MULTIPLE LINIER REGRESSION ANALYSIS TO PREDICT INUNDATION IN THE KRUKUT WATERSHED

Boris Karlop Lumbangaol[1], Agustinus Purna Irawan[2], Wati A. Pranoto[3], Toni Hartono Bagio[4]*
[1] Civil Engineering Doctoral Program, Universitas Tarumanagara-Jakarta, Indonesia
Email: boris.karlop90@gmail.com
[2] Civil Engineering Doctoral Program, Universitas Tarumanagara-Jakarta, Indonesia
Email: agustinus@untar.ac.id
[3] Civil Engineering Doctoral Program, Universitas Tarumanagara-Jakarta, Indonesia
Email: watip@ft.untar.ac.id
[4] Civil Engineering Doctoral Program, Universitas Tarumanagara-Jakarta, Indonesia
Email: inotube@gmail.com

ABSTRACT: Urban areas, particularly in the Krukut watershed, face a significant issue with inundation. One factor that contributes to the rise in inundation is the decrease in permeable surfaces and the corresponding increase in impermeable surfaces. Despite numerous attempts, controlling inundation in the area has not been effectively mitigated. Therefore, a predictive model is required to anticipate the occurrence of inundation in a watershed. This study aims to develop a predictive model for estimating the extent of inundation. This model aids in predicting and mitigating the rise in inundation events and runoff rates and this report presents information on the determination of the previous area in the Krukut watershed with the aim of reducing runoff. This study will employ multiple linear regression techniques to forecast the extent of inundation in the Krukut watershed. The analysis will incorporate rainfall, land use variables, and drainage system capacity as predictors. Data on inundation events from 2010 to 2020 was collected from reliable social media sources, while rainfall data from 2003 to 2018 was obtained from ST. The 2019 Citra Landsat data provides information on the land use of the UI Campus. Regression analysis was conducted using SPSS software to develop inundation area prediction models. The classical assumption test analysis confirmed that the data follows a normal distribution, allowing for the application of multiple linear regression. The analysis utilised the T test and F test to determine the impact of Building (X2) on the coverage in the Krukut watershed over a 25-year period. The results indicated a significant influence, as evidenced by the model equation Y = -0.0003 + 0.0026 X2. The test results indicate that the model application has a high level of accuracy, with a kappa coefficient value of 0.83. This suggests that the model is highly reliable and suitable for implementation in the Krukut watershed. Additionally, the model predicts that the Krukut watershed will experience flooding over an area of 17.6 hectares within a 25-year period.

Keywords: Building Open Space, Inundation, Land Use, Prediction, SPSS

1. Introduction

A watershed is a land area within an ecosystem that includes rivers and tributaries, serving the purpose of naturally collecting, storing, and discharging rainfall into lakes or seas (Degife et al., 2019; Rajaei et al., 2021). Land boundaries serve as topographic separators, while sea boundaries delineate irrigation areas that can still be influenced by land-based activities (UU No.7/2004 on water resources). Land use change is a contributing factor to environmental degradation in watersheds (Astuti et al., 2019; Tang et al., 2005). The conversion of agricultural land for non-agricultural purposes is driven by the policy of establishing economic growth centres, trade hubs, and tourist destinations, with the aim of expediting the development of residential areas (Berta Aneseyee et al., 2020; Li et al., 2022).

Desta and Fetene (2020) found that the development of infrastructure in urban areas, including housing, recreation areas, shops, roads, and parking lots, can lead to an increase in impermeable land coverage. Consequently, this can result in a reduction in the ability of the land to absorb water through infiltration. Consequently, the increase in the flow coefficient leads to enhanced surface flow and a shorter time for discharge concentration. Alterations in discharge flow patterns can have an impact on the hydraulic flow within established drainage systems (Bailey et al., 2020; Russo, Valentín, & Tellez-Álvarez, 2021). Inundation poses a significant problem in urban areas, specifically in the Krukut watershed of DKI Jakarta Province (Dammayatri, Susantoro, & Wikantika, 2023; Fitriyanto & Helmi, 2019). The issue of inundation is caused by a combination of factors, including heavy rainfall, urbanisation leading to the construction of impermeable structures, the narrowing of riverbanks, and the reduction of areas that can collect rainwater. The period from 2010 to 2020 has had a significant impact on Krukut. The

Krukut River receives water from 29 inundation points located in 10 sub-districts within the Krukut watershed.

The river is located in the northwestern region of Java Island, which has a tropical rainforest climate (Ruan et al., 2019). According to the Köppen Geiger climate classification, the climate code for this region is Af. The average annual temperature is approximately 27 °C.March has the highest average temperature of 30 oC, while May experiences the lowest average temperature of approximately 26 oC.The mean annual precipitation is 3674 mm. December has the highest monthly rainfall, averaging 456 mm, while September experiences the lowest, with an average of 87 mm. The Krukut watershed covers an area of 73.53 km2 and is characterised by a main river that spans 31.39 km. The Comprehensive River Water Management Plant in Jabotabek (1997) measures the average daily rainfall in this area at 129 mm, and the peak discharge, known as Q25, at 135 m3/sec. The Krukut watershed originates from Situ Citayam and flows through several areas, including Bogor, Depok, Jagakarsa, Cilandak, Pasar Minggu, Kemang, Mampang Prapatan, Gatot Subroto, Setiabudi, and Tanah Abang, before reaching its final destination at the West Canal Flood.

Various integrated flood management measures, encompassing both structural and non-structural approaches, commonly mitigate the occurrence of inundation. One such approach involves the expansion of the cross-section of rivers and reservoirs, thereby enhancing their flow capacity (Hu et al., 2019). In urban areas, the implementation of certain flood risk reduction measures can be challenging due to either a lack of political will or the need for substantial financial resources, such as those required for settlement relocation. Therefore, it is imperative to implement additional measures, such as source-level rainwater runoff management, in order to safeguard urban regions. Inundation is a result of the conversion of urban land into impermeable built-up areas, leading to increased occurrences of flooding. Insufficient drainage storage capacity in the drainage area causes the flow coefficient to increase and the reservoir volume to decrease during the rainy season, as excess water cannot be accommodated. Additionally, the normalisation of the Krukut River is hindered by challenges in acquiring land.

According to Regulation of the Minister of Public Work No. 11/PRT/M/2014, there are three distinct facilities available for the purpose of rainwater management in urban areas. These facilities include rainwater storage facilities, retention facilities, and detention facilities. On June 24, 2009, the Minister of Public Works issued Regulation No. 12/PRT / M / 2009. This regulation outlines the guidelines governing the allocation and utilisation of non-green land within urban areas. The infrastructure planning, facilities, and utilities of RTNH are guided by the Low Impact Development (LID) Concept. However, a comprehensive discussion regarding the design for determining the area of the LID unit has not been provided. In order to mitigate the impact of land use change on flooding within a watershed, it is imperative to employ a prediction model to accurately estimate the appropriate size of the Low Impact Development (LID) unit within a developed area.

Therefore, it is imperative to conceive a sustainable urban drainage system that effectively handles rainwater at its origin and constructs retention and detention facilities. Additionally, the efficiency and effectiveness of LID units depend on the size of each individual unit and the combined coverage area of all units. Therefore, it is necessary to develop a prediction model for the area of inundation with a specific recurrence period in order to enable anticipation of the occurrence of inundation events. The land cover classification, as defined by SNI 7645-1:2014, is considered an independent variable that influences the occurrence of inundation, which is the dependent variable, within a watershed. This relationship is analysed using the multiple linear regression method. The objective of the regression analysis is to forecast the extent of inundation in the Krukut watershed. The aforementioned data can be used to calculate the infiltration land area at the location of flooding by employing the LID concept within the framework of initiatives aimed at reducing runoff.

The objective of this study is to develop a predictive model for inundation and determine the factors that influence inundation events based on land use patterns. The practical model employed in this study will benefit the development of infiltration and pervious land areas in the Krukut watershed. Its purpose is to address the anticipated increases in runoff rates.

2. Material and Method

The study was conducted in the Krukut Watershed using land cover data from the USGS's downloadable Landsat 8 imagery in 2019 (available at http://earththexplorer.usgs.gov/). The land cover data at the research site was obtained using ArcGIS 10.6.1 software's area of interest (AOI) capabilities. This data was supported by field data, Google Earth maps, and high-resolution satellite imagery. The researchers identified five land cover types in the Krukut watershed through visual interpretation and knowledge analysis. These types include water bodies (blue), buildings (yellow), grass shrubs (light green), soil (light brown), and vegetation (dark green). The researchers collected secondary data for hydrological and hydraulic studies through intermediary media, which were then documented.

Over a 16-year period, from 2003 to 2018, we collected rainfall data from the UI Campus rainfall station. The following data represents the annual maximum rainfall from 2003 to 2018, measured in mm/day. The data set consists of the following values: 102, 117, 95, 93.5, 156.5, 152, 137, 109, 117.4, 262.4, 101.7, 151.5, 97.2, 141.5, 105.7, and 95.2. Hydrological analysis requires the utilisation of data that is stationary, consistent, and homogeneous. After obtaining the regional rainfall value, researchers subject it to testing. The researchers subsequently determined the dependent and independent variables within the model. The dependent variable in this study is the area of inundation (Y). The researchers obtained the variable by collecting area unit (km2) data from a research website covering the years 2010 to 2020. The study's independent variables include water (X1), building (X2), grass (X3), ground (X4), and vegetation (X5). The following prediction model will be utilised to estimate the incidence of inundation in the Krukut watershed, enabling the prediction of flooding.

Multiple Linear Regression Model:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + e$$

Notes:

Y: Flood Area
a: Constant
b_1, b_2, b_3, b_4, b_5: X variable regression coefficient
X_1: Water
X_2: Building
X_3: Grass
X_4: Ground
X_5: Vegetation
e: Error/Residual

The study presents the results of the descriptive analysis using tables and graphs. Additionally, data distribution is assessed by employing statistical parameters such as the mean, standard deviation, and individual variable values. This analysis serves as an extension of descriptive analysis, as it utilises data collection and hypothesis testing to make predictions. The analysis employs the multiple linear regression method. This technique is applicable once the regression model satisfies the assumptions of classical regression analysis. The classical assumption test employs the Kolmogorov-Smirnov test to assess the normality of the data. If the asymptotic significance level exceeds 5%, it indicates that the data follows a normal distribution (Aslam, 2019).

A multicollinearity test was conducted to assess the presence or absence of multicollinearity among variables. This was accomplished by examining the variance inflation factor (VIF) or tolerance value (ToL) of each independent variable in relation to the dependent variable. A model is considered to have no multicollinearity when the VIP is below 10 and the tolerance limit is typically set at 0.01. The Glejser test was used to assess heteroskedasticity in the regression model. Heteroskedasticity can be identified by observing the regression coefficients of each independent foreign variable, regardless of the magnitude of the residual value. If the p-value of the test is greater than the significance level α (0.05), it can be concluded that the model does not exhibit heteroskedasticity.

Hypothesis testing is conducted to evaluate the acceptability of a hypothesis in order to address a research problem that has been previously formulated. Hypothesis testing is conducted using multiple linear regression analyses. The coefficient of determination test (R2), f-test (simultaneous test), and t-test (partial test) are conducted by comparing the statistical values with the critical value from the t-table (specifically 2.145) at a 95% confidence level and a 5% margin of error. The hypothesis test is conducted by evaluating the alternate hypothesis (H1), which states that there is a significant relationship between the independent variable and the dependent variable. The null hypothesis (H0) posits that there is no relationship between the independent variable and the dependent variable. The decision criterion for accepting or rejecting hypotheses is as follows: reject H0 if the test statistic > t-table value, and reject H1 if the test statistic < t-table value. The stages of this research are reported in Figure 1.

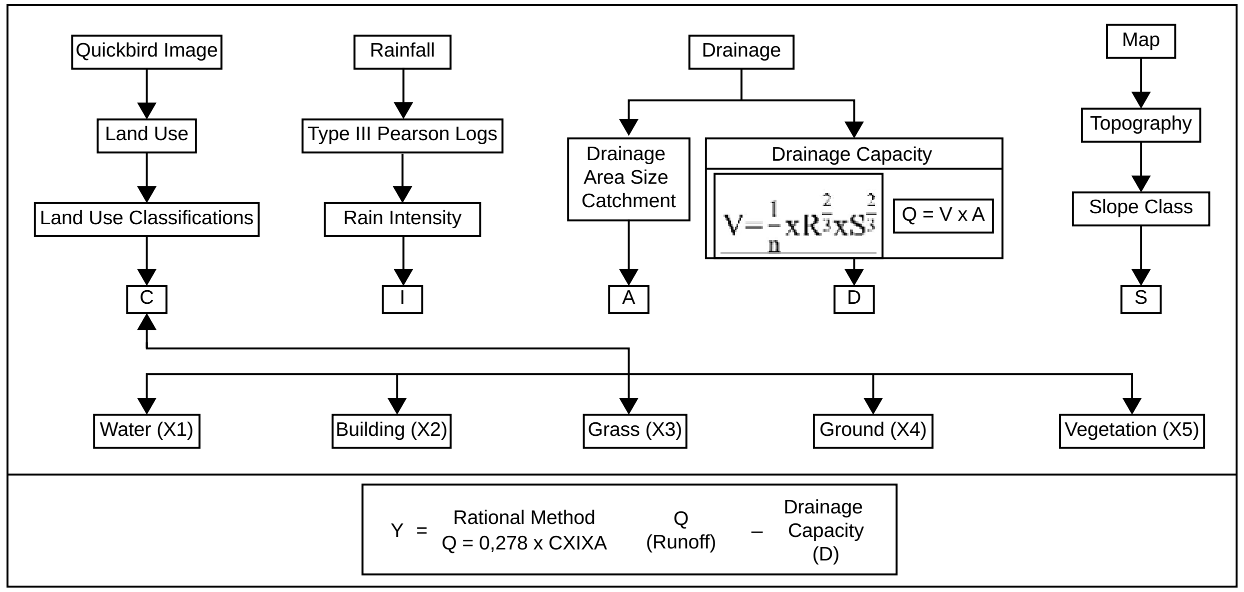

Figure 1. Research Stages

3. Results

The inundation map and table in Figure 2 were created by combining data from two sources. The sources used in this study consisted of data from inundation events in the Krukut watershed area from 2010 to 2020, obtained from reliable social media sources. Additionally, data from inundation-affected events in specific locations such as the Cilandak sub-district, Pasar Minggu district, Kebayoran Baru district, Mampang Prapatan district, and Tanah Abang district were also included.

No	Sub Watershed	Inundation Point	Inundation Area	Incident	Source
1	DTA Mampang Depok	3	Kawasan Pancoran Mas, Depok	Potentially (6x)	https://jabar.jpnn.com/jabar-terkini/1507/belasan-rumah-di-pancoran-mas-depok-terendam-banjir-setinggi-2-meter
2	DTA Salak	5	Kawasan Tanah Baru, Beji, Depok	Potentially (6x)	https://wartakota.tribunnews.com/2017/04/20/penanganan-banjir-di-tanah-baru-sudah-diajukan-di-musrenbang-2017
3	DTA Perikanan	9	Jl.Bango Pondok Labu Kecamatan Cilandak	**Potentially (8x)**	https://www.liputan6.com/news/read/4488195/foto-banjir-2-meter-rendam-pondok-labu?page=1
4	DTA Danyong	8	Jl.Margasatwa pondk labu, Kec.Cilandak	Potentially (6x)	https://jakarta.tribunnews.com/2020/01/01/air-kali-krukut-meluap-jalan-margasatwa-terendam-banjir
5	DTA Pinang Kali	2,4,6,7	Kaw, Kel.Pasir Putih, Depok; Kaw.Sawangan Raya Pancoran Mas, Depok; Kaw. Grogol Limo, Depok, Kaw.Perumahan Graha Cinere Limo, Depok.	Potentially (8x)	https://jakarta.tribunnews.com/2021/11/08/banjir-di-pasir-putih-sawangan-3-kk-harus-dievakuasi-pakai-perahu-karet
6	DTA Elnusa			**No Potential**	
7	DTA Palm	12	Jl.Kemang Selatan XII	**Potentially (8x)**	https://www.antaranews.com/berita/1764709/jalan-kemang-selatan-xii-masih-tergenang-
8	DTA Asem	21	Jl.H.Nawi ITC Fatmawati Keb Baru.	Potentially (8x)	https://www.instagram.com/p/B_jyUMgJtTo/
9	DTA Nipah			**No Potential**	
10	DTA S.Mampang	10,11,14,15,16,17,18,20	Jl.TB.Simatupang, Plaza Oleos Kec.Ps.Minggu; Jl.Pejaten barat Raya, Pejaten Village Kec,Mampang Prapatan; Jl.Kemang Timur V Kec.Mampang Prapatan; Jl.Kemang Utara IX Pasar Jagal Buncit Kec.Mampang Prapatan, Jl.Duren Tiga Raya Kec.Mampang Prapatan, Jl.Bangka XI Pela Mampang, Jl.Pondok Jaya Raya, Pela Mampang, Jl.Pondok Karya Komplek Polri Kec.Mampang	Potentially (8x)	https://news.detik.com/berita/d-4914218/kompleks-polri-pondok-karya-terendam-banjir-60-cm-akses-terputus
11	DTA Benhil	26	Jl.Bendungan Hilir, depan Jakarta Printer Kec.Taah Abang	Potentially (8x)	https://www.tribunnews.com/images/editorial/view/1828149/jalan-bendungan-hilir-terendam-banjir
12	DTA S.Krukut	1,13,19,22,23,24,25,27,28,29	Kaw.Ratu Jaya, Pasir Putih, Depok; Jl.Kemang Raya, Kemang Mansion; Jl.Canadiyanti, Pela mampang; jl.Pulo Raya, Petogogan;Jl.Wijaya Timur Dalam IV Petogogan; Jl.Wijaya Chandra Raya, Gedung Lipi; Jl.Jend.Sudirman; Benhil, RSAL Dr.Mintoharjo; Jl.Penjernihan I, TPU Karet bivak; Jl.Penjernihan I Polsek Tanah Abang Kec.Tanah Abang	Potentially (8x)	https://news.detik.com/berita/d-5400740/sejarah-kemang-rumahnya-air-yang-kini-langganan-banjir.

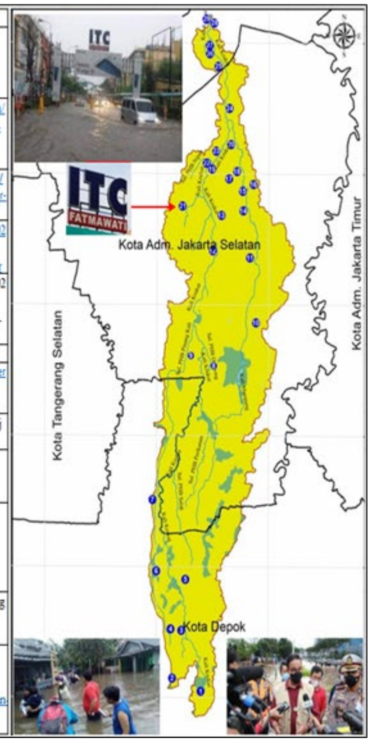

Figure 2. Inundation Map of the Krukut Watershed

Thiessen's Polygon method was utilised to calculate the rainfall results. This method incorporates the station's area as a weighting factor when calculating the average rainfall. This method is considered

superior to the average algebraic method for estimating the average rainfall in watersheds with limited station coverage and uneven rainfall distribution, despite its inability to provide an exact weight (Shen et al., 2019). In the context of hydrological analysis, it is imperative that the rainfall data exhibit three key characteristics: stationarity (unchanged), consistency, and homogeneity. The frequency analysis method determines the results of the rainfall analysis.

In order to determine the most appropriate distribution pattern, a frequency distribution match test was conducted. This test involved several statistical parameter tests, including the MAPE test, RMS test, Sminrov Kolmogorov test, and Chi Square test. The Pearson Type III Log Method is determined to be the most suitable method for matching the distribution of the available data based on the test results. This determination is made due to its minimal error degree and successful fulfilment of the requirements outlined in table 1.

Table 1. Rainfall Period Plan for the Krukut Watershed UI Campus Station

Return Period	Normal	Log-Normal	Pearson III	Log Pearson III	Gumbel
100	171.17	179.73	179.7	189.02	189.44
50	165.03	170.89	171.1	177.18	177.18
25	158.2	161.57	161.94	165.25	164.82
10	147.64	148.13	148.57	149.03	148.16
5	137.72	136.54	136.9	135.94	134.98
2	118.77	116.85	116.83	115.52	115.07

The analysis of flood calculations relies solely on the maximum daily rainfall (mm/24 hours) observed in a single year. Therefore, the Mononobe formula approach is employed for this purpose. In regards to the flood calculation design, the rainfall hyetograph is distributed over a span of 6 hours at the flood calculation station in order to derive the critical rainfall. The rain distribution table utilising the Mononobe Method is presented in Table 2.

Table 2. Table of distribution of rain in the Krukut watershed Mononobe method (within 6 hours)

Mononobe	Tr = 2	Tr = 5	Tr = 10	Tr = 25	Tr = 50	Tr = 100
	115.52	135.94	149.03	165.25	177.18	189.02
0.067	7.79	9.17	10.05	11.15	11.95	12.75
0.1	11.59	13.64	14.95	16.58	17.78	18.97
0.55	63.57	74.81	82.01	90.94	97.51	104.02
0.143	16.52	19.44	21.32	23.64	25.34	27.04
0.08	9.23	10.86	11.9	13.2	14.15	15.1
0.059	6.81	8.02	8.79	9.74	10.45	11.15

Flood discharge calculation is necessary for the design of flood control structures. Several methods (Synthetic Unit Hydrograph), such as HSS-Nakayasu and HSS SCS-CN, can be used to calculate flood discharge using Synthetic Unit Hydrograph (SUH) techniques. In order to determine the planned flood discharge, an analysis of the peak flood discharge is conducted using the aforementioned SUH methods, with a time interval of 1 hour. Table 3 presents the findings of the Krukut River Peak Discharge. Table 3 indicates that the HSS SCS-CN method exhibits a higher value than Nakayasu's HSS results. Consequently, the SCS-CN Hydrograph with a peak discharge value (Qp) of 322.13 m3/sec is selected for the 25-year scenario.

Tabel 3. Results of Krukut River Peak Discharge Calculation Various Methods

HSS	TP	QTR2	QTR5	QTR10	QTR25	QTR50	QTR100
	Jam	(m3/det)	(m3/det)	(m3/det)	(m3/det)	(m3/det)	(m3/det)
SCS-CN	5,45	194.67	246.20	279.87	**322.13**	353.52	384.88
NKY_	3,55	167,67	197,31	216,31	239,86	257,17	277,75

By analysing Landsat 8 imagery and employing optimal band combinations for land cover classification, the accuracy of land cover objects was assessed through visual observation in the field. This assessment led to the identification of five distinct land cover classes. The land cover class includes Water, Building, Grass, Ground, and Vegetation. The image exhibits distinct colours to represent various types of land cover. Water Land is depicted in blue; Building Land is depicted in keune colour, Bush Grass Land is depicted in light green, Desert Land is depicted in light brown, and Vegetation Land is depicted in dark green.

This study employed both primary and secondary data sources. The primary data was obtained by downloading Landsat 8 imagery from the United States Geological Survey (USGS) Website (http://eartthexplorer.usgs.gov/). The Geospatial Information Agency utilised the Indonesian Earth Maps (RBI) to aid in the interpretation of the images. Visual interpretation of imagery relies on the spatial recognition of object characteristics. Object characteristics can be determined by analysing various interpretive elements, including colour, shape, size, pattern, texture, image, location, and associations with other objects.

Land cover data for specific areas of interest (AOI) was collected using tools available in ArcGIS 10.6.1 software. This data was supplemented by field observations, Google Earth maps, and high-resolution satellite imagery. The distribution of pixels within the Krukut watershed area is uniform. Table 4 presents the land use classification for the Krukut watershed.

Tabel 4. Krukut Watershed Land Use Classification

Object Color	Object	Description	Variable
Blue	water	All the features of the water, both natural and semi-natural. Examples: reservoirs, dams, rivers, channels, etc.	X_1
Yellow	building / impervious	Areas that have undergone substitution of land cover, all types of buildings are watertight (building), both semi-permanent and permanent. Examples: roofs of buildings, concrete, roads, sidewalks, parking lots, etc.	X_2
Light green	grass	Shrub Group, grass with a height of ≤ 50 cm examples: grass and shrubs	X_3
Light brown	Ground	Dry land with no grass and shrubs	X_4
Dark green	Vegetation.	All broadleaf plants and trees taller than shrubs > 50 cm	X_5

The Krukut watershed is classified into building land use (92.54%), vegetation land (5.79%), and water land (1.67%). Table 5 presents the land use data for the Krukut watershed in the year 2019.

Table 5. Land Use in the Krukut Watershed in 2019

Classification	Area (km²)	Percentage (%)
Water	1.45	1.67
Building	68.05	92.54
Grass	0	0
Ground	0	0
Vegetation	4.03	5.79
TOTAL	73.53	100

The land use of the Krukut watershed in 2019 is divided into 12 sub-watersheds, arranged in order from upstream to downstream. These sub-watersheds are: 1. Mampang Depok; 2. Salak; 3. Perikanan; 4. Danyong; 5. Pinang Kali; 6. Elnusa; 7. Palm; 8. Asem; 9. Nipah; 10. Sungai Mampang; 11. Benhil; and 12. Sungai Krukut. Table 6 presents the land use classification of the Krukut inlet catchment area in 2019.

Table 6. Land use classification of the Krukut inlet catchment area in 2019

No	Sub Watershed	Water	Building	Vegetation
	Water Catchment Area	(km²)	(km²)	(km²)
1	Mampang Depok	0.0169	0.5065	0.2206
2	Salak	0.0877	2.5553	0
3	Perikanan	0.0892	2.5614	0.1219
4	Danyong	0.0016	0.5135	0.0006
5	Pinang Kali	0.1675	5.9758	0.3408
6	Elnusa	0.0007	0.4588	0
7	Palm	0.0056	1.6238	0
8	Asem	0.0039	2.1263	0.0039
9	Nipah	0.0053	1.6188	0
10	Sungai Mampang	0.5778	29.4002	2.3828
11	Benhil	0.0078	0.6983	0
12	Sungai Krukut	0.4891	20.0093	0.9591

The analytical technique was used to calculate the probability of inundation area for the 25-year plan year, taking into account the existing drainage capacity. The findings indicate that the drainage system experiences overflow when assuming an average inundation height of 25cm. Consequently, the researchers quantified the area of inundation in square kilometres. The variable in question is commonly known as the dependent variable, as indicated in Table 7.

Table 7. Probability of inundation in the Krukut watershed for a 25-year return period

No	Sub Watershed	Existing	QTR_{25}	YTR	Assumption	YTR_{25}
	Water Catchment Area	(m³/sec)	(m³/sec)	(m³/sec)	(Km²)	(Km²)
1	2	3	4	5 = (4-3)	6	7 = (5*6)
1	Mampang Depok	14.62	23.62	9.01	0.0000695	0.0006
2	Salak	12.07	111.52	99.45	0.0000695	0.0069
3	Perikanan	22.2	112.63	90.43	0.0000695	0.0063
4	Danyong	6.55	22.41	15.86	0.0000695	0.0011
5	Pinang Kali	16.37	263.15	246.78	0.0000695	0.0172
6	Elnusa	9.62	20.02	10.41	0.0000695	0.0007
7	Palem	8.83	70.86	62.04	0.0000695	0.0043
8	Asem	8.05	92.82	84.77	0.0000695	0.0059
9	Nipah	12.07	70.65	58.58	0.0000695	0.0041
10	Sungai Mampang	134.68	1,299.52	1,164.84	0.0000695	0.081
11	Benhil	14.12	30.47	16.35	0.0000695	0.0011
12	Sungai Krukut	238.03	879.87	641.84	0.0000695	0.0446

The Regression Correlation Test is used to analyse the association between land cover data collected in 2019 and the probability of floods in a specific area. Data analysis and interpretation were conducted using SPSS version 25 software. The model development is presented in Table 8. The research description is presented in Table 9.

Table 8. Model Development

No	Sub Watershed	X_1	X_2	X_3	X_4	X_5	YTR25
	Water Catchment Area	(km²)	(km²)	(km²)	(km²)	(km²)	(km²)
1	Mampang Depok	0.016916	0.506475	0	0	0.22057	0.000626
2	Salak	0.087691	2.555297	0	0	0	0.006912
3	Perikanan	0.089229	2.561434	0	0	0.121911	0.006285
4	Danyong	0.001577	0.513475	0	0	0.000555	0.001102
5	Pinang Kali	0.167464	5.975758	0	0	0.340835	0.017151
6	Elnusa	0.000725	0.458753	0	0	0	0.000723
7	Palem	0.005621	1.62376	0	0	0	0.004312
8	Asem	0.003882	2.126307	0	0	0.003882	0.005892
9	Nipah	0.005294	1.618779	0	0	0	0.004071
10	Sungai Mampang	0.577785	29.400151	0	0	2.382791	0.080956
11	Bendungan Hilir	0.00776	0.698285	0	0	0	0.001136
12	Sungai Krukut	0.489098	20,009,349	0	0	0.959134	0.044608

where:
X_1 = Water; X_2 = Building ; X_3 = Grass; X_4 = ground; X_5 =Vegetation YTR_{25} =Inundation

Table 9. Research Description

Description	N	Minimum	Maximum	Mean	Standard Deviation
Inundation (YTR25)	12	0.000626	0.080956	0.014481	0.024275
Water (X_1)	12	0.000725	0.577785	0.121087	0.200279
Building (X_2)	12	0.458753	29.400150	5.670652	9.237591
Grass (X_3)	12	0.000000	0.000000	0.000000	0.000000
Ground (X_4)	12	0.000000	0.000000	0.000000	0.000000
Vegetation (X_5)	12	0.000000	2.382791	0.335807	0.702213

Table 10 demonstrates a significant correlation and strong relationship between the independent variables (Water, Building, Shrubs, Soil, and Vegetation) and Inundation. The research hypotheses testing results are presented in Table 11. Thus, the variables influencing inundation are Building (X2) with a *p*-value of 0.05 and *T* Statistic > 2. The remaining variables with a *p*-value greater than 0.05 are removed from the model.

Table 10. Correlation Between Variables

Relationship Between Variables			Pearson Correlation	Relationship Level
Water	→	Inundation	0.966	Very strong
Building	→	Inundation	0.994	Very strong
Vegetation	→	Inundation	0.982	Very strong
Building	→	Water	0.984	Very strong
Vegetation	→	Water	0.924	Very strong
Building	→	Vegetation	0.965	Very strong

Table 11. Research Hypothesis Testing Results

Hypothesis	Analysis	Test			Conclusion
		T Statistic	Sig.	Note	
H1	Water	< 2	>0.05	Insignificant	Rejected
H2	Building	>2	<0.05	Significant	Accepted
H3	Grass	< 2	>0.05	Insignificant	Rejected
H4	Ground	< 2	>0.05	Insignificant	Rejected
H5	Vegetation	< 2	>0.05	Insignificant	Rejected

Table 11 displays the Pearson product-moment correlation coefficients, indicating a significant positive association (> 0.9) among the independent variables Water, Building, Vegetation, and inundation. However, when the traditional assumptions are tested, it is clear that only Building has a substantial effect on the *t* statistic (> 2) and the *p*-value (> 0.05). Since the remaining factors had no influence, a stage 2 regression was performed, with the results shown in Table 12.

Table 12. Correlation Coefficient / Pearson Product Moment

		Inundation (YTR_{25})	Building (X_2)
Inundation (YTR_{25})	Pearson Correlation	1	1.000**
	Sig. (2-tailed)		0
	N	11	11
Building (X_2)	Pearson Correlation	1.000**	1
	Sig. (2-tailed)	0	
	N	11	11
**. Correlation is significant at the 0.01 level (2-tailed).			

The Pearson product-moment correlation coefficient is computed for the variable “Building”. As it approaches 1, it is considered to have greater significance. Positive values indicate a connection, while negative values indicate the absence of a connection. According to the table 11 above, the association between building and floods is considered positive, with a Pearson correlation *r* value of 1 > 0 and a *p*-value of 0.00 - 0.05.

Researchers analyse the R Square and adjusted R Square values to assess the explanatory power of the independent variable on the dependent variable. The R-square score of 0.988, along with the adjusted R-square value of 0.988, exceeding the threshold of 0.5, indicates a strong ability of the independent variable to accurately predict the dependent variable. Table 13 presents the model summary.

Table 13. Model Summary

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1	0.994[a]	0.988	0.987	0.002803996
a. Predictors: (Constant), Building (X_2)				

The regression is considered legitimate based on the ANOVA table, which shows a significant F value of 0.05. It also suggests the difference in F_{Count} and F_{Table} of 814.435. In the numerator, df1 = 1 (number of independent variables) and df2 = 10 (number of samples - number of independent variables -1). $F_{Count} > F_{Table}$ because F_{Table} has a value of 4.96. The results of *F* value are reported in Table 14.

Table 14. Anova

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	0.006	1	0.006	814.435	.000[b]
	Residual	0	10	0		
	Total	0.006	11			
a. Predictors: (Constant), Building (X_2)						

The Normality Test assessed the normal distribution of the data. The data exhibits a diagonal spread and the histogram displays a bell-shaped distribution, suggesting that the standardised residuals follow a normal distribution. Figure 3 displays the results of the normality and histogram tests.

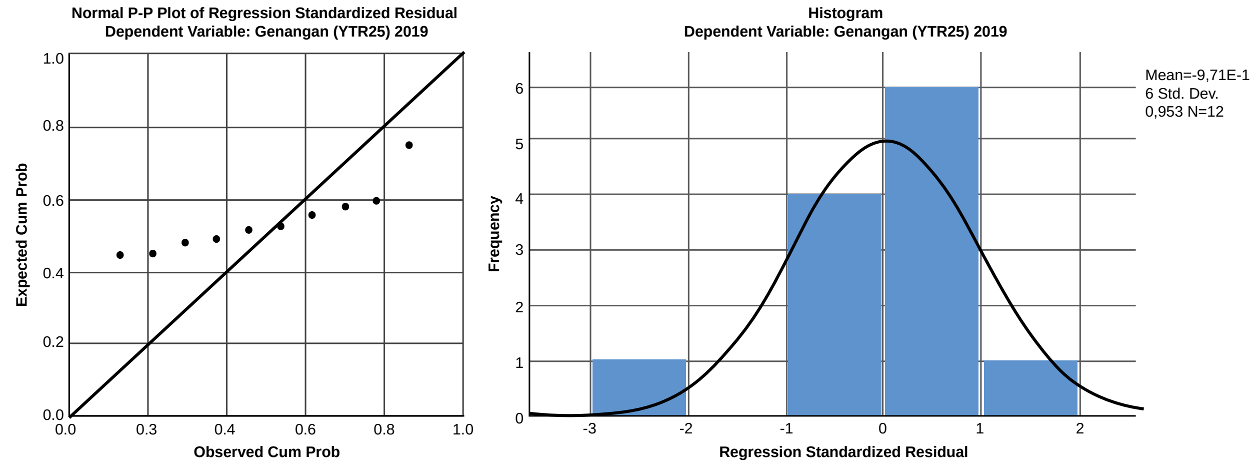

Figure 3. Normality and Histogram Test

A t-test was conducted to assess the extent to which the independent variable (Building) accounts for the dependent variable (inundation), with a confidence level of 95%. Given a condition where the value of TCount is greater than TTable and the degrees of freedom (df) is 6, the corresponding TTable value is 1.943. The T count exceeds 1.943. Hair et al. (2019) found that the significance value is less than 0.05, suggesting a partial effect on the dependent variable (Y). Table 14 presents the coefficients.

Table 14. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-0.00033	0.001		-0.343	0.739		
	R.T.B (X_2)	0.00261	0	0,994	28.538	0	1	1
a. Dependent Variable: Inundation (YTR_{25})								

After successfully passing all the classical assumption tests, including the T-test and the F-test, the regression equation can be observed in equation form (1)

$$TR_{25} = -0.0003 + 0.0026\, X_2 \quad (1)$$

where:

TR_{25} = Inundation TR25
X_2 = Building

4. Discussions

Urban areas experience flooding and inundation issues due to alterations in land use, inadequate drainage systems, the presence of sloping terrains, and the formation of basin areas. The rise in the construction of impermeable land surfaces has been found to have several implications, including increased runoff, elevated rainfall levels, and challenges associated with river widening and settlement relocation. Moreover, the occurrence of inundation can be influenced by various factors, including rainfall and the conversion of water catchment land to building land within a watershed. The research location exhibited a building land area percentage of 92.54%, with the remaining 7.46% designated as pervious water catchment area. As per the provisions outlined in Law UU. No. 26 of 2007, it is mandated that the previous area in spatial planning must constitute 30% of the overall area. The study findings indicate that the location being examined does not meet the required previous area as specified by current regulations. Therefore, the occurrence of inundation is unavoidable.

Based on the analysis of the data, it has been determined that the conversion of pervious land to buildings within the Krukut watershed is a significant contributing factor to the observed increase in inundation events. A highly pronounced positive correlation exists between the occurrence of inundation events and the presence of buildings. Consequently, it is imperative to implement measures aimed at effectively managing and mitigating inundation at the research site. The estimated equation model represents Y = -0.0003 + 0.0026 X2. One can interpret the equation as follows: The building area spans 68.04 square kilometres, and as part of the planned 25-year period, an inundation event is expected to affect an area of 0.17 square kilometres. Table 15 documents and presents the inundation potential.

Table 15. Inundation Potential

No	Water Catchment Area	Potency	YTR_{25} (Ha)	Note
1	Mampang Depok	Potential	0.1	Potentially Flooded
2	Salak	Potential	0.63	Potentially Flooded
3	Perikanan	Potential	0.64	Potentially Flooded
4	Danyong	Potential	0.1	Potentially Flooded
5	Pinang Kali	Potential	1.52	Potentially Flooded
6	Elnusa	Potential	0.09	Potentially Flooded
7	Palem/Pelita	Potential	0.39	Potentially Flooded
8	Asem	Potential	0.52	Potentially Flooded
9	Nipah/Ciragil	Potential	0.39	Potentially Flooded
10	Sungai Mampang	Potential	7.61	Potentially Flooded
11	Bendungan Hilir	Potential	0.15	Potentially Flooded
12	Sungai Krukut	Potential	5.17	Potentially Flooded

The Model Development Analysis demonstrates that the presence of inundation (Y) resulting from runoff discharge (R) that exceeds the capacity of the drainage system (D) results in an elevated runoff discharge (R'). The increased runoff discharge is a result of the construction of impervious land surfaces. Figure 4 visually depicts the analysis of model development, as described earlier. This figure serves as an implication of the study.

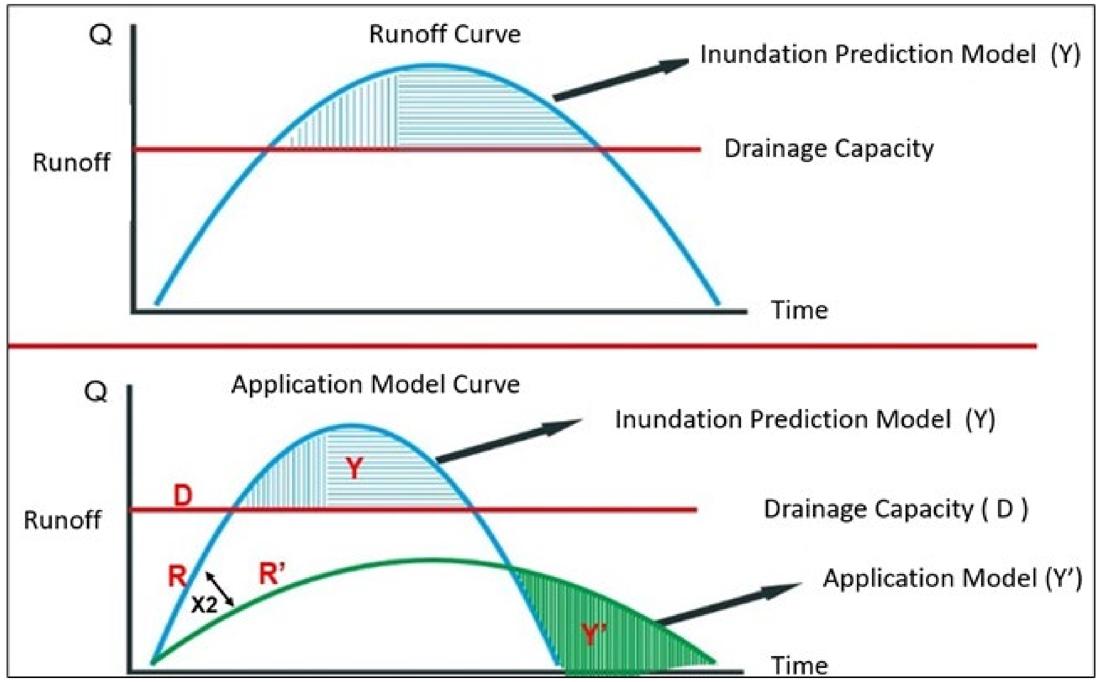

Figure 4. Inundation Map of the Krukut Watershed

Based on the illustration depicted in Figure 4, the formation of two runoff curves can be observed. The blue curve represents the pre-model application inundation, while the green curve represents the post-model application inundation. The horizontal axis represents time, while the vertical axis displays the runoff discharge. The variable "R" represents the initial runoff, while "R'" denotes the runoff trajectory after applying the model. D represents the maximum capacity of the city's drainage system. On the other hand, Y refers to the Inundation Prediction model, while Y' represents the Application Model. The analysis infers that the implementation of the application model has altered the trajectory of the R curve, forming the R' curve. This indicates that the presence of previous areas can effectively mitigate runoff.

Model Accuracy Test Analysis

The accuracy evaluation test stage measures the level of correctness in the final model output. The model outputs consist of area and location points that are identified as having the potential for inundation. These results are then compared to the findings from field checks conducted in each catchment area. The contingency matrix, also known as the error matrix or confusion matrix, along with kappa analysis, is employed for mathematical evaluation. Table 16 presents a comparison between the outcomes data of the model and the results obtained from field checks, error matrices, and the findings of the model accuracy evaluation. Table 17 displays the error matrix comparing the model results with the field data. The evaluation of modelling results accuracy is presented in Table 18. Table 19 presents the results of Cohen's Kappa Agreement. The study achieved an overall accuracy rate of 91.67%, with a kappa (k) accuracy of 83%. The modelling output in this study demonstrates a high level of realism.

Table 16. Comparison of Model and Field Data

No	Sub System	Potential Inundation Category	
		Model Data	Field Data
1	Mampang Depok	Potential	Potential
2	Salak	Potential	Potential
3	Perikanan	Potential	Potential
4	Danyong	Potential	Potential
5	Pinang Kali	Potential	Potential
6	Elnusa	Potential	No Potential
7	Palem/Pelita	Potential	Potential
8	Asem	Potential	Potential
9	Nipah/Ciragil	Potential	No Potential
10	Sungai Mampang	Potential	Potential
11	Bendungan Hilir	Potential	Potential
12	Sungai Krukut	Potential	Potential

Table 17. Error matrix of model results against field data

		Field Data		Σ1
		T	B	
Model Data	B	12	0	12
	T	2	10	12
Σ2		14	10	24

Notes:
B = Potential Inundation Category, T = Category not potentially inundation, **Σ1** = Number of Row , **Σ2** = Number of Column

Table 18. Assessment of Modeling Result Accuracy Evaluation

No	Evaluation	Potency (%)	No Potency (%)
1	UA	50,00	58,33
2	PA	50,00	41,67
3	OA	91,67	
4	κ	0,83	

UA= user's accuracy; PA = producer's accuracy; OA= overall accuracy; κ = kappa coefficient

Table 19. Cohen's Kappa Agreement

K	Strength of agreement
<0,20	Poor
0,21 – 0,40	Fair
0,41 – 0,60	Moderate
0,61 – 0,81	Good
0,81 - 1	Very Good

5. Conclusions

The analysis and discussion in this study indicate that the area of inundation in the Krukut watershed is strongly influenced by buildings/impervious (X2), with a significant positive correlation and an R2 value of 98.7%. The prediction model equation is as follows: Y_{TR25} = -0,0003 + 0,0026 $X_{2; coverage}$ Krukut watershed. The Interpretation Analysis of Land Use in the Krukut Watershed indicates that building land use accounts for 92.54% of the total, while water land use only represents 1.67%. Based on the results of field applicability testing and accuracy testing, the prediction models demonstrate a high level of accuracy, falling within the Very Strong or Very Good category. A kappa coefficient value of 0.83 supports these prediction models' high level of accuracy.

Based on the projected rainfall of 165 mm/day and the peak discharge of the Krukut River at 322.13 m3/sec, it is anticipated that the Krukut watershed will experience a flooding area of 17.6 hectares. In order to effectively manage inundation, it is recommended to focus on restoration efforts and develop policies that prioritise environmental interests. Specifically, it is important to prioritise the target of achieving 17.6 hectares of infiltration/pervious land use in the Krukut Watershed.

6. Suggestions

The study recommends that the government should decrease the rate of impervious area development in urban areas. To optimise model performance, it is advisable to utilise up-to-date land use data, as this will yield more precise values for accuracy tests during application. Model applications can be employed to mitigate flood and inundation disasters on the Krukut River through the establishment of an early warning system along its course. This study has practical implications for modelling applications and mitigation efforts related to the Krukut River.

Reference

Aslam, M. (2019). Introducing Kolmogorov–Smirnov tests under uncertainty: an application to radioactive data. *ACS omega, 5*(1), 914-917. https://doi.org/10.1021/acsomega.9b03940

Astuti, I. S., Sahoo, K., Milewski, A., & Mishra, D. R. (2019). Impact of land use land cover (LULC) change on surface runoff in an increasingly urbanized tropical watershed. *Water Resources Management, 33*, 4087-4103. https://doi.org/10.1007/s11269-019-02320-w

Bailey, O., Zlatanovic, L., van der Hoek, J. P., Kapelan, Z., Blokker, M., Arnot, T., & Hofman, J. (2020). A stochastic model to predict flow, nutrient and temperature changes in a sewer under water conservation scenarios. *Water, 12*(4), 1187. https://doi.org/10.3390/w12041187

Berta Aneseyee, A., Noszczyk, T., Soromessa, T., & Elias, E. (2020). The InVEST habitat quality model associated with land use/cover changes: A qualitative case study of the Winike Watershed in the Omo-Gibe Basin, Southwest Ethiopia. *Remote Sensing, 12*(7), 1103. https://doi.org/10.3390/rs12071103

Dammayatri, R., Susantoro, T. M., & Wikantika, K. (2023). Green Open Space and Barren Land Mapping for Flood Mitigation in Jakarta, the Capital of Indonesia. *The Indonesian Journal of Geography, 55*(2), 197-205. https://doi.org/10.22146/ijg.76452

Degife, A., Worku, H., Gizaw, S., & Legesse, A. (2019). Land use land cover dynamics, its drivers and environmental implications in Lake Hawassa Watershed of Ethiopia. *Remote sensing applications: society and environment, 14*, 178-190. https://doi.org/10.1016/j.rsase.2019.03.005

Desta, H., & Fetene, A. (2020). Land-use and land-cover change in Lake Ziway watershed of the Ethiopian Central Rift Valley Region and its environmental impacts. *Land use policy, 96*, 104682. https://doi.org/10.1016/j.landusepol.2020.104682

Fitriyanto, B. R., & Helmi, M. (2019). Analyzing spatiotemporal types and patterns of urban growth in watersheds that flow into Jakarta Bay, Indonesia. *Remote sensing applications: society and environment, 14*, 170-177. https://doi.org/10.1016/j.rsase.2019.04.002

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European business review, 31*(1), 2-24. https://doi.org/10.1108/EBR-11-2018-0203

Hu, R., Fang, F., Salinas, P., Pain, C., Domingo, N. S., & Mark, O. (2019). Numerical simulation of floods from multiple sources using an adaptive anisotropic unstructured mesh method. *Advances in Water Resources, 123*, 173-188. https://doi.org/10.1016/j.advwatres.2018.11.011

Li, Y., Wang, H., Deng, Y., Liang, D., Li, Y., & Shen, Z. (2022). How climate change and land-use evolution relates to the non-point source pollution in a typical watershed of China. *Science of The Total Environment, 839*, 156375. https://doi.org/10.1016/j.scitotenv.2022.156375

Rajaei, F., Dahmardeh Behrooz, R., Ahmadisharaf, E., Galalizadeh, S., Dudic, B., Spalevic, V., & Novicevic, R. (2021). Application of integrated watershed management measures to minimize the land use change impacts. *Water, 13*(15), 2039. https://doi.org/10.3390/w13152039

Ruan, Y., Mohtadi, M., van der Kaars, S., Dupont, L. M., Hebbeln, D., & Schefuß, E. (2019). Differential hydro-climatic evolution of East Javanese ecosystems over the past 22,000 years. *Quaternary Science Reviews, 218*, 49-60. https://doi.org/10.1016/j.quascirev.2019.06.015

Russo, B., Valentín, M. G., & Tellez-Álvarez, J. (2021). The relevance of grated inlets within surface drainage systems in the field of urban flood resilience. A review of several experimental and numerical simulation approaches. *Sustainability, 13*(13), 7189. https://doi.org/10.3390/su13137189

Shen, Y., Morsy, M. M., Huxley, C., Tahvildari, N., & Goodall, J. L. (2019). Flood risk assessment and increased resilience for coastal urban watersheds under the combined impact of storm tide and heavy rainfall. *Journal of Hydrology, 579*, 124159. https://doi.org/10.1016/j.jhydrol.2019.124159

Tang, Z., Engel, B., Pijanowski, B. C., & Lim, K. (2005). Forecasting land use change and its environmental impact at a watershed scale. *Journal of environmental management, 76*(1), 35-45. https://doi.org/10.1016/j.jenvman.2005.01.006