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Application of Geographical Information Systems in Sustainability in the Malaysian Context: A Review

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Abstract: The depletion of natural resources to meet growing demands for food, fuel, and fibre due to population growth and urbanisation has led to significant environmental damage in Malaysia. Hence, greenhouse gases have increased atmospheric greenhouse gas (GHG) levels, contributing to global warming and climate change. From developing software to analysing data, GIS is influenced by political, economic, and social factors throughout its production process. This paper introduces a structured framework aimed at conducting an extensive literature review study on the application of the Geographic Information System (GIS) to sustainability in Malaysia. The framework delineates essential steps and factors for identifying pertinent literature, assessing prior research, amalgamating outcomes, and pinpointing research voids. Adhering to this framework enables researchers to methodically scrutinise and appraise existing literature, furnishing a thorough depiction of the present state of knowledge within the application of GIS to sustainability in Malaysia. This literature review highlights GIS as a critical tool for promoting sustainable management across various domains, including flood hazard management, urban planning, agriculture, forest monitoring, transportation, air quality management, and water resource management, by providing access to data, models, and mapping.

Keywords: Environmental Management; Environmental Planning; Environmental Sustainability; GIS.

1.0 Introduction

Many countries have suffered from environmental deterioration, including Malaysia, which has seen significant environmental damage since the 1980s (Hasnu and Muhammad, 2022). It is imperative to prioritise sustainability over the excessive use of natural resources. The goal of sustainable development is to address human needs while protecting the environment so that they can be satisfied for both present and future generations (Băneș, 2010). Since 2015, the United Nations has adopted 17 SDGs and urged countries, stakeholders, and individuals worldwide to work together to solve serious concerns such as climate change, urbanisation, an ageing society, urban deterioration, and others (Chen et al., 2019). Hence, the application of GIS technology has become the focus of sustainable development in the resolution of numerous planning and management difficulties. This research presents the function of the application of geographical information systems (GIS) to sustainability in Malaysia.

2.0 Literature Review

2.1 Geographical Information System (GIS)

GIS refers to computer-based techniques and technologies used in the gathering, organising, processing, modelling, and presenting of geographic data (Selamat et al., 2012). GIS arranges geographic data such that it can be easily selected by someone viewing a map in order to complete a particular activity or project (Băneș, 2010). GIS can be used for problem-solving and decision-making, as well as data visualisation in a spatial setting (Yew et al., 2019). Unsustainable development is frequently characterised by economic imbalances, social insecurity, and environmental degradation that many countries still face today (Patil, 2022). Therefore, GIS can also be used for remote sensing, hazard assessment, resource management, land-use planning, hydrology, waste management, wildlife management, and riparian zone regulation and is also employed in transportation, military operations, public health, and disaster management (Goyal, Sharma, and Surampalli, 2020). All of these functionalities have established GIS as one of the most effective and complete methodologies in a variety of fields (Xhafa and Kosovrasti, 2015).

2.2 GIS in Environmental Planning and Management

ICT advancements have transformed urban planning and management significantly. In Malaysia, a systematic planning approach involving identifying needs, setting goals, evaluating options, and monitoring programs has been adopted. GIS has been implemented as a support system, which the government has mandated in Act 172 of the Town and Country Planning Act (1976), with the latest amendment in 2001, and is integral to Malaysian planning due to its ability to capture, store, and analyse geospatial data. Yaakup et al. (2005) advocate for GIS integration into development plans, aligning with objectives to forecast and strategize future development considering physical, environmental, and socio-economic factors.

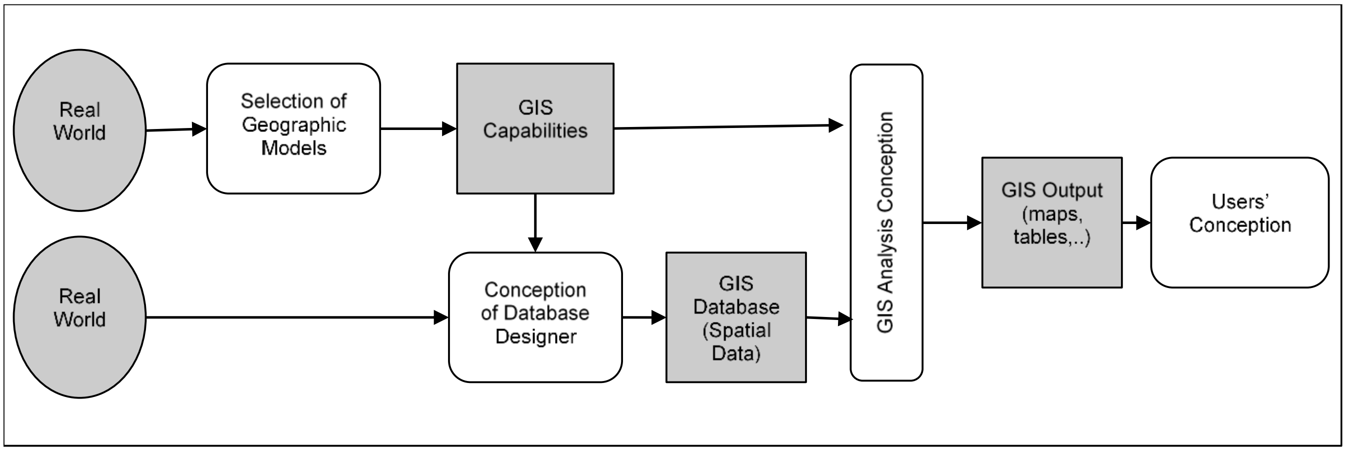

Figure 1: A model of communication for GIS (Bunch, 2001)

Figure 1 depicts a communication model for GIS by Bunch (2001), which highlights concepts and systems like Cartesian space, Pythagorean geometry, and Boolean logic to represent and manipulate spatial entities (Sheppard, 1995; Bunch, 2001; Patil, 2022). This illustrates the central role of GIS in preparing conceptual and environmental spatial information to support decision-making in planning and management. Figure 2 demonstrates various ways in which GIS is utilised in environmental planning and management.

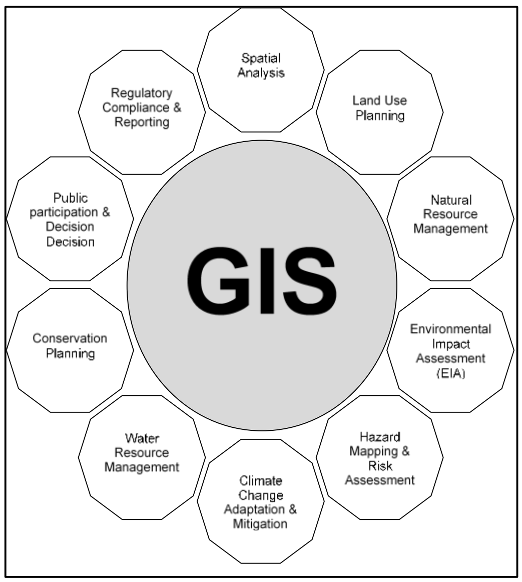

Figure 2: Function of GIS for Environmental Planning and Management

IS is essential in Planning Support Systems (PSS) and Decision Support Systems (DSS) for environmental planning, especially in urban management (Yaakup et al., 2005). It facilitates data visualisation, aiding decision-making through maps and charts. GIS models past conditions and future scenarios, supporting environmental planning. The evolution of information technology towards PSS highlights GIS's growing importance. DSS enhances decision-making by providing tools for informed choices.

2.3 GIS in Environmental Sustainability

GIS plays a crucial role in natural resource management, enabling the study of resources like LULC, groundwater, climate change, and others for sustainability planning. Patil (2022) emphasises the importance of considering regulatory systems and expected distributions for environmental sustainability. GIS integrates geographical and attribute data to create optimal resource (land use, water, and others) plans and supports decision-making, ensuring wise choices for sustainability. Goyal, Sharma, and Surampalli (2020) highlight GIS's role in providing environmental information across disciplines, particularly in planning and resource management. Moreover, its ability to analyse environmental changes and design 3D structures underscores its significance in sustainability efforts. (Goyal et al., 2020; Malczewski, 1996; Patil, 2022). Patil (2022) also emphasises GIS's role in planning and controlling environmental threats, serving as a crucial tool for evaluation, mitigation, arrangement, scientific analysis, and training. In essence, GIS acts as a powerful tool that integrates spatial data, analysis, and decision support systems to promote environmental sustainability, discuss sustainable development practices, protect natural resources, and create resilient communities for future generations.

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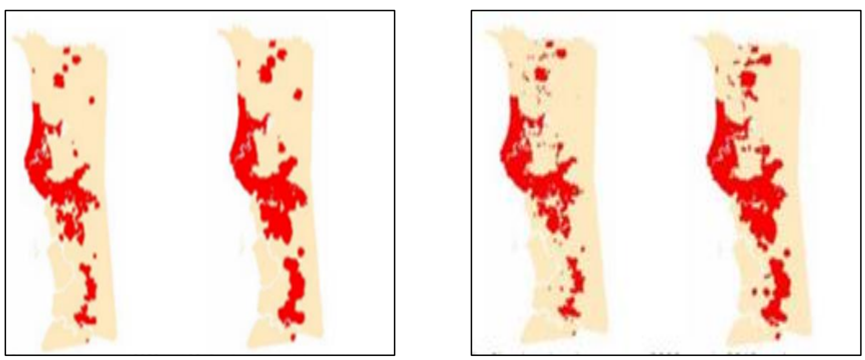
3.0 Application of GIS in Sustainability Development

3.1 Management of flood hazards

Floods occur almost every year in Malaysia and are the most devastating disasters, with large and small impacts. Floods such as flash floods, which develop from strong and continuous rainfall, can damage infrastructure, agricultural products, and displace people, animals, and aquatic life (Lawal et al., 2011). GIS enables environmental managers to build GIS maps that depict how natural resources adapt to changes over time, such as coastal, vegetation, and geological shifts (Ameen et al., 2019). GIS has emerged as a promising and excellent tool for flood hazard management as well as for assessing risk areas based on specific geographical locations (Lawal et al., 2011). Its extensive capabilities allowed it to create a flood danger map by defining flood-prone zones. According to Hassan and Kamarudzaman (2023), the Flood Hazard Index (FHI) was calculated using the Analytical Hierarchy Process (AHP) approach in ArcGIS, which includes six parameters: annual rainfall, slope, river density, land use and land cover (LULC), elevation, and soil permeability in the Kelantan River catchment. The results showed Tanah Merah and Jeli were primarily located in a very high flood zone that would experience regular flooding during the rainy season towards the end of the year. This is because those areas are flat in slope and the elevations are low (Hassan and Kamarudzaman, 2023). In addition, data and information help planners and decision-makers take timely, proactive steps in pre-disaster situations. It will also be useful in post-disaster activities to assess flood damage and losses (Mohd, Alias, and Daud, 2006).

3.2 Urban Planning

The physical, environmental, and socioeconomic components appear to have been the most affected by unregulated and uncontrollable growth such as urbanisation (Yaakub et al., 2005). The benefits of using GIS in urban planning include improved mapping accessibility, increased map prevalence, the most efficient thematic mapping, and reduced maintenance costs (Patil, 2022). Spatial queries in the database can be utilised by planners to extract relevant information (Yeh, 199). In this context, GIS plays an important role in urban planning by facilitating the establishment and development of archival, management, analytical, and modelling tools (Xhafa and Kosovrasti, 2015). Based on Samat's (2007) research, Cellular Automata (CA) is one of the models that can be used to examine the planning approach outlined in the national spatial plan to determine whether such development would have a detrimental long-term impact. Figure 3 shows the two scenarios modelled, which are planned development and uncontrolled growth, to simulate urban spatial patterns from 1990 to 2000 and 2010. The result showed that although agricultural land development near existing urban areas was deregulated in preparation for an uncontrolled growth scenario, no large-scale new development took place in Seberang Perai, Penang, Malaysia. Moreover, urban growth appears to be moving towards the southern district, assuming that the transition regulations and the MCE-suitability index estimated were reasonable. Therefore, GIS helps specialists in urban planning assess land use in an area and can make judgements to implement development plans (Yew, 2019).



(i) Simulated urban area 2000 and 2010 using planned development growth scenario

(ii) Simulated urban area 2000 and 2010 using uncontrolled growth scenario

Figure 3: Simulated urban spatial pattern produced using a GIS-based CA model (Samat, 2007)

3.3 Agriculture and Food Security

GIS is a valuable technology for both designing and managing agricultural areas. It can be used in tasks like crop yield estimation, soil fertility analysis, crop mapping, drought assessment, pest detection, precision agriculture, and weed management (Mathenge, Sonneveld, and Broerse, 2022). Additionally, GIS integrates diverse maps and satellite data to model complex ecosystems, aiding in the creation of images, maps, and animations. Patil (2022). It plays a significant role in agriculture by facilitating research-based assessments of production data, particularly those conducted by farm managers. For instance, Mohammed et al. (2005) studied an urban expansion's impact on agriculture in the Balik Pulau region of Penang State by integrating GIS with remote sensing by using Landsat TM (Thematic Mapper) images from 1992 and 2002 at a 30m resolution and Landsat ETM (Enhanced Thematic Mapper) imagery from 2010. Findings show a substantial increase in built-up areas over four decades, leading to a decline in agricultural land from 1960 to 2000. Specifically, built-up areas expanded from 1793.22 ha to 3235.38 ha, while agricultural areas decreased from 6171.32 ha to 4727.83 ha between 1992 and 2002. They highlight that rapid economic growth, robust infrastructure, and industrialization significantly contribute to the depletion of arable land, particularly affecting fertile areas like paddy fields nationwide. So, GIS integrates spatial data, conducts analysis, and employs decision support systems to optimise resource use, mitigate risks, and enhance resilience amidst changing agricultural landscapes and growing food demand due to rapid urbanisation and industrialization. Patil (2022) also stated how GIS boosts global agricultural productivity through efficient land management and cost reduction via tasks like assessing output, studying soil, and addressing erosion, despite lax regulation on inputs.

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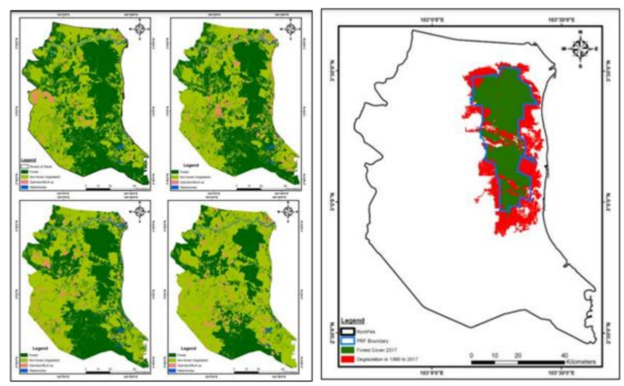
3.4 Forest Monitoring and Management

GIS plays a crucial role as a planning tool for mapping and zoning forests, which can enhance the quality of information accessible to forest management (Ilham, Ponachi, and Bohari, 2020). Besides, forestry management is a highly intricate environment where data can change from time to time and demands the efficient and meticulous handling of vast amounts of data and information. Thus, Ilham, Ponachi, and Bohari (2020) emphasise that careful planning is essential to safeguarding forest areas from human activities. Furthermore, this tool also helps forestry specialists monitor the changing conditions of forests to make sustainable decisions for protection and management. For nearly two- decades, government agencies like the Forestry Department of Peninsular Malaysia (FDPM) and global NGOs like the World Resource Institute (WRI) and World Wildlife Fund (WWF) have utilised geospatial technology to plan, manage, and monitor forest areas (Hamid and Rahman, 2016).

There are also many studies by forestry specialists to monitor trends in forest areas, such as forest degradation, especially in tropical forests in Malaysia. A prior study by Othman et al. (2019), titled "Forest Degradation Analysis Using Geospatial Techniques Approach in the Tropical Region of Pahang, Malaysia," demonstrates the use of these tools in sustainable forest monitoring, planning, and management. This paper aims to assess forest dynamics in the Rompin and Pekan districts of Pahang State using satellite imagery and land use modelling. Pekan was chosen as the study location because it was the largest peat swamp forest (PSF) in Peninsular Malaysia, alongside the inland dipterocarp forest (Othman et al., 2019). During the research, they classified land use using maximum likelihood classification (MLC) and analysed it further with the Land Change Modeller (LCM). Results indicate that the net loss of forest land use has been 15% over the past 25 years, mainly converted to other vegetation types, with a 45% overall loss and a 20% gain. The PSF also experienced continuous degradation from 1990 to 2017, with a total loss exceeding 700 km2, as shown in Figure 4.

This study also underscores the exploitation of forest land use and highlights the necessity for detailed forest monitoring to identify contributing factors. In addition, the role of Permanent Reserved Forest (PRF) appears significant, as deforestation primarily occurs outside PRF boundaries, with some disturbed areas undergoing reforestation efforts. In essence, this system is crucial for forest monitoring, involving tasks such as mapping forest cover, detecting deforestation, evaluating forest health, monitoring fires, managing carbon sequestration, preserving biodiversity, preventing illegal logging, involving stakeholders, and informing policy decisions.



(i) Spatial land use distribution in Rompan & Pekan district in Pahang; (from top left) 1990, 2000, 2010, and 2017

(ii) Peat Swamp Forest (PSF) Degradation

Figure 4: Result of Study using GIS (Othman et al., 2019)

3.5 Transportation and Air Quality Management

The number of private cars and motorcycles per thousand populations in Malaysia has grown rapidly in recent decades (Othman and Ali, 2020). However, transportation contributes to air pollution, which poses major health concerns for humans. Therefore, GIS measures by utilising existing monitoring networks and estimates pollution levels, which can be modified to account for traffic flow patterns and atmospheric conditions (Kumar, Mishra, and Singh, 2015). Based on the Jumaah et al. (2019) study, the Inverse Distance Weighted (IDW) geostatistical technique and the Ordinary Least Squares (OLS) model in GIS were applied to predict the air quality index (AQI) levels and spatial variability of air pollutants in Kuala Lumpur. They used IDW to produce five parameters that map range by colour, which are AQI, temperature, humidity, precipitation, and wind speed. Meanwhile, the OLS regression model was used to test the correlation between the AQI and the independent variables in June, July, and August 2018. For example, the value of a regression coefficient greater than 0.05 is considered a good correlation, such as humidity (0.07), wind speed (0.07), and (0.93) except temperature (0.01) in July 2018. Figure 5 depicts the regression resulting map of the AQI estimate by each prediction model from June to August 2018.

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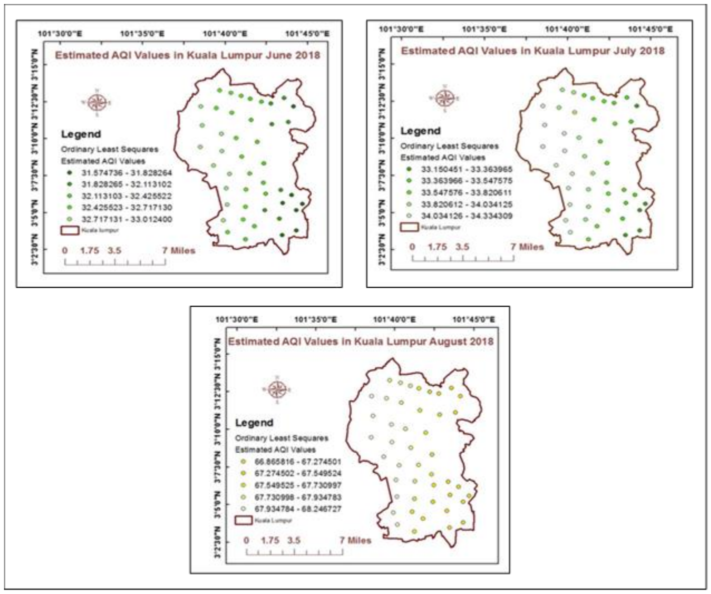

Figure 5: The regression resulting map of AQI estimation of each prediction model from June to August 2018 (Jumaah et al., 2019)

Not only that, they used two types of validation to assess the ability of the produced models, which are OLS model validation and OLS model testing validation. Consequently, these models provide precise information and accurate maps of the spread of air pollutants, as well as air quality predictions (Jumaah et al., 2019). In addition, GIS is also a useful tool for local governments to forecast air quality pollution alert levels (Kumar, Mishra, and Singh, 2015).

3.6 Water Resources Management

With the looming threat of water scarcity prompting competition among diverse water users, there is a growing necessity for enhanced irrigation management to attain greater water use efficiency (Masud & Bastiaanssen, 2017). Goyal, Sharma, and Surampalli (2020) also emphasise that both developed and developing countries are facing the challenge of water resource security, with water resource managers utilising remote sensing-based Earth Observation (EO) for river basin management, hydrologic parameter observations, and drought monitoring. Malaysia has experienced swift development accompanied by population growth, urbanisation, industrialization, logging, and agricultural expansion that have resulted in intricate environmental issues, particularly affecting water resources. So, necessities in the integration of disparate geographic datasets underscore the essential role of GIS and remote sensing technology due to the complexity and scale of these databases for water resource management (Goyal, Sharma, and Surampalli, 2020).

Furthermore, Malaysia is well endowed with abundant natural water resources crucial for socio-economic development and has had shifts in its water situation over the past decades (Ahmad, Shahabi, and Ahmad, 2015). Hence, a study has been conducted by Bakhtyar et al. (2015), which utilised GIS to pinpoint optimal water reservoir locations in Batu Pahat, Johor. Through the study, the main criteria, including pipelines, elevation, rivers, land use, road and water supply networks, and slope, have been chosen to do an analytical hierarchy process (AHP) and weighted overlay (WO) method. This method will identify the key reservoir locations by considering projected population growth by 2050. The analysis detected five new sites for water resources in the future, as shown by Figure 6. This study shows the effectiveness of AHP analysis integrated with GIS analysis in reservoir location determination to search for new water resources for future generations. Besides, this study shows that GIS can be a valuable tool for identifying suitable locations for water reservoirs in Malaysia, where future water demand represents a significant concern in water supply planning, with estimates indicating a projected demand of 206 M/L/day by 2020 (Ahmad, Shahabi, and Ahmad, 2015).

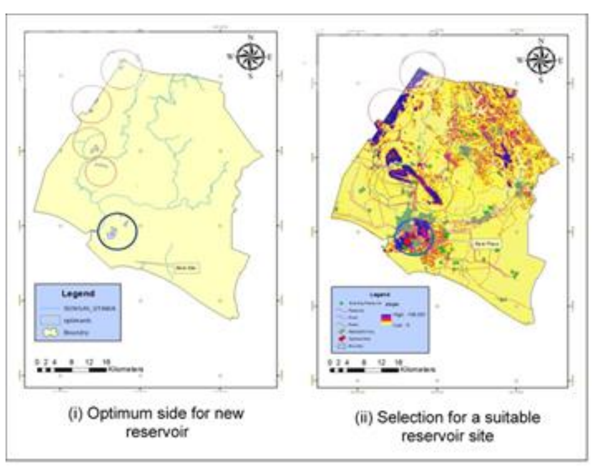

Figure 6: Five New Reservoir Site (Ahmad et al., 2015)

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In addition, GIS also helps to identify the pollutant sources in other areas of the river, as demonstrated by a study by Hua (2017) at the Malacca River using water sampling and GIS. Nine sampling stations across the Malacca River sub-basins were analysed. Results showed stations 4 and 5 as polluted, while stations 8 and 9 were clean. Principal Component Analysis (PCA) identified agricultural, residential, industrial, animal husbandry, and sewage treatment plant activities as pollution sources. GIS identified hotspots such as agricultural activities in station 5 and residential activities in stations 1, 2, 5, 6, and 7. Recommendations include controlling pollutant sources and using GIS data for better river quality management and urban planning. Overall, GIS plays a crucial role in enhancing the efficiency, effectiveness, and sustainability of water resource management practices by providing valuable spatial insights and decision support tools with supporting technology such as remote sensing. Goyal, Sharma, and Surampalli (2020) emphasise remote sensing, and GIS can be seamlessly integrated for environmental modelling and analysis.

4.0 Conclusions

The results of this literature review study showed the impacts on the utilisation of GIS applications through various methods in Malaysia. Although GIS has the potential to offer innovative representation methods in planning activities, it also supports social coordination between humans and technology. GIS applications play an important role through the data, models, and mapping accessibility in flood hazards management, urban planning, agriculture and food security, forest monitoring and management, transportation and air quality management, and water resource management. Therefore, this technology can be a significant tool for assisting individuals in developing plans for the successful implementation of sustainable management techniques at both the local and global levels.

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References

Ameen, A. A. A., Ameen, K. M., Malavika, K. V., Manchakkal. M., & Johnson, A. A. (2019). Flood Mapping and Impact Analysis using GIS. International Journal of Engineering Research & Technology, 8(5), 904-906.

Ahmad, B. A., Shahabi, H. & Ahmad, B. B. (2015). Application of GIS Based Multi-criteria Analysis in Site Selection of Water Reservoirs (Case Study: Batu Pahat, Malaysia). Research Journal of applied Sciences, Engineering and Technology, 9(11), 995-1005.

Băneș, A., Orboi, M. D., Monea, A., & Monea, M. (2010). Sustainable development by GIS. Research Journal of Agricultural Science, 42(3).

Bunch, J. (2001). GIS for Marginalization or Empowerment in Environmental Management: A South Indian Example. The Indian Geographical Journal, 76(2), 71-88.

Bunch. J, Kumaran. T., & Joseph. R. (2012). Using Geographic Information Systems (GIS) For Spatial Planning and Environmental Management in India: Critical Considerations. International Journal of Applied Science and Technology, 2(2), 40-54.

Chen, C. W., Lin, C. Y., Tung, C. H., Liao, H. M., Jang, J. J., Lai, K. C., Li, M. Y., & Huang, Y. L. (2019). Employing GIS Towards Shaping A Smart and Sustainable Future: A Brief Policy Survey of Global and Taiwan's Efforts. Proceedings of the International Cartographic Association, 2, 1-8.

Food and Agriculture Organization of the United Nations. (n.d.). Remote Sensing and GIS for Sustainable Agriculture and Food Security Contributes to FAO's Strategic Objective 5 Increase the Resilience of Livelihoods to Threats and Crises. Retrieved from https://www.fao.org/3/i4588e/i4588e.pdf

Goyal, M. K., Sharma, A., & Surampalli, R. Y. (2020). Remote Sensing and GIS Applications in Sustainability. Sustainability: Fundamentals and Applications, 605-626.

Hamid, W. A., & Rahman, S. B. W. A. (2016). Comparison Results of Forest Cover Mapping of Peninsular Malaysia using Geospatial Technology. IOP Conference Series: Earth and Environmental Science, 37. doi: 10.1088/1755-1315/37/1/012027

Hasnu, N. N. M., & Muhammad, I. (2022). Environmental Issues in Malaysia: Suggestion to Impose Carbon Tax. Asian-Pacific Management Accounting Journal, 17(1), 65-95.

Hassan, Z., & Kamarudzaman, A. N. (2023). Development of Flood Hazard Index (FHI) of the Kelantan River Catchment Using Geographic Information System (GIS) Based Analytical Hierarchy Process (AHP). Pertanika Journal of Science & Technology, 31(1), 203-215.

Hua, A. K. (2017). Identifying The Source of Pollutants in Malacca River using GIS Approach. Applied Ecology and Environmental Research, 15(4), 571-588. DOI: http://dx.doi.org/10.15666/aeer/1504_571588

Ilham, H. B. M., Ponachi, N. S. B., & Bohari, H. B. (2020). Geographic Information System In Forest Management. Journal Online Jaringan Pengajian Seni Bina (JOJAPS), 18, 27-37. https://www.geocities.ws/apacc/paper04_haslienda_vol18_renewed.pdf

Jumaah, H. J., Ameen, M. H., Kalantar, B., Rizeei, H. M., & Jumaah, S. J. (2019). Air Quality Index Prediction using IDW Geostatistical Technique and OLS-based GIS technique in Kuala Lumpur, Malaysia. Geomatics, Natural Hazards and Risk, 10(1), 2185-2199.

Kumar, A., Mishra, R. K., & Singh, S. K. (2015). GIS Application in Urban Traffic Air Pollution Exposure Study: A Research Review. Suan Saiandha Science and Technology Journal, 2(1), 25-37.

Lawal, D. U., Matori, A. N., Hashim, A. M., Chandio, I. A., Sabri, S., Balogun, A. L., & Abba, H. A. (2011). Geographic Information System and Remote Sensing Applications in Flood Hazards Management: A review. Research Journal of Applied Sciences, Engineering and Technology, 3(9), 933-947.

Malczewski, M.(1996). A GIS-Based Approach to Multiple Criteria Group Decision-Making. International Journal of Geographical Information Systems, 10(8), 955-971. Doi: 10.1080/02693799608902119

Masud, M. J., & Bastiaanssen, W. G. (2017). Remote Sensing and GIS Applications in Water Resources Management. 351-373. Retrieved from https://www.researchgate.net/publication/321966058

Mathenge, M., Sonneveld, B. G. J. S., & Broerse, J. E. W. (2022). Application of GIS in Agriculture in Promoting Evidence-Informed Decision Making for Improving Agriculture Sustainability: A Systematic Review. Sustainability, 14(16), 9974. https://doi.org/10.3390/su14169974

Mohammed, K. S., Elhadary, Y., Samat, N., & Omar, N. Q. (2015). GIS and Remote Sensing Techniques for Measuring Agriculture Land Loss in Balik Pulau Region of Penang State, Malaysia. Asian Journal of Agriculture and Rural Development, 5(2), 30-41. http://aessweb.com/journal-detail.php?id=5005

Mohd, M. S., Alias, B., & Daud, D. (2006). GIS Analysis for Flood Hazard Mapping: Case Study Segamat, Johor, West Malaysia. Seminar Nasional GIS, 1-15.

Article Journal of Asian Geography, 2024, Volume 3 (Issue 1), 54-60.
https://doi.org/10.36777/jag2024.3.1.7

Norizah, K., Hasmadi, I. M., & Misnah, E. O. (2014). Remote Sensing and GIS Application in Best Harvest Management Planning in Sultan Idris Shah Forestry Education Centre (SISFEC), UPM. IOP Conference Series: Earth and Environmental Science, 18(18), 012138. https://doi.org/10.1088/1755-1315/18/1/012138

Othman, M. A., Ash'aari, Z. H., Aris, A. Z., & Ramli, M. F. (2019). Forest Degradation Analysis Using Geospatial Techniques Approach in Tropical Region of Pahang, Malaysia. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 511-514. doi: https://doi.org/10.5194/isprs-archives-xlii-4-w16-511-2019.

Patil, M. (2022). Geographical Information System (GIS) Recent Approach in Environmental Sustainability. IJARIIE, 8(6), 771-776.

Sai, H. L., Amin, M. S. M., Puong, L. L. & Yau, S. M. (2008). Applications of GIS and Remote Sensing in The Hydrological Study of The Upper Bernam River Basin, Malaysia. Journal - The Institution of Engineers, Malaysia, 69(1), http://dspace.unimap.edu.my/jspui/bitstream/123456789/13746/1/013-018_Flood%20Flows%203pp.pdf

Samat, N. (2007). Integrating GIS and Cellular Automata Spatial Model in Evaluating Urban Growth: prospects and challenges. Jurnal Alam Bina, 9(1), 79-93.

Sheppard. E. (1995). GIS and Society: Towards a Research Agenda. Cartography and Geographic Information Science, 22(1), 5-16.

Selamat, M. H. B., Othman, M. S. B., Hassan, A. F. B., Zukepli, N. I. B. M., Shamsuddin, N. H. B. M., Selamat, A. B., & Yusuf, L. B. M. (2012). A Review on Application of Geographical Information System in Town Planning in Malaysia. Journal of Information Systems Research and Innovation, 38-47.

Xhafa, S., & Kosovrasti, A. (2015). Geographic Information Systems (GIS) in Urban Planning. European Journal of Interdisciplinary Studies, 1(1), 74-81.

Yaakup, A., Ludin, A. N. M., Sulaiman, S., & Bajuri, H. (2005). GIS in Urban Planning and Management: Malaysian Experience. International Symposium & Exhibition on Geoinformation, 27-29.

Yeh, A. G. (1999). Urban planning and GIS. Geographical Information Systems, 2, 877-888.

Yew, V. W. C., Tahir, Z., Sia, M. K., Besar, J. A., Saad, S., Rose, R. A. C., Sutaro, Y., Geraldine, C. K. L., Lim, J. W., & Ramlan, S. F. M. (2019). GIS for Sustainable Urban Development. Journal of Science Review, 1(1), 36-59.