Development of Flood Vulnerability and Risk Indices for Kelantan District, Peninsular Malaysia

A.M.A. Bahar*, M. Muhammad*, M. T. Anees* and M. M. A. Khan*†
*Department of Geoscience, Faculty of Earth Science, Universiti Malaysia Kelantan, Campus Jeli, 17600 Jeli, Kelantan, Malaysia
†Corresponding author: Mohammad Muqtada Ali Khan; muqtada@umk.edu.my, muqtadakhan@gmail.com

ABSTRACT
Natural hazards are inevitable which required proper monitoring and application of mitigation measures to reduce vulnerability and risk. Flood is one of the most common natural hazards in Malaysia. The present study was conducted to identify vulnerable flood zones using flood vulnerability and risk indices and to minimize flood damage by suggesting mitigation measures. Four sub-districts of the Kelantan state, Peninsular Malaysia were selected based on the availability of the data and flooding history. For this purpose, demographic, social, economic, and flood event data were collected to develop flood vulnerability and risk index. Descriptive and inferential statistics were used to analyze the results. The results revealed that developed flood vulnerability and risk indices accurately predict high-priority zones. Overall, it was found that flood risk is relatively higher in a rural area compared to an urban area.

INTRODUCTION
Flooding is a frequent natural hazard that causes the loss of human lives and the economy. Spatio-temporal patterns of flooding can be influenced by uncontrolled construction of buildings and land-use changes. The primary cause of the flooding is a storm which is due to high rainfall in a short duration. In high rainfall conditions, the intensity of flood is generally accelerated by settlements along the floodplains. Additionally, other factors include topographic variation, geomorphological changes, dense drainage networks, engineering structures, and dynamic climatic conditions.

Flooding is common in Malaysia which causes 90 percent losses due to natural hazards. The average annual flood damage is approximately US$100 million (Chan 2015). In the state of Kelantan, the Kelantan River bank periodically overflow from November to February. Under the 50-year flood situation at Kusial Bridge, the projected flood volume is around 6 billion m$^3$. In 1926 and 1967, significant flooding occurred and in the year 1967 floods, 84 percent of the population of Kelantan (537,000 people) was badly affected (Hassan & Rozi 2006). About 125,000 individuals have been evacuated and 38 have drowned.

Resilience principles must be implemented to provide adequate protection against the rising trend of flash flooding and its effects on civilization. To create a clear theoretical and practical foundation for flood resilience, the idea of flood vulnerability in flood-prone areas needs to be addressed. Although, several methods of flood impact assessment have been developed (Penning-Rowsell et al. 2005, Yahya et al. 2016). Adaptation and advancement of theory, methodology, and practice in vulnerability assessment involve sudden changes in the present city areas. Although the definition of vulnerability is closely linked to susceptibility, impact assessment begins with a quantitative approach. This applies not only to retrospective evaluations but even to a large degree to prospective cases where future flood impact assessments can address the disruption of the socio-economic backbones of society and their effects on regional, national, and even transnational networks, due to the increasing availability of data. Due to the influence of several factors, vulnerability varies in different conditions (Ibrahim et al. 2017). The cumulative impact of several factors can be assessed using a vulnerability index. The primary task of vulnerability index development is to identify the most vulnerable area to flooding which is an important tool in flood management.

A significant unit of the population is affected by flood risk in Peninsular Malaysia. Rapid increment in settlement on floodplains causes exposure of a large number of people and property to flooding risk (JICA 1982). Vulnerability increases due to inaccurate responses from the public living in floodplains. Flood mitigation should be able to address severe risks in an area. Information about the level of danger,
exposure, and vulnerability is required for priority action in overcoming flood problems. Flood damage can be reduced by identifying flood-prone areas and applying proper mitigation measures (Lee & Choi 2018). Therefore, the objectives of the study are to identify vulnerable flood zones using flood vulnerability and risk indices and to minimize flood damage by suggesting mitigation measures.

MATERIALS AND METHODS

Location and Details of the Study Area

This work was conducted in the Kelantan state of Peninsular Malaysia. The area of the state is approximately 15000 km² (Anees et al. 2019). The highest elevation is 2187 m above mean sea level. The northern part of the state is surrounded by the South China Sea. Gua Musang Town of the district Gua Musang, Kuala Krai Town of the district Kuala Krai, and its two sub-districts such as Manik Urai and Kuala Pergau were selected based on administrative similarities in status and flooding exposure among locations (Fig. 1).

The area has a tropical and humid climate with mean variation in temperature as 20 to 30°C. High precipitation is generally recorded from November to January, while low precipitation is in June and July. The mean annual precipitation is 3020 mm while the mean daily annual wind speed is 1.50 m·s⁻¹ (Anees et al. 2018).

Data Used

Primary data was collected directly from main sources through interviews, surveys, and questionnaires. Whereas, secondary data was collected from the literature. Secondary data is accessible through different public and government records and online sources. The summary of the data is given in Table 1.

Methodology

Primary Data Collection

Primary data include field surveys, field photographs, interviews with regional government offices, and household surveys with GPS locations. The survey was conducted within flood-prone areas. Factors considered for sampling were the vicinity of the flood-prone area, past flood records, and tenancy by infrastructure, land properties, and settlements in collaboration with community leaders.

- Interviews were conducted with representatives of stakeholders consisting of experts relating to floods, local government, and communities in various circles. Interviews were conducted with 200 respondents.
Documentation study, which is to collect and study data or documents that support research, at least several relevant agencies such as the Malaysian Meteorological and Public work.

The questionnaire was given to 200 residents who experienced this disaster to find out their condition and response to the flood. The questions given in the questionnaire are important variables in analyzing flood risk. The components of the question are Flood hazard experience, related to depth, duration, and other flood characteristics such as distance from rivers and physical impressions. All questions are expected to become significant data in discussing flood hazards. Flood exposure, about the elements at risk that are affected around the respondent, especially those of vital value to the respondent, and flood vulnerability, which relates to the economic and social impacts of the respondent due to the flood, either directly or indirectly while flood risk, concerning vigilance and action in anticipation of floods.

### Development of Flood Risk Classification

Flood Risk is analyzed and grouped into four parameters, namely flood hazard, exposure, and vulnerability. The analysis was carried out with 2 analytical methods, namely spatial analysis, and scoring analysis. These results are then converted spatially using the Weighted Linear Combination (WLC) method to ensure that the weighted translations of different variables derived from the Analytic Hierarchy Process (AHP) equation can be converted into maps in a relevant way. The WLC is the most common methodology in multi-scale evaluation analysis.

Development of spatial risk index using spatial layer overlay for all areal units (Census Tract) of each flood hazard region. The operation was between the hazard and the spatial layers of flood impact. Based on the spatial vulnerability intersection and exposed layers, the impact layers were formed. The Raster multiplication technique was used for the spatial intersection. The calculation of index value and map ranking for all raster grid cells were based on created index values (Rucinska 2014). Therefore, “the flood risk (RF) map” is the “spatial intersection of flood hazard, social (population) and exposure vulnerability” (Equation 1).

\[
RF = HF_i \cap VP_i \cap VE_i
\]  

(1)

where HF is a spatial layer of flood hazard which is equal to \( \cap_{HFi} \) HFi is the several flood hazards related to areal components, VP is a spatial layer of social vulnerability which is equal to \( \cap_{VPi} \) VPi is different population vulnerabilities related to the areal components, VE is a spatial layer of vulnerability due to infrastructure exposure which is equal to \( \cap_{VEi} \) VEi is different infrastructure related to the areal components.

Scoring is a decision-making technique in a process that involves factors together by assigning a value to

### Table 1: Summary of data used in this study.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Parameter/Variable</th>
<th>Frequency</th>
<th>Duration</th>
<th>Source/Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic data</td>
<td>Population Size</td>
<td>Study Area</td>
<td>2014, 2015</td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td>Social Data</td>
<td>• Household size</td>
<td>Household-level</td>
<td>N/A</td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td></td>
<td>• Gender of household</td>
<td></td>
<td></td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td></td>
<td>• Educational level</td>
<td></td>
<td></td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td></td>
<td>• Health status</td>
<td></td>
<td></td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td></td>
<td>• Age</td>
<td></td>
<td></td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td></td>
<td>• Occupation</td>
<td></td>
<td></td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td>Economy</td>
<td>Household income</td>
<td>Household</td>
<td>N/A</td>
<td>Questionnaire Survey</td>
</tr>
<tr>
<td>Flood events</td>
<td>Flood, flood extreme, flood hazard, exposure, and vulnerability.</td>
<td>Flood events in Kelantan and Malaysia</td>
<td>Various periods and time</td>
<td>Previous researcher, publication, and government records</td>
</tr>
</tbody>
</table>

Nature Environment and Pollution Technology • Vol. 21, No. 4, 2022
each factor. In determining the scoring assessment can
subjective scoring is carried out, namely by setting a score
based on certain considerations and based on an under-
standing of the process, or objective scoring is by statistical
calculations.

The scoring process is useful for assigning a score to
each score parameter that affects flooding. The greater the
influence, the higher the score. For scoring, a score of 1 is
given to parameters that have a minor effect and a score of
5 is given to the parameter which has a major effect on
flooding.

The procedure of the decision-making method using AHP
analysis for the appropriate site selection zone is as follows:

- Hierarchy building at several levels. Hierarchy design-
ing for all parameters of flood hazard, exposure, and
vulnerability.
- Based on the couple, element comparison of the decision
to reduce the decision-making concept.
- Determination of parameters by the normalization of
the Eigenvector associated with the maximum Eigen
matrix ratio. Comparison matrix couples are shown in
Table 2.
- Calculation of each parameter weight using pair ratio
with an assumption. If the consistency ratio (CR) value
is 0.10, then the judgment is inconsistent or bad sensi-
tivity value.

Spatial analysis is the aggregation weights relative that
has been produced in the previous stage to produce composite
weight as the final score of spatial decision making.

**Statistical Analysis**

In general, the analysis used in this research is quantitative
analysis techniques based on statistical analysis. This
analysis is divided into two groups, namely:

- Use descriptive statistics to analyze collected data
to avoid general conclusions or generalizations. The
analysis is only in the form of an accumulation of
basic data and descriptions, in the sense that it does
not seek or explain relationships, test hypotheses,
make predictions, or draw conclusions. For example, in
analyzing questionnaire data, field measurement data,
and secondary data from Hyetograph and Hydrographs.
- Inferential statistics It is concerned with drawing
conclusions and making assumptions based on
observations, such as correlational analysis and
comparative analysis, that have been carried out. Correlational research is to find an association or effect
between the Independent Variables and the Dependent
Variables. Comparative Analysis Comparative
analysis is a method of mathematical analysis aimed
at comparing the circumstances between two or more
types. The measurement methodology used is often
quite varied, depending on the type of data size and
the number of categories, and the application of these
analysis techniques. For example, the relationship
between facets of floods, such as flood risk, exposure,
and vulnerability, is studied.

**RESULTS AND DISCUSSION**

In this study, flood vulnerability has been defined as a
combination of three types of distinctive vulnerabilities such
as economic, infrastructure, and social. Each of these three
types can further be categorized in Table 3. To determine
Infrastructure, a social and economic vulnerability that was
impacted by the flood in 2014, a survey using a questionnaire
and interviews with 200 respondents, as illustrated in figure
(Fig. 2), was undertaken. The questionnaire containing
seventeen questions was provided to the community of Gua
Musang, Kuala Krai, Kuala Pergau, and Manik Urai to those
who experienced the flood occurrence in 2014. The Analytic
Hierarchy Process (AHP), a quantitative analysis technique,
is used to compare flood vulnerability index components
like the social vulnerability index, economic vulnerability
index, and infrastructure vulnerability index, especially in
determining the weight of all associated parameters.

**Economic Vulnerability**

Economic vulnerability (EV) is represented by total loss
data including losses in transportation, buildings, household,
shop, and farms. For this study, economic vulnerability is
classified into 3 classes based on the below calculation:

\[
\text{Total loss (RM) = \frac{(\text{high total loss}) - (\text{low total loss})}{3 \text{ (classes)}} \ldots (2)}
\]

Based on data survey in the study areas (Gua Musang,
Kuala Krai, Kuala Pergau dan Manik Urai), three classes
of economic vulnerability can be determined - High total
loss (H), Medium loss, and Low loss. Where, H > RM 100
000, M < RM 100 000 and > RM 50 000, and Low (L) <
RM 50 000.

<table>
<thead>
<tr>
<th>Value</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equally important</td>
</tr>
<tr>
<td>3</td>
<td>Quite important</td>
</tr>
<tr>
<td>5</td>
<td>High importance</td>
</tr>
<tr>
<td>7</td>
<td>Very high importance</td>
</tr>
<tr>
<td>9</td>
<td>Extremely high interests</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Values between each criterion</td>
</tr>
</tbody>
</table>

Table 2. Comparison matrix couples (Imanda & Andono 2015).
The results of the classification study Economic vulnerability in the 4 study areas can be seen in the graph (Fig. 3):

Based on the data above, economic vulnerability by area is calculated in Table 4:

### Social Vulnerability

The focus of social vulnerability on occupation, gender, and age is shown in Fig. 4. These factors have important physical or mental characteristics which affect a person’s ability to take preventive measures against flooding.

Fig. 4 shows that, in December 2014 Kelantan flood, people below the age of 20 years are exposed more. It also showed that young people are more vulnerable to flooding than older people. In Fig. 4, fewer gender differences mean no effect in identifying the flood-level social vulnerability during the flood.

Fig. 5 shows the Respondents’ classification based on their occupation. Based on collected data, most people are involved in the business which affects more during the flood. Additionally, unemployed people experienced the same. Overall results showed that flood vulnerability can be determined based on the impact experienced by the type of

<table>
<thead>
<tr>
<th>Area</th>
<th>Total Lost</th>
<th>EV Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang</td>
<td>2,600,000.00</td>
<td>Medium</td>
</tr>
<tr>
<td>Kuala Krai</td>
<td>5,100,000.00</td>
<td>High</td>
</tr>
<tr>
<td>Dabong</td>
<td>2,795,000.00</td>
<td>Medium</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>4,140,000.00</td>
<td>High</td>
</tr>
</tbody>
</table>
Calculation of the Social Vulnerability Index (SVI) is the result of accumulating all vulnerability parameters into the following equation:

\[ SVI = \left( \text{weight} \times \text{ratio} \frac{F}{M} \right) + (\text{weight} \times \text{range of age}) + (\text{weight} \times \text{occupation}) \]  

...(3)

Through calculations using AHP, the weight of each SVI parameter is shown in Table 5.

\[ SVI = (0.24 \times \text{ratio gender}) + (0.54 \times \text{range of age}) + (0.21 \times \text{occupation}) \]  

...(4)

By combining all elements of social risk, including multipliers, the overall score results are obtained as shown in Table 6.

Physical Vulnerability

The final category is infrastructure vulnerability, which includes road networks, railways, bridges, hospitals, and schools. Infrastructure is one of the basic requirements for population, communication, and safety which can be affected by floods. Schools can be used as evacuation places or centers of aid during a flood. Hospitals require special protection during floods. If hospitals get affected by flooding, it could worsen the treatments. As to be concluded, critical facilities tend to give special attention to vulnerability analysis to provide a more accurate estimate of the flood.

### Table 5: Weight of elements of social vulnerability.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Gua Musang</th>
<th>Kuala Krai</th>
<th>Kuala Pergau</th>
<th>Manik Urai</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>40.00</td>
<td>46.00</td>
<td>48.00</td>
<td>47.00</td>
<td>0.54</td>
</tr>
<tr>
<td>Gender</td>
<td>1.00</td>
<td>1.04</td>
<td>1.08</td>
<td>1.13</td>
<td>0.24</td>
</tr>
<tr>
<td>Occupation</td>
<td>2.25</td>
<td>1.75</td>
<td>1.00</td>
<td>1.00</td>
<td>0.21</td>
</tr>
</tbody>
</table>

### Table 6: Social vulnerability score, classification of social vulnerability, and social vulnerability class.

<table>
<thead>
<tr>
<th>Area</th>
<th>Score</th>
<th>SV Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang</td>
<td>22</td>
<td>High</td>
</tr>
<tr>
<td>Kuala Krai</td>
<td>26</td>
<td>High</td>
</tr>
<tr>
<td>Dabong</td>
<td>26</td>
<td>High</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>26</td>
<td>High</td>
</tr>
</tbody>
</table>

Fig. 4: Percentage of age and gender composition by area.

Fig. 5: Percentage of occupation composition by area.
The results of data processing related to physical vulnerability are shown in graphic images that represent each component (Fig. 6).

The physical vulnerability weight or index calculated by using the AHP method can be seen in Table 7.

The following method is used to calculate physical vulnerability across the entire study region. It adds up all components of physical risk, in this example, generally referred to as physical infrastructure, such as buildings, roads, railroads, and bridges, and multiplies them by their weights,

\[ PV = (0.411 \times \text{building}) + (0.288 \times \text{road}) + (0.185 \times \text{railways}) + (0.411 \times \text{bridges}) \]  

... (5)

The results of calculations using Eq. 5 produce a total score as shown in Table 8.

Table 8 shows the physical vulnerability score from all areas based on their weight. Physical vulnerability is classified as Low (<8333), Medium (>8333 and <16666), and High (>16666). Based on the classification, Bandar Kuala Krai obtain the biggest score followed by Gua Musang, Kuala Pergau, and Manik Urai. The results of the analysis shown in Table 8 also conclude that urban areas, Kuala Krai and Gua Musang Town are more vulnerable in terms of physical aspects than rural areas in Manik Urai and Kuala Pergau areas. By using the classification method in the table above, the level of Physical vulnerability can be determined as in Table 9.

**Table 8: Physical vulnerability score.**

<table>
<thead>
<tr>
<th>Sub-district</th>
<th>Building</th>
<th>Railways</th>
<th>Road</th>
<th>Bridge</th>
<th>PV Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang Town</td>
<td>481</td>
<td>1.945</td>
<td>15.647</td>
<td>3</td>
<td>18,076</td>
</tr>
<tr>
<td>Bandar Kuala Krai</td>
<td>776</td>
<td>920</td>
<td>23,252</td>
<td>2</td>
<td>24,950</td>
</tr>
<tr>
<td>Kuala Pergau</td>
<td>187</td>
<td>1,316</td>
<td>3,430</td>
<td>0.3</td>
<td>4,933.3</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>423</td>
<td>1,372</td>
<td>12,811</td>
<td>0.7</td>
<td>14,606</td>
</tr>
</tbody>
</table>

**Flood Vulnerability Classification**

To determine the vulnerability index for the entire study area, the method used is in principle the same as the method used in calculating vulnerability in the portion of the study area. Based on calculations made, a comparison of the overall vulnerability class area can be seen in the following Table 10.

While the Total Vulnerability Index in the study area is shown in Table 11. Total vulnerability is obtained by adding up all the vulnerability component indexes throughout the blood of the study. Since the index value is known, then the vulnerability index classification is determined from the entire study area. The vulnerability was classified as Low (<33), Medium (>33 and <66), and High (>66). Based on the classification, it is

**Table 9: Physical vulnerability class**

<table>
<thead>
<tr>
<th>Area</th>
<th>PV Score</th>
<th>PV Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang</td>
<td>18.076</td>
<td>High</td>
</tr>
<tr>
<td>Kuala Krai</td>
<td>24.950</td>
<td>High</td>
</tr>
<tr>
<td>Dabong</td>
<td>4.933</td>
<td>Low</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>14.606</td>
<td>Medium</td>
</tr>
</tbody>
</table>
known that the Kuala Krai and Manik Urai areas are in the classification of areas with a high-level classification, while Dabong and Gua Musang are in the middle of the face in the Kelantan flooding event in 2014 (Table 12).

In terms of the economic impact at the community level, in remote rural areas, the loss of service facilities and shops can have a major impact on the community’s economy. Urban areas typically see less of an economic impact than rural areas, in part because there are more options for amenities that can boost the local economy there.

The social impacts are discussed in two ways. First by direct examination of relationships between scarcity and density. Second particular social impacts indirect relationships between key demographic variables.

The population of old people is large in rural areas. Among them, mostly living alone increases flood vulnerability. Those people who migrate from urban to rural areas have less knowledge of flooding. It will also increase flood vulnerability. Migration, in general, is a key issue for both urban and rural areas.

**Risk Assessment**

Flood risk is defined in this study as a function of flood hazard, Flood exposure, and Flood vulnerability. The risk assessment was done based on the flood hazard model simulation results, flood exposure data, and the identified vulnerable elements at risk. Two factors were considered while the assessment i.e., the magnitude and the probability of occurrence of the risk. Flood risk assessment is calculated qualitatively according to a certain class level and then spatially presented as a Flood Risk Map.

**Quantitative Risk Assessment**

Flood risk can be considered as the actual threat. The estimation of flood risk results either in monetary or loss of life units, if the losses are measurable, or in qualitative terms (e.g. allocation in classes) in the case of intangible damages (social, environmental, cultural) to the affected areas. However, not all the values for the quantification of risk were available.

Based on flood hazard and the flood vulnerability for the different study areas using classes the qualitative assessment of risk was performed. The risk classes were weighted according to their level of importance. Follow the equation below:

\[
\text{Flood Risk} = \sum FH + \sum FV + \sum FE
\]  

The Flood Risk value of the data processing results shown in Table 13 shows that the greatest flood risk during the Kelantan extreme floods in 2014 based on the selected study area occurred in the Kuala Krai area, especially in terms of flood vulnerability.

Based on these data, flood risk is classified according to value into 3 classes High, Moderate and Low levels. Based on the classification, the class interval was obtained from Eq. (6):

\[
\text{Class Interval} = \frac{273 - 0}{3} = 91
\]

The highest flood risk value is 273, the lowest flood risk is 0. Flood risk in extreme flood conditions can be classified into 3 levels Low (0 to 91), Moderate (91 to 182), and High (>182). Based on the data collected, Gua Musang comes under the class Moderate while the rest is in the class High.

Based on Table 13, it can be said that flood risk is relatively higher in the rural area compared to the urban area as shown in Fig. 7. Risk assessment refers to the tolerability estimation based on the local society’s acceptability criteria. The estimated risk comparison was based on the

### Table 10: Vulnerability scores and vulnerability index of areas.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Gua Musang</th>
<th>Kuala Krai</th>
<th>Kuala Pergau</th>
<th>Manik Urai</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>22</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>0.541</td>
</tr>
<tr>
<td>Economy</td>
<td>1.00</td>
<td>1.04</td>
<td>1.08</td>
<td>1.13</td>
<td>0.241</td>
</tr>
<tr>
<td>Physical</td>
<td>2.25</td>
<td>1.75</td>
<td>1.00</td>
<td>1.00</td>
<td>0.211</td>
</tr>
</tbody>
</table>

### Table 11: Total Vulnerability scores in all study areas

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Gua Musang</th>
<th>Kuala Krai</th>
<th>Kuala Pergau</th>
<th>Manik Urai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>22</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Economy</td>
<td>16</td>
<td>51</td>
<td>28</td>
<td>41</td>
</tr>
<tr>
<td>Physical</td>
<td>18</td>
<td>24</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>101</td>
<td>59</td>
<td>81</td>
</tr>
</tbody>
</table>

### Table 12: Vulnerability level by areas.

<table>
<thead>
<tr>
<th>Area</th>
<th>Score</th>
<th>VI Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang</td>
<td>56</td>
<td>Medium</td>
</tr>
<tr>
<td>Kuala Krai</td>
<td>101</td>
<td>High</td>
</tr>
<tr>
<td>Dabong</td>
<td>59</td>
<td>Medium</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>81</td>
<td>High</td>
</tr>
</tbody>
</table>

### Table 13: Flood Risk value in the study area

<table>
<thead>
<tr>
<th>Area</th>
<th>FH</th>
<th>FV</th>
<th>FE</th>
<th>FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gua Musang</td>
<td>41</td>
<td>56</td>
<td>69</td>
<td>166</td>
</tr>
<tr>
<td>Kuala Krai</td>
<td>68</td>
<td>101</td>
<td>123</td>
<td>292</td>
</tr>
<tr>
<td>Manik Urai</td>
<td>63</td>
<td>59</td>
<td>129</td>
<td>251</td>
</tr>
<tr>
<td>Kuala Pergau</td>
<td>71</td>
<td>81</td>
<td>121</td>
<td>273</td>
</tr>
</tbody>
</table>
risk of the particular affected system and risk reduction application.

Research on economic flood impacts at the community level is lacking. As was already said, remote rural areas with little amenities and services were anticipated to have suffered greater economic losses. These setbacks further deplete rural residents’ motivation to rebuild their businesses. It may also harm people’s perceptions of the country as a desirable location for investments.

Before 2014, Kelantan experienced extreme flooding at least three times, in 1886, 1926, and 1967. However, because there was a lack of information at the time, it was unable to adequately prepare for the 2014 floods, which resulted in a loss of life and property. It may also be that the period between flood events is very long. The results of the survey and interviews only included one respondent who experienced severe floods in 1967. When there is extreme flooding, response actions should be expedited based on priority. This project is a methodical approach to addressing the flood issue in the field. It is vital to establish a specific value, whether it be the index, score of the extreme flood formula, or quantity, to ensure that this priority applies equally to all. All aspects of floods, including hazards, exposure, and vulnerability, should be covered by this value.

In the case of extreme flooding, deforestation is not the main factor. It can be ascertained that deforestation in Kelantan in 1967 or earlier was still at a low stage, or not yet significant, and extreme flooding occurred. The results of the analysis show that the main cause of extreme flooding in Kelantan is the high intensity of rainfall. When a flood happened, the intensity of the rainfall in some places was very high. On the slopes of Mount Gagau, rainfall intensity of up to 515 mm.day\(^{-1}\) was recorded for 3 days before the flood occurred.

**CONCLUSION**

Three vulnerability classes such as economic, social, and physical were assessed using a questionnaire that contain 200 respondents’ (flood 2014 affected people) interviews. In terms of economic vulnerability, Kuala Krai and Manik Urai are classified as High while Gua Musang and Kuala Pergau are classified as Medium. The social vulnerability which is focused on age, gender, and occupation, for all studies are classified as high. Physical vulnerability score from all areas shows Bandar Kuala Krai obtain the highest score followed by Gua Musang, Manik Urai, Kuala Pergau,
Kuala Krai and Bandar Gua Musang. Gua Musang Town is more vulnerable in terms of physical aspects than rural areas in this case the Manik Urai and Kuala Pergau areas. Total vulnerability is obtained by adding up all the vulnerability component indexes and the result is Kuala Krai and Manik Urai areas are in the high-level class, while Dabong and Gua Musang are in the medium class.

The risk classes were weighted according to their level of importance. The Flood Risk Value data processing results show that the greatest flood risk during the Kelantan extreme floods in 2014 based on the selected study area occurred in the Kuala Krai area, especially in terms of vulnerability. Flood risk is relatively higher in rural areas as compared to urban areas.

ACKNOWLEDGEMENT

The authors gratefully acknowledged all staff of the Faculty of Earth Science, University Malaysia Kelantan for providing the facilities to carry out this research. The financial assistance provided by the short-term research grant project (Ac No: R/SGJP/A08.00/00644A/001/2012/000080), Universiti Malaysia Kelantan, and also from Fundamental Research Grant (FRGS) (Ac No: R/FRGS/A0800/00644A/003/2018/00556) is gratefully acknowledged.

REFERENCES