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Social Vulnerability and Flood Risk among Affected Households in the East Coast States of Peninsular Malaysia

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***Abstract*:**
The aims of this paper are to compare the differences in social vulnerability levels and evaluate the effects of social vulnerability on flood risk among affected households in the East Coast states of Peninsular Malaysia. By partially developing the component of social vulnerability within a household flood vulnerability index (FVI) given a total sample of 380 households and employing a multiple regression analysis, the findings vary by district, state and region. Among others, the districts of Kota Bharu, Kuala Krai, Kemaman, Kuantan and Temerloh are highly and socially vulnerable to floods. Meanwhile, Kelantan, Pahang and the East Coast states altogether are found to possess their highest social FVI ratings locally and regionally. Also, the regression results can have significant implications to various stakeholders; affected households, community leaders and policy makers to help mitigating the social vulnerability, thus leading to the flood risk reduction among the households at the state and regional levels. Thus, one policy recommendation for increasing the social resilience to floods among affected households is to constantly reassess the suitability of coping strategies, evacuation routes and relief centres so that the currently adopted ones are relevant and well-equipped to handle floods.

Keywords: Social vulnerability, Flood risk, Affected households

1. Introduction

Commonly, social vulnerability is characterized by individual characteristics of people such as age, income, type of dwelling unit and employment. Also, it covers the social inequalities that influence various susceptible groups to hazardous floods and govern their abilities to cope with floods. Additionally, it includes place inequalities, which are the characteristics of communities and built environments, such as economic and urbanization levels and growth rates that contribute to defining the social vulnerability of places. Typically, the social vulnerability exacerbates the riskiness of a flood as it involves the social features of the people with insufficient coping capacities. Due to the increasing frequency and magnitude of extreme floods as stemmed from urbanization, deforestation, population growth, climate change and consequent rise in sea level, the number of people vulnerable to such floods is expected to

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rise (Tyagi, 2009). Historically, it was reported from the East Coast states of Peninsular Malaysia in Table 1 that the annual floods affect more than 1.49 million people and about 10,130 km2 flood prone areas with the average of RM271 million is lost across the states of Kelantan, Terengganu and Pahang (Department of Irrigation and Drainage [DID], 2007; Ranhill Consulting, 2011).

Table 1: Recorded Flood Losses in the East Coast States against the Overall Loss in Malaysia.

	On Average Before 2007	**Major Floods in 2014**
East Coast States of Peninsular Malaysia:		
Affected Populations	1.49 million people	374,184 people
Affected Households		90,899 families
Flood Prone Areas	10,130 km^2	
Economic Losses	RM271 million	
Malaysia:		
Affected Populations	4.82 million people	403,879 people
Affected Households		98,332 families
Flood Prone Areas	29,000 km^2	
Economic Losses	RM915 million	
Ratio of Affected Populations (in %)	30.91	92.65
Ratio of Affected Households (in %)		92.44
Ratio of Flood Prone Areas (in %)	34.93	
Ratio of Economic Losses (in %)	29.62	

Source: Authors' Calculations based on DID (2007), Ranhill Consulting (2011) and JPW (2015)

From the table, the East Coast states of Peninsular Malaysia accounts for about 31 percent of total affected populations as compared to other regions in Malaysia. Based on the 2014's major floods, the East Coast states of Peninsular Malaysia registers with the highest shares of affected populations and affected households with about 93 percent and 92 percent, respectively. Hence, the impacts from social vulnerability and flood risk especially faced within the East Coast states of Malaysia have been regarded as high in the country's disaster management policy. Therefore, the motivation to undertake this paper hinges upon the aims of comparing the differences in social vulnerability levels to floods via the use of a household flood vulnerability index *(FVI)* and evaluating the effects of social vulnerability on flood risk among affected households by district, state and region through a multiple regression analysis.

From the empirical observations, social vulnerability to floods has increasingly grown its significance in the literature. One example is by Kissi*et al.* (2015) who studied on the use of *FVI* methodology for the eight villages in the counties of Togo country within the West African region. In the study, significant indicators such as lack of vegetation along the river, closeness of farmlands to the river, size of household, low level education among the head of household, insufficient diversification of livelihood strategies, inadequate flood

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warning system, unwillingness to take responsive actions and deficient emergency services contribute to explaining the rise in the social vulnerability to floods among the communities. Another example is by Dwyer *et al.* (2004) who developed the Social Vulnerability Index *(SoVI)* model, which is an urban *SoVI* methodology, to identify the social conditions of individuals at risk to natural hazards. In their works, the *SoVI* can be assessed from four different scales namely individual, community, regional or geographical and administrative or institutional. On the selection of indicators, 13 vulnerability variables (e.g. socio-economic indicators characterized individual characteristics) and two hazard variables (e.g. indicators characterized the impact of hazard) were chosen by Dwyer *et al.* (2004) based on a literature review, researchers' discussion and relevance to the research framework. As such, some hypothesized indicators to affect individual vulnerability include emergency services, local government policies and political climate.

Other examples of flood vulnerability (i.e. including the social vulnerability component) and flood risk assessments are undertaken by authors such as Villordon (2015) and Danumah*et al.* (2016). Villordon (2015) developed the community based*FVI* model based on a total sample of 357 households from 12 affected communities in the Dumaguete City and 30 local government and non-governmental representatives in understanding the social vulnerabilities and risks associated with the urban floods in the Philippines. Among others, Villordon (2015) disclosed that the community based*FVI* model at the aggregated basis remains at its comparatively low level, albeit the exposure factor was relatively high. This implies that considerably high levels of communities' resilience in terms of their withstand capacities and adaptation options that effectively being capitalized during the 2011's flood. Meanwhile, Danumah*et al.* (2016) performed a flood risk analysis within the Abidjan district in the southern Cote d'Ivoire of the West African region as means to identify and map areas that were potentially exposed to flood risk. In the study, the Multi-Criteria Decision Analysis for flood risk mapping of vulnerable areas can be employed given there was an integration of flood hazard map (e.g. slope, drainage density, soil type and isohyet) and flood vulnerability map (e.g. population density, urban structure types and drainage system). Of the findings, Danumah*et al.* (2016) unfolded that the Analytic Hierarchy Process flood risk map indicated about 34 percent of the study areas (eight out of 13 municipalities) were highly exposed to the risk of flooding.

This paper is structured as follows. Section 2 describes the used methodology and various results are discussed in Section 3. Finally, Section 4 wraps up with the policy implication and conclusion of the study.

2. Methodology

2.1 Theoretical Framework

This study strategically adopts the Turner *et al.* (2003)'s expanded vulnerability framework whereby the local setting e.g. a village, town or district is a unit of analysis. The framework covers linkages to the broader human and environmental conditions and processes within the coupled system, perturbations and stressors or stress. Vulnerability exists within these conditions and related process and the coupled system

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including exposure and response elements such as adaptations, adjustments, coping and impacts (Turner *et al.*, 2003). Since these elements are interactive and scale dependent, the analysis is affected up to the extent that the coupled system is conceptualized in this study. Specifically, the vulnerability factors in Figure 1 are distinguished to contain exposure *(E)*, susceptibility or sensitivity *(S)* and resilience *(R)*, thus enabling for the interpretation of local indicators. More importantly, the interactions among these factors will affect the current system, thus providing the insight of an area's vulnerability.

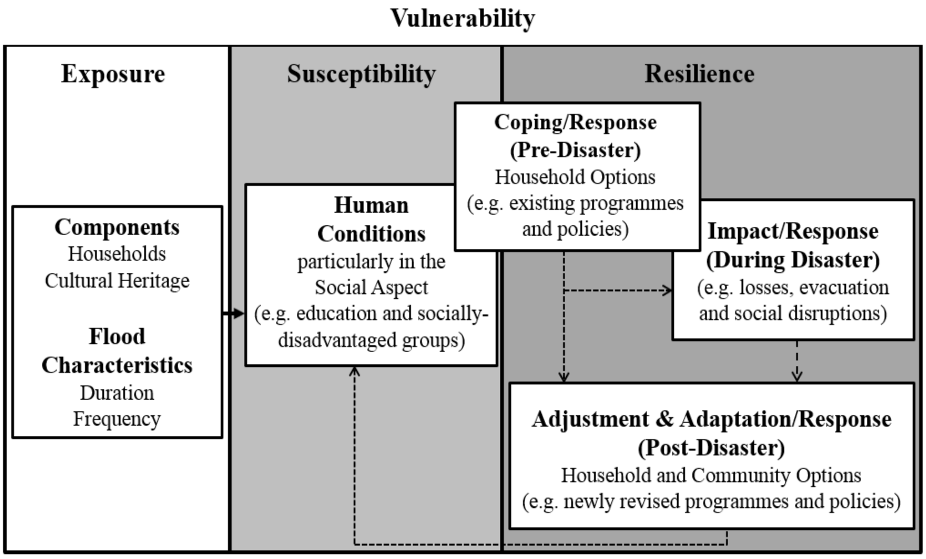
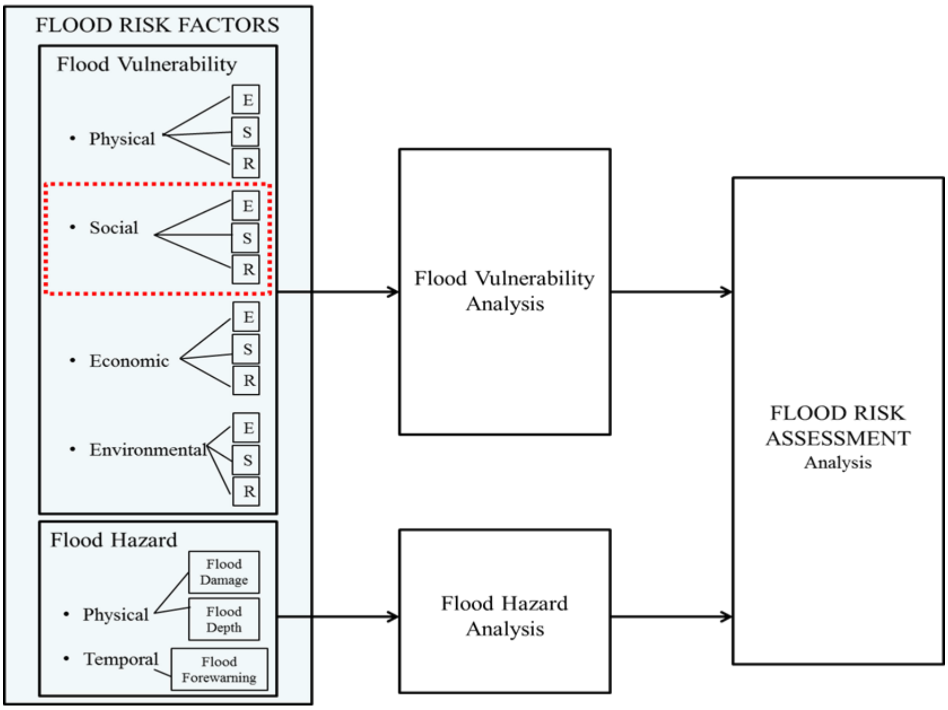


Figure 1: Details of Interactions among Vulnerability Factors

Source: Author's Modifications from Turner *et al.,* 2003

Exposure covers threatened elements like households, states and cultural heritage places that are subjected to damages and threat characteristics; duration, frequency and magnitude. Susceptibility is influenced by the human (i.e. as well as environmental) conditions of the system whereas resilience is enhanced by adaptive and coping capacities. In term of resilience, pre-disaster activities are taken to reduce human and property losses caused by a hazard. The activities so-called mitigation and preparedness efforts cover initiatives ((e.g. building codes and warning systems) to strengthen the preparations of disaster management at the household and community levels. During disaster activities, these emergency response efforts include initiatives (e.g. search and rescue and emergency relief) to ensure that the provisions of victims are catered and impacts are minimized. Post-disaster activities, these response and recovery efforts comprise of initiatives (e.g. temporary shelters) are taken in response to a disaster for achieving early recovery and rehabilitation of affected individuals, households and communities immediately after a disaster strike.

Additionally, Figure 2 illustrates that vulnerability and risk are closely related to each other in the case of a hazard (e.g. flood). While vulnerability particularly reflects the social conditions apart from other aspects; physical, economic and environmental, that increase susceptibility to a disaster, risk combines with the probable size of the impact, the type and magnitude of the hazard. Thus, the flood risk analysis constitutes as a combination of the two analytical analyses of flood vulnerability and flood hazard. Flood vulnerability analysis represents the study of a person's ability or element to withstand, neutralize, avoid or absorb the impact of hazardous floods. There are two steps involved in the analysis. The first step is to identify the potentially vulnerable households and elements via the data collection activities. The second step involves the identification and analysis of factors; exposure *(E)*, susceptibility *(S)* and resilience *(R)* associated with the multi-sided flood vulnerability with the key focus is on the social aspect.



Note: *E*, *S* and *R* are vulnerability factors that denote as Exposure, Susceptibility and Resilience.

Figure 2: Social Aspect of Flood Vulnerability and Flood Hazard as Flood Risk Factors

Source: Authors' Modifications from UNISDR, 2009.

Meanwhile, flood hazard analysis covers the identification of underlying causes that may influence the occurrence probability of a hazard (e.g. a flood) in an area within the specific timeframe. Feasibly, the analysis is done to evaluate the event based on the indication of physical and temporal characteristics.

With the availability of the two analyses, the estimation on damages, losses and consequences that are heavily inflicted from a flood event can be undertaken. Thus, flood risk analysis is increasingly used as a key instrument of the disaster risk management.

2.2 Study Area

This study investigates the coverage of 2014's major floods in the East Coast region of Peninsular Malaysia via focusing on the states of Kelantan, Terengganu and Pahang. As can be seen in Figure 3, two selected districts in each state represent the study areas.

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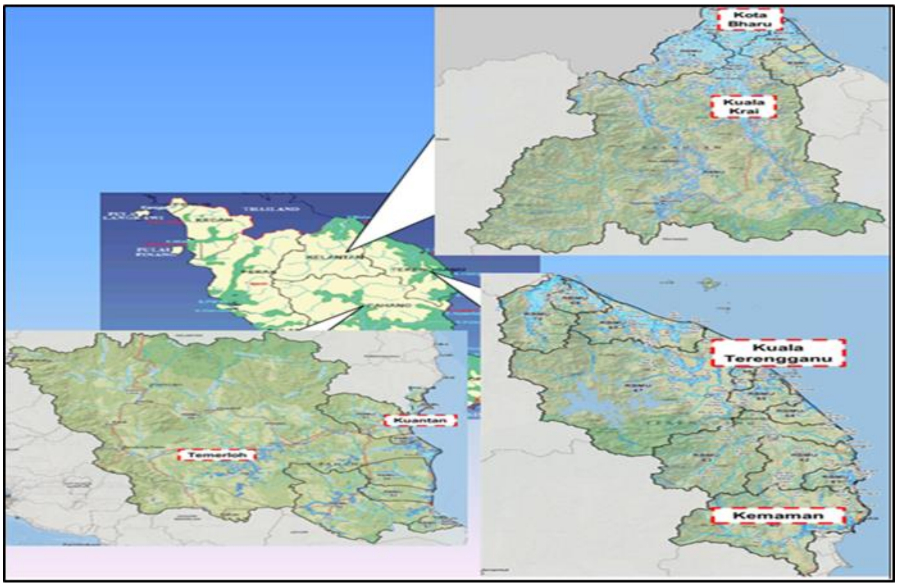

Figure 3: Geographical Areas of Study across the East Coast States of Peninsular Malaysia

Note: The collection of study area maps is meant for illustrative purpose only. No specific scalar is referred.

The selection is based on high severity levels of floods in 2014 that inflicted households across various communities in respective districts.

2.3 Data and Sampling Method

In this study, the construction of social vulnerability component under the household *FVI* is sourced from the primary and secondary data. While some primary data were collected through the households' submission of questionnaire sets, few secondary indicators; affected population, population density and population growth were obtained from organizations in Malaysia such as Department of Statistics (DOS) and Jabatan Pembangunan Wanita (JPW). Thus, specific descriptions on used indicators are covered in Table A.1. Based on the overall affected households of 43,816 families within the six districts that survived from the 2014's floods as reported in JPW (2015), 380 household respondents in total were determined to be the sample of this study. Hence, this suffices to reach the 95 percent significance level in the produced results (Lin, 1976 as cited in Zikmund, 1991). Specifically, the sample comprises of 160 respondents from the districts of Kota Bharu and Kuala Krai in Kelantan, 110 respondents from the district of Kuala Terengganu and Kemaman in Terengganu and 110 respondents from the districts of Kuantan and Temerloh in Pahang. On the study samples, registered household respondents who provided their feedbacks through submitted questionnaires were chosen via the combined methods of stratified and random sampling.

2.4 Modeling

To analyse the relationship between flood risk *(FR)* and social vulnerability *(SV)*, a multiple linear regression analysis was employed in this study. A total of four flood risk models, i.e. Equation [1] – Equation [4], were developed in the analysis. In each model, the dependent variable is *FR* whereas the independent variables are the social *(SV)* aspect of vulnerability, flood hazard *(FH)* and control terms; *HLCT* (housing location) and *HMTL* (housing material). Nevertheless, the details of the chosen independent variables are described in Table 2.

Table 2: Inclusion of Chosen Independent Variables into the Regression Models

State	Component	Variable*	Description
Kelantan	Flood Hazard *(FH)*	*FDMG*	Flood Damage
		FDEP	Flood Depth
		FWNG	Flood Forewarning
	Social Vulnerability *(SV)*	*AWPR*	Awareness/Preparedness
		COPM	Coping Mechanisms
		EVRT	Evacuation Routes
	Control	*HLCT*	Housing Location
		HMTL	Housing Material
Terengganu	Flood Hazard *(FH)*	*FDMG*	Flood Damage
		FDEP	Flood Depth
		FWNG	Flood Forewarning
	Social Vulnerability *(SV)*	*AWPR*	Awareness/Preparedness
		COPM	Coping Mechanisms
		WSYS	Warning Systems
	Control	*HLCT*	Housing Location
		HMTL	Housing Material
Pahang	Flood Hazard *(FH)*	*FDMG*	Flood Damage
		FDEP	Flood Depth
		FWNG	Flood Forewarning
	Social Vulnerability *(SV)*	*AWPR*	Awareness/Preparedness
		EVRT	Evacuation Routes
		WSYS	Warning Systems
	Control	*HLCT*	Housing Location
		HMTL	Housing Material
East Coast States	Flood Hazard *(FH)*	*FDMG*	Flood Damage
		FDEP	Flood Depth
		FWNG	Flood Forewarning
	Social Vulnerability *(SV)*	*EVRT*	Evacuation Routes
		PEXP	Past Floods Experience
		WSYS	Warning Systems
	Control	*HLCT*	Housing Location
		HMTL	Housing Material

Note: * indicates the chosen three indicators of social vulnerability that are highly correlated to flood risk as determined from the correlation results in Table A.2.

The complete models are shown in Equation [1] – Equation [4]:

<u>Kelantan Model 1 *(KM1)*</u>:

$$FR_{i1}^{SV} = \lambda_0 + \lambda_1 FDMG_{i1} + \lambda_2 FDEP_{i1} + \lambda_3 FWNG_{i1} + \lambda_4 AWPR_{i1} + \lambda_5 COPM_{i1} + \lambda_6 EVRT_{i1} + \lambda_7 HLCT_{i1} + \lambda_8 HMTL_{i1} + \varepsilon_{i1}$$

[1]

<u>Terengganu Model 2 *(TM2)*</u>

$$FR_{i2}^{SV} = \psi_0 + \psi_1 FDMG_{i2} + \psi_2 FDEP_{i2} + \psi_3 FWNG_{i2} + \psi_4 AWPR_{i2} + \psi_5 COPM_{i2} + \psi_6 WSYS_{i2} + \psi_7 HLCT_{i2} + \psi_8 HMTL_{i2} + \varepsilon_{i2}$$

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[2]

<u>Pahang Model 3 *(PM3)*</u>

$$FR_{i3}^{SV} = \varpi_0 + \varpi_1 FDMG_{i3} + \varpi_2 FDEP_{i3} + \varpi_3 FWNG_{i3} + \varpi_4 AWPR_{i3} + \varpi_5 EVRT_{i3} + \varpi_6 WSYS_{i3} + \varpi_7 HLCT_{i3} + \varpi_8 HMTL_{i3} + \varepsilon_{i3}$$

[3]

<u>East Coast States Model 4 *(ECM4)*</u>

$$FR_{i4}^{SV} = \rho_0 + \rho_1 FDMG_{i4} + \rho_2 FDEP_{i4} + \rho_3 FWNG_{i4} + \rho_4 EVRT_{i4} + \rho_5 PEXP_{i4} + \rho_6 WSYS_{i4} + \rho_7 HLCT_{i4} + \rho_8 HMTL_{i4} + \varepsilon_{i4}$$

[4]

where $\lambda_i, \psi_i, \varpi_i$ and $\rho_i (i = 0,1,2,\ldots, 8)$ are the coefficients. Also, ε_i represents the white-noise error term, $\varepsilon_i = iid(0, \sigma_\varepsilon^2)$.

2.5 Justification of Variables

2.5.1 Flood Risk (Social Vulnerability)

Flood risk (FR^{SV}) is defined as the function of flood hazard on an exposed household's social condition that is vulnerable to the hazard. To measure it, the value is expected to be in the interval between nearly zero (i.e. very low risk to floods) and one (i.e. very high risk to floods). Thus, it is regarded as the dependent variable to be regressed against the independent variables of flood hazard, flood vulnerability and control components in an estimated model.

2.5.2 Flood Damage

Flood damage *(FDMG)* is indicated by the extent of impact faced by business, farmland and housing areas due to the occurrence of a flood event. It is measured in the local currency (RM). As the impact of floods becomes greater, the vulnerability levels to floods among affected households increase, thus leading to a rise in flood risk. Past authors such as Asube and Garcia (1995) and Ouma and Tateishi (2014) claimed that flood damage is positively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that flood damage is positively related with flood risk since it represents a characteristic of flood hazard.

2.5.3 Flood Depth

Flood depth *(FDEP)* is defined as the inundation depth of a flood event. It is measured in metre. As flood depth gets deeper, the vulnerability levels to floods among affected households become higher, thereby causing an increase in flood risk. Past authors such as Mohit and Sellu (2013), Ouma and Tateishi (2014) and Kissi*et al.* (2015) asserted that flood depth is positively related with flood vulnerability and flood risk in their studies. Thus, it is hypothesized in this study that flood depth is positively related with flood risk since it is a flood hazard indicator.

2.5.4 Flood Forewarning

Flood forewarning *(FWNG)* is interpreted as the interval of time between identification, warning and impact of flood hazard. The interval time of warning dissemination to affected households periodically takes place before floods. Thus, it is measured in the percentage value. As the timing of warning dissemination delays, vulnerability levels to floods among the affected households rise, thus rendering to an increase in flood risk. Past authors such as Smith (1994) and Kreibich*et al.* (2005) claimed that flood forewarning is positively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that flood forewarning is positively related with flood risk since it is also an indicator of flood hazard.

2.5.5 Awareness/Preparedness

Awareness/Preparedness *(AWPR)* refers to

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the attentiveness of a threatened household in dealing with a hazardous event (e.g. flood). It is measured in the percentage value. As a household's level of awareness/preparedness turns out higher, the social vulnerability to floods tends to be lower, thus leading to a decrease in flood risk. While Kissi*et al.* (2015) argued that awareness/preparedness is positively related with flood vulnerability and flood risk, authors like Balica (2007), Balica and Wright (2010), Balica*et al*. (2012) and Karmaoui*et al.* (2016) claimed that it is negatively related with flood vulnerability and flood risk in their studies. Hence, it is hypothesized in this study that awareness/preparedness is negatively related with flood risk since it serves as a resilience factor of flood vulnerability.

2.5.6 Coping Mechanisms

The indicator of coping mechanisms *(COPM)* is reflected by effective measures (e.g. put valuable things at higher grounds) that were implemented by households to withstand the magnitude of floods. It is measured in the percentage value. As the effectiveness of coping capacities among the affected households to floods becomes higher, the social vulnerability to floods will be lower, thus rendering to a reduction in flood risk. Past authors such as Kissi*et al.* (2015) claimed that coping mechanism is positively related with flood vulnerability and flood risk in their studies. However, it is hypothesized in this study that coping mechanism is negatively related with flood risk since it represents a resilience factor of flood vulnerability.

2.5.7 Evacuation Routes

Evacuation routes *(EVRT)* are defined as the withdrawal actions of an affected household from a vulnerable area via a specified course due to a real or anticipated threat or hazard (e.g. a flood). It is represented by the probability of households to temporarily evacuate from hit areas to safer places. Thus, it is measured in the percentage value. As many households able to evacuate from disaster areas, the social vulnerability to floods can be reduced, thus causing a reduction in flood risk. Past authors such as Balica and Wright (2010) and Karmaoui*et al.* (2016) revealed that evacuation route is negatively related with flood vulnerability and flood risk in their studies. Likewise, it is hypothesized in this study that evacuation route is negatively related with flood risk since it constitutes as a resilience factor of flood vulnerability.

2.5.8 Past Floods Experience

Past floods experience *(PEXP)* is characterized by the usefulness of accumulated experiences from previous flood events among the affected households towards facing the recent 2014's major floods. Thus, the experience is measured in the percentage value whereby it is to be ranked from the very high relevance to the very least relevance among the households. Typically, those with non-experience are more socially vulnerable to floods than those who have experience in dealing with floods. Kissi*et al.* (2015) asserted that past floods experience is positively related with flood vulnerability and flood risk whereas Balica and Wright (2010) and Karmaoui*et al.* (2016) claimed that it is negatively related with flood vulnerability and flood risk. Therefore, it is hypothesized in this study that past floods experience is negatively related with flood risk since it is classified as a resilience factor of flood vulnerability.

2.5.9 Warning Systems

Warning systems *(WSYS)* refer to the availability of flood warning systems in a community that indicates the early warning of onset floods. Essentially, the

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implementation of flood warning systems is aimed at reducing material, human and cultural damages (Parker & Fordham, 1996). It is a dummy variable as measured either one (i.e. it is available, operational and reachable) or zero (i.e. it is not available in-place). With the currently operational warning systems in-place, the community area's vulnerability to floods can be socially reduced, thus contributing to a decrease in flood risk. Past authors such as Balica and Wright (2010), Kissi*et al.* (2015) and Karmaoui*et al.* (2016) stressed that warning system is negatively related with flood vulnerability and flood risk in their studies. Thus, it is hypothesized in this study that warning system is negatively related with flood risk since it is a resilience factor of social vulnerability.

2.5.10 Housing Location

Housing location *(HLCT)* is defined as the strategic location of an affected household to reside in a community area. It is a dummy variable as measured either one (i.e. an urban settler) or zero (i.e. a rural settler). This aligns with that the severity of flood events in urban areas are more impactful than those in rural areas especially when considering the magnitude and duration of the events (Van Sluis& Van Aalst, 2006). However, its significant effect on flood risk is held constant in a model since it is treated as a control variable of this study.

2.5.11 Housing Material

Housing material *(HMTL)* is characterized by the housing conditions of the affected households within a community. The houses owned by households are made of either cement, wood, or cement and wood. Typically, wooden houses are more susceptible to floods than cemented houses (Messner & Meyer, 2005). It is a dummy variable as measured either one (i.e. being a wooden house) or zero (i.e. being a cemented house). Past authors such as Villordon (2015) incorporated its effect in his study in order to understand the social vulnerabilities and risks of floods among the urban communities. In each model, its effect is held constant as it is also a control variable of this study.

2.6 Method of Analysis

2.6.1 Developing and Estimating the Social Vulnerability from the Household *FVI*

Smith (2004) considers disaster risk as the product of two components i.e. probability and consequence whereas Blaikie *et al.* (1994) treat disaster risk to be the product of hazard and vulnerability. It is written in Equation [5] as taken from the Pressure and Release (PAR) model:

$$Risk = Hazard \times Vulnerability \qquad [5]$$

To specifically relate with a flood event, Equation [5] is then converted into Equation [6]:

$$Flood\ Risk = Flood\ Hazard \times Flood\ Vulnerability \qquad [6]$$

Separately, a vulnerability assessment is undertaken to determine the conditions of social vulnerability to the flood effect at a point of time. Overall, the combined effects of social vulnerability indicators are evaluated in order to calculate the social *FVI* values at the districts, state and regional levels via using Equation [7]:

$$FVI_i = \left(\frac{E*S}{R}\right)_i ; i = SV \qquad [7]$$

where *E* is Exposure, *S* is Susceptibility, *R* is Resilience and *SV* is Social Vulnerability.

Prior to that, all datasets were normalized using the normalization formula as expressed in Equation [8]. The datasets were transformed into non-dimensional units by interpolating the maximum and minimum of obtained data variables (Connor & Hiroki,

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2005; Balica*et al.* 2013):

$$Z_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})} \quad [8]$$

where X_{ij} denotes as the value of *j*indicator *(j = 1,2,…,40)* in the *i*district *(i = 1,2,…,6)* and Z_{ij} is the matrix that corresponds to the normalized score in which its scaled value spans from zero to unity. While the value of unity refers to the maximum value, the value of zero represents the minimum value.

Generally, the produced results adhere to the value designations of *FVI* model in Table 3 that were developed in Balica (2007), Balica*et al.* (2013) and Villordon (2015).

Table 3: The Interpretation of Household-Based FVI Values

Index Value	Description
0.75 – 1.00	Very high vulnerability to floods An area has a very high vulnerability to floods. Either the physical, social, economic, environmental or all aspects are very highly vulnerable to floods. Thus, the households should make more efforts to address the areas' low resilience.
0.50 – 0.75	High vulnerability to floods An area has a high vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are highly vulnerable to floods. Hence, the households should make efforts to address the areas' high vulnerability.
0.25 –0.50	Vulnerable to floods An area has a moderate vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are vulnerable to floods. Hence, more works could be done to improve the households' resilience.
0.01 – 0.25	Low vulnerability to floods An area has a low vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are lowly vulnerable to floods. Hence, the households are well-prepared for a flood event.
< 0.01	Very low vulnerability to floods An area has a very low vulnerability level to floods. Either the physical, social, economic, environmental or all aspects are very low vulnerable to floods. Hence, the households are very well-prepared for a flood event.

Source: Balica, 2007; Balica*et al.*, 2013; Villordon, 2015

Hence, the table assists to interpret values of the *FVI* model signifying from very low to very high vulnerability to floods for a given area. More importantly, the designations of *FVI* model are useful in providing a broad overview of flood vulnerability levels that would suggest for more appropriate measures to be prioritized for the flood vulnerability and flood risk responses of affected communities by the community leaders, affected households and policy makers.

2.6.2 Estimation Method

A multiple linear regression analysis was employed to analyse potential effects of social vulnerability on flood risk among affected households at the state and regional levels. Altogether, four flood risk models, i.e. Equation [1] – Equation [4] from Section 3.4, are established in the analysis. In each model, the dependent variable; flood risk to be regressed against the components of flood hazard, economic vulnerability and control variables. For more descriptions on the four flood risk models at the state and regional levels, their details are discussed under the topic of modeling in Section 3.4.

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3. Discussion of Results

After applying the normalization formula in Equation [8], the normalized values of social vulnerability indicators at the district, state and regional levels are displayed in Table 4.

Table 4: Normalized Values of Indicators at the District, State and Regional Levels

Level	Factor	Indicator	Kota Bharu ($n_1 = 80$)	Kuala Krai ($n_2 = 80$)	Kuala Terengganu ($n_3 = 50$)	Kemaman ($n_4 = 60$)	Kuantan ($n_5 = 60$)	Temerloh ($n_6 = 50$)
District	*E*	Cultural Heritage	0.938	0.988	0.880	0.850	0.933	0.840
		Population Density	0.501	0.501	0.495	0.494	0.495	0.499
		Affected Households	0.218	0.192	0.056	0.516	0.328	0.242
	S	Education	0.850	0.650	0.760	0.583	0.900	0.680
		Household Size	0.713	0.750	0.480	0.617	0.450	0.620
		Female	0.566	0.423	0.386	0.488	0.393	0.452
		Disabled Persons	0.521	0.474	0.443	0.450	0.300	0.485
		Population Growth	0.501	0.501	0.495	0.494	0.495	0.499
		Farmers	0.125	0.563	0.160	0.583	0.195	0.580
	R	Shelters	0.963	0.950	0.920	0.933	0.917	0.900
		Emergency Services	0.963	0.950	0.920	0.933	0.917	0.900
		Awareness/Preparedness	0.788	0.800	0.700	0.817	0.717	0.740
		Long Term Residents	0.663	0.763	0.720	0.700	0.617	0.860
		Communication Rate	0.575	0.675	0.507	0.646	0.621	0.590
		Past Floods Experience	0.375	0.513	0.350	0.361	0.356	0.433
		Evacuation Routes	0.358	0.319	0.400	0.542	0.417	0.330
		Coping Mechanisms	0.350	0.375	0.420	0.529	0.400	0.485
		Warning Systems	0.175	0.163	0.020	0.233	0.083	0.180

			Kelantan ($n_7 = 160$)	Terengganu ($n_8 = 110$)	Pahang ($n_9 = 110$)
State	*E*	Cultural Heritage	0.963	0.865	0.887
		Population Density	0.501	0.495	0.497
		Affected Households	0.205	0.286	0.285
	S	Education	0.750	0.672	0.790
		Household Size	0.732	0.549	0.535
		Female	0.495	0.437	0.423
		Disabled Persons	0.498	0.447	0.393
		Population Growth	0.501	0.495	0.497
		Farmers	0.344	0.372	0.388
	R	Shelters	0.957	0.928	0.910
		Emergency Services	0.957	0.928	0.910
		Awareness/Preparedness	0.794	0.758	0.738
		Long Term Residents	0.713	0.710	0.739
		Communication Rate	0.625	0.577	0.606
		Past Floods Experience	0.444	0.356	0.395
		Evacuation Routes	0.339	0.471	0.374
		Coping Mechanisms	0.363	0.475	0.443
		Warning Systems	0.169	0.127	0.135

"Table 4 Continued"

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Level	Factor	Indicator	East Coast States of Peninsular Malaysia (N = 380)
Region	*E*	Cultural Heritage	0.905
		Population Density	0.498
		Affected Households	0.259
	S	Education	0.737
		Household Size	0.605
		Female	0.451
		Disabled Persons	0.446
		Population Growth	0.498
		Farmers	0.368
	R	Shelters	0.931
		Emergency Services	0.931
		Awareness/Preparedness	0.763
		Long Term Residents	0.721
		Communication Rate	0.602
		Past Floods Experience	0.398
		Evacuation Routes	0.394
		Coping Mechanisms	0.427
		Warning Systems	0.144

Note: *E, S* and *R* are vulnerability factors that denote as Exposure, Susceptibility and Resilience

From the table, high values of affected cultural heritage places comingled with low to moderate shares of population density and affected population contribute to aggravating a district's social vulnerability to floods. Apart from that, the rise in a district's social vulnerability to floods is propelled by mild to high contributions of increasing education levels and expanding household sizes. Also, it is observed from the table that the increase in social vulnerability is contributed by fair shares of population growth and socially-disadvantage sub-groups; female, disabled persons and farmers across the six districts.

Meanwhile, the availability of temporary shelters and access to emergency services at operational shelters are found to be commendable within the communities across the districts. Thus, both indicators contribute to reducing vulnerability to floods socially. Under the households' resilience, the deficient factors during the 2014's floods were determined to be unapplied practice of past floods experience, unease paved of evacuation routes, ineffective coping mechanisms and inadequate coverage of flood warning systems. Adversely, these lacking strategies contribute to rising social vulnerability, thus impeding the overall recovery process by affected households to recover from the floods.

Furthermore, very high values of affected cultural heritage alongside low to fair shares of population density and affected population appear to increase a state's social vulnerability to floods. Also, the rise in the social vulnerability is backed by mild to high contributions of increasing education levels and expanding household sizes. Similar to the district's case, it is observed that the

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increase in a state's social vulnerability to floods is contributed by fair shares of population growth, female, disabled persons and farmers. Moreover, higher values of indicators under the exposure and susceptibility factors will render to increasing the region's social vulnerability to floods. While very high shares of resilience indicators; shelters and emergency services will lower the social vulnerability to floods, the remaining indicators within the households' resilience may contribute to rising social vulnerability to floods of the region.

By using the normalized values in Table 4, the aggregate values of exposure, susceptibility and resilience factors are calculated for the district, state and regional levels. The results at the district, state and regional levels are exhibited in Table 5.

Table 5: Aggregate Values of Vulnerability Factors at the District, State and Regional Levels

Level	**Factor**	**Kota Bharu (n_1 = 80)**	**Kuala Krai (n_2 = 80)**	**Kuala Terengganu (n_3 = 50)**	**Kemaman (n_4 = 60)**	**Kuantan (n_5 = 60)**	**Temerloh (n_6 = 50)**
District	*E*	0.103	0.095	0.024	0.217	0.151	0.101
	S	0.011	0.028	0.005	0.023	0.005	0.027
	R	0.002	0.004	0.0003	0.008	0.001	0.004
		Kelantan (n_7 = 160)		**Terengganu (n_8 = 110)**		**Pahang (n_9 = 110)**	
State	*E*	0.099		0.122		0.006	
	S	0.023		0.013		0.304	
	R	0.003		0.003		0.003	
		East Coast States of Peninsular Malaysia (N = 380)					
Region	*E*	0.117					
	S	0.016					
	R	0.003					

Based on the results in Table 5, exposure and susceptibility constitute as the most dominant factors in affecting the social vulnerability to floods of a district, state and the region. Specifically, indicators under the exposure and susceptibility factors contain certain weightages in determining the social vulnerability to floods at the district, state and regional levels. However, relatively low resilience values in most cases play their parts in putting the involved districts, states and the region to be ranked as socially vulnerable to floods at varying levels.

Given the aggregate values of factors in Table 4, the social *FVI* results at the district, state and regional levels are calculated and subsequently reported in Table 6.

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Table 6: Results of Social *FVI* Values at the District, State and Regional Levels

Level	**Kota Bharu (n_1 = 80)**	**Kuala Krai (n_2 = 80)**	**Kuala Terengganu (n_3 = 50)**	**Kemaman (n_4 = 60)**	**Kuantan (n_5 = 60)**	**Temerloh (n_6 = 50)**	***FVI* Average**
District	0.501	0.706	0.464	0.632	0.559	0.664	0.588
	Kelantan (n_7 = 160)		**Terengganu (n_8 = 110)**		**Pahang (n_9 = 110)**		
State	0.771		0.601		0.704		
			East Coast States of Peninsular Malaysia (N = 380)				
Region			0.693				

From the table, the average social *FVI* for all districts is 0.588. Among the districts, Kuala Krai, Temerloh and Kemaman with their associated *FVI* values of 0.706, 0.664 and 0.632 are highly vulnerable to floods in the social aspects. The tendency of these districts to have high vulnerability to floods is due to the disclosure of higher values in cultural heritage, education and household size indicators. Specifically, indications of cultural heritage (e.g. mosque or musollah), rising education levels and expanding sizes of household contribute to posing challenges among the households to successfully deal with floods, thus adversely lead them to be vulnerable to floods. For example, the vulnerable conditions of a mosque or musollah due to floods may complicate committee members to meet up and organize any social-related event on occasional basis involving the members of a community. Also, highly vulnerable of these districts can be explained by low indicative values of past floods experience, evacuation routes, coping mechanisms and flood warning systems (Wan Hussin*et al.*, 2015; Zakaria *et al.*, 2016; Gulsan, 2017; Hashim*et al.*, 2018b).

In a state's setting, Kelantan and Pahang are found to be the most socially vulnerable to floods with their *FVI* values of 0.771 and 0.704 (Hashim *et al.*, 2018b). On one hand, this can be explained via higher values of some exposure and susceptibility indicators. Indicators such as cultural heritage, education and household size appear to significantly influence the rise in the social vulnerability. For instance, some households are seen having difficulties to survive from the floods as stemmed from having bigger families and the separation of few members from their families possibly due to the studying, marriage, migration and work commitments elsewhere. Among others, this is harmonious with Chan (1995) that argued the closed kinship systems in the flood-prone 'kampungs' can socially reduce the flood vulnerability levels among rural Malays in the eastern Peninsular Malaysia. On the other, both states have lower resilience values, thus inevitably facing high social vulnerability to floods. Regionally, the East Coast States altogether are socially vulnerable to floods with its estimated *FVI* value of 0.693.

Further, to analyse the relationship between flood risk and social vulnerability among affected households at the state and regional levels, a multiple linear regression analysis in Table 7 was employed in this study. Prior to that, a correlation analysis was undertaken to assess the strength and direction of association among the variables. Thus, the correlation results as shown in Table A.2 justify the inclusion of all variables into four regression models.

Table 7: Results on Regression Analysis of *KM1*, *TM2*, *PM3* and *ECSM4* Models

Variable	**Coefficient**	**Standard Error**	***t*-statistic**	***p*-value**
<u>Dependent Variable: *FR*</u>				
<u>Kelantan Model 1 *(KM1)*</u>				
C	0.112	0.027	4.074	0.001*
FDMG	2.280×10^{-6}	3.180×10^{-7}	7.166	0.000*
FDEP	0.012	0.012	0.978	0.330
FWNG	0.065	0.018	3.680	0.000*
AWPR	-0.014	0.016	-0.923	0.358
EVRT	-0.218	0.032	-6.820	0.000*
COPM	-0.117	0.032	-3.702	0.000*
HLCT	0.025	0.015	1.711	0.089**
HMTL	-0.016	0.013	-1.271	0.206
R^2	0.531	Diagnostic	Heteroscedasticity, Prob *F* (8, 151)	0.259
Adjusted R^2	0.506	Tests:	Normality, Prob (*JB*-statistic)	0.442
Prob (*F*-statistic)	0.000			
<u>Terengganu Model 2 *(TM2)*</u>				
C	-0.105	0.027	-3.952	0.000*
FDMG	1.510×10^{-5}	1.810×10^{-6}	8.303	0.000*
FDEP	0.081	0.010	7.992	0.000*
FWNG	0.137	0.014	9.743	0.000*
AWPR	0.011	0.012	0.903	0.369
COPM	-0.092	0.025	-3.701	0.000*
WSYS	-0.026	0.015	-1.711	0.090**
HLCT	0.038	0.012	3.172	0.002*
HMTL	0.019	0.013	1.423	0.258
R^2	0.546	Diagnostic	Heteroscedasticity, Prob *F* (8, 101)	0.240
Adjusted R^2	0.526	Tests:	Normality, Prob (*JB*-statistic)	0.332
Prob (*F*-statistic)	0.000			
<u>Pahang Model 3 *(PM3)*</u>				
C	-0.019	0.040	-0.465	0.643
FDMG	6.220×10^{-6}	1.510×10^{-6}	4.130	0.000*
FDEP	0.050	0.018	2.704	0.008*
FWNG	0.088	0.025	3.572	0.001*
AWPR	-0.058	0.024	-2.367	0.020*
EVRT	-0.241	0.044	-5.458	0.000*

WSYS	-0.081	0.024	-3.293	0.001*
HLCT	0.104	0.023	4.534	0.000*
HMTL	0.045	0.019	2.436	0.017*
R^2	0.518	Diagnostic	Heteroscedasticity, Prob F (8, 101)	0.310
Adjusted R^2	0.480	Tests:	Normality, Prob (JB-statistic)	0.292
Prob (F-statistic)	0.000			
East Coast States Model 4 *(ECSM4)*				
C	0.229	0.023	10.052	0.000*
FDMG	2.070×10^{-6}	2.450×10^{-7}	8.460	0.000*
FDEP	0.042	0.009	4.509	0.000*
FWNG	0.106	0.013	7.591	0.000*
EVRT	-0.144	0.024	-6.115	0.000*
PEXP	-0.038	0.023	-1.694	0.091**
WSYS	-0.022	0.013	-1.647	0.100**
HLCT	0.013	0.012	1.091	0.276
HMTL	-0.002	0.010	-0.209	0.835
R^2	0.409	Diagnostic	Heteroscedasticity, Prob F (8, 371)	0.375
Adjusted R^2	0.396	Tests:	Normality, Prob (JB-statistic)	0.524
Prob (F-statistic)	0.000			

Note: * and ** indicate H_0: $\beta_i = 0$ to be rejected at the five percent and 10 percent significance levels.

All coefficients of the variables except *FDEP*, *AWPR* and *HMTL* in Kelantan Model 1, *AWPR* and *HMTL* in Terengganu Model 2 and *HLCT* and *HMTL* in the East Coast States Model 4 are statistically significant at the five percent and 10 percent significance levels. Thus, these variables particularly social vulnerability indicators such as *EVRT* and *COPM* in Kelantan Model 1, *COPM* and *WSYS* in Terengganu Model 2, *AWPR*, *EVRT* and *WSYS* in Pahang Model 3 and *EVRT*, *PEXP* and *WSYS* in the East Coast States Model 4 significantly influence any decrease in the variation of flood risk among the households at the state and regional levels.

As the effectiveness levels of evacuation route, coping mechanism, flood awareness or preparedness, flood warning systems and past floods experience before and during floods elevate, these would cause reasonable reductions in flood risk among the households in Kelantan, Pahang and the East Coast states of Peninsular Malaysia altogether. For instance, the results indicate that a percent rise in evacuation route would lead to about 0.22 percent decrease in the formation of flood risk among the households in Kelantan. Another instance is that the results indicate that a percent increase in coping mechanisms would render to about 0.09 percent decrease in the flood risk formation among the households in Terengganu. Among others, the findings are aligned with Chan (1995) who highlighted that the potential for the rise in both flood damage savings and resilience to floods are generally high when the flood warning dissemination systems can be further improved and closely linked to local needs in terms of increasing the warned proportion and warning lead time. Apart from that, the findings are seen to be harmonious with Kienzler*et al.* (2015) who asserted that the risk to flood losses is likely to be higher due to shorter lead time, lesser past floods

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experience and perceived probability of being potentially affected and lower knowledge on pre-caution level in facing the floods.

Further, to ensure the goodness fit of a regression model, two diagnostic checking exercises such as heteroscedasticity and normality tests developed by Koenker and Bassett (1982) and Jarque and Bera (1987) as cited in Gujarati (2004) were accordingly conducted. Due to high *p*-values of *F*-statistics and *JB*-statistics posted by the models, i.e. over 0.1 or 10 percent significance level, it can be concluded that all regression models exhibit no unequal residual variances and their associated residuals are likely to follow the normal distributions.

4.Policy Recommendation and Conclusion

Pertaining to the social *FVI* results in Table 5, Kelantan, Pahang and the East Coast states altogether are found to exhibit a feature in common whereby their social vulnerabilities to floods constitute as the highest *FVI* ratings locally and regionally. Also, the results report that the districts of Kota Bharu, Kuala Krai, Kemaman, Kuantan and Temerloh, i.e. excluding Kuala Terengganu, are highly vulnerable to floods in the social aspects. Additionally, the regression results in Table 7 feasibly help to address the social vulnerability, thus leading to a reduction in flood risk among the households at the state and regional levels.

In this regard, one policy recommendation is via increasing the social resilience to floods among affected households particularly in the aspects of awareness or preparedness, coping mechanism, evacuation route, warning system and past floods experience. On the early warning of floods, it is crucial to develop the people-based early warning systems. Thus, it is recommended that the newly improved systems, which feature flood sirens or warnings that are timely and understandable to the affected households, are taken into consideration in terms of the demographic, livelihood, gender and cultural attributes associated with the targeted groups or stakeholders. Also, there is a need to constantly reassess the suitability of coping strategies, evacuation routes, methods and centres so that the currently adopted ones are relevant and well-equipped to handle flood.

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APPENDIX

Table A.1: Reference Data Sources

No.	Indicator	Definition	Unit	Past Studies*
1	Cultural Heritage	The number of historical buildings and religious places were in danger when the recent 2014's major floods hit.	%	Balica and Wright (2010); Karmaoui*et al.* (2016)
2	Population Density	Higher concentration of people at an area implies that higher social vulnerability to floods for the area.	%	Balica and Wright (2010); Karmaoui*et al.* (2016)
3	Affected Households	The ratio of affected households in the district over the total affected households in the entire state from the2014's floods.	%	Connor and Hiroki (2005); Balica and Wright (2010)
4	Education	The percentage of households who receive education at the secondary and above levels in the sample.	%	Connor and Hiroki (2005); Villordon (2015)
5	Household Size	The percentage of expanding household sizes (i.e. more than 4 persons in a family) in a community.	%	Asube and Garcia (1995); Kissi*et al.* (2015)
6	Female	The percentage of female members that belong to a household in the sample.	%	Rashid (2000); Bathi and Das (2016)
7	Disabled Persons	The percentage of persons (i.e. old people aged 60 and above and children under-15 years old and disabled) in a community.	%	Balica and Wright (2010); Balica*et al.* (2012)
8	Population Growth	The rates of population growth in an area over the 2010 – 2014 timeframe.	%	Balica and Wright (2010); Karmaoui*et al.* (2016)
9	Farmers	The percentage of households who are farmers and manage agriculture activities.	%	Mwape (2009); Kissi*et al.* (2015)
10	Shelters	The percentage of households who come forward to get shelters or refuges at times of floods.	%	Balica and Wright (2010); Balica*et al.* (2012)
11	Emergency Services	The percentage of households who seek necessary assistance either from the	%	Balica and Wright (2010);

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		government or other institutions following the floods.		Kissi*et al.* (2015)
12	Awareness/Preparedness	The awareness or preparedness levels of households on how to respond in the wake of the floods.	%	Balica and Wright (2010); Kissi*et al.* (2015)
13	Long Term Residents	The availability of long term residents (i.e. with the staying duration of more than 10 years) in a community.	%	Kissi*et al.* (2015)

Note: *Past author or authors who consolidated the effect of corresponding variable in their flood vulnerability and risk assessments, respectively.

"Table A.1 Continued"

No.	**Indicator**	**Definition**	**Unit**	**Past Studies***
14	Communication Rate	The rate of communication among households that have access to available sources of information on floods.	%	Connor and Hiroki (2005); Karmaoui*et al.* (2016)
15	Past Floods Experience	The usefulness of past floods experience by affected households to deal with the recent 2014's major floods.	%	Balica and Wright (2010); Kissi*et al.* (2015)
16	Evacuation Routes	The probability of households to temporarily evacuate from hit areas to safer and higher places.	%	Balica and Wright (2010); Karmaoui*et al.* (2016)
17	Coping Mechanisms	The effectiveness of coping mechanisms in-place by households to withstand the magnitude of floods.	%	Kissi*et al.* (2015)
18	Warning Systems	The availability of flood warning systems to indicate the early warning of floods.	1 or 0	Balica and Wright (2010); Karmaoui*et al.* (2016)

Note: *Past author or authors who consolidated the effect of corresponding variable in their flood vulnerability and risk assessments, respectively.

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Table A.2: Results of Correlation Analysis

Kelantan Model 1 *(KM1)*

	Dependent	FH			SV															C	
	FR	***FDMG***	***FDEP***	***FWNG***	***FEML***	***DSAB***	***COMR***	***PEXP***	***EVRT***	***COPM***	***CHTG***	***EDUC***	***HSZE***	***FMRS***	***WSYS***	***LTRS***	***ESVAC***	***AWPR***	***SHTR***	***HLCT***	***HMTL***
FR	1.00																				
FDMG	0.56	1.00																			
FDEP	0.31	0.38	1.00																		
FWNG	0.05	-0.17	-0.22	1.00																	
FEML	0.00	0.03	-0.08	-0.13	1.00																
DSAB	-0.05	-0.07	0.13	0.22	-0.55	1.00															
COMR	0.00	0.03	0.29	-0.11	-0.03	0.10	1.00														
PEXP	-0.03	-0.08	0.18	-0.02	-0.15	0.19	0.27	1.00													
****EVRT***	**-0.47**	-0.18	-0.25	0.21	-0.11	0.06	-0.05	0.02	1.00												
****COPM***	**-0.38**	-0.12	-0.26	0.04	0.11	-0.11	0.10	0.11	0.29	1.00											
CHTG	-0.12	0.04	0.05	0.07	-0.03	0.18	0.20	0.17	-0.11	-0.06	1.00										
EDUC	-0.12	-0.22	-0.10	0.14	0.04	0.16	0.03	-0.06	0.06	-0.03	0.11	1.00									
HSZE	-0.15	-0.13	0.07	0.09	-0.19	0.31	0.11	0.19	0.17	-0.01	0.03	0.11	1.00								
FMRS	0.01	0.17	0.06	-0.1	0.03	-0.	0.11	0.31	-0.2	-0.	0.07	-0.1	-0.	1.00							

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				3		12			5	01		3	13								
WSYS	-0.02	-0.05	-0.17	0.17	-0.13	0.08	0.01	0.00	0.22	0.00	-0.09	-0.05	0.16	-0.05	1.00						
LTRS	0.01	-0.06	-0.05	-0.05	0.11	-0.13	-0.07	0.08	-0.08	-0.07	-0.05	-0.18	0.11	0.11	0.06	1.00					
ESVC	-0.01	-0.03	-0.07	0.03	0.13	0.04	0.10	0.14	0.01	0.06	0.31	0.11	0.03	-0.06	0.09	0.09	1.00				
****AWPR***	**-0.23**	0.05	0.15	0.13	-0.19	0.07	0.39	0.16	0.15	0.09	0.06	0.03	0.00	0.08	0.23	-0.26	0.14	1.00			
SHTR	-0.06	-0.06	0.04	0.07	-0.01	0.10	0.10	0.11	0.04	0.02	0.13	0.11	0.03	0.00	0.09	-0.13	0.48	0.39	1.00		
HLCT	-0.17	-0.27	-0.52	0.16	-0.05	0.04	-0.20	-0.43	0.26	0.17	-0.13	0.23	-0.04	-0.46	0.02	-0.11	0.00	-0.02	0.00	1.00	
HMTL	-0.17	-0.04	-0.03	-0.10	0.05	-0.03	-0.01	0.23	0.01	0.15	0.07	-0.07	-0.08	0.06	0.14	0.23	0.21	-0.05	0.01	-0.13	1.00

Note: FH = Flood Hazard, SV = Social Vulnerability and C = Control

* represents the chosen three social vulnerability indicators that are highly correlated to flood risk. A negative (-) sign indicates that an indicator is inversely related with flood risk.

Terengganu Model 2 *(TM2)*

	Dependent	**FH**			**SV**															**C**	
	FR	***FDMG***	***FDEP***	***FWNG***	***FEML***	***DSAB***	***COMR***	***PEXP***	***EVRT***	***COPM***	***CHTG***	***EDUC***	***HSZE***	***FMRS***	***WSYS***	***LTRS***	***ESVC***	***AWPR***	***SHTR***	***HLCT***	***HMTL***
FR	1.00																				
FDMG	0.51	1.00																			
FDEP	0.40	0.11	1.00																		
FWNG	0.56	0.08	-0.10	1.00																	
FEML	0.20	-0.22	0.05	0.10	1.00																

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DSAB	0.18	0.04	-0.08	0.05	-0.13	1.00													
COMR	0.21	0.11	0.23	0.07	0.06	-0.09	1.00												
PEXP	0.14	0.04	0.02	-0.03	0.02	0.06	-0.05	1.00											
EVRT	0.11	-0.08	-0.21	0.00	0.03	0.04	-0.09	0.01	1.00										
****COPM***	**-0.43**	0.16	0.17	0.29	-0.12	0.12	0.25	0.02	0.01	1.00									
CHTG	-0.08	-0.15	0.24	-0.04	-0.01	0.05	0.03	-0.11	-0.35	-0.03	1.00								
EDUC	-0.02	-0.01	-0.24	0.07	0.19	0.02	0.17	0.02	-0.14	0.00	0.17	1.00							
HSZE	0.12	-0.15	0.16	0.01	0.13	0.16	0.15	0.11	0.08	0.30	-0.14	0.17	1.00						
FMRS	0.09	0.23	0.34	-0.02	-0.25	0.09	-0.12	0.06	-0.11	0.04	0.16	-0.18	0.08	1.00					
****WSYS***	**-0.24**	0.47	0.30	0.04	-0.22	0.00	0.14	0.28	-0.35	0.10	0.08	-0.05	-0.12	0.17	1.00				
LTRS	-0.10	0.24	-0.09	-0.26	-0.17	0.00	-0.08	0.07	-0.04	-0.06	-0.14	-0.07	-0.21	0.06	0.25	1.00			
ESVC	0.01	-0.15	0.03	0.16	0.12	-0.12	-0.02	0.02	0.00	-0.22	-0.01	0.02	-0.11	0.08	-0.19	-0.10	1.00		
****AWPR***	**-0.23**	0.00	-0.03	-0.35	-0.04	-0.17	-0.01	0.20	0.24	-0.13	-0.22	-0.12	0.06	-0.04	-0.03	0.26	0.26	1.00	
SHTR	0.01	-0.15	0.03	0.16	0.12	-0.01	-0.02	0.02	0.00	-0.22	-0.01	0.02	-0.11	0.08	-0.19	-0.10	1.00	0.26	1.00

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						2															
HLCT	-0.34	-0.31	-0.36	-0.26	0.13	0.04	-0.03	-0.32	0.07	-0.51	0.04	0.19	-0.14	-0.43	-0.31	0.02	-0.03	-0.14	-0.03	1.00	
HMTL	-0.04	0.10	0.24	-0.30	0.06	-0.09	0.08	-0.10	0.03	-0.13	0.17	-0.19	0.05	0.29	0.10	0.09	0.06	0.37	0.06	-0.03	1.00

Note: FH = Flood Hazard, SV = Social Vulnerability and C = Control

* represents the chosen three social vulnerability indicators that are highly correlated to flood risk. A negative (-) sign indicates that an indicator is inversely related with flood risk.

Pahang Model 3 (*PM3)*

	Dependent	**FH**			**SV**															**C**	
	FR	***FDMG***	***FDEP***	***FWNG***	***FEML***	***DSAB***	***COMR***	***PEXP***	***EVRT***	***COPM***	***CHTG***	***EDUC***	***HSZE***	***FMRS***	***WSYS***	***LTRS***	***ESVC***	***AWPR***	***SHTR***	***HLCT***	***HMTL***
FR	1.00																				
FH ***FDMG***	0.51	1.00																			
FDEP	0.27	0.60	1.00																		
FWNG	0.06	-0.22	-0.38	1.00																	
SV ***FEML***	0.05	-0.05	-0.14	0.10	1.00																
DSAB	-0.17	-0.07	0.04	0.00	-0.43	1.00															
COMR	-0.08	-0.17	-0.11	-0.03	0.16	-0.04	1.00														
PEXP	-0.03	0.20	0.37	-0.32	-0.20	-0.06	0.04	1.00													
****EVRT***	**-0.45**	-0.32	-0.33	0.22	0.23	-0.18	0.06	-0.2	1.00												

									4													
	COPM	-0.08	0.24	0.17	-0.08	0.00	-0.20	0.29	0.35	-0.12	1.00											
	CHTG	0.07	0.00	0.02	-0.18	0.09	-0.01	0.11	-0.10	0.03	-0.08	1.00										
	EDUC	-0.10	-0.27	-0.27	0.19	-0.11	0.07	0.16	-0.25	0.16	-0.15	0.12	1.00									
	HSZE	-0.03	0.16	0.18	0.00	-0.05	0.04	0.19	0.05	-0.04	0.12	-0.04	0.16	1.00								
	FMRS	0.11	0.30	0.37	-0.30	-0.21	0.09	0.15	0.26	-0.31	0.20	0.15	-0.13	0.20	1.00							
	****WSYS***	**-0.28**	-0.08	0.08	0.15	-0.01	-0.07	0.04	0.04	0.11	0.20	0.05	0.07	0.32	0.19	1.00						
	LTRS	0.17	0.34	0.51	-0.29	-0.06	-0.01	-0.04	0.22	-0.24	0.00	0.11	-0.31	0.20	0.13	0.12	1.00					
	ESVC	-0.01	0.04	0.03	-0.04	0.06	0.07	0.13	0.01	0.03	-0.12	0.19	0.08	0.08	0.11	0.13	0.09	1.00				
	****AWPR***	**-0.22**	-0.18	-0.11	0.17	-0.07	0.12	0.37	-0.04	0.22	0.06	-0.01	0.22	0.09	-0.09	0.00	-0.18	0.17	1.00			
	SHTR	0.14	0.08	0.12	-0.06	0.00	0.06	0.13	-0.08	0.11	-0.02	0.40	0.08	-0.11	0.24	0.03	0.09	0.23	0.17	1.00		
C	***HLCT***	-0.03	-0.47	-0.68	0.29	0.22	-0.05	0.06	-0.60	0.36	-0.40	0.15	0.27	-0.17	-0.39	-0.12	-0.27	0.03	-0.01	0.03	1.00	
	HMTL	0.07	0.09	0.19	-0.28	-0.17	0.05	-0.12	0.25	-0.09	0.05	0.15	-0.14	-0.14	0.24	0.10	0.15	-0.09	-0.16	-0.02	-0.21	1.00

Note: FH = Flood Hazard, SV = Social Vulnerability and C = Control

* represents the chosen three social vulnerability indicators that are highly correlated to flood risk. A negative (-) sign indicates that an indicator is inversely related with flood risk.

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East Coast States Model 4 *(ECSM4)*

	Dependent	FH			SV															C	
	FR	***FDMG***	***FDEP***	***FWNG***	***FEML***	***DSAB***	***COMR***	***PEXP***	***EVRT***	***COPM***	***CHTG***	***EDUC***	***HSZE***	***FMRS***	***WSYS***	***LTRS***	***ESVC***	***AWPR***	***SHTR***	***HLCT***	***HMTL***
FR	1.00																				
FDMG	0.46	1.00																			
FDEP	0.31	0.38	1.00																		
FWNG	0.21	-0.12	-0.24	1.00																	
FEML	0.06	-0.05	-0.09	-0.03	1.00																
DSAB	-0.01	0.00	0.06	0.06	-0.36	1.00															
COMR	0.04	0.00	0.14	-0.04	0.07	-0.01	1.00														
****PEXP***	**-0.18**	-0.07	0.19	-0.13	-0.11	0.06	0.13	1.00													
****EVRT***	**-0.33**	-0.20	-0.28	0.14	0.07	-0.04	-0.03	-0.04	1.00												
COPM	-0.07	-0.12	-0.06	0.07	0.03	-0.09	0.20	0.20	0.11	1.00											
CHTG	0.00	0.07	0.12	-0.05	0.00	0.07	0.10	-0.02	-0.17	-0.09	1.00										
EDUC	-0.04	-0.13	-0.17	0.15	0.04	0.08	0.10	-0.11	0.01	-0.07	0.14	1.00									
HSZE	-0.01	0.01	0.16	0.02	-0.06	0.19	0.15	0.10	0.05	0.08	-0.03	0.14	1.00								
FMRS	0.04	0.12	0.21	-0.14	-0.13	0.02	0.05	0.24	-0.22	0.08	0.12	-0.15	0.03	1.00							
****WSYS***	**-0.15**	-0.01	0.02	0.12	-0.12	0.01	0.06	0.06	0.02	0.07	0.02	-0.02	0.13	0.08	1.00						

LTRS	0.02	0.01	0.11	-0.17	-0.04	-0.05	-0.06	0.11	-0.11	-0.04	-0.03	-0.17	0.04	0.10	0.13	1.00					
ESVC	0.00	0.02	0.01	0.03	0.08	0.01	0.07	0.05	0.00	-0.10	0.15	0.07	0.02	0.04	0.02	0.03	1.00				
AWPR	-0.08	0.03	0.03	-0.01	-0.11	0.02	0.26	0.10	0.19	0.01	-0.06	0.03	0.06	-0.01	0.09	-0.08	0.19	1.00			
SHTR	0.04	0.00	0.08	0.04	0.03	0.02	0.07	0.01	0.04	-0.08	0.19	0.07	-0.05	0.11	-0.01	-0.04	0.56	0.27	1.00		
HLCT	-0.12	-0.21	-0.51	0.09	0.09	0.00	-0.08	-0.45	0.23	-0.20	0.03	0.23	-0.11	-0.43	-0.11	-0.12	0.00	-0.05	0.00	1.00	
HMTL	-0.07	0.01	0.11	-0.22	-0.03	-0.01	-0.01	0.17	-0.01	0.03	0.14	-0.13	-0.04	0.17	0.12	0.17	0.06	0.05	0.02	-0.13	1.00

Note: FH = Flood Hazard, SV = Social Vulnerability and C = Control

* represents the chosen three social vulnerability indicators that are highly correlated to flood risk. A negative (-) sign indicates that an indicator is inversely related with flood risk.