153401>.
- Tran, T.A., Tran, P., Tuan, T.H., Hawley, K., 2012. Review of housing vulnerability: Implications for climate resilient houses. Discussion Paper. Institute for Social and Environmental Transition-International.
- Tschakert, P., Barnett, J., Ellis, N., Lawrence, C., Tuana, N., New, M., Elrick-Barr, C., Pandit, R., Pannell, D., 2017. Climate change and loss, as if people mattered: values, places, and experiences. *Wiley Interdiscip. Rev. Clim. Chang.* 8, 1–19. <https://doi.org/10.1002/wcc.476>.
- UNICEF, 2015. *Unless we act now: The impact of climate change on children*. United Nations Children's Fund, New York.
- UNISDR, 2015. *Sendai Framework for Disaster Risk Reduction 2015-2030*. The United Nations Office for Disaster Risk Reduction, Geneva.
- Vaghefi, N., Shamsudin, M.N., Radam, A., Rahim, K.A., 2016. Impact of climate change on food security in Malaysia: economic and policy adjustments for rice industry. *J. Integr. Environ. Sci.* 13 (1), 19–35. <https://doi.org/10.1080/1943815X.2015.1112292>.
- Vaghri, Z., 2018. Climate Change, An Unwelcome Legacy: The Need to Support Children's Rights to Participate in Global Conversations. *Child. Youth Environ.* 28, 104–114. <https://doi.org/10.7721/chilyoutenvi.28.1.0104>.

- Wall, E., Marzall, K., 2006. Adaptive capacity for climate change in Canadian rural communities. *Local Environ.* 11 (4), 373–397. <https://doi.org/10.1080/13549830600785506>.
- Wang, C.-H., Baynes, T., McFallan, S., West, J., Khoo, Y.B., Wang, X., Quezada, G., Mazouz, S., Herr, A., Beaty, R.M., Langston, A., Li, Y., Wai Lau, K., Hatfield-Dodds, S., Stafford-Smith, M., Waring, A., 2016. Rising tides: adaptation policy alternatives for coastal residential buildings in Australia. *Struct. Infrastruct. Eng.* 12 (4), 463–476. <https://doi.org/10.1080/15732479.2015.1020500>.
- Wardekker, J.A., de Jong, A., Knoop, J.M., van-der-Sluijs, J.P., 2010. Operationalising a resilience approach to adapting an urban delta to uncertain climate changes. *Technol. Forecast. Soc. Change* 77, 987–998. doi:10.1016/j.techfore.2009.11.005.
- Williams, G.A., Helmuth, B., Russell, B.D., Dong, Y.-W., Thiyagarajan, V., Seuront, L., 2016. Meeting the climate change challenge: pressing issues in southern China and SE Asian coastal ecosystems. *Reg. Stud. Mar. Sci.* 8, 373–381. <https://doi.org/10.1016/j.rsma.2016.07.002>.
- Wu, C.C., Jhan, H.T., Ting, K.H., Tsai, H.C., Lee, M.T., Hsu, T.W., Liu, W.H., 2016. Application of social vulnerability indicators to climate change for the southwest coastal areas of Taiwan. *Sustain.* 8, 1270. <https://doi.org/10.3390/su8121270>.
- Yamane, T., 1973. *Statistics: An Introductory Analysis*. Harper and Row, New York.
- Yanda, P.Z., Mabhuye, E., Johnson, N., Mwajombe, A., 2019. Nexus between coastal resources and community livelihoods in a changing climate. *J. Coast. Conserv.* 23 (1), 173–183. <https://doi.org/10.1007/s11852-018-0650-9>.
- Zacarias, D.A., 2019. Understanding community vulnerability to climate change and variability at a coastal municipality in southern Mozambique. *Int. J. Clim. Chang. Strateg. Manag.* 11 (1), 154–176. <https://doi.org/10.1108/IJCCSM-07-2017-0145>.