

Ecological Balance Towards Sustainable Index of Tasik Kenyir



**Muhamad Na'eim Abdul Rahman, Muhamad Safih Lola,
Mohd Noor Afiq Ramlee, Mohd Tajuddin Abdullah,
and Muhammad Syamsul Aznan Ariffin**

Abstract The assessment of ecological sustainability index for Tasik Kenyir is always related to selection of indicators for sustainable development. There are few initiatives to integrate indicators from various sectors to become an ecological index for Tasik Kenyir, where issues of sustainable development are interrelated. The purpose of this study is to develop a set of criteria, indicators and indices for sustainability assessment of Tasik Kenyir. The focus is on ecological indicators and a framework that has been developed. The results determined the suitable indicators to monitor the ecological balance in the largest man-made lake in Peninsular Malaysia.

Keywords Urban sustainable development · framework · indicators index · Tasik Kenyir

M. N. A. Rahman (✉) · M. S. Lola
Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu
Malaysia, Kuala Nerus, Terengganu, Malaysia
e-mail: safihmd@umt.edu.my

M. N. A. Ramlee · M. T. Abdullah · M. S. A. Ariffin
Institute of Tropical Biodiversity and Sustainable Development, Universiti Malaysia
Terengganu, Kuala Nerus, Terengganu, Malaysia
e-mail: mohd.tajuddin@umt.edu.my

© The Author(s), under exclusive license to Springer Nature
Switzerland AG 2021

M. T. Abdullah et al. (eds.), *Resource Use and Sustainability of Orang Asli*,
https://doi.org/10.1007/978-3-030-64961-6_14

Introduction

Tasik Kenyir is the biggest man-made lake in Southeast Asia that was inundated in 1986 as a result of the construction of the Sultan Mahmud hydroelectric dam. It contains more than 340 islands in a flooded area of 38,000 hectares (Lola et al. 2019; Yusof et al. 2011), which is almost as big as Singapore. Tasik Kenyir derives its name from Sungai Kenyir, where the dam was built. The islands in Tasik Kenyir host diverse forms of flora and fauna which may be unique. Sustainability involves taking different factors like economic, social, environmental, political and financial aspects into consideration to ensure continuity of resources and survival of an environment for the long term (Siche et al. 2008). The term “sustainability” was introduced as an international issue in the World Conservation Strategy summit in 1980. Since then, the term has been used with increased frequency to debate decisions on economic, social and environmental dimensions, besides searching for alternative forms of development that are environment-friendly (Siche et al. 2008). Many experts agreed that the sustainable urban concept must retain economic development, social development and environmental development success where the concept of sustainable exists as a complete entity and can also be independent (Drakakis-Smith 1997).

Ecology is an inherent interdisciplinary science with physical and biological components. However, ecologists do engage social scientists, economists, planners and policy-makers in working together to develop the country. Ecological knowledge has greatly contributed to our understanding of the natural world and impact of humans on the ecosystem. Ecological sustainability refers to the capacity of the biosphere to meet the needs of the present generation, without hindering future generations from being able to meet their needs (Houda and Lamia 2016).

Chapter 40 of the United Nations' Agenda 21 (United Nations Commission on Sustainable Development 1996) emphasises the development of indicators for Sustainable Development (SD). It is a non-binding action plan for countries to achieve sustainable development, and government and non-governmental organisations are encouraged to formulate indicators to monitor such development (United Nations 1993). That agenda has since evolved into the newer [Agenda 2030](#), which contains 17 [Sustainable Development Goals](#).

Indicators have long been used to obtain information on human health, weather and economic welfare. Compared to economic and social aspects, environmental and sustainable development indicators are a fairly new phenomenon. Indicators are useful tools for decision-makers and provide information on major issues of development as well as the distinct image on progress towards sustainable development. Moreover, sustainable decision-making involves political will at local, national and regional levels to create and promote a balanced environment (Huang et al. 2008). The measurement of urban sustainability becomes crucial and its indicators, through results input, must be integrated as an index. The index is an aggregation of indicators that is readily understandable in the context of sustainability, and it plays a distinctive role. A composite index can be obtained from all dimensions, objectives,

indicators and variables used (Munda 2005). Indicators and indices provide communication tools that provide a common framework for scientists and the authorities to work together (Malkina-Pykh 2002).

This study aims to define the ecological sustainability indicators for Tasik Kenyir to develop an index. Ecological sustainability index (ESI) is an effective tool to determine whether the developments in the lake area are being carried out in a sustainable manner. It monitors the ecological achievements in Tasik Kenyir and provides guidance for decision-makers to develop the lake in a right manner.

Methods

Study Area

The study was conducted in Tasik Kenyir in the state of Terengganu in Peninsular Malaysia (Fig. 1). The islands in Tasik Kenyir were actually high grounds and hill-tops that were not submerged by the construction of the Sltan Mahmud hydroelectric dam. There were now 30 rivers flowing into the lake, with 25 waterfalls at

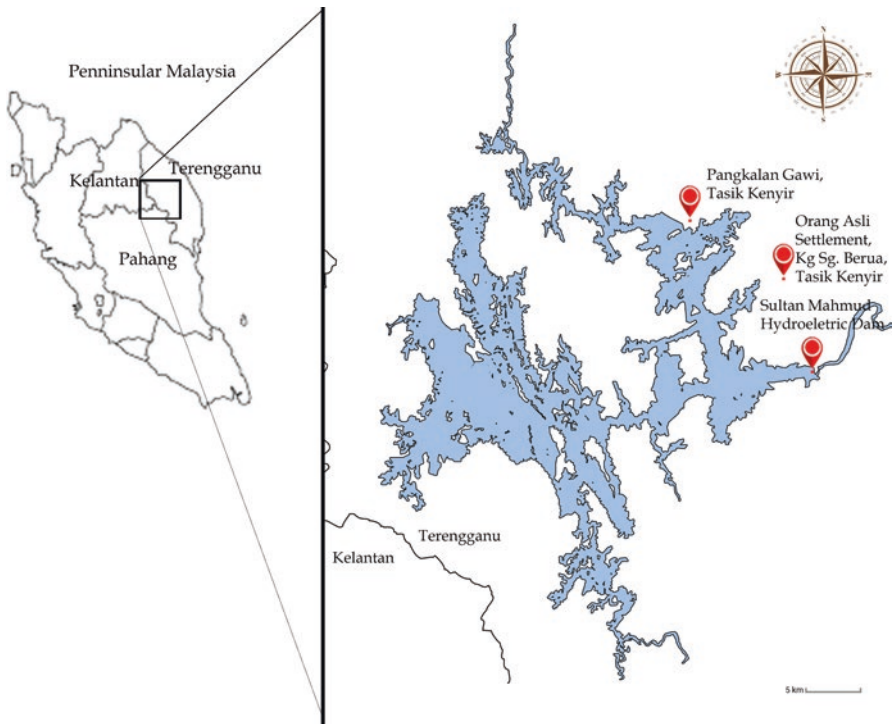


Fig. 1 Map of Tasik Kenyir (Google Map)

various points. It had been identified as a habitat for 25 species of fish (Kenyir Lake 2009), which made it a popular angling destination. The lake also offered fascinating views of surrounding waterfalls, limestone caves and lush tropical forests that host more than 8000 species of flowers, 2500 species of plants and trees, and 300 species of fungi. Furthermore, 800 species of butterflies, 370 species of orchids, 1000 species of birds and 200 species of animals had been observed in the area (Yusof et al. 2011).

Data Collection

The potential indicators were based on data obtained from questionnaires, interviews and surveys at Tasik Kenyir. The questionnaires were distributed among the local residents of Tasik Kenyir. They comprise questions on demographic characteristics (composition, age, education and migration). Respondents were also asked about their livelihood status and subjective evaluation towards environmental aspects in Tasik Kenyir according to the sustainable livelihood framework by the International Development Department (1999). Data on the water quality and air pollution in the lake were gathered from federal agencies like the Environment Department, Orang Asli Development Department (JAKOA) and Wildlife and National Parks Department (DNWP), besides state agencies like the Terengganu Economic Planning Unit (UPEN) and Terengganu Tengah Development Board (KETENGAH).

Index Calculation

In this study, the index calculation involved some choices during data processing. This study chose the standard method [0, 1] using the minimum and maximum values for each objective indicator. Using the values from 0 to 1 was simple and more understandable. All indicators chosen were given a positive or negative sign to show the impact they had on achieving a sustainable ecological outcome. A higher positive indicator refers to better sustainability. The standard formula is stated in Eq. 1:

$$\text{Index} = \frac{X - \min_{i=1} X}{\max_{i=1} X - \min_{i=1} X} \quad (1)$$

The X indicate the relative value of indicator where min of X is the lowest value of indicator X at i time and max X are the highest value of X indicator of i time. The highest value and lowest value of each indicator achieved in the study areas were chosen as the maximum and minimum value in the standardisation process. The value of indices fell within 0 to 1, where a value closer to 1 denoted better sustainable development and closer to 0 denoted the opposite.

According to several studies, different indicators should have equal weight (Esty et al. 2005, 2006; Barrera-Roldán and Saldívar-Valdés 2002). Differently-weighted determination would introduce a subjective component to indice development. For indicator aggregation, the averaging method was used. Sensitivity analysis was a measure of how far the composite index had developed that depended on information and assumptions. It was necessary to conduct this analysis due to a lack of theory in allowing the aggregation of different categories into an index. A change in weightage was used to observe changes in the composite index. Sensitivity analysis for uncertainty in weighted selection was used to prevent conflicts in policies. According to previous research, this study assumed an equal weightage system, which meant every criterion and sub-criterion was considered equally important. Then, the indicators were tested in the sensitivity level sustainable index.

Criteria Selection

The framework of ecological sustainability for Tasik Kenyir was a combination and modification based on the theme indicators of a framework by the United Nations Commission on Sustainable Development (1996) and the Barometer of Sustainability (Kunasekaran et al. 2017; IUCN 1996). The "barometer" was divided into four aspects, namely the environment, management, natural resources and politics.

Reflective

Based on Goldberg (2002), indicators did not cater to scientific demands only, but must also be seen as a symbol of achievement of the best knowledge or idea. Therefore, only indicators that described sustainable development were selected.

Availability, Continuity and Trustworthiness

Good development index and application played important roles to ensure that the data was available. According to Barrera-Roldán and Saldívar-Valdés (2002), the availability and trustworthiness of data were very important factors in the methodology stated by Agenda 21 and the Organisation for Economic Cooperation and Development (OECD). Empirical success depended on the availability of a series of continuous and significant data. For this study, chosen indicators were depended on what was available in Tasik Kenyir.

Affordability and Simplification

Data on affordability was important to develop an index and its application. All sustainability index formation must be in cost-effective. Referring to Atkinson et al. (1997), no matter how good the theoretical construction of an index, it would only be useful if the key indicator development was at reasonable cost. According to Lee and Huang (2007), indicators should be easily understood by respondents without professional knowledge, and also precise and easy to apply.

Quantifiable and the Framework Ecological Sustainable Index (ESI)

According to Roldan and Valdes (2002), indicators should be based on data that has sufficient and high-quality information. The framework is stated in Fig. 2.

Results and Discussion

The urban methodology was used to analyse the ecological sustainability index in Tasik Kenyir. The method by Pearce and Giles (1995), through classification of the sustainability index, were used as shown in Table 1. This classification was also adopted from a study in China study by van Dijk and Mingshun (2005).

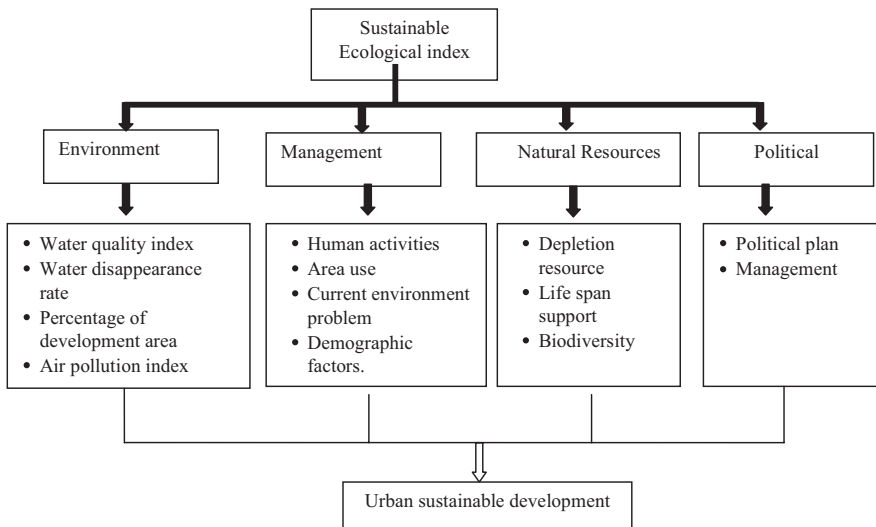


Fig. 2 The framework of an ecological sustainable index (ESI)

Table 1 The classification of an ecological sustainability index (Pearce and Giles 1995)

Score	Definition
≥ 0.75	Sustainable
$\geq 0.5, < 0.75$	Moderate
$\geq 0.25, < 0.5$	Weak
< 0.25	Unsustainable

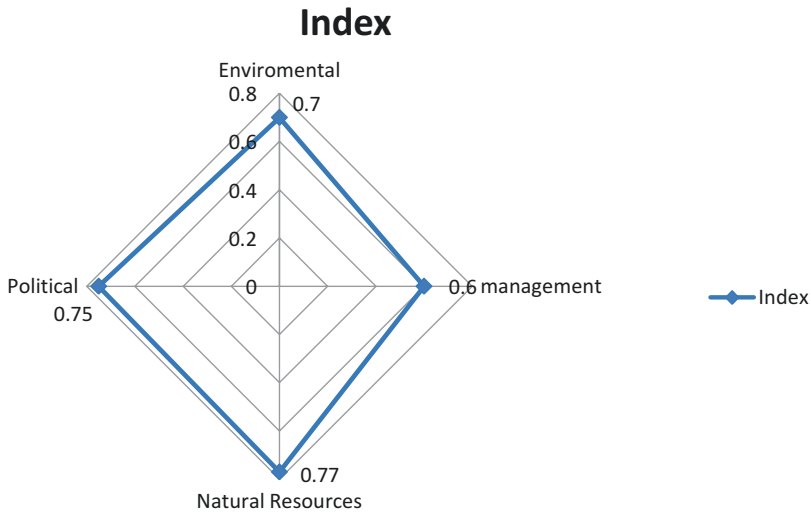


Fig. 3 Average performance of sub-criteria for ecological sustainability index

Figure 3 shows the average of sustainability index on sub-criteria for management with average value of about 0.6, followed by an environmental index of 0.7. The political average was 0.75 and natural resources was 0.77. The average of all sub-criteria was moderate according to the classification of the ecological index by van Dijk and Mingshun (2005). Sustainability index indicated a moderate level of performance, and the sustainability criteria were not within reach, hence indicating the need for more action. Therefore, from the measurement of ESI, we propose that the local authorities in Tasik Kenyir should strengthen their action plan to empower management, while conserving natural resources and the environment. However, the political will for sustainability should be imposed rather than letting it remain idle towards nature to meet both ends in sustainability development.

Conclusion

Sustainability measurements indicated that Tasik Kenyir was moderate in all four aspects of sustainability – political will, environment, natural resources and management aspect as a whole. There were some actions that could be taken to promote

the ESI of Tasik Kenyir, such as; (1) promoting a balanced usage of natural resources from surrounding water catchment areas e.g. catch-and-release fishing, limiting catchment by introducing the Tagal system and reduce hunting of animals; (2) implementing sustainable visits for tourists e.g. counting their litter when exiting Tasik Kenyir and penalising them for throwing too much rubbish; (3) empowering the management by regular surveillance and maintenance to promote a vibrant surrounding and provide comfortable amenities; and, (4) local politicians pledging to promote sustainable developments in the lake. Hence, by residing to this alternative, we hypothesise that Tasik Kenyir could achieve a high index rating in 5–10 years' time, and boosts its economy with better development and tourist experience.

Acknowledgements This study was supported by the Tran-disciplinary Research Grant Scheme (TRGS/UMT/2015/59373). Special thanks to all participants from KETENGAH, UPEN, DWNP and Universiti Malaysia Terengganu.

References

- Atkinson, G., Dubourg, R., Hamilton, K., Munasinghe, M., Pearce, D., & Young, C. (1997). *Measuring sustainable development: Macroeconomics and the environment*. London: Edward Elgar Publishing.
- Barrera-Roldán, A., & Saldivar-Valdés, A. (2002). Proposal and application of a Sustainable Development Index. *Ecological Indicators*, 2, 251–256.
- David, P., Giles, A., & Kirk, H. (1995). *Theory and implementation of economic models for sustainable development* (Economy and Environment) (Vol. 15). Dordrecht: Kluwer Academic Publishers.
- Department for International Development. (1999). *Sustainable livelihoods guidance sheets*. London: Department for International Development.
- Dijk, M. P., & Zhang, M. S. (2005). Sustainability indices as a tool for urban managers, evidence from four medium-sized Chinese cities. *Environment Impact Assessment Review*, 25, 667–688.
- Drakakis-Smith, D. (1997). Third world cities: Sustainable urban development III-basic needs and human rights. *Urban Studies*, 34, 797–823.
- Esty, D. C., Levy, M. A., Srebotnjak, T., & de Sherbinin, A. (2005). *Environmental sustainability index: Benchmarking national environmental stewardship*. New Haven: Yale Center for Environmental Law and Policy.
- Esty, D. C., Levy, M. A., Srebotnjak, T., de Sherbinin, A., Kim, C. H., & Anderson, B. (2006). *Pilot 2006 environmental performance index*. New Haven: Yale Center for Environmental Law and Policy.
- Goldberg, E. (2002). *Aggregated environmental indices: Review of aggregation methodologies in use*. Paris: Organisation for Economic Co-operation and Development.
- Google Maps. (2014). Tasik Kenyir, Terengganu, Malaysia. Retrieved from <https://www.google.com/maps/place/Kenyir+Lake/@4.9975358,102.5101097,11z/data=!3m1!4b1!4m5!3m4!1s0x31b62bfa9e9475cd:0x250d30b733b4ae9e!8m2!3d5.0039622!4d102.6388451>
- Houda, B., & Lamia, M. J. (2016). Interaction between financial development and sustainable development, evidence from developing countries: A panel data study. *International Journal of Economics and Finance*, 8, 243–255.
- Huang, S. L., Chia, T. Y., Budd, W. W., & Chen, L. L. (2008). A sensitivity model (SM) approach to analyze urban development in Taiwan based on sustainability indicators. *Environment Impact Assessment Review*, 29, 116–125.

- IUCN. (1996). *Barometer of sustainability: What it's for and how to use it*. Bern: World Conservation Union.
- Kenyir Lake. (2009). Kenyir Lake. Retrieved from <http://www.kenyirlake.com/home.htm>
- Kunasekaran, P., Gill, S. S., Ramachandran, S., Shuib, A., Baum, T., & Herman Mohammad Afandi, S. (2017). Measuring sustainable indigenous tourism indicators: A case of Mah Meri ethnic group in Carey Island, Malaysia. *Sustainability*, 9, 1256–1275.
- Lee, Y. J., & Huang, C. M. (2007). Sustainability index for Taipei. *Environmental Impact Assessment Review*, 27, 505–521.
- Lola, M. S., Ramlee, M. N. A., Hussin, M. F., Abdullah, M. T., Kamil, A. A., Mohamad Yusof, I., Ibrahim, Y., & Khadar, N. Z. A. (2019). Sustainable development of Tasik Kenyir eco-tourism using system dynamis. In: M. Abdullah, A. Mohammad, M. Nor Zalipah, M. Safih Lola (eds.), *Greater Kenyir landscapes: Social development and environmental sustainability: From ridge to reef* (pp. 257–270).
- Malkina-Pykh, I. G. (2002). Integrated assessment models and response function models: Pros and cons for sustainable development indices design. *Ecological indicators*, 2, 93–108.
- Munda, G. (2005). Measuring sustainability – A multi-criterion framework. *Environment, Development and Sustainability*, 7, 117–134.
- Pearce, D., & Giles, A. (1995). Measuring sustainable development. In B. Daniel (Ed.), *Handbook of environmental economics*. Cambridge: Blackwell Publishers.
- Peterson, P. J. (1997). *Indicators of sustainable development in industrializing countries: Management response strategies*. Bangi: National University of Malaysia.
- Peterson, P. J., Sham, S., & Nordin, M. (1999). *Indicators of sustainable development in industrializing countries: Key indicators for tropical cities*. Bangi: National University of Malaysia.
- Roldan, A. B., & Valdes, A. S. (2002). Proposal and application of a sustainable development index. *Ecological Indices*, 2, 251–256.
- Siche, J. R., Agostinho, F., Ortega, E., & Romeiro, A. (2008). Sustainability of nations by indices: Comparative study between environmental sustainability index, ecological footprint and the energy performance indices. *Ecological Economics*, 66, 628–637.
- Smith, D. (1997). Third world cities: Sustainable urban development III-basic needs and human rights. *Urban Study*, 34, 797–823.
- United Nations. (1993). *Agenda 21: The United Nations programme of action from Rio*. New York: United Nations.
- United Nations Commission on Sustainable Development. (1996). *Indicators of sustainable development: Framework and methodologies*. United Nations: United Nations Commission on Sustainable Development.
- van Dijk, M. P., & Mingshun, Z. (2005). Sustainability indices as a tool for urban managers, evidence from four medium-sized Chinese cities. *Environmental Impact Assessment Review*, 25, 667–688.
- Yusof, N. A., Said, I., & Rahman, F. A. (2011). Sustainable attributes in Lake Kenyir, Malaysia: Expectation and experience of ecotourists. *Journal of Environmental Sciences*, 5.

Muhamad Safih Lola, currently an Associated Professor in Department of Mathematics, Faculty of Ocean Engineering Technology and Informatics (FTTKI) and a research fellow in Institute of Biodiversity and Sustainable Development (BIOD TROPIKA), Universiti Malaysia Terengganu. His research interest is Econometric, Applied Statistics, Community Development, Green Economy and Utilization and Application of Big Data. Muhamad Saffih also actively involved in several nonprofits association (NGO) as a technical advisor and actively acts as reviewers in several journals.

Mohd Noor Afiq Ramlee, is a researcher in Institute of Biodiversity and Sustainable Development (BIOD TROPIKA), Universiti Malaysia Terengganu and Head Coordinator in ESC Group Malaysia. He actively participates in several social enterprise movement and currently acting as a chairman elect of KOPERMA T BHD. His research interest is Green Economic, Applied Statistics, Business Development, Environmental Protection, Big Data and Analytical.

Mohd Tajuddin Abdullah, is a professor and was the former Director of the Institute of Tropical Biodiversity and Sustainable Development (BIO-D TROPIKA), Universiti Malaysia Terengganu (UMT). He has conducted his fieldworks in Malaysia, Indonesia and Thailand with a broad interest in biodiversity, biogeography, molecular ecology, mammalogy, park and wildlife conservation. Recently, he received the best zoological and ecotourism book awards in the Malaysia National Book Award 2017 and 2019 respectively. He has published about 100 indexed journal manuscripts and co-edited nine books, two of which by Springer Nature Publisher. Currently, he is an active independent researcher affiliated to the Academy of Sciences Malaysia of which he is a fellow and a new found hobby as a YouTuber (Taj Abdullah).

Muhammad Syamsul Aznan Ariffin, is a researcher in Institute of Biodiversity and Sustainable Development (BIOD TROPIKA), Universiti Malaysia Terengganu. His research interest is in freshwater fish, Orang Asli anthropology and utilization of resources, sustainable development and environmental protection.