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Evaluating the impacts of climate disasters and the integration of adaptive flood risk management

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ABSTRACT

Climatic change and its related impact are among the most challenging threats facing the world at present. Most developing countries are particularly vulnerable to the impact of climate change due to their economic circumstances. As such, they are often less able to implement adaptation strategies to reduce climate-related impact. Based on this, this study deals with the risk, vulnerability and adaptive measures in the case of sudden disasters (i.e. heavy floods and tsunami) by applying the disaster vulnerability approach, using a case study in Malaysia. This study applies three basic indicators of climatic disasters' impact and issues – (i) flood disaster vulnerability (Ω); (ii) flood disaster magnitude (Π); and (iii) integration of adaptive flood risk management (§) using public risk perception of climate disasters and flood prevention strategies. Following the findings, this study proposes procedural and theoretical frameworks which are comparatively new to the research of climate threats (climate change, variability and disasters). Additionally, it offers decision makers' valuable insights which may assist in promoting greater awareness of flood risk management, in both Malaysia and other communities facing similar climate threats and disaster trends.

1. Introduction

From the existing scientific evidence, it can be seen that natural disasters[1] affect the economy, society and state of an environment [1–4]. The severe catastrophic impact of climate change has the potential to impact on both the economics of disasters and perception of natural hazards as addressed by recent studies [5–9]. It can lead to loss of life, injury or ill health, and disrupts human settlements which can result in a community migrating away from their initial habitat [7,10–12]. Damage to infrastructure and environment may also reshape entire landscapes [13–18]. Unexpected climate threats (climate change, variability and disasters) that affect the environment are due to carbon dioxide concentration in the atmosphere, temperature fluctuation, uneven distribution of rainfall, and unpredictable weather patterns [19–21]. The effects of climatic change have been well studied and described, as is evidenced in recent works [22–25]. However, aspects of vulnerability[2] and its links with natural disasters have been largely overlooked [5,11,26–28].

Particularly on issues of adaptive capacity[3] and adaptation strategies to reduce climate-related impacts [29–34]. As a result, some fundamental aspects of disaster due to climate change have remained unpredictable, even though the relative vulnerability to natural disasters has been identified by recent climate change research [19]. The review work by Stern helped to bring to light some fundamental grounds of climate change, and the relative vulnerability of an economy that is particularly at risk and related to natural disasters; suggesting actions to mitigate the effects of future recurrence [25]. Although there may exist a certain level of doubt around the timescales of the related impacts and

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[1] A sudden natural event or a catastrophe that causes damage to the environment or loss of life.
[2] The degree to which people are susceptible to, or are unable to cope with sensitivity, exposure and adaptive capacity.
[3] The capacity of a plan of action to adapt if the environment where the system exists is changing.

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environmental exposures of future events, the vulnerability concerns to society are eminent [19]. Documented scientific evidence has established the interconnectivity of natural disasters and climate change, as well as the climatic effects on the frequency of environmental disaster occurrence [3,17,35–38].

The scale of natural disasters is now growing at an alarming rate. This is due to the rate at which climate change is occurring [39–42]. Soaring urban populations, damage to existing infrastructures, environmental degradation, poverty and disease have all added to the burden of seasonal hazard droughts and floods in several communities. Therefore, several alternative means in quantifying the vulnerability of natural disasters are needed [43,44]. The issues of natural disasters that obstruct economic activity by reshaping an entire landscape are not new. However, scientists are working to explore various contexts, as it impacts on natural disasters, climate change and its related impacts [16, 20,45–50]. Recent existing modelling work has been extensively employed to help assess the direct impact on the various contexts of natural disaster and climatic alteration [3,51].

However, the indirect impact (as expressed by several recent publications) has received similar research attention [13, 25, 45, 47, 49, 50,52–54]. A significant model on perceived behavioural control (PBC) has been developed and applied to related areas. This model is a way of assessing individual's belief and their ability to reduce their impact on the existing situation [55–61]. The application of the model to natural disaster and climatic change is thought to be a useful tool in understanding the response level to natural disasters amongst individuals in Malaysia. Therefore, the true incidence of disaster events and their apparent magnitudes could be determined based on individual information gathered. Thus, the overall incidence of events and their significance can be estimated by using the volatility of events as a measure for the incidence of impact, and can identify the overall effects on the macro-economy. However, the application of the approach may not be able to reveal the total impact, and may overlook the critical impact associated indirectly to an event and its resultant influence on society.

A significant number of direct scientific works are available that assess and measure the impact of changes in economic variables associated with the occurrence of natural disasters. However, indirect physiological or behavioural contexts by different disaster episodes and views about risks are obscure [71,56,58,62]. This study is predominantly focused on the indirect impact resulting from disaster, as a way of contributing information on the psychological and physical vulnerability of individuals. Thus, it is evident that there is a need for a strategy that can capture the risk and vulnerability of individuals in the event of a sudden disaster (both directly and indirectly). This would lead to the correct application of disaster-related guidelines and frameworks, such as in the paradigm of flood risk management.

Flood risk management planning is a process where the risk and vulnerability of sudden disaster occurrence, that requires adequate attention for its management and involvement of relevant stakeholders, is used as a way of addressing climate change and natural disasters' incidents. The quantification of impacts and vulnerabilities adopted measures play a fundamental role. However, quantification of impacts should be included in the planning process using public risk awareness of disasters, which may lead to similar decision support systems. It is well-known that capacity building always accompanies the planning system and process in order to make decisions on the adaptive strategies to be adopted [63–65]. However, how the capacity building should be brought in to the adaptive strategies, action and planning process is still obscure in the related research in Malaysia. Principally, (not only in Malaysia) the national actions for a sudden disaster has suffered due to lack of policy alteration in emergencies and the absence of research in to proper mitigation action in most developing and transitional countries.

Therefore, to overcome the fundamental issues raised in exploring climate disasters, such as floods, this study deals with the risk and vulnerability in the case of sudden disaster, by applying the natural disaster vulnerability evaluation model (NDVE-model) together with the perceptions of flood risks.[4]The study employed three indicators- (i) the flood vulnerability propensity rate, (ii) flood devastation magnitude rate,[5] and (iii) public perception, to establish the different levels of susceptibility and destruction arising from flood disasters to the national economy. Also, major technical foundations related to direct and indirect outcomes which concern public perception are addressed as part of a strategy of flood disasters management. The objective of the study is to offer decision makers assistance in promoting greater public awareness of flood risk management in Malaysia and elsewhere with similar economic backgrounds. Since developing countries are especially vulnerable to disaster events, which claim many thousands of lives each year, it is essential to perform research and document examples which show how these risks may be better understood and managed. This is a further aim which this paper intends to achieve.

2. Research method

Two modules on impact and risk perception[6] were adopted to help address the research framework using natural disasters vulnerability evaluation (NDVE) model. The 'impact' and 'risk perception' modules explored the integration of adaptive flood risk management using a pilot study, to lessen the disasters vulnerability by expanding the theory of reasoned action (TRA) particularly from the Theory of Planned Behaviour (TPB). Thus, this study applied three basic indicators: (i) natural disaster vulnerability (NDV); (ii) natural disaster magnitude (NDM); and (iii) adaptive risk awareness (ARA) to better understand the overall flood risk management and flood prevention activities as further described below:

2.1. Impact module-evaluation of climatic disasters' impact

The natural disasters vulnerability evaluation (NDVE) model assumes that Malaysia is susceptible to a flood disaster anytime. Data were taken into consideration in the application of the NDVE model that considered possible natural disaster scenarios.[7] The NDVE model includes the overall flood disaster ($\boldsymbol{\lambda}$i); floods ($\boldsymbol{\lambda}_1$); tsunami ($\boldsymbol{\lambda}_2$); cyclonic storms ($\boldsymbol{\lambda}_3$) and considered three parameters to estimate the overall flood disaster ($\boldsymbol{\lambda}$i) caused by the natural disasters vulnerability propensity rate ($\boldsymbol{\Omega}$), natural disaster devastation magnitude rate ($\boldsymbol{\Pi}$) and the economic degrowth and risk rate ($\boldsymbol{\Psi}$). The model assumes that $\boldsymbol{\lambda}$i is directly connected to the events of natural disasters over a certain time (t).[8] The quantification of natural disaster vulnerability assumed an interval of probability between zero and one as follows:

$$\text{If } f\,(X!_{n+1})\text{exist}[0,1]\ \forall\ \{X/X\epsilon\ \Omega\ \square\ R_+\}$$
$$P(X!_{n+1}) = \sum R_+\epsilon\ X!_n$$
$$\sum R_+\epsilon\ X!_{n+1} = 1 \quad (1)$$

According to the NDVE, the study applied the rule of irregular series by factorial numbers ($X!_n$) as a function of n as follows:

$$X!_{n+1} = f\,(x!_n) \quad (2)$$

The NDVE model allows for different scales of impacts which are

[4] This study has attempted to find one common strategy by using a pilot region, and dual approach has been developed intensified.

[5] In this part of the model a new concept was introduced "economic degrowth ($\boldsymbol{\delta}$)" [3].

[6] Understood here as the subjective judgement of people about natural hazards and threats to the environment and the severity of a risk.

[7] The NDVE is adopted from Ref. [69] and considered that a natural disaster is an event that can create massive destruction anywhere and anytime without advance notice.

[8] The data captured for time (t) periods are from 1970 to 2011.

assumed to incur some uneven series of events as[9]:

$$X!_{n+1} = T(x!_n) = 2x!_n$$
$$2 - 2x!_n \quad (3)$$

$$X!_{n+1} = T(x!_n) = [T(x!_n)/B(x!_n)] = > 2\,x!_n\ (0 \le x!_n \le 1)$$
$$2 - 2x!_n (0 \le x!_n \le 1) \quad (4)$$

The natural disasters vulnerability propensity rate (**Ω**) is assumed to be directly connected to the Gross Domestic Product (GDP) growth rate (**Ψ**) and natural disasters vulnerability propensity rate (**Ω**) with an interval between 0 and 1 as follows:

$$\Psi_{n+1} \equiv f(\Omega_n) \quad (5)$$

$$\Omega \in [0,1] \quad (6)$$

Thus, the natural disasters vulnerability propensity rate (**Ω**) is considered with a constant (**Λ**) of 6.25 to normalize the result as:

$$\Omega = \sum [\Lambda^*(\lambda_1) + \Lambda^*(\lambda_2) + \Lambda^*(\lambda_3)] \quad (7)$$

$$\Omega = \left(\sum_{i=0}^{\infty} \lambda_i (T/\lambda_i \Lambda)\right)^{t+1} \{i=0,1,2,3...n\ \zeta\ j=0,1,2,3...n\} \quad (8)$$

Where, **λ**i represent the probability with time (**t**) by $0 \le \boldsymbol{\lambda}\mathbf{i_t} \le 1$ and **λ**i = {if $\boldsymbol{\lambda}\mathbf{i} \in \mathbf{0} \le \boldsymbol{\lambda}\mathbf{i_{t+1}} \le \mathbf{1}$} and vulnerability propensity rate (**Ω**) has fallen under three different levels of impacts: as level 1: high vulnerability: 1–0.75; level 2: average vulnerability: 0.74–0.34; and level 3: low vulnerability: 0.33–0.

To calculate the natural disaster devastation magnitude rate (**Π**), the study assumed capital devastation (**Φ**)[10] As:

$$\prod (\Phi, \lambda) = [\Phi_{k(x+1)}] + [\gamma_{L(x+1)}] \quad (9)$$

The GDP risk (**Ψ**) was established based on the partial differentiation between two time periods over the last past year (t) and the present year (t+1) as:

$$\Delta\Psi = \delta\Psi_{t+1}/\delta\Psi_t \ge n \text{ where } n = \{-\infty...,-1,\ 0,\ 1,\ ...\infty+\} \quad (10)$$

Finally, the economic growth decelerates (**–ΔΩ**), and growth domestic product rates (ΔΨ) are assumed based on the natural disasters risk level (**ΔΩ**) and risk rate (**ΔΨ**) as:

$$-\Delta\Omega = \Delta\Psi \text{ x } \Delta\Omega \quad (11)$$

$$\Psi_{final} = \Delta\Psi - \Delta\Omega \quad (12)$$

2.2. Risk perception module-public risk perception of climate disasters and flood prevention actions

The TPB proposes a model capable of measuring how human actions are guided in terms of risk perception and risk experience. Flood prevention activities in society were considered to be dependent variables to understanding the perception of risks. Here, risk perception is a function of TPB and climate disasters awareness and flood prevention actions were functions of indirect flood disasters, and considered as dependent variables. On the other hand, the intention to participate in flood prevention actions were assigned the function of independent variables. The intent is to assess risk perception of climatic disaster, flood risk experience, subjective norms and government and societal actions in the form of intention to participate, which are considered independent variables. The module identified the relationship between dependent and independent variables, together with insight into climatic disaster impact and issues. In this study, we considered several risk perception variables such as by RPCD = Risk perception of climatic disaster, PFRE = Previous Flood Risk Experience, SN = Subjective Norm, G&S = Government & Society and IPFPA = Intention to Participate in Flood Prevention Activities, and PFPA = Participation in Flood Prevention activities. The linkages between PFPA (Participation in Flood Prevention activities with RPCD, IPFPA, and PFPA are shown in Fig. 1.

2.3. Study area and location choice

This study considered Kuala Lumpur and its associated territories as a case study. As a pilot test, Gombak riverbank was used for the study. Located in the Gombak District in Selangor state, its lower zone is situated in the Malaysian capital Kuala Lumpur (Fig. 2). This area has the largest Gross Domestic Product (GDP) and population in Malaysia [66]. The area is considered to be flood and disaster-prone in terms of flood-related disasters, political context, and the status quo of adaptive flood risk management. Essentially, flooding in the greater Kuala Lumpur areas is a recurring phenomenon and has some unique characteristics such as sudden, unexpected and violent hazards in nature that causes environmental, social and economic impact. Notably, the Gombak riverside pilot area has a history of extreme hydrological events which demonstrated the exposure of the territory and overall state. The significant impact and indirect losses such as traffic disturbance, damage to drainage systems, water ponding on parking spaces and on concrete buildings are mostly higher than the direct losses due to hydrological events. The understanding of those hydrological events could provide an enhanced understanding of flood incidents and their magnitudes, from which lessons could be drawn for improved hazard management in other great areas. For these reasons, this area was chosen for the study.

2.4. Sample size and sampling technique

In order to determine the appropriate sample size from the estimated population of 4 million, the following formula was applied to arrive at a sample size of 300.

S= X2NP (1−P)/ d2 (N−1) + X2 NP (1−P)

Where, S = required sample size; X2 = the table value of chi-square for 1° of freedom at the desired confidence level (3.841), N = the population size, P = the population proportion (assumed to be 0.50); d = the degree of accuracy expressed as a proportion (0.05). Interviews were used in support of the general survey and provided useful first-hand information. Thirty questions were asked, and 300 samples (people) took part in the survey.

2.5. Data sources and sample distribution

Data for the study was gathered in September through December from the year 2014–2018. Target respondents were household head residents of Gombak riverside area. Purposive sampling method was employed in this study as the location was the best-suited area for yearly improved hazard management, and the population was too large to include every individual. This sampling technique was chosen because it is fast, inexpensive, and importantly, represents the study objectives. However, to minimise the sampling bias, this study identified all types of respondents and residents such as students, teachers, professionals, farmers, and non-professionals within the study area.

Structured questionnaires were distributed and further face-to-face interviews were conducted. A purposive sampling method and a non-probability survey method was used for the study [67]. A total of 350 questionnaires with 30 questions were distributed to individual respondents with an 85.7% (300) return rate, of which seven of the

[9] The x_{n+1} are random intervals which are related to different natural disasters events with linear and non-linear functions under Lorenz transformation assumptions [70].

[10] The **Φ** is the value is arrived at by dividing the area of infrastructure hit by natural disaster (km^2) by the total area (km^2) in the national economy with the value of human capital devastation (γ).

FIGURES

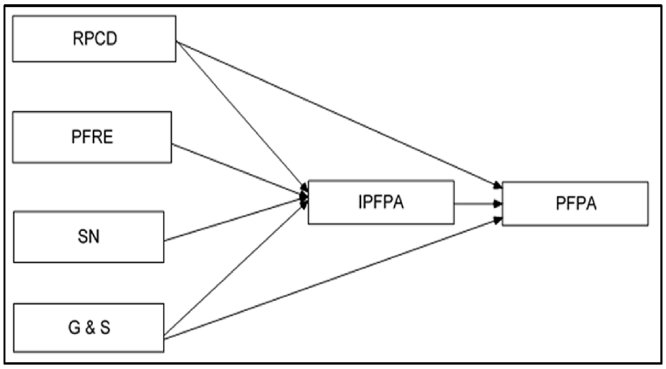

Fig. 1. Proposed research scope.

Public risk perception of climate disasters and flood prevention activities were estimated using econometric analysis. The Cronbach's alpha was applied as a measure of the reliability of the coefficient, which indicates the consistency of the entire scale, to the reliability of the questionnaire. An adapted Confirmatory Factor Analysis (CFA) approach (developed by David and Cosenza [68] was used to confirm the quality of the data that was collected. The data collected included issues on public perception and awareness, integrated and adaptive flood risk management and was used to determine the discriminant validity of our results. Four fit indices; chi-squared statistic; normed chi-square; root mean square approximation (RMSEA); and comparative fit index (CFI) were performed.

3. Results

Fig. 2. Flood-prone areas in Peninsular Malaysia.

returned questionnaires were excluded from further analysis due to non-conformity and missing data. In developing the questionnaire, particularly the problems of flood risk management, questions were considered and based on three sections that gathered demographic data on the respondents. Specifically, on gender, age, race, education, occupation and income. The second section relates to flood risk management awareness. Finally, he third section measured the impact of perceptions of climatic disaster, previous flood risk experience (PFRE), subjective norm (SN), government and society (GS), intention to participate in flood prevention activities (IPFPA) and participation in flood prevention activities (PFPA). The third section considered questions using a 5-point Likert-scale.[11]

[11] It indicates by "1- strongly disagrees" to "5 –strongly agree" and used in the study to allow the respondents the flexibility when answering the questions and to get an overall opinion measurement of the participants around the subject.

Considering the natural disasters vulnerability evaluation (NDVE) model, the vulnerability propensity rate (**Ω**) was measured at three different levels of impacts. Level 1 which is high vulnerability where the value of **Ω** fall under 1–0.75; level 2 which is an average vulnerability, where the value of **Ω** fall under 0.74–0.34; and level 3 which is low vulnerability where the value of **Ω** fall under 0.33–0. The results indicate that natural disasters vulnerability propensity rate (**Ω**) for flood is 0.75, a tsunami is 0.75, and a cyclonic storm is 0.85. This indicates that the vulnerability of the study area in Malaysia, as a flood prone area, has a flood-related disasters' probability of about 78.3% yearly. According to the results, there is no doubt that the possible exposure to climatic disaster impact and flood risk issue is very high and falls under the level of 1. Moreover, the findings indicate that the natural disaster magnitude (Π) for flood in the area is 25, a tsunami is 25, and the cyclonic storm is 10. This shows that the likely yearly flood risk magnitude rate is 25%, likely tsunami risk magnitude rate is 15%, and likely cyclonic storm magnitude rate is 9%. The overall likely flood

Table 1
The climatic disasters' impact and flood risk in Malaysia.

Events	Risk level (ΔΩ)	Magnitude (Π)	Risk rate (Ψ)	Risk perception (§)
Floods	0.75	25	18.5	0.22
Tsunami	0.75	15	11.3	0.20
Cyclonic storm	0.85	9	7.6	0.23

disaster magnitude rate of the area was determined to be 16.67% yearly, and this was considered to be high compared to the rest of the ASEAN (Association of Southeast Asian Nations) regions. The flood risk rate was 18.5%; the tsunami risk rate was found to be 11.3% and 7.6% for cyclonic storm yearly (Table 1). The likelihood of yearly flood disaster risk rate was determined to be 12.46% and is considered to have a higher impact in the event of any occurrence. Finally, the risk perception (§) data from the model revealed that flood risk in the area is 0.22, a tsunami is 0.20, and the cyclonic storm is 0.23 (Table 1).

The result of the risk perception module gathered demographic information; including gender, age, race, education, occupation and income of the respondents. The demographic characteristics showed that males made up 57% of the respondents and females made up 43%. The age distribution of respondents ranged between 18 and over 60 years of age. The highest number of respondents was 47.6% from the age group between 31 and 45 years. The second largest group of respondents was 44.6% between 18 and 30 years old. Lastly, 7.6% of the respondents ranged from age 46–60 years. Regarding the educational status of the respondents, 26.66% had a university degree, 24.66% had a diploma, 21% had higher secondary education, 17.66% had lower secondary education, 6.66 had primary education, and 3.33% had no formal education (Table 2). In this study, we found that the majority of respondents' (48.66%) averaged a monthly income range between RM 2001 and RM 4000, while approximately 43.33% of the respondents earned between RM 4001 and RM6000.[12]

The questionnaire results also revealed that:

a) 56% of the respondents in the flood-prone area were willing to have insurance against floods; while
b) 52% were willing to involve themselves in different flood preventing activities;
c) 38% were willing to collaborate in voluntary work;
d) 36% were willing to contribute money toward water generation;
e) 33% were willing to prepare food;
f) 30% were willing to prepare for water, and
g) 25% were willing to contribute money towards a warning system and move to a safer region (Fig. 3).

Based on the survey, 60% of the respondents take their family away when there is a safety concern, 55% are careful of their valuable effects, 40% take their animals to safety, and 40% call a warning centre (Fig. 4).

However, in order to prevent flood risk, respondents face several challenges. 50% of the respondents mentioned that they do not have adequate insurance against floods, 45%, indicate that they are not experts in handling flood recovery issues, 40% mentioned that they are often delayed in receiving warnings, 30% indicate that they receive inadequate information, and 24% mentioned that they do not have adequate access in the community for flood prevention activities (Fig. 5).

The result of the CFA tests indicate that all seven dimensions had adequate model-to-data fit: the normed chi-square value was below 2.41; the CFI value was above 0.95, and the RMSEA value was less than 0.080 (Table 2). The test evaluated the reliability and construct

Table 2
Demographic information of the respondents.
Source: [22].

Variables	Frequency	Percentage (%)
Gender		
Male	171	57
Female	129	43
Age		
18–30 years	134	44.6
31–45 years	143	47.6
46–60 years	23	7.6
Race		
Malay	250	83.33
Indian	33	11
Chinese	15	5
Others	2	0.66
Education		
No formal education	10	3.33
Primary education	20	6.66
Lower secondary school	53	17.66
Higher secondary school	63	21
Diploma	74	24.66
University Degree	80	26.66
Income		
RM 2000 and less than	23	7.66
RM 2001- RM 4000	146	48.66
RM 4001- RM 6000	130	43.33
RM 6001- RM 8000	23	7.66
RM 8001 and above	13	4.33

validity. All six dimensions were found to have reliability values above 0.70, which indicates that the questionnaire was reliable and consistent. The results found that all the variables considered had significant factor loadings (i.e. all were higher than 0.70), which indicates adequate discriminant and convergent validity (Table 3).

Structural Equation Modelling (SEM) was used to examine the relationship between the perception of climatic disasters, previous flood risk experience, subjective norm, and government and society intention to participate in flood prevention activities. The relationship between those factors was used to assess the possible plans to '*participate*' in flood prevention activities and '*intention* (e.g. interest) to participate in flood prevention activities[14] (Fig. 6). The findings from SEM are important, as using the relationship between these variables will provide decision makers with more information on how to formulate adequate and adaptive flood risk management. It will also help to promote greater awareness on flood risk management should these events occur. The model had an adequate fit: chi-squared per degree of freedom (7.511/4) = 1.877 (i.e. less than 3); CFI = 0.997 (i.e. greater than 0.90); p = 0.11 (i.e. less than $p \geq 0.005$); and RMSEA = 0.055 (i.e. less than 0.088). The R-squared for the two dependent (endogenous) variables (the intention to participate in flood prevention activities had a value of 0.71 and participation in flood prevention activities 0.63) indicated that the independent (exogenous) factors could clarify a large percentage of variance in the dependent factors. All hypotheses in our study supported in the SEM were significant ($p = < 0.001$), except hypothesis 3 (Table 4).[13]

In addition, the SEM model shows that three factors – namely, risk perception of climatic disasters ($\beta = 0.251$, $p < 0.01$), previous flood risk experience, ($\beta = 0.261$, $p < 0.01$) and government and society ($\beta = 0.382$, $p < 0.01$) – had a positive and significant influence on the intention to participate in flood prevention activities. There was also an indication that the intention to participate in flood prevention activities

[12] US$ 1 = RM4.1 (Ringgit Malaysia), as of February 2019.

[13] The other relevant results are given in the appendix.

[14] **Legend** = **RPCD** = Risk perception of climatic disaster, **PFRE** = Previous Flood Risk Experience, **SN** = Subjective Norm, **G&S** = Government & Society and **IPFPA** = Intention to Participate in Flood Prevention Activities, **PFPA** = Participation in Flood Prevention activities.

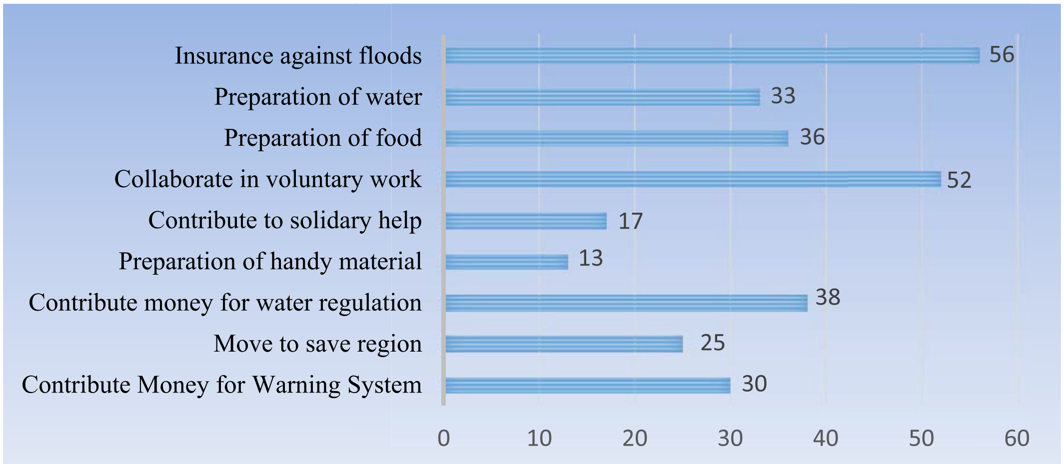

Fig. 3. Willingness to take measures against floods.

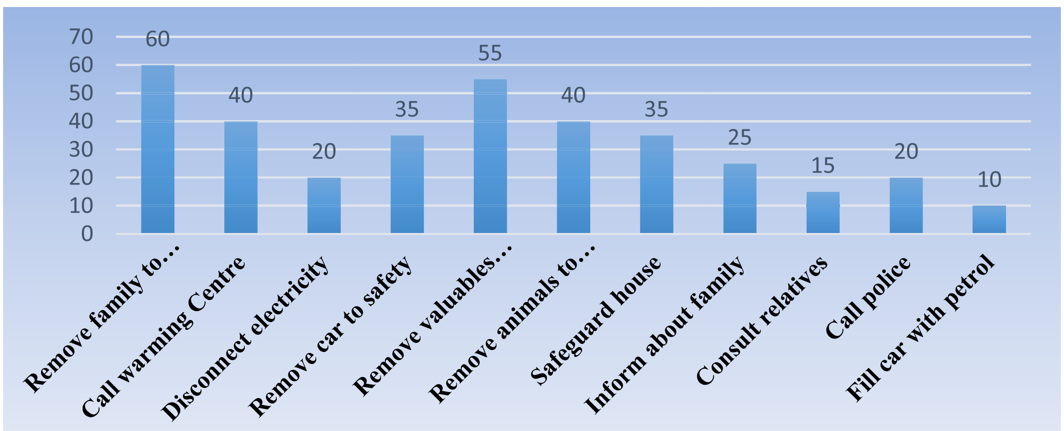

Fig. 4. Activities due to the threat of flood.

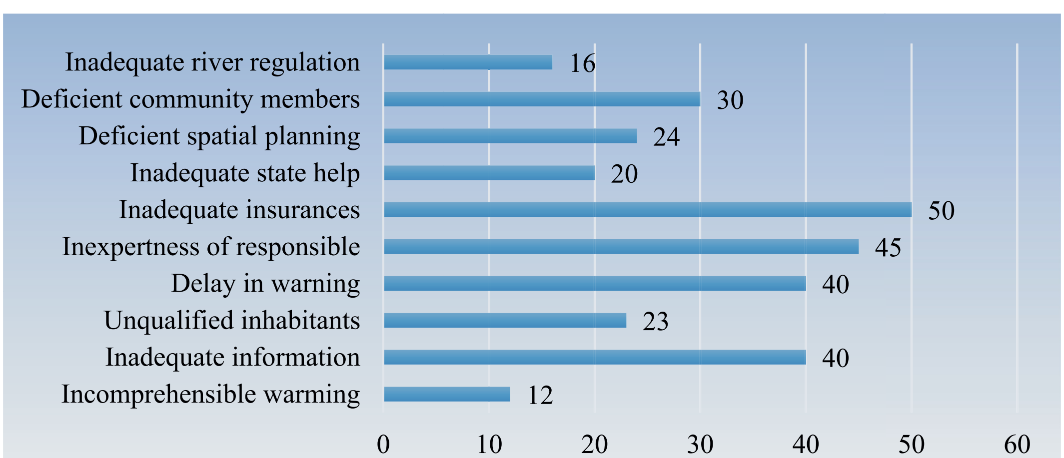

Fig. 5. Deficiencies in counter-measures.

had a positive and significant influence on participation in flood prevention activities ($\beta = 0.221$, $p < 0.01$). The results also indicate that risk perception of climatic disaster ($\beta = 0.201$, $p < 0.01$) and government and society ($\beta = 0.231$, $p < 0.01$) had a direct and significant positive impact on participation in flood prevention activities. This resulted in a partial mediating effect between the risk perception of climatic disasters, government and society and participation in flood prevention activities.

4. Discussion and policy implications

This study showed that climate change related disaster, mainly flood disaster, should be considered among the top priority for the Malaysian policy and decision-makers. The values of risk level ($\Delta\Omega$), magnitude (Π), risk rate (Ψ) and risk perception (§) justify the need for the aim that was under consideration by the study goal. The world's scientists express concern regarding climate-related transformational

Table 3
Construct validity of confirmatory factor analysis.

Items	Stand. loadings	Reliability
Risk Perception of Climatic Disasters (RPCD) (*Normed* X^2 = 1.536, *CFI = 0.905, RMSEA = 0.062)*		0.86
Climatic disaster is a serious problem	0.76	
Economic instability	0.80	
Impacts on agricultural production	0.82	
Increased flooding	0.65	
Increased food costs	0.60	
Previous Flood Risk Experience (PFRE) (*Normed X^2 = 1.19, CFI = 0.911, RMSEA = 0.050)*		0.80
Freshwater shortage	0.77	
Not enough safe food	0.84	
Loss of wetland	0.69	
Loss of farming land	0.68	
Energy shortage	0.61	
Human diseases outbreak	0.62	
Subjective Norm (*Normed* X^2 = 2.246, *CFI = 0.943, RMSEA = 0.075)*		0.85
I will feel ashamed if I do not prepare while my relatives and family were taking action for flood protection	0.77	
If I take action for flood protection, I think my close friends will be impressed with what I do	0.75	
I will feel ashamed if I do nothing while my neighbours are taking measures for flood protection	0.85	
Government & Society (GS) (*Normed X^2 = 1.335, CFI = 0.922, RMSEA = 0.061)*		0.89
The government takes action to protect people against environmental risks.	.77	
The government is concerned about environmental risk impacts on ecosystems.	.85	
The government makes effective policies to adapt to global environmental change.	.89	
Decisions made by the government to deal with environmental risks are good ones.	.87	
People in our society could deal with environmental hazards with the help of others.	0.62	
Social insurance systems can help the public deal with damages from environmental problems	0.67	
Intention to Participate in Flood Prevention Activities (IPFPA) (*Normed X^2 = 1.663, CFI = 0.945, RMSEA = 0.081)*		0.87
I want to participate in disaster preparedness classes or drills	0.65	
I want to join a voluntary disaster prevention organization	0.67	
If administrative organizations hold disaster prevention drills, I want to participate	0.70	
I think that flood damage can be minimized if everyone takes disaster prevention measures	0.78	
I am interested in involving for flood damage mitigation measures and flood control works	0.68	
Participate in Flood Prevention activities (PFPA) (*Normed x^2 = 1.672 CFI = 0.934, RMSEA = 0.071)*		0.81
I will do everything to prevent flood	0.74	
I used to clean private drainage systems and encourage others	0.66	
Sometimes I use to pick up garbage and debris materials that may wash into storm drain inlets or gutters	0.71	
It is my responsibility to encourage my neighbours to take necessary steps to prevent flooding dispose	0.69	
I feel mitigation strategies become necessary for all of us	0.63	

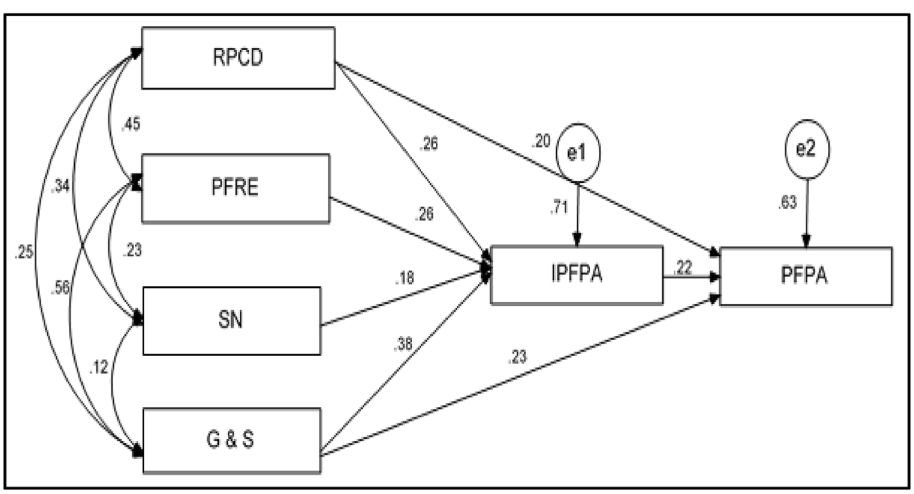

Fig. 6. Relationship among RPCD, PFRE, SN, G&S, RPCD and IPFPA.

Table 4
Hypothesis path coefficients.

Hypothesized paths		Coefficient (β)	P-value (sig.)	Remarks
H1	RPCD → IPFPA	0.253	0.000	Supported
H2	PFRE → IPFPA	0.261	0.000	Supported
H3	SN → IPFPA	0.180	0.070	Unsupported
H4	G&S→ IPFPA	0.382	0.000	Supported
H5	RPCD→ PFPA	0.201	0.000	Supported
H6	G&S → PFPA	0.231	0.000	Supported
H7	IPFPA → PFPA	0.221	0.000	Supported

effects for unexpected events like heavy floods, tsunami and cyclones on the earth and ecosystem. This was found to be the case in our analysis and can be seen in the Malaysian national economy. Thus, there may be a disparity in the time-scale of global issues, but it is doubtless that natural disasters, particularly flood-related disasters, are prone in Malaysia. Climate change, accompanied by frequent temperature changes and rainfall, has helped to increase the occurrence of disaster events recorded. Worldwide, scientists are looking for a possible way to lessen these impacts. Therefore, this study explored a better approach to climate change issues (and resultant natural disasters) as a further step in understanding possible measures to lessen its impact using the natural disaster vulnerability evaluation technique alongside behavioural analysis. This is a new approach, particularly when looking at Malaysia, providing insight into the natural disaster's vulnerability propensity, natural disaster devastation magnitude rate and how public perception and awareness on sudden disaster could further improve flood prevention actions.

The adoption of the NDVE model considered floods (λ_1), tsunami (λ_2), and cyclonic storms (λ_3) as the three fundamental factors related to the natural disasters vulnerability propensity rate, magnitude rate and economic degrowth rate. These three factors are considered to have significant environmental impacts directly related to the study area, (in particular given the time of the year) with either having a high vulnerability, average vulnerability, or low vulnerability probability of resulting in any flood-related disaster. The study used two periods between the present year ($t+1$) and past year (t) to measure the economic degrowth and risk rate. The study then proceeded to measure economic growth deceleration ($-\Delta\Omega$) based on the determinant of the natural disasters risk level ($\Delta\Omega$). In contrast, the risk perception module by TPB takes the essence of the NDVE model and explores the integration of adaptive flood risk management to lessen the disaster vulnerability using econometric analysis; the Theory of Reasoned Action (TRA). The planned behaviour indicates a significant relationship by developing the linkages between public risk perception to overall flood risk management and flood prevention activities while developing an integrated adaptive strategy around risk management through awareness actions.

In addition, the results from the TPB indicate that the β value (awareness activities before the sudden flood disaster event) was significant ($\beta = 0.221$, $p < 0.01$) to the risk perception of climatic disaster, previous flood risk experience, government and society and an intention to participate in flood prevention activities. In reality, the awareness activity if taken on board in the flood prevention strategy, will contribute towards possible mitigation measures for sudden flood-related disaster. They are thereby forming part of a vital component of adaptive risk management guidelines and frameworks. Flood prevention participation analysis and intention to learn more about risk perception of climatic flood disaster analysis from the data were also found to have a significant effect ($\beta = 0.231$, $p < 0.01$) around partial mitigating of risk and disaster. It was concluded that awareness activities should be a dynamic component in the risk management frameworks, where government and society should be involved simultaneously in the process. Stakeholder participation in the decision-making process was found to be necessary. The study results are ideal for developing into a national framework by taking the public perception and applying to flood prevention activities.

Considering the results from the NDVE model and TPB, it is essential to develop strategies that will involve all stakeholders, suitable resource applications, and applicable process design in order to assess the efficiency and effectiveness of measures that would be adopted for an adaptive flood risk management. There is now an urgent need for the adoption of a new approach aimed at sustainable integrated flood disaster framework, due to the ever-increasing global environment-related disasters, especially in the ASEAN region.

This study also has some limitations. Firstly, the sample is not very large, so the findings obtained need to be contextualised. Secondly, the focus of the work was in Malaysia. t would be helpful to add other countries in Asia in order to gain a more thorough geographic coverage. Finally, the 'impact' and 'risk perception' modules could be complemented by other modules, to explore the integration of adaptive flood risk management better.

Despite the above, the present study's findings shows the importance of stakeholder's participation and public perception in flood prevention activities as an avenue for managing environmental disaster impact through an adaptive flood risk management approach. Flood disaster frameworks can be developed by using direct measures with the occurrence of natural disaster events. However, without risk perception the public may interpret disasters as unexpected events, and their patterns may hide huge variations between different disaster episodes. This study tried to solve the limitations of direct modelling measures as no such research to date has been carried out using this concept in Malaysia. A strategy that can capture possible vulnerability in all related aspects of a sudden disaster and can lead to the correct outcome is found in this study. Therefore, the study guides relevant agencies in the technical grounds and shows a way forward for adaptive flood risk management frameworks in the national climate policy. Importantly, it offers fundamental insights on stakeholder participation in adaptive risk management outlines.

5. Conclusion

The national policy in Malaysia has suffered from sudden natural disaster-related effects; mainly flood related. Appropriate policy adjustment in emergencies is fundamental to suitable mitigation measures; agile adaptation to policy is currently lacking. Flood prevention activities were found to be absent in Malaysia with this backdrop, the study highlights three fundamental issues in sudden disaster management; (i) the natural disasters vulnerability propensity rate (Ω); (ii) the natural disaster devastation magnitude rate (Π); (iii) economic desgrowth rate (δ) and how it affects public risk perception of climate change disasters, and prevention activities applied to flood-related impacts and vulnerabilities. The study also addresses critical messages on climate change and related adverse outcomes, and delivers opportunities which are relatively novel to evaluate the climatic disasters' impact. It also highlights the importance of the integration of an adaptive flood risk management framework. It also brings to light public perceptions and risk observation experience on impact and vulnerability in the case of sudden flood-related disaster events. The experience of public perceptions and risk observation is a vital tool that can assist in promoting greater awareness of flood risk management events.

6. Ethical statement

Authors appearing on the submission have contributed sufficiently to the scientific work and therefore share collective responsibility and accountability for the findings and discussions.

Conflicts of interest

The authors declare that there is no conflict of interest in the manuscript.

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Appendix A. Supplementary data

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