

## Analysis of Flood Mitigation Infrastructure in Kuala Lumpur, Malaysia

By JiaYin Yu

### AUTHOR BIO

Jiayin Yu is an International Baccalaureate (IB) student at the International School of Kuala Lumpur with strong interests in environmental protection and sustainable infrastructure. Their research focuses on flood mitigation strategies in Malaysia, particularly the effectiveness of the SMART Tunnel and green infrastructure in Kuala Lumpur. Beyond academics, Jiayin has engaged in environmental protection projects in Cambodia and Nepal, attended a service and sustainability summit in Thailand, and founded a school club dedicated to advancing sustainability on campus. They aspire to pursue Environmental Science to develop sustainable solutions to climate challenges worldwide.

### ABSTRACT

Flooding in Malaysia, especially Kuala Lumpur (KL), has intensified due to rapid urbanization and climate change. Despite major investments in flood mitigation, including the SMART tunnel and green infrastructure, KL still faces recurring surface run-off and flooding. Using remote sensing, Google Earth Pro, and scholarly resources, this study evaluates the effectiveness of these infrastructures. Findings suggest both systems have strong potential to reduce flooding, but challenges such as clogged drainage hinder their performance. This analysis could act as a reference to KL future development in flood mitigation infrastructure by highlighting potential areas of improvement.

**Keywords:** *Flood, Kuala Lumpur, Infrastructure, Remote Sensing, SMART tunnel, Impervious surface, Green infrastructure*

## INTRODUCTION

Malaysia gets a lot of rainfall every year due to its geographic location, which brings both northwest and southeast monsoons (Ministry of Energy Transition and Water Transformation 2017). The heavy rainfall increases risks of flooding with an average of 170 flooding events annually (2003-2022) (Ahmad et al. 2025), causing physical and financial damage. There are mainly two types of flooding in Malaysia: Monsoon floods and flash floods. Monsoon floods are floods that are caused by long term accumulation of rainfall causing extensive periods of flooding, while flash floods are sudden fast floods that are caused by immediate intense rainfall (Abid et al. 2024). A rainfall that is more than 60 mm in 2-4 hours might cause flash floods (The Official Web of Public Infobanjir 2025). The west coast of Malaysia peninsula, where Kuala Lumpur (KL) lies, is more prone to flash floods due to heavy rains. In recent years from 2000 to 2015, the frequency of flash floods has been increasing, with 33.6% more people exposed to flooding during this period (Global Flood Database 2025), increased urbanization, limited amount of soil surfaces to absorb water, inadequate flood management infrastructure such as drainage systems, and poor maintenance of existing water infrastructure blocking water flow may be causing an increase of flash floods. These flooding events displace thousands of people and cost the government millions of Ringgit in damage. Between 1980 and 2010 alone, there were 31 major flood events classified as disasters, resulting in an average of 41 deaths, the displacement of 20,000 individuals, and annual damages reaching up to RM100 million in Malaysia (Ahmad et al, 2025).

Other countries around the world are facing similar problems as Malaysia. For example, Jakarta, Indonesia experiences major issues with sea level rising, causing around 40% of the city to be below sea level (Voilanda 2021). As climate changes rapidly, coastal countries are becoming increasingly vulnerable to major flooding events, potentially causing more physical and financial damages, displacement, and even loss of life. Flood mitigation infrastructure can reduce displacement, casualties, and/or economic loss for the government (Rubinyi and Doeffinger 2023). By analyzing actions taken by Kuala Lumpur (KL), other countries could implement similar or different infrastructure based on the effectiveness of these infrastructure in KL. The objective of this paper is to what extent has KL taken action on flood mitigation infrastructure, mainly analysing the Stormwater Management and Road Tunnel (SMART) tunnel solution and green space initiatives.

Additionally, this study seeks to contribute to raising awareness of the importance of flood mitigation efforts from both the government and the community. As climate change risks increase, it is important for a city to have sufficient and effective infrastructure that prevents damage caused by extreme weather events.

## PHYSIO-ECONOMIC CHARACTERISTICS OF KUALIA LUMPUR

As the capital of Malaysia, KL (Figure 1) is the center of Malaysia economics, business, and urban-heart, any disturbance – especially flooding events – could have a nationwide impact (Bhuiyan et al. 2018). The geography of KL makes the city more vulnerable to flooding events. KL is surrounded by higher elevation mountains on the northwest side, reaching as high as around 1300m (OVHcloud. 2022). While KL itself is lying flat at 80m elevation, prompting water gathering. Higher elevation areas are more

prone to rainfall in general, making the mountain ranges act as a drainage divide, rainwater up in the mountains are channeled through rivers to reach lower elevations, increasing KL's risk of flooding near rivers (Ever 2023). Several rivers run along the mountain range slopes on the northern and eastern side of KL as shown in figure 2. Google Earth Pro (GE Pro) software was used to visualize and analyze the topographic, hydrologic and vegetated characteristics of KL. By using the terrain layer and high resolution satellite imagery in GE Pro and exaggerating the topography a 3D visualization can be achieved that highlights how the city is partially surrounded by steep slopes. For example, Gombak river is a large river that starts deep in the mountains and flows all the way to the city center of KL. This makes excessive rain in the mountains detrimental to KL, as overflows of rivers will occur in flattened elevation areas where KL lies. The GE 3D visualization further shows the vegetation cover within and around the city. Vegetation is an important factor in reducing runoff rate coming from the mountains. Further, the extent of built up areas is clearly shown in this figure.

The city planners have implemented a plan to deal with the flash flood problem, by channeling the flow of flood water and investing in green initiatives. By investigating these actions taken in KL and identifying flood-prone areas we can suggest solutions to mitigate the negative impacts of flooding. The aim of this study is to analyze the existing flood mitigation infrastructure in KL by identifying strong and weak points, as well as their benefits.

**Figure 1**

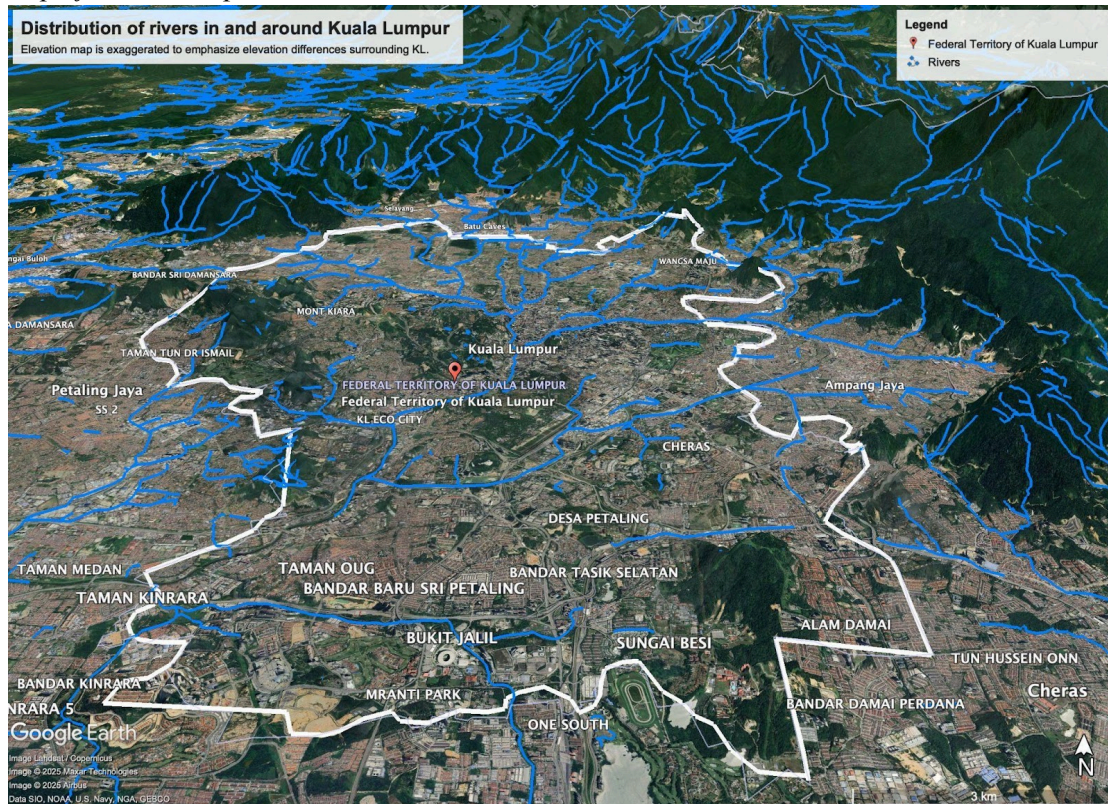
*Map of Malaysia, specifically indicating location of KL.*



*Note:* Malaysia represented in light beige color, KL location indicated on the left with an arrow. Public domain image. Reproduced from CIA World Factbook by the Central Intelligence Agency 2005.

**Figure 2**

*Map of Kuala Lumpur with river distribution*



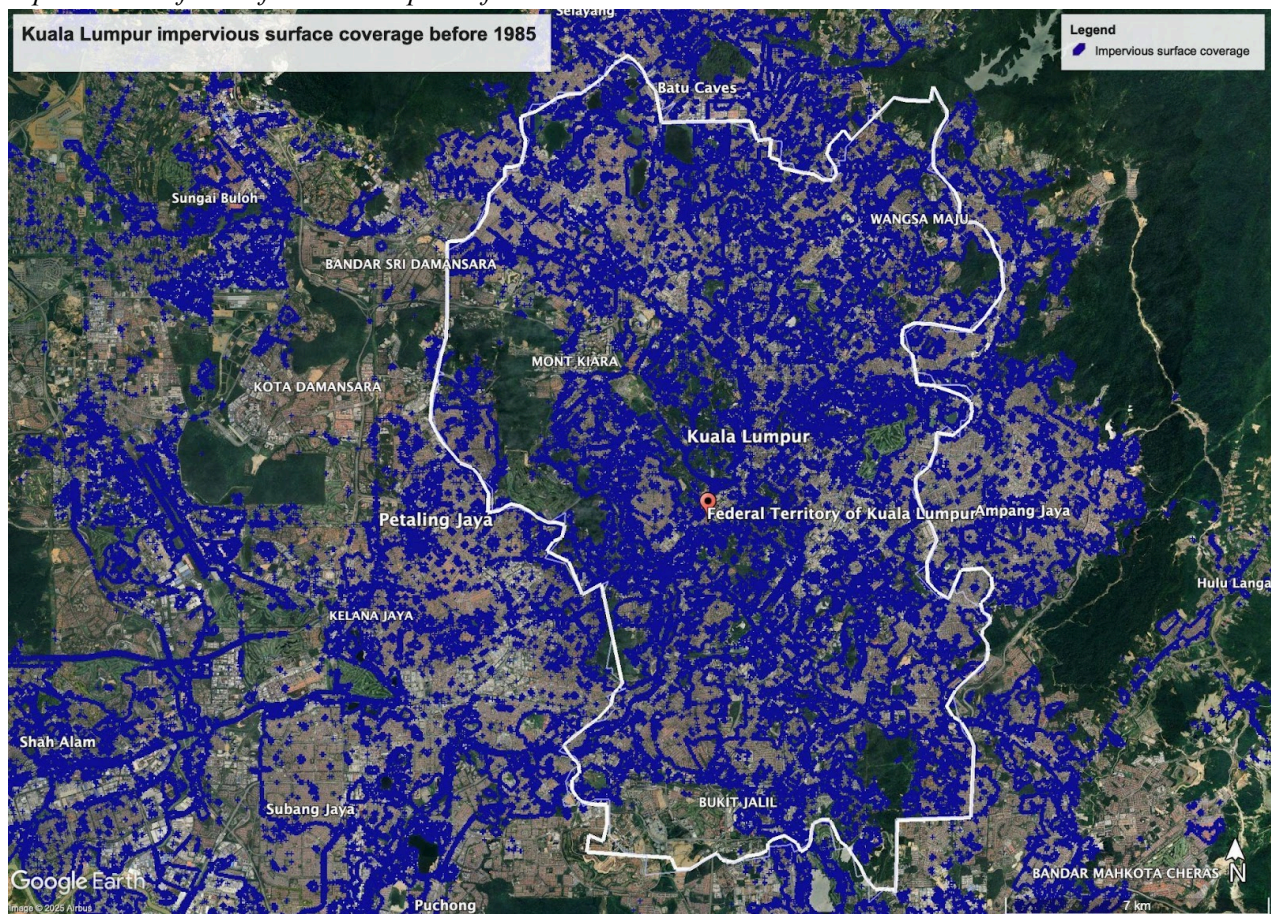
*Note:* Figure made in Google Earth Pro with elevation exaggeration factor of 3 and overlaid water way lines layer. River layer retrieved from Humanitarian Data Exchange portal (Figure created by the author using Google Earth Pro, 2024), (Borderlines source: Runfola, D. et al. 2020).

## CONTRIBUTORS TO FLOOD

Currently there are many factors that can contribute to the increase in flooding in KL, such as an increase in impervious surfaces that can be monitored by earth observation satellites such as Landsat. Data was obtained from Zhang et al (2022), who used a time series of Landsat data to generate a global dataset of impervious surfaces. Utilizing Google Earth Engine (GEE), a cloud computing platform, they automatically extracted training samples from existing Landsat land-cover products to classify impervious surfaces (Figures 3 & 4). When surfaces are paved, excessive water cannot be absorbed into the soil, increasing the probability of flooding or surface runoff. Impervious coverage has expanded each year, causing water to accumulate in the city center where natural infiltration areas, such as soil, are absent. Although KL's government has installed drainage systems, the development of drainage systems cannot catch up with the pace that new land is being paved. Furthermore, Dewan Bandaraya Kuala Lumpur (DBKL), the KL city hall through its divisions is in charge of drainage systems in KL, does not

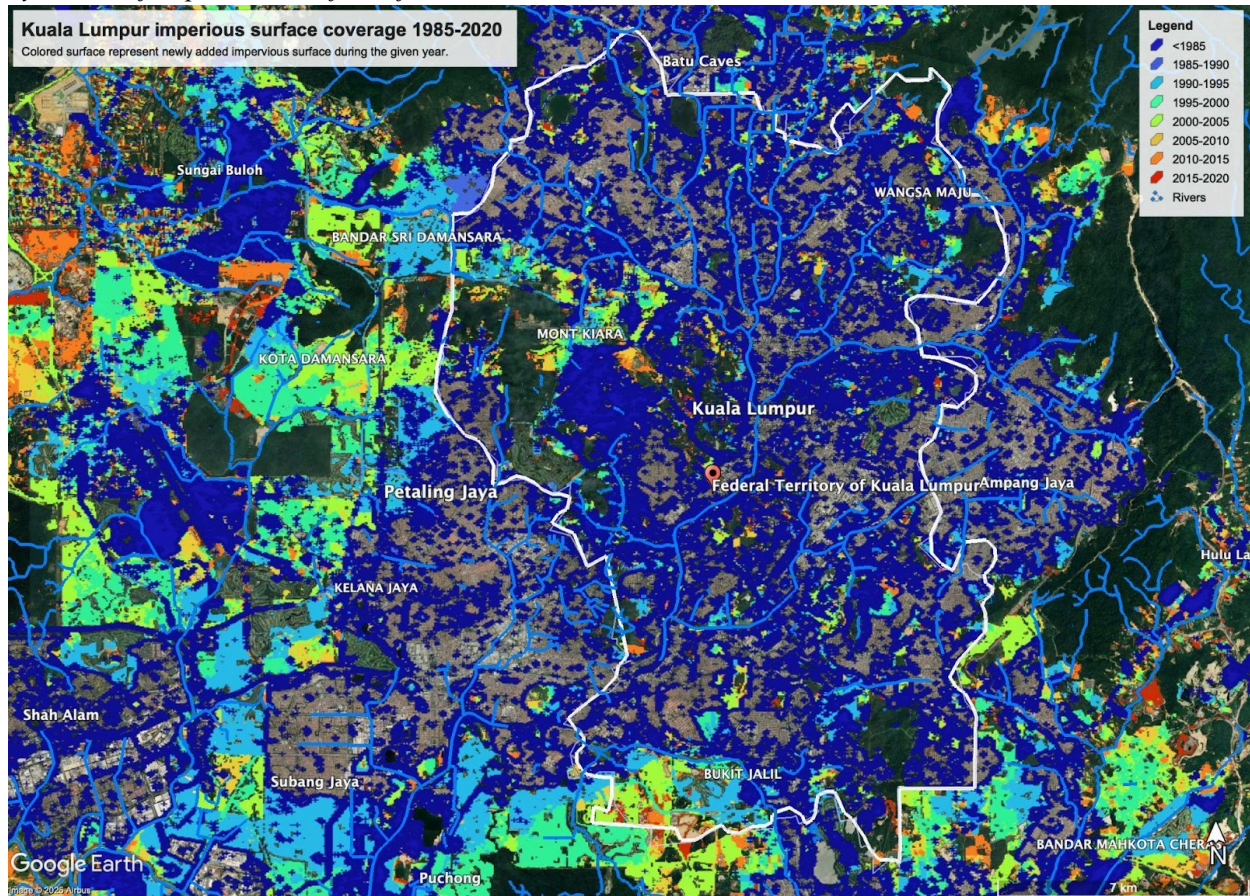
effectively enforce urban planning regulations for water drainage systems in the city. Maintenance of the existing drainage systems and water infrastructure is also an issue. Without regular maintenance the drainage systems are easily clogged up with trash, limiting the amount of water that can pass through. Although DBKL has said to improve these water infrastructure, the process is very slow (Abdullah 2024).

**Figure 3**  
*Impervious surfaces of Kuala Lumpur before 1985*



*Note:* Figure generated in Google Earth Pro. Created by the author, using the global 30m impervious-surface dynamic dataset produced by Zhang et al. 2022.

**Figure 4**  
*Dynamics of impervious surfaces from 1985 to 2020*



*Note:* Data obtained from the global 30m impervious-surface dynamic dataset (Zhang et al). Figure displayed on Google Earth Pro.

### **Analysis on KL impervious surfaces**

Kuala Lumpur experienced rapid urbanization during the 1980s–1990s, marked by the construction of numerous high-rises (Wikipedia contributors, 2025). This era is often regarded as the city’s fastest phase of development, which is why impervious surfaces prior to 1985 are included (Figure 3).

Impervious surfaces have not expanded to the northeast side (Figure 4). This can be attributed to the increased elevation in that area. The mountain ranges are mainly located on the northeast side of KL (Figure 2), the high elevated surfaces act as barriers, stopping the spread of urbanization in that direction.

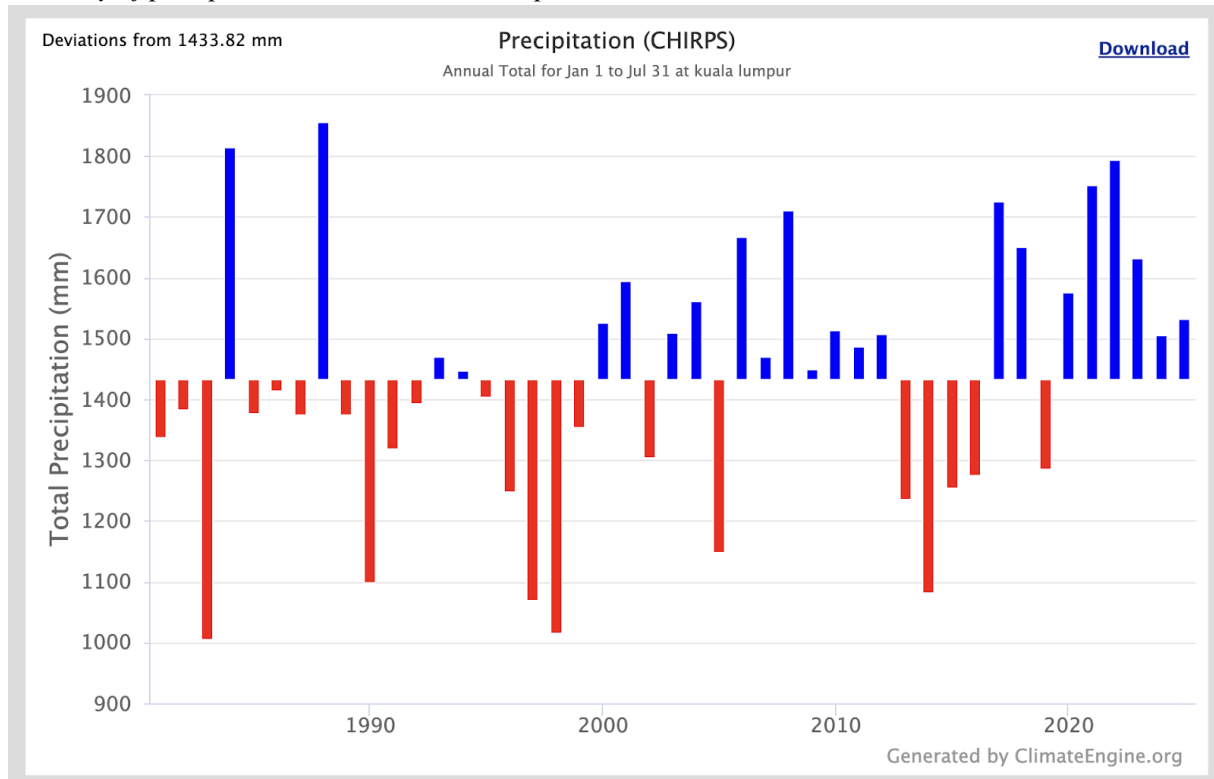
Instead, impervious surfaces have expanded mainly to the south and west, enlarging settlement areas but reducing the surrounding land's drainage capacity. This has left the city more prone to waterlogging.

### **Analysis on precipitation rates**

Another major contributor to the increased risk of flash floods in KL is the trend of increased annual precipitation. In order to examine precipitation amounts over time in KL and how they may play a role in increasing flash flood hazard risk in this city, Climate Engine, a cloud computing platform that archives climate related data and provides the tools to visualize, graph and perform time series analysis of the data, is used (ClimateEngine.org). For this project, I selected The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), which is a dataset produced by Climate Hazards Center at the University of California Santa Barbara that provides global rainfall data in mm from satellites sensor measurements and modeled data from 1981 to present (updated monthly). Using a point location to identify the analysis region (Figure 6), a precipitation graph was generated for an annual average. The mean rainfall from 1981 to the present is 1433.82 mm, which serves as the reference for deviations shown in Figure 5. According to the data, rainfall has generally increased from 1981 to 2024, although the increase is not uniform (Figure 5). Before 2000 there were only 4 incidents where the average precipitation of that year is above the average precipitation from 1981 to 2024 (blue bars). However, the number of above average rainfall years largely increased after the year 2000. Counting 2000 itself, there are 19 years of above average precipitation occurring out of 25 years. This is a dramatic increase in the amount of years that have above average rainfall, showcasing the overall trend of increase in precipitation. With more water raining on KL, it increases the risk of flooding. Furthermore, with expansion of impervious surface, rain water cannot be drained away, causing the water to be stagnant on the surface, contributing to flooding.

**Figure 5**

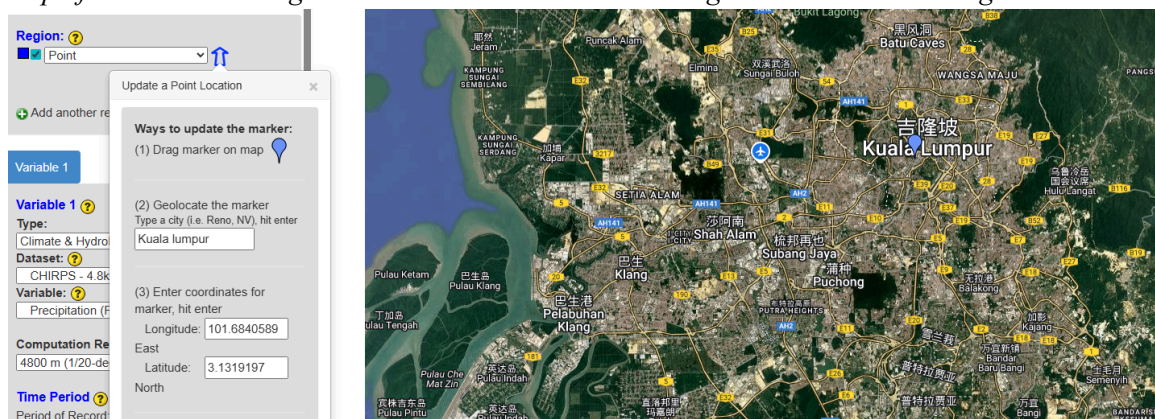
Summary of precipitation rates in Kuala Lumpur over 1981-01-01 to 2025-07-31.



Note: Data obtained from CHIRPS 4.8km daily (Climate Engine).

**Figure 6**

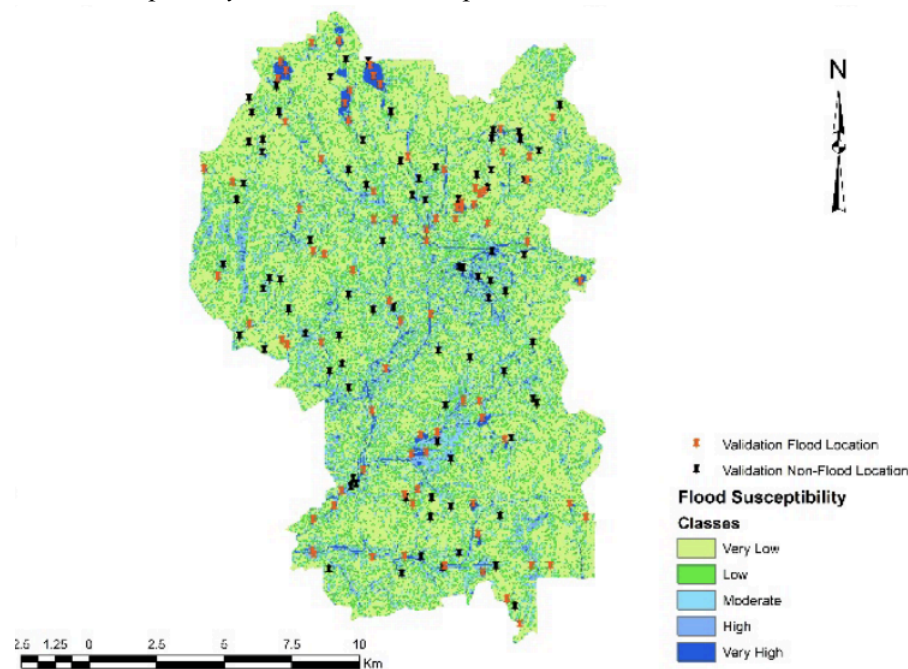
Map of location used to get the time series data shown in Figure 5 with Climate Engine



## FLOOD PRONE ZONES IN KL

A study analyzing flood prone regions in KL has shown that places nearer to the rivers are more prone to flooding (Figure 7, Tella et al. 2022). While this is true, locations with high levels of impervious surface coverage are the most prone to flooding (figure 4), this explains the drainage difficulty in paved surfaces. Accordingly, the government should invest more in flood mitigation methods for areas near rivers to maximize the effectiveness of flood infrastructure. In general, KL is more prone to flooding than other countries in Malaysia due to high levels of urbanization and old, overwhelmed drainage systems.

**Figure 7**  
*Flood susceptibility rate in Kuala Lumpur*



*Note:* Color coding used to identify different flood susceptibility, generated by Logistic regression models by Tella et al.

**Table 1**  
*Specific breakdown of flash flood occurrences in specific areas in KL with individual rankings.*

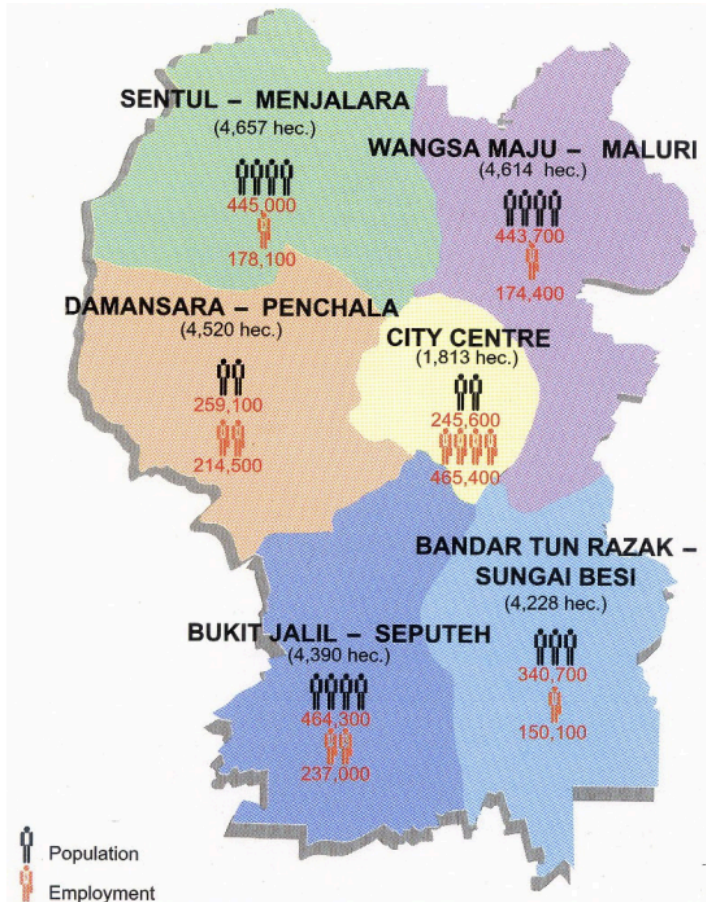
Column 1	2011	2012	2013	2014	2015	2016 (June)	Total	Rank
Citycenter	6	2	6	4	1	6	25	1
Damansara-Penchala	2	0	4	2	0	5	13	2
Wangsa Maju-Maluri	2	0	1	3	6	0	12	3

Bdr. Razak-Sg.Desi	Tun	1	1	1	4	2	1	10	4
Sentul-Menjalara		1	0	0	1	1	1	4	5
Bukit Jalil-Seputeh		0	0	1	0	0	0	1	6
Total:		12	3	13	14	10	13	65	

Note: Table made by author, Information from Bhuiyan, 2018.

**Figure 8**

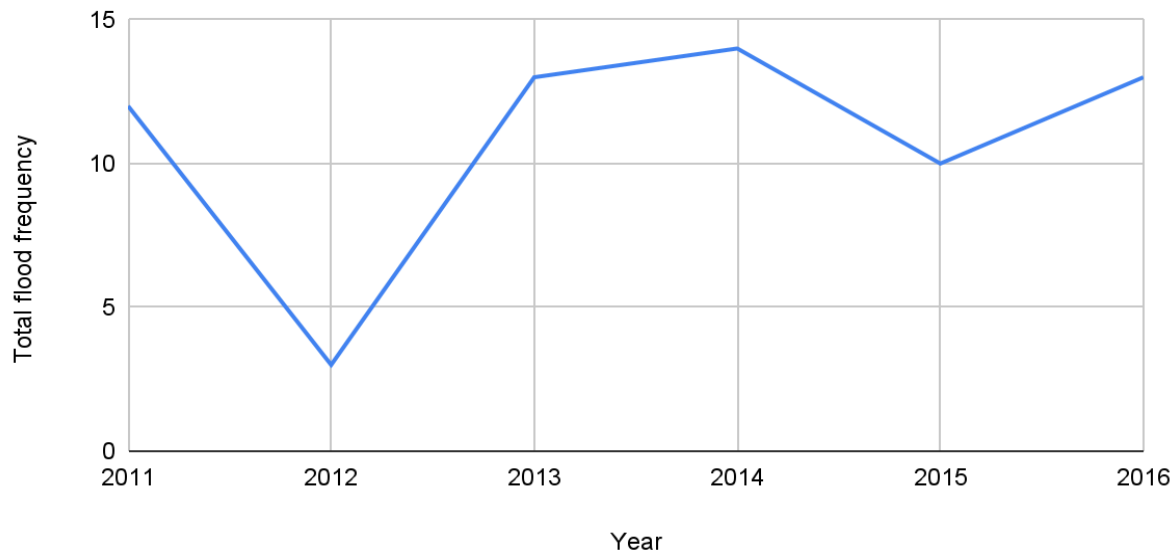
Population and Employment according to Kuala Lumpur Strategic Zone in 2020.



Note: Reprinted from Shuid 2004

**Figure 9**

*Total occurrences of flooding in KL from 2011-2016 (June)*



*Note:* Figure made by author. Information from Bhuiyan et al. 2018

Through analyzing online news reports and previous peer-reviewed publications and reports, Bhuiyan et al collected data on flood occurrences in different strategic zones in KL. Based on their data, the city centre is most prone to flooding in KL with the highest number of 25 occurrences from 2011-2016 (Table 1). This further exemplifies the poor drainage maintenance in KL mentioned above. This emphasizes the need for targeted intervention by Malaysian authorities to prioritize these high-risk zones in flood mitigation efforts. Many of the most flood prone areas are in high density employment areas like the city center (Figure 8), which increases economic loss in each flood occurrence. In dense populated areas drainage tunnels are more vulnerable to trash clogging the waterways. As more people create more waste, the amount of trash in drainage can be significantly larger compared to more rural areas. Moreover, these areas have a limited amount of natural pervious surfaces to reduce the amount of runoff further contributing to water accumulation. That being said, KL has taken action to increase the amount of greenery in the city, adding permeable surfaces to drain water.

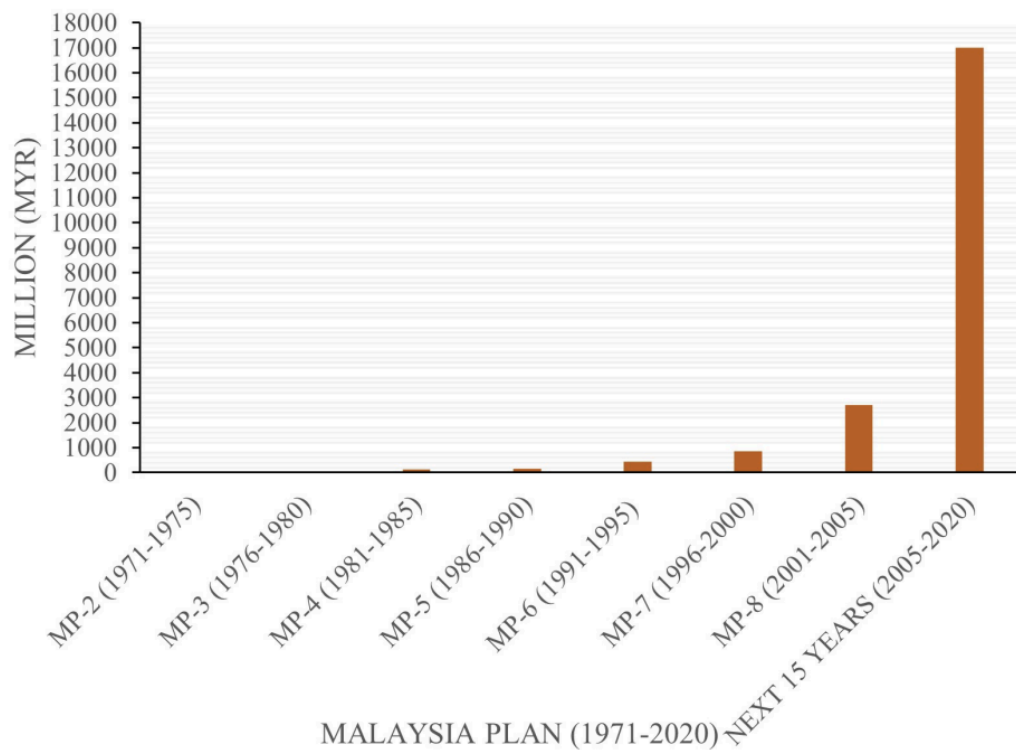
## **ACTIONS TAKEN BY THE GOVERNMENT TO MITIGATE FLOOD**

Malaysia is heavily increasing investments in flood mitigation infrastructure. The amount of money being invested is constantly increasing, and it is projected to have a major rise in investment over the next 15 years based on the report (Figure 10. Ahmad et al. 2025). Malaysia is noticing its increased vulnerability in facing detrimental flooding events and paying more attention to mitigation strategies. Current water infrastructure that mitigates flooding in KL includes dams, levees, drainage systems, green spaces like parks, and exposed soil. As a flood prone country, Malaysia's flood management has relied heavily on this infrastructure throughout the city. The country invested in a total of 17 billion dollars

targeting flood mitigation projects from 2005-2020, trying to both prevent and curate flooding (Ahmad et al. 2025).

**Figure 10**

*Bar graph of Malaysian government financial investigation 5 year plan for flood mitigation infrastructure from 1971 to 2020*



*Note:* Reprinted from Ahmad et al. 2025.

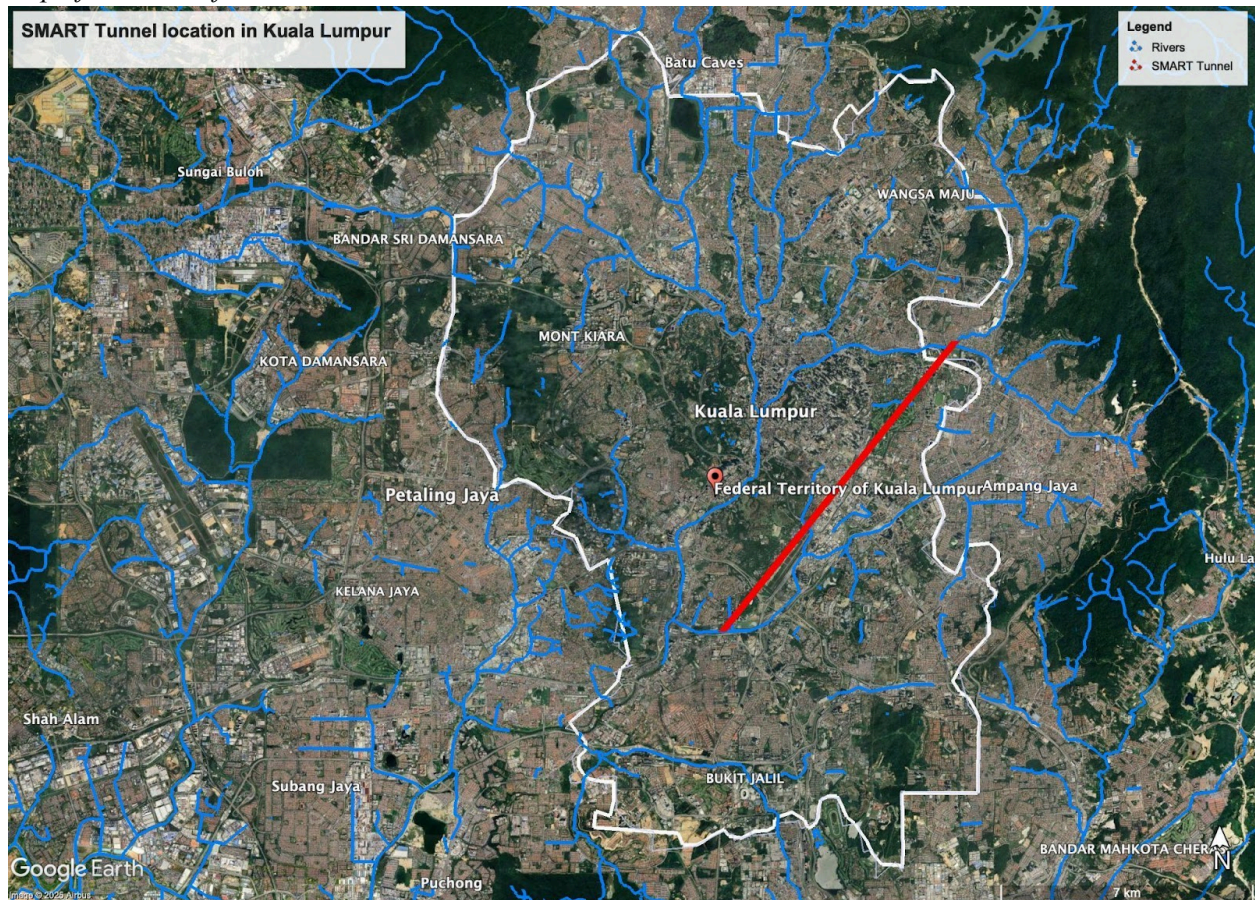
## SMART Tunnel

One major project that was carried out in KL is the Stormwater Management and Road Tunnel (SMART) project. The project aims to detect rainfall and flood amounts, collect flood water, and divert excessive water into detention ponds and downstream rivers via tunnels. Addressing the high probability of flooding near water bodies in KL, the SMART's aim is mainly focused on the flooding of the Klang river (ITS International. 2012). Figure 11 indicates the location of the SMART. The approximate location of tunnel starting and end points are plotted on GE Pro based on information from Stormwater Management and Road Tunnel website and Wikipedia (Stormwater Management and Road Tunnel (SMART); (Wikipedia contributors, 2025). The infrastructure is multi-use, where the upper levels consist of traffic ways and the lower a waterway for floods (Figure 12). Under normal conditions with no

flooding risk, the upper levels accommodate vehicular traffic, reducing congestion at the surface level. In contrast, during flooding events, the tunnel is closed to traffic and functions entirely as a water conduit, channeling excess water into detention ponds and nearby rivers. With its three-layer design, the tunnel can efficiently allocate levels for either water conveyance or vehicular traffic, depending on the volume of water at a given time. This solution not only addresses the diverting flooding from the city, but also increases efficiency in traffic (Stormwater Management and Road Tunnel (SMART)).

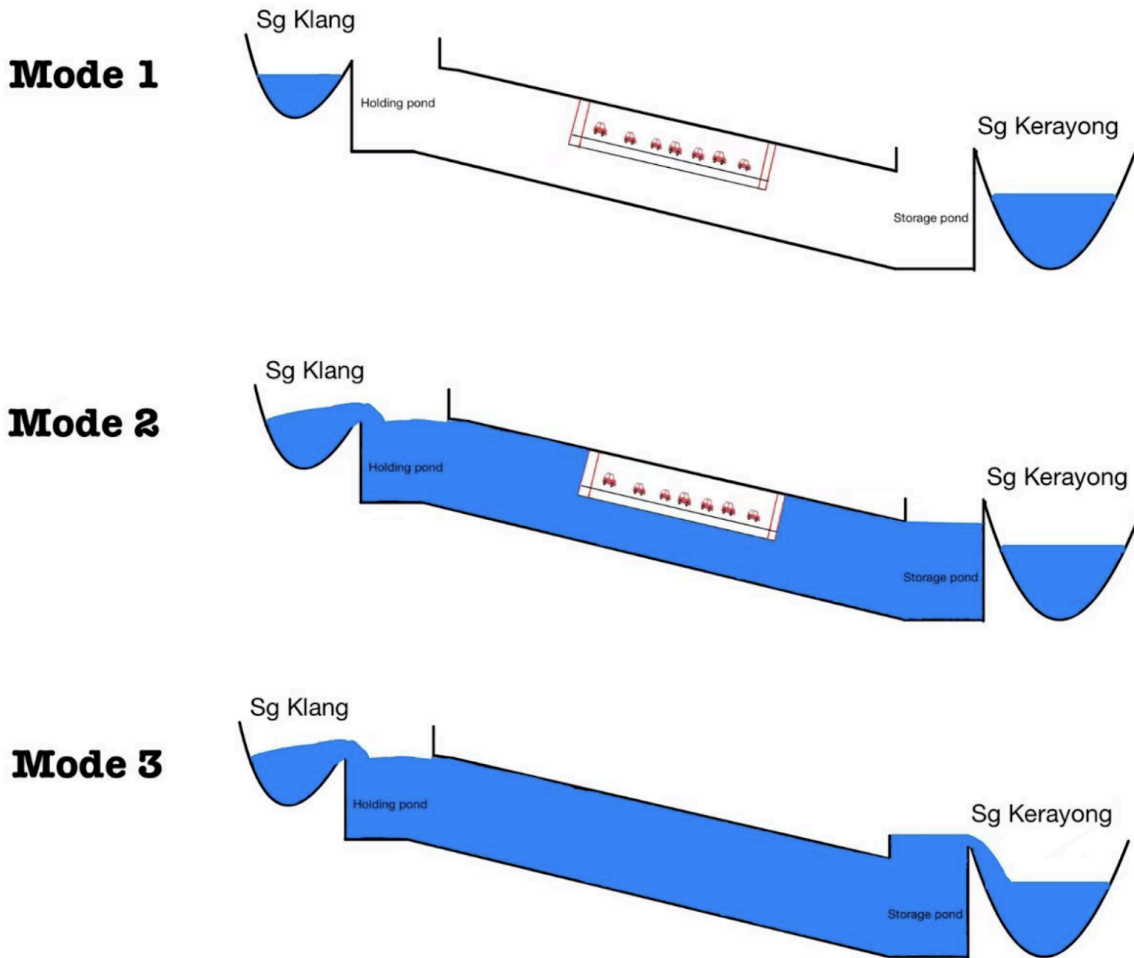
**Figure 11**

*Map of SMART infrastructure location in KL*



*Note:* Blue lines are rivers and red lines represent SMART tunnels. Figure created by author on GE Pro.

**Figure 12**  
*Visual representation of different SMART tunnel operation modes*



*Note:* Figure created by author

Due to the innovative idea and multipurposeness of the SMART tunnel, it won the UN Habitat Scroll of Honour award. This showcases the large potential benefits that the SMART tunnel could bring to KL if used effectively. At 9.7km total in length, it is the longest multipurpose tunnel in the world and longest drainage tunnel in South East Asia (Institution of Civil Engineers, 2007). The SMART tunnel can bring KL multiple benefits including, but not limited to, economic benefits and decrease in flood fatality damages. It is projected to prevent US\$1.58 billion of possible flood damage, and save \$1.26 billion from increasing traffic efficiency. Over the years, Mode 2 of the SMART Tunnel (Figure 12) has been activated numerous times, while Mode 3 has been activated seven times—twice each in 2007, 2008, and 2012 (up

to May), and once in 2011. These activations have played a critical role in preventing major flood damage in the city (ITS International, 2012).

Although there are several benefits to the SMART tunnel in diverting flood water stated above, only relying on SMART does not solve the problem. After SMART was implemented in KL there are still numerous occurrences of flooding in KL (Figure 9). In order for SMART to divert flood water to other waterways, it needs to first collect water from surrounding drainage systems in the city. Clogged drainage tunnels, though, will impede the amount of water to reach the SMART tunnels, not allowing SMART to perform at its highest ability. Therefore, the root cause of flooding goes back to maintenance of the existing drainage system in KL. With efficient, unclogged drainage systems water could flow in the way that the government intended, reducing the risk of flooding. (Malaysian Digest. 2016)

In addition, from an ecological perspective, it is not really environmentally friendly to divert all the excessive flood water into nearby rivers, as rivers are an ecosystem not a pipeline for humans (Euklidiadas 2021). Flood water may carry pollutants or debris from underground tunnels or populated areas, these pollutants will largely affect the health of an ecosystem. Furthermore, runoff waters are not treated before discharge, it can contaminate the water quality in the rivers, having detrimental effects on both aquatic plants and animals. These problems of the SMART tunnel sparked many controversial opinions on the effectiveness of this large engineered solution.

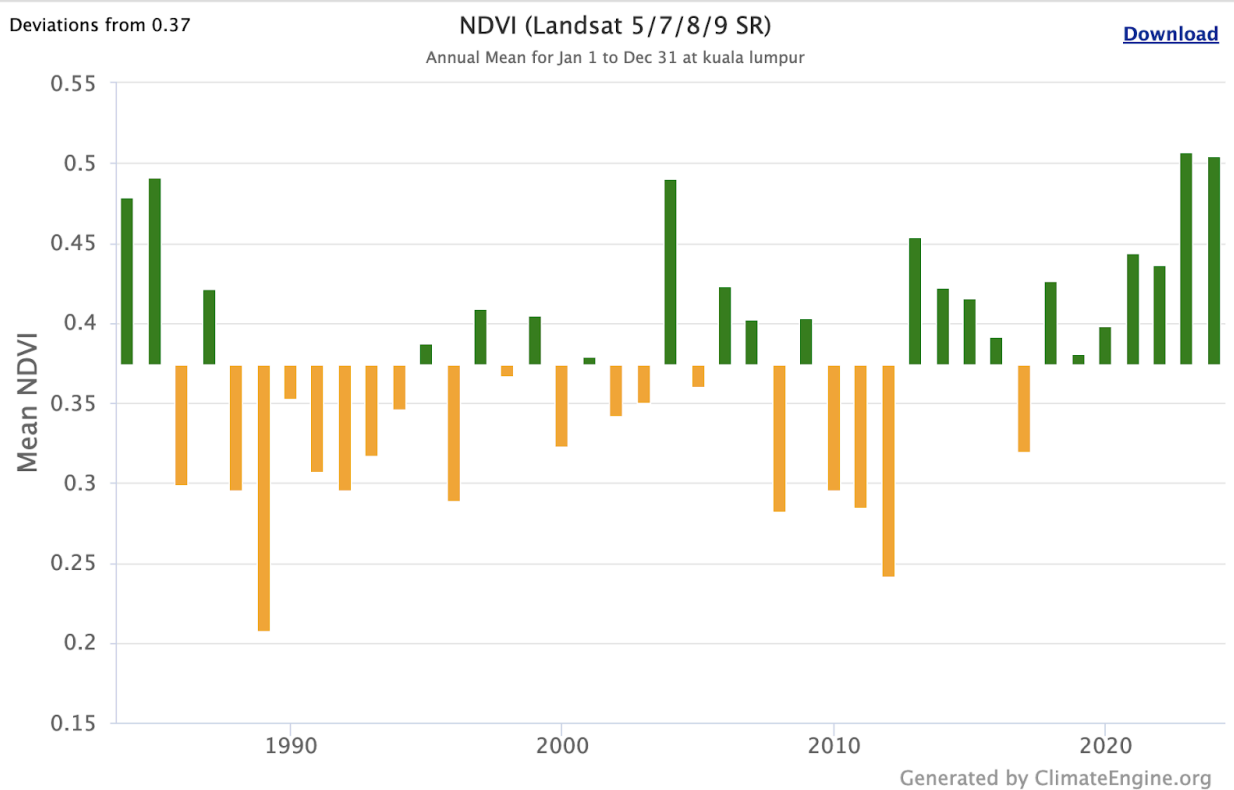
After the SMART tunnel started operating in 2007, there were several flash flood events each year in KL. The peninsula of Malaysia experienced 745 cases of flooding events from 2014-2019, with up to 60% of flooding subsumed to be caused by insufficient draining system and water infrastructure (Maqtan et al. 2025). For example, on August 18, 2021 a major flood event occurred in KL and nearby areas affecting approximately 4,395 people. All these flooding events are caused by heavy rainfall (Maqtan et al. 2025).

## **Green infrastructure**

A time series analysis of Normalized Difference Vegetation Index (NDVI) was performed in Climate Engine using Landsat 5/7/8/9 satellite data with 30m resolution. Figure 13 shows a graph of annual mean NDVI for KL city from 1984 to 2025. NDVI is often used as a proxy for open green spaces in urban areas. The amount of green vegetation that is present in Kuala Lumpur from 1984 to 2025 has increased after 2000. After 2010 there are more occurrences of having a higher than average year of greenery land cover (Figure 13). This showcases that green spaces in KL are increasing over the years although not at an uniform rate. Green spaces are known to act as a flood mitigation infrastructure, since vegetation and soil could effectively absorb excessive surface water and store them as ground water (US EPA, 2025). Theoretically, more green spaces would reduce the amount of flooding events that happen in KL.

**Figure 13**

*Average Normalized Difference Vegetation Index per year from 1984-01-01 to 2025-08-30 compared to the Mean NDVI over the entire time period*



*Note:* Data obtained from Landsat 5/7/8/9 SR - 30m satellite and representing the same location as in Figure 6 (Climate Engine).

Overall, multiple factors contribute to the flash floods in KL, such as increase in impervious surface and precipitation. Therefore, the KL government took action on increasing the drainage ability of KL by adding draining pathways like the SMART tunnel and expanding coverage of green infrastructure in the city.

## FUTURE OUTLOOK

This report aims to analyze the flood mitigation strategies and infrastructure that KL has implemented. The report is focused mainly on the advanced SMART tunnel flood mitigation infrastructure implemented in KL, and an analysis of greenery development in KL using remote sensing data. As weather patterns become increasingly unstable over the years, flooding is an important natural disaster that KL has to address in order to prevent fatalities and economic loss. Overall KL has taken action in upgrading flood mitigation infrastructures with aims to prevent flooding events. KL already has

efficient flood mitigation infrastructure and the fundamental drainage systems in place, but flooding events are still happening throughout the city. These infrastructure, though effective, cannot fully mitigate the flood problem in KL altogether.

### **Improving flood infrastructure maintenance:**

An actionable plan for KL in the future is that besides constantly upgrading the existing flood mitigation infrastructure that is in place, KL's government could mainly focus on the maintenance of the fundamental drainage system. Since KL already has an extensive drainage system and SMART tunnel in place, the government should take action to ensure that they work as intended. By solving the clogging of drainage systems, the root cause of many flash flood events could be prevented, mitigating KL could possibly mitigate many overflowing events. Furthermore, KL should improve public education on the importance of the drainage tunnels. Oftentimes, these tunnels are clogged up in trash such as plastic wrappers and bottles. These materials are not permeable, therefore easily precluding water flow in the drainage systems and leading to severe flooding. By advocating for the importance of drainage to mitigate flooding, KL could potentially limit the amount of trash that enters the drainage, allowing water to flow through during critical flood events.

### **Sponge city**

Another possible solution is the concept of a sponge city, where flood water could naturally be absorbed through the ground and not limited to a single drainage tunnel. A Sponge City is an urban area with a water management system highly adaptable to environmental changes and natural disasters. It functions like a sponge—absorbing, storing, infiltrating, cleaning, and purifying rainwater before releasing it for reuse (Wu et al, 2015). Key components of a Sponge City include permeable roads, wetlands, expanded green spaces, natural soil areas, and bioretention systems. There are many benefits to sponge cities such as promoting sustainable urbanization in cities, where increased greenery not only reduces the risk of flooding but also combats climate change by absorbing greenhouse gases. The solution also allows rainwater to be reused conserving natural resources and ecological systems.

**Figure 14**  
*Model of sponge city concept*



*Note:* Figure made by Shi et al. 2023

## CONCLUSION

The analysis of the current flood mitigation system in KL provides insights into areas that KL has done well and areas for further improvement. Problems like drainage clogging can be exposed through analysis, allowing KL to act to increase effectiveness of current infrastructure. Better maintenance of infrastructure and flood mitigation strategies increases the resilience of KL for flooding, making it less vulnerable to heavy damages caused by flooding. Granted, the report is limited in addressing the multi-faced solution that KL has developed other than the SMART tunnels and green infrastructure. Without a whole picture of all flood mitigation infrastructure and strategies it is hard to determine the effectiveness of flood mitigation of KL as a whole.

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