FORMULATION OF AN ENVIRONMENTAL RESILIENCE INDEX AS AN INDICATOR OF SUSTAINABILITY IN SELANGOR, MALAYSIA

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ABSTRACT: It is evident that global climate change has significantly affected the local environmental context in many towns. The abundance of environmental resources in Malaysia provides many environmental services towards the nation's development. However, disasters such as flooding, landslides and earthquakes stress the importance of environmental sensitive areas (ESAs) as natural defence agents for a resilient and sustainable town. Thus, the presence of a framework to measure the level of resilience for an area is crucial. However, there is no detailed model explicitly dedicated to environmental resilience in the Malaysian context. This research aims to develop a methodological framework to measure the environmental resilience index (ERI) in Selangor, Malaysia, which stakeholders could use, especially the Local Planning Authority (LPA). The state of Selangor is chosen as a study area, taking into consideration its rapid economic growth and the availability of its enormous natural resources. The objectives are to identify critical factors of environmental resilience, generate the ERI results to understand the spatial distribution pattern and produce a model of environmental resilience index in the Geographical Information System (GIS) database system. The research undertook comprehensive document analysis and systematic literature review in developing the ERI. This data used to analyse are majorly secondary data from official reports of responsible technical departments and agencies in Malaysia to ensure validity and reliability of data. The research developed a framework of ERI, consisting of five environmental components: environmental resources, built environment, climate condition, natural disasters, and environmental issues with 40 indicators. The output of this analysis was generated using ArcGIS software related to the weightage of different components and sub-components. The results show that all the districts in Selangor have an ERI level of moderate level, reflecting the resilience status should there be any disaster.

1. INTRODUCTION

Global climate change has significantly affected the local environmental context in many towns. Malaysia is fortunate to have an abundance of environmental resources that provide many environmental services to the nation's development. Simultaneously, natural disasters ranging from monsoon and flash floods, landslides, and even earthquakes are experienced in Malaysia. In this regard, environmentally sensitive areas such as forest areas, coastal areas, and wetlands, to name a few, are essential to provide ecosystem services and become the natural defence agents for a resilient town while maintaining its sustainability.
Thus, the presence of a framework to measure environmental resilience performance is vital to encourage development towards environmental resilience and sustainability. However, there is no detailed model explicitly dedicated to environmental resilience in the Malaysian context. Therefore, this research aims to develop a methodological framework to measure the environmental resilience index (ERI) for towns in Malaysia that stakeholders, especially LPAs, could use from the existing research gap. This research focuses on LPA as they are in the grassroots level for development approval. With an environmentally resilient and sustainability centric development at the grassroots level, it would significantly change the nation's development. The objectives of this research are (1) to identify key components and indicators for ERI; (2) to generate the ERI results to understand the spatial distribution pattern; and (3) to produce a model of ERI in the Geographic Information System (GIS) database system.

2. LITERATURE REVIEW

The literature review is conducted to understand the concept of resilience and sustainability as it is frequently used and interchanged, where Table 1 compares these two concepts. Other than that, a literature review on past indexes is carried out to identify indicators used to measure the environment, which is generally divided into two that focus on urban sustainability performance or specifically on environmental performance. Examples of studies focusing on urban sustainability are Climate Disaster Resilience Index (Kyoto University, 2019; Wan Mohd Rani, Kamarudin, Razak, Che Hasan, & Mohamad, 2018) and Sustainable Cities Index (Arcadis, 2018). Other studies conducted by researchers such as Bharma (2015); Romero-Lankao, Gnatz, Wilhelmi, & Hayden (2016); Sharifi & Yamagata (2014) as well as Suárez, Gómez-Baggethun, Benayas, & Tilbury (2016) that developed an urban resilience index that assess the sustainability of 50 Spanish cities. In addition, researchers focusing on environmental performance are Environmental Performance Index (Yale Center for Environmental Law & Policy; Yale University & Center for International Earth Science Information Network; Columbia University, 2018); Environmental Vulnerability Index (Pratt, Kaly, & Mitchell, 2004); and Environmental Sustainability Index (Yale Center for Environmental Law & Policy; Yale University & Center for International Earth Science Information Network, 2005).

Table 1: Comparison between the concept of sustainability and resilience

Sustainability	Criteria	Resilience
A condition where the current and future populations' needs are met without drawing down the carrying capacity of their hinterlands and regions that they are dependent on	Definition	The ability of a complex system to change, adapt, and transform in response to both internal and external stresses and pressures.
A set of protection goals concerning capitals that should be maintained for future generation.	Concept	A way of thinking and set of methods to cope with changes.
A normative set of socially derived goals, combining social, economy and social aspects.		A conceptual and modelling framework to operationalise sustainability.
Timeframe to build sustainability is usually during the long-term timeframe.	Timeframe	Timeframe affecting resilience can occur both in the short-term and long-term period.

Source: (Romero-Lankao et al., 2016; Saunders & Becker, 2015)

Table 2: Identification of environmental indicators from past studies

Past studies	Summary	Indicators on environment
Climate Disaster Resilience Index (2019)	CDRI considers five dimensions which are physical, social, economic, institutional and natural (environment)	a. Intensity/severity of natural hazards b. Frequency of natural hazards c. Ecosystem services d. Land-use in natural terms e. Environmental security and food security
Sustainable Cities Index (2018)	An index that ranks 100 global cities on three pillars of sustainability: people (social), planet (environment) and profit (economic)	a. Energy b. Air pollution c. Greenhouse emission d. Waste management e. Water & sanitation f. Green spaces g. Bicycle infrastructure h. Electric vehicle incentives i. Environmental exposure j. Negative emission technologies k. Natural disasters
Bharma (2015)	A resilience framework that measures development covering on social, environment, governance and economic	a. Disaster resilience b. Environmental quality – air, water, soil, biodiversity c. Ecological footprint
Romero-Lankao, Gnatz, Wilhelmi, & Hayden (2016)	A study covering on urban resilience and the inter-relationship between different urban sectors which are socio-demographics, economy, technology, environment and governance.	a. Hazards exposure: temperature, topography & land cover b. Sensitivity and capacity: land use & land use cover, deforestation and erosion, greenways
Sharifi & Yamagata (2014)	A study to develop an integrated framework for assessment of urban resilience covering infrastructure, security, environment, economy and institution	a. Biodiversity b. Hydrology restoration c. Conservation of ecologically vulnerable areas d. Proximity of different habitats e. Erosion rates

Environmental Performance Index	An index that measures environmental trends and progress providing a foundation for effective policymaking focusing on environmental health and ecosystem vitality.	a. Environmental health: environmental burden of disease, water & air pollution b. Ecosystem vitality: biodiversity & habitat, forestry, fisheries, agriculture & climate change
Environmental Vulnerability Index	An index to understand the issue between environmental vulnerability and resilience towards sustainable development.	a. Hazards b. Resistance c. Damage d. Climate change e. Biodiversity f. Water g. Agriculture and fisheries h. Human health aspects i. Desertification j. Exposure to natural disasters
Environmental Sustainability Index	An index that monitors natural resources, past and present pollution level, environmental management efforts and the capacity of a society.	a. Air quality, biodiversity, land, water quality and quantity and air pollution b. Waste management, environmental health, natural disasters, greenhouse emission and environmental pressures c. Governance, eco-efficiency, private sector responsiveness, science and technology & international collaborative efforts

On the other hand, this research also identified environmental sensitive areas (ESAs) and policies pertaining to environmental sustainability to understand Malaysia's development and planning scenario. This is important as it helps identify the suitable indicators for Malaysia and the availability of data for collection. For example, according to the Development Guidelines for Environmental Sensitive Areas, there are nine categories of ESAs; coastal areas, water catchment areas, flood-prone areas, mineral reserves, solid waste disposal sites, agricultural areas, wildlife reserves, forest areas as well as cultural and heritage areas (PLANMalaysia, 2017).

Some policies referred to identify Malaysia's stand-point and effort for the development direction of the nation. These policies are also referred to identify the related departments or agencies for data collection. These policies are to are the National Water Resources Policy, National Policy on Biological Diversity, Malaysian Forestry Policy, National Policy on Climate Change and Low Carbon Cities Framework and Assessment Systems (Fitria, 2013; Kementerian Tenaga dan Sumber Asli, 2021; Ministry of Natural Resources and Environment, 2009, 2016; Ministry of Energy, Green Technology and Water, 2011)

3. STUDY AREA

For this research, the study area chosen is the state of Selangor located in Peninsular Malaysia. This third largest state in Peninsular Malaysia has an acreage of 795,736.59 hectares, with nine districts, namely Sabak Bernam, Kuala Selangor, Hulu Selangor, Klang, Petaling, Gombak, Kuala Langat, Hulu Langat and Sepang. Having the capital of Malaysia, Kuala Lumpur, within its boundary results to the spillover of economic activities and a high rate of urbanisation to neighbouring districts such as Petaling, Klang and Gombak.

As of 2019, the Department of Statistics Malaysia reported that Selangor has a major contribution to the nation's Gross Domestic Product (GDP) at 24.2%, whereby the major sectors are services and manufacturing. Table 3 details on the main economic activities for the districts in Selangor. Due to this, it can be inferred that the rate of urbanisation and environmental performance will differ between districts. Hence, making Selangor is chosen as the study is for rapid economic growth and natural resources.

Figure 1: Map of the districts within Selangor state.

Table 3: Main economic activities in the districts in Selangor.

Districts	Main Economic Activities	Districts	Main Economic Activities
Sabak Bernam	Agricultural activities focusing on paddy	Kuala Selangor	Eco-tourism and supporting tourism services
Hulu Selangor	Industrial cluster	Gombak	Heavy industries, services and recycling industries
Klang	Port and maritime industrial cluster	Petaling	State financial centre Hi-tech industrial cluster
Kuala Langat	SME Halal industrial cluster	Hulu Langat	Hi-tech industrial cluster R&D institutions
Sepang	Aero-polis and aerospace, industrial cluster		

Source: (PLANMalaysia Selangor, 2015)

4. RESEARCH METHODOLOGY

Figure 1 shows the research flow undertaken in this paper. Content analysis was conducted to identify the component of indicators for ERI. Next, for data collection, data are mainly collected through secondary sources. Data have been extracted from the GIS database obtained from the Department of Town and Country Planning, Malaysia (PLANMalaysia) for retrieved the area. Other data are collected from related government departments and related agencies on the subject matter (refer to Table 4). This ensures that all the data extracted from various reports are valid and reliable to produce valid output results (Goundar, 2019). However, data of the acreage of sandy and mangrove beaches is not available in any departments. Thus, LANDSAT imagery collected in 2020 has been used to extract these data. Land use classification analysis has been used for the calculation of the acreage.

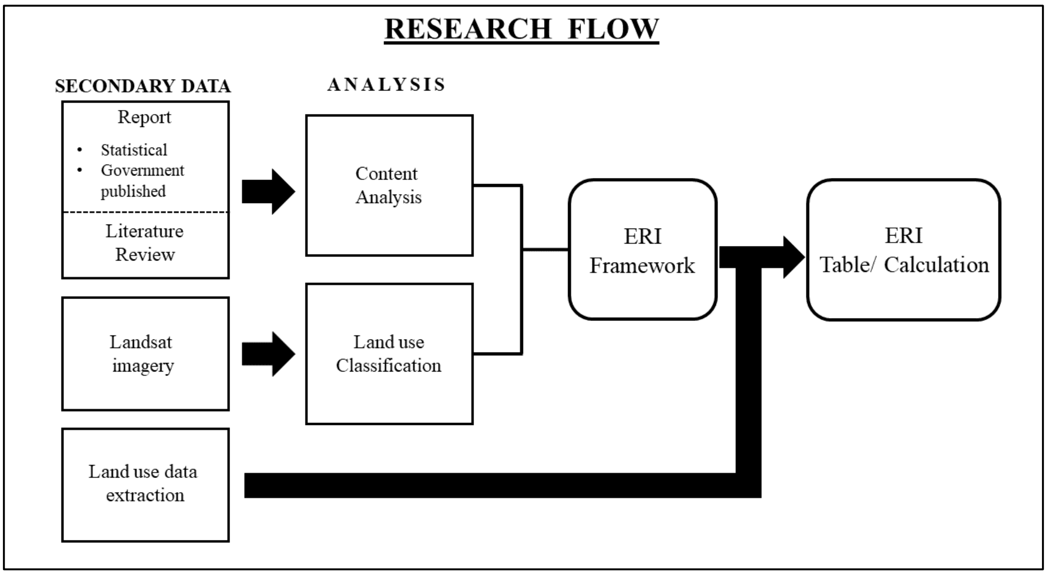

Figure 1: ERI research flow

On the other hand, the identification of the finalised ERI components and indicators is shown in Figure 2 contains 5 components, 20 sub-components, and 40 indicators necessary for data collection and analysis. Moving on, the ERI framework is developed to score and put weightage for every indicator that will produce the ERI result for every district and a composite ERI for the state of Selangor.

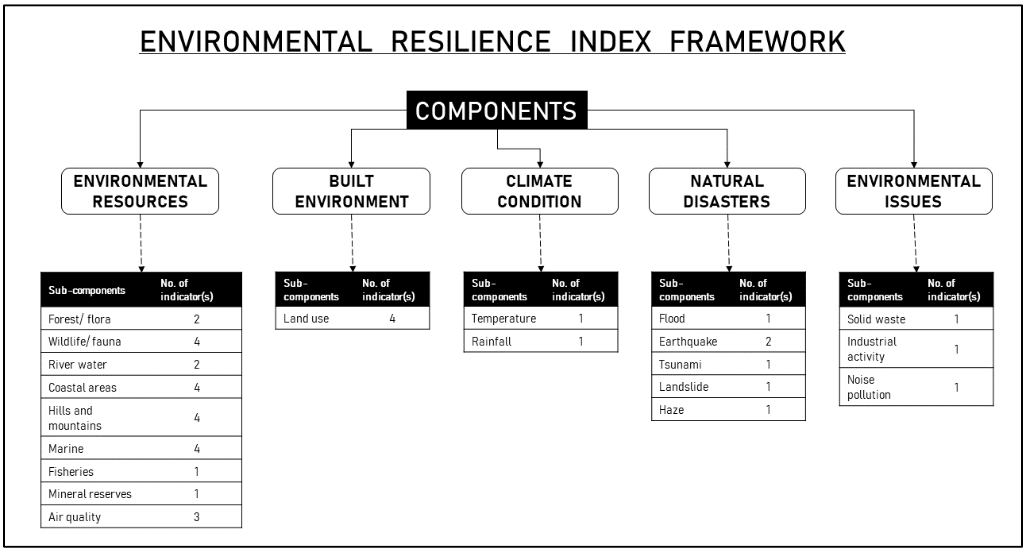

Figure 2: ERI framework with components, sub-components and indicators.

As this study aims to assess the environmental resilience of Selangor for the year 2019, the year range for data collection is from the year 2004 – 2020. This is due to the fact that certain data and surveys are not collected annually. For example, for the indicator Important Bird Areas (IBAs) under the sub-component wildlife/fauna and the component of environmental resource whereby the latest survey was conducted in 2004 by the International Birdlife Society. Another example is the number of endangered species under the sub-component wildlife/fauna, where the latest survey was undergone in the year 2018 by the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN). Therefore, the latest available data is being used for the ERI assessment. On the other hand, specific report data are backdated, for example, indicators under the component of climate condition, whereby data on those indicators are reflected on the 2020 Environmental Compendium Statistic from Department of Statistics Malaysia (DOSM).

Table 4: Department/agencies referred for data collection.

Department/ agencies referred for data collection	Components
Department of Town and Country Planning, Malaysia (PLANMalaysia)	ER, BE, EI

Selangor State Structure Plan Review Report 2035 (2015)	ER, EI
Malaysia National Physical Plan 2	ER
National Disaster Management Agency (NADMA)	ND
Department of Statistics Malaysia (DOSM)	ER, CC
Department of Environment (DOE)	ER, ND
Department of Irrigation and Drainage (DID)	ER, ND
Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN)	ER
Water Management Board of Selangor (LUAS)	ER
International Birdlife Society	ER
Reef Check Malaysia	ER

ER= Environmental Resources, BE= Built Environment, EI= Environmental Issues, ND= Natural Disasters, CC= Climate Condition

For data analysis or ERI assessment, every district is asses individually according to the framework. Consisting of five components and 40 indicators, each component has different weightage due to the number of indicators present in a component, whereby each indicator is given is given a score of three. Hence, Table 5 reflects the allocated score for every component. From the score for each component, the final ERI score and level is being categorised into nil (0 score), low ERI level (1 – 40 score), moderate ERI level (41 – 80 score) and high ERI level (81 -120 score) that is being used to identify the ERI level for districts in Selangor or the Composite ERI for the state of Selangor (refer Table 6).

In order to measure the district ERI or Composite ERI for Selangor, the performance of each indicator is analysed whereby the availability of each indicator is categorised into nil, low, moderate or high given a score from 0 to 3 respectively. Figure 3 shows an example in categorising the availability of forest cover for a district whereby if more than 50% of the land area of a district is forest area, a score of 3 is given and that the district has a high level of resilience for the forest cover indicator. In order to find the ERI of a district, the score for all five components and 40 indicators are summed up. On the other hand, to attain the Composite ERI for Selangor, the ERI score of all the nine districts in Selangor is being averaged.

Table 5: Allocation of score per component in the ERI framework

Component	**Number of indicators**	**Score/component**
Environmental Resources (ER)	9	75
Built Environment (BE)	1	12
Climate Condition (CC)	2	6
Natural Disasters (ND)	5	18
Environmental Issues (EI)	3	9

Table 6: ERI level and score

Resilience level	**Nil**	**Low**	**Moderate**	**High**
Score	0	1 – 40	41 – 80	81 – 120

ENVIRONMENTAL RESILIENCE INDEX

Component: Environmental resources **Sub- component**: Forest/Flora

Indicator: Forest cover **Indicator scaling**: The percentage of forest area to the total measurements of the district.

Level	Low resilience	Moderate resilience	High resilience
Score	1	2	3
Forest cover	0 - 25(%)	26 – 50 (%)	More than 50%

Figure 3: Example for the scoring of an indicator for the ERI assessment.

5. RESULTS

This section tabulates the calculation for the ERI according to the ERI framework (Table 7). There are three level of ERI in Selangor where the category of low ERI resilience is from 1 to 40, moderate ERI resilience is from 41 to 80 and the high ERI resilience is from 81 to 120. Based on the calculation, it shows that all the districts in Selangor is categorised in the moderate ERI level with scores ranging from 47 to 66. Where else, Figure 8 shows the Composite ERI for the state of Selangor is also categorised in the moderate level with a score of (59/120).

Table 7: Calculation of the ERI for the districts of Selangor according to the ERI framework.

District / Components	ER	BE	CC	ND	EI	District ERI score	ERI level
Component score	**75**	**12**	**6**	**18**	**9**	**120**	
Sabak Bernam	23	6	4	18	6	57	Moderate
Kuala Selangor	28	7	4	17	5	61	Moderate
Hulu Selangor	32	7	4	18	5	66	Moderate
Klang	27	4	4	16	6	57	Moderate
Petaling	20	2	4	16	5	47	Moderate
Gombak	29	5	4	16	5	59	Moderate
Kuala Langat	28	8	4	18	7	65	Moderate
Hulu Langat	29	5	5	16	4	59	Moderate
Sepang	31	3	5	17	4	60	Moderate

ER= Environmental Resources, BE= Built Environment, EI= Environmental Issues, ND= Natural Disasters, CC= Climate Condition

Table 8: Calculation of the Composite ERI for Selangor according to the ERI framework.

COMPOSITE ERI FOR SELANGOR		
Component	Score allocated	Score attained
Environmental Resources	75	27.4
Built Environment	12	5.2
Climate Condition	6	4.2
Natural Disasters	18	16.9
Environmental Issues	9	5.2
Selangor Composite ERI score	120	59
Selangor Composite ERI level	**MODERATE**	

The study shows that the district with the lowest ERI score is Petaling (47). This is due to the major land use of the district being built-up area and being one of the most urbanised districts in Selangor. On the other hand, the district with the highest score is Hulu Selangor (66). This district has a forest cover area of 51% and the availability of wildlife reserves, important bird areas (IBAs) and central forest spine (CFS) that increases the score for this district.

6. DISCUSSION AND CONCLUSION

In addition, through the ERI framework, coastal districts, namely Sabak Bernam, Kuala Selangor, Klang, Kuala Langat and Sepang, will be prone to environmental disturbance as the elevation of all these districts are less than 150 meters above sea level. These districts faced moderate to high risk for coastal erosion with no coral reef areas that increase the chances of environmental disasters such as tsunami, coastal erosion, and the reduction of district land area in the future.

Further studies that can be undertaken to enhance this framework further is on carbon emission, this indicator could not be included in this research as of currently, there is no existing data in the district level but only in the national level or individual private companies on their company level. Hence, it is also essential for Local Planning Authorities (LPAs) and the Department of Environment or related government agencies to start data collection on carbon emission to further improve this framework and clarify a district's environmental performance

The Environmental Resilience Index (ERI) framework enables stakeholders in the Local Planning Authority to identify the level of environmental resilience in their municipal. This framework also clarifies the component/s which have poor performance to be improved through either design/development, law enforcement, formulation of guidelines and community participation.

7. ACKNOWLEDGEMENT

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REFERENCES

Arcadis. (2018). Citizen Centric Cities : The Sustainable Cities Index 2018.
Bhamra, A. S. (2015). Resilience framework for measuring development. Brief for GSDR 2015.
Fitria. (2013). Dasar Sumber Air Negara. In Dasar Sumber Air Negara (Vol. 53, pp. 1689–1699).
Goundar, S. (2019). Chapter 3 – Research Methodology and Research Method. (May).
Kementerian Tenaga dan Sumber Asli. (2021). Dasar Perhutanan Malaysia. Kementerian Tenaga Dan Sumber Asli, 136.
Kyoto University. (2019). Climate and Disaster Resilience Initiative (CDRI) Project : Background Location Need for Further Actions.
Ministry of Natural Resources and Environment, M. (2009). National Policy on Climate Change. In Ministry of Natural Resources and Environment Malaysia. https://doi.org/10.3362/9781780445250.005
Ministry of Natural Resources and Environment, M. (2016). National Policy on Biological Diversity 2016 - 2025.
Minstry of Energy, Green Technology and Water, M. (2011). Low Carbon Cities Framework and Assessment System.
PLANMalaysia. (2017). Garis Panduan Perancangan Pemuliharaan Dan Pembangunan Kawasan Sensitif Alam Sekitar (KSAS).
PLANMalaysia Selangor. Rancangan Struktur Negeri Selangor 2035. , (2015).
Pratt, C. R., Kaly, U. L., & Mitchell, J. (2004). Manual: How to Use the Environmental Vulnerability Index (EVI). SOPAC Technical Report 383., 98. Retrieved from http://islands.unep.ch/EVI Manual.pdf
Romero-Lankao, P., Gnatz, D. M., Wilhelmi, O., & Hayden, M. (2016). Urban sustainability and resilience: From theory to practice. Sustainability (Switzerland), 8(1224).
Saunders, W. S. ., & Becker, J. S. (2015). A discussion of resilience and sustainability: Land use planning recovery from the Canterbury earthquake sequence, New Zealand. International Journal of Disaster Risk Reduction, 14, 73–81.
Sharifi, A., & Yamagata, Y. (2014). Resilient urban planning: Major principles and criteria. Energy Procedia, 61, 1491–1495.
Suárez, M., Gómez-Baggethun, E., Benayas, J., & Tilbury, D. (2016). Towards an urban resilience index: A case study in 50 Spanish cities. Sustainability (Switzerland), 8(8). https://doi.org/10.3390/su8080774
Wan Mohd Rani, W. N. M., Kamarudin, K. H., Razak, K. A., Che Hasan, R., & Mohamad, Z. (2018). Measuring urban resilience using climate disaster resilience index (CDRI). International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 42(4/W9), 237–242. https://doi.org/10.5194/isprs-archives-XLII-4-W9-237-2018
Yale Center for Environmental Law & Policy; Yale University, & Center for International Earth Science Information Network; Columbia University. (2018). Global metrics for the environment: Ranking country performance on high-priority environmental issues. 2018 Environmental Perfomance Index, 1–4.
Yale Center for Environmental Law & Policy; Yale University, & Center for International Earth Science Information Network, C. U. (2005). 2005 Environmental Sustainability Index.