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Development of Environmental Resources Management Model Among Community Settlements Along Terengganu River Basin and Kenyir Lake, Terengganu, Malaysia

Noorjima Abd Wahab[1,3]*, Frankie Marcus Ata[2], Wan Nor Azilawanie Tun Ismail[1], Sianturi Novdin Manoktong[4], Wan Marlin Rohalin[5], and Fazureen Azaman[3]

[1]Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia
[2]Centre for Research in Development, Social and Environment, Faculty of Social Sciences and Humanities, National of University of Malaysia, 43600 bangi, Selangor, Malaysia
[3]East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, 21300 Kuala Nerus, Terengganu, Malaysia
[4]Studi Teknik Sipil Fakultas Teknik Universitas Simalungun, 21142 Kota Pematang Siantar, Sumatera Utara, Indonesia
[5]Centre of Bioaromatic Research, Universiti Malaysia Pahang Al–Sultan Abdullah, 26300 Gambang, Kuantan, Pahang, Malaysia

ABSTRACT

The sustainability of natural resources is vital for global well-being. Environmental awareness involves understanding the environment's importance. Strategies like Environmental Planning and Management (EPM) have been developed to address environmental degradation. However, development pressures have increased resource exploitation. Therefore, community awareness and involvement are key to ensuring sustainable resource management. This study aims to develop an Environmental Resource Management Model (ERMM) based on the level of Knowledge, Practice, and Attitude of local communities. The study involved 380 respondents from local community settlements along the Terengganu River Basin and Kenyir Lake. Primary data were collected through a structured questionnaire, and the data were analysed using appropriate chemometric techniques to identify patterns and relationships among KAP variables. The development of the Environmental Resource Management Model (ERMM) integrated the results of statistical analyses with Geographic Information System (GIS)-based spatial modelling using Inverse Distance Weighted (IDW) interpolation. The ERMM was created based on three sub-models: Model A: Guidance from those responsible for environmental management; Model B: The

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E-mail addresses:
noorjimaabdwahab@unisza.edu.my (Noorjima Abd Wahab)
frankie@ukm.edu.my (Frankie Marcus Ata)
azilawanieismail@unisza.edu.my (Wan Nor Azilawanie Tun Ismail)
sianturinovdin@gmail.com (Sianturi Novdin Manoktong)
wanmarlin@unisza.edu.my (Wan Marlin Rohalin)
fazureenazaman@unisza.edu.my (Fazureen Azaman)
* Corresponding author

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development of an environmental resource management system; and Model C: Innovation of the existing environmental resource management system. The proposed ERMM provides an integrated framework that connects community-based KAP evidence with spatial information to support more targeted and sustainable environmental resource management. The ERMM has produced a valuable model as a policymaking tool for both governments in rural areas. The sustainable policymaking tool will preserve the wealth of natural resources.

Keywords: Environmental awareness, environmental planning and management (EPM), environmental resource management model (ERMM), geographic information systems (GIS), inverse distance weighted (IDW)

INTRODUCTION

Rural communities in Malaysia continue to face various environmental challenges, including natural resource exploitation and environmental degradation. The degradation of natural resources is primarily driven by anthropogenic activities, especially along the river basin. These activities disrupt ecological balance and adversely affect the sustainability of natural ecosystems. According to Baging et al. (2020), Kumari et al. (2023) and Santika et al. (2019), it has become a critical issue of growing concern because of environmental degradation. The increased anthropogenic activities surrounding rural communities have increased the pollution and contamination of surface and groundwater with harmful pollutants like heavy metals, pesticides and fertilisers, industrial chemicals, and organic waste, as well as contamination of soil by oil spills and leaks in river water.

The conservation of forest ecosystems is also severely impacted by anthropogenic activities and climate change, as noted by Rasul et al. (2015) and Razali et al. (2018). This issue is particularly relevant to the Terengganu River Basin and Kenyir Lake, which represent important socio-ecological systems in Malaysia. The Terengganu River Basin supports local communities and diverse ecosystems, while Kenyir Lake, surrounded by extensive tropical forest and a major hydroelectric reservoir, provides important ecological, economic, and social benefits to surrounding communities. However, increasing ecotourism activities, agricultural expansion and associated runoff, resource extraction, and hydroelectric development have created localised pressures on natural resources and ecosystem sustainability in these areas. Population expansion and unlimited development activities will cause changes in resource use. The community's settlements, the unbounded evolution of natural resources, and human activities all affect how resources are used. Numerous disputes over land usage, harvesting forest products, and the distribution of resources among villages will result from the overexploitation of natural resources (Alam et al., 2017). Some members of indigenous groups or outsiders engage in timber product trading without following community-accepted guidelines for responsible natural resource use. Natural forest fragmentation

and significant anthropogenic regeneration are predicted outcomes of the rapid growth of these rural communities into protected areas. Degradation of ecological services obtained from the sustainability of forest ecosystems, as well as additional deterioration of biodiversity, fauna's habitat, and forest structure of essential natural tropical forest resources (Liu et al., 2019; Wahab et al., 2023). In the Terengganu River Basin and Kenyir Lake, these localised pressures further highlight the importance of strengthening community knowledge, attitudes, and practices in environmental resource management to support the long-term sustainability of the area's interconnected forest and aquatic ecosystems.

The development, structure, and operation of human civilisation, the environment, and socioeconomics will all suffer from a few aspects of soil and natural resource degradation. Compaction, loss of soil structure, nutrient deterioration, erosion, sedimentation, and soil salinity are a few consequences. As illustrated in Figure 1, soil degradation represents an important pathway of environmental deterioration in the Terengganu River Basin. Land-use changes, deforestation, and unsustainable development activities may accelerate soil erosion and increase sediment transport into river systems. These processes can contribute to riverbank erosion and sediment accumulation downstream, potentially leading to lake siltation and deterioration of aquatic ecosystems, including the Kenyir Lake area. Therefore, soil degradation should not be viewed in isolation but as part of a broader interconnected process

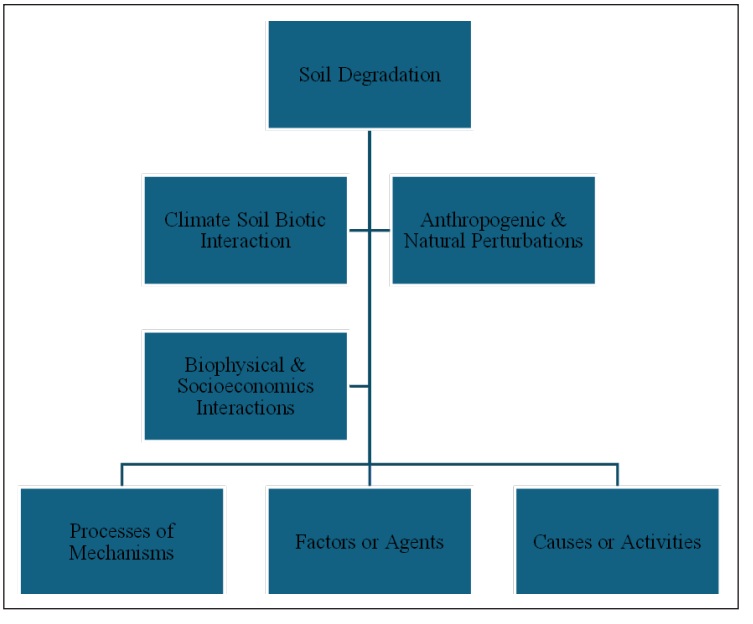


Figure 1. The main classifications and factors of environmental resource deterioration
Source: Lal, 2015

affecting terrestrial and aquatic resources within the river basin. These problems can occasionally be rather serious. However, existing environmental planning and management (EPM) approaches in Malaysia have generally addressed community participation, environmental perceptions, or spatial environmental conditions separately. Limited empirical attention has been given to integrating community Knowledge, Attitude, and Practice data with spatial Geographic Information System (GIS) modelling, particularly the Inverse Distance Weighting (IDW) technique, to identify spatial patterns of community-related environmental conditions and translate these findings into practical decision-making sub-models. This limitation constrains the ability of existing EPM approaches to provide spatially explicit and community-responsive decision support for rural environmental management. These studies contribute towards a deeper understanding of the interconnected dynamics between human activities and environmental sustainability, providing essential insights for shaping integrated forest conservation policies, promoting sustainable community development, and ensuring the long-term resilience of tropical forest ecosystems.

To operationalise the degradation of natural resources, all stakeholders, including communities, the government, non-governmental organisations, and academic researchers, should work together to develop actor-specific environmental action plans. The Environmental Planning and Management (EPM) method is becoming increasingly popular to address environmental degradation, particularly in rural areas (Lekwot et al., 2014; Nhu et al., 2020; Saeed & Cek, 2024). Figure 2 explains that the performance management procedures, including environmental policy, environmental planning, environmental implementation, environmental checking and correction, and environmental management review, are all part of the

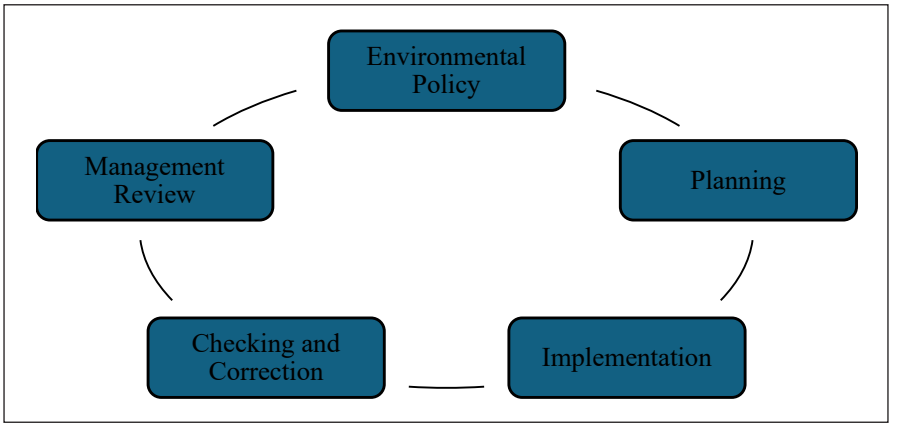


Figure 2. The performance of environmental planning and management
Source: Steger, 2000

EPM process (Steger, 2000). In rural areas, particularly in the vicinity of rural communities, the ability to accomplish more sustainable natural resource management is strengthened by the participation of local authorities and their public, commercial, and community sectors.

The effectiveness of the Environmental Management System (EMS) cycle is closely influenced by the level of Knowledge, Attitude, and Practice among local communities. Within the Planning stage, local community knowledge provides important context-specific information regarding environmental conditions, resource utilisation patterns, local environmental issues, and community needs. Such knowledge can support the identification of priority environmental problems and the formulation of appropriate management strategies. The Attitude component is particularly relevant to the implementation of environmental management initiatives, as positive environmental attitudes can strengthen community commitment, awareness, willingness to participate, and support for management interventions. Meanwhile, the Practice component reflects the actual behavioural actions of local communities, including the adoption of sustainable resource-use practices and participation in environmental conservation activities. These practices also contribute to the Checking and Corrective Action stages by enabling communities to monitor environmental conditions, identify implementation gaps, provide feedback, and participate in continuous improvement. Therefore, the level of Knowledge, Attitude, and Practice among local communities should not be viewed as independent community characteristics but as interconnected components that support each stage of the EMS performance cycle, thereby strengthening the effectiveness and sustainability of the proposed Environmental Resource Management Model.

Incorporating local perspectives, indigenous knowledge systems, and lived experiences into the EPM process. EPM ensures that strategies are culturally sensitive and context-specific, making them more effective for the local population. The relevance and effectiveness of environmental action plans by aligning them with community values, traditional land use practices, and socio-economic conditions. The EPM process in community settlements in Malaysia will improve ecological sustainability. This development is also promoting equitable and efficient use of natural resources. Besides that, it manages ecological hazards within development planning. According to Susilawati et al. (2017) and Mohiuddin et al. (2018), these efforts are grounded in basic systematic planning and resource management. These are contributing to decision-making based on the broader political-administrative environment. Besides that, local perspectives ensure that EPM initiatives are relevant and build a sense of community ownership and empowerment.

Traditional ecological knowledge, including indigenous water management techniques, seasonal agricultural cycles,

and local conservation practices, provides invaluable insights into sustainable resources. Furthermore, understanding the lived experiences of the communities, including their social structures, belief systems, and historical interactions with the environment, allows for more nuanced and inclusive environmental planning. Recognising and valuing these diverse knowledge systems, the EPM process strengthens community resilience, enhances adaptive capacities to climate and ecological changes, and fosters long-term stewardship of natural resources. Such participatory approaches contribute significantly towards bridging the gap between scientific planning and grassroots realities, ultimately leading to more holistic, effective, and enduring environmental governance. Therefore, this study assesses the Knowledge, Attitude, and Practice of rural communities regarding environmental resource management and integrates the resulting community-based data with GIS spatial modelling using the Inverse Distance Weighting (IDW) technique. This integration is intended to identify spatial variations in communities' Knowledge, Attitude, and Practice and environmental conditions and to support the formulation of practical decision-making sub-models within the EPM framework. By linking community-derived evidence with spatial analysis, the study seeks to strengthen the applicability of EPM for locally responsive and spatially informed environmental management in rural Malaysia.

METHODS

Study Area

The Terengganu River Basin and Kenyir Lake areas are characterised by a diverse network of rural settlements distributed along the riverbanks and surrounding the vast man-made Kenyir Lake. This region covers an expansive landscape, with Kenyir Lake alone spanning approximately 260,000 hectares and hosting over 340 islands. Additionally, the area boasts more than 14 waterfalls, rapids, rivers, limestone caves, and lush tropical forests, offering significant ecological and tourism value. The Terengganu River, flowing from Kenyir Lake through various rural and urban settlements before reaching the South China Sea, is a vital natural and socio-economic artery for local communities. The basin remains predominantly forested, with over 60% of its landscape undeveloped, enhancing its ecological importance and contributing to regional climate regulation, carbon sequestration, and biodiversity conservation (Wahab et al., 2025; Wahab et al., 2026).

Communities residing along the Terengganu River and Kenyir Lake, including Malay settlers and traditional fishing and farming communities, depend heavily on natural resources for their livelihoods, such as fishing, agriculture, and ecotourism. The total population along these settlements is estimated to be around 8,000 to 12,000 residents, dispersed across numerous villages. Given their reliance on the natural environment, development pressures have sometimes triggered

socio-environmental challenges such as deforestation, water pollution, biodiversity loss, and socio-economic vulnerabilities. The proximity to the Taman Negara National Park, a UNESCO-recognized biosphere reserve, further elevates the need for integrated, balanced conservation efforts that promote environmental stewardship and socio-economic resilience. Recognising these dynamics, the study applied an area sampling method, involving the selection of more than 10 villages along the Terengganu River Basin and the Kenyir Lake. These villages were selected based on geographical distribution, proximity to water resources, livelihood patterns, and vulnerability to environmental changes. Figure 3 illustrates the study location map for developing a collaborative model for environmental resources management tailored to the needs and sustainability of the community settlements in the Terengganu River Basin and Kenyir Lake Basin (Universiti Sultan Zainal Abidin (UniSZA), 2025).

Research Methodology

A quantitative survey of rural villages around the Terengganu River Basin and Kenyir Lake was used to gather the primary data, and the questionnaires were self-administered. In this study, the questionnaires were distributed using a

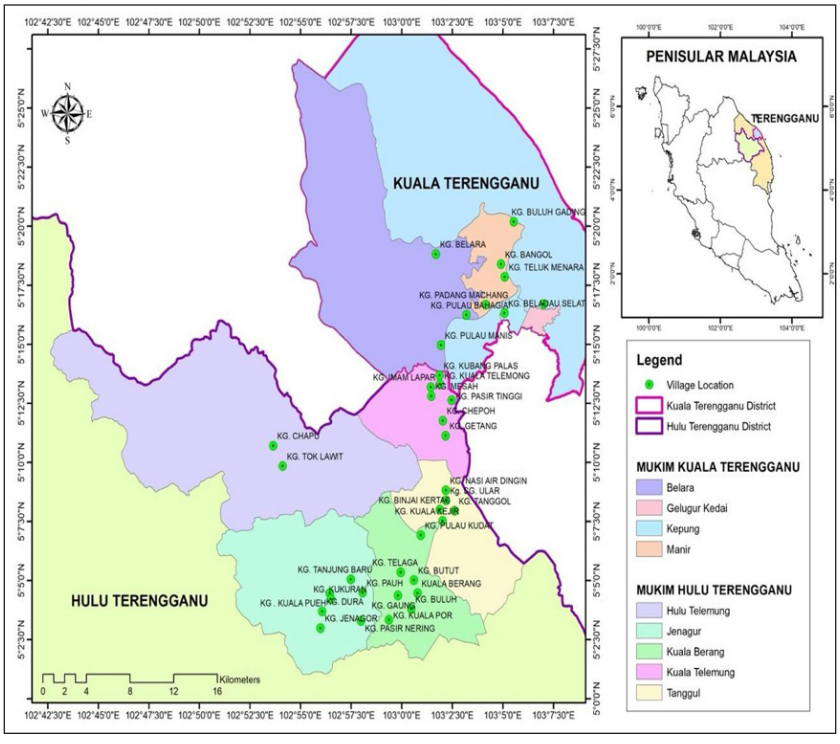


Figure 3. The study location for the collaborative model study of environmental resources management in the Terengganu River Basin and Kenyir Lake
Sources: Universiti Sultan Zainal Abidin (UniSZA), 2025

sampling technique known as convenience sampling. The study employed a multistage area-based sampling approach combined with convenience sampling at the respondent level. First, the study areas were selected based on the geographical distribution of local community settlements within the Terengganu River Basin and Kenyir Lake to ensure appropriate spatial coverage of the study area. Selected villages and settlements were then included as sampling locations. Within these selected locations, individual respondents were recruited using convenience sampling based on their availability, accessibility, willingness to participate, and fulfilment of the established study criteria. Therefore, the sampling procedure combined area-based selection of sampling locations with convenience sampling for the recruitment of individual respondents. A total of 380 respondents from the selected local community settlements participated in the study. The sample size for this study was determined based on the total population of the local communities residing in the selected villages within the Terengganu River Basin and Kenyir Lake area. Using an appropriate sample size determination approach with a 95% confidence level and a 5% margin of error, a minimum sample size of 380 respondents was considered adequate for the study. The respondents were distributed among the selected villages based on the relative population size of each village. However, considering the accessibility of respondents and their willingness to participate, a convenience sampling approach was applied for the final selection of respondents within each village. This approach ensured adequate representation of local communities across the selected study areas while accommodating fieldwork accessibility and respondent availability.

A non-probability convenience sampling approach was adopted to recruit respondents from the selected villages. This approach was selected due to practical constraints associated with accessing dispersed rural communities, the availability of eligible respondents during the fieldwork period, and the voluntary nature of participation. In addition, the absence of a complete and updated sampling frame of eligible residents across all selected villages made the implementation of probability-based sampling difficult. Efforts were nevertheless made to obtain responses from different villages and community settings to capture variation in local community perspectives. The final sample comprised 380 respondents. The use of convenience sampling may introduce sampling bias because respondents were selected based on accessibility, availability, and willingness to participate rather than through random selection. Consequently, the findings may not be fully generalisable to the entire population of residents in the Terengganu River Basin and Kenyir Lake area. The results should therefore be interpreted as reflecting the perceptions, knowledge, attitudes, and practices of the surveyed respondents rather than representing all residents in the study area. Future studies could employ probability-based

sampling, such as stratified or systematic random sampling, using an updated population sampling frame to improve representativeness and generalisability.

According to Van der Waldt (2020), the sampling approach has the following features: every individual who fits the requirements is invited to participate; the researcher's judgement is utilised to choose individual subjects; it is a more straightforward and cost-effective process than random selection. Well-established measuring scales found in earlier studies were used to create this research tool. Modifications were made to ensure the chosen products fit within the framework of resource management (Razak et al., 2019; Wahab et al., 2019; Wahab et al., 2024; Yunus et al., 2019). The questionnaires contain a few main sections such as demographics, practice, attitude, and knowledge of environmental resource management. The questionnaire consisted of three constructs. Knowledge was assessed using binary (True/False) items, while Attitude and Practice were measured using a five-point Likert scale. The questionnaire was reviewed by experts for content validity and pre-tested with respondents having similar characteristics to the study population. The internal consistency was satisfactory, with KR-20 = 0.81 for Knowledge, Cronbach's $\alpha = 0.86$ for Attitude, and Cronbach's $\alpha = 0.84$ for Practice. This study applied three statistical methods: Discriminant Analysis (DA), Descriptive Analysis, Hierarchical Agglomerative Cluster Analysis (HACA), and extended to a GIS spatial model using interpolation using *Inverse Distance Weighting* (IDW). For the spatial analysis, GPS coordinates were assigned to each selected village based on the village reference/central location rather than individual household coordinates. The mean Knowledge, Attitude, and Practice scores for each village were linked to these coordinates and used as the input points for IDW interpolation. The continuous variables interpolated were the composite Knowledge, Attitude, and Practice scores, which generated the corresponding spatial layers used in the Environmental Resource Management Model (ERMM).

According to Chua (2009), Discriminant Analysis (DA) is an inferential statistical technique used to predict study respondents, specifically whether they are correctly classified into the dependent variable category by considering several predictor variables. In addition, this analysis is a unidimensional test used to examine specific parameters only, and not all questions will be selected for analysis. While Descriptive Statistical Analysis is a type of statistics used to describe the characteristics of variables, the t-test is an inferential statistical test used to examine the differences between two or more data groups. In addition, HACA was used in this study as a cluster analysis technique, which aims to create a hierarchy of environmental resource management cluster questionnaires. The clustering outcome will help the settled communities develop an implementation strategy for the environmental resource management model. Subplots that will be separated based on the primary criteria in this classification showed the clustering

of ecological resource management implementation plans. Based on the HACA classification for implementation planning in the environmental resource management model in the Terengganu River Basin and Kenyir Lake, Figure 4 depicts the HACA illustration (Azid et al., 2015; Wahab et al., 2017). Every branch represents a data point (independent and dependent variables), whereas the root represents the entire dataset (questionnaires). Cutting at the correct times is based on the final clustering derived from the dendrogram.

RESULTS AND DISCUSSION

Discriminant Analysis (DA)

Discriminant Analysis (DA) was conducted to determine the Knowledge, Attitude, and Practice items that significantly discriminate between respondents based on residential location/village. The categorical grouping variable was used as the dependent variable, while the KAP items were treated as discriminating variables. The analysis was initially performed using the Tests of Equality of Group Means to identify individual items that differed significantly between the groups. To provide a complete multivariate interpretation of the discriminant function, the analysis also considered the multivariate test statistics, including Wilks' Lambda, Chi-square, degrees of freedom, significance level, and other relevant discriminant function statistics. The results for the Knowledge, Attitude, and Practice components are presented in Table 1.

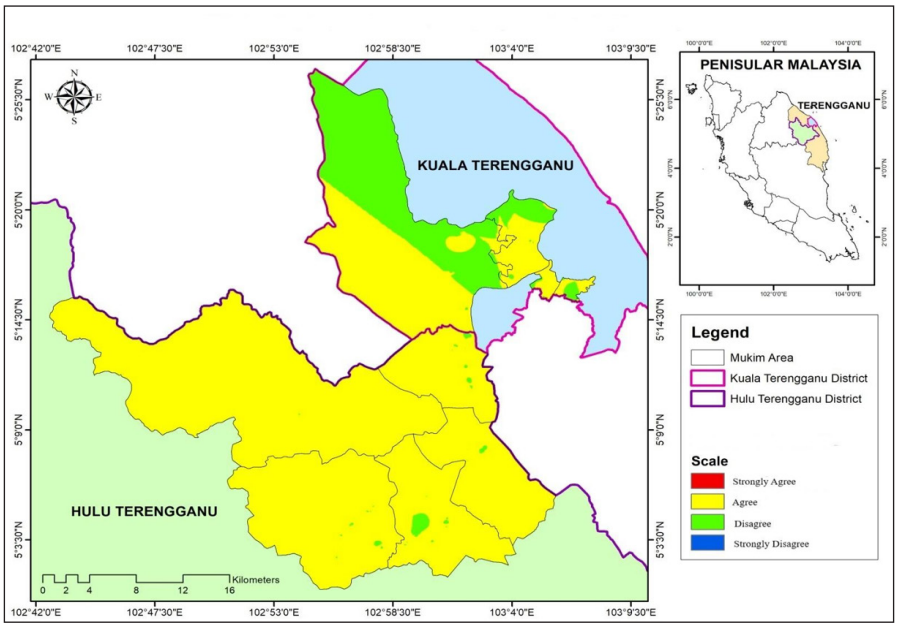


Figure 4a. The implementation planning in the environmental resource management model (Model A: Guidance from those responsible for environmental management)
Sources: Universiti Sultan Zainal Abidin (UniSZA), 2025

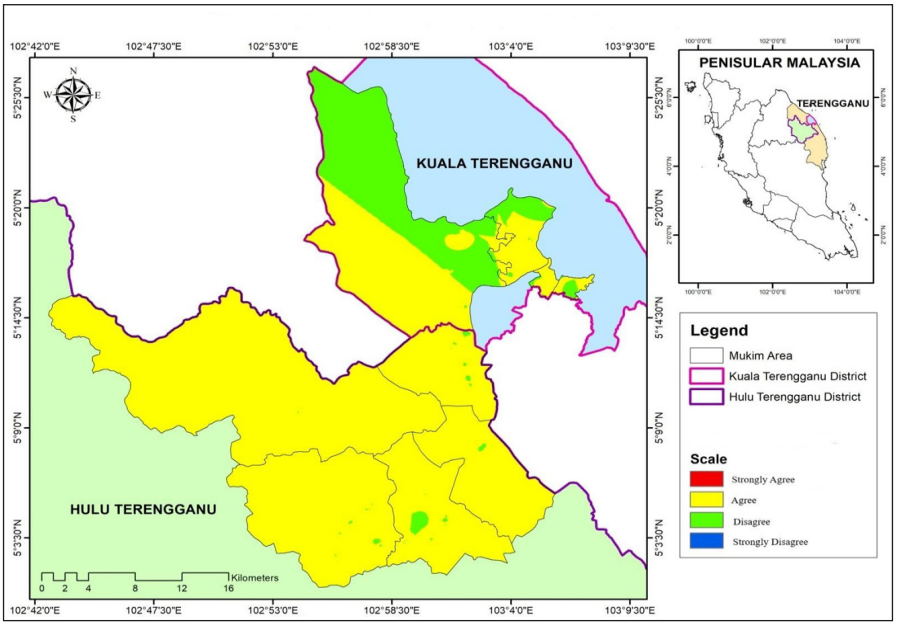


Figure 4b. The implementation planning in the environmental resource management model (Model B: The development of the environmental resource management system)
Sources: Universiti Sultan Zainal Abidin (UniSZA), 2025

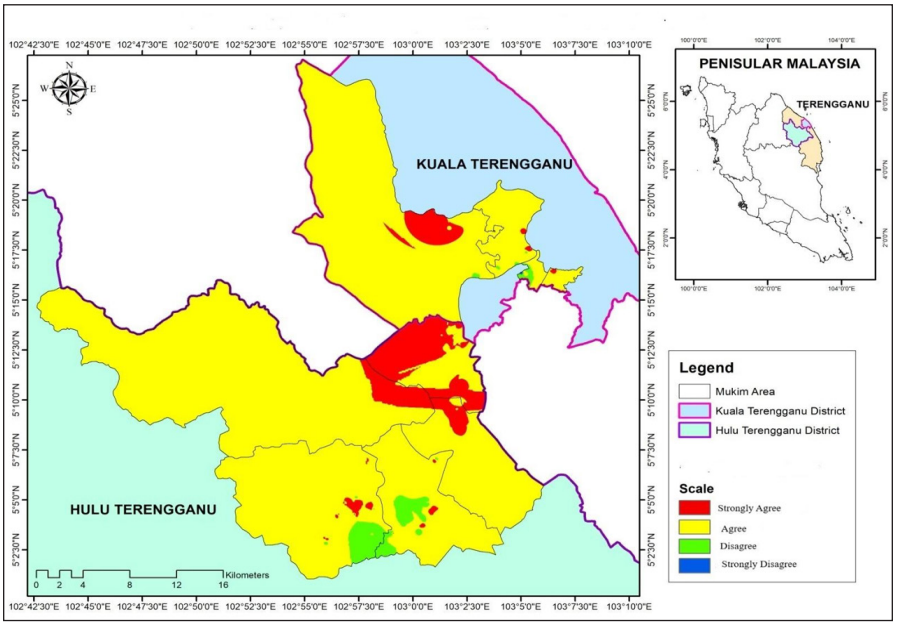


Figure 4c. The implementation planning in the environmental resource management model (Model C: Innovation of the existing environmental resource management system)
Sources: Universiti Sultan Zainal Abidin (UniSZA), 2025

Table 1
The community's practice, attitude and knowledge level regarding environmental resource management of the Terengganu River Basin and Kenyir Lake

Variable	Lambda	F	DF1	DF2	p-value
Community's Practice Level					
SA1	**0.9882**	**4.7595**	**1**	**380**	**0.0297**
SA2	0.9954	1.8324	1	380	0.1766
SA3	0.9945	2.2075	1	380	0.1381
SA4	0.9937	2.5190	1	380	0.1133
SA5	1.0000	0.0005	1	380	0.9816
SA6	**0.9779**	**9.0447**	**1**	**380**	**0.0028**
SA7	0.9945	2.1985	1	380	0.1389
SA8	0.9999	0.0277	1	380	0.8679
SA9	0.9991	0.3555	1	380	0.5513
SA10	0.9989	0.4473	1	380	0.5040
Community's Attitude Level					
SB1	0.9968	1.2731	1	380	0.2599
SB2	1.0000	0.0052	1	380	0.9423
SB3	1.0000	0.0095	1	380	0.9226
SB4	**0.9833**	**6.7929**	**1**	**380**	**0.0095**
SB5	0.9991	0.3739	1	380	0.5412
SB6	0.9928	2.9187	1	380	0.0883
SB7	0.9938	2.4789	1	380	0.1162
SB8	0.9989	0.4596	1	380	0.4982
SB9	1.0000	0.0036	1	380	0.9525
SB10	0.9972	1.1401	1	380	0.2863
Community's Knowledge Level					
SC1	0.9991	0.3483	1	380	0.5554
SC2	0.9950	2.0172	1	380	0.1563
SC3	0.9965	1.4198	1	380	0.2341
SC4	0.9961	1.5818	1	380	0.2092
SC5	**0.9900**	**4.0339**	**1**	**380**	**0.0453**
SC6	**0.9889**	**4.4988**	**1**	**380**	**0.0345**
SC7	1.0000	0.0028	1	380	0.9580
SC8	0.9969	1.2490	1	380	0.2644
SC9	**0.9871**	**5.2139**	**1**	**380**	**0.0229**
SC10	0.9770	9.4328	1	380	0.0023

Sources: Universiti Sultan Zainal Abidin (UniSZA) (primary survey data), 2025

Table 1 shows the unidimensional test of practice, attitude, and knowledge of environmental resource management. The DA for the practice, attitude, and knowledge domains of environmental resource management, respectively. There are two questionnaires (SA1 and SA6) (with significant values, p-value < 0.05). In DA, a statistically significant p-value ($p < 0.05$) indicates that the corresponding variable significantly differentiates the study groups and contributes to the discrimination between groups. Therefore, the significant variables identified in the analysis should be interpreted as discriminating variables rather than as indicators of a high level of agreement, attitude, practice, or knowledge. The level of agreement or knowledge should instead be assessed using descriptive statistics such as means, standard deviations, frequencies, or percentage distributions. The p-value of SA1 = 0.0297, and SA6 = 0.028. SA1 was statistically significant ($p = 0.0297$), indicating that this variable significantly differentiated the study groups with respect to practice related to improving environmental resource management through an integrated and sustainable management system. SA6 was also statistically significant ($p = 0.0028$), indicating that this variable significantly differentiated the study groups in terms of practice related to government regulations and commitment to environmental resource management modelling. The variable SA1 recorded a p-value of 0.0297, which refers to the question "Improving the environmental resource management system with an integrated and sustainable approach". This indicates that most respondents agree that a management system with integrated sustainability. Furthermore, the variable SA6 also shows a p-value of less than 0.05, specifically 0.0028, which refers to the question "Determination of government regulations and commitment to environmental resource management modelling". This means the results show that most respondents agree that the government regulations and commitment are important for collaboration in environmental sustainability. SB4 showed a statistically significant difference between the study groups ($p = 0.0095$), indicating that this variable significantly discriminated the groups in terms of their attitudes towards the development of an environmental management model based on community attitudes. Table 1 shows the unidimensional test of attitude toward environmental resource management. Only one out of 10 questionnaires recorded significant values as p-value < 0.05, as SB4. The p-value for SB4 = 0.0095. SB4 refers to the question, "Development of environmental management model based on the attitudes of communities". In the real world, environmental management in the community's attitudes, this model fosters bottom-up environmental stewardship rather than top-down enforcement. It's a dynamic, responsive, and human-centered approach crucial for long-term sustainability.

Besides that, Table 1 shows a unidimensional test of knowledge of environmental resource management.

There are four questionnaires (SC5, SC6, SC9, and SC10) (the significant values as p-value < 0.05). The p-value of SC5 = 0.0453, SC6 = 0.0345, SC9 = .0.0229 and SC10 = 0.0023. SC5 was statistically significant (p = 0.0453), indicating that this variable significantly differentiated the study groups in terms of knowledge concerning the arrangement of an environmental resource management system based on community knowledge. SC6 was statistically significant (p = 0.0345), indicating that this variable contributed significantly to discriminating the study groups regarding the integration of environmental and traditional management systems based on community knowledge. SC9 showed a statistically significant result (p = 0.0229), indicating that this variable significantly differentiated the study groups with respect to the integration of environmental management systems with community needs. SC10 was statistically significant (p = 0.0023), indicating that this variable significantly differentiated the study groups in relation to guidance and counselling from those responsible for natural resource management among communities. The variable SC5 obtained a p-value of 0.0453, which refers to the question "Arrange the environmental resource management system based on the knowledge of the communities". Community-based environmental resource management places local knowledge and participation at the core of sustainable practices. It empowers communities to manage resources through inclusive decision-making, adaptive strategies, and support from external stakeholders, ensuring ecological balance and social well-being. The variable SC6 recorded a p-value of 0.0345, referring to the question "Integration of environmental and traditional management systems based on the knowledge of communities". This shows that most respondents know the importance of an integrated management system. Furthermore, variables S9 and SC10 recorded p-values of 0.0229 and 0.0023, respectively. S9 refers to the question "The development of management and environmental management systems is integrated with the needs of communities". In contrast, SC10 refers to the "Guidance and counselling from those responsible for natural resource management among communities". Most respondents know the benefits of properly maintained environmental resource management and conservation. Based on these four variables, communities have a high level of knowledge regarding these issues.

Hierarchical Agglomerative Cluster Analysis (HACA)

The classification of implementation planning in the environmental resource management model is related to the practice, attitudes, and knowledge level among community settlements along the Terengganu River Basin and Kenyir Lake using HACA. Hierarchical Agglomerative Cluster Analysis (HACA) was conducted to group the questionnaire items (variables) based on the similarity of their response patterns across the sample. The analysis

was performed to identify clusters of related environmental management variables, which were subsequently used to develop the three sub-models of the Environmental Resource Management Model (ERMM). The resulting dendrogram illustrates the rescaled distance at which the variables were combined and supports the selection of a three-cluster solution (Table 2).

Based on the clustering results, the questionnaire items were grouped into three clusters corresponding to Model A, Model B, and Model C. HACA was used to classify each variable (the questionnaire consists of seven questions based on practice, attitudes, and knowledge, such as SA1, SA6, SB4, SC5, SC6, SC9, and SC10). The HACA analysis method transfers the data according to the classes of variables to form the implementation planning in environmental resource management models. The models formed, Model A, Model B, and Model C, are based on the homogeneity class of seven questions related to the practice, attitudes, and knowledge level in the sub-plot based on the specific characteristics. HACA aims to identify the implementation planning in the environmental resource management model based on the practice, attitudes, and knowledge level among community settlements. Then, the results from the classification model from HACA will be extended for a GIS spatial model using interpolation using the Inverse Distance

Table 2
The clustering classification model of the Terengganu River Basin and Kenyir Lake

Model	Question	Statement
MODEL A Guidance from those responsible for environmental management	SA1	Improving the environmental resource management system with an integrated and sustainable.
	SA6	Determination of government regulations and commitment to environmental resource management modelling.

Model A is referring to the guidance from those responsible for environmental resource management among among community settlements along the Terengganu River Basin and Kenyir Lake. If government regulations are established, natural resource management modelling is dedicated, and the environmental resource management system is enhanced with an integrated and sustainable approach, communities' awareness and behaviour regarding the importance of maintaining environmental resources will improve. One effective method for achieving sustainable development is community involvement guided by environmental specialists. Figure 4(a) showed the distribution requirements of implementation planning in developing process of model based on the practice, attitude, and knowledge. Based on the distribution, most of the communities strongly agree with the guidance and education as well as knowledge on the environmental resource management. In addition, the spatial analysis showed most respondents in this study agree with the guidance measures from those responsible in managing natural resources and guiding them to be more sensitive to the latest information of environmental sustainability. It is estimated that almost 90% of the respondents around the study area represent the entire communities strongly agree and agree with this management modelling. This is because, communities in location study starting to accept the opinion that sustainable development offers a balanced form of development between current development opportunities and survival for future generations.

Table 2 (*continued*)

Model	Question	Statement
MODEL B The development of environmental resource management system	SB4	Development of environmental management model based on the attitudes of communities.
Model B refers to the development in various specific aspects such as the human capital development among the communities based on the education system of environmental resource management. Figure 4(b) showed the requirement distribution the implementation planning in environmental resource management model (Model B: The development of natural resource management system) based on the attitudes level among communities Terengganu River Basin and Kenyir Lake. The spatial distribution stated most respondents in agree with the development of environmental resource management which involves developing in aspects of education system, policy, dissemination of technology information and pollution control methods as well as an effective of conservation and preservation programmes of natural resources management. Meanwhile, mostly of communities also agree with this management model. In addition, 70% of respondents in whom agree with question SB4 ("Development of environmental management model based on the attitudes of communities"). It can be said that the communities are now increasingly attitudes level of environmental resource management policies where they seem more sensitive to the latest information on environmental management. Besides that, Malaysia is now more committed in the environmental resource management especially in conservation and preservation's programmes especially forests sources, which are the natural resources closest to the communities. The ministry through agencies related the environment such as Department of Agriculture (DOA), Department of Wildlife and National Park (DWNP) and Department of Environment (DOE) constantly alert and sensitive about any problems and latest information about development of environmental resource management especially along the rural areas (Entezami et al., 2024; Goessens et al., 2014; Otieno et al., 2016).		
MODEL C Innovation of existing the environmental resource management system	SC5	Arrange the environmental resource management system based on the knowledge of the communities.
	SC6	Integration of environmental and traditional management systems based on the knowledge of communities.
	SC9	The development of management and environmental management systems is integrated with the needs of communities.
	SC10	Guidance and counselling from those responsible for natural resource management among indigenist's communities.
Model C refers to the innovation of the current natural resource management system, which means that rather than being abolished, the management system that has been implemented needs to be improved in accordance with the needs of rural communities as determined by the level of technological development. Addressing poverty reduction, food security, and environmental sustainability in an integrated way is the biggest challenge facing rural development, particularly in rural areas (Fauziah & Agamuthu, 2012; Fuzi et al., 2019; Miao et al., 2017). In addition, combating land degradation and desertification, stopping deforestation, encouraging appropriate management of water resources, and safeguarding biodiversity are other difficult issues that must be addressed in order to improve the innovation of the current environmental resource management system. To do this, rural communities in the Kenyir Lake Basin must actively participate in communication processes. Most rural communities agree with the Model A's natural resource management, but it is estimated only 5% of respondents do not agree with the implementation of this model management (Refer Figure 4(a)). From the GIS spatial model showed the respondents from southeastern part of study location who not really agree with this model. However, it can be seen most of rural communities agree with the improvement of innovation of existing the environmental resource management system. In conclusion, the knowledge level about natural resource management among rural communities is improving and it needs to be nurtured from an early age		

Sources: Universiti Sultan Zainal Abidin (UniSZA), 2025

Weighting (IDW) method to determine the distribution pattern of respondents about the environmental resource management model. For the spatial analysis, the categorical responses obtained from the questionnaire were first transformed into numerical agreement scores based on the Likert scale. For each selected village, the mean agreement score was calculated for each ERMM sub-model (Model A, Model B, and Model C) based on respondents' responses in that village. These village-level mean scores were then assigned to the corresponding spatial locations (village centroids) and used as continuous input values for the Inverse Distance Weighted (IDW) interpolation. Thus, the IDW analysis did not directly interpolate categorical or cluster-membership responses or percentage values; rather, it interpolated village-level mean agreement scores for each sub-model to generate continuous spatial surfaces.

Based on the HACA, the total number of respondents was 380, and they were classified into three classes of implementation planning in the environmental resource management model. Table 2 shows the questionnaires about implementation planning in natural resource management based on the clustering classification of the model at rural community settlements along the Kenyir Lake Basin. These questions are classified into three clusters using HACA, such as Cluster 1 (Model A: Guidance from those responsible for environmental management), Cluster 2 (Model B: The development of a environmental resource management system), and Cluster 3 (Model C: Innovation of the existing environmental resource management system). Model A refers to an element of the guidance from those responsible for environmental management, which consists of questions SA1 and SA6. At the same time, Model B focused on developing the ecological resource management system, which consists of question SB4. Model C refers to the innovation of the existing natural resource management system, which consisted of SC1, SC2, SC9, and SC10.

CONCLUSION

Resource management is essential to enhancing the community's ability to care for the environment. Addressing structural and behavioral dimensions is critical to fostering environmental consciousness, ethical values, skills, and sustainable behavior among communities. Based on respondents' opinions and requirements, several strategic actions are necessary, including guidance from those responsible for environmental management, developing an ecological resource management system, and innovating the existing one. The empirical Knowledge, Attitude and Practice findings provided the baseline for developing these three strategic components as Model A (Guidance), Model B (System Development), and Model C (Innovation), respectively. The spatial analysis using IDW interpolation further identified variations in KAP responses across the settlements along the Terengganu River Basin and Kenyir Lake, indicating areas

that may require greater management attention. Integrating the Environmental Resources Management Model (ERMM) provides a systematic approach to balancing environmental, economic, and social factors through participatory planning and decision-making. This model emphasizes community involvement, inter-agency collaboration, and the sustainable use of resources. Concurrently, implementing an Environmental Management Plan (EMP) ensures that all environmental impacts are identified, monitored, and mitigated effectively through proactive planning and regulatory compliance. The synergy between the ERMM and EMP frameworks offers a holistic and adaptive strategy for addressing environmental challenges in community settlements, particularly in ecologically sensitive areas like the Terengganu River Basin and Kenyir Lake.

IMPLICATIONS OF THE STUDY

This study provides valuable insights into the role of community awareness, practice, and knowledge in the process of developing sustainable environmental resource management. The proposed Environmental Resource Management Model (ERMM) can serve as a strategic tool for policymakers, local authorities, and environmental stakeholders. These outputs contributed to enhancing participatory environmental governance. The findings emphasise the importance of integrating traditional knowledge with scientific approaches, fostering community empowerment, and promoting localised environmental education. The novelty of studies to ensure the long-term sustainability of natural resources in rural Malaysia.

LIMITATIONS AND RECOMMENDATION FOR FUTURE RESEARCH

Based on past studies, several have examined environmental degradation and resource management in Malaysia, but only a few studies have integrated quantitative and spatial techniques to develop a comprehensive environmental community-based model. There is limited attention, particularly from the perspective of local community practices, knowledge, and attitudes, about the environmental dynamics of the Terengganu River Basin and Kenyir Lake. Despite the comprehensive data collected, this study is limited by its focus on selected villages within the Terengganu River Basin and Kenyir Lake, which may not fully represent the diversity of environmental perceptions across different regions. Future studies could expand the geographic scope and include comparative analyses across other river basins in Malaysia. Additionally, incorporating qualitative methods such as focus groups or interviews may deepen the understanding of socio-cultural dimensions influencing environmental attitudes. Future research should also explore the impact of specific policy interventions and assess the long-term effectiveness of the proposed management model through continuous monitoring.

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