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Landslide Risk in Kuala Lumpur: Examining the Impact of Shifting Rainfall Patterns Amidst Climate Change

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Abstract

Climate change has altered seasonal precipitation and temperature in a certain region. Unpredictable weather conditions have significantly increased the risk of climatic hazards, especially landslides. This paper studies the rainfall variables such as rainfall amount and rain days and their correlation towards landslide events in the capital city of Malaysia; the Federal Territory of Kuala Lumpur. Pearson correlation analysis found that the rain days variable has a higher significant positive correlation with landslide incidents compared to the rainfall amount variable. Only landslide incidents in the year 2010 show a significant negative correlation with rain days (r = -0.166). Both rainfall amount and rain days attributes in the years 2011, 2012, and 2015 show a significant positive correlation with landslide incidents reported. Meanwhile, landslide incidents reported in the years 2012 and 2013 show a significant negative correlation with rainfall amount but positively correlated with rain days attribute for both years. Further investigation using linear regression analysis also corresponds to the same result where landslide events increase by 0.039 for every unit of rain days but landslide incidents remain constant when there is an increase for every unit of rainfall. Therefore, rainfall amount was not a significant predictor in this study. Since land scarcity is the main issue in Kuala Lumpur, the results of this study help to provide insight on rainfall pattern and behavior for proper urbanization especially in changing climate condition.

Keywords: Landslide, Rainfall, Urban, Kuala Lumpur, Malaysia

Introduction

As the world rapidly changes and develops to cater to the needs of billions of populations, this modernization eventually poses threats to human civilization as the consequence of changes in global climate. Landslides were considered as one of the climatic hazards along with floods, windstorms, droughts, fires, heat and cold waves, and sea level rise (IPCC, 2012). Other numerous physical factors cause landslide events which are occasionally related to each other such as lithological features, slopes steepness, rapid stream erosion, geomorphological processes, and human activities It attributes information to Kouli et al (2010); Skilodimou et al (2018) as the sources for the mentioned factors contributing to landslide events. However, increased landslides frequency nowadays has been a heated debate around the world as climate change caused either direct or indirect factor towards soil movement. Climate change has resulted in long-duration extremes of heat and rainfall in certain regions (Pall et al., 2011). Inconsistencies in precipitation during the climate change era were one of the key factors that contributed greatly to landslide occurrences (Feng et al., 2017; Hong et al., 2017). Acknowledging the high correlation between rainfall and climate within human settlements, especially those with steep slopes, recent studies on the global distribution of landslides have focused on rainfall-triggered incidents (Dowling & Santi, 2013; Kirschbaum et al., 2012, 2015). Until 2016, Froude and Petley (2018) found that approximately 79% of non-seismic landslide incidents were triggered by rainfall, with the peak of these events occurring in Southeast Asia from August to October. Additionally, Kyriou et al., (2021) noted that landslides in developing countries are occasionally associated with landscape-shifting activities such as construction, development, deforestation of slopes, quarrying, road construction, and urbanization.

Malaysia, as one of the developing countries in Southeast Asia, also experienced landslides, especially in major cities undergoing urbanization. This geohazard is usually found in the form of slope failures on artificial slopes engineered by humans, especially slopes that involved reclamation activities in urban areas along highways and housing (Muhamad et al., 2013; Nhu et al., 2020). Land clearing for construction unearths the deep roots of vegetation and forests, thus disturbing the slope surface's soil stability. Upon development completion, urban areas are often planted with shallow-rooted greenery for aesthetics, which has less infiltration capability and can loosen soil particles during heavy rainfall, leading to slope movement and landslides (Huang et al., 2013). While construction activities can trigger landslides, most cases in Malaysia over the past decade occurred after heavy and prolonged downpours (BERNAMA, 2011). The country's year-round hot and humid conditions expose it to landslide risk. With an average annual rainfall exceeding 2,000 mm, which is above the global average, frequent intense rainfall becomes a trigger factor for landslides as it enhances the ability of raindrops to break and loosen soil particles (Sulaiman et al., 2019). Moreover, Mukhlisin et al., (2015) found that most catastrophic landslides were triggered by major rainfall exceeding 70 mm per day.

Contributing to 8.3% of Malaysia's total landslides, a total of 142 landslide incidents were reported across all 14 states between 2010 and 2016 (EM-DAT, 2015). The state of Selangor has encountered the most landslides since the 1970s, as it is the most populated district in Malaysia (DOSM, 2021). It is followed by the major city center in the country, the Federal Territory of Kuala Lumpur, as well as other fast-growing states such as Pahang, Penang, and Sabah (Sulaiman et al., 2019; JKR, 2008). However, Kuala Lumpur's rapid urbanization has been relatively more associated with frequent landslides within the capital city (Mahmud et al., 2013; Majid et al., 2020). Researchers and experts have been conducting landslide studies throughout the years for effective landslide management and to deliver the best information and solutions for responsible organizations (Nhu et al., 2020). Thus, the economic and social losses caused by landslide incidents can be measured and mitigated through proper planning and management (Nhu et al., 2020). Therefore, this study aims to analyze the correlation of rainfall on landslide incidents in the Federal Territory of Kuala Lumpur.

Method and Study Area

Study area

The Federal Territory of Kuala Lumpur was selected as the study area, which covers approximately 243.6 sq km within the state of Selangor (Figure 1). Located at latitude 03º 2´N to 03º 12´N and longitude 101º 38´E to 101º 46´E, Kuala Lumpur is part of the Klang Valley, with a population of 1.7 million as of 2015 (Alnaimat et al., 2017). Situated on the west coast of Peninsular Malaysia, the Kuala Lumpur territory receives a higher amount of rainfall during the southwest monsoon from April to November annually (Saadatkhah et al., 2014). The temperature in Kuala Lumpur remains fairly constant at 22-33 °C all year round, with average annual precipitation around 2,800 mm (Jabatan Pengairan dan Saliran Malaysia, 2018). With an average population growth of 2% per year, increasing housing and facility demands have led to developments taking place in hilly areas around Kuala Lumpur. However, slope, drainage, and vegetation are disrupted during these developments, exposing neighborhoods to potential landslide risks (Mahmud et al., 2013). Apart from human factors, the lithological structure of Kuala Lumpur and its surroundings, comprising a pre-existence of a variety of weak zones in granite and ski rocks, has led to slope movements (Yusoff et al., 2016).

Data Acquisition

The landslide coordinates (latitude and longitude) were obtained from the Department of Survey and Mapping Malaysia (JUPEM) and the Hazard Map With Landslide Historical Sites website (Hazard Map With Landslide Historical Sites, 2021). This study evaluated landslide incidents that occurred for 6 years period from the year 2010 to 2015. Combination and cross references of landslide events were selected, processed, and analyzed in a geographic information system (GIS) environment using ArcMap 10.7 software to generate a landslide inventory map represented in point features.

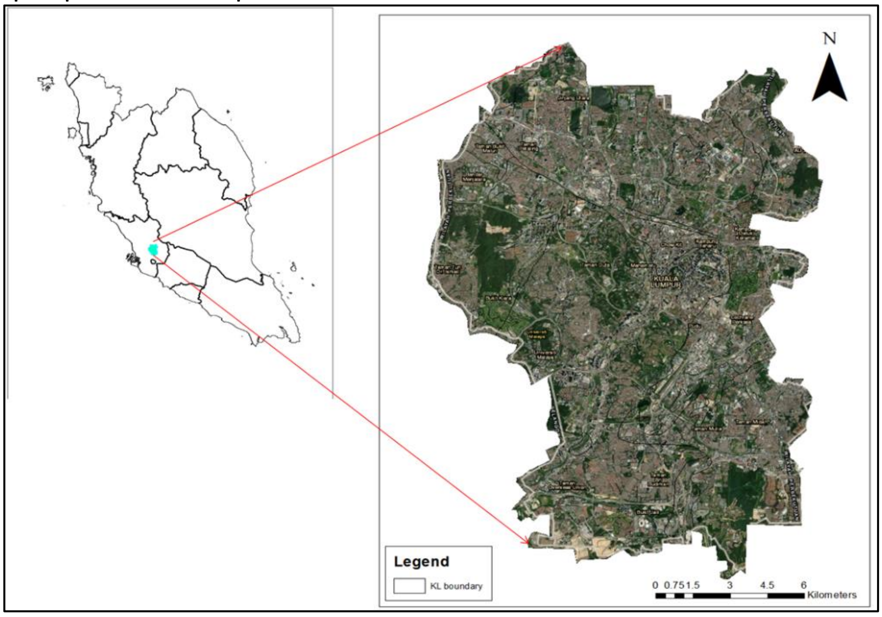

Figure 1. Map of Kuala Lumpur in Peninsular Malaysia

This study breaks down rainfall variables into two separate attributes which are monthly rainfall amount and rain days in Kuala Lumpur from year 2010 to 2015. These rainfall data were obtained from the Meteorological Department Malaysia (MET Malaysia). Each attribute was analyzed to find their correlation towards landslide events in the study area by applying

Pearson's correlation and the level of significance chosen for this study was $p<0.05$ using SPSS software (Ruzman and Rahman, 2017).

Results

The highest landslide incidents were in November of year 2010 with 6 cases reported compared to these other study period (Figure 2). This situation leads to the most reported landslides occurred in year 2010 with a total of 20 cases documented in Kuala Lumpur. Meanwhile, the year 2015 was found with the least landslide incidents with only one cases reported in November. Overall, it is shown that there was no landslide reported in all months of June from year 2010 to 2015. Figure 2 also shows that the number of landslide events was observed declining throughout the study period.

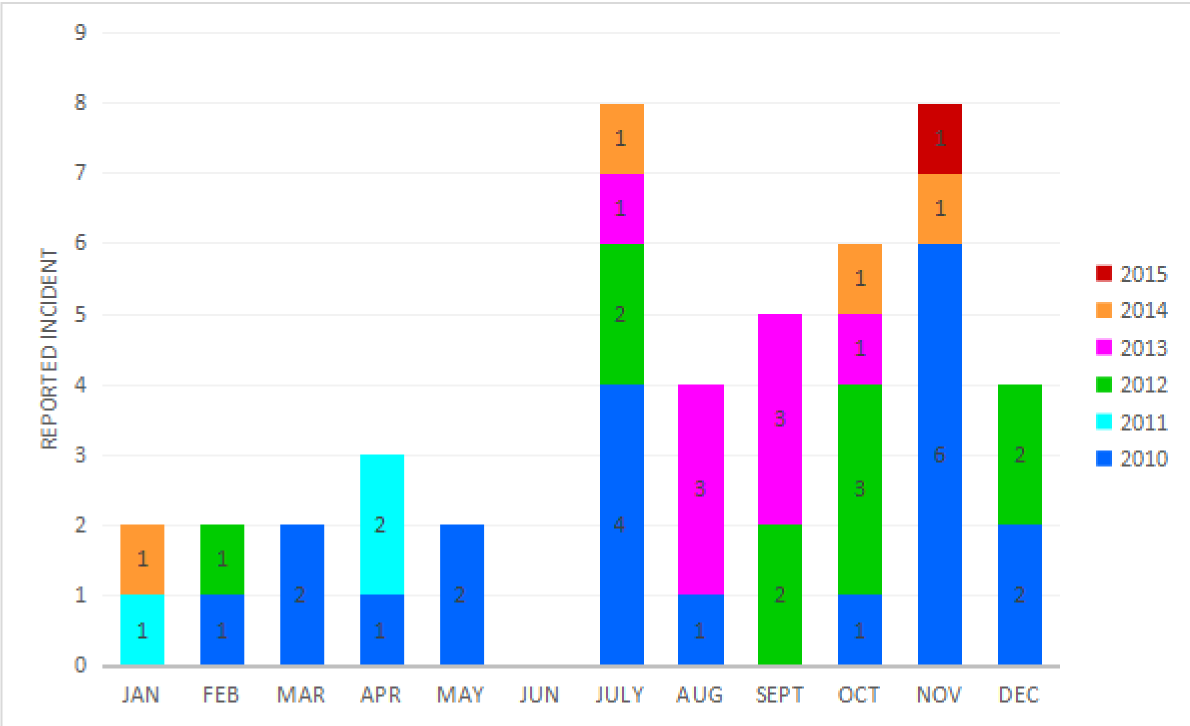

Figure 2. Landslide incidents were reported in Kuala Lumpur from the year 2010 to 2015

Figure 3 reveals a distinct spatial pattern of landslide incidents throughout the study period. Notably, the years 2010, 2012, and 2013 exhibited a wider distribution of landslides compared to 2014 and 2015. In 2010, landslides were concentrated in the northwest and spread towards the southeast. While the central area remained the most frequent location for landslides throughout the period, 2011 saw a unique occurrence documented in the south of Kuala Lumpur. By 2013, the number of reported landslides began to decline, with incidents primarily concentrated closer to the central region.

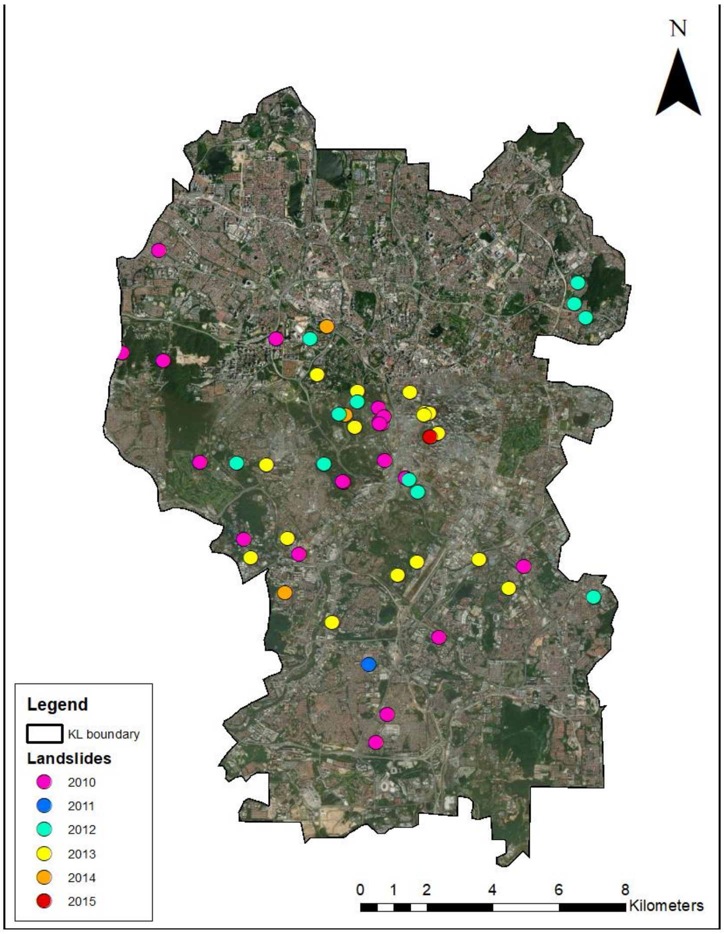

Figure 3. Distribution of landslide incidents reported in Kuala Lumpur from year 2010 to 2015

The relationship of landslide incidents with rainfall is presented in Figure 4. The rainfall amount in April 2014 shows the highest downpour during the observed study period with 301.6 mm recorded but there was no landslide event reported. The year 2010 and 2012 received the highest annual rainfall amount, where the most landslide incidents were reported throughout these two observed years.

Figure 4. Graph of landslide incidents reported in Kuala Lumpur against rainfall amount from year 2010 to 2015

Rain days as another variable were also plotted against landslide incidents reported in Kuala Lumpur during the study period (Figure 5). It is shown in Figure 5 (b) that the year 2011 has the highest number of rain days within the study site with 360 days of rain documented, followed by 355 rain days in the year 2010. However, there were only 3 landslide incidents reported in January and April during year 2011 compared to the previous year.

Figure 5. Graph of landslide incidents reported in Kuala Lumpur against rain days from year 2010 to 2015

Overall, it is shown in Figure 6 that rainfall amount peaked or rainfall extreme occurred in April and November throughout all years. A prolong rain days were identified from August towards November.

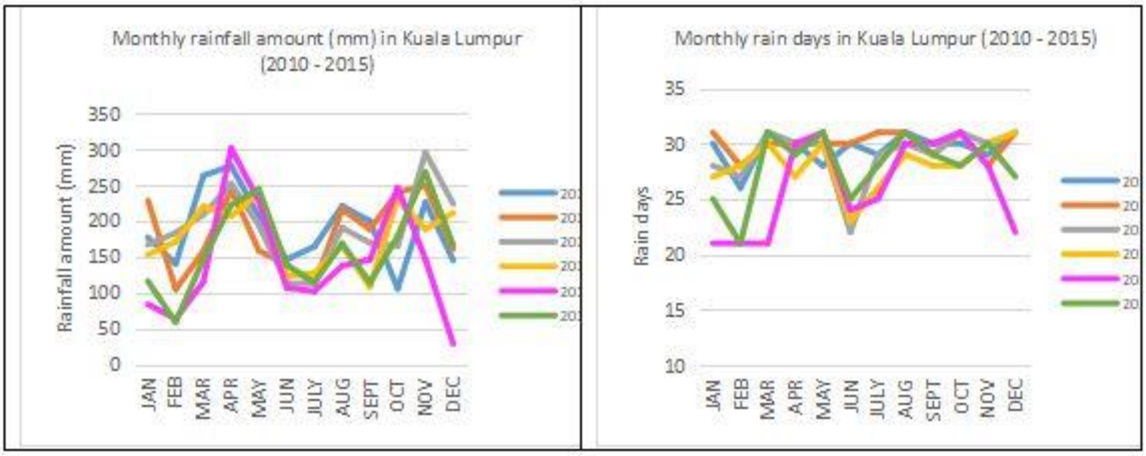

Figure 6. Monthly rainfall amount and rain days in Kuala Lumpur from year 2010 to 2015

A scatter plot graph was built in Figure 7 and it shows that the landslide incidents in Kuala Lumpur from year 2010 to 2015 were triggered with minimum monthly rainfall amount of 80 mm and a cumulative of 21 rain days monthly. Furthermore, most of landslide events happened after a heavy rainfall with a cumulative of more than 100 mm monthly and raining for more than 25 days onwards.

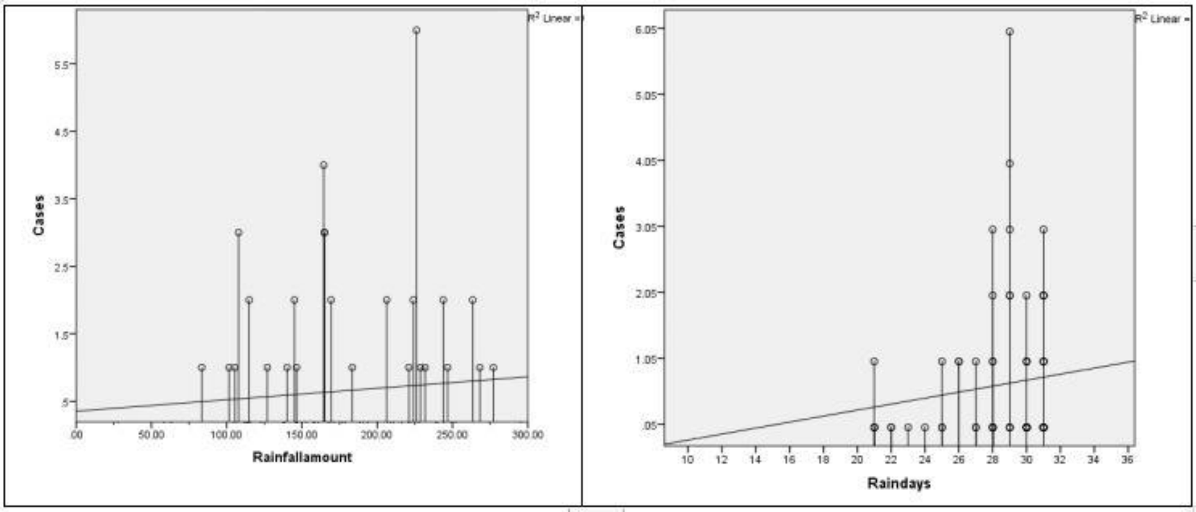

Figure 7. Scatter plot graph of landslide incidents against rainfall amount and rain days in Kuala Lumpur

From Pearson's correlation coefficient analysis conducted, it is observed that landslide incidents in year 2010 shows a significant positive correlation (r = 0.197) with rainfall amount attribute, however, there is a significant negative correlation with rain days (r = -0.166) with reported incidents in the same year (Table 1). Both rainfall amount and rain days attributes in year 2011, 2012, and 2015 show a significant positive correlation with landslide incidents reported. Meanwhile, landslide incidents reported in year 2012 and 2013 show a significant negative correlation with rainfall amount but positively correlated with rain days attribute for both years.

Table 1
Pearson's correlation coefficient analysis result of landslides with rainfall amount and rain days from year 2010 to 2015

Year	Rainfall amount	Rain days
2010	0.197	-0.166
2011	0.471	0.130
2012	-0.318	0.259
2013	-0.444	0.012
2014	0.024	0.015
2015	0.555	0.217

All significance level was set at p-value < 0.05 (2-tailed)

To study the relationship between rainfall variables and landslides, a linear regression analysis was applied. From Table 2, given intercept is the Y-intercept when X is 0, it is predicted that there is -0.548 cases with zero rainfall amount and rain days. This means that there will be no landslide incidents when there is no rainfall variables induced. These two variables are statistically correlated where it shows that the Beta values of standardized coefficients for rainfall amount is 0.025 and rain days is 0.098 (Table 2). With 95% confidence interval for Beta values, it is shown that the lower boundary of landslides is -3.537 and upper boundary of 2.442 landslides if rainfall amount and rain days is zero.

Table 2
Linear regression analysis result of landslides with rainfall amount and rain days.

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	p	Lower Bound	Upper Bound
1	Constant/Intercept	-0.548	1.498	-	-0.365	0.716	-3.537	2.442
	Rainfall amount	0.000	0.003	0.025	0.162	0.872	-0.006	0.007
	Rain days	0.039	0.062	0.098	0.626	0.533	-0.085	0.163

a. Dependent Variable: Cases

Therefore, a regression equation that can be generated from this analysis such as below:
Landslides = -0.548 + 0.000 (rainfall amount) + 0.039 (rain days)
Based on the equation generated, landslide incidents remain constant when there is an increase for every unit of rainfall, given that rain days remain unchanged. However, landslide events increase by 0.039 for every unit of rain days, given that the rainfall amount is unchanged. Based on the Beta values suggested to identify the dominant significant predictor in Table 2, it is shown that rain days have the highest Beta value. Thus, this indicates that rain days were the most significant predictor of landslide incidents.

Discussion

This study's results provide an understanding of how rainfall variables correlate with landslide occurrences in Kuala Lumpur. From Figure 2 in this study, there is no landslide occurrence every June observed during this study period as June in Kuala Lumpur received the minimum amount of precipitation, meanwhile, the highest landslide incidences reported were in November as the maximum precipitation recorded in this month every year during southwest monsoon (Saadatkhah et al., 2014).

The generated equation from this study shows that landslide events increase by 0.039 for every unit of rain days, given that the rainfall amount remains unchanged. Prolonged and low-intensity rainfall could result in a relatively greater amount of infiltration and eventually cause the slope to be more susceptible to failure (Mukhlisin et al., 2015). Moreover, there were a few cases of rainfall days above the threshold that did not develop landslides, but medium amounts of rainfall caused some landslide incidents (Althuwaynee et al., 2015).

However, this regression equation does not clearly show the relationship between monthly rainfall amount and rain days with landslide occurrences. Daily and hourly rainfall amount could be used in future study for rainfall-induced landslides where additional rainfall variables combination significantly contributed to trigger landslide incidents (Mukhlisin et al., 2015). A well distributed rain gauge stations across study area to monitor daily rainfall would be useful for further study instead of a single rainfall station.

Climate change alter the frequency and severity of extremes such as an increase in heavy rainfalls may affect the infrastructures of the region where it increase the risk and can affect the capacity and maintenance of storm water, drainage, and sewerage infrastructure especially in urban area (IPCC, 2012).

Since Malaysia experienced higher precipitation during the transition period between monsoon seasons, or also known as the inter-monsoon period, thus, April and May normally receive the highest rainfall amount, followed by October and November (Lee et al., 2014). Therefore, a huge differences of rainfall amount between March to April and October to November create extreme rainfall which could be the factor triggering landslides (Figure 6). This situation is also in line with projections of a previous study imply that rainfall intensity and distribution in monsoon regions and tropical areas predicted to become more extreme under climate change situation (IPCC, 2007).

Urbanization process in this territory is a challenge. The relations between landslides and precipitation are generally complex and usually even more in human-modified environments. Living in high pace environment where urbanites want to live by the road or as close as possible to amenities, therefore, development and construction add up more pressure towards high-risk area to cater the growing population needs. Road construction creates cut slopes that disturb the natural topology and affect slope stability (Chen et al., 2017; Pradhan et al., 2010). Cliffs and high-slope areas in Kuala Lumpur are composed of limestone (Althuwaynee et al., 2012). This structural condition is vulnerable during heavy rainfall as water penetrates the pores or saturates, acting as a lubricant, which then causes the static compressive and tensile strength of limestone to weaken drastically (Yusoff et al., 2016).

The short study period could be the limiting factor since only 6 years of landslide incidents and rainfall to observe the relation during the changing climate era. Therefore, an enhanced solutions are required to mitigate landslides at critical area in this territory. This includes provides a technical support for the design and implementation of safety solutions for the steep slopes. Instantaneously hindering developments in risky and hillside areas seems to be not resolving the situation where the land use demand is growing urgently (Lee et al., 2014).

Further appropriate solutions can be achieved with resourceful risk assessment and restoration planning.

Conclusion
This study investigated the influence of rainfall on landslides within Kuala Lumpur's Federal Territory. While both rain amount and rain days exhibited positive correlations with landslides, rain days emerged as a statistically significant predictor through Pearson correlation and linear regression analysis. The developed model suggests that rainfall amount wasn't a significant factor during this specific timeframe, highlighting the potential influence of other contributing factors and non-linearities in the rainfall-landslide relationship. These findings align with recent studies by Dahal et al (2020); Triglia et al (2022), who observed similar inconsistencies between precipitation and landslides.
Future research could delve deeper by investigating additional rainfall factors proposed by Kim et al (2016), such as antecedent rainfall, duration, return period, runoff ratio, and volume. Additionally, incorporating factors like soil properties, slope characteristics, and land-use patterns Hamid et al (2023) would provide a more holistic understanding of landslide susceptibility. This comprehensive approach would yield a more nuanced understanding of landslide triggers and inform the development of more robust prediction models.
The knowledge gained from this study, particularly the importance of analyzing rainfall patterns and behavior in conjunction with other factors, holds immense value for Kuala Lumpur's future. By incorporating these insights into construction practices, development plans, and slope or soil rehabilitation efforts, policymakers can develop more effective landslide mitigation strategies. Ultimately, this comprehensive approach will safeguard Kuala Lumpur's urban environment, infrastructure, and most importantly, the safety of its residents in the face of potential landslides.

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References
Alnaimat, A., Choy, L. K., & Jaafar, M. (2017). An assessment of current practices on landslides risk management: a case of Kuala Lumpur territory. *Geografia-Malaysian Journal of Society and Space*, *13*(2).
Althuwaynee, O. F., Pradhan, B., & Ahmad, N. (2015). Estimation of rainfall threshold and its use in landslide hazard mapping of Kuala Lumpur metropolitan and surrounding areas. *Landslides*, *12*(5), 861-875.
Althuwaynee, O. F., Pradhan, B., & Lee, S. (2012). Application of an evidential belief function model in landslide susceptibility mapping. *Computers & Geosciences*, *44*, 120-135.
BERNAMA. (2021). 58 kawasan perumahan berbukit di kl, selangor hadapi risiko tanah runtuh - semasa. *MStar*. https://www.mstar.com.my/lokal/semasa/2011/05/27/58-kawasan-perumahan-berbukit-di-kl-selangor-hadapi-risiko-tanah-runtuh.
Chen, W., Pourghasemi, H. R., Panahi, M., Kornejady, A., Wang, J., Xie, X., & Cao, S. (2017). Spatial prediction of landslide susceptibility using an adaptive neuro-fuzzy inference system combined with frequency ratio, generalized additive model, and support vector machine techniques. *Geomorphology*, *297*, 69-85.

Comprehensive global database of earthquake-induced landslide events and their impacts. Available online: https://www.sciencebase.gov/catalog/item/5ec70f9d82ce476925eddc9e (accessed on 16 April 2021).

Dahal, D. K., Nawaratne, N. C., Rathnayaka, K. D., & Basiri, H. (2020). Rainfall-induced landslides: Susceptibility, hazard zonation and triggering mechanisms in the Mahaweli River Basin, Sri Lanka. Landslides, 17(2), 291-309.

Department of Statistics, Malaysia. Available online: https://www.dosm.gov.my/v1/index.php?r=column/ctheme&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09&bul_id=MDMxdHZjWTk1SjFzTzNkRXYzcVZjdz09 (accessed on 22 April 2021.)

Dowling, C. A., & Santi, P. M. (2014). Debris flows and their toll on human life: a global analysis of debris-flow fatalities from 1950 to 2011. *Natural hazards*, *71*(1), 203-227.

EM-DAT. (2015) - The OFDA/CRED - International Disaster Database http://www.emdat.be - Universite catholique de Louvain Brussels – Belgium

Feng, Z. Y., Lo, C. M., & Lin, Q. F. (2017). The characteristics of the seismic signals induced by landslides using a coupling of discrete element and finite difference methods. *Landslides*, *14*(2), 661-674.

Froude, M. J., & Petley, D. N. (2018). Global fatal landslide occurrence from 2004 to 2016. *Natural Hazards and Earth System Sciences*, *18*(8), 2161-2181.

Hamid, S. B. A., Pradhan, B., Bui, D. T., Prakash, N., & Vu, T. T. (2023). Spatial assessment of landslide susceptibility using GIS-based machine learning models in the Cameron Highlands, Malaysia. Science of the Total Environment, 857, 159422.

Hong, H., Pradhan, B., Sameen, M. I., Chen, W., & Xu, C. (2017). Spatial prediction of rotational landslide using geographically weighted regression, logistic regression, and support vector machine models in Xing Guo area (China). *Geomatics, Natural Hazards and Risk*, *8*(2), 1997-2022.

Huang, H., Yu, W., Yu, Q., & Zhang, G. (2013). Landslide surface deformation analysis based on geographically weighted regression model. *EJGE*, *18*, 2693-2704.

IPCC. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Solomon,. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*.

Jabatan Kerja Raya. (2008). Appendix B: Landslide Inventory and Total Estimated Costs. National Slope Master Plan 2009- 2023.

Jabatan Pengairan dan Saliran Malaysia. (2018). Laporan Banjir Tahunan 2017/2018 (Annual Flood Report 2017/2018)

Kim, J., Ivanov, V. Y., & Fatichi, S. (2016). Environmental stochasticity controls soil erosion variability. *Scientific reports*, *6*(1), 1-7.

Kirschbaum, D. B., Stanley, T., & Simmons, J. (2015). A dynamic landslide hazard assessment system for Central America and Hispaniola. *Natural Hazards and Earth System Sciences*, *15*(10), 2257-2272.

Kirschbaum, D., Adler, R., Adler, D., Peters-Lidard, C., & Huffman, G. (2012). Global distribution of extreme precipitation and high-impact landslides in 2010 relative to previous years. *Journal of Hydrometeorology*, *13*(5), 1536-1551.

Kouli, M., Loupasakis, C., Soupios, P., & Vallianatos, F. (2010). Landslide hazard zonation in high risk areas of Rethymno Prefecture, Crete Island, Greece. *Natural hazards*, *52*(3), 599-621.

Kyriou, A., Nikolakopoulos, K., Koukouvelas, I., & Lampropoulou, P. (2021). Repeated UAV Campaigns, GNSS Measurements, GIS, and Petrographic Analyses for Landslide Mapping and Monitoring. *Minerals*, *11*(3), 300.

Lee, M. L., Ng, K. Y., Huang, Y. F., & Li, W. C. (2014). Rainfall-induced landslides in Hulu Kelang area, Malaysia. *Natural hazards*, *70*(1), 353-375.

Mahmud, A. R., Awad, A., & Billa, R. (2013). Landslide susceptibility mapping using averaged weightage score and GIS: A case study at Kuala Lumpur. *Pertanika Journals*, 473-48.

Majid, N., Taha, M., & Selamat, S. (2020). Historical landslide events in Malaysia 1993–2019. *Indian J. Sci. Technol*, *13*, 3387-3399.

Muhamad, N., Lim, C. S., Reza, M. I. H., & Pereira, J. J. (2013). Input geologi untuk Sistem Sokongan Membuat Keputusan dalam pengurusan risiko bencana: Kajian kes Universiti Kebangsaan Malaysia (In Malay), Geological input for Decision Support System to manage the risk of disasters: A case study of Universiti Kebangsaan Malaysia.

Mukhlisin, M., Matlan, S. J., Ahlan, M. J., & Taha, M. R. (2015). Analysis of rainfall effect to slope stability in Ulu Klang, Malaysia. *Jurnal Teknologi*, *72*(3).

Nhu, V. H., Mohammadi, A., Shahabi, H., Ahmad, B. B., Al-Ansari, N., Shirzadi, A., ... & Nguyen, H. (2020). Landslide detection and susceptibility modeling on cameron highlands (Malaysia): a comparison between random forest, logistic regression and logistic model tree algorithms. *Forests*, *11*(8), 830.

Pall, P., Aina, T., Stone, D. A., Stott, P. A., Nozawa, T., Hilberts, A. G., ... & Allen, M. R. (2011). Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature*, *470*(7334), 382-385.

Pradhan, B., Lee, S., & Buchroithner, M. F. (2010). A GIS-based back-propagation neural network model and its cross-application and validation for landslide susceptibility analyses. *Computers, Environment and Urban Systems*, *34*(3), 216-235.

Ruzman, N. S. L. N., & Rahman, H. A. (2015). *The association between climatic factors and dengue fever: a study in Subang Jaya and Sepang, Selangor* (Doctoral dissertation, Universiti Putra Malaysia).

Saadatkhah, N., Kassim, A., & Lee, M. L. (2014). Spatial patterns of precipitation, altitude and monsoon directions in Hulu Kelang area, Malaysia. *EJGE C*, *19*, 521-534.

Skilodimou, H. D., Bathrellos, G. D., Koskeridou, E., Soukis, K., & Rozos, D. (2018). Physical and anthropogenic factors related to landslide activity in the Northern Peloponnese, Greece. *Land*, *7*(3), 85.

Sulaiman, M. S., Nazaruddin, A., Salleh, N. M., Abidin, R. Z., Miniandi, N. D., & Yusoff, A. H. (2019). Landslide occurrences in Malaysia based on soil series and lithology factors. *Int. J. Adv. Sci. Technol*, *28*, 1-26.

Triglia, C., Iadicola, P., & Guerricchio, A. (2022). A Rainfall Threshold-Based Approach for Regional Landslide Early Warning Systems: The Case of Southern Italy. *Frontiers in Earth Science,* 10.

Yusoff, Z. M., Raju, G., & Nahazanan, H. (2016). Static and Dynamic Behaviour of Kuala Lumpur Limestone. *Malaysian Journal of Civil Engineering*, *28*.