International Journal of GEOMATE, Jan., 2017, Vol. 12, Issue 29, pp. 107-114
Geotec., Const. Mat. & Env., ISSN: 2186-2982(P), 2186-2990(O), Japan

IDENTIFICATION OF VULNERABLE AREAS TO FLOODS IN KELANTAN RIVER SUB-BASINS BY USING FLOOD VULNERABILITY INDEX

Nurul Farahen Ibrahim[1], Noorul Hassan Zardari[1,2,*], Sharif Moniruzzaman Shirazi[1,3], Mohd Ridza Bin Mohd Haniffah[1], Shazwin Mat Talib[1] and Zulkifli Yusop[4], Siti Mariam Akilah Binti Mohd Yusoff[1]

[1]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
[2]Faculty of Water Resource Management, Lasbela University of Agriculture, Pakistan
[3]Department of Civil and Environmental Engineering, Uttara University, Dhaka, Bangladesh
[4]Resource Sustainability Research Alliance, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

ABSTRACT: Flood vulnerability indices for the Kelantan River sub-basins were developed from various flood-related variables. The vulnerability indices of the Kelantan River sub-basins involved flood depth-inundation area, soil erosion potential, and potential of soil for agricultural use, population vulnerability, road infrastructure vulnerability and market infrastructure vulnerability. These indices were developed from the use of Geographic Information System (GIS) technique. The result indicates that the flood vulnerability indices of sub-basins were mostly ranked high in the areas with high concentration of development activities and densely populated region with large infrastructure existence that are more flood-prone group than others especially in major metropolitan areas. In order to steer against probable damage caused by flood, it remains important to develop a tool that is most beneficial for river basin managers and policy makers, so that they can conduct vulnerability assessment and flood risk in term of human lives losses and property damages during future massive floods. The output of this study can guide decision makers to reduce flood risks Kelantan River basin in future.

Keywords: Flooding, Vulnerability indices, Kelantan River basin, Geographic Information System (GIS), Flood risk

1. INTRODUCTION

Natural disasters are happening every year and their impact and frequency seem to have greatly increased in recent decades [1]. Floods are among the most prevalent of natural risks, which impacting upon human lives and causing huge economic loss in various regions. Malaysia is one of many the Asian countries where floods are occurring more frequently [2]. Floods are directly threatening to human lives and property and indirectly to the country's economy [3]. The frequent floods have caused considerable damages to highways, settlements, agriculture and livelihood with an average annual flood damage cost nearly a billion ringgit of property and many lives. Malaysia is affected by flood because of the heavy monsoonal and conventional rainfall, flat topography on both coasts of Peninsular Malaysia, heavy siltation of rivers and human activities such as deforestation, agricultural practices and urbanization. It is understood that floods occur because of the unplanned rapid urbanization, change in land use and poor watershed management mainly in flood plains become important issues for consideration as the flood causes. These all factors have contributed to increasing flood risk in the country.

The efficiency of flood management system is essentially important because it influences two vital components; losses of human lives and damages to property [4]. If the government practices efficient flood management system, the extent of flood damages and human lives can be reduced [5]. One of the most important sections of flood management is assessing flood vulnerability. Flood vulnerability is the key element in flood risk assessment and damage evaluation. There is a need to enhance our understanding of the vulnerability because nowadays it is understood that vulnerability is the root cause of disasters. Regard to UN guidelines, vulnerability can be evaluated as a percentage of the assumed losses caused by threats with determined amount and was expressed as a scale from 0-1 which are include two groups no damage and total damages [6]. As the flood vulnerability in an area depends on some environmental, economic, social and even political factors it is difficult to measure vulnerability [7]. That means the vulnerability is influenced by several factors including human settlements conditions, infrastructure, authorities' policy and abilities, social imbalances, economic patterns, where the flood vulnerability is different for people in different conditions [8]. For achieving this goal, developing vulnerability indices is the main approach that can determine which areas are most vulnerable to flooding and they should be focused in future flood events.

The flood in Kelantan was mainly due to the continuous heavy rainfall from 21-23 December 2014 which was equivalent to more than 60 days of rainfall, whereby the water level in the river exceeded those of recorded floods of 1967 and 2004.

From 1961 to 2006, the Kelantan River basin has experienced flooding for a total 275 times at early warning level, 92 times at warning level and 23 times at dangerous level [9]. This scenario illustrates higher flood risk tendency if relevant parties do not take prudent mitigation measures including flood management system especially for the three stages before, during and after flood occurrence.

The identifying flood-prone areas within a river basin and application of the remediation measures in the flood-prone areas can significantly reduce flood damages. In this study, the proposed river basin approach to minimize flood damages is by identifying the flood-prone areas in the Kelantan River basin. A GIS-based analysis of the Kelantan river sub-basins with the main objective of developing flood vulnerability indices is proposed. The vulnerability of river basin is proposed to be computed by measuring different indices, soil erosion risk, potential of soil for agriculture, population vulnerability, road infrastructure vulnerability, market infrastructure vulnerability, flood depth-inundation area vulnerability and total infrastructure vulnerability were assessed with respect to flooding risk. These developed indices framework will be helpful to the river basin managers and policy makers to develop a systematic plan in the river basin so the losses of human lives and property would be minimized during future massive floods.

1.1 Study Area

The Kelantan River basin is located in the north eastern part of Peninsular Malaysia between latitudes 40 40’ and 60 12’ North, and longitudes 1010 20’ and 1020 20’ East. Sub-basins in the Kelantan River basin are shown in Fig. 1. The river is about 248 km long and drains an area of 13,100 km^2, occupying more than 85% of the Kelantan state. The Kelantan River system flows northward passing through such major towns as Kuala Krai. Tanah Merah, Pasir Mas and Kota Bharu, before finally discharging into the South China Sea. About 95% of the catchment is steep mountainous country rising to a height of 2,183 m while the remainder is undulating land. The mountainous areas are covered with virgin jungle while rubber and some paddy are planted in the lowlands. The eastern and western portions, consisting of mountain ranges, have a granitic soil cover consisting of a mixture of fine to coarse sand and clay. The flood prone area in the Kelantan River basin has a population more than 600,000, which is about one third of the Kelantan’s total population of 1.675 million. The major economic activities in the Kelantan River basin are agricultural based, mainly the cultivation of paddy rice, rubber, oil palm and tobacco. Fishing and livestock farming are also an important occupation found in the Kelantan River basin.

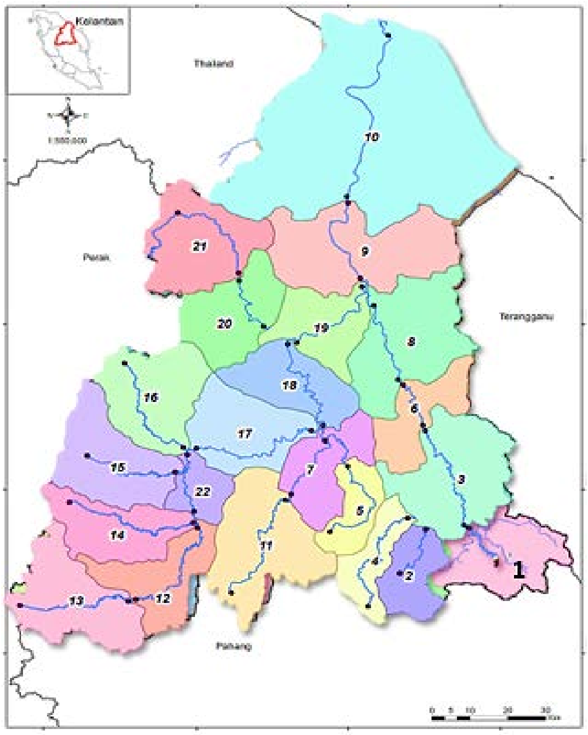

Fig.1 Sub-basins in Kelantan River basin

2. METHODOLOGY

2.1 GIS Spatial database creation

A GIS-based tool was used to identify Kelantan’s most vulnerable sub-basins and create flood risk maps that reflect the spatial distribution of risk and the locations and frequency of events likely to occur. This tool takes into account flood related parameters shown in Table 1. Each parameter was transformed in to a grid spatial database using the GIS. The methodology is based on ranking the relative vulnerability of the Kelantan River basin and sub-basins by using indices devised to measure different types of flood risk.

2.2 Flood vulnerability indices

When assessing an area for flood risk, many variables need to be taken into account [10] - [12]. In this study, we used population, soil to erosion potential, the utility of soil for agriculture, transportation network, shopping market locations, irrigation infrastructure and total infrastructure for developing flood vulnerability index in the Kelantan River basin.

Table 1 Data layer of study area

Parameters	Sub-Classification	GIS Data Type
Floods	Flood depth, Flood extent	Polygon coverage
Topology	Digital elevation models (DEM), slopes, lithology	Grid
Hydrography	River network	Grid
Land Use	Vegetation cover, land use	Grid
Population	Population density, building categories	Grid
Infrastructure & Utilities	Communication channels (roads, market) & public buildings	Grid
Flood depth & inundation area	Maximum weighted flood depth and weighted inundation area	Grid

Depending on the weight applied to these variables (i.e., is it more important to protect roads from flood rather than voluble soil), decision makers can use the proposed tool to know where to build flood control devices in the flood affected areas. Once databases are built, decision makers with limited or even no experience with GIS can use these indices. The methodology adopted in this study can be divided into the following steps;

Step-1[Sub-basins]: Determine the boundaries and the drainage area for the "priority" river basins by creating sub-basins (e.g. SB_1, SB_2, SB_3,…SB_{22}).

Step-2 [Erosion Risk Index]: Use the Intersect command in ArcGIS to intersect SBi (Sub-basin) & ER (Erosion Risk) = SBER. Determine the drainage area fraction by category, *where;*

$SBER_i = ER_{W1} \times ER_{value}$;

and $SBER_1 = \sum_{i=1}^{n=22} ER_{Wi} \times ER_{i\ value}$,

Calculate [$\sum SBER_i = SBER_1 + SBER_2 + \ldots\ldots + SBER_{22}$] then, normalized the scores and produced ranking of the Sub-basin Erosion Risk,

Step-3 [Soil Potential Index]: Intersect Sub-basin (SBi) & Potential Soil (PS) = SBPS (Sub-basin Potential Soil). This index is the inverse of erosion risk index. We then multiply the drainage area fraction by index category, where

$SBPS_i = PS_{W1} \times PS_{value}$

and $SBPS1 = \sum_{i=1}^{n=22} PS_{Wi} \times PS_{i\ value}$

We then sum the categories to compute a "sub-basin soil potential" score.

[$\sum SBPS_i = SBPS_1 + SBPS_2 + \ldots\ldots\ldots\ldots\ldots.. + SBPS_{22}$].

Step-4 [Population Vulnerability Index]: Use the Intersect command to intersect SBi & FPA (Flood Prone Area) = $SBFPA_i$. Then,

[$SBFPA_i$ x PD (Population Density) = FPAPDi].

Later, we determine the population density in the flood plain area and ranked the highest to the lowest vulnerable population.

Step-5 [Road Vulnerability Index]: Intersect $SBFPA_i$ & RN (Road Network). Determine road categories and assign weights as proxy of "road replacement value" *(5=national highway. 4=arterial road, 3=local road, 1=service road).* Then, multiplying (road weights X road distance per weight X flood plain category) where,

$SBRN_i = [\sum RN_w \times RN_d \times FP_{category}]$

and $SBRN_1 = \sum_{i=1}^{n=22} RN_{wi} \times RN_{di} \times FP_{i\ category}$

Then sum the weight values,

[$\sum SBRN_i = SBRN_1 + SBRN_2 + \ldots\ldots\ldots + SBRN_{22}$]

and compute the "road vulnerability" for each sub-basin by intersecting with SBFMi (Sub-basin Flood Map).

Step-6 [Market Vulnerability Index]: Intersect SBFPAi and Market Locations (M). Determine market category and assign weight as (*urban=3, regional=3 and rural=1).* We then multiplying (number of markets X market per category X Flood plain category) where,

$SBM_i = [\sum M_n \times M_c \times FP_{category}]$

and, $SBM_1 = \sum_{i=1}^{n=22} M_{ni} \times M_{ci} \times FP_{i\ category}$

Then, calculate "sub-basin market values" by summing the category values and produce ranking of

[$\sum SBMi = SBM_1 + SBM_2 + \ldots\ldots\ldots\ldots\ldots.. = SBM_{22}$]

Step-7 [Flood Depth Vunerability Index]: Intersect SBFAi with flood inundation area (FIA) and flood depth (FD) and = SBFID. We assigned weights to flood depth (0.7) and inundation area (0.3) variables. Where,

$SBFID_i = \sum(FD \times 0.7) \times (FI \times 0.3)$

and $SBFID_1 = \sum_{i=1}^{n=22} (FD_i \times 0.7) \, X \, (FI_i \times 0.3)$

Finally, we used Overlay command and assigned a color ramp to show the population density, road network, market network, and flood depth & inundation area layers to graphically display vulnerability of population and infrastructure that prone to flooding.

3. RESULT AND DISCUSSION

The choice of variables used in the vulnerability analysis and their classification into risk classes is very important [13].The choice of criteria that have a spatial reference is an important in GIS-based decision analysis. Hence, the criteria considered in this study were chosen due to their significance in causing flood in the study area. The parameters considered are shown in Table 1.

3.1 Erosion Risk Index

The risk of soil erosion is an important parameter for vulnerability analysis of Kelantan River basin. The soil erosion risk map in Fig. 2 shows the result for deriving an erosion risk index. It combines four factors: slope, soil erodibility, climate erositivity and land use cover. The weight of each factor is determined by its relative importance to soil erosion, Thus, slope is given the highest weight (5), followed by soil erodibility and land use cover (2), then erosive climate factors (1). Erosion is then computed into five categories ranging from 0 (very low risk) to 5 (extreme risk).

A map of the erosion risk index (Fig. 2) was computed for 22 sub-basins. The highest ranked of river basins for erosion risk located roughly in the west of the state. This is due to the primarily steep terrain and high elevations (around 100-500m), whereas the lowest ranked of river basin occur at the downstream are generally characterized by low mountains and large alluvial plains (around 0-50m). It suggests that the upstream sub-basins 12, 16, 17, 21 and 22 had relatively high level of forest cover; these areas still scores high for erosion risk. To understand this conflict, it should be noted that the erosion risk analysis weights slope much higher than ground cover and even the measures of the present rate of erosion should not be compared with the risk of soil erosion. The significance of this analysis shows that the sub-basin's heightened erosion risk were highly vulnerable due to high mountain ranges.

3.2 Soil Potential Index

The ranking of the sub-basins in terms of their soil potential index is basically the inverse of the erosion risk index ranking. Soil potential map of the Kelantan is shown in Fig. 3. It shows that the highest index values are mostly located at sub-basin 10 that is covered by the flat/alluvial surface, and the lowest ranked of sub-basin occur along the high ridges which are located at the mountainous area. Sub-basin 10 is covered by the quaternary soils, this soil type is good in terms of soil stability and infiltration that easily allows the water to infiltrate into the ground and the soil moisture rise as well as the growth for plants and crops is advantages in the future.

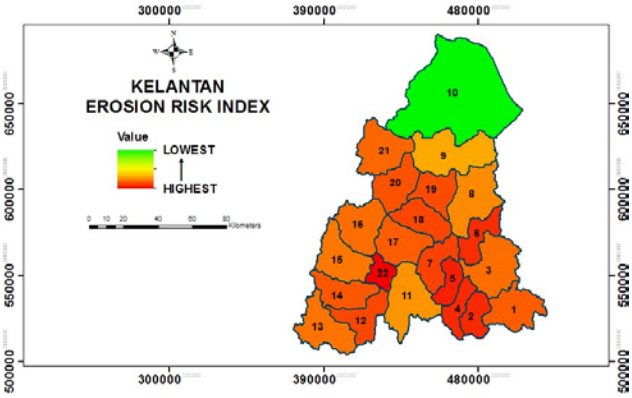

Fig.2 Erosion risk index of Kelantan River basin

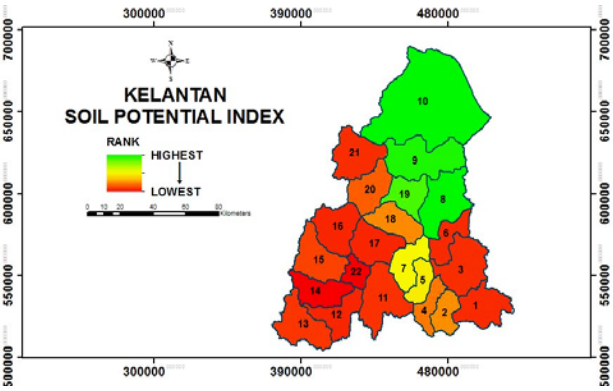

Fig.3 Soil potential index of Kelantan River basin

Even though the surrounding land use types within this area are impermeable surface like concrete, buildings, and roads which will decreased penetration capacity of the soil and increase the water runoff, but their land use types and the large alluvial plains are very suitable for agronomic purpose. Therefore, by the presence of thick vegetative or plants cover at sub-basin 10 will reduce the amount of runoff and at the same time decrease the rate of extreme floods from happening in future.

3.3 Population Vulnerability Index

The vulnerability of the population is defined here as the intersection of population density with flood-prone areas. The intersection of the population density map with the flood prone area map serves as the basis for estimating the population exposed to floods, and therefore a population vulnerability index of Kelantan River basin is shown in Fig. 4.

The sub-basin 10 representing the major urban areas of Kelantan state (Kota Bharu region) generated the highest index of population vulnerability where the high population densities residing at low coastal plain. At the other extreme, the lowest indices of sub basins were characterized by relatively low population densities residing in areas with elevated plains. Sub-basin with the darkest green color scored low index because there is no flood plain in this steeply sloped mountain areas and therefore population living in a flood plain is less. This is not to say that populations with relatively low index values are not vulnerable to the extreme flood e.g. Kuala Krai, Manek Urai, Dabong in December 2014, it is just that the potential for a large-scale disaster is not as great. Nevertheless, this index accurately points to the extremely high level of vulnerability in Kelantan's densely populated urban flood plains.

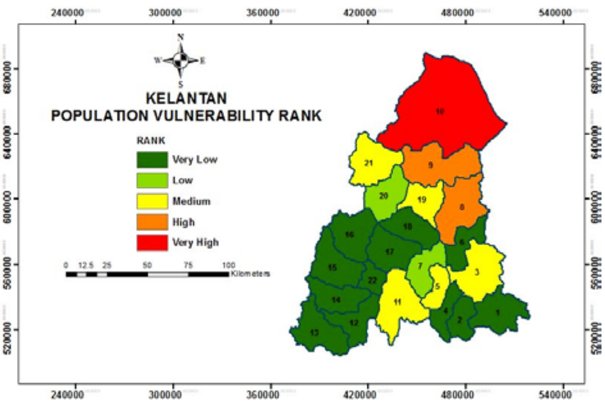

Fig.4 Population vulnerability map of Kelantan

3.4 Infrastructure Vulnerability Index

Productive infrastructure is defined in this study assessment as the total of roads, and markets. The portion of infrastructures falling within the flood-prone area of the sub-basins is the basis of the combined infrastructure vulnerability index. Fig. 5 shows the distribution of major roads, markets and river network infrastructure that were available in GIS database for the present analysis.

3.5 Road Vulnerability Index

A ranking of road vulnerability index is determined by the road distance, road category and flood plain category that are weighted according to estimated life cycle costs and their location within the flood prone areas. Densely concentration of paved roads is probably located in the vicinity of urban areas, and many of these are located in large flood plains along the main Kelantan river network. Fig. 6 shows that sub-basin 10 again had the highest vulnerability index compared to other sub-basins because of the major roads network are mostly centralized and integrated within the major metropolitan areas. Furthermore, road category in this urban area is federal highway and departmental road.

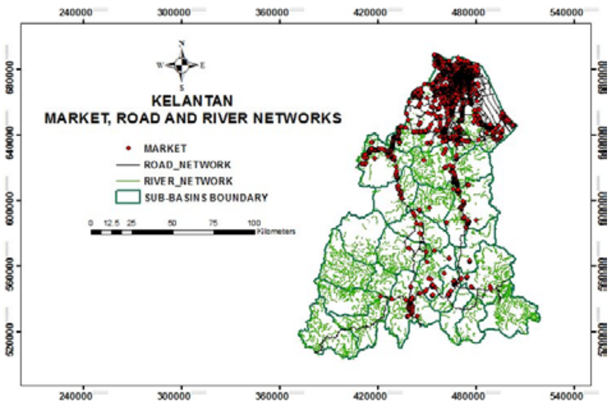

Fig.5 Major Roads and market networks of Kelantan

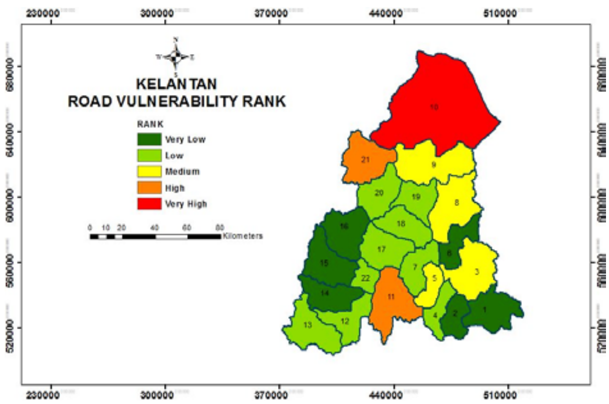

Fig.6 Road vulnerability map of Kelantan River basin

This index gives the highest weight index that falls into the sub-basin 10. The lowest index category for road vulnerability index can be shown in lowest part of Kelantan state (dark green colour) are dominated by local or unpaved roads and less connected with federal highway provided within the rural areas. The floodplain of this mountainous zone explains its lowest ranked value.

3.6 Market Vulnerability Index

The market vulnerability index is based on the weighted value of markets (rural, regional or urban) falling within flood-prone areas. Fig. 7 shows the highest indices reflect the importance of urban markets located in the large areas of high flood potential (low elevated plain).The most vulnerable sub-basins are those located at sub-basin 10 (major urban areas) followed by the sub-basins 9, 8, 11 and 21. The markets are located along the major road network (Fig. 5) and are easily accessible to the public by the transportation network. The lowest ranking index for market is inverse, where the sub-basins with less major road network is surely less market concentration falling into the Gua Musang areas (e.g. sub-basins 12, 13,14 and 15) which still covered by the thick forest and less development. In general, this analysis shows the positively correlated between the market vulnerability index with the road vulnerability index, where the road network influence the higher the concentration of market situated in the sub-basins.

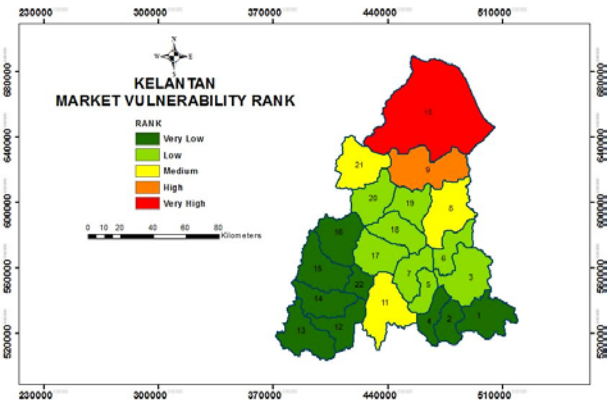

Fig.7 Market vulnerability for the Kelantan River basin

3.7 Flood depth-inundation area vulnerability index

We have developed an index from flood depth an inundation area for all sub-basins in the Kelantan River basin. As this variable will have different impact in terms of flood damages, we consulted water experts from Universiti Teknologi Malaysia (UTM) to get priority weights to flood depth and inundation area variables. The expert agreed that the flood depth has more impact on society compared to inundation area. Therefore, 70% of total weight was assigned to flood depth and 30% to inundation area. The weighted multiplication of these two variables produced vulnerability index named as "Flood Depth & Inundation Area".

Fig. 8 shows that the result of flood depth & inundation area in Kelantan River basin. It is observed that high rank zone covers few areas and it is located mostly in built up area and low lying area which is Kota Bharu region (sub-basin 10). The inundation area is wider though the flood depth is falls in medium risk category which is about to 3 m compared to the worst affected sub-basin from recent floods which are Kuala Krai, Manek Urai and Dabong. This area is high risk because most of the coverage area is houses and high developments with high population density. It represents the area where people are more exposed to flooding than those living in other locations. Followed by Kuala Krai and Manek Urai areas (sub-basins 8 and 9), are also represent high index though the area is less populated but the inundation depth is the highest about 5 to 10 m. The very low index covers an area at Gua Musang region (dark green colour). It is observed that it is risk-free where no inundation in this area. The risk index is zero because most of the areas were covered by forest and hilly steep.

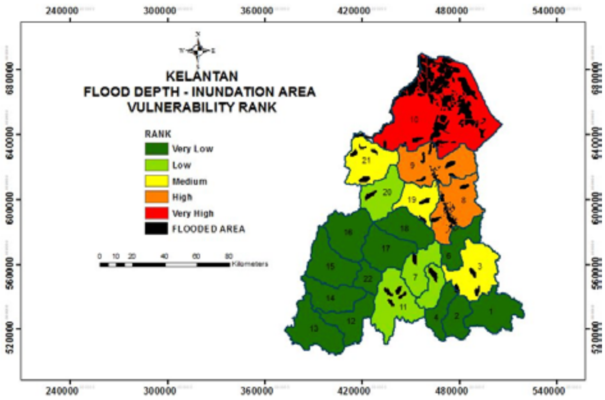

Fig.8 Flood depth and Inundation area map of Kelantan

3.8 Composite map based on all indices

Overall flood vulnerability index for the Kelantan River basin is shown in Fig. 9. There are several groups of sub-basins that consistently score high in two or more indices. It shows, the overlap of risk factors tends to define their status as the priority river basins. Sub-basin 10 (Kota Bharu region) is the most vulnerable of all of Kelantan River basin in terms of the threat of loss of human life and livelihood due to the flooding (Fig. 9). This is primarily due to the large number of people living in densely populated urban districts. However, the other central districts such as Tanah Merah, Pasir Mas, Pasir Putih that also situated in sub-basin 10 were exempt from this vulnerability and potentially suitable for being the shifted metropolitan areas for mitigating the risk of major disaster in future.

Next group were focused on the high population and infrastructural vulnerability combined with highly soil potential. The top sub-basin in this group correlate those most vulnerable in terms of population-and-infrastructure with those that offer heightened economic opportunity, again shows the analysis points to sub-basin 10 where the largest cities as well the densely populated. The high erosion risk combined with protected areas is one of the group of sub-basins was identified in relation to the erosion risk index. These sub-basins respond directly to priorities for reducing erosion vulnerability and for protection of high priority of the forest reserve especially in Gua Musang region (e.g. sub-basins 12,13,114,15,16, 17 and 22). The vulnerability index for these selected sub-basins group score the lower ranked index which means that they are slightly prone to flooding.

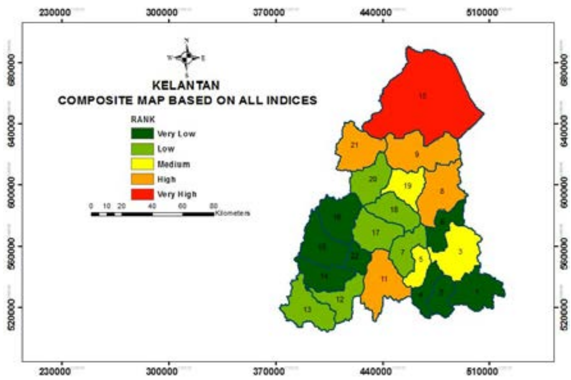

Fig.9 Overall flood vulnerability index of Kelantan River basin

4. CONCLUSION

Comprehensive flood vulnerability indices and risk analysis require detailed information on field conditions, such as hydrologic, geology, topography and many other features of flood variables that must be taken into account while developing any strategy on reducing flood damages. The paper presented a GIS-based approach for mapping vulnerability indices to flooding in Kelantan River basin through the selected indices including population, soil erosion and potential for agriculture, road networks, market locations and flood depth & inundation area. The proposed approach can help policy makers and river basin managers in the rapid assessment and evaluation of flooding phenomenon in Kelantan River basin. Once database are built, decision makers with limited or even no experience with GIS can use them for decision making towards planning for flood management.

The result of this study indicates that the areas with an active and high concentration of development activities and densely populated regions with large infrastructure investment are more vulnerable than the other areas. Likewise, there are areas that are not highly prioritize for flood protection either because there is nothing valuable to protect or they are not the most critical prone to flooding. Therefore, the most vulnerable sub basin in Kelantan River basin is identified and the flood vulnerability indices of each sub-basin were generated respect to flooding risks.

In future, the study on Integrated Flood Vulnerability Index is highly recommended in Kelantan river sub-basins. This is to show that better knowledge of all elements at risk (i.e. social, economic, environment and ecological) can help to identify the exact areas of potential vulnerability for the particular elements at risk and evaluate past or probable future flood events which may occur.

5. ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Higher Education (MOHE) Malaysia and Universiti Teknologi Malaysia (UTM) for financial and technical support. The study has been supported by project Vot. 08H43 (FRGS Grant) and Vot. 4L827 (TRGS-Flood Grant). The study was partially supported by JSPS-ACP (Japan Society for the Promotion of Science – Asian Core Program) Integrated Watershed Management (IWM).

6. REFERENCES

[1] Huang, Y.F., Mirzaei, M. and Yap, W.K. "Flood analysis in Langat river basin using stochastic model", International Journal of GEOMATE, 11, 2016, pp. 2796-2803.

[2] Alaghmand, S., Bin-Abdullah, R., Abustan, I., and Vosoogh, B. "GIS-based River Flood Hazard Mapping in Urban Area: A Case Study in Kayu Ara River Basin, Malaysia." International Journal of Engineering and Technology, 2, 2010, pp. 488–500.

[3] Chan, N.W. "Impacts of disasters and disasters risk management in Malaysia: The case of floods." In: Aldrich, D.P., Oum, S., Sawada, Y. (Eds.). Resilience and Recovery in Asian Disasters (Community Ties, Market Mechanisms, and Governance), Springer, 2015, pp. 239-265.

[4] Gao J.E.J. "An assessment of flood hazard vulnerability in the Dongting Lake Region of China." Lakes & Reservoirs: Research and Management, 12 (2007): 27-34.Islam MR, "Conference proceedings", in Proc. 2nd Int. Conf. on GEOMAT, 2011, pp. 8-13.

[5] Hassan, A.J., Ghani, A.A. and Abdullah, R. "Development of flood risk map using GIS for Sg. Selangor Basin." Universiti Sains Malaysia, Penang, 2006.

[6] Hussain, T.P.R.S., Nor, A.R.M. and Ismail, H. "The level of satisfaction towards flood management system in Kelantan, Malaysia." Pertanika Journal of Social Science and Humanities, 22, 2014, pp. 257-269.

[7] Khan S. "Vulnerability assessments and their planning implications: a case study of the Hutt

Valley, New Zealand." Natural Hazards, 64, 2012, pp. 1587– 1607.

[8] Nasiri, H. and Shahram, S.K. "Flood vulnerability index as a knowledge base for flood risk assessment in urban area." Journal of Novel Applied Sciences, 2, 2013, pp. 269-272.

[9] NRE. "Flood and drought management in Malaysia." Ministry of Natural Resources & Environment, Government of Malaysia, 2007.

[10] Pandey, A.C., Singh, S.K. and Nathawat M.S. "Waterlogging and flood hazards vulnerability and risk assessment in Indo Gangetic plain." Natural Hazards, 55, 2010, pp. 273–289.

[11] Smith, S.E. and Hersey, D. "Analysis of watershed vulnerability to flooding in Haiti." World Applied Sci. J., 4, 2008, pp. 869-885.

[12] United Nations. "Proceedings of the Seminars on Flood Vulnerability Analysis and on the Principles of Floodplain Management for Flood Loss Prevention." Bangkok, 1982.

[13] Vari, A. "Public involvement in flood risk management in Hungary." Journal of Risk Research, 5, 2002, pp. 211-224.

International Journal of GEOMATE, Jan., 2017, Vol. 12, Issue 29, pp. 107-114.
MS No. 11110 received on May 06, 2016 and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in Dec. 2017 if the discussion is received by June 2017.
Corresponding Author: Noorul Hassan Zardari