sustainability

MDPI

Review

Integrative Approaches in Remote Sensing and GIS for Assessing Climate Change Impacts Across Malaysian Ecosystems and Societies

Ricky Anak Kemarau [1,*], Stanley Anak Suab [2], Oliver Valentine Eboy [3], Zulfaqar Sa'adi [4], Daniel Ugih Echoh [5] and Zaini Sakawi [1]

[1] Earth Observation Centre, Institute of Climate Change, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia; zaini@ukm.edu.my
[2] Institute for Tropical Biology and Conservation, University Malaysia Sabah, Jalan UMS, Kota Kinabalu 88400, Sabah, Malaysia; stan@ums.edu.my
[3] Geography Program, Faculty Social Sciences and Humanities, University Malaysia Sabah, Jalan UMS, Kota Kinabalu 88400, Sabah, Malaysia; oliver@ums.edu.my
[4] Centre for Environmental Sustainablility and Water Security, Research Institute for Sustainable Environment, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia; zulfaqar@utm.my
[5] Faculty of Social Sciences and Humanities, Universiti Malaysia Sarawak, Kota Samarahan 94300, Sarawak, Malaysia; edugih@unimas.my
* Correspondence: rickykemarau@ukm.edu.my

Abstract: Climate change presents significant problems to Malaysia, impacting its ecology and socio-economic structure through modified precipitation patterns, heightened flooding, coastal erosion, and agricultural susceptibility. This review methodically evaluates the utilization of remote sensing (RS) and geographic information systems (GISs) in comprehending these effects, employing a systematic approach following the PRISMA protocol. Through the examination of peer-reviewed papers from 2010 to 2024, we underscore the progress in remote sensing (RS) and geographic information system (GIS) technologies and their contribution to improving the spatial analysis of climate change impacts. Our research indicates considerable regional variations in the effects of climate change, highlighting the need for customized adaptation and mitigation efforts. The research Illustrates how advancements In remote sensing (RS) and geographic information systems (GISs) have enhanced forecasting skills and real-time surveillance, offering essential insights into ecosystem susceptibilities and socio-economic threats. This analysis underscores the necessity for cohesive policy strategies that leverage remote sensing and geographic information system insights to tackle the complex difficulties posed by climate change in Malaysia while pushing for additional research on the amalgamation of artificial intelligence and big data analytics to bolster climate resilience.

Keywords: climate change; Malaysia; remote sensing; geographic information systems; adaptation strategies; ecosystem vulnerability; socio-economic impacts

check for updates

Academic Editor: Antonio Miguel Martínez-Graña

Received: 24 November 2024
Revised: 3 February 2025
Accepted: 5 February 2025
Published: 7 February 2025

Citation: Kemarau, R.A.; Suab, S.A.; Eboy, O.V.; Sa'adi, Z.; Echoh, D.U.; Sakawi, Z. Integrative Approaches in Remote Sensing and GIS for Assessing Climate Change Impacts Across Malaysian Ecosystems and Societies. *Sustainability* **2025**, *17*, 1344. https://doi.org/10.3390/su17041344

1. Introduction

Climate change, characterized by increasing atmospheric carbon dioxide levels and global temperature elevations, presents a significant challenge to environmental and socio-economic systems worldwide. The Intergovernmental Panel on Climate Change (IPCC) has consistently highlighted the broad-reaching effects of these changes, emphasizing the need for comprehensive research to understand their full spectrum [1,2]. The historical rise in atmospheric CO_2 levels, from 284 ppm in 1832 to 397 ppm in 2013, primarily due to fossil fuel consumption and land use changes, underscores the anthropogenic roots of this global phenomenon [3]. This increase is mirrored by a consistent uptick in global temperatures since the mid-19th century, further corroborated by extensive studies across various sectors, including agriculture [4,5], water resources [6,7], biodiversity [8,9], and coastal zones [10,11].

The impacts of climate change are particularly profound in Asia, affecting economies heavily reliant on environmental resources [12–14]. In Malaysia, recent climate anomalies, including rising temperatures and shifting rainfall patterns, have led to an increase in research aimed at understanding these trends and their broader implications [15,16]. The agricultural sector, vital to Malaysia's GDP, has been a focal point of the study, exploring the economic impacts of climate change on crucial crops such as rice [17–19] and the adaptation strategies within this sector [18]. However, the effects on other key components of the Malaysian economy and food security, like oil palm and fisheries, remain underexplored [20,21].

Remote sensing (RS) and geographic information systems (GISs) have become essential instruments in the analysis of climate change. Remote sensing offers comprehensive, timely, and precise data on environmental variables, facilitating the observation of climatic patterns, vegetation dynamics, and land use alterations across various spatial and temporal scales. Meanwhile, GIS facilitates the integration, analysis, and visualization of geographical data, allowing researchers to identify trends, correlations, and climate-related hotspots. Together, these technologies have revolutionized climate research methodologies, offering robust capabilities for forecasting future scenarios, designing targeted adaptation strategies, and assessing the effectiveness of mitigation efforts.

Given the urgency of these challenges, this review aims to address the existing research gap by systematically examining the recent trends in the application of RS and GIS technologies in studying climate change in Malaysia. These tools offer critical insights into climate patterns, environmental changes, and the formulation of adaptation and mitigation strategies. Through a comprehensive literature review, this paper highlights the pivotal role of RS and GIS in analyzing the diverse impacts of climate change across Malaysia's unique geographical and socio-economic landscape. This study not only underscores the crucial role of these technologies in navigating climate challenges but also underscores the necessity for targeted research and action to mitigate its adverse effects on Malaysia.

2. Methodology

In our comprehensive scoping review, we employed the structured methodology outlined by Kemarau et al. [22], focusing on the application of RS and GIS in climate change research within Malaysia. This systematic approach began with delineating the review's scope, followed by the meticulous selection of pertinent studies, thorough data analysis, synthesis of findings, and the delineation of overarching themes. A pivotal aspect of our review process was the adherence to the PRISMA protocol established by Moher et al. [23], which guided the article selection process through four key stages: identification, screening, eligibility assessment, and final inclusion.

Our search strategy targeted reputable databases such as Web of Science, SCOPUS, and ScienceDirect, employing carefully chosen keywords and search criteria to retrieve peer-reviewed publications spanning from 2010 to 2024. These keywords were strategically designed to match our research objectives and questions directly, ensuring a focused and efficient search process in Table 1.

Table 1. Objective, research question, and keywords for Boolean search applied to this study.

Objective	Research Question	Keywords for Boolean Search
Identifying climate change impact using remote sensing and GIS	What are the impacts of climate change, including temperature variations, sea-level fluctuations, changes in precipitation, and the occurrence of extreme weather using remote sensing and GIS in Malaysia?	"climate change" AND Malaysia AND ("spatial distribution" OR "geographic information systems" remote sensing OR GIS) AND ("temperature changes" OR "sea-level rise" OR "precipitation variability" OR "extreme weather")

In the article inclusion stage, we meticulously assessed the full texts, prioritizing studies that explore the application of RS and GIS to explore climate change impacts within Malaysia. To ensure objectivity and maintain consistency in our review process, each article was independently evaluated by two authors. This evaluation utilized a straightforward checklist approach, marking 'Yes' or 'No' across five specified criteria (Table 2). Articles satisfying at least four criteria were deemed to be of moderate quality, whereas those fulfilling all criteria were classified as high-quality contributions.

Table 2. Five criteria questions to include high-quality articles in this literature.

No	Inclusion Criteria Questions	Answer Options
1	Does the study utilize remote sensing and GIS technologies?	Yes/No
2	Is the focus on the impacts of climate change within Malaysia?	Yes/No
3	Does the research provide empirical evidence of climate change impacts?	Yes/No
4	Is the study peer-reviewed and published between 2010 and 2024?	Yes/No
5	Does the research explicitly address the spatial distribution of climate change impacts?	Yes/No

Adhering to the rigorous selection standards comparable to those applied in prior reviews by Srivastava et al. [24], Kähkönen et al. [25], and Vlacic et al. [26], our review strictly included peer-reviewed journal articles. This decision was made to uphold the highest levels of conceptual clarity and methodological rigor, excluding non-peer-reviewed sources such as book chapters and conference proceedings from our analysis. Furthermore, our search encompassed articles published in both English and Malay across diverse disciplines including business, psychology, and environmental science, leading to an initial tally of 740 papers from the specified period.

During the phases of screening and eligibility assessment, we first eliminated duplicates, which reduced our pool from 291 to 201 articles. Subsequently, these articles were evaluated for their relevance to our defined research questions, further refining our selection to 33 papers that directly contributed to understanding the spatial dynamics of climate change impacts in Malaysia. This methodical approach ensured a comprehensive review, positioned to offer valuable contributions to the field of climate change research in Malaysia.

3. Result and Discussion

RS and GIS are essential technologies in climate change research, offering detailed insights into environmental transformations induced by climate variability. RS, a technique for obtaining data about the Earth's surface without physical contact, employs satellite or airborne sensor technologies to capture changes across the globe, including shifts in land use, vegetation cover, and temperature patterns [27]. GIS complements RS by providing a framework for storing, manipulating, and analyzing geographical data, facilitating the visualization of complex climate data and trends in an accessible manner [28].

3.1. RS and GIS Methodologies in Climate Impact Studies

RS and GIS have revolutionized the study of climate change impacts. They enable the precise monitoring of phenomena such as sea-level rise [29] and changes in biodiversity habitats [30], with an unprecedented level of detail and over extensive spatial and temporal scales [1]. For instance, the deployment of high-resolution satellites like Landsat 8 offers critical Earth observation data that are instrumental in assessing environmental changes and supporting climate change mitigation and adaptation strategies [15,31,32]. These technologies facilitate a multi-scalar understanding of climate change effects, from local to global levels, supporting targeted interventions. By integrating diverse datasets, including RS-derived spatial data, GIS tools aid in constructing dynamic models that predict future climate scenarios, assess vulnerability, and inform policy decisions aimed at combating climate change impacts [33].

Previous studies have demonstrated the essential function of remote sensing in various applications (Table 3). Initial research conducted between 2010 and 2015 mostly utilized single-source satellite images, including Landsat, MODIS, and SPOT, in conjunction with topographic maps for the evaluation of climate change (Salleh et al. [34]; Azhar et al., 2018 [35]). Recent research from 2018 to 2024 indicates a transition towards multi-source datasets, incorporating ground-based observations, UAV imagery, AI-driven predictions, and climate reanalysis datasets such as CHIRPS, Princeton, and ERA5 to improve the precision of climate modeling [10,36,37]. The integration of field-based data collection techniques, such as water sampling, household surveys, and UAV imagery, enhances the real-time validation of remote sensing outcomes, yielding a more thorough comprehension of climate dynamics [4,38].

Recent studies demonstrate an increased reliance on climate model outputs, particularly the integration of downscaled General Circulation Model (GCM) outputs to enhance regional climate projections [36,39]. Time-series climate datasets, such as CHIRPS, tide gauge, sea surface temperature (SST), and Princeton databases, are crucial for monitoring long-term climate variability, especially concerning sea-level rise [8,10]. The advancements in data collecting underscore the growing dependence on varied and high-resolution datasets to enhance the precision of climate change evaluations. The methodologies employed in climate change evaluations have progressed significantly over time. Previous research conducted between 2010 and 2018 predominantly utilized fundamental GIS-based vulnerability mapping, encompassing flood risk analysis, coastal erosion evaluation, and urban heat island (UHI) investigations through interpolation techniques and spatial overlays [34,40]. Recent research from 2019 to 2024 integrates sophisticated machine learning (ML) and artificial intelligence (AI) models, including Support Vector Machines (SVMs), Random Forest (RF), Artificial Neural Networks (ANNs), Analytical Hierarchy Process-Multi Criteria Decision Making (AHP-MCDM), and deep learning techniques, thereby substantially improving climate risk assessments [10,37,41].

Moreover, there has been a significant shift towards predictive modeling in climate forecasting. The growing utilization of predictive models, including ANNs, NARX, MOS-RF, and SVM, for applications such as sea-level rise projections, flood risk assessment, landslip susceptibility analysis, and air pollution forecasting, signifies a transition towards proactive climate resilience strategies [23,42]. Furthermore, GIS-based index models, such as the Composite Index, Livelihood Vulnerability Index (LVI), Coastal Vulnerability Index (CVI), Air Pollution Index (API), and Mangrove Vulnerability Index (MVI), have been widely applied to measure socio-economic vulnerabilities associated with climate change [30,38,43].

These advancements indicate a shift towards more sophisticated and integrated methods for evaluating climate change and strategizing mitigation efforts. The validation of remote sensing results has become a crucial element of climate change research, guaranteeing the precision and dependability of outcomes. Numerous contemporary research studies utilize statistical validation methods like the Mann–Kendall test, ANOVA, and the Taylor diagram, in conjunction with empirical observations such as UAV imaging and in situ water sampling, to enhance data precision [4,44]. Moreover, performance metrics including Area Under the Curve (AUC), correlation coefficients, Root Mean Square Error (RMSE), and R^2 values have been extensively utilized to evaluate the efficacy of remote sensing and GIS methodologies in climate risk prediction, demonstrating notable enhancements in model performance [42,45].

Furthermore, there is an increasing focus on real-time monitoring platforms that integrate remote sensing, GIS, and IoT-based climate sensors to improve early warning systems [39,46]. The integration of big data analytics and AI-driven predictive models is being investigated as a prospective research avenue to enhance the real-time assessment of climate change effects [10,37]. These developments highlight the increasing role of technology in refining climate change assessments and strengthening adaptation and mitigation methods.

Table 3. Data collection, analysis, and spatial techniques in the study impact climate change in Malaysia.

Authors	Data Collection	Analysis and Spatial Techniques	Accuracy and Effectiveness of RS and GIS
Sa'adi et al. [47]	CHIRPS dataset (1983–2018)	CI, SI, PCI, MK test	Validated rainfall regime classification
Sa'adi et al. [48]	CHIRPS	Multi-filtration for GCM ranking SPI analysis	GCM evaluation validated with a Taylor diagram
Yusof et al. [42]	Climate data, landslide inventory	SDSM, SVM for LSM	AUC = 85.75, reliable LSM performance
Zheng et al. [49]	Hourly climate and pollution data	Pearson correlation, CCA	Significant correlation between climate change and air quality
Bahari et al. [46]	Lightning data, rainfall data, radar data	Lightning and weather data analysis	-
Jumari et al. [44]	Landsat-8 imagery	NDVI for emissivity correction	Validated temperature changes via ANOVA tests
Eboy and Kemarau [15]	Landsat data	LST retrieval from Landsat-8	Higher LST in urban areas
Sa'adi et al. [50]	Princeton datasets	MK and m-MK tests, RClimDex	High correlation in trend analysis validation
Sah et al. [4]	Field sampling, UAV imagery	NDVI, BNDVI, NDRE, MIKE 21 modeling	-
Ariffin et al. [51]	GEBCO, Landsat, mapping data	CVI calculation, PCA, HACA	-
Ramli et al. [38]	Household surveys, government data	Composite index, ArcGIS	Identified areas with high vulnerability

Table 3. *Cont.*

Authors	Data Collection	Analysis and Spatial Techniques	Accuracy and Effectiveness of RS and GIS
Bagheri et al. [29]	Sea-level data (1991–2012)	NARX model for sea-level changes	Rising sea-level trends confirmed
Bagheri et al. [10]	Tide gauge, SST, wind, SLP data	ANNs, Bruun model, GIS	Validated coastal erosion prediction models
Anuar et al. [52]	Secondary data collection	AHP-MCDM, GIS	A comprehensive flood risk map provided
Oad et al. [53]	Landsat data, Google Earth Engine	Time series, NDVI, NDWI	Rise in temperatures over thirty years identified
Kamarudin et al. [54]	In situ and secondary data	GIS for river evaluation	Strong correlations indicating river changes
Payus et al. [39]	Air quality data (DOE)	API, Mann–Kendall test	Increase in pollution levels during El Nino
Nurul Ashikin et al. [43]	Field surveys	LVI technique	LVI approach to quantify vulnerability
Kemarau and Eboy [54]	MODIS, Landsat data	LST analysis pre-processing	High correlation between satellite and meteorological data
Sah et al. [4]	Water sampling at paddy plots	IDW method in ArcGIS	Effective in estimating water quality parameters
Ahmad et al. [40]	Topographic maps, SPOT 5 images	GIS for coastal mapping	Effective in identifying coastal changes
Ehsan et al. [55]	Satellite data, historical data, projections	Impact analysis of sea-level rise	Significant concerns highlighted due to sea-level rise
Al-Amin et al. [56]	Mixed methods: quantitative and qualitative	Case study approach, NDVE model	-
Pour et al. [57]	ML methods on climatological data	SVM, RF, and BANN for spatial prediction	High accuracy in predicting seasonal rainfall extremes
Bahgeri et al. [29]	Bruun Rule model, GIS analysis	Shoreline erosion prediction and GIS mapping	Effective integration of observed data for erosion risk assessment
Hazir et al. [58]	Secondary data analysis, GIS modeling	GIS for drought, flood, and sea-level rise projections	Preliminary climate change impact assessments on rubber areas
Selamat et al. [59]	GIS and remote sensing data	GIS for spatial analysis of erosion and accretion	Identified critical erosion and accretion areas
Azhar et al. [35]	Topographic maps (1993), SPOT 5 images (2013)	GIS-based shoreline analysis	Identified critical areas affected by erosion and accretion
Yunus et al. [30]	GIS for vulnerability assessment	MVI calculation	Categorized mangrove vulnerability into five levels
Hamid et al. [45]	Satellite altimeter data, processed through RADS	Data optimization, regression analysis for SLAs	High correlation coefficients (>0.9) for SLA determination
Sa'adi et al. [36]	Statistical downscaling of CMIP5 models	MOS with RF and SVM for mapping	SVM showed high accuracy in downscaling
Suparta and Rahman [60]	GPS, surface meteorological, rainfall data analysis	Spatial interpolation methods	High accuracy in estimating GPS PWV and temperature predictions

Table 3. *Cont.*

Authors	Data Collection	Analysis and Spatial Techniques	Accuracy and Effectiveness of RS and GIS
Anthony et al. [61]	Historical tidal data analysis, GIS for inundation mapping	Pivot Table tools, linear regression, MIKE 21 FM	Identified inundation areas and sea-level trends
Maulud and Rafar [62]	GIS for spatial analysis	Topographic maps, SPOT 5 image (2013), MIKE 21	Effective in identifying flood risk areas
Mogaji et al. [63]	Ensemble projections from GCMs	Empirical modeling, GIS-based technique	Predicted changes in monthly recharge rates
Salleh et al. [34]	Landsat	LST extraction, land use/cover analysis	Demonstrated complexity of UHI phenomenon

The period between 2011 and 2024 witnessed a predominant reliance on quantitative approaches. Studies utilized statistical analyses, machine learning models, and hydrodynamic modeling to dissect climate change impacts. Notable methodologies include the Mann–Kendall test, Support Vector Machine (SVM) models, Canonical Correlation Analysis (CCA), and Artificial Neural Networks (ANNs), as prominently featured in works by Sa'adi et al. [37] and Din et al. [64] who recorded sea-level trends ranging from 2.65 ± 0.86 mm/year to 6.03 ± 0.79 mm/year across selected sub-areas, indicating significant regional subsidence. Additionally, Bagheri et al. [10] identified a rising trend in sea level, with a simulation showing a maximum rate of 28.73 mm/year and predictions revealing a maximum rate of 79.26 mm/year. The incorporation of mixed methods in studies such as Sah et al. [4] added depth, combining quantitative modeling with qualitative insights to provide a nuanced understanding of the data.

The reliance on RS data has been pivotal, with Landsat satellite imagery, Moderate Resolution Imaging Spectroradiometer (MODIS) data, SPOT data, and satellite altimeters being extensively employed for capturing surface reflectance records, Land Surface Temperature (LST) retrieval, and sea-level measurements. For instance, Jumari et al. [44] utilized Landsat-8 satellite imagery to map urban heat islands, revealing statistically significant temperature increases validated through Analysis of Variance (ANOVA) tests. Climate and weather datasets, including the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) rainfall datasets and Coupled Model Intercomparison Project Phase 6 (CMIP6) climate models, underpin these studies. Field surveys and secondary data from governmental and international databases have been instrumental in providing a robust empirical foundation for these analyses.

The application of remote sensing technology has been instrumental in providing spatial and temporal data critical for understanding climate change impacts. Studies by Jumari et al. [44], Kemarau and Eboy [32], Eboy and Kemarau [15], and Anak Kemarau et al. [65] utilized Landsat-8 satellite imagery to map urban heat islands, demonstrating the capacity of remote sensing to detect surface temperature variations and land use changes. Similarly, Din et al. [64] and Ehsan et al. [7] employed satellite altimeters to derive absolute sea levels, highlighting the utility of remote sensing in monitoring coastal dynamics and sea-level rise, a direct consequence of global warming. These examples underscore remote sensing's critical role in offering precise and real-time environmental data that are otherwise challenging to obtain [65].

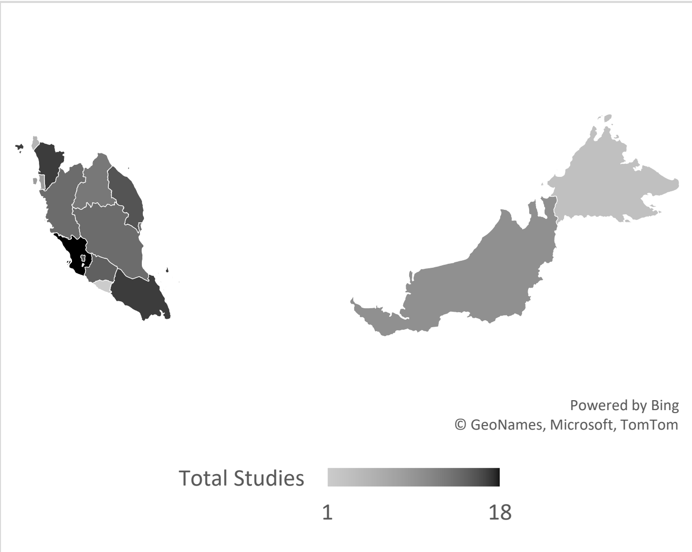
A wide array of statistical and spatial analysis techniques have been employed, from simple Pearson correlation to complex machine learning models like the Nonlinear Autoregressive Network with Exogenous Input (NARX) and SVMs. The integration of Geographic Information Systems (GIS) for spatial analysis, mapping, and vulnerability assessment has been a consistent theme, evident in the work of Oad et al. [53], who reported a 1.06 °C increase in annual mean temperatures over the last three decades in the Bakun-Murum catchment region. Hydrodynamic and climate modeling, facilitated by models such as the Soil and Water Assessment Tool (SWAT), MIKE 21, and the Statistical Downscaling Model (SDSM), have enabled the simulation of climate impacts on hydrology, sea levels, and agricultural productivity. The integration of remote sensing and GIS has proven to be highly effective in conducting comprehensive environmental assessments.

Bagheri et al. [10] exemplified this approach by employing both technologies to simulate and predict sea-level changes, showcasing the synergistic potential of remote sensing and GIS in modeling and forecasting environmental phenomena. The use of RS data for surface and atmospheric observations, combined with GIS's analytical and mapping capabilities, offers a powerful toolset for understanding and addressing climate change impacts. GIS has been extensively used to analyze spatial data, offering invaluable insights into the distribution and magnitude of climate change impacts, as seen in Oad et al. [53], who reported on the increase in annual mean temperatures over the last three decades in the Bakun–Murum catchment region, employing GIS for spatial analysis. This methodological approach facilitates the identification of trends and patterns in climate variables across geographic spaces, enabling targeted interventions. Sa'adi et al.'s [47] work on rainfall variability employs GIS for mapping precipitation patterns, demonstrating how spatial analysis can reveal critical insights into changing climate conditions and their implications on water resources.

The validation of models through comparison with observed data, historical records, and ground truthing underscores the robustness of these studies. For instance, Azran et al. [66] validated their sea-level prediction using the Taylor diagram, which showed a strong agreement between observed and modeled data, reinforcing the predictive accuracy of their models. These comprehensive studies have unearthed significant insights into climate variability, extreme weather events, sea-level rise, coastal erosion, urban heat islands, and agricultural vulnerability. For example, Sa'adi et al. [37] highlighted the increasing variability in rainfall patterns, corroborated by statistical analyses indicating significant trends in precipitation changes. Similarly, Din et al. [64] provided concrete data on the progressive subsidence affecting various sub-areas in Malaysia. The emphasis on model validation and accuracy is a recurrent theme, ensuring the reliability of findings derived from remote sensing and GIS. This rigorous validation process is essential in climate change research, where policy and decision making depend on highly accurate and reliable data.

3.2. Spatial Patterns of Climate Change in Malaysia

From intensified flood risks in Johor and Kedah to coastal erosion in Terengganu and Selangor and the exacerbation of urban heat islands in Kuala Lumpur, the evidence indicates a significant impact of climate change in Malaysia (Figure 1). The synthesis of climate change research across Malaysia reveals a strategic and region-specific approach to understanding the multifaceted impacts of this global phenomenon. Selangor, as the most studied region with 18 studies, underscores the significant attention given to flood events, a reflection of its vulnerability and the recurrent challenges faced in this area. Studies by Ramli et al. [38] and Ehsan et al. [67] in Selangor contribute critical insights into flood dynamics and management, complemented by research on extreme temperatures and sea-level rise by Kemarau and Eboy [68] and Azhar et al. [35]. This broad research scope not only highlights Selangor's acute climate challenges but also establishes a model for comprehensive climate change exploration.



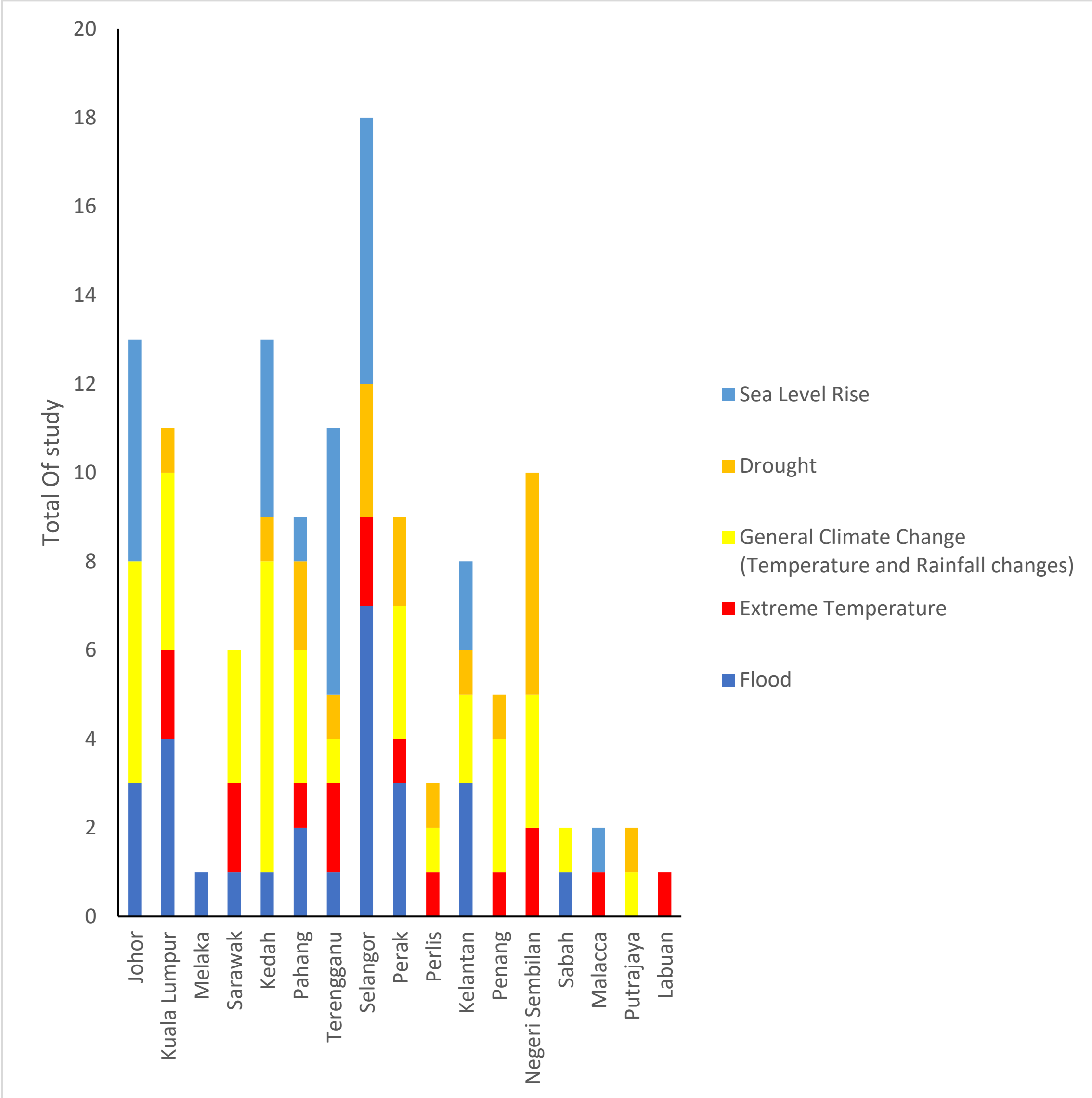


Figure 1. The distribution studies' application of remote sensing and GIS in the study of climate change impact in Malaysia.

Similarly, Johor and Kedah, each contributing 13 studies, depict a diversity in research foci that mirrors their unique environmental and geographical contexts. Johor's research diversity, spanning flood impacts to sea-level rise effects, illustrates the state's complex climate vulnerabilities, with Bahari et al. [46] providing notable insights into flood research. The emphasis on Kedah's general climate change impacts and sea-level rise, particularly highlighted by Sah et al. [4], underscores a regional concern towards broader climatic shifts and their tangible impacts on the state's geography and livelihoods. Kuala Lumpur and Terengganu, each with 11 studies, present distinct research themes reflecting urban and coastal climate concerns, respectively. Kuala Lumpur's emphasis on floods, extreme temperatures, and general climate impacts, as analyzed by Jumari et al. [44], provides an urban-centric perspective on climate challenges. Conversely, Terengganu's research focus, particularly on sea-level rise, as demonstrated in studies by Bagheri et al. [29] and Bagheri et al. [8], highlights its coastal vulnerabilities.

Negeri Sembilan, seeing a specific emphasis on drought, demonstrates the state's prioritization of water scarcity issues, while Pahang and Perak, each with nine studies, present a broad scope covering floods, extreme temperatures, and general climate change. This variety underscores the states' exposure to a wide range of climate-induced challenges and their efforts to address them through diverse research angles. Kelantan's broad spectrum of climate change topics, including floods and drought, illustrates the region's dynamic climate realities and vulnerabilities. Meanwhile, Penang focuses on extreme temperatures and drought, signaling specific climate-related challenges that impact its urban and natural environments. The research output from smaller volume contributors like Perlis, Malacca, Putrajaya, and Sabah enriches the national discourse by highlighting unique climate change aspects pertinent to each area, such as extreme temperature in Perlis and sea-level rise implications in Malacca. Labuan, with its singular study on extreme temperature, adds to the national understanding of temperature-related climate challenges, albeit on a smaller scale.

In examining the impacts of climate change across Malaysia, a detailed analysis reveals significant vulnerabilities and changes across various states, underpinned by robust data and statistical evidence. The Johor River Basin (JRB) in Johor, as observed by Sa'adi et al. [47,48], showcases an increased risk of flooding, with Concentration Index (CI) values ranging between 0.61 and 0.72, signaling a notable concentration of rainfall. This trend is mirrored in Johor and urban centers like Kuala Lumpur and Melaka, where Bahari et al. [46] found correlations between lightning activity and a rise in flash floods and hailstorms, emphasizing the complex interactions between atmospheric phenomena and climate change. In Kedah, specifically within the SG. Kedah basin, Anuar et al. [52] highlighted the challenges faced by paddy fields due to waterlogging, exacerbated by the region's flat terrain and clay soils. Conversely, Ramli et al. [38] identified Sepang, Labu, and Jugra in Selangor as less vulnerable to floods due to controlled urban development and lower population densities. Similarly, Nurul Ashikin et al. [43] found that the Temerloh district in Pahang is highly susceptible to flooding, driven by socio-economic factors such as high dependency ratios and agriculture-based livelihoods.

Regarding coastal vulnerabilities, Sah et al.'s [4] predictions for Kuala Kedah, Kedah, indicate significant future coastal flooding due to sea-level rise, a threat that spans across Malaysia's coastline. Bagheri et al.'s [10] study underscores this, predicting a maximum sea-level rise rate of 79.26 mm/year in areas from Merang Kechil to Kuala Marang, Terengganu. This is corroborated by Ahmad et al. [40], who highlight the coastal regions of Selangor, from Sabak Bernam to Kuala Langat, as particularly prone to the ramifications of rising sea levels. Urban heat islands present another critical challenge, particularly in Kuala Lumpur, where rapid development and industrial growth, as documented by Jumari et al. [44], lead to increased vulnerability to heat. This phenomenon is exacerbated during El Niño events, as noted by Payus et al. [39], with Northern Peninsular Malaysia and Sarawak experiencing deteriorated air quality due to heightened Air Pollution Index (API) values.

Furthermore, the nationwide trend of climate change, including temperature and rainfall fluctuations, is evident. Zheng et al. [49] recorded a significant warming trend with an increase of 1.14 °C in air temperature from 2000 to 2019. Oad et al.'s [53] findings in the Rajang River Basin, Sarawak, showing an increase in annual mean Land Surface Temperature (LST) by 1.06 °C, reflect the broader climatic shifts impacting vegetation and water bodies. In addressing drought, Hazir et al.'s [58] research points to the Kemaman, Kuantan, and Dungun Watershed in Terengganu as having the highest drought frequency by 2024, affecting vital agricultural sectors such as rubber production. These findings collectively underscore the urgent need for targeted climate change mitigation and adaptation strategies across Malaysia.

Addressing the growing threats posed by flooding, coastal erosion, urban heat islands, and broader climate shifts demands a regionally tailored approach to ensure resilience and sustainable development for affected communities and ecosystems. Figure 1 illustrates the spatial distribution and thematic emphasis of climate change research employing remote sensing (RS) and geographic information systems (GIS) in Malaysia. The left panel of the picture displays a heat map illustrating the concentration of research among Malaysian states, with darker hues signifying a greater number of studies. The right panel displays a stacked bar chart that categorizes studies according to various climate change consequences, such as sea-level rise, flooding, droughts, high temperatures, and overall climate change effects (alterations in temperature and precipitation). The allocation of research on climate change utilizing remote sensing (RS) and geographic information systems (GIS) in Malaysia exhibits a distinct regional concentration. Research predominantly concentrates on Selangor, Johor, and Sarawak because of their significant urbanization, susceptibility to coastal threats, and recurrent climate-induced catastrophes including flooding and sea-level rise. Conversely, regions like Labuan and Putrajaya exhibit markedly fewer studies. This geographical disparity indicates that certain areas experiencing significant climate threats are inadequately represented in scientific studies.

The primary climate change consequences examined indicate a significant emphasis on flood-related concerns, especially in Selangor, Sarawak, and Johor, where flooding is a persistent issue. Sea-level rise constitutes a significant research focus, particularly in coastal regions like Penang, Kedah, and Terengganu, where coastal erosion and seawater intrusion provide substantial hazards. Nevertheless, investigations into drought (yellow) and severe temperature (red) are still insufficient, indicating possible deficiencies in evaluating the effects of prolonged heatwaves and water scarcity. This disparity suggests that while urgent threats garner significant focus, enduring climatic stressors like extended droughts and increasing temperatures remain insufficiently examined.

A significant trend in climate change research utilizing remote sensing (RS) and geographic information systems (GISs) in Malaysia is its essentially reactive approach, focusing mainly on immediate risks such as flooding and sea-level rise rather than on long-term threats like temperature extremes and droughts. This signifies the necessity for a more proactive strategy that incorporates predictive modeling and risk evaluation for future climate resilience. The regional variation in study distribution indicates that certain locations may be susceptible yet lack adequate scientific inquiry, underscoring the necessity for expanded research coverage.

Table 3 presents a comprehensive overview of the data collection methodologies, geographical analysis approaches, and the efficacy of remote sensing and geographic information systems in climate change research. The examined research utilizes several datasets, including satellite images (Landsat, MODIS, CHIRPS), in situ field sampling, UAV photography, and governmental databases (DOE, tide gauges). Datasets on precipitation, sea level, temperature, and land cover are the most frequently utilized, indicating a strong emphasis on hydrological and coastal research.

There is a notable progression in analytical methodologies, with conventional statistical approaches such as Mann–Kendall tests, Pearson correlation, and composite indices remaining prevalent for trend analysis and spatial interpolation. Nonetheless, machine learning (ML) methodologies, including Support Vector Machines (SVMs), Random Forest (RF), and Artificial Neural Networks (ANNs), are progressively incorporated, especially in landslip susceptibility assessment, sea-level rise modeling, and precipitation forecasting. Furthermore, multi-criteria decision making (AHP-MCDM) and time-series modeling (NARX, Bruun Rule) suggest a transition to more sophisticated spatial risk evaluations.

The effectiveness of RS and GIS applications is evidenced by research that reveals great precision in climate-related evaluations, as reflected by AUC scores, Taylor diagrams, and regression models. GIS mapping techniques have effectively identified locations susceptible to flooding, sea-level rise, and extreme weather events, assisting policymakers in spatial planning and disaster mitigation. Nonetheless, despite these developments, several research studies lack validation metrics, underscoring the necessity for standardized accuracy assessments to guarantee the dependability of climate change models.

Figure 1 and Table 3 underscore the essential function of RS and GISs in evaluating climate change in Malaysia while also revealing deficiencies in research emphasis and geographical scope. Although flooding and coastal studies are predominant, research on drought and extreme temperatures is insufficiently established, highlighting an urgent necessity to broaden climate resilience studies to encompass long-term and less-explored climatic hazards. The increasing use of machine learning and AI methodologies offers a chance to refine climate modeling; still, further incorporation of real-time data sources, including IoT sensors, UAV photography, and crowd-sourced climate information, could augment forecasting precision. Future research should prioritize under-represented states and underexplored climate risks, ensuring a holistic, data-driven approach to enhance Malaysia's climate resilience.

Even though they are exposed to a variety of climate concerns, several other states, including Perlis (2 studies), Putrajaya (1 study), and Negeri Sembilan (3 studies), have less research coverage than Sabah and Labuan. For instance, Perlis is dealing with a growing drought, whereas Putrajaya and Negeri Sembilan are dealing with localized flooding and increasing urban heat effects. Lower population densities, fewer extreme climate occurrences being documented, or restricted access to high-resolution remote sensing data could all be contributing factors to the paucity of research in these areas. However, more research is necessary to create localized adaption techniques because of their susceptibility to climate change. To guarantee a more thorough and regionally balanced framework for climate resilience in Malaysia, future studies applying RS and GIS technology more widely across under-represented states are needed.

3.3. Ecosystem Vulnerabilities and Adaptation Mechanisms

Sa'adi et al. [47,48] examined the delicate equilibrium within the Johor River Basin and Machap dam areas. Their projections indicate an increase in rainfall by 5–9% under different Shared Socioeconomic Pathways (SSPs), which poses challenges to water resources and elevates flood risks. This variability in precipitation highlights the urgent need for adaptive water management strategies that prioritize flood resilience and water quality preservation, essential for maintaining natural landscapes and biodiversity. This emphasizes how changing climatic conditions necessitate dynamic management approaches to ensure the sustainability of critical water resources. Yusof et al. [42] provide a detailed assessment of how anticipated increases in rainfall and temperature could heighten landslide susceptibility on Penang Island, especially under RCP8.5 scenarios. By identifying the northeast of Penang as particularly vulnerable, the study underscores the importance of implementing soil and slope management practices informed by evolving climate patterns. This is crucial for preventing natural landscape erosion and degradation, thus protecting these areas from the adverse effects of climate change.

Zheng et al. [49] examined the trends in air quality, documenting notable increases in O3 and PM10 concentrations. These shifts not only reflect changing climate patterns, as evidenced by a warming trend of 1.14 °C from 2000 to 2019, but also suggest a potential deterioration in air pollution. This research underscores the link between air quality and ecosystem health, indicating the need for measures to mitigate pollution and enhance ecosystem resilience in the face of changing climatic conditions. Bahari et al. [46] investigate flash floods and hailstorms in Johor, Kuala Lumpur, and Melaka, highlighting the significant influence of atmospheric phenomena on severe weather occurrences. The connection between lightning activity and severe weather events sheds light on broader environmental changes due to climate change, stressing the importance of integrated storm and water management systems for the protection of natural habitats. Jumari et al. [44] and Eboy and Kemarau [15] focus on the urban heat island effects, particularly in rapidly developing areas of Klang Valley. Their findings highlight the environmental shifts resulting from urbanization and stress the significance of green infrastructure in mitigating urban heat effects, thereby indicating the impacts on urban ecosystems and the necessity for strategies to counter these effects.

Sah et al. [4], Ariffin et al. [51], and Bagheri et al. [8,10,29] collectively address the challenges of sea-level rise and coastal erosion, especially in coastal regions such as Kuala Kedah, Bachok, Kuala Nerus, and the East Coast Peninsular area. Their studies emphasize the vulnerability of coastal ecosystems to climate-induced changes, advocating for coastal protection measures, mangrove reforestation, and habitat restoration to bolster ecosystem resilience. Anuar et al. [52] and Oad et al. [53] investigate the effects on paddy fields and natural landscapes, pointing out significant alterations in land surface temperature (LST), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI). These changes underscore the impacts on vegetation and water availability, necessitating adaptive agricultural practices and water resource management to maintain food production and ecosystem health.

Payus et al. [39], and Nurul Ashikin et al. [43] discuss the ramifications of climate change on river planform alterations, air quality deterioration, and flood damage in agricultural sectors. Their focus on the role of anthropogenic and hydrological factors in exacerbating flood risks and air quality degradation during El Nino events illustrates the complex relationship between climate change factors and ecosystem vulnerabilities. Kemarau and Eboy [54], Sah et al. [4], Ahmad et al. [40], and Tan et al. [69] extend the discourse on ecosystem vulnerabilities by examining El Niño events, salinity intrusion, coastal erosion, and shifts in streamflow and drought characteristics.

The anticipation of coastal flooding and the delineation of vulnerable districts by Sah et al. [4] and Ariffin et al. [51] necessitate comprehensive coastal management strategies. These strategies should encompass both physical protections, such as the restoration of mangroves, and socio-economic resilience planning to safeguard communities and ecosystems against sea-level rise. Bagheri et al.'s [8,10] work on coastal erosion and sea-level rise impacts along the East Coast Peninsular region further elucidates the pressing need for sediment management and coastal defenses. These measures are essential for preventing erosion, protecting coastal biodiversity, and ensuring the sustainability of marine and coastal ecosystems. Additionally, studies by Payus et al. [39] on flood forecasting and the effects of El Niño on air quality, respectively, highlight the importance of advanced forecasting tools and international cooperation in environmental management. These measures are crucial for preparing for and mitigating the impacts of climate-induced natural disasters on ecosystems and human health.

These contributions emphasize the broad range of climate change effects throughout Malaysia's regions and ecosystems, highlighting the necessity for cohesive policies that integrate remote sensing (RS) and GIS technologies with sustainable development and climate adaptation strategies. Sa'adi et al. [47,48] and Yusof et al. [42] illustrate how RS-driven forecasts of rainfall variability and landslip vulnerability might enhance adaptive water and slope management. Similarly, Zheng et al. [49] and Bahari et al. [46] utilize geospatial data to correlate air quality trends and extreme weather patterns with ecosystem health, underscoring the necessity for legislative frameworks to institutionalize investments in RS/GIS infrastructure and promote multi-stakeholder collaboration.

Sah et al. [4], Ariffin et al. [51], and Bagheri et al. [10,29] support the restoration of mangroves and sediment management, emphasizing that remote sensing-enabled coastal monitoring should be integrated with policy-oriented habitat protection and community resilience initiatives. Urban heat island studies conducted by Jumari et al. [44] and Eboy and Kemarau [15] emphasize the significance of GISs in informing green infrastructure plans to alleviate ecological degradation. Simultaneously, the agricultural adjustments suggested by Anuar et al. [52] illustrate the potential of incorporating RS-derived NDVI and LST data into adaptive land use planning, contingent upon cross-sectoral governance. These findings necessitate a cohesive strategy that integrates RS/GISs into national climate agendas, guaranteeing data accessibility to local authorities, academics, and policymakers. This requires a legislative directive to standardize climate monitoring infrastructure, promote public–private collaborations, and emphasize ecosystem-centric adaptation—aligning technological breakthroughs with Malaysia's socio-ecological priorities.

3.4. Socio-Economic and Human Health Implications of Climate Change

The socio-economic implications of climate change in Malaysia are multifaceted, affecting agriculture, urbanization, human health, and livelihoods in profound ways. Agriculture, particularly rice production, is one of the most vulnerable sectors, with potential yield losses of up to 75% in flood-prone areas due to seawater intrusion [70]. Anuar et al. [52] further highlight the threats of increased flooding and high salinity on paddy cultivation, particularly during critical growth stages, which could reduce national rice output and exacerbate food insecurity. The 2014 Kelantan flood, which submerged over 100,000 hectares of agricultural land, caused economic losses exceeding RM 2.6 billion [71], exemplifying the severe financial strain climate-induced disasters place on rural farmers. The interplay between natural climate phenomena and agricultural productivity underscores the urgent need for sustainable farming practices and precision agriculture using Remote Sensing (RS) and Geographic Information Systems (GIS) to optimize water management and flood prediction models.

Jumari et al. [44], Kemarau and Eboy [32], and Salleh et al. [34] examined the urban heat island (UHI) phenomenon, exacerbated by rapid urbanization. Urban temperatures in Kuala Lumpur have increased by an average of 1.64 °C over the past three decades [44], intensifying energy consumption and public health risks. Salleh et al. [34] report that UHI contributes to an estimated 15% increase in electricity demand for air conditioning in major Malaysian cities, translating to higher household energy costs and economic burdens. Moreover, extreme heat exposure reduces job productivity, particularly in outdoor labor sectors such as construction and agriculture, leading to economic losses. A GIS-based UHI analysis in Klang Valley revealed that densely built-up areas experience up to 7 °C higher temperatures than surrounding rural regions, highlighting the need for climate-smart urban planning with increased green spaces, reflective surfaces, and sustainable building designs.

Ariffin et al. [51] constructed socio-economic vulnerability indices using GIS, revealing how gender and agriculture are significant socio-economic parameters influencing coastal vulnerability in Kelantan and northern Terengganu. Their GIS-based risk analysis shows that over 60% of coastal-dependent businesses in these regions are operated by women, making them disproportionately affected by rising sea levels and extreme weather events. These findings stress the need for gender-responsive adaptation strategies, such as microfinance programs and capacity-building initiatives, to support female entrepreneurs in climate-vulnerable sectors.

The impact of climate change on human health is significant, with Zheng et al. [33] documenting a 0.5 °C increase in average temperatures over the past decade, correlating with a 12% rise in heat-related morbidity cases in urban hospitals. Ehsan et al. [7] and Hazir et al. [58] further illuminate the health risks from vector-borne diseases such as dengue, which saw a 50% surge in incidence following prolonged monsoon seasons in 2021 [72]. Additionally, waterborne diseases, including cholera and leptospirosis, have increased by 30% in flood-affected communities due to deteriorating water quality [73], reinforcing the need for enhanced real-time monitoring systems for disease outbreaks using RS and GIS.

Livelihood vulnerabilities were extensively discussed by Sah et al. [4], Kamal et al. [74], and Mogaji et al. [63], who examined the implications of climate change on fisheries and agriculture. Sah et al. [4] highlight that seawater intrusion, particularly in Selangor and Perak, threatens 40% of Malaysia's coastal rice cultivation areas, endangering food security and economic stability. Kamal et al. [74] point to RM 1.8 billion in estimated damages due to flood-induced fishery losses in the East Coast region between 2015 and 2022, affecting thousands of small-scale fishers dependent on coastal ecosystems for their livelihoods. These economic disruptions stress the importance of comprehensive risk mapping and micro-spatial analysis using RS and GIS to predict high-risk zones and improve resilience strategies for affected communities.

These studies underscore the pervasive socio-economic impacts of climate change across Malaysia, ranging from a projected 10% decline in agricultural productivity by 2050 (IPCC, 2021) and worsening urban heat effects to health crises and livelihood disruptions in coastal and agrarian communities. The breadth of research highlights the critical intersections between climate change and socio-economic structures, emphasizing the urgent need for data-driven mitigation and adaptation strategies. A holistic approach integrating remote sensing, AI-driven predictive modeling, and GIS-based spatial analysis will be essential for guiding targeted interventions that ensure climate resilience, particularly for vulnerable populations.

3.5. Technological Advances in Climate Change Research

Machine learning (ML) and artificial intelligence (AI), when combined with GISs and RS, offer robust tools for analyzing vast amounts of environmental data. These technologies enhance our ability to predict climate change impacts, monitor ecosystem vulnerabilities, and devise adaptation strategies with greater precision and specificity. The research underscores the importance of developing real-time monitoring platforms that combine ML, AI, GIS, and RS to assess climate change impacts comprehensively. Such integration not only facilitates a deeper understanding of current and future climate scenarios but also enables the development of targeted mitigation and adaptation strategies. Moreover, the spatial distribution of climate change impacts, as highlighted in the studies, calls for localized approaches to climate change adaptation and mitigation. Big data analytics and AI-driven models, namely Google Earth Engine, provide the means to tailor these strategies to specific regions, ecosystems, and communities, ensuring that responses are both effective and sustainable.

The integration of technological advancements in climate change research, particularly using ML, AI, and GIS, has significantly enhanced climate change forecasting models and the monitoring of climate change impacts. These technologies, especially when applied to RS data, have opened new avenues for understanding and addressing the multifaceted aspects of climate change. For instance, AI-based predictive modeling has demonstrated significant potential in enhancing early warning systems and decision-making processes. A study on ML and AI for enhancing GIS and RS applications conducted by Sa'adi et al. [47,48] leveraged ML algorithms to analyze rainfall patterns and predict flood risks in the Johor River Basin, showcasing the potential of integrating ML with GISs for detailed spatial analysis and prediction. Yusof et al. [42] employed ML techniques to assess landslide susceptibility on Penang Island under various climate change scenarios, highlighting ML's role in enhancing GIS-based vulnerability indices for ecosystem assessment. Oad et al. [53] utilized ML and AI to analyze river planform changes and environmental impacts over the Bakun–Murum catchment area, respectively, demonstrating the technologies' applicability in monitoring ecosystem changes and predicting future scenarios.

Future directions in RS for climate change prediction and monitoring were assessed by Bagheri et al. [10,29], who focused on coastal erosion and sea-level rise using remote sensing data, emphasizing future directions in monitoring shoreline changes and sedimentation patterns. Their work illustrates the critical role of remote sensing in capturing real-time data on coastal dynamics. Ahmad et al. [40] and Sah et al. [4] applied remote sensing techniques to identify areas affected by sea-level rise and to monitor salinity intrusion in agricultural lands, respectively. These studies underscore remote sensing's potential in assessing and forecasting the impacts of climate change on natural and agricultural ecosystems. In conclusion, the contributions from various authors underscore the transformative potential of integrating machine learning, artificial intelligence, GIS, and remote sensing in climate change research. Expanding research on AI-driven climate models and integrating multi-source data streams into real-time monitoring platforms marks a significant step forward in our ability to predict, monitor, and respond to the complex challenges posed by climate change, offering hope for more resilient ecosystems and societies in the face of this global threat.

3.6. Policy Implications and Future Directions

Policy formulation and decision making, such as that by Sa'adi et al. [47,48] which examined rainfall patterns and water resource management, underscore the criticality of fine-resolution data in formulating adaptive policies for flood risk management. Similarly, Yusof et al. [42] and Zheng et al. [49] highlight the importance of incorporating climate change projections into urban and land use planning to mitigate landslide and air quality risks, respectively. These insights direct policy formulation towards a holistic approach that integrates climate change impacts into broader environmental management and disaster preparedness strategies. Moreover, community involvement via educational and awareness initiatives is crucial for improving the efficacy of these measures. Empowering local populations with geospatial knowledge, specifically through drones in citizen science monitoring at a local scale [3,22], critically provides near-real-time information on the impacts of climate change, such as sea-level rise, and tools for adaptation. This not only enhances resilience but also fosters greater acceptance and implementation of mitigation measures.

Integrated coastal management and urban planning emphasis on coastal and urban vulnerabilities as seen in the works of Sah et al. [4], Ariffin et al. [51], and Bagheri et al. [10,29] suggests a pressing need for policies that encompass coastal protection, sustainable agricultural practices, and urban heat mitigation. These studies advocate for comprehensive management strategies that not only address the immediate impacts of climate change but also bolster long-term resilience against sea-level rise, erosion, and urban heat islands. Incorporating capacity-building initiatives for local communities in these management strategies ensures that technological advancements, such as remote sensing and AI-driven predictive modeling, are effectively utilized at the local level.

The call for future research is evident across the spectrum of studies, highlighting areas for further exploration such as the socio-economic impacts of climate change [50], the effectiveness of green infrastructure in reducing urban heat [44], and the potential of ML and AI in enhancing the predictive capabilities of RS and GIS [3,53]. These recommendations underscore the dynamic nature of climate change research, pointing towards an evolving landscape of technological advancements and methodological approaches that can significantly improve our understanding and management of climate impacts. Future research should also explore the role of participatory approaches in climate adaptation, integrating local knowledge with advanced remote sensing techniques to develop tailored, community-driven solutions. Furthermore, the emphasis on future research directions, particularly in the realm of technological advancements in RS and GISs, signifies a forward-looking perspective that seeks to harness innovation in monitoring, predicting, and mitigating climate change impacts. This approach not only enhances our adaptive capacities but also ensures that policymaking remains responsive to the evolving nature of climate change dynamics.

4. Conclusions

This review highlights the essential role of remote sensing (RS) and geographic information system (GIS) technologies in evaluating and alleviating the effects of climate change on Malaysia's diverse ecosystems and socioeconomic frameworks, in light of the increasing evidence of climate change and its extensive repercussions. This work employs a systematic analysis to synthesize essential results about climatic variability, flooding, coastal erosion, and agricultural vulnerabilities, emphasizing the necessity for region-specific adaptation measures.

Utilizing RS and GIS, we have shown the spatial patterns of climate change in Malaysia, demonstrating considerable regional diversity in climatic effects. This paper highlights the innovative contributions of technical breakthroughs, namely in utilizing real-time data and predictive modeling for climate adaptation, rather than restating previous issues. These findings enhance our comprehension of climate dynamics and underscore the urgent necessity for specific adaptation and mitigation policies that address the distinct vulnerabilities of each location.

This study highlights emerging research opportunities at the convergence of AI, ML, RS, and GIS, facilitating a more cohesive approach to climate change monitoring. This review consistently highlights the crucial impact of technology improvements on climate change research. The amalgamation of machine learning, artificial intelligence, remote sensing, and geographic information systems has not only improved climate impact forecasts and early warning mechanisms but also created new opportunities for comprehending and tackling the many dimensions of climate change. These technologies enhance decision making and resource allocation by optimizing the integration of climatic data from many sources.

Given these findings, policymakers and stakeholders must utilize the insights from RS and GIS technology to develop comprehensive climate change policies that tackle the identified risks and issues. This paper advocates for the enhancement of policy frameworks via AI-driven forecasting models, augmented multi-source data integration, and fortified early warning systems. Integrated coastal management, urban planning, and the integration of climate change projections into comprehensive environmental management programs are vital for enhancing Malaysia's resistance to climate change.

Moving forward, a heightened focus on real-time data collecting, machine learning-based forecasting, and implementable policy recommendations will be essential in tackling Malaysia's climate concerns. The insights obtained from this assessment should establish a basis for informed decision making, directing Malaysia towards sustainable development and climate resilience. Immediate action, informed by empirical research and technology advancements, is crucial to alleviate climate change threats and improve national readiness.

Author Contributions: Conceptualization by R.A.K., D.U.E. and O.V.E.; R.A.K. developed the methodology; R.A.K. and O.V.E. validated; S.A.S. and D.U.E. performed the formal analysis; R.A.K. and O.V.E. conducted the investigation; D.U.E. provided resources; D.U.E. curated data; R.A.K. and D.U.E. wrote the initial draft; O.V.E. and S.A.S. reviewed and edited; Z.S. (Zaini Sakawi), Z.S. (Zulfaqar Sa'adi) supervised; O.V.E. managed the project. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Thank you to Ryanne Zephyra Dema and Rossifedora Currie Tipong for motivating me to complete this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. IPCC. Climate Change 2014. Impacts, Adaptation and Vulnerability. In *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C., Ed.; IPCC: Geneva, Switzerland, 2014. Available online: https://www.ipcc.ch/report/ar5/wg2/ (accessed on 10 January 2024).
2. IPCC. Technical Summary. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Climate Change 2021: The Physical Science Basis*; IPCC: Geneva, Switzerland, 2021. Available online: https://www.ipcc.ch/report/ar6/wg1/ (accessed on 10 January 2024).
3. Kemarau, R.A.; Sakawi, Z.; Eboy, O.V.; Suab, S.A.; Ibrahim, M.F.; Rosli, N.N.B.; Nor, N.N.F.M. Planetary boundaries transgressions: A review on the implications to public health. *Environ. Res.* **2024**, *260*, 119668. [CrossRef]
4. Sah, S.S.; Maulud, K.N.A.; Karim, O.A.; Sharil, S.; Yaseen, Z.M. Extensive assessment of climate change impacts on coastal zone paddy growth using multispectral analysis and hydrodynamic modeling. *Sci. Total. Environ.* **2023**, *868*, 161585.
5. Isia, I.; Hadibarata, T.; Hapsari, R.I.; Jusoh, M.N.H.; Bhattacharjya, R.K.; Shahedan, N.F. Assessing social vulnerability to flood hazards: A case study of Sarawak's divisions. *Int. J. Disaster Risk Reduct.* **2023**, *97*, 104052. [CrossRef]
6. Kemarau, R.A.; Eboy, O.V.; Suab, S.A.; Nor NN, F.M.; Sakawi, Z. Using Remote Sensing to Study Impact El Niño Southern Oscillation on Reservoir Level at Murum and Bakun Dam Hydropower, Sarawak. *Int. J. Sustain. Constr. Eng. Technol.* **2023**, *14*, 117–128. [CrossRef]
7. Ehsan, S.; Begum, R.A.; Maulud KN, A.; Mia, M.S. Assessing household perception, autonomous adaptation and economic value of adaptation benefits: Evidence from West Coast of Peninsular Malaysia. *Adv. Clim. Change Res.* **2022**, *13*, 738–758. [CrossRef]
8. Bagheri, M.; Zaiton Ibrahim, Z.; Bin Mansor, S.; Abd Manaf, L.; Badarulzaman, N.; Vaghefi, N. Shoreline change analysis and erosion prediction using historical data of Kuala Terengganu, Malaysia. *Environ. Earth Sci.* **2019**, *78*, 477. [CrossRef]
9. Hamdan, M.E.; Ahmad, N.; Samah, B.A.; Shaffril, H.A.M. Measuring Islanders' Adaptive Capacity towards the Impact of Climate Change: A Case of Community in Langkawi Island. *Int. J. Acad. Res. Bus. Soc. Sci.* **2018**, *8*, 273–281.
10. Bagheri, M.; Ibrahim, Z.Z.; Mansor, S.; Abd Manaf, L.; Akhir, M.F.; Talaat, W.I.A.W.; Wolf, I.D. Hazard Assessment and Modeling of Erosion and Sea Level Rise under Global Climate Change Conditions for Coastal City Management. *Nat. Hazards Rev.* **2023**, *24*, 04022038. [CrossRef]

11. Maulud, K.N.A.; Rafar, R.M. Determination of the impact of sea level rise on shoreline changes using GIS. In Proceedings of the 2015 International Conference on Space Science and Communication (IconSpace), Langkawi, Malaysia, 10–12 August 2015; IEEE: New York, NY, USA, 2015; pp. 352–357.
12. Dong, W.S.; Ismailluddin, A.; Yun, L.S.; Ariffin, E.H.; Saengsupavanich, C.; Maulud, K.N.A.; Ramli, M.Z.; Miskon, M.F.; Jeofry, M.H.; Mohamed, J.; et al. The impact of climate change on coastal erosion in Southeast Asia and the compelling need to establish robust adaptation strategies. *Heliyon* **2024**, *10*, e25609. [CrossRef]
13. Arouri, M.; Nguyen, C.; Youssef, A.B. Natural disasters, household welfare, and resilience: Evidence from rural Vietnam. *World Dev.* **2015**, *70*, 59–77. [CrossRef]
14. Hijioka, Y.; Lin, E.; Pereira, J.J.; Corlett, R.T.; Cui, X.; Insarov, G.E.; Lasco, R.D.; Lindgren, E.A.S. Asia. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2014. [CrossRef]
15. Eboy, O.V.; Kemarau, R.A. Study Variability of the Land Surface Temperature of Land Cover during El Niño Southern Oscillation (ENSO) in a Tropical City. *Sustainability* **2023**, *15*, 8886. [CrossRef]
16. Tang, K.H.D. Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Sci. Total Environ.* **2019**, *650*, 1858–1871. [CrossRef] [PubMed]
17. Vaghefi, N.; Shamsudin, M.N.; Makmom, A.; Bagheri, M. The economic impacts of climate change on the rice production in Malaysia. *Int. J. Agric. Res.* **2011**, *6*, 67–74. [CrossRef]
18. Alam, M.M.; Siwar, C.; Al-Amin, A.Q. Climate change adaptation policy guidelines for the agricultural sector in Malaysia. *Asian J. Environ. Dis. Manag.* **2010**, *2*, 463–469. [CrossRef]
19. Masud, M.M.; Rahman, M.S.; Al-Amin, A.Q.; Kari, F.; Filho, W.L. Impact of climate change: An empirical investigation of Malaysian rice production. *Mitig. Adapt. Strateg. Glob. Chang.* **2014**, *19*, 431–444. [CrossRef]
20. Fitzherbert, E.B.; Struebig, M.; Morel, A.; Danielsen, F.; Bruhl, C.; Donald, P.; Phalan, B. How will oil palm expansion affect biodiversity? *Trends Ecol. Evol.* **2008**, *23*, 538–545. [CrossRef]
21. Butler, R.A.; Laurance, W.F. Is oil palm the next emerging threat to the Amazon? *Trop. Conserv. Sci.* **2009**, *2*, 1–10. [CrossRef]
22. Kemarau, R.A.; Jaafar, W.S.W.M.; Sakawi, Z.; Abu Bakar, N.A.; Kamarulzaman, A.M.M.; Suab, S.A.; Eboy, O.V.; Harun, S.N.; Sa'Adi, Z. UAVs and Social Science: A Transformative Perspective. *Soc. Sci. Q.* **2025**, *106*, e13484. [CrossRef]
23. Moher, D.; Stewart, L.; Shekelle, P. Implementing PRISMA-P: Recommendations for prospective authors. *Syst. Rev.* **2016**, *5*, 15. [CrossRef]
24. Srivastava, A. COVID-19 and air pollution and meteorology-an intricate relationship: A review. *Chemosphere* **2021**, *263*, 128297. [CrossRef] [PubMed]
25. Kähkönen, T.; Blomqvist, K.; Gillespie, N.; Vanhala, M. Employee trust repair: A systematic review of 20 years of empirical research and future research directions. *J. Bus. Res.* **2021**, *130*, 98–109. [CrossRef]
26. Vlačić, B.; Corbo, L.; Costa e Silva, S.; Dabić, M. The evolving role of artificial intelligence in marketing: A review and research agenda. *J. Bus. Res.* **2021**, *128*, 187–203. [CrossRef]
27. Lillesand, T.; Kiefer, R.W.; Chipman, J. *Remote Sensing and Image Interpretation*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
28. Longley, P.A.; Goodchild, M.F.; Maguire, D.J.; Rhind, D.W. *Geographic Information Science and Systems*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
29. Bagheri, M.; Ibrahim, Z.Z.; Mansor, S.; Abd Manaf, L.; Akhir, M.F.; Talaat, W.I.A.W.; Wolf, I.D. Sea-level projections using a NARX-NN model of tide gauge data for the coastal city of Kuala Terengganu in Malaysia. *Environ. Sci. Pollut. Res.* **2023**, *30*, 81839–81857. [CrossRef] [PubMed]
30. Yunus, M.Z.M.; Ahmad, F.S.; Ibrahim, N. Mangrove vulnerability index using GIS. In *AIP Conference Proceedings, Proceedings of the International Conference on Engineering and Technology (IntCET 2017), Putrajaya, Malaysia, 23–24 November 2017*; AIP Publishing: Melville, NY, USA, 2018; Volume 1930.
31. Roy, D.P.; Wulder, M.A.; Loveland, T.R.; Woodcock, C.E.; Allen, R.G.; Anderson, M.C.; Helder, D.; Irons, J.R.; Johnson, D.M.; Kennedy, R.; et al. Landsat-8: Science and product vision for terrestrial global change research. *Remote Sens. Environ.* **2014**, *145*, 154–172. [CrossRef]
32. Kemarau, R.A.; Eboy, O.V. Exploring the Impact of El Niño–Southern Oscillation (ENSO) on Temperature Distribution Using Remote Sensing: A Case Study in Kuching City. *Appl. Sci.* **2023**, *13*, 8861. [CrossRef]
33. Zheng, S.; Pu, Y.; Lu, H.; Zhang, J.J.; Wang, D.; Ma, X. Global climate policy effectiveness: A panel data analysis. *J. Clean. Prod.* **2023**, *412*, 137321. [CrossRef]
34. Salleh, S.A.; Abd.Latif, Z.; Mohd, W.M.N.W.; Chan, A. Factors Contributing to the Formation of an Urban Heat Island in Putrajaya, Malaysia. *Procedia-Soc. Behav. Sci.* **2013**, *105*, 840–850. [CrossRef]
35. Azhar, M.M.; Maulud, K.N.A.; Selamat, S.N.; Khan, M.F.; Jaafar, O.; Jaafar, W.S.W.M.; Abdullah, S.M.S.; Toriman, M.E.; Kamarudin, M.K.A.; Gasim, M.B.; et al. Impact of shoreline changes to the coastal development. *Int. J. Eng. Technol.* **2018**, *7*, 191–195. [CrossRef]

36. Sa'adi, Z.; Shahid, S.; Chung, E.S.; bin Ismail, T. Projection of spatial and temporal changes of rainfall in Sarawak of Borneo Island using statistical downscaling of CMIP5 models. *Atmos. Res.* **2017**, *197*, 446–460. [CrossRef]
37. Sa'adi, Z.; Al-Suwaiyan, M.S.; Yaseen, Z.M.; Tan, M.L.; Goliatt, L.; Heddam, S.; Halder, B.; Ahmadianfar, I.; Homod, R.Z.; Shafik, S.S. Observed and future shifts in climate zone of Borneo based on CMIP6 models. *J. Environ. Manag.* **2024**, *360*, 121087. [CrossRef]
38. Ramli, M.W.A.; Alias, N.E.; Yusof, H.M.; Yusop, Z.; Taib, S.M.; Wahab, Y.F.A.; Hassan, S.A. Spatial multidimensional vulnerability assessment index in urban area- A case study Selangor, Malaysia. *Prog. Disaster Sci.* **2023**, *20*, 100296. [CrossRef]
39. Payus, C.M.; Syazni, M.N.; Sentian, J. Extended air pollution index (API) as a tool of sustainable indicator in the air quality assessment: El-Nino events with climate change driven. *Heliyon* **2022**, *8*, e09157. [CrossRef] [PubMed]
40. Ahmad, H.; Maulud, K.N.A.; Karim, O.A.; Mohd, F.A. Assessment of erosion and hazard in the coastal areas of Selangor. *Malays. J. Soc. Space* **2021**, *17*, 14–30. [CrossRef]
41. Pour, S.M.; Masoumi, A.M.; Dujardin, N.S. Towards a Technology-Driven Adaptive Decision Support System for Integrated Pavement and Maintenance strategies (TDADSS-IPM): Focus on risk assessment framework for climate change adaptation. *Transp. Res. Procedia* **2023**, *72*, 4468–4475. [CrossRef]
42. Yusof, M.K.T.M.; Rashid, A.S.A.; Khanan, M.F.A.; Rahman, M.Z.A.; Manan, W.A.A.; Kalatehjari, R.; Dehghanbanadaki, A. Assessing the impact of RCP4. 5 and RCP8. 5 scenarios on landslide susceptibility mapping using support vector machine: A case study of Penang Island, Malaysia. *Phys. Chem. Earth Parts A/B/C* **2024**, *133*, 103496. [CrossRef]
43. Nurul Ashikin, A.; Nor Diana, M.I.; Siwar, C.; Alam, M.M.; Yasar, M. Community preparation and vulnerability indices for floods in Pahang state of Malaysia. *Land* **2021**, *10*, 198. [CrossRef]
44. Jumari, N.A.S.K.; Ahmed, A.N.; Huang, Y.F.; Ng, J.L.; Koo, C.H.; Chong, K.L.; Sherif, M.; Elshafie, A. Analysis of urban heat islands with landsat satellite images and GIS in Kuala Lumpur Metropolitan City. *Heliyon* **2023**, *9*, e18424. [CrossRef]
45. Hamid, A.I.A.; Din, A.H.M.; Hwang, C.; Khalid, N.F.; Tugi, A.; Omar, K.M. Contemporary sea level rise rates around Malaysia: Altimeter data optimization for assessing coastal impact. *J. Asian Earth Sci.* **2018**, *166*, 247–259. [CrossRef]
46. Bahari, N.; Mohammad, S.A.; Esa MR, M.; Ahmad, M.R.; Ahmad, N.A.; Malek, Z.A. Analysis of lightning flash rate with the occurrence of flash floods and hailstorms in Peninsular Malaysia. *J. Atmos. Sol.-Terr. Phys.* **2023**, *250*, 106121. [CrossRef]
47. Sa'adi, Z.; Alias, N.E.; Yusop, Z.; Ramli, M.W.A.; Muhammad, M.K.I. CHIRPS rainfall product application for analyzing rainfall concentration and seasonality in Johor river basin, Malaysia. *J. Atmos. Solar-Terr. Phys.* **2024**, *256*, 106203. [CrossRef]
48. Sa'adi, Z.; Alias, N.E.; Yusop, Z.; Chow, M.F.; Muhammad, M.K.I.; Mazilamani, L.S.; Ramli, M.W.A.; Shiru, M.S.; Mohamad, N.A.; Rohmat, F.I.W.; et al. Spatiotemporal assessment of rainfall and drought projection for integrated dam management in Benut River Basin, Malaysia under CMIP6 scenarios. *Environ. Chall.* **2024**, *15*, 100892. [CrossRef]
49. Zheng, Y.; Ooi, M.C.G.; Juneng, L.; Wee, H.B.; Latif, M.T.; Nadzir, M.S.M.; Hanif, N.M.; Chan, A.; Li, L.; Ahmad, N.B.; et al. Assessing the impacts of climate variables on long-term air quality trends in Peninsular Malaysia. *Sci. Total. Environ.* **2023**, *901*, 166430. [CrossRef] [PubMed]
50. Sa'adi, Z.; Yaseen, Z.M.; Farooque, A.A.; Mohamad, N.A.; Muhammad, M.K.I.; Iqbal, Z. Long-term trend analysis of extreme climate in Sarawak tropical peatland under the influence of climate change. *Weather Clim. Extrem.* **2023**, *40*, 100554. [CrossRef]
51. Ariffin, E.H.; Mathew, M.J.; Roslee, A.; Ismailluddin, A.; Yun, L.S.; Putra, A.B.; Yusof, K.M.K.K.; Menhat, M.; Ismail, I.; Shamsul, H.A.; et al. A multi-hazards coastal vulnerability index of the east coast of Peninsular Malaysia. *Int. J. Disaster Risk Reduct.* **2023**, *84*, 103484. [CrossRef]
52. Anuar, A.; Abdullah, J.; Muhammad, N.S. Quantifying the flood risk index of the Malaysian "rice bowl". *J. Hydrol. Reg. Stud.* **2023**, *46*, 101324. [CrossRef]
53. Oad, V.K.; Szymkiewicz, A.; Khan, N.A.; Ashraf, S.; Nawaz, R.; Elnashar, A.; Saad, S.; Qureshi, A.H. Time series analysis and impact assessment of the temperature changes on the vegetation and the water availability: A case study of Bakun-Murum Catchment Region in Malaysia. *Remote. Sens. Appl. Soc. Environ.* **2023**, *29*, 100915. [CrossRef]
54. Kemarau, A.R.; Eboy, V. Evaluation of the Effectiveness of the Use of Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat Satellites in Studying Land Surface Temperature Values: Penilaian Keberkesanan Penggunaan Satelit Moderate Resolution Imaging Spektroradiometer (MODIS) dan Landsat dalam Mengkaji Nilai Suhu Permukaan Darat. *GEOGRAFI* **2021**, *9*, 41–61. [CrossRef]
55. Ehsan, S.; Begum, R.A.; Nor, N.G.M.; Maulud, K.N.A. Current and potential impacts of sea level rise in the coastal areas of Malaysia. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 228, p. 012023.
56. Al-Amin, A.Q.; Nagy, G.J.; Masud, M.M.; Leal Filho, W.; Doberstein, B. Evaluating the impacts of climate disasters and the integration of adaptive flood risk management. *Int. J. Disaster Risk Reduct.* **2019**, *39*, 101241. [CrossRef]
57. Pour, S.H.; Abd Wahab, A.K.; Shahid, S. Physical-empirical models for prediction of seasonal rainfall extremes of Peninsular Malaysia. *Atmos. Res.* **2020**, *233*, 104720. [CrossRef]
58. Hazir, M.H.M.; Kadir, R.A.; Abd Karim, Y. Projections on future impact and vulnerability of climate change towards rubber areas in Peninsular Malaysia. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2018; Volume 169, p. 012053.

59. Selamat, S.N.; Maulud, K.N.A.; Mohd, F.A.; Rahman, A.A.; Zainal, M.K.; Wahid, M.A.A.; Hamzah, M.L.; Ariff, E.H.; Awang, N.A. Multi method analysis for identifying the shoreline erosion during northeast monsoon season. *J. Sustain. Sci. Manag.* **2019**, *14*, 43–54.
60. Suparta, W.; Rahman, R. Spatial interpolation of GPS PWV and meteorological variables over the west coast of Peninsular Malaysia during the 2013 Klang Valley Flash Flood. *Atmos. Res.* **2016**, *168*, 205–219. [CrossRef]
61. Anthony, D.U.N.S.T.A.N.; Shaaban, A.; Aung, T.H.; Saleh, E.J.R.I.A.; Hamid, R.A.; Osman, A.R. Sea level changes along the coast of Sandakan Town, Sabah, Malaysia: Projection and inundation coverage. In Proceedings of the E-Proceedings of the 36th IAHR World Congress, Hague, The Netherlands, 28 June–3 July 2015; Volume 28.
62. Abdul Maulud, K.N.; Mohd, F.A.; Md Noor, N.; Wan Mohd Jaafar, W.S.; Wan Mohtar, W.H.M.; Adnan, N.A.; Syed Abdul Rahman, S.A.F. Vulnerability Assessment and Management for Coastal Erosion. In *Advances in Geoinformatics Technologies: Facilities and Utilities Optimization and Management for Smart City Applications*; Springer Nature: Cham, Switzerland, 2024; pp. 91–105.
63. Mogaji, K.A.; Lim, H.S.; Abdullah, K. Regional modeling of climate change impacts on groundwater resources sustainability in peninsular Malaysia. *Mod. Appl. Sci.* **2013**, *7*, 72. [CrossRef]
64. Din, A.H.M.; Zulkifli, N.A.; Hamden, M.H.; Aris, W.A.W. Sea level trend over Malaysian seas from multi-mission satellite altimetry and vertical land motion corrected tidal data. *Adv. Space Res.* **2019**, *63*, 3452–3472. [CrossRef]
65. Anak Kemarau, R.; Boo, W.H.; Sakawi, Z.; Dambul, R.; Suab, S.A.; Wan Mohd Jaafar, W.S.; Eboy, O.V.; Fakhry Norzin, M.A. Impact of El Niño, Indian Ocean dipole, and Madden–Julian oscillation on land surface temperature in Kuching City Sarawak, during the periods of 1997/1998 and 2015/2016: A pilot study. *J. Water Clim. Chang.* **2024**, *15*, 3702–3723. [CrossRef]
66. Azran, N.I.; Jeofry, H.; Chung, J.X.; Juneng, L.; Ali, S.A.S.; Griffiths, A.; Ramli, M.Z.; Ariffin, E.H.; Miskon, M.F.; Mohamed, J.; et al. Southern South China Sea Dynamics: Sfea Level Change from Coupled Model Intercomparison Project Phase 6 (CMIP6) in the 21st Century. *J. Mar. Sci. Eng.* **2023**, *11*, 458. [CrossRef]
67. Ehsan, S.; Begum, R.A.; Maulud, K.N.A. Household external vulnerability due to climate change in the Selangor coast of Malaysia. *Clim. Risk Manag.* **2022**, *35*, 100408. [CrossRef]
68. Kemarau, R.A.; Eboy, O.V. Spatial-Temporal Variability of Vegetation Health During El Niño 2015/2016 and La Niña 2017/2018: A Case Study of Sarawak. *Malays. J. Soc. Sci. Humanit. (MJSSH)* **2022**, *7*, e001232. [CrossRef]
69. Tan, M.L.; Ibrahim, A.L.; Yusop, Z.; Duan, Z.; Ling, L. Impacts of land-use and climate variability on hydrological components in the Johor River Basin, Malaysia. *Hydrol. Sci. J.* **2015**, *60*, 873–889. [CrossRef]
70. Firdaus, R.R.; Leong Tan, M.; Rahmat, S.R.; Senevi Gunaratne, M. Paddy, rice and food security in Malaysia: A review of climate change impacts. *Cogent Soc. Sci.* **2020**, *6*, 1818373. [CrossRef]
71. Malaysia National Disaster Management Agency. 2015. Available online: https://www.nadma.gov.my (accessed on 10 January 2024).
72. Masrani, A.S.; Nik Husain, N.R.; Musa, K.I.; Yasin, A.S. Prediction of Dengue incidence in the Northeast Malaysia based on weather data using the generalized additive model. *BioMed Res. Int.* **2021**, *2021*, 3540964. [CrossRef]
73. World Health Organization. *WHO Guidance on Research Methods for Health Emergency and Disaster Risk Management, Revised 2022*; World Health Organization: Geneva, Switzerland, 2022.
74. Kamal, N.I.A.; Ash'Aari, Z.H.; Abdullah, A.M.; Kusin, F.M.; Yusuff, F.M.; Sharaai, A.H.; Muharam, F.M.; Ariffin, N.A.M. Extreme heat vulnerability assessment in tropical region: A case study in Malaysia. *Clim. Dev.* **2022**, *14*, 472–486. [CrossRef]