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Enhancing climate resilience through geospatial analysis for use cases of JC3 climate data catalogue by Bank Negara Malaysia[1]

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[1] This contribution was prepared for the workshop. The views expressed are those of the authors and do not necessarily reflect the views of the Central Bank of the Republic of Türkiye, the BIS, the IFC or the other central banks and institutions represented at the event.

Enhancing Climate Resilience through Geospatial Analysis for Use Cases of JC3 Climate Data Catalogue by BNM[1]

Muhammad Nadzif Bin Ramlan

Abstract

Climate change threatens agriculture, water supply, health, and public infrastructure. Therefore, this paper discusses the creation of a resource by Bank Negara Malaysia (BNM) to mitigate these risks: the JC3 Climate Data Catalogue. Designed to address data gaps and support increased climate resilience in the Malaysian financial sector, the catalogue is developed in collaboration with the Securities Commission Malaysia. It supports scenario planning, product development, macroeconomic modelling, and stress testing. The paper describes the research and development around the catalogue's functionality and enhancements in the 2023 version, as well as the use cases pertinent to Malaysia including the socioeconomic impact of floods and the urban heat island (UHI) effect linked to deforestation. Using GeoTranslator and QGIS, the author created maps of affected areas, documenting socioeconomic impacts and highlighting regional disparities in flood damage, underscoring the need for tailored mitigation strategies. Google Earth Engine was utilised to analyse Land Surface Temperature (LST) data illustrating the UHI effect, emphasising the importance of effective urban planning and reforestation efforts.

The paper also addresses challenges in data availability, reliabiliyu, and comparability to provide suggestions for further developing the ICT infrastructure and maintaining stakeholder engagement. In a world where climate risks are becoming immediate concerns, financial institutions need the JC3 Climate Data Catalogue to support strategic and operational risk management processes while identifying opportunities in the transition to sustainable, low-carbon economies. This research demonstrates how comprehensive climate data can build resilience in Malaysia's financial sector and supports continued action to address the challenges posed by climate change.

Keywords: data gaps, data catalogue, geospatial analysis, socioeconomic impact, urban heat island, deforestation

JEL classification: G18, Q01, Q50, Q54, Q56

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This paper was originally titled "The Use Cases of JC3 Climate Data Catalogue by BNM In Bridging Data Gaps and Building Climate Resilience" at the CBRT-IFC Workshop on 6-7 May 2024.

Contents

1. Introduction

Climate change is a global issue and the challenges surrounding it take place over long periods of time, involving interactions between environmental, economic, political and institutional factors, facilitated by society or technology. It is anticipated to have strong impacts on the climate-sensitive sectors of agriculture, water, coast and health that manifests into significant international and intergenerational adverse effects (Ibrahim *et al.*, 2016). The Network for Greening the Financial System (NGFS) serves as an international platform to combat global warming. This voluntary grouping of central bankers and supervisors are the leaders in their efforts to help guide sustainability within financial systems.

In their report dating back to April 2019 entitled "A call for action: Climate change as a source of financial risk", they have released several recommendations in which Recommendation No. 3 is Bridging the Data Gaps. NGFS reckoned that public authorities share relevant data for Climate Risk Assessment (CRA) and make it publicly available. They also suggested setting up a joint working group to bridge existing data gaps, resulting in a detailed list of data items needed by authorities and financial institutions (FIs) to enhance the assessment of climate-related risks and opportunities. Currently, available data covers brief period, and risk-weighted assets are calculated on a one-year forward-looking basis. The NGFS is ready to initiate work with interested parties to establish a detailed list of currently lacking data items, allowing data providers to mine relevant data and progressively bridge gaps. This initiative aims to move from observation to action and improve the assessment of climate-related risks and opportunities.

Considering the general global call to act upon climate efforts, in September 2019, the Joint Committee on Climate Change (JC3) rose as a platform of collaboration within the Malaysian financial sector. This platform forged by Bank Negara Malaysia (BNM) and the Securities Commission Malaysia (SC) embodies the crucial role of regulatory cooperation in building climate resilience. The interconnectedness of financial and environmental strategies is further underscored by integrating climate data into national development plans, recognising both sectors as pillars of sustainable development. The fifth sub-committee, Bridging Data Gaps on Climate Change (Subcommittee), has been entrusted with facilitating the prioritisation of the initial use cases, which included scenario analysis, product development, macroeconomic modelling, and stress testing in addition to data to support investment and lending decisions. The Subcommittee collaborates with key public and private sector partners to identify and map critical data requirements to pertinent data sources for the use cases. The financial sector now has access to a catalogue of climate data compiled by the Subcommittee in 2022, followed by the enhanced version in 2023 entitled "JC3 Climate Data Catalogue".

In order to provide a local perspective, this paper analyses Bank Negara Malaysia's policies and actions via two research objectives:

i. Delves into the functionality and usage of JC3 Climate Data Catalogue

In this part, we examine how the Subcommittee strategically identifies climate-related issues and promotes comprehensive data availability, providing a full

understanding of its multidimensional approach as we explore the functionality of the data catalogue.

ii. Use cases of JC3 Climate Data Catalogue

We will investigate two pertinent case studies relevant to the Malaysian context: Flood (Natural Disasters) and linking deforestation with urban heat island (UHI) as well as to consider any other risk related (e.g. transition risk).

2. The Highlight: JC3 Data Catalogue

The JC3 Climate Data Catalogue, inaugurated in December 2022, serves as a crucial reference point for climate and environmental data relevant to the financial sector.

As shown in Table 1, the Subcommittee has identified eight use cases along with their brief descriptions. This is based on the use cases identified by NGFS and consultations with five key stakeholder groups comprising financial sector regulators (BNM, SC, Bursa Malaysia), pension and provident funds, asset managers, banking institutions, insurers and takaful operators, and asset managers. Product development is an additional use case in comparison to the NGFS' use cases, given the critical role that FIs play in financing transitions via the expansion and upscaling of green financial solutions.

Use Cases Identified by the Subcommittee on Bridging Data Gaps — Table 1

Use Case	Description
Climate-related disclosures	Reports by corporations on climate-related factors, used for analysis and monitoring. Global frameworks like TCFD facilitate consistent disclosure. Malaysia's Bursa Malaysia has enhanced its Sustainability Reporting Framework, requiring Main Market listed issuers to provide TCFD-aligned disclosures by 2025.
Exposure quantification	Potential loss on financial instruments, assessing physical risk and transition risk, and assessing portfolio adjustments towards low-carbon economies.
Financial stability monitoring	Assessment of financial system vulnerabilities, recognising systemic risks and climate change-related impacts. Malaysia's regulators – BNM and SC – assess climate-related risks' potential impact on the financial system and capital market.
Investment and lending decisions	The decision-making process involves both demand-side and supply-side factors such as footprint, vulnerability, mobilisation, and alignment when deciding on funds for investment opportunities or loans, focusing on low carbon activities.
Macroeconomic modelling	Analyses of climate-related impacts on GDP, employment, and inflation in Malaysia, focusing on transition risk and physical risk/vulnerability associated with extreme weather conditions.
Product development	The development of new financial products and solutions to support green growth and industry alignment with climate agendas, exploration of intermediation structures, and increased financing and protection solutions.
Scenario analysis	The NGFS has designed six scenarios to assess climate change risks, while BNM issued the Policy Document on Climate Risk Management and Scenario Analysis in December 2022, aiming to enhance financial institutions' resilience and facilitate a low-carbon economy transition.

Stress testing	BNM proposes a risk framework method focusing on climate change's impact on exposures' actual risk, with industry-wide Climate Risk Stress Testing (CRST) exercise set to be implemented in 2024.

Finally in October 2023, The Joint Committee on Climate Change (JC3)'s Subcommittee on Bridging Data Gaps released an enhanced JC3 Climate Data Catalogue (DC), tackling critical data gaps in climate and environmental information for the financial sector. This part dives into the upgraded DC, highlighting its newest structure, accessibility, and functionality.

The new Relational Spreadsheet Structure (RSS) streamlines search and updates, making the DC user-friendly and intuitive in discovering 128 unique environmental and climate-related data items with 249 granular data, categorised into 14 data groups, and mapped to relevant NGFS use cases. This data catalogue with a 68% availability rate, empowers users to conduct in-depth analyses and make informed decisions.

With improved navigation, filtering, and even potential API integration, users can access and analyse data with ease. Its structured format allows for future expansion and seamless integration with diverse platforms, paving the way for a robust, fully relational database. This ensures the DC stays relevant and adaptable, serving the evolving needs of users and the financial sector. New data inputs are readily accommodated, integrated into the existing framework without compromising coherence. This ensures a consistently high-quality dataset that users can trust to inform vital decisions.

Homepage of the JC3 Climate Data Catalogue — Diagram 1

Source: https://www.jc3malaysia.com/data-catalogue. Accessed on 19 April 2024.

The 2023 JC3 Climate Data Catalogue (DC) improves in terms of data availability, marking a major step forward in supporting the Malaysian financial sector's climate resilience endeavours. Referring to Chart 1, compared to the 2022 edition, available data items increase from 49% to 68%, representing a 19% increase in overall accessibility.

Even when accounting for the expanded scope of data items in 2023, the availability of existing items from the 2022 DC showed a 6% improvement, rising from

49% to 55%. This positive trend owes credit to broader data dissemination by government agencies, such as flood-related information from the Department of Irrigation and Drainage (DID) and the Department of Statistics Malaysia (DOSM).

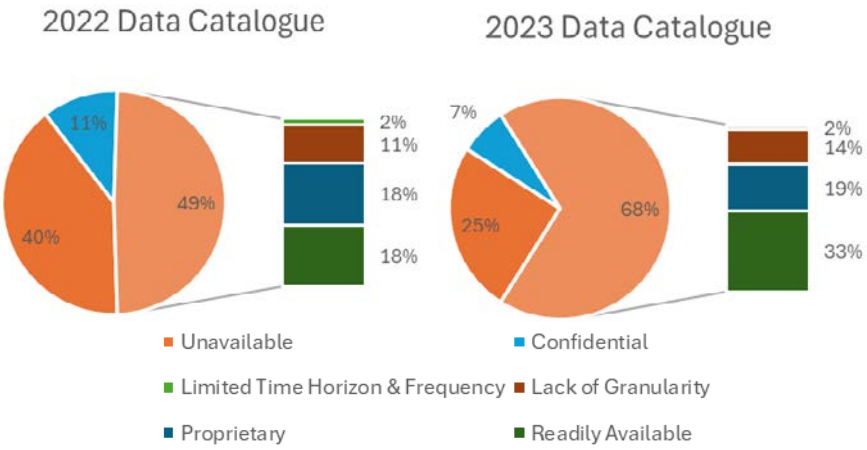
The DC now also features:

i. A richer data ecosystem with 399 data sources across 135 providers, spanning diverse institutions like the World Bank, the International Energy Agency, and domestic players like the Department of Statistics Malaysia (DOSM) and the Energy Commission.

ii. A 56% increase in data items, offering 46 new data points for exploration, primarily focusing on critical areas like energy, water, physical risk exposure, and GHG emissions aligned with TNFD and ISSB requirements.

iii. Enhanced existing data: 43 items from the 2022 DC have been updated with improved standards, methodology, time series coverage, and additional data sources, ensuring greater accuracy and depth.

Comparison of DC Content Between 2022-2023 Chart 1



Source: JC3 Climate Data Catalogue, as of April 2024.

While the 68% availability mark is plausible, further work remains. Within this category: 33% of data is readily available, offering direct access without barriers; 19% remains proprietary, requiring subscription or other forms of access limitation; 16% faces gaps due to granularity and time horizon limitations, particularly in areas like government sustainability-related financing needs and flood-related impacts.

The DC's progress underscores the increasing commitment to filling critical data gaps and equipping the financial sector with the tools needed to navigate climate change challenges. Continued collaboration between data providers, regulators, and users is crucial for unlocking the full potential of this valuable resource and building a robust climate-resilient future for Malaysia.

Diagram 2 shows the summary for Data Groups, Data Items and Status of Availability in the Climate Data Catalogue scrutinising the composition of data availability within the data groups.

Data Groups, Data Items and Status of Availability of JC3 Climate Data Catalogue Diagram 2

Source: Data Groups, Data Items and Status of Availability from Appendix A (https://www.jc3malaysia.com/about-data-catalogue), as of April 2024.

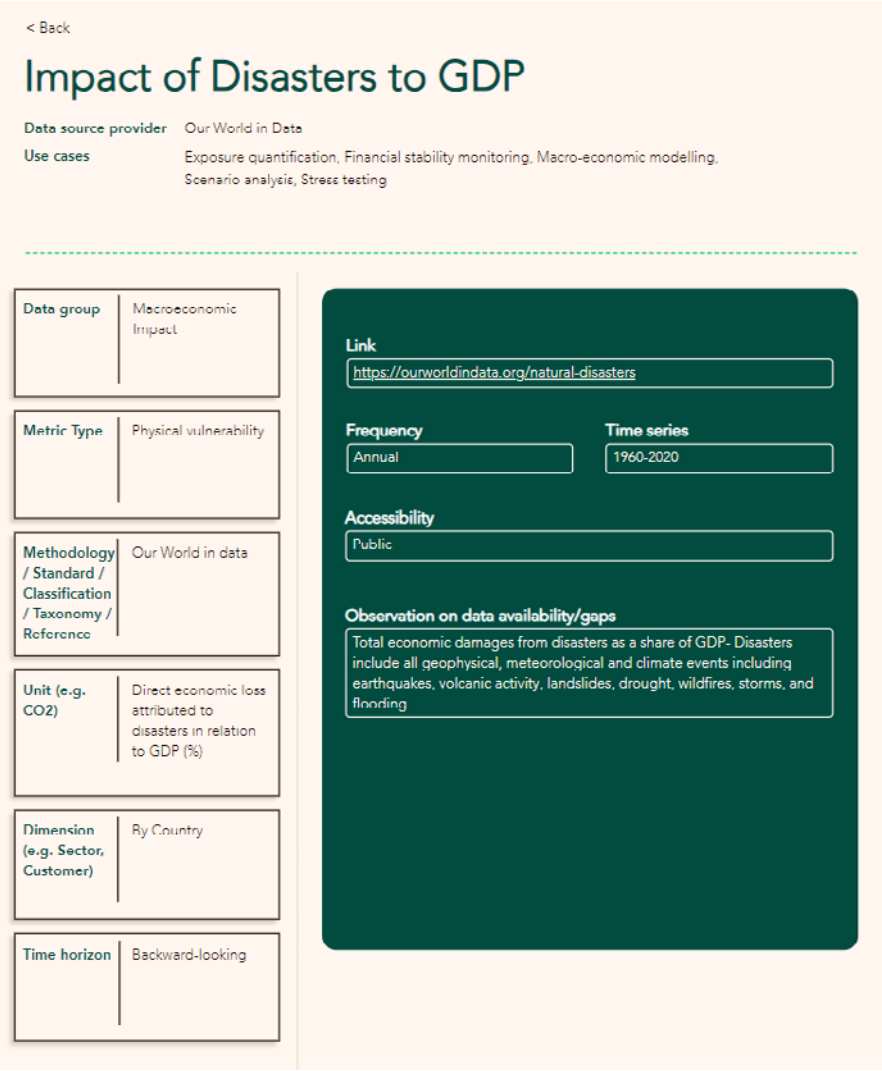
The DC is more than just a reference point. It actively promotes awareness of data gaps, urging data providers to improve accessibility and fill critical knowledge voids. This collaborative approach fosters a robust climate data ecosystem that benefits everyone. The DC prioritises Malaysian climate and environmental data, aligning with the Network for Greening the Financial System (NGFS) protocols. However, its reach extends beyond borders, incorporating relevant global data sources for a comprehensive view. It lays the groundwork for a national-level climate data catalogue, empowering all stakeholders across Malaysia to address climate challenges effectively.

3. Use Cases of JC3 Climate Data Catalogue

Socioeconomic Impact of Flood

Utilising the data catalogue, a reference to comprehend the effect of flood upon Malaysia would be *Our World in Data* (Natural Disasters - Our World in Data) as shown from the data catalogue interface below.

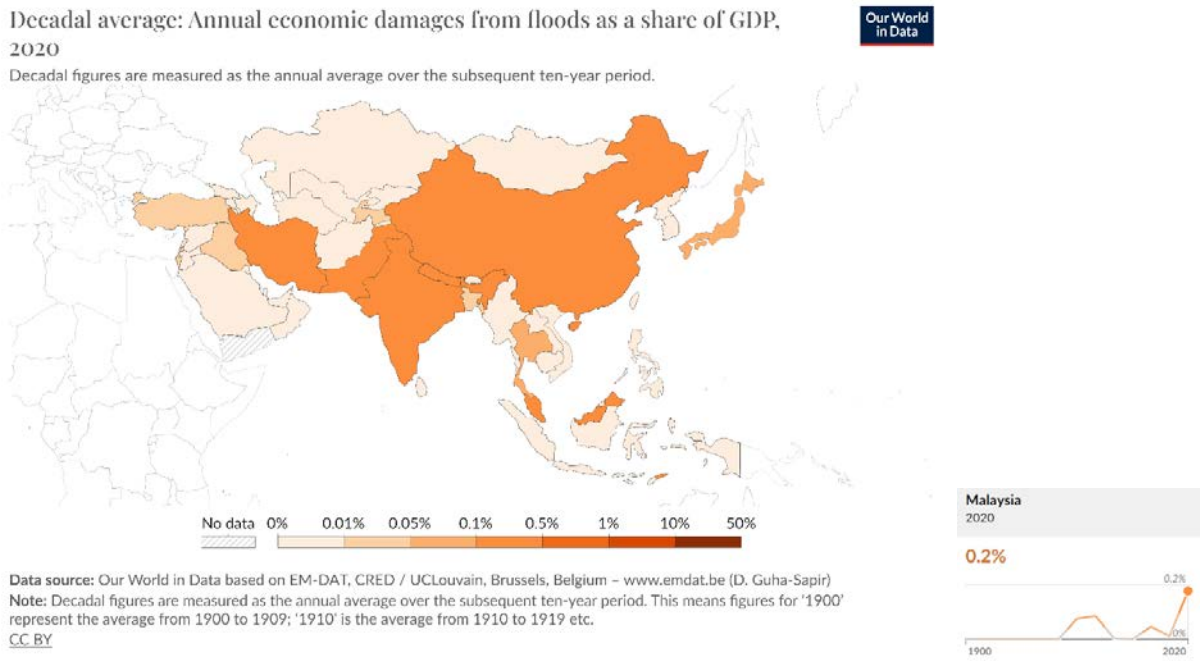
Impact of Disasters to GDP in JC3 Climate Data Catalogue Finding — Diagram 3



Source: https://www.jc3malaysia.com/data-catalogue/impact-of-disasters-to-gdp/424. Accessed in April 2024.

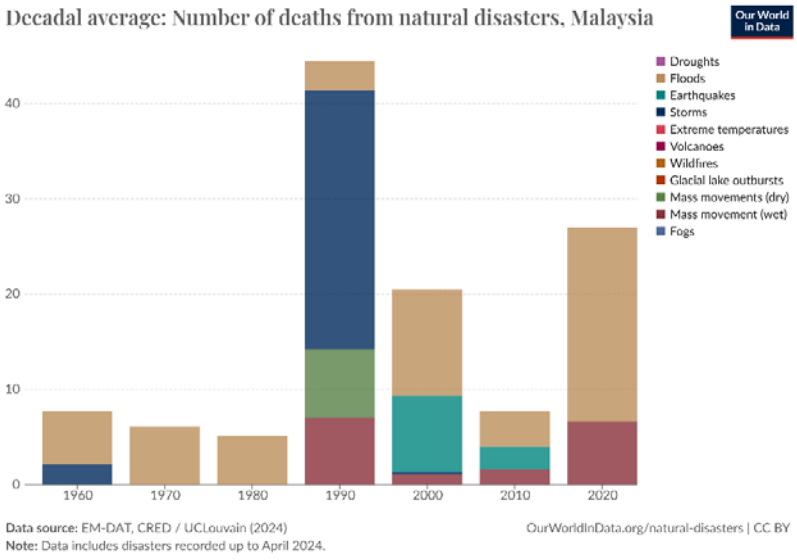
The preliminary information about the website is already provided such as the data group, metric type (in terms of measurement dimension), reference or taxonomy, the subject of measurement, dimension and the time horizon associated. This would aid researchers in getting prior insights into such data and thus facilitate more time-efficient research endeavours.

Decadal Average of Economic Damages from Floods Upon GDP (%), 2020 Diagram 4



Source: Ritchie and Rosado (2022) - "Natural Disasters". Data adapted from EM-DAT, CRED / UCLouvain

Decadal Average of Number of Deaths from Natural Disasters in Malaysia Chart 2



Source: Ritchie and Rosado (2022) - "Natural Disasters". Data adapted from EM-DAT, CRED / UCLouvain.

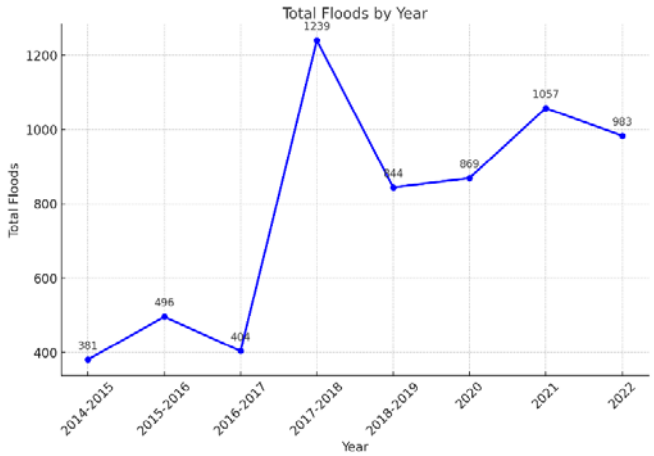
Diagram 4 shows the decadal average for the yearly economic impact of flood upon GDP in the Asian region for the 2011-2020 period and Malaysia records the 5th highest figure at 0.2% from GDP after Iran (0.33%), India (0.27%), Pakistan (0.25%), and Timor-Leste (0.23%). Chart 2 meanwhile ascertains the severity of flood in

Malaysia as it is prevalent among the major cause of deaths from natural disasters from 1960-2020. Malaysia will likely experience significant consequences from climate change, as demonstrated by a predicted average annual surface temperature increase of 1.9 to 2.1°C by the end of the century and a sea level rise of roughly 0.7m by the end of the twenty-first century. This might have an impact on the country's economy, agriculture, industry, tourism, and energy, disproportionately affecting the population.

Malaysia is using both structural and non-structural solutions to adapt to and mitigate floods. These encompass the adoption of nature-based solutions, the development of plans for sub-national implementation, and the periodic maintenance of flood mitigation infrastructures and early warning and forecasting systems. Effective CEPA and regulatory intervention are required to promote sustainable and future-proof water management. Malaysia is implementing a comprehensive strategy to address identified critical and vulnerable areas, which includes subnational cooperation and routine river basin maintenance. The financial provisions designated for flood mitigation initiatives have been augmented by RM19 billion and RM5 billion, respectively, in the Eleventh and Twelfth Malaysia plans. Incorporating nature-based solutions, integrating water resources management, integrating river basin management, and implementing integrated flood management are all components of non-structural flood mitigation.

Therefore, the methodology to be utilised would be via i) geocoding via the Malaysian government's application GeoTranslator to specifically locate the affected or risky locations pertaining to flood across the country, based on the government information such as Public Info Banjir (Public Flood Info) and also data extraction from Annual Data Reporting by the Department of Irrigation and Drainage (DID) from 2014-2022; followed by ii) utilising the QGIS software for the geomapping of the specific locations involved to evaluate the socioeconomic impact upon the residents and the specific policy recommendations for this situation.

Annual Flood Occurrences by Year — Chart 3

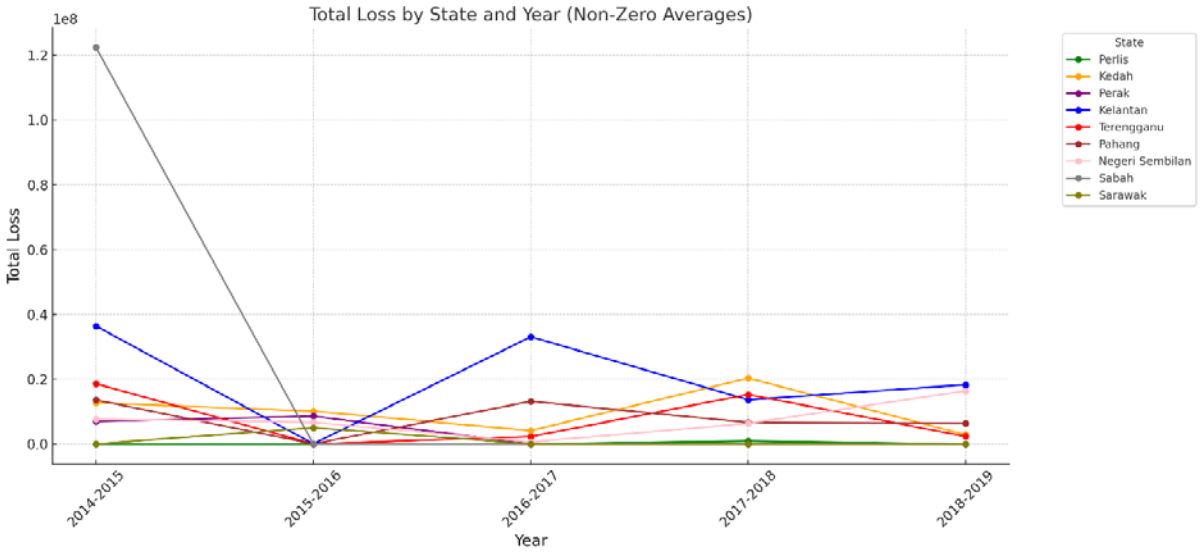


Source: Annual flood reports since 2014-2022 by Department of Irrigation and Drainages (DID), Malaysia, author's own illustration

The Malaysian flood data from 2014 to 2022 in Chart 3 reveals a volatile pattern with a significant spike in 2017, prompting a review of flood mitigation tactics,

suggesting the need for sturdier infrastructure, and highlighting the necessity of factoring flood risks into urban planning and resource distribution. This trend also emphasises the importance of public awareness and the urgency for ongoing research aimed at sustainable environmental practices in the face of climate change. Despite a marginal decrease in floods in 2022, the data remains essential for refining flood management strategies and enhancing emergency preparedness.

Total Loss by State and Year (Non-Zero Averages) Chart 4



States with recorded zero average losses are not included: FT Kuala Lumpur, FT Labuan, FT Putrajaya, Selangor, Melaka, Johor, Penang. The loss estimation figures are no longer available in the 2020 Annual Flood Report and beyond

Source: Annual flood reports since 2014-2019 by Department of Irrigation and Drainages (DID), Malaysia, author's own illustration

These are the average loss estimation from 2014-2019 based on Chart 4 across 5 years (in descending order):

Sabah: 24,491,000; Kelantan: 20,281,880; Kedah: 10,016,680

Pahang: 7,945,800; Terengganu: 7,685,400; Negeri Sembilan: 7,534,900

Perak: 3,103,900; Sarawak: 1,001,000; Perlis: 178,000

The data reveals significant variability in collateral losses across states and years, with some regions being more vulnerable to catastrophic events. These losses can have profound socioeconomic consequences, such as disruptions to infrastructure, food security, health, and economic activities. Some states have managed to reduce losses over time, indicating effective recovery efforts and improved resilience. However, high collateral damages may affect insurance premiums, availability of insurance, and financial health, potentially impacting the region's economic viability. Repeated high losses in certain areas could deter investment and lead to migration to less risky areas, affecting the local labour market and economy. Government policy and aid may be influenced by the pattern of losses, potentially leading to more targeted disaster preparedness and mitigation programmes. Social cohesion can also be impacted by disaster responses, with effective community response strengthening social ties. Yearly trends show decreases in losses, suggesting improvement or less

severe flood events. The data can be used for forecasting and planning, guiding risk assessments and designing socioeconomic policies to mitigate the adverse effects of future flooding events.

To further assist the risk assessments as such, we can utilise the geospatial analysis to visualise the extent of impact across the country, by referencing the latest Annual Flood Report (2022) for such purposes. Based on the report, we geocoded 2,290 locations using the Malaysian government website, GeoTranslator.

Afterwards, the geomapping is done via the QGIS software according to the Malaysian districts, with the overlaying of coordinates above. Below are some of the findings from the geocoding:

Unique Count of Affected Locations by State

In Descending Order

Table 2

No.	State	Total	No.	State	Total
1	Sarawak	479	8	Negeri Sembilan	114
2	Sabah	419	9	Pahang	99
3	Kedah	315	10	Melaka	64
4	Selangor	226	11	Penang	56
5	Johor	173	12	Federal Territories	49
6	Kelantan	144	13	Perak	15
7	Terengganu	131	14	Perlis	6

Note: Sarawak and Sabah have much more granular flood locations such as schools, offices, indigenous community houses etc. compared to those in Peninsular Malaysia based on the 2022 Annual Flood Report. The counting is based on one-time occurrence.

Most Affected District by State

Table 3

State	District	Total	State	District	Total
Sarawak	Sibu, Kanowit & Selangau	233	Negeri Sembilan	Kuala Pilah	41
Sabah	Beluran	87	Pahang	Raub	39
Kedah	Baling	158	Melaka	Alor Gajah	45
Selangor	Klang	84	Penang	Barat Daya	25
Johor	Batu Pahat	60	Federal Territories	Kuala Lumpur	46
Kelantan	Kuala Krai	42	Perak	Kinta	7
Terengganu	Besut	31	Perlis	Kangar	4

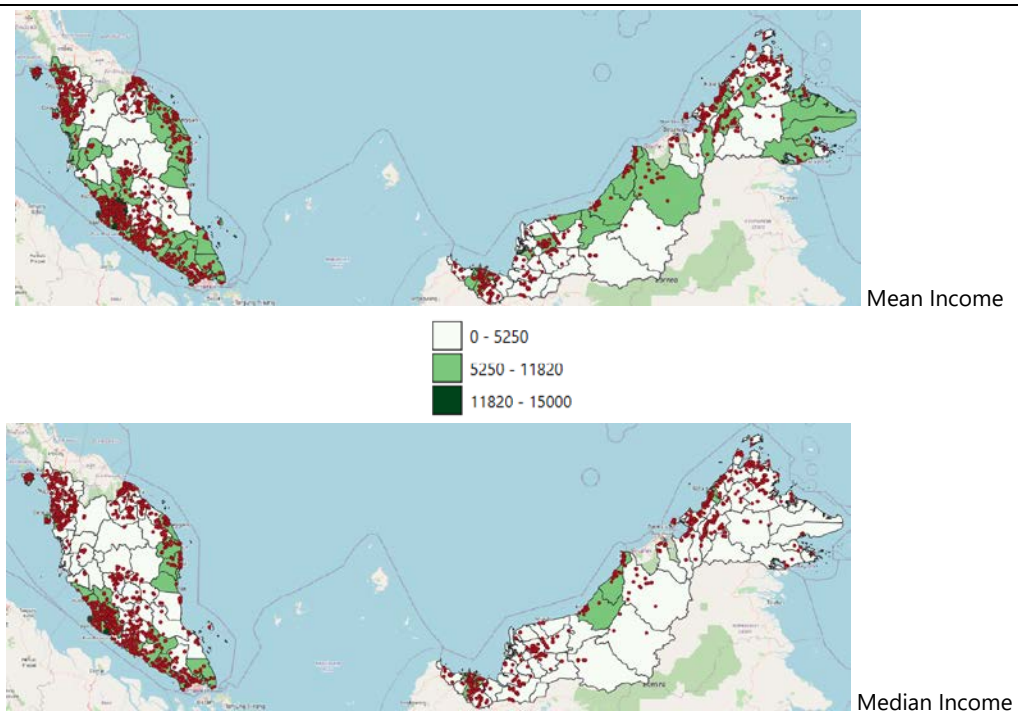
Note: Sarawak and Sabah have much more granular flood locations such as schools, offices, indigenous community houses etc. compared to those in Peninsular Malaysia based on the 2022 Annual Flood Report. The counting includes repetitive cases.

The interrelation of socioeconomic factors and flood incidence in Malaysia, as depicted through analytical mapping, paints a multifaceted picture of how disparities in wealth both shape and are shaped by the onslaught of natural disasters. The color-coded maps not only demarcate districts by income levels and Gini coefficients — a

statistical measure of income inequality — but also overlay the stark realities of flood occurrences, visualised through red dots that mar the landscape.

Mean & Median Income Distribution by District

Diagram 5



[2]Bottom 40 (B40) monthly income threshold is below RM5,250; Middle 40 (M40) monthly income threshold is between RM5,250-RM11,820; Top 20 (T20) monthly income threshold is beyond RM11,820

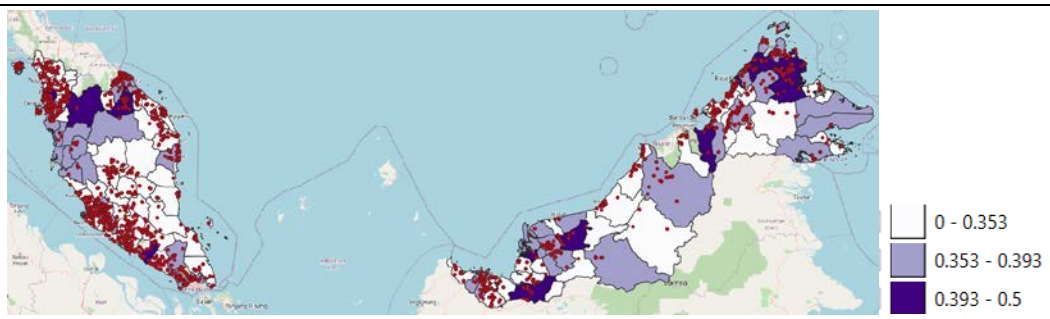
Source: QGIS, author's own illustration

In the economically vulnerable B40 districts where both the mean and median incomes suggest limited financial means, a high density of flood occurrences (36.65% for mean income, 60.56% for median income) reveals the disproportionate impact on these already strained communities. These are not mere watermarks on a map but indicators of deeper susceptibility to disaster, where the lack of resources amplifies the hardships wrought by flooding. Meanwhile, the green-coded M40 districts, which exhibit greater economic stability, still show a significant presence of flood events (55.89% for mean income, 59.12% for median income). These districts face the dual challenge of ensuring their infrastructural and fiscal capacities can weather the floodwaters while avoiding a false sense of security due to their middle-ground economic status. Conversely, the dark green T20 districts, with their sparse flood occurrences (7.46% for mean income, 1.44% for median income, exclusively in Sepang district), illustrate the buffering effect of affluence against floods. Here, robust economic underpinnings presumably support stronger flood defences and recovery strategies. However, the infrequent but present flood events remind us that wealth

[2] Refer to the Household Income Survey Report 2022, page 52. Released by Department of Statistics Malaysia (DOSM): https://www.dosm.gov.my/portal-main/release-content/household-income-survey-report--malaysia--states

cannot entirely ward off the vagaries of nature; affluence can mitigate but not wholly eliminate flood risk.

Gini Coefficient for Disposable Income by District — Diagram 6

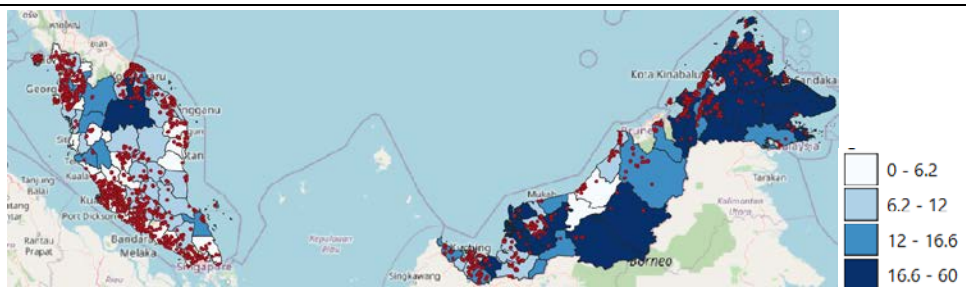


[3]0.353 is the average GC in rural region for disposable income, 0.393 is the national GC for disposable income

Source: QGIS, author's own illustration

The purple hues on the maps indicate a Gini coefficient reflective of the national average, portraying a moderate level of income inequality. Flood events distributed across these districts suggest that while income disparities are prevalent, they are not the sole determinants of flood risk. Notably, 9.60% of floods occurred in districts with a higher-than-national Gini coefficient of 0.393, and 45.16% of flood occurrences are in areas with a Gini coefficient beyond the rural average of 0.353. This distribution implies that greater income inequality within a district may correlate with increased vulnerability to floods. These findings underscore the need for policies that bridge the divide, ensuring that relief and recovery efforts effectively reach the most disadvantaged communities.

Poverty Rate (%) by District — Diagram 7



[4]6.2% is the national absolute poverty rate, 12% is the absolute rural poverty rate, 16.6% is national relative poverty rate

Source: QGIS, author's own illustration

[3] Refer to the 2022 Highlights: Income, Expenditure Poverty Inequality, page 168. Released by DOSM: https://www.dosm.gov.my/uploads/release-content/file_20230808213355.pdf

[4] Refer to the 2022 Poverty in Malaysia report, page 4. Released by DOSM: https://www.dosm.gov.my/uploads/release-content/file_20230806212629.pdf

Layered atop this narrative is the reality of poverty rates, represented by varying shades of blue indicating escalating percentages from below the national average to areas where relative poverty ensnares a sizable portion of households. The overlapping of flood locations with these regions delivers a stark message: the higher the poverty rate, the more pronounced the impact of flooding. Notably, 45.86% of flood occurrences are in districts with poverty rates exceeding the national average of 6.2%. Furthermore, 16.89% of flood occurrences are in districts with poverty rates higher than the national relative poverty rate of 16.6%, with larger concentrations in states like Kelantan in Peninsular Malaysia, and Sabah and Sarawak on Borneo Island. This is especially alarming in Sabah, where one district, Pitas, registered ~2.3% (53) of flood locations with a poverty rate of 52.7%, indicating that half the population lives in subnormal conditions exacerbated by natural disasters. This reveals an urgent need for targeted interventions to address the dual challenges of poverty and flood risk, highlighting the critical importance of building robust support systems for the most vulnerable, not just for immediate relief but also for enduring risk reduction and poverty alleviation.

The academic discourse on disaster management would emphasise the strategic integration of development planning with disaster preparedness, stressing that effective poverty reduction is integral to enhancing societal resilience to environmental hazards. To mitigate the compounded threats of poverty and flooding, policies must be devised to bolster infrastructural defences, enhance early warning systems, and foster equitable access to disaster response mechanisms. Furthermore, fortifying the economic base of communities through diversification of livelihoods and the strengthening of social safety nets can augment their intrinsic resilience.

In sum, the maps advocate for a comprehensive and integrative approach that recognises poverty reduction as an essential component of disaster resilience. This approach calls for a calibrated distribution of resources that acknowledges the differential impacts of flooding, aspiring to a harmonious balance where resilience becomes a shared asset of the Malaysian nation, ensuring that no district is left to navigate the tempest alone.

Urban Heat Islands Relating to Deforestation

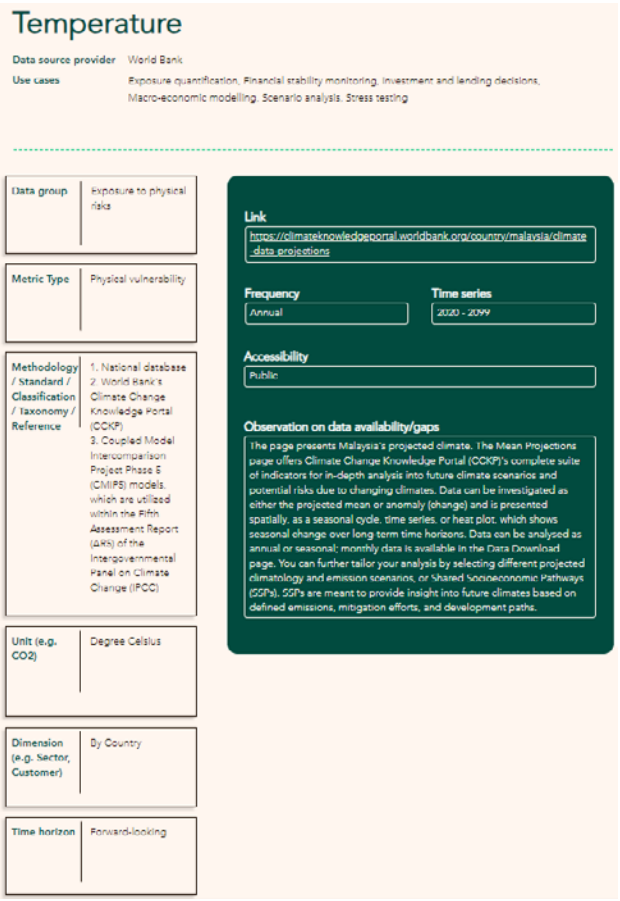
Urban heat islands (UHIs) are geographical territories characterised by notably elevated temperatures in comparison to their surroundings. This phenomenon is the result of land surface temperature (LST), deforestation, and urbanisation interacting in a complex manner.

Deforestation causes fluctuations in the reflectivity of the land surface and disrupts natural cooling mechanisms such as evapotranspiration; both factors contribute to heightened heat absorption in urban regions. Urbanisation exacerbates the UHI effect through its proliferation of heat-generating activities and an abundance of impervious surfaces (Ramakreshnan, 2022). The LST, which is quantified via remote sensing, is an essential metric for assessing the intensity of UHI by illuminating the spatial pattern and gravity of the issue. Preserving and restoring forests, promoting sustainable urban design with an emphasis on green spaces, and utilising LST data to inform heat mitigation strategies are all elements that must be addressed in order to mitigate UHIs. We can only construct more resilient and

comfortable cities in the face of rising temperatures by adopting such a comprehensive strategy.

To start off, one of the appropriate sources to acquire the general view of Malaysian temperature landscape would be the Climate Knowledge Portal by the World Bank[5] and can be shown via the data catalogue interface below:

Malaysia's Projected Climate in JC3 Climate Data Catalogue Finding — Diagram 8

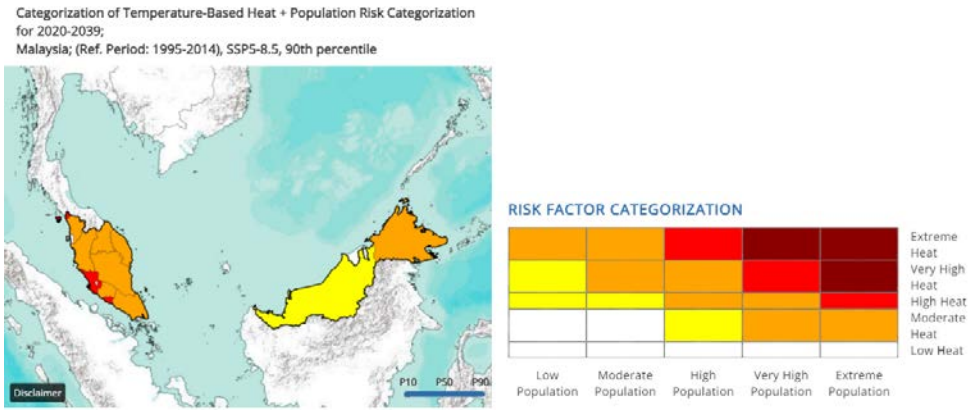


Source: JC3 Climate Data Catalogue (https://www.jc3malaysia.com/data-catalogue/temperature/179). Accessed on 15 Jan 2024.

Some of the insights we can acquire from the website include Heat Risk, Climate Data Projections as shown in Diagram 9:

[5] Refer to the following website: https://climateknowledgeportal.worldbank.org/country/malaysia

Risk-Factor Categorisation for Malaysia, 2020-2039 Diagram 9



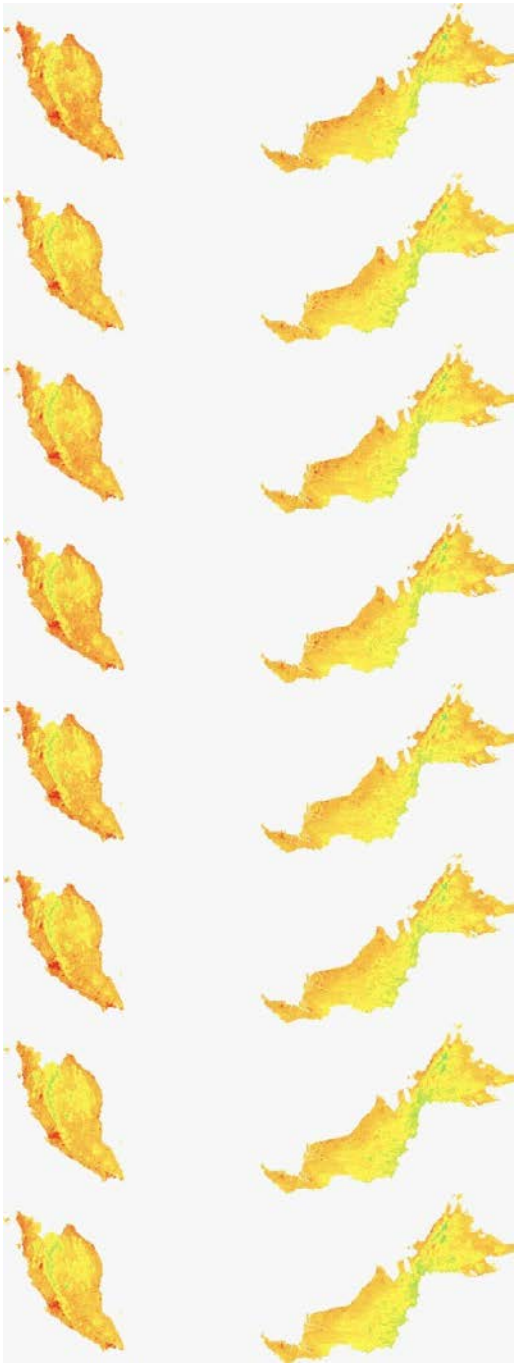
Source: World Bank, Climate Change Knowledge Portal (2024). URL: https://climateknowledgeportal.worldbank.org/ Date Accessed on 15 Jan 2024.

In the face of a 'boiling' world, FIs find themselves at the crossroads of risk and responsibility. The climate data, encapsulated in Diagram 9, provides a categorical risk framework for Malaysia from 2020 to 2039 under the SSP5-8.5 high-emission scenario, forecasting a substantial increase in days with temperatures exceeding 35°C. This backdrop lays the groundwork for an acute understanding of the environmental challenges and opportunities that FIs face. The elevated risk of heat stress, particularly in the interior of the Malay Peninsula as well as the northern regions of East Malaysia, would suggest significant exposure to physical risks due to climate change. This is a key input for FIs as they assess the vulnerability of their investments, especially in sectors like agriculture, real estate, and infrastructure. With hot temperatures correlating with increased energy demand, FIs must recalibrate their portfolios to prioritise resilience and adaptability.

Because heatwaves can have severe consequences for human health particularly for vulnerable populations such as the elderly, small children, and those with chronic conditions, these projections are cause for concern. Additionally, wildfires, water scarcity, and elevated air pollution levels can result from heatwaves (Bansal *et al*., 2023).

Therefore, the paper has explored the technicalities of this aspect, using tools such as Google Earth Engine to analyse the impact of LST on urban climate dynamics, revealing trends and correlations with factors like urbanisation, deforestation, and precipitation across Malaysia. The study emphasises the importance of strategic urban planning and sustainable practices to mitigate adverse effects and envision future LST trends, advocating for collaborative efforts for climate action and sustainable development.

LST Trend Across Malaysia from 2016 - 2023 Diagram 10

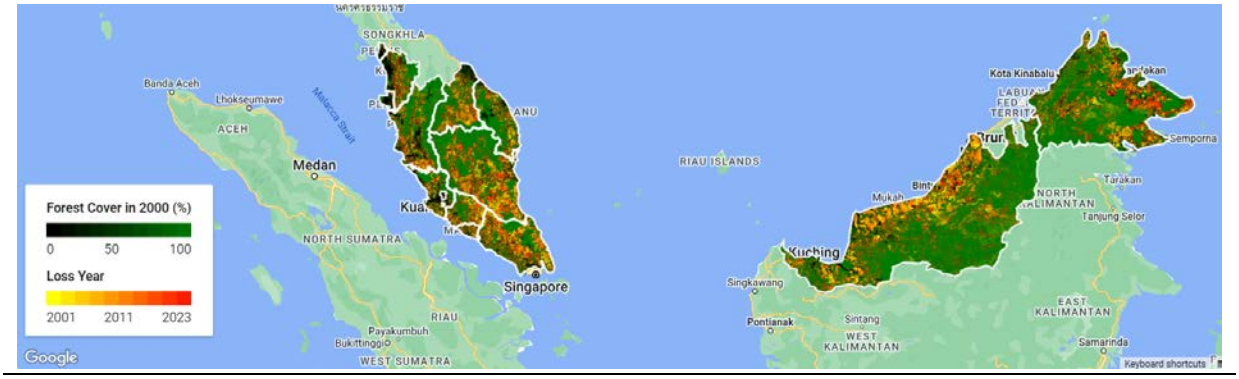


Source: Google Earth Engine

Starting with Diagram 10 showing recent LST analysis for Malaysia spanning from 2016 to 2023, there is a discernible warming trend, particularly in regions like Kuala Lumpur and Johor Bahru. The red hues, indicative of higher temperatures, suggest an intensification of the urban heat island (UHI) effect. This phenomenon is critical for financial institutions (FIs) to consider as it directly impacts energy consumption patterns, with elevated demand for cooling infrastructure potentially influencing

energy sector investments. The updated data from Chart 5 reinforces this warming trend, highlighting several key observations. Kuala Lumpur's LST has shown consistently high temperatures throughout the years, peaking around 2020 before stabilising slightly, yet remaining at elevated levels. Johor Bahru's LST data reveals high temperatures, with slight fluctuations but an overall steady trend, emphasising the growing UHI effect in urban areas. Sabah and Sarawak have demonstrated a relative increase in LST over the years, suggesting broader climatic changes beyond just urban influences. The general trend across most regions shows a slight upward movement in LST, indicating a national trend towards warmer LST. Labuan has shown notable increases in LST, which can be attributed to both natural climatic changes and possibly localised urbanisation effects. Other states, such as Selangor, Penang, and Pahang, exhibit moderate increases in LST, further supporting the overall warming trend. Financial institutions may face risks associated with assets that do not comply with new standards or that are rendered obsolete by emerging technologies. Consequently, FIs can use LST data to anticipate these regulatory and technological shifts, steering investments towards adaptive infrastructure and innovations in cooling technologies that align with the trajectory towards a cooler, sustainable urban environment.

Annual Forest Cover Loss from 2001-2023 Diagram 11



Source: Hansen *et al.*, 2013, Google Earth Engine

Complementing the LST analysis, the deforestation trends from 2001 to 2023 in Malaysia, as shown in Diagram 11, particularly in regions such as Sabah and Sarawak, present a stark visual narrative of environmental degradation. Chart 6 and Table 4 reveal fluctuating yet substantial annual forest cover loss, with peaks around 2009 and 2013, and a notable increase again in 2023. The conversion of forested areas, visualised through a shift from green to red on the map, underscores the loss of natural carbon sinks, thereby exacerbating greenhouse gas concentrations. These trends serve as a clarion call for FIs to reevaluate investments in sectors associated with deforestation and to seek opportunities in conservation and sustainable land management practices. The deforestation data for regions like Sabah and Sarawak signals not only ecological degradation but also exemplifies transition risks, particularly for industries heavily reliant on forest resources. As the world moves towards a low-carbon economy, these industries face risks from policy changes that incentivise forest conservation, shifts in consumer preferences towards sustainability, and the potential for stranded assets. FIs equipped with this knowledge can divest from high-risk sectors and channel funds into sustainable forestry, agriculture that

integrates reforestation, and other enterprises that support carbon reduction efforts, effectively managing transition risks. The integration of deforestation and LST data into risk assessment frameworks enables FIs to make informed decisions that align with the trajectory towards a sustainable and resilient future.

Incorporating temperature-based and population risk categorisations with LST and deforestation analyses provides FIs with a comprehensive framework to navigate climate risks, including pivotal transition risks associated with a global shift to sustainability. FIs' recognition of the risks and opportunities associated with climate change would influence their use of environmental data. The positive correlation between consumers' attitudes towards sustainability and their behaviour, as demonstrated by Chamhuri *et al.* (2023), reflects the financial sector's increasing reliance on comprehensive climate-related data from the JC3 Climate Data Catalogue to inform risk assessments and investment decisions. Emphasising the requirement of easily available and trustworthy data to support such decisions, this shows a more general tendency towards sustainability in both consumer and business actions. By means of a proactive approach to risk management, FIs not only facilitate to reduce possible losses but also seize opportunities resulting from the change to a sustainable, low-carbon economy. Key elements of a climate-smart investing approach —environmental, technological, and regulatory changes — will determine the direction of the financial sector.

4. Challenges & Opportunities

i. Data Availability: The challenge of accessing comprehensive climate-related information is significant for FIs in assessing risks and shaping investment strategies. Often, available data do not adequately cover essential aspects such as asset types, sectors, geographies, and predictive timeframes. Issues with granularity and proprietary barriers further complicate the scenario. Enhancing data availability require a concerted effort among data providers, regulatory bodies, and FIs to create standardised, transparent, and detailed climate datasets that are crucial for informed decision-making in the financial sector.

ii. Data Reliability: The reliability of climate data is often compromised by uncertainties and a lack of consistency across different sources. Quality issues, including discrepancies in accuracy and audit trails, contribute to a lack of confidence in the data. The varied methodologies and frameworks used by different data providers add further complexity. Addressing these challenges will necessitate a collaborative approach to establish stringent quality controls and improve transparency, thereby ensuring that climate data is dependable enough to support resilient financial decision-making in response to climate change.

iii. Data Comparability: The ability to compare climate data across different sources is hindered by variations in data formats, structures, and definitions. The complexity is exacerbated due to many disparate disclosure frameworks positioned on different areas of focus, creating more challenges for investors trying to wrangle all the information together to produce meaningful

insights. Efforts to standardise methodologies and harmonise reporting standards are necessary to ensure that climate data can be used well in an era when risk assessment segues into just plain observation.

iv. Miscellaneous Issues: Beyond the challenges of availability, reliability, and comparability, the management of climate data also grapples with issues arising from its decentralised nature, which complicates comprehensive risk assessments for financial institutions. Legal and regulatory constraints, along with fragmented data ownership and access issues, add further layers of complexity. The cultivation of data-sharing agreements, streamlining of access protocols, and addressing of legal impediments, as suggested by Gao et al. (2020), are crucial steps in overcoming the challenges associated with decentralisation and restricted data flow. Moreover, the limited data contributions from small and medium enterprises (SMEs) obscure vital portions of the economic spectrum, necessitating initiatives focused on enhancing disclosure and building capacity among these entities. Through these efforts, it is possible to develop a unified and accessible climate data resource that empowers financial institutions to make informed decisions and effectively contribute to sustainable development.

5. Conclusion

While BNM has made notable progress in bridging data gaps via its JC3 Subcommittee, challenges persist in the journey toward climate resilience. Data gaps and quality issues in climate-related information remain, signalling the need for continued investment in data infrastructure. Building capacity within BNM and the broader financial sector to effectively assess and manage climate risks remains a top priority. Long-term strategies for adapting the financial system to a changing climate are deemed crucial, emphasising the need for sustained efforts. Leveraging innovation in data analytics and technology to improve climate risk assessment and monitoring points to a more technologically sophisticated and resilient financial industry, therefore pointing out prospects.

By tackling these issues and leveraging current projects, BNM aims to be especially important in creating a financially climate-resilient system for Malaysia. This guarantees long-term stability of the financial system in addition to helping to create a more sustainable economy. By means of national and international partnerships, creative frameworks, and proactive attitude toward changing climate threats, BNM's multifarious strategy positions Malaysia as a leader to attain finance sector climate resilience.

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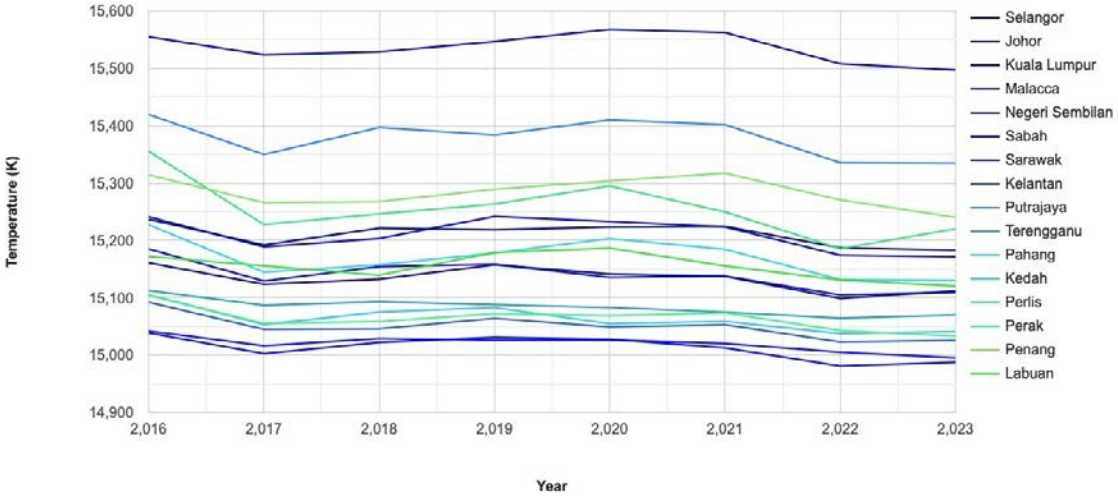
7. Annex

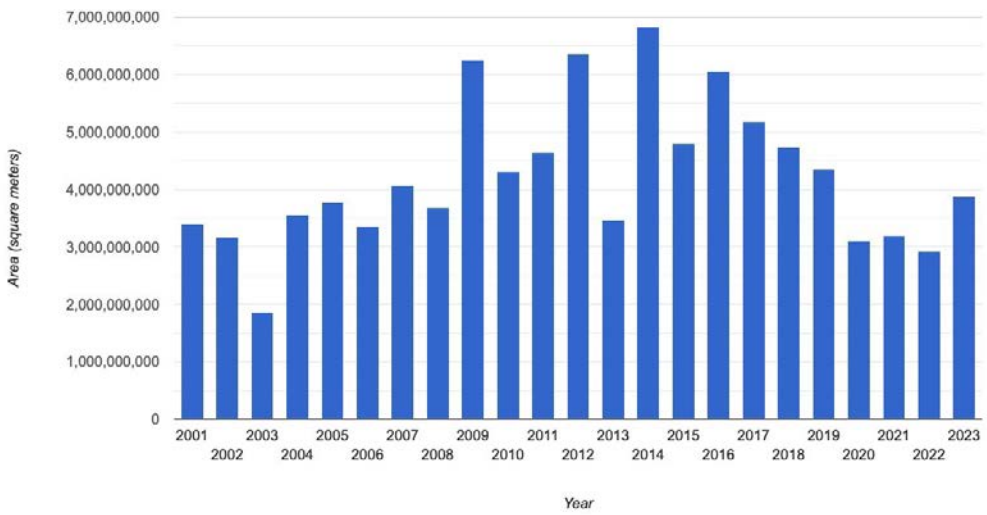
Annual Average Land Surface Temperature (LST) by Region from 2016-2023 Chart 5



Note: The Federal Territories of Putrajaya, Kuala Lumpur, and Labuan are illustrated separately.

Source: Google Earth Engine, author's own calculation

Annual Cumulative Forest Loss per Square Meters of Area from 2001-2023 Chart 6



Source: Hansen *et al.*, 2013, Google Earth Engine, author's own illustration

Decadal Forest Loss per Square Meter of Area by Region from 2001-2011, 2012-2023 Table 4

State/Year	2001-2011	2012-2023
Johor	4,067,764,449.82	4,307,419,675.90
Kedah	869,309,258.46	1,547,134,820.17
Kelantan	1,873,670,052.55	2,951,229,332.06
Kuala Lumpur	8,273,992.81	7,871,899.91
Labuan	3,892,888.92	9,210,471.78
Melaka	272,613,420.88	442,977,240.75
Negeri Sembilan	1,421,046,996.09	1,550,338,046.49
Pahang	5,383,082,924.05	7,797,807,293.02
Penang	51,665,496.39	82,818,746.52
Perak	2,090,526,155.70	3,055,025,618.80
Perlis	19,916,423.92	81,081,003.65
Putrajaya	3,049,702.88	1,791,236.64
Sabah	8,166,123,171.31	11,994,571,355.87
Sarawak	15,750,171,844.35	18,180,966,831.20
Selangor	888,299,252.09	1,059,428,978.80
Terengganu	1,252,526,767.94	1,837,288,107.03

Note: The Federal Territories of Putrajaya, Kuala Lumpur, and Labuan are illustrated separately

Source: Hansen *et al*., 2013, Google Earth Engine, author's own calculation