REPORT

SYMPOSIUM IN INDONESIA

Theme:

(Toward Success of Relocation and Revival of The Capital City in Indonesia: Hydrologic Flood Modeling and Local Adaptation to Climate Change)

Location and Time :

Bandung Institute of Technology (ITB) – October, 15^{th} 2024

Pertamina University (UPER) – October, 17^{th} 2024

SYMPOSIUM TOWARD SUCCESS OF RELOCATION AND REVIVAL OF THE CAPITAL CITY IN INDONESIA: HYDROLOGIC FLOOD MODELING AND LOCAL ADAPTATION TO CLIMATE CHANGE

Key Note Speakers

Prof. Shuichi Kure
Toyama Prefectural University
Japan

Dr. Mohammad Farid
Institut Teknologi Bandung
Indonesia

Dr. Naoki Koyama
Chuo University
Japan

SYMPOSIUM CONTENTS

First Session

Topic

"Flood Mitigation Strategies of Each Country"

Speaker

1. **Prof. Shuichi Kure**
   Toyama Prefectural University
2. **Dr. Muhamad Farid**
   Institut Teknologi Bandung

Second Session

Topic

"Toward Success of Relocation and Revival of the Capital City in Indonesia"

Speaker

1. **Akbar Rizaldi**
   Toyama Prefectural University
2. **I Gede Putu Indra Aditya**
   Toyama Prefectural University

Third Session

Topic

"Research on Flood Modeling and Local Adaptation to Climate Change"

Speaker

1. **Dr. Naoki Koyama**
   Chuo University
2. **Ryuto Fujishita**
   Toyama Prefectural University
3. **Hasune Numazawa**
   Toyama Prefectural University

Additional Session — **How to Study Abroad in Japan**

FREE

Join Via
zoom

Jatinangor Campus, Lab Tek. 1-B (LD18)
Sediment Lab. (General Lecture Room)
Institut Teknologi Bandung

09:00 A.M - 05:00 PM GMT+7
October 15th, 2024

SYMPOSIUM TOWARD SUCCESS OF RELOCATION AND REVIVAL OF THE CAPITAL CITY IN INDONESIA: HYDROLOGIC FLOOD MODELING AND LOCAL ADAPTATION TO CLIMATE CHANGE

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Japan

Dr. Naoki Koyama
Chuo University
Japan

Dr. Adhi P.
Sultan Ageng Tirtayasa
University, Indonesia

Dr. Idham Riyando Moe
PUPR
Indonesia

Dr. Nurul Fajar Januriyadi
Pertamina University
Indonesia

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   Ministry of Public Works & Housing
3. **Dr. Naoki Koyama**
   Chuo University

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   Toyama Prefectural University

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FREE

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Auditorium in the Griya Legita Building
Pertamina University

09:00 A.M - 05:00 PM GMT+7
October 17th, 2024

Oct.15, 2024
Symposium toward Success of Relocation and Revival of the Capital City in Indonesia @ ITB

Japan’s new policy: River Basin Disaster Resilience and Sustainability by All

Prof. Dr. Shuichi Kure
Toyama Prefectural University, Japan

TOYAMA Prefectural University

流域治水とやま

disaster potential study laborotory

Acknowledgements

This symposium is supported

by

JSPS Bilateral Programs

for open partnership Joint Research Seminars.

Acknowledgements

We owe special gratitude to the late Dr. Akira Mano, Professor of Tohoku University, Japan. Dr. Mano's activity and network in Indonesia made this seminar possible. His kindness and passion were a gift to the scientific community, and he will be sorely missed.

Presentation Outline

Japan's new river management policy

Comprehensive Flood Control Measures

(Integrated Basin Management for Flood Control)

What is the difference???
Why did Japan change???

River Basin Disaster Resilience and Sustainability by All

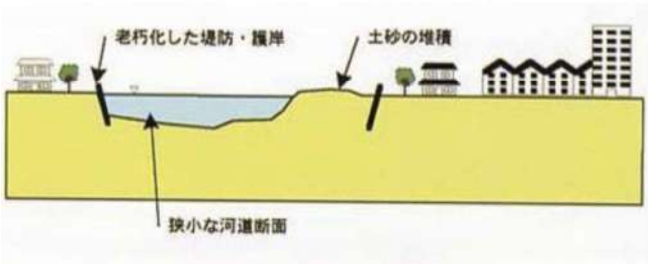
Flood Management in Japan

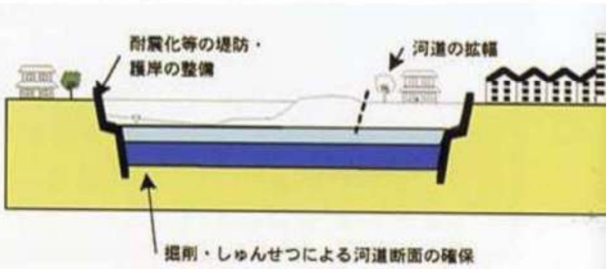
River channel Improvement (Ikeuchi, MLIT, 2012)

Widen and dredge rivers

before

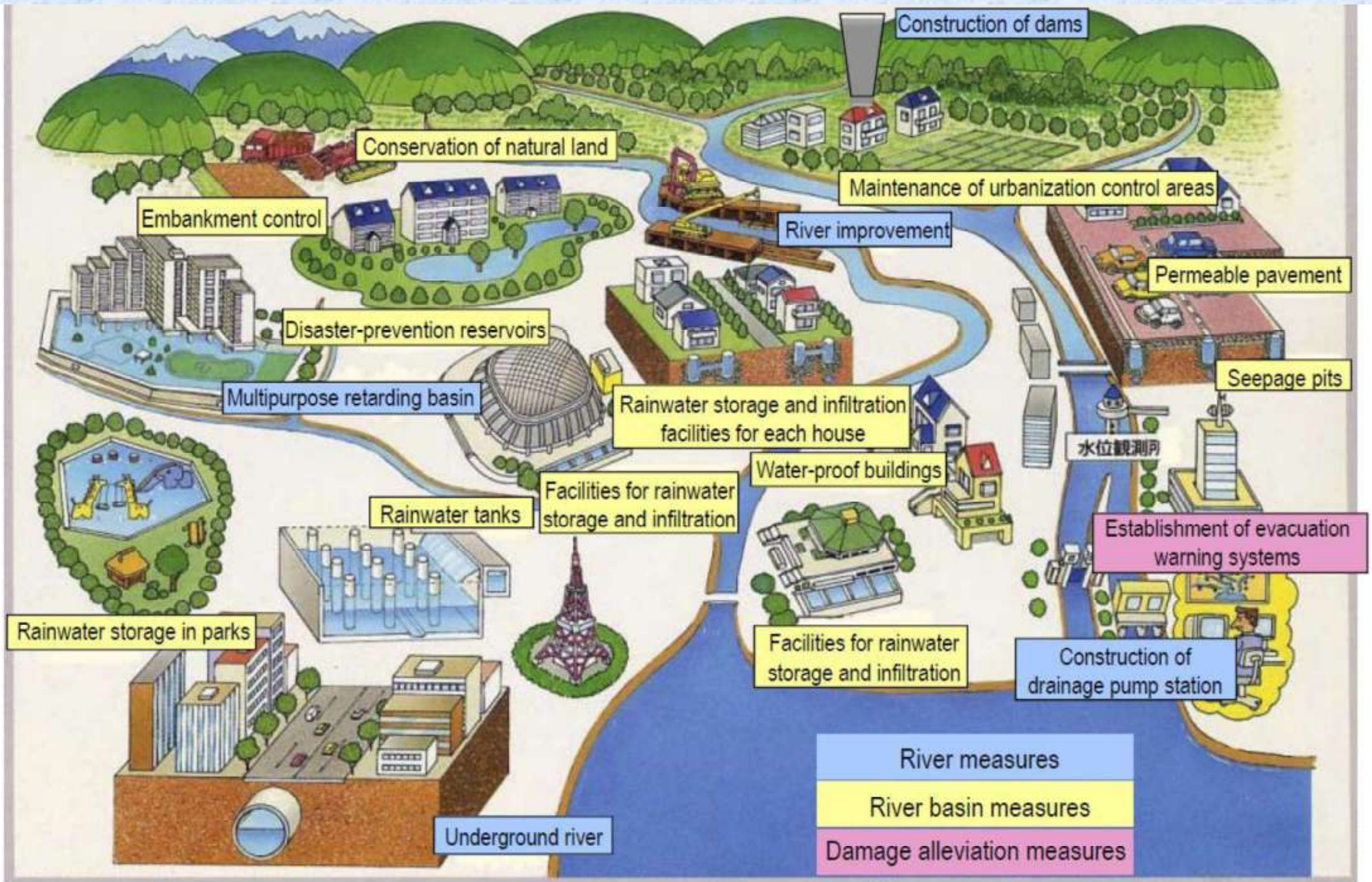
after





http://www.mlit.go.jp/river/basic_info/english/pdf/conf_01-0.pdf

Comprehensive Flood Control Measures in River Basin (Ikeuchi, MLIT, 2012)



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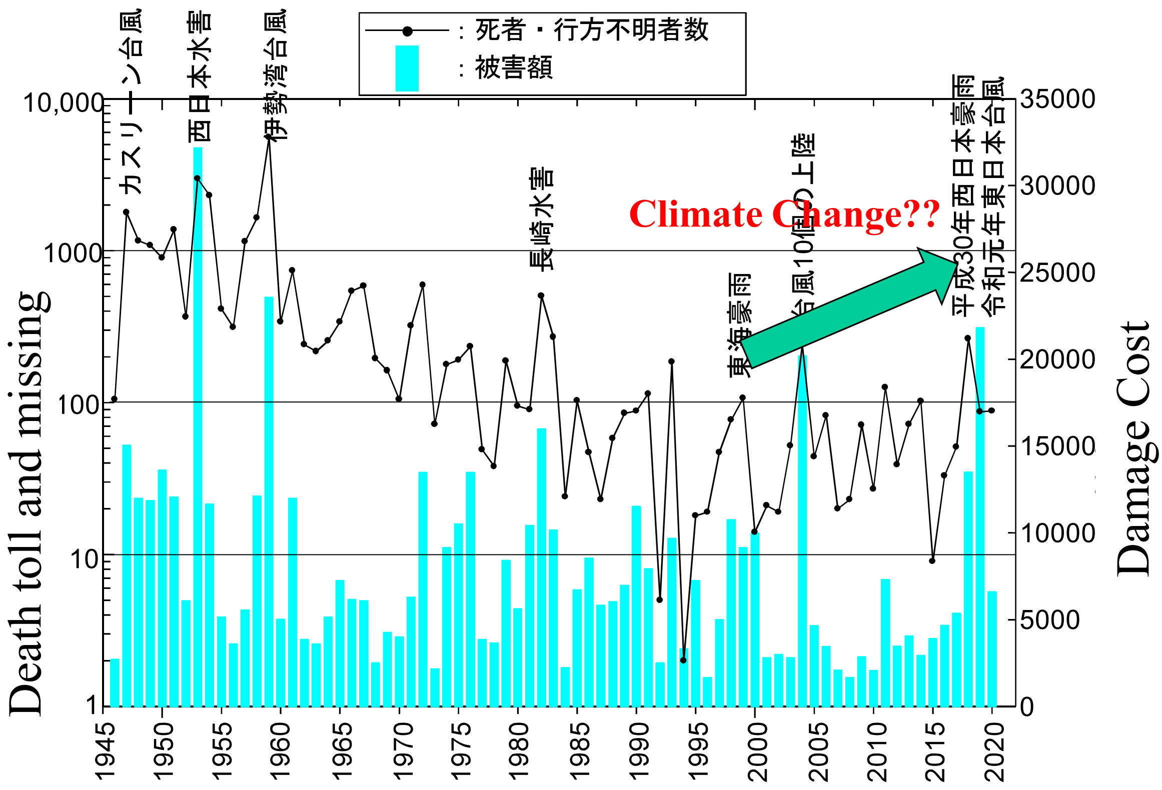
Historical Flood Damage in Japan



Based on river channel improvement, flood damage has been decreased in Japan dramatically. However, climate change may change this trend in the far future.

Recent Flood Disasters in Japan

Kinu River Flood disaster in 2015

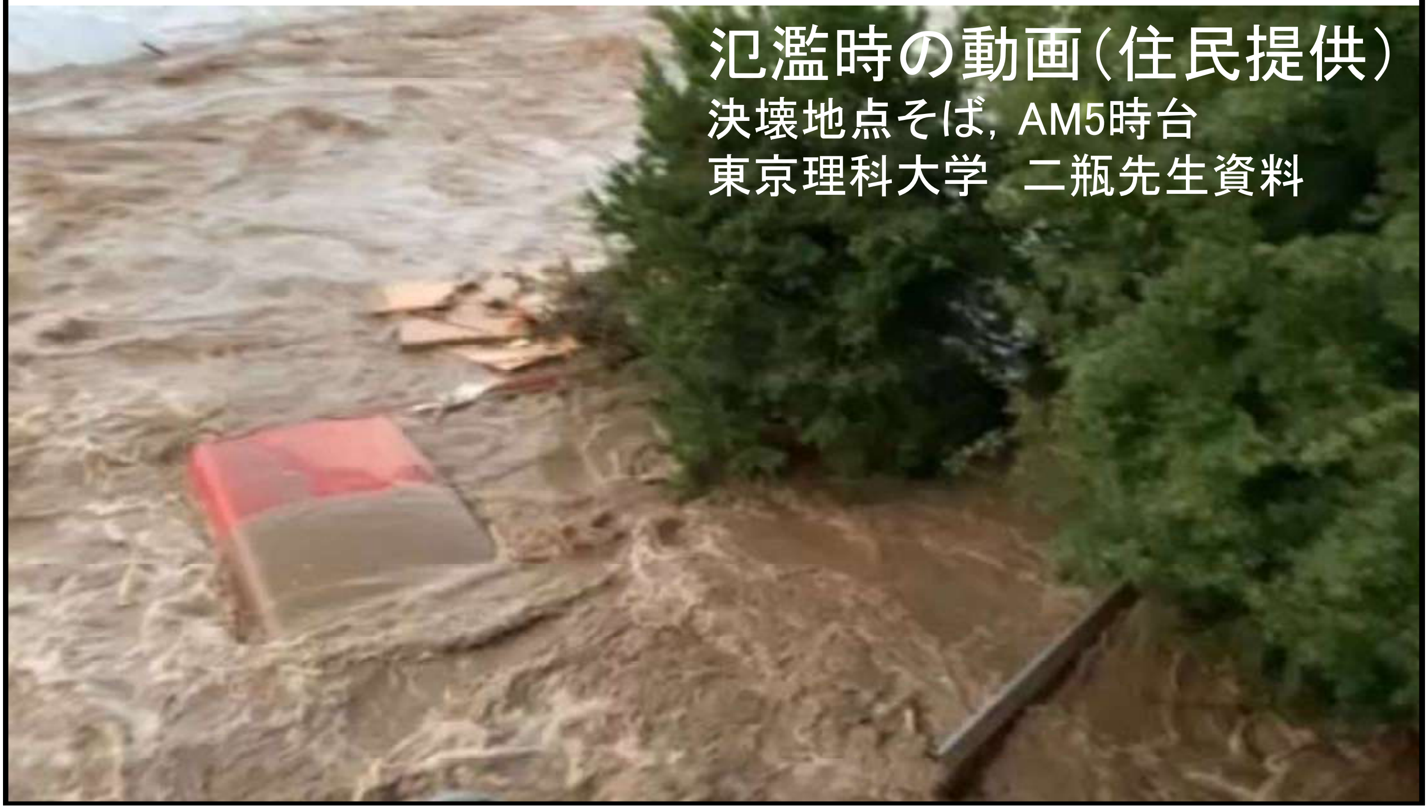
鬼怒川決壊状況（平成27 年9 月10 日 撮影:国土交通省関東地方整備局）

Recent Flood Disasters in Japan

Chikuma River Flood disaster in 2019

Recent Flood Disasters in Japan

Chikuma River Flood disaster in 2019



Problems in Japan

- Due to Climate Change, **magnitude and frequency of the floods are unbelievably increasing**.

- Many local residents and companies still **underestimate flood risk**.

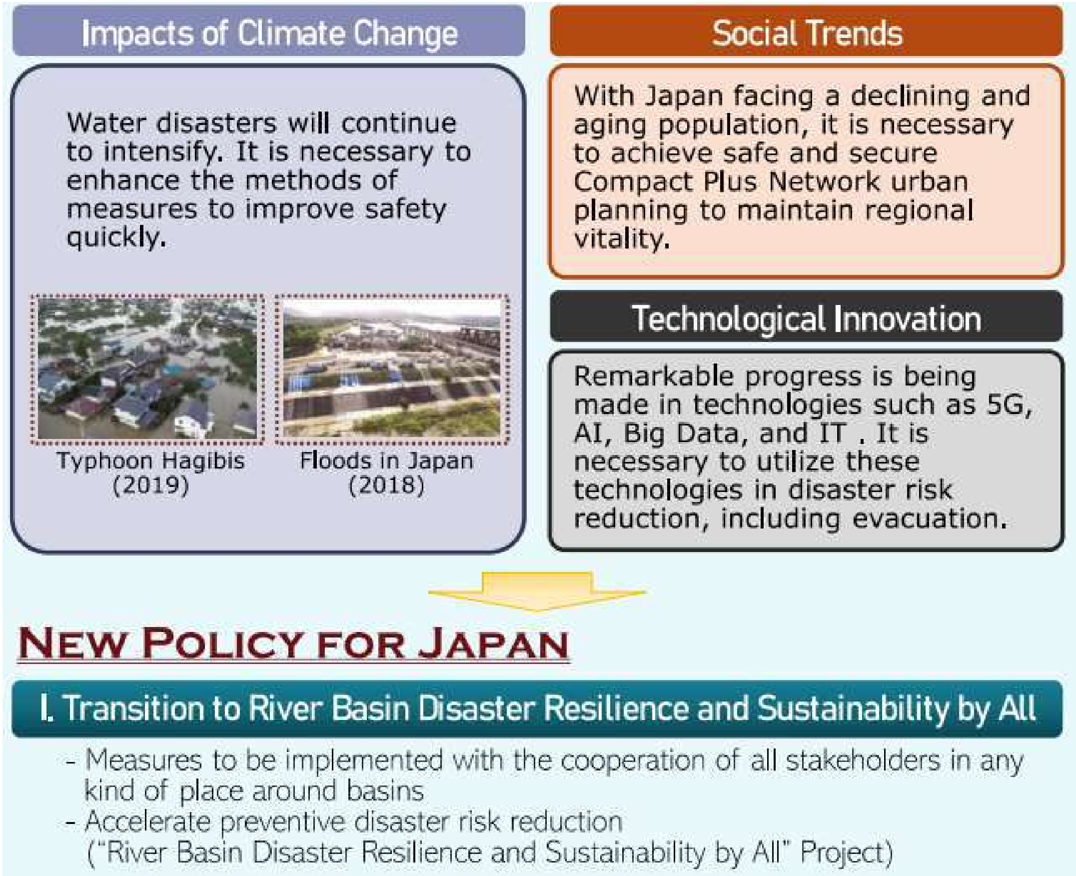
However, there is **no space and budget** to increase flood capacity in rivers and storage volume in basins. We cannot make any more dams and widen rivers!!!!!!

So, new policy has started:

River Basin Disaster Resilience and Sustainability **by All**

We have to ask other sectors (rather than river manager) and local residents to fight against the flood and use existing facility (dam and paddy fields) more effectively.

River Basin Disaster Resilience and Sustainability by All



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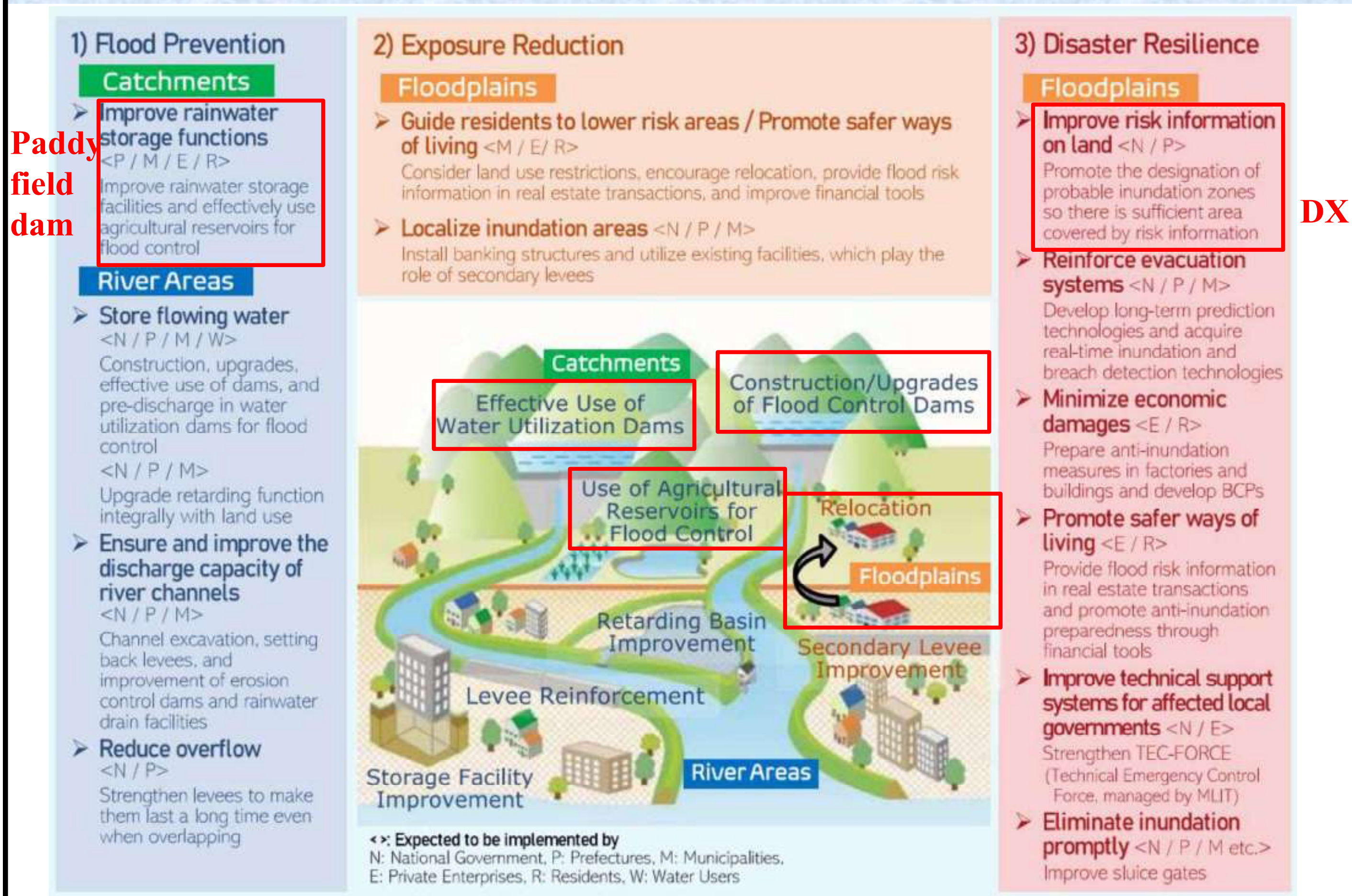
https://www.mlit.go.jp/river/kokusai/pdf/pdf21.pdf

River Basin Disaster Resilience and Sustainability by All



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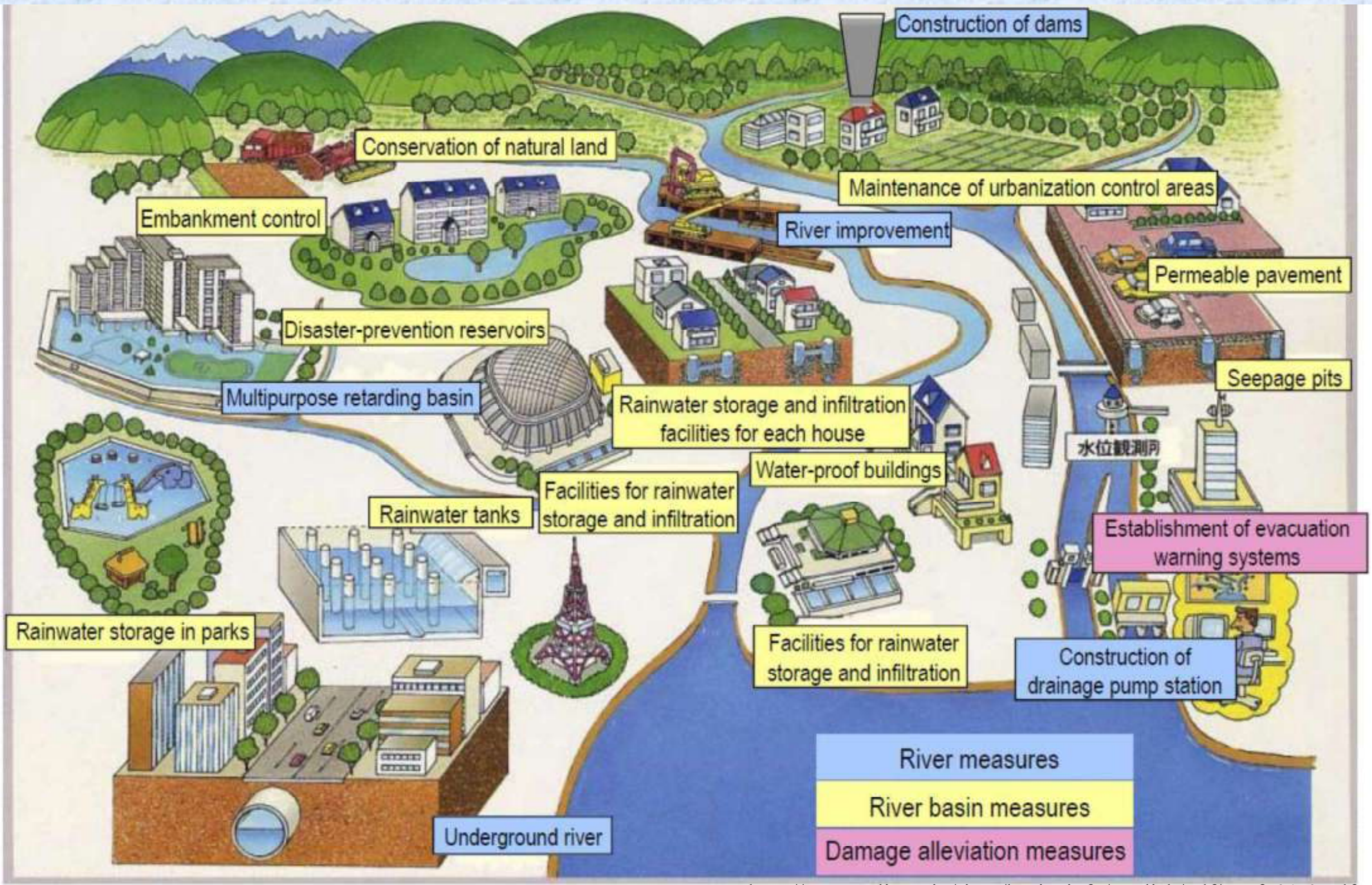
Comprehensive Flood Control Measures in River Basin (Ikeuchi, MLIT, 2012)



http://www.mlit.go.jp/river/basic_info/english/pdf/conf_01-0.pdf

Main differences

- DX (Digital Transformation)
- Cooperation with Agricultural Sector

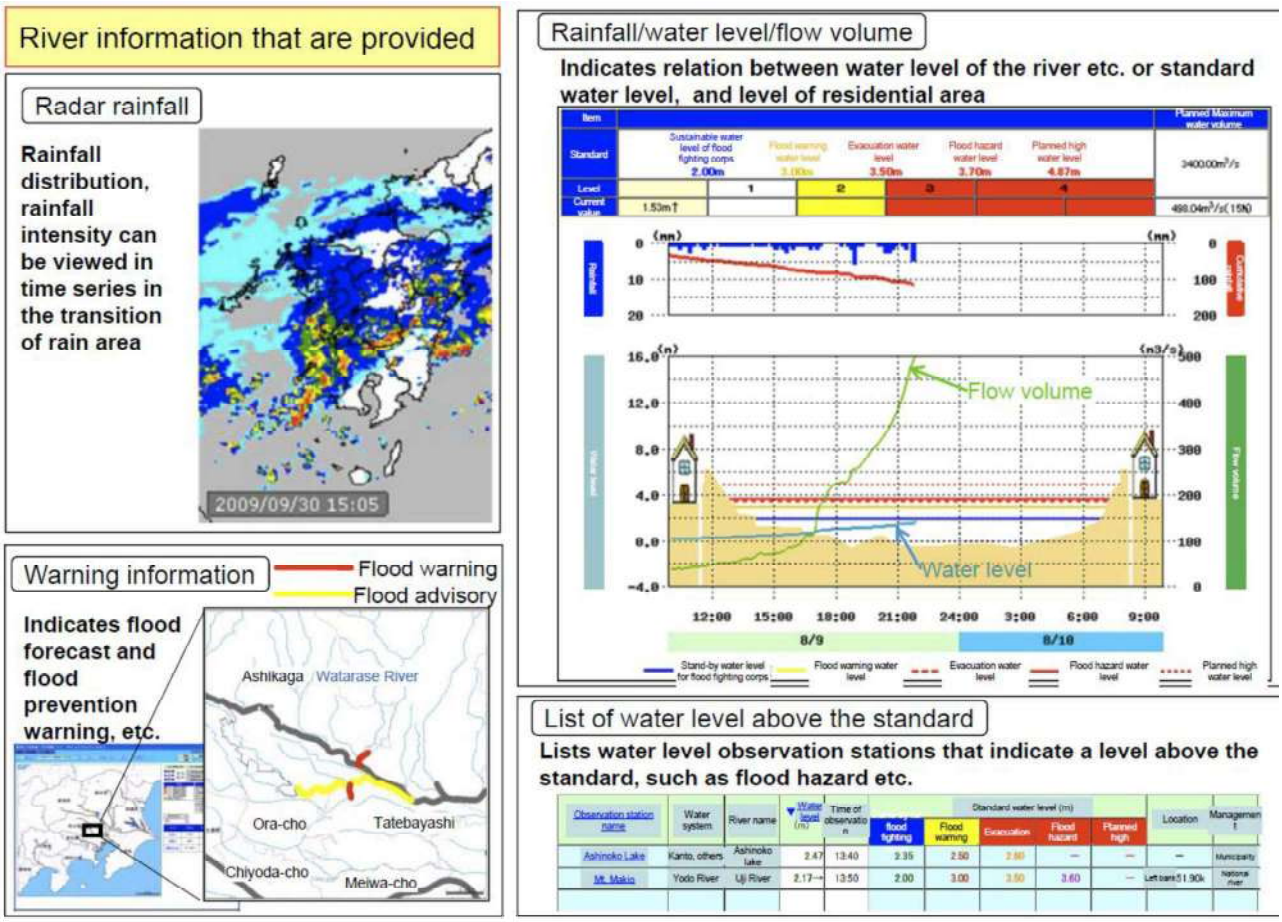
Effective use of water utilization dams (Dr. Koyama) by gate operations

Paddy field dam (Mr. Rizaldi and Ms. Numazawa)

- Etc.

DX

Provision of River Information (Ikeuchi, MLIT, 2012)



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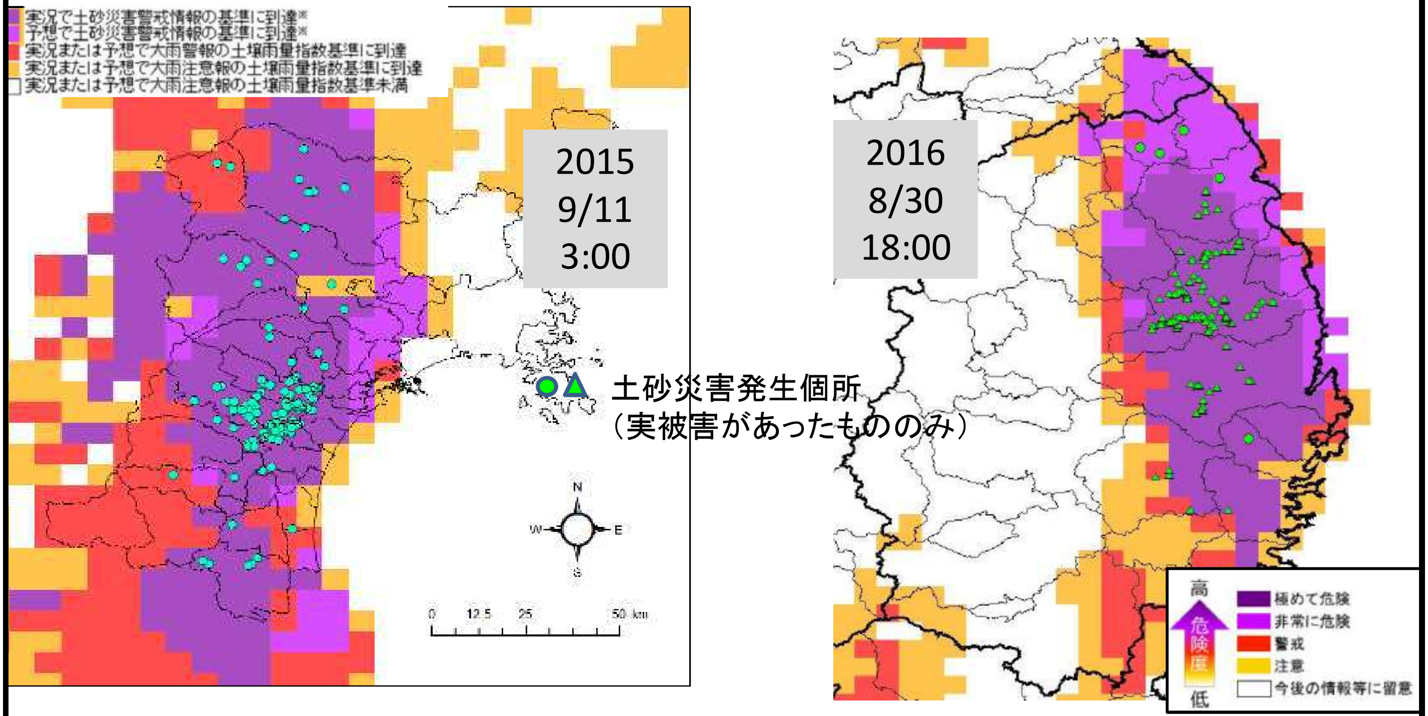
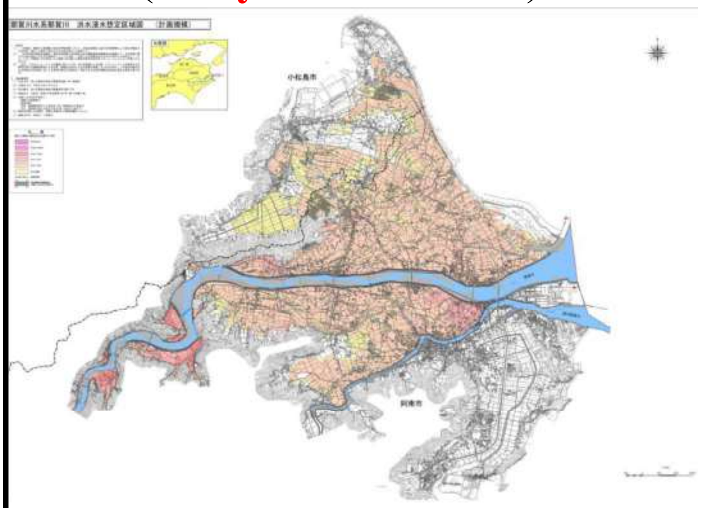
Real Time Landslide Risk Map (Sato et al., JDR, 2017)



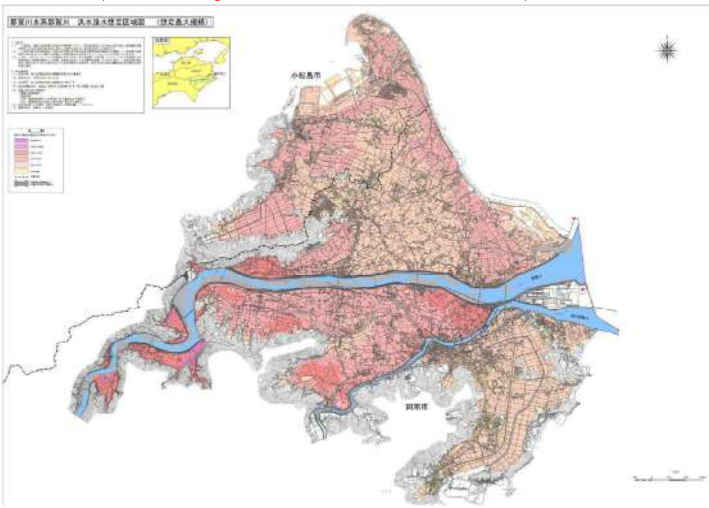
Correspondence between Real-time Landslide Risk Map and Locations of landslide occurrence in 2015 and 2016

Hazard Maps in Japan

L1 level
(**100 y-r**: 640mm/2d)



L2 level
(**1000 y-r**: 1198mm/2d)

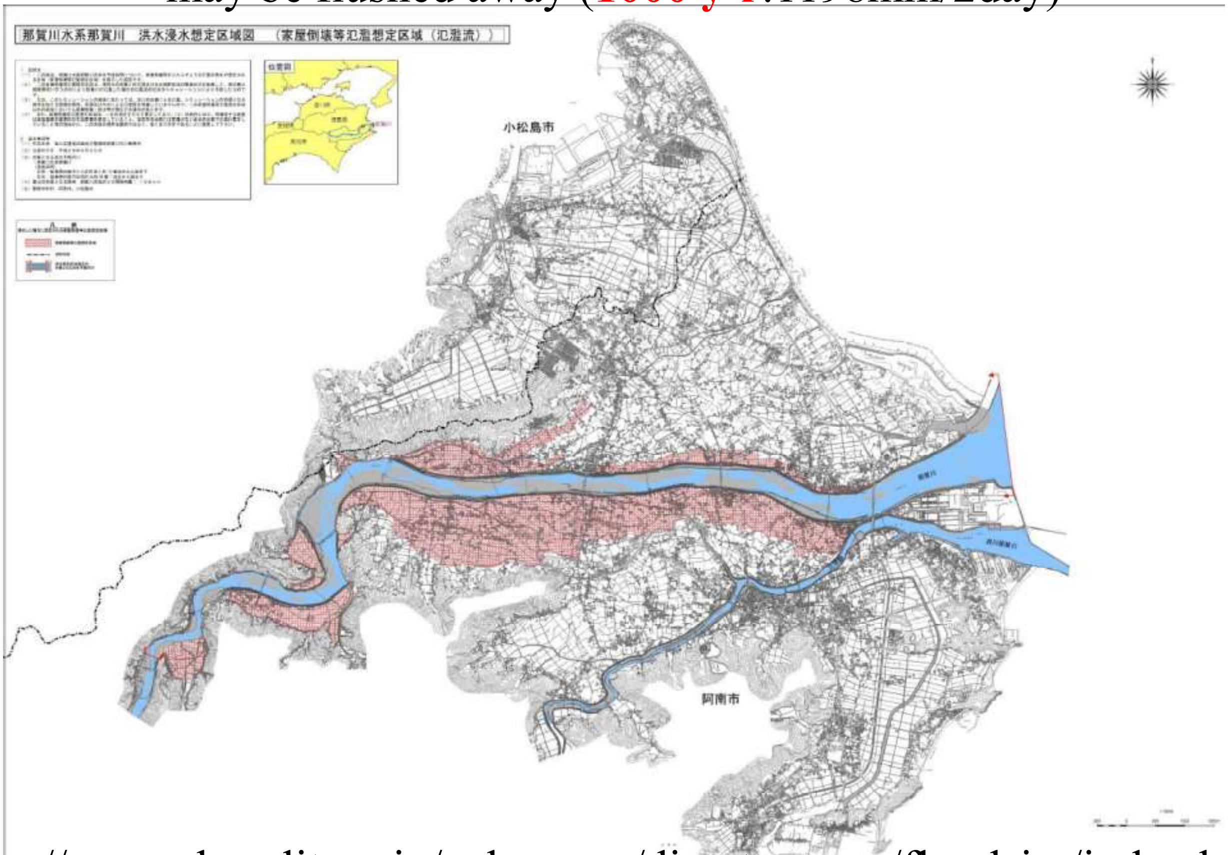


Flood Hazard map of L1 and L2 in Naka River basin

http://www.skr.mlit.go.jp/nakagawa/disaster-prev/floodsim/index.html

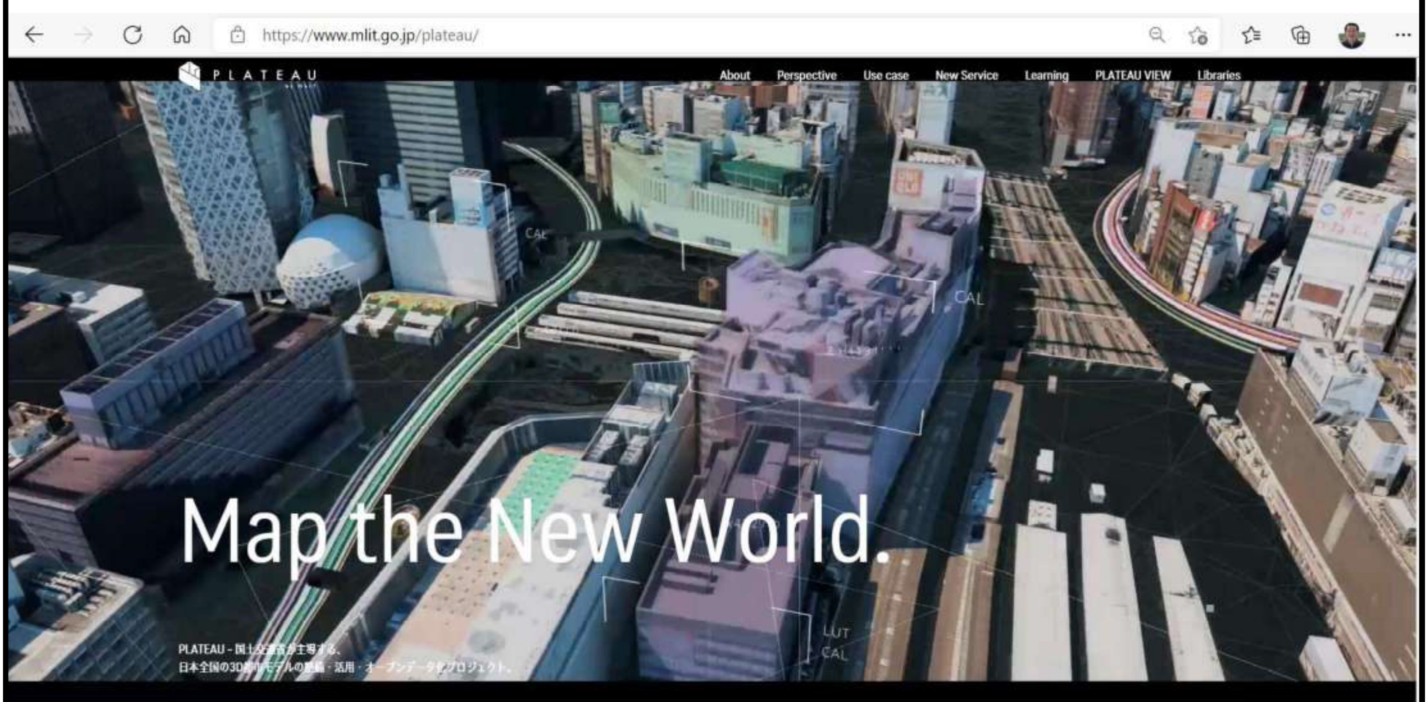
Hazard Maps in Japan

Hazard map also specified a High risk zone where houses may be flushed away (**1000 y-r**:1198mm/2day)



http://www.skr.mlit.go.jp/nakagawa/disaster-prev/floodsim/index.html

Toward Digital Twin：3D Urban Model



MLIT Project (PLATEAU)

https://www.mlit.go.jp/plateau/

3D Flood Inundation Map

浸水している範囲

破堤地点

富山駅

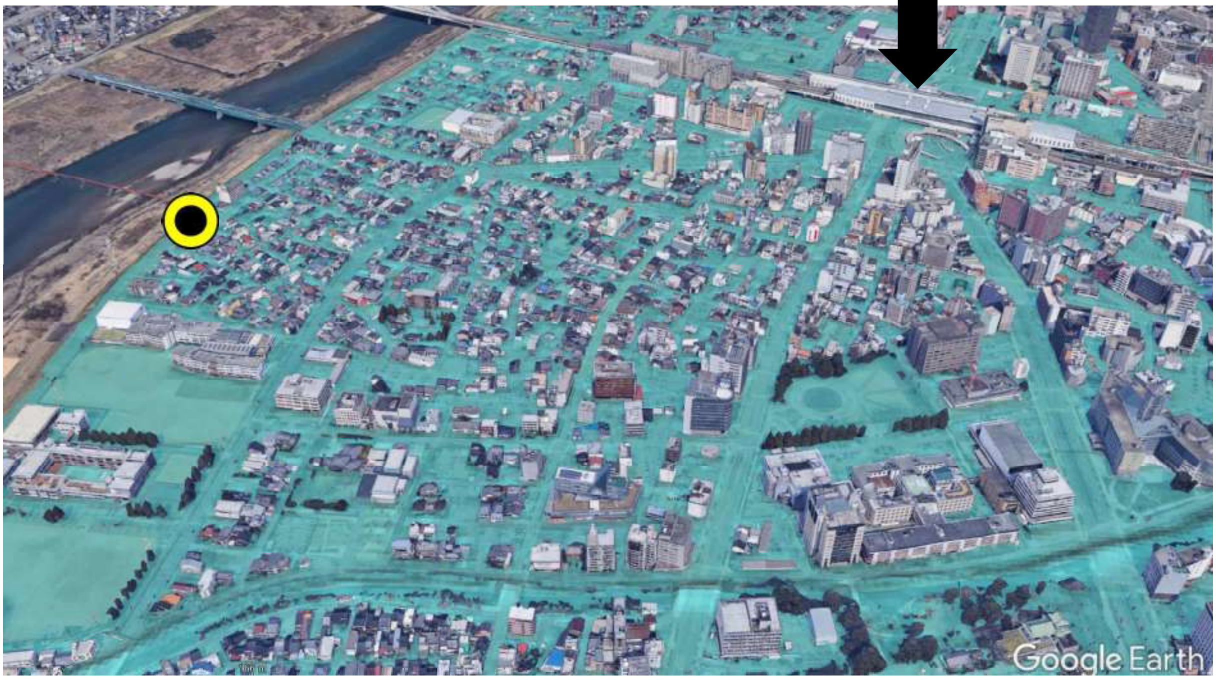


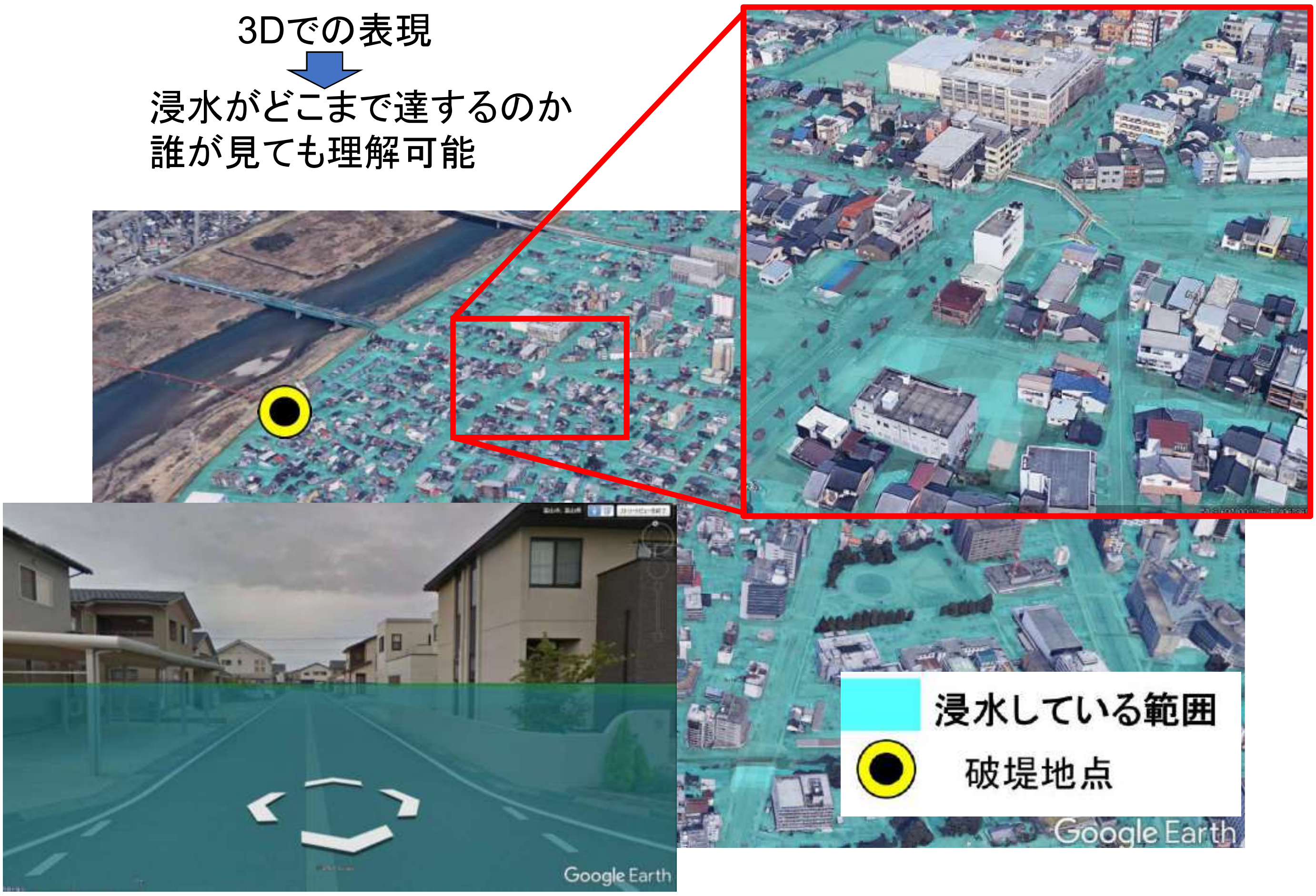
図8 3Dによる浸水状況の可視化
(家屋を高さによって考慮した結果より)

3D Flood Inundation Map

3Dでの表現

↓

浸水がどこまで達するのか
誰が見ても理解可能



Computer Graphics

東北大学保田真理先生・森口周二先生ご提供

東北大学森口周二先生ご提供

The movie was provided by Dr. S. Moriguch, Tohoku University

Main differences

- DX

- Use of Agricultural Sector

Effective use of water utilization dams (Dr. Koyama) by gate operations

Paddy field dam (Mr. Rizaldi and Ms. Numazawa)

- Etc.

Summary

In Japan, due to climate change and sever flood disasters, we have changed our flood control policy.

This is because too much water (floods) is coming due to climate change but there is no budget and space to storage this too much water.

So, now we need ask another sector such as agricultural department (paddy filed and dam reservoir) and local people by evacuation.

This is the meaning of River Basin Disaster Resilience and Sustainability by All .

Also, we are trying to employ DX for the flood control.

STUDY ON FLOOD HAZARD DUE TO CLIMATE CHANGE IN JAVA ISLAND, INDONESIA

Mohammad Farid, Ph.D.
Associate Professor
Faculty of Civil and Environmental Engineering
Institut Teknologi Bandung

Presented in:
Sympsium Toward Siccess of Relocation and Revival of the Capital City in Indonesia:
Hydrologic Flood Modeling and Local Adaptation to Climate Change
Bandung, 15th October 2024

REFERENCES

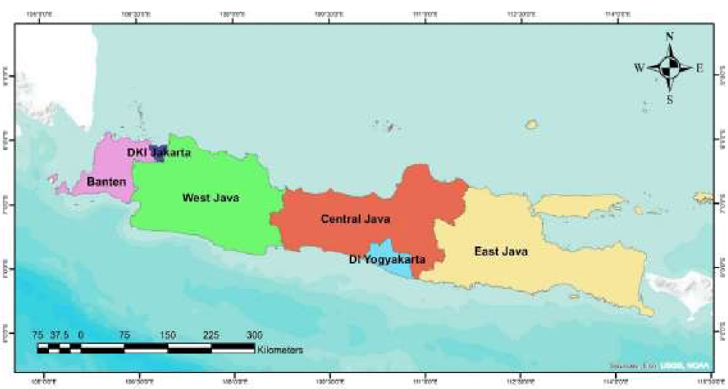
- Mohammad Farid, Yeremia Immanuel Sihombing, Arno Adi Kuntoro, Mohammad Bagus Adityawan, Muhammad Marshal Syuhada, Nurul Fajar Januriyadi, Idham Riyando Moe, Ardhi Nurhakim, "Development of flood hazard index under climate change scenarios in Java Island", Progress in Disaster Science, Vol. 20, 100302, 2023
- Yeremia Immanuel Sihombing, Mohammad Farid, Mohammad Bagus Adityawan, Arno Adi Kuntoro, Idham Riyando Moe, Rusmawan Surmawan, Muhammad Rais Abdillah, "Anticipating the Amplification of Flood Hazards in Java Island: A Climate Change Projection", AOGS 2024, Pyeongchang, Gangwon-do, South Korea, 25th June 2024

TREND OF FLOOD FREQUENCY IN INDONESIA

- Indonesia's National Disaster Management Agency (BPNB) has released a dataset revealing a stark rise in the number of flood occurrences until 2020
- This incremental increase can potentially be attributed to alterations in rainfall patterns induced by anthropogenic climate change on a global scale (Alexander, et al., 2006).
- The results of such extreme climatic shifts are evident in alterations to precipitation patterns, increased instances of drought, and fluctuations in seawater levels across the globe (Scoccimaro et al., 2013; Rohmat, et al., 2023; Vu, et al., 2018)

POTENTIAL INCREASE IN FUTURE NUMBER OF FLOOD IN JAVA

- **Java Island** stands as one of the world's most densely **populated** landmasses, accommodating a staggering **152 million individuals**, which equates to approximately **63.98% of Indonesia's total population** as of (BPS, 2022)
- **Java Island** also comprises **of 24 distinct basin areas**, each overseen and monitored by the Indonesian Ministry of Public Works and Housing.
- According to BNPB, the **number of flood events** experienced on Java Island in 2021 alone reached **approximately 560 incidents**, accounting for **48.25% of the entire spectrum** of flood-related disasters across Indonesia.
- **The number of floods might increase due to the future climate alteration**

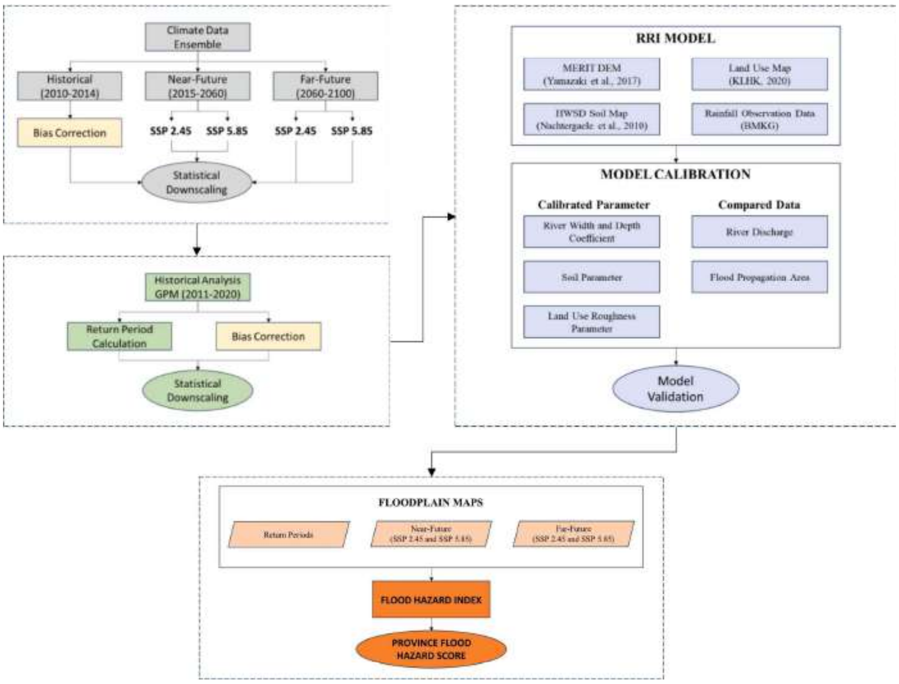


OBJECTIVE

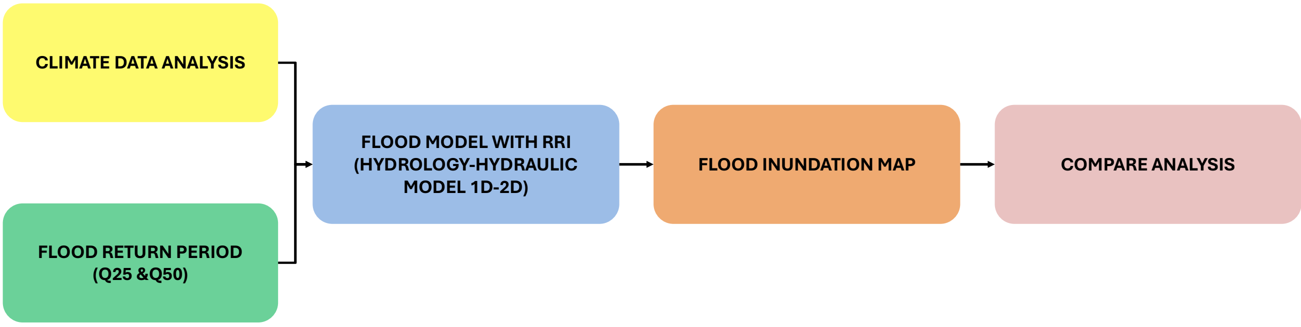
- To understand how climate change will impact the current flood mitigation system through comparative analysis.

SATREPS BRICC Project (2021-2026)

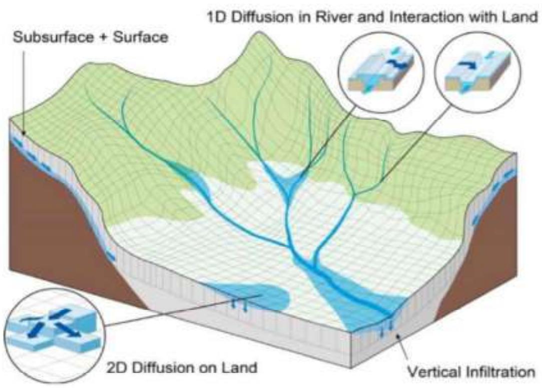
FRAMEWORK



HOW GREAT IS THE CLIMATE EFFECT COMPARED TO CURRENT FLOOD DESIGN?

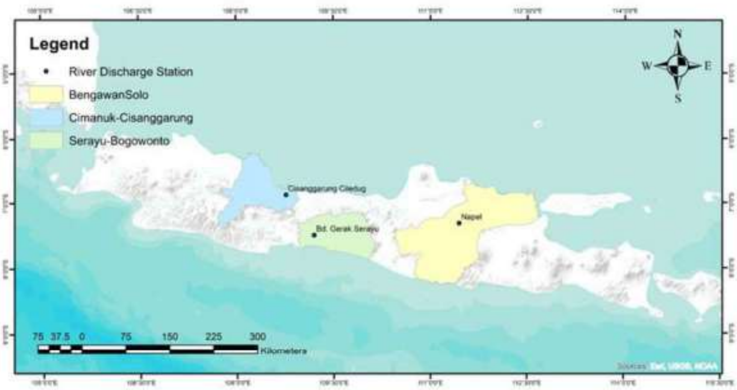


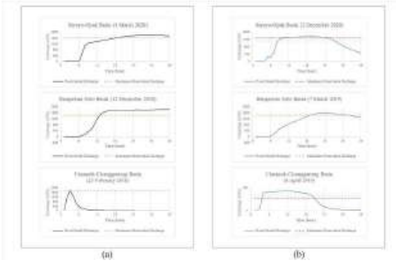
RRI MODEL (RAINFALL-RUNOFF-INUNDATION)



- Rainfall-Runoff-Inundation (RRI) model is a two-dimensional model capable of simulating rainfall-runoff and flood inundation simultaneously (Sayama et al., 2012, Sayama et al., 2015a, Sayama et al., 2015b).
- The model deals with slopes and river channels separately. At a grid cell in which a river channel is located, the model assumes that both slope and river are positioned within the same grid cell. The channel is discretized as a single line along its centerline of the overlying slope grid cell. The flow on the slope grid cells is calculated with the 2D diffusive wave model, while the channel flow is calculated with the 1D diffusive wave model.
- The RRI model simulates also lateral subsurface flow, vertical infiltration flow and surface flow. The lateral subsurface flow, which is typically more important in mountainous regions, is treated in terms of the discharge-hydraulic gradient relationship, which takes into account both saturated subsurface and surface flows.

FLOOD MODEL CALIBRATION & VALIDATION





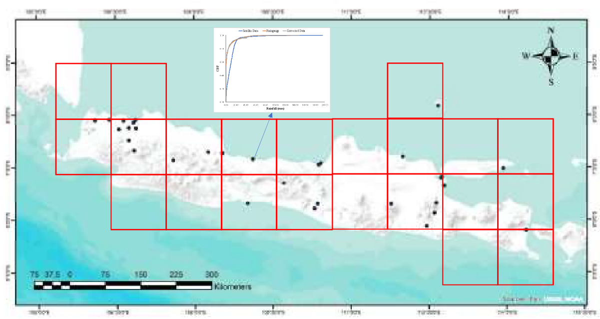
Discharge Calibration and Validation

Basin	Process	City(es)	Flood Propagation Area (km^2)		
			Low	Medium	High
Bengawan Solo	Calibration	Sukoharjo	36.10	27.14	19.42
		Surakarta	6.22	4.73	0.50
	Validation	Ngawi	28.65	2.33	11.30
		Lamongan	1.60	0.00	0.15
Cisanggarung	Calibration	Cirebon	5.03	0.75	0.20
	Validation	Cirebon	54.75	47.02	4.30
		Indramayu	64.74	142.30	45.42
Serayu	Calibration	Banyumas	5.12	9.53	16.76
		Purbalingga	26.19	9.33	39.33
	Validation	Banyumas	1.97	2.55	0.07
		Purbalingga	19.68	14.73	0.87

Flood Location Calibration and Validation

CLIMATE MODEL

Model	Resolution	Institution
CanESM5	2.8° x 2.8°	Canadian Centre for Climate Modelling and Analysis, Canada
CESM2	1° x 1°	National Center of Atmospheric Research (NCAR), USA
CESM2-WACCM	1° x 1°	National Center of Atmospheric Research (NCAR), USA
CNRM-CM6-1	1.4° x 1.4°	Centre National de Rcherces Meteorologiques, France
CNRM-ESM2-1	1° x 1°	Centre National de Rcherces Meteorologiques, France
IPSL-CM6A-LR	1° x 1°	Institut Pierre-Simon Laplace, France

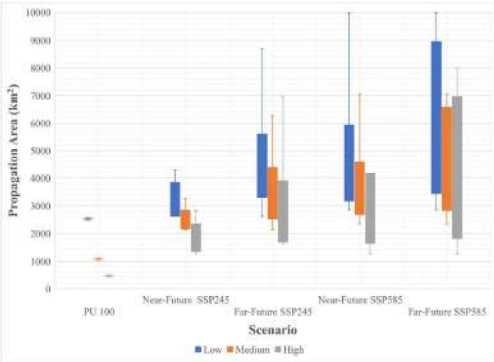


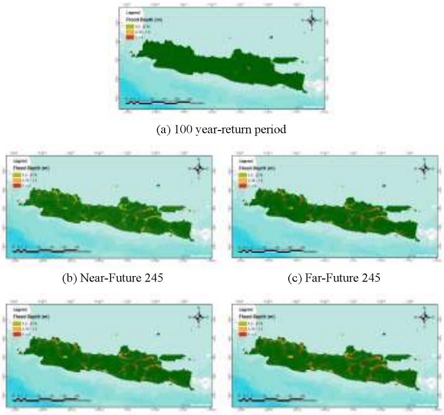
Maximum Precipitation in every scenarios was used in the flood model

Scenarios	*Period 2015-2060*	*Period 2061-2100*
SSP 2.45	1 **Moderate Near Future**	2 **Moderate Far Future**
SSP 5.85	3 **Extreme Near Future**	4 **Extreme Far Future**

SATREPS BRICC Project (2021-2026)


PROJECTED FLOOD INUNDATION





(a) 100 year-return period

(b) Near-Future 245

(c) Far-Future 245

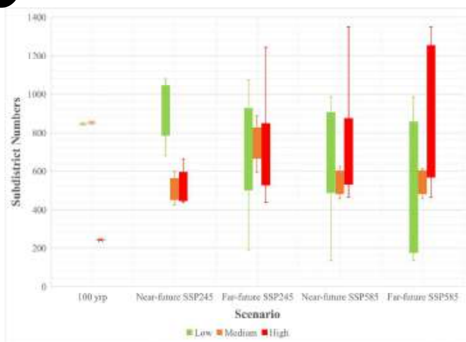
(d) Near-Future 585

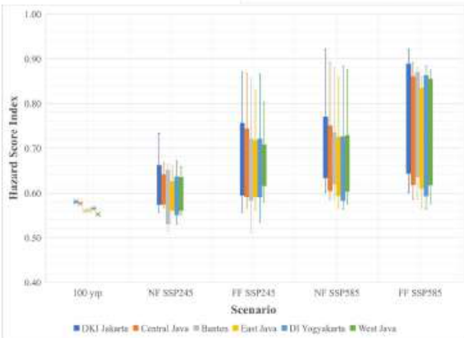
(e) Far-Future 585

- Notably, the flood propagation area in all classifications exceeded the 100-year return period.
- This dynamic is particularly intriguing as it highlights a continuous expansion of flood propagation areas over time. Furthermore, the shift toward more severe scenarios contributed to the amplification of flood propagation extents.

PROJECTED FLOOD HAZARD INDEX AND SCORES

- In this study, the Flood Hazard Index (FHI) mapping approach hinges on the maximum inundation depth within subdistrict areas. This methodology involves overlaying flood propagation maps onto administrative subdistrict maps
- The computation of flood hazard scores was predicated on the average hazard score index of subdistricts within each province
- This trend underscored that, much like flood propagation areas, the FHI for high hazards intensified with the passage of time and the exacerbation of scenarios
- The numerical modeling outcomes for Java Island highlight that DKI Jakarta and Central Java face the most pronounced flood hazard risk





COMPARE ANALYSIS

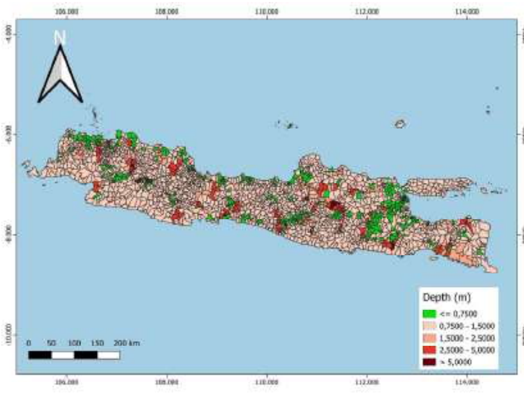
MODEL AGREEMENT TO DIRECTION OF CHANGE

This method illustrates the partial agreement in the direction of change (increase or decrease) in maximum flood extent across all climate scenarios. Each number indicates the percentage of models that agree on the direction of change.

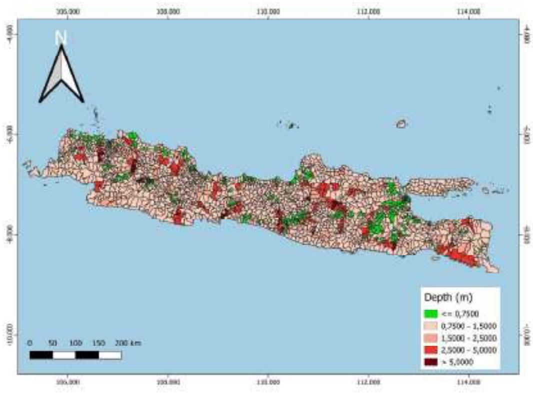
SIGNAL TO NOISE RATIO

The signal-to-noise ratio, {ΔT}/σ2T, compares the strength of the climate signal to the variability of noise. The signal stands out against the noise when and where this ratio is large. As the size of the ensemble grows, the signal will be better represented by the ensemble mean, and the noise will be averaged out over more independent realizations.

FLOOD MAP BASED ON SUB-DISTRICT



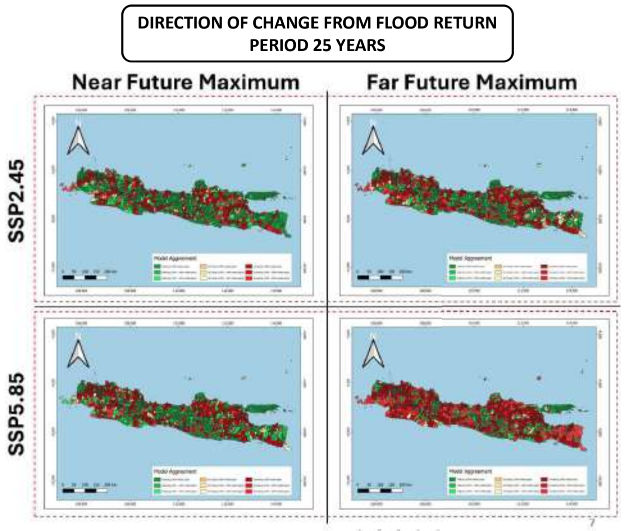
(a) Flood Extent for 25-year Return Period

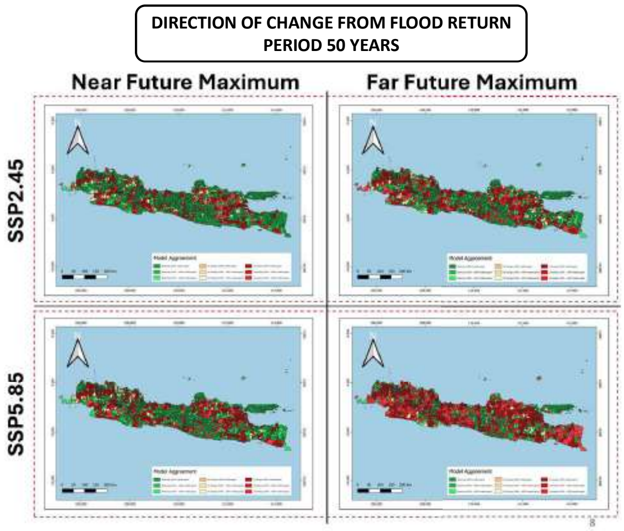


(b) Flood Extent for 50-year Return Period

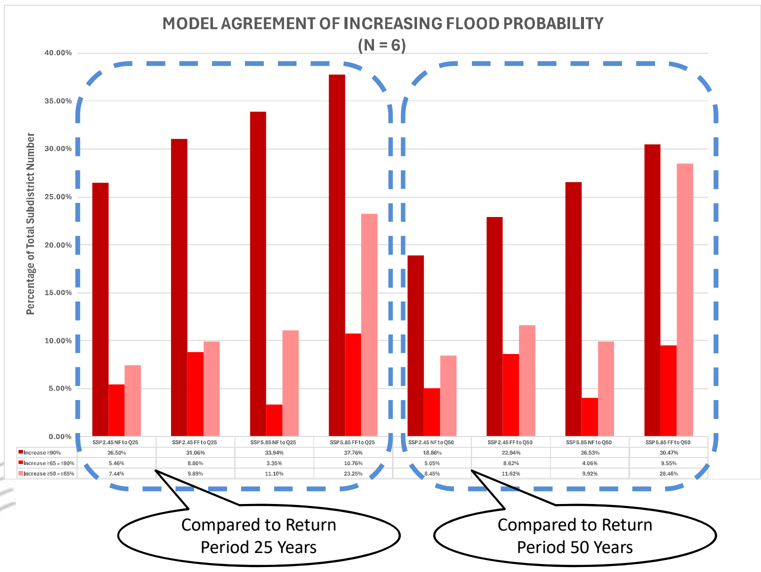
- In further analysis, the flood map will be categorized based on the maximum flood depth in each sub-district on Java Island.
- This approach will help indicate changes in flood extent based on specific areas.

MODEL AGREEMENT TO DIRECTION OF CHANGE





MODEL AGREEMENT TO DIRECTION OF CHANGE



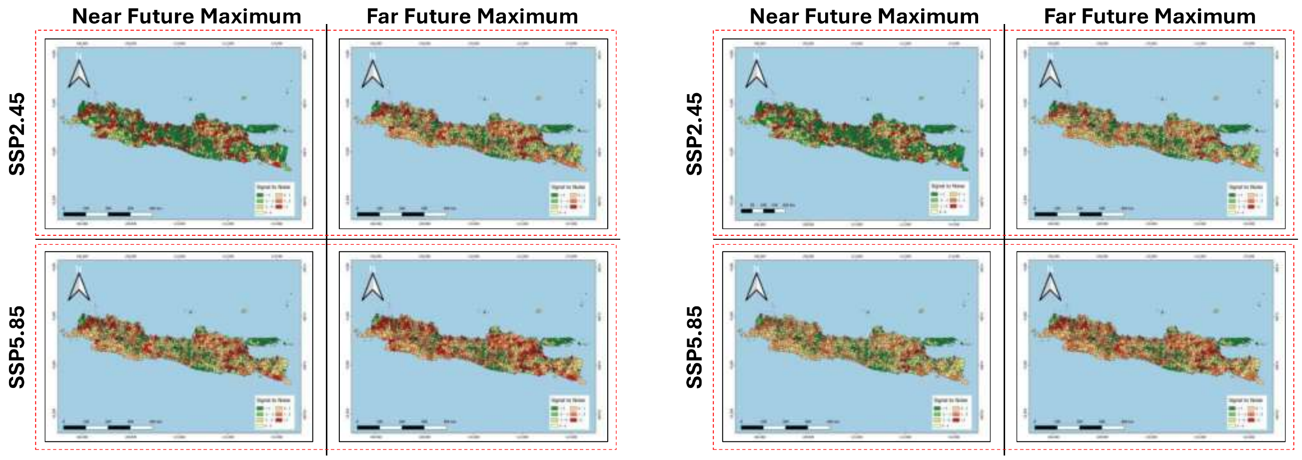
	SSP2.45 NF to Q25	SSP2.45 FF to Q25	SSP5.85 NF to Q25	SSP5.85 FF to Q25	SSP2.45 NF to Q50	SSP2.45 FF to Q50	SSP5.85 NF to Q50	SSP5.85 FF to Q50
Increase ≥90%	26.50%	31.06%	33.94%	37.76%	18.86%	22.94%	26.53%	30.47%
Increase ≥65 - ≤90%	5.46%	8.80%	3.35%	10.76%	5.05%	8.62%	4.06%	9.55%
Increase ≥50 - ≤65%	7.44%	9.89%	11.10%	23.25%	8.45%	11.62%	9.92%	28.46%

- The flood predictions from the GCM model were compared to the design flood return periods to determine the direction of change and model agreement.
- The results show that the difference between the GCM model and the 25-year return period is greater than the difference for the 50-year return period.
- The model indicates a consistent increase in flood probability over time and with scenario enhancements in both comparisons. However, there appears to be increasing low agreement in the projections.
- **Therefore, the higher the return period gave the more similar result climate change flood extent due to the small number of gap.**

SIGNAL TO NOISE RATIO

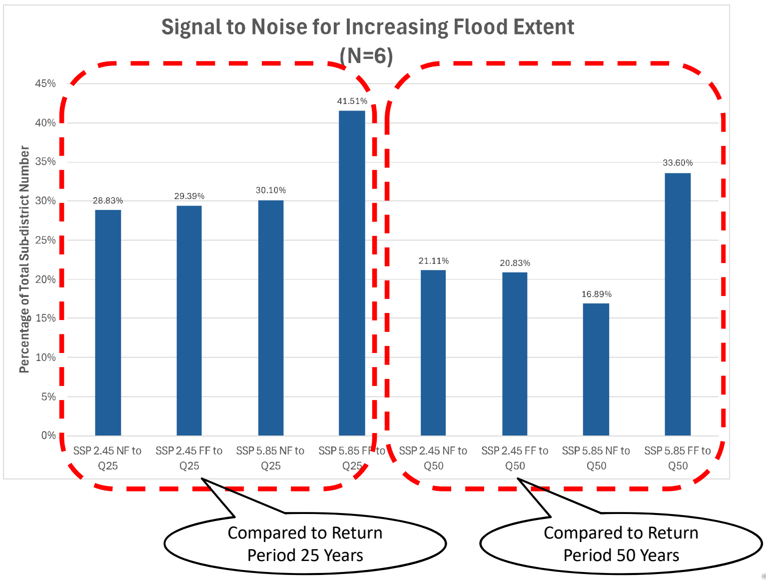
DIRECTION OF CHANGE FROM FLOOD RETURN PERIOD 25 YEARS

DIRECTION OF CHANGE FROM FLOOD RETURN PERIOD 50 YEARS



SIGNAL TO NOISE RATIO

- Assuming a signal-to-noise ratio greater than 1 indicates a strong climate signal of increasing flood inundation levels
- The calculation suggests a high likelihood of increasing flood extent in several areas for both comparisons.
- For the first, second, and third scenarios, the percentage of areas with a strong climate signal did not grow significantly compared to the 25-year return period and tended to decline when compared to the 50-year return period.
- However, in the last scenario, the percentage of areas with a strong climate signal jumped significantly in both comparison.
- **This indicates that the first three scenario have similar signal strength that weaker than last scenario.**



CONCLUSION

- The results indicate a gradual increase in flood-prone areas as scenarios change. Notably, the highest return period closely matches the GCM's flood projections, despite higher low agreement results.
- The provinces with the highest hazard scores are DKI Jakarta (0.61 – 0.77) and Central Java (0.62 – 0.76), primarily due to concentrated rainfall and urban growth.
- The signal-to-noise ratio reveals a stronger climate change signal in the final scenario for both return periods, indicating a significant shift in flood extent. However, this ratio decreases at higher return periods, suggesting a decline in change.
- In conclusion, despite increasing low agreement with escalating scenarios and return periods, higher return periods appear more suitable for future flood analysis due to their closer alignment with climate projections.
- Extreme far future conditions must also be considered, given highest strength of climate signals.
- It is crucial for the Indonesian government and other authorities to incorporate climate change probabilities into future flood mitigation planning standards to prevent miscalculations and effectively manage higher flood risks.

ACKNOWLEDGEMENT

- 2023 ITB Excellent Research of Institute for Research and Community Service
- 2023 ITB Multidisciplinary Research of Faculty of Civil and Environmental Engineering
- SATREPS Building Sustainable System for Resilience and Innovation in Coastal Community (BRICC) Project


Thank You!
SATREPS BRICC Project (2021-2026)

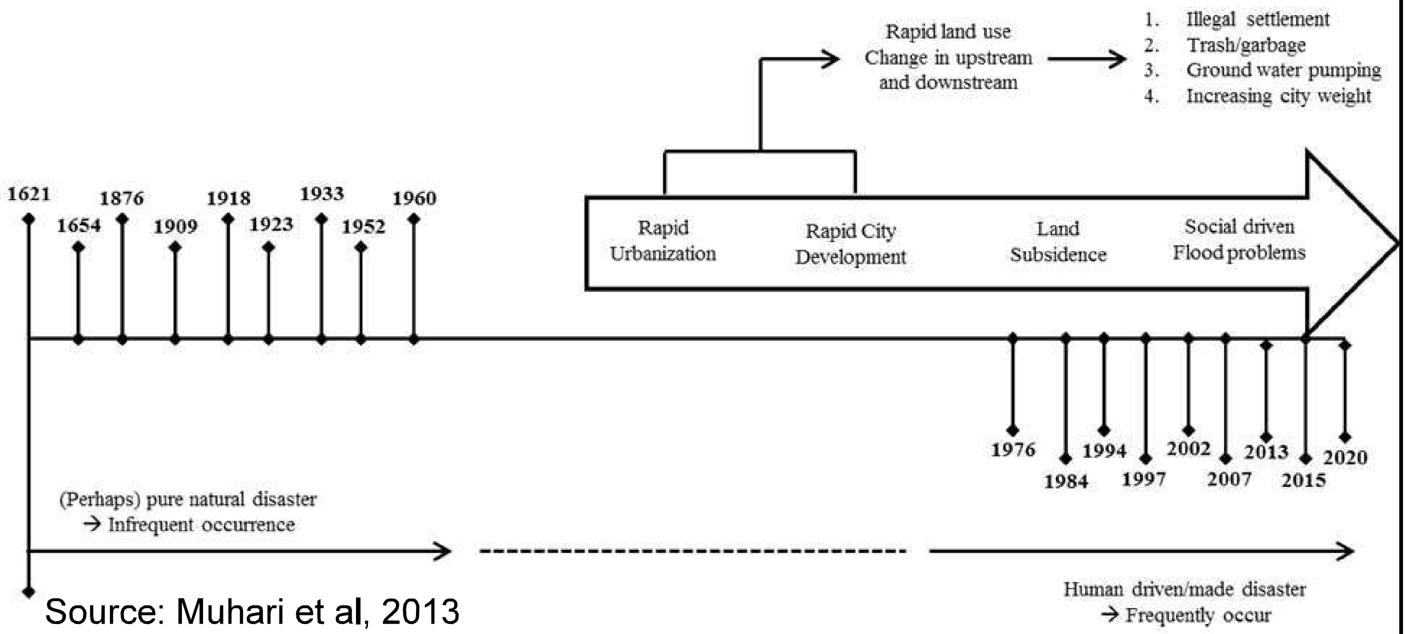
Future Flood Projections in Jakarta, Indonesia based on Urban Development and Urban Climate Change

Bambang Adhi Priyambodho
2024

ITB - Jatinangor

Chapter 1 : Introduction

Problem



Source: Muhari et al, 2013

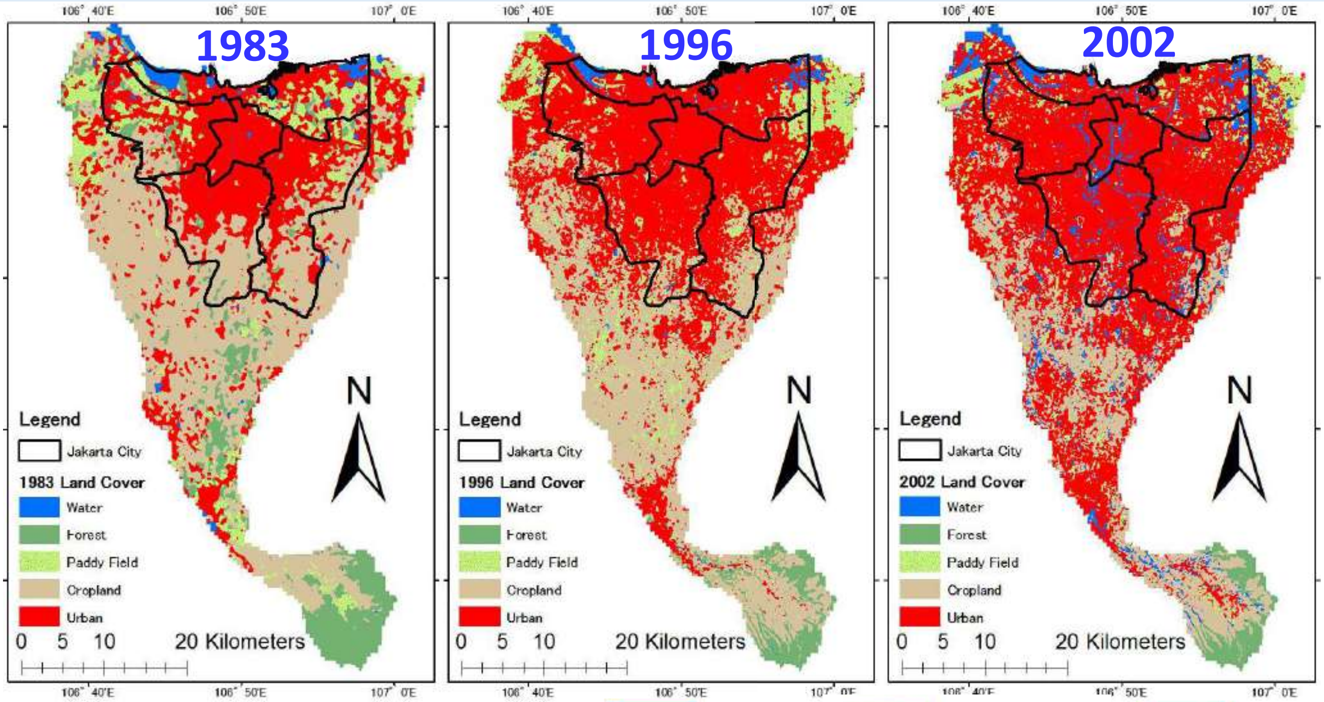
Floods were occurring since 1621 in Jakarta and it continued until today, but frequency of floods are increasing nowadays because of rapid urbanization, land subsidence and social problems.

Problem : Flood Inundation

17.1.2013 (Pictures taken by Mr. Tokunaga (MLIT, Japan))

These pictures show flood inundation in Jakarta in January 2013. Flood inundated road and highway. The flood event was occurred because of heavy rainfall and embankment failure.

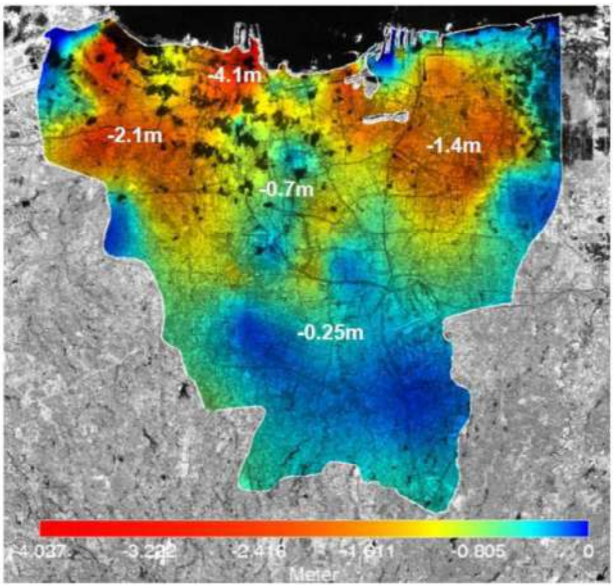
Problem : Land Use/Cover Change

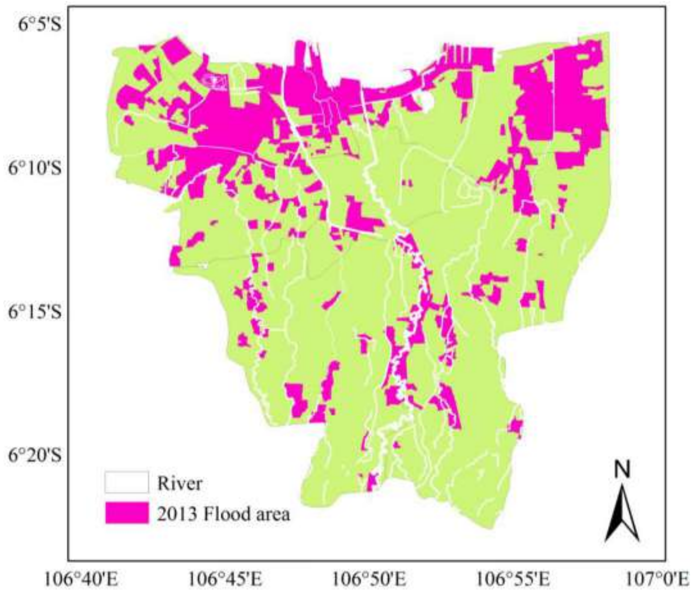


Land Use/Cover Changes (Idham et al., 2017)

Urban area (red color) is keep increasing and this has been affecting rainfall runoff processes and flood situations in Jakarta.

Problem : Land Subsidence

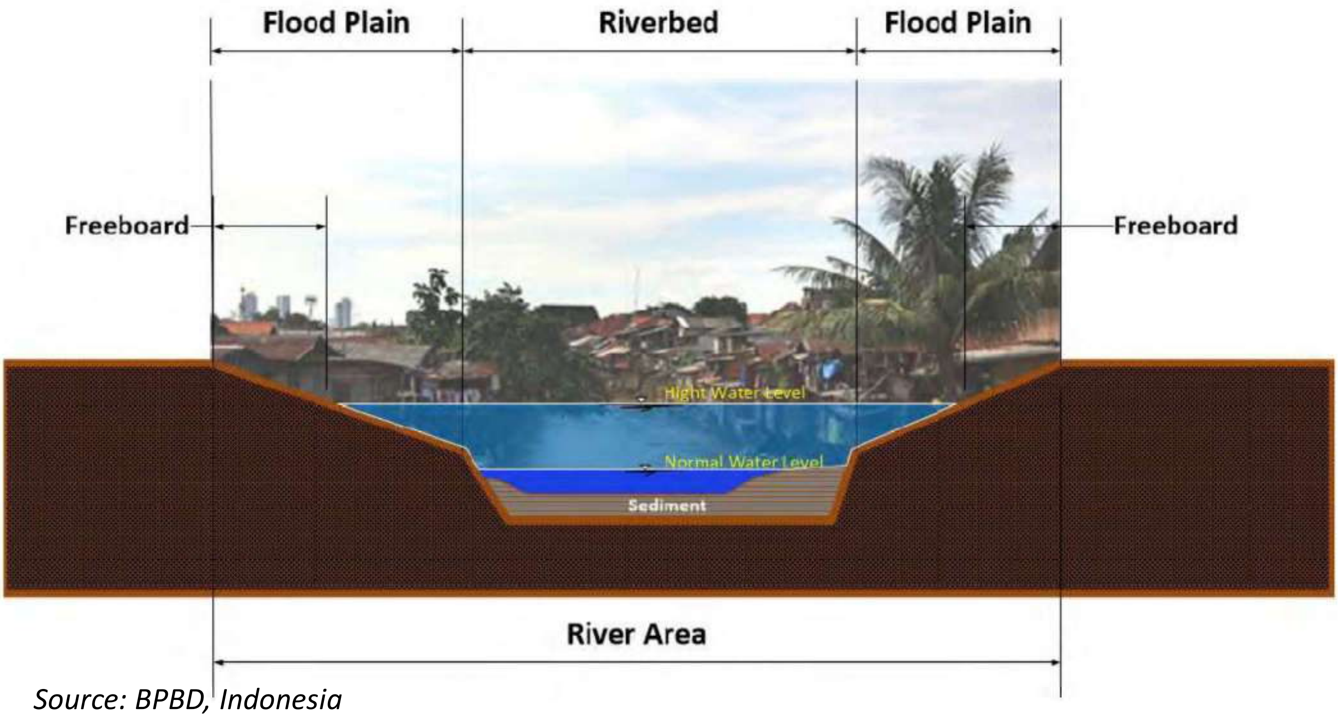




Accumulated land subsidence (left) and flooding map (right)

Land subsidence may be also contributing to urban flooding in lowland areas. Many parts of the lowland areas are located bellow mean sea level, so these areas are easily inundated.

Problem : Shortage of capacity flow



Source: BPBD, Indonesia

There is a section with the shortage of capacity flow in the upper part because of the narrow river cross sections and illegal developments in the floodplain.

IPCC 6th Report WGI (2021)

Brief summary of IPCC 6th report :

1. monitoring and observing human activities because these will influence global warming in the climate,
2. preparing the climate risk information for regional adaptation,
3. maintaining the global temperature increase within 1.5 degree Celsius, and
4. reducing emissions of CO_2 and related green house gasses

Especially, control of human activities and regional adaptation are important in Jakarta.

COP26

Important decisions from COP26:

1. Mitigating global temperature increase within 1.5 degree Celsius,
2. Compensate for loss & damage because of COP26 agreement,
3. Regulation for countries to use coal as an energy, because the coal will be increase global warming,

A problem of COP26:
Some developing countries still claimed that they need to use coal as an energy.

However, developing countries need to know some climate crisis such as the heat island phenomena is because of their urban development.

Literature Review of Jakarta Flood

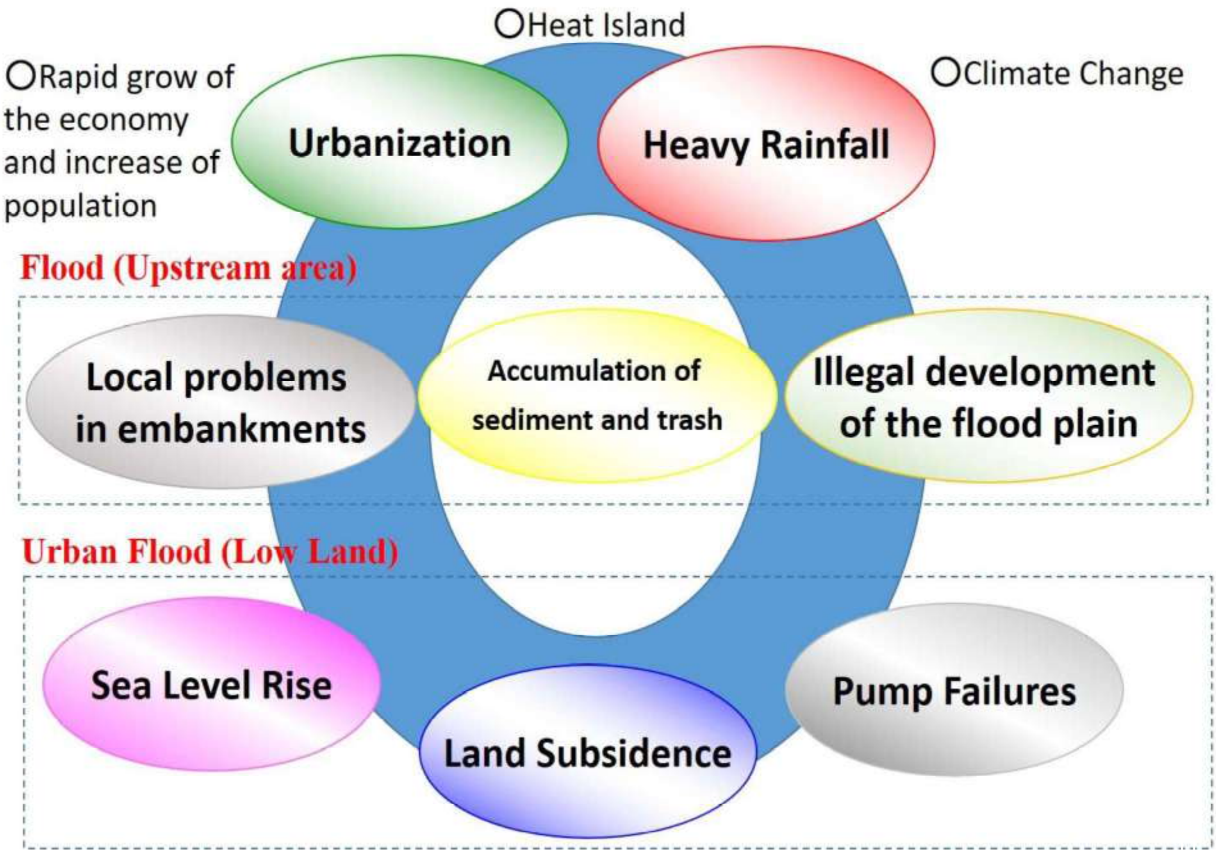
Land Use/Cover Change (LU/CC) :
1. Faried et al (2011) → analyzed historical LU/CC impact
2. Moe et al (2017) → analyzed future LU/CC impact

Land Subsidence (LS) :
1. Abidin et al (2011) → LS gave environmental impacts
2. Budiyono et al (2016) → LS increased future coastal flood risk

Climate Change (CC) :
1. Budiyono et al (2016) → analyzed future flood risk
2. Januriyadi et al (2018) → analyzed future flood damage cost

Countermeasures :
1. Moe et al (2015) → increased flood flow capacity,
2. Januriyadi et al (2020) →B/C analysis

Summary of the Flood Mechanism



Conclusions of Literature Review

Previous studies consider below matters :

1. Urban development (land use/cover change),
2. Land subsidence,
3. Climate change,

However, **below matters *were not discussed* and *considered***:

1. Urban thermal environment (heat island)
2. Several scenarios of the urban development
3. Sea level rise,

These 3 matters are **missing** for previous study as a " **GAP** " to next future researches.

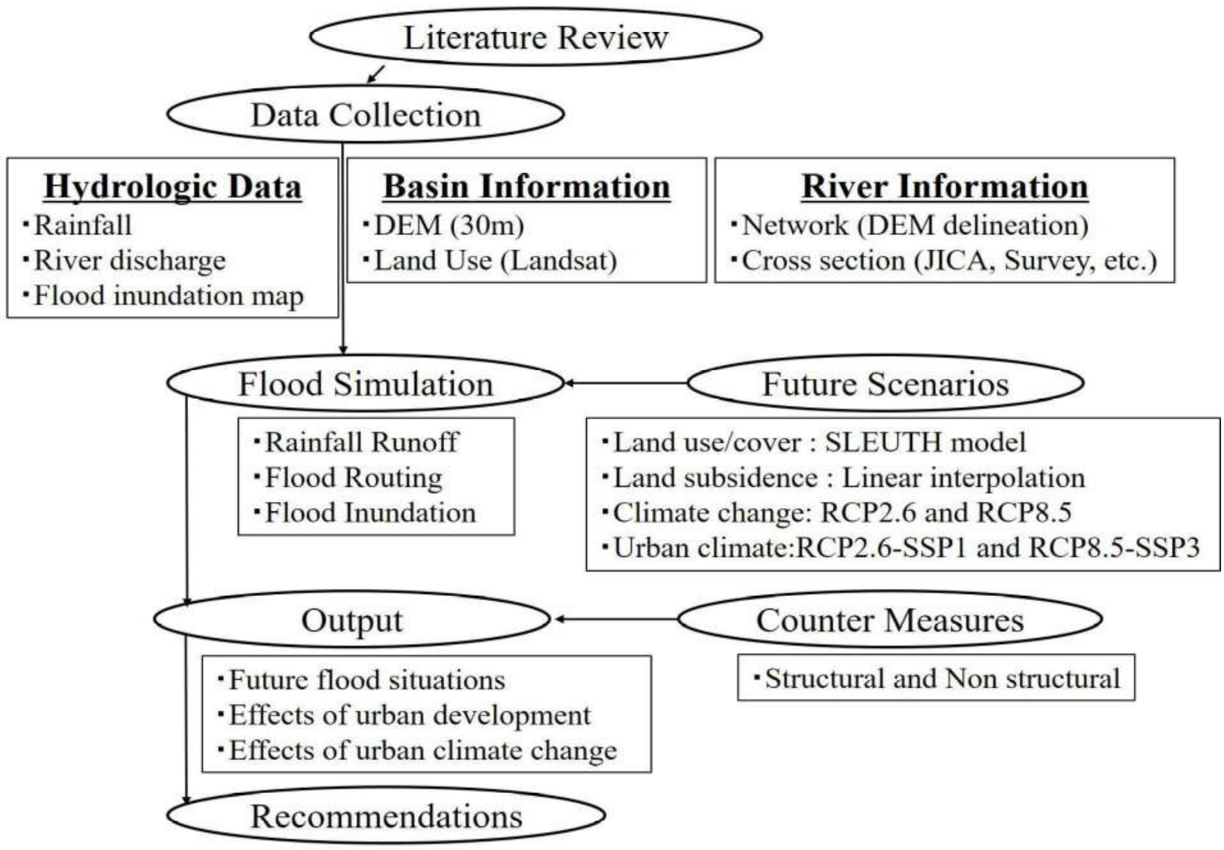
Main Objectives

to quantify the effects of both land use and climate change on future rainfall and flood inundation in Jakarta based on future urban growth and climate change scenarios including the heat island effects.

ORIGINALITY :

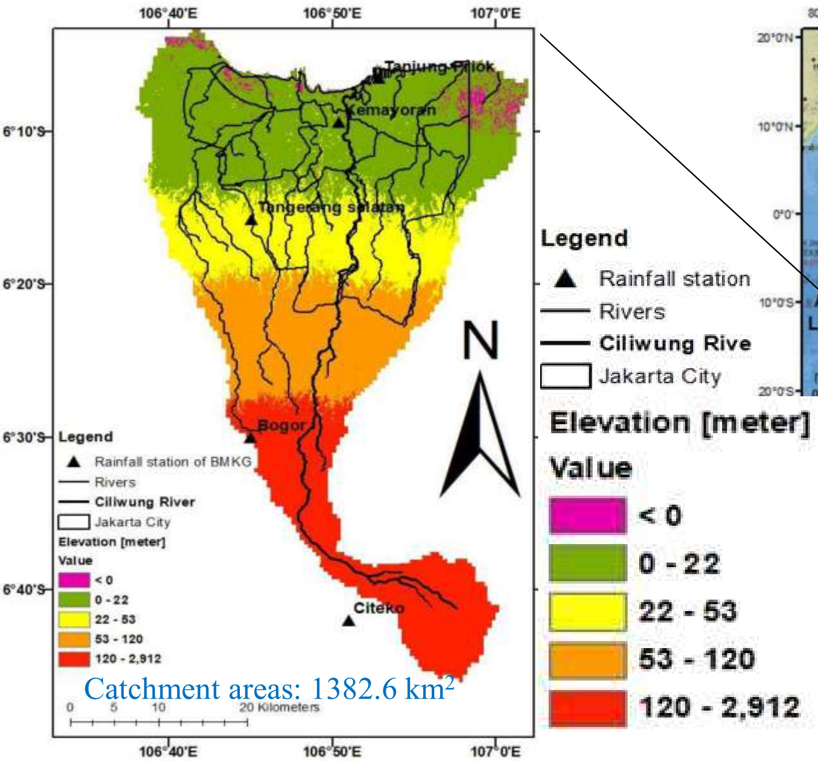
1. Consider the urban thermal environment (heat island) effects for the future scenarios,
2. Consider the several future development scenarios based on the RCPs and SSPs
3. Consider the sea level rise (but this will be written in the Appendix of the thesis)

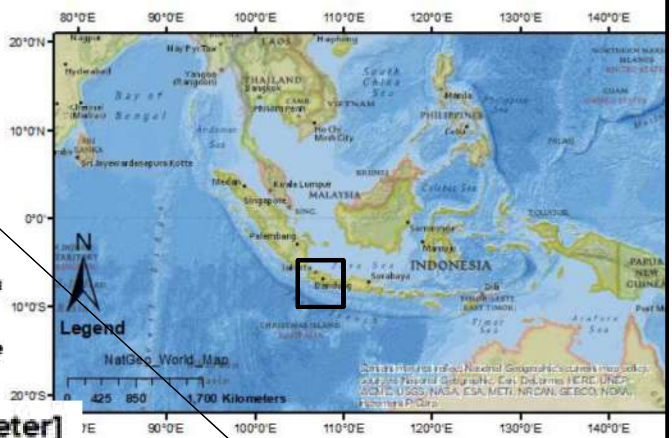
Flowchart of this study



Chapter 2 : Study Area

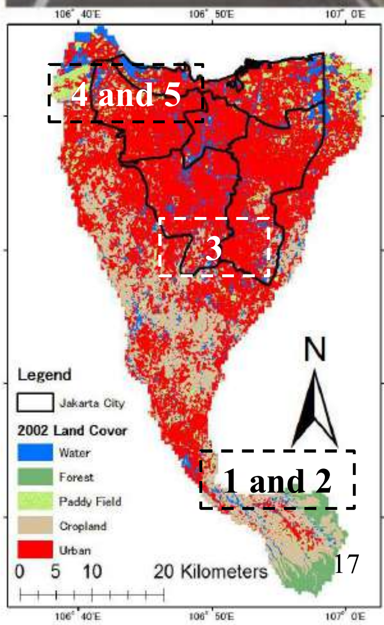
Study Area





- ✓ Jakarta city is located in the north – west of Java Island, Indonesia
- ✓ Jakarta city has 13 river which Ciliwung river as a main river and longest (117 km).

Land Use Information



Photos taken by Bambang Priyambodho (2021)

Water Paddy Field
Forest Cropland Urban

Main vegetations are Fern, Pinus merkusii, Treelets and Rattan and main agricultures are rice, tea and coffee plantation.

Historical Flood Events

Year	Averaged rainfall (mm/day)	Maximum water level (cm) at Manggarai	Flood area (km^2)	Death Person	Main damage	Damage Cost (IDR)
1996	421	970	-	10	529 houses were highly damaged	6.4 Trillion
2002	464	1050	160	32	Electrical System Shutdown	9.9 Trillion
2007	340	1060	397	80	Electrical System Shutdown	8.8 Trillion
2013	168	1020	132	41	Embankment failure	1.5 Trillion
2014	581	830	201	26	134,662 persons were affected	5 Trillion
2015	310	890	196	5	Electrical System Shutdown	1.5 Trillion
2016	275	580	152	2	-	3 Trillion
2017	322	700	139	6	1,178 houses were inundated	147 Billion
2018	346	775	79	1	42 houses were highly damaged	150 Billion
2019	154	890	84	2	-	100 Billion
2020	196	965	150	67	Electrical System Shutdown	1 Trillion

2007 event is highest for water level, flood area and death person. Only 2013 event, embankment failure was reported. Even 2020 after some counter measures were implemented in Jakarta, 67 persons were dead due to the flood.

Flood Situations

2013

Damages of 2013 flood event

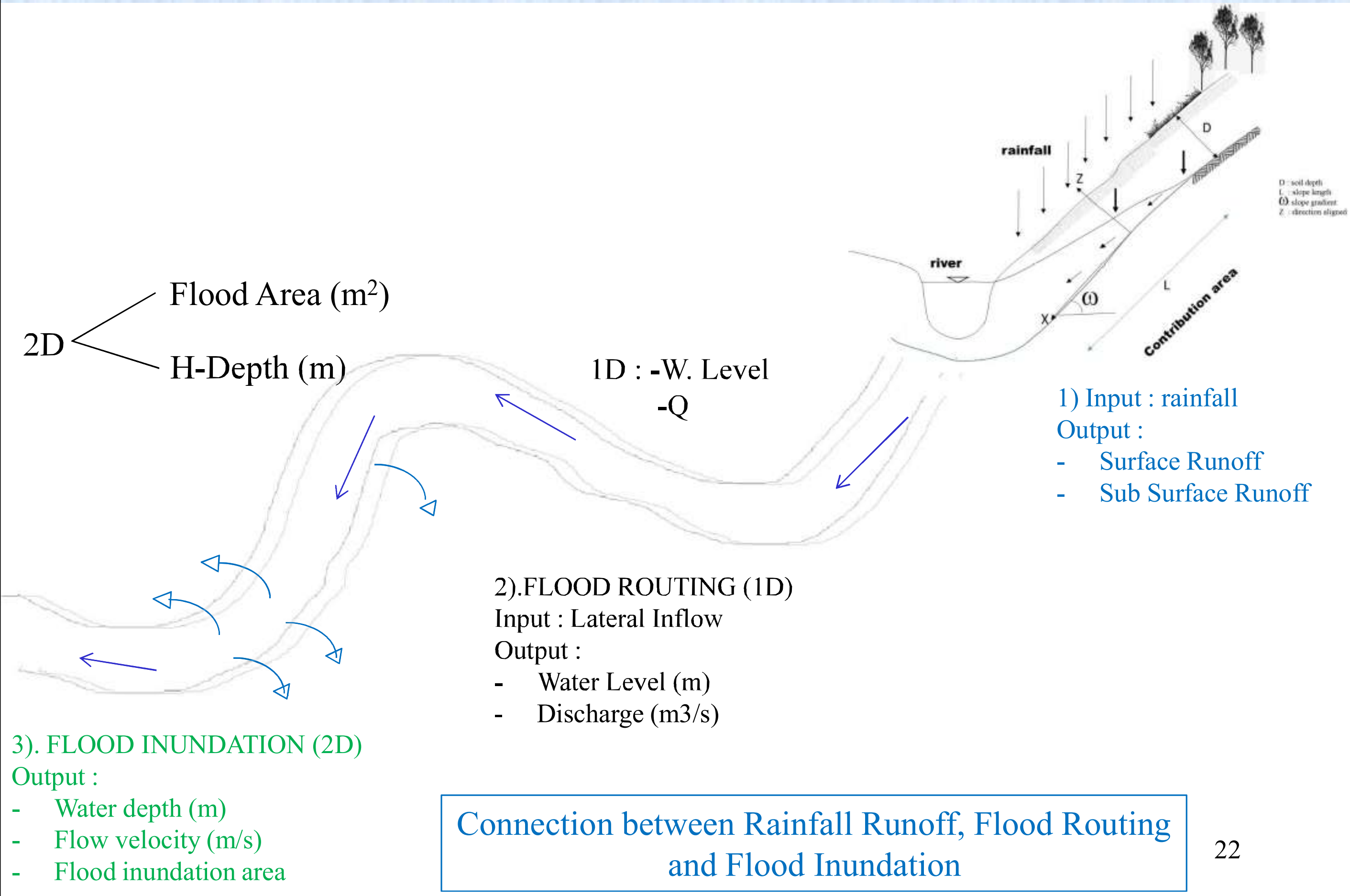
Damage	Value (US$) million	Percentage (%)
1 Direct		
1a Structural damage	43	13.96
1b Content damage (inside and outside)	193	62.66
2 Indirect		
2a Clean-up cost	25	8.12
2b Loss of income	30	9.74
2c Evacuation and temporary house	12	3.90
2d Cost of illneses	5	1.62
Total	308	100

Other social problems:

1. Deaths person because of leptospirosis and dengue; the people died becasue of have no access to sewage or septic systems,
2. Acute respiratory infections (ARI), diarrhea, gastritis, typhoid and skin disease,
3. Lack of hygiene and sanitation in flooded and refuge areas,
4. Sanitary conditions is not good,
5. Interrupting of supply of clean water and electricity,
6. Facilities of health care out of operation

Chapter 3 : Flood Inundation Model

Flood Inundation Model

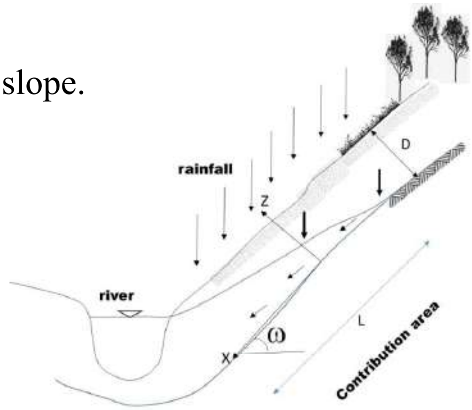


Connection between Rainfall Runoff, Flood Routing and Flood Inundation

Rainfall Runoff Model (Kure and Yamada, 2008)

1st step for flood inundation simulation

Lumped kinematic wave model considering two layer flow in a slope.



$$\frac{dq_s}{dt} = a_s q_s^{\beta_s}\left(r(t) - q_0 - q_s\right)$$ Surface flow

$$\frac{dq_*}{dt} = a_0 q_*^{\beta}\left(q_0 - q_*\right)$$ Subsurface flow

$$\frac{dq_0}{dt} = \left(r(t) - q_0\right)\frac{q_0 - K_s}{h + h_k} - \frac{q_0}{\left(\theta_s - \theta_i\right)}\frac{\left(q_0 - K_s\right)^2}{K_s\left(h + h_k\right)}$$ Vertical infiltration flow

$$\frac{dh}{dt} = r(t) - q_0 - q_s$$ Surface water depth

$r(t)$:effective rainfall (mm/h), q_0 :vertical infiltration rate (mm/h), q_s :surface runoff (mm/h), q_* :subsurface runoff (mm/h), h :water depth of overland flow (mm), K_s :saturated hydraulic conductivity (mm/h), h_k :capillary negative pressure of the wet line (cm), θ_s :saturated water content of the soil, θ_i :residual water content of the soil, a_0, a_s, β, and β_s are runoff parameters

Numerical scheme: Runge Kutta
Δt: 3 second
Subbasin number: 40
Computation time: 14,400
Initial condition: t = 0 s, q = 0.1

The output of these equations are :
- Surface runoff,
- Subsurface runoff,

Will be used as input to flood routing in rivers

- Vertical infiltration,
- Surface Water Depth,

23

Flood Routing in Rivers

Flood routing in rivers and drainage system

2nd step for flood inundation simulation

One dimensional unsteady flow model.
A flood routing in rivers and a drainage system were solved in Mike11

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_l$$

$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\alpha \frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{n^2 gQ|Q|}{AR^{4/3}} = 0$$

Q :discharge [m^3/s], A :area of cross-section [m^2], q_l :lateral inflow [mm/h], R :hydraulic radius [], h : water level [m], n :manning's roughness coefficient, α :momentum distribution coefficient, g :acceleration of gravity,

Numerical scheme: one dimensional unsteady flow method
Δt: 3 second
Δx: 0.5
Computation time:28,800
Initial condition: water depth 1 m
discharge 2 m^3/s

- The Input is Lateral Inflow (surface and subsurface runoff),
- The Output is discharge (Q) [m^3/s], and water level [m],

Boundary condition: inflow (point of source) in the upstream and water level in the downstream,

Connection to the flood inundation: the water will be overtopping or overflow when the water level increase until the river bank height,

Flood Inundation Simulation

Flood Inundation simulation

3rd step for flood inundation simulation

Unsteady two-dimensional flow equations consist of the continuity equation and momentum equation are numerically solved in MIKE 21.

$$\frac{\partial h}{\partial t}+\frac{\partial p}{\partial x}+\frac{\partial q}{\partial y}=0$$

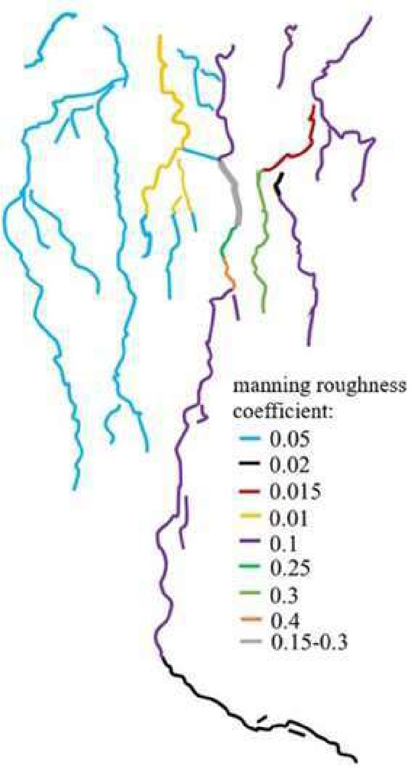
$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial x}+\frac{gp\sqrt{p^2+q^2}}{C^2-h^2}-\frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx})+\frac{\partial}{\partial y}(h\tau_{xy})\right]=0$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial y}\left(\frac{q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial y}+\frac{gq\sqrt{p^2+q^2}}{C^2-h^2}-\frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy})+\frac{\partial}{\partial x}(h\tau_{xy})\right]=0$$

C :Chézy resistance [$m^{1/2}$ s^{-1}], ρ_w :density of water [kg m^{-3}], τ_{xx}, τ_{xy}, and τ_{yy} :effective shear stress [kg m^{-1} s^{-2}], ζ :water level [m], p, q :flux densities (m^3 s^{-1} m^{-1}) in the x- and y-directions, respectively and h :water depth [m].

Numerical scheme: Continuity equation and momentum equation Method
Δt: 3 second
Δx, Δy: 0.5
Computation time : 104,400
PC's ability : 16 MB RAM, x64-bit
Model Grid Size for this computation X : 2569 and Y : 1455

Model Parameters



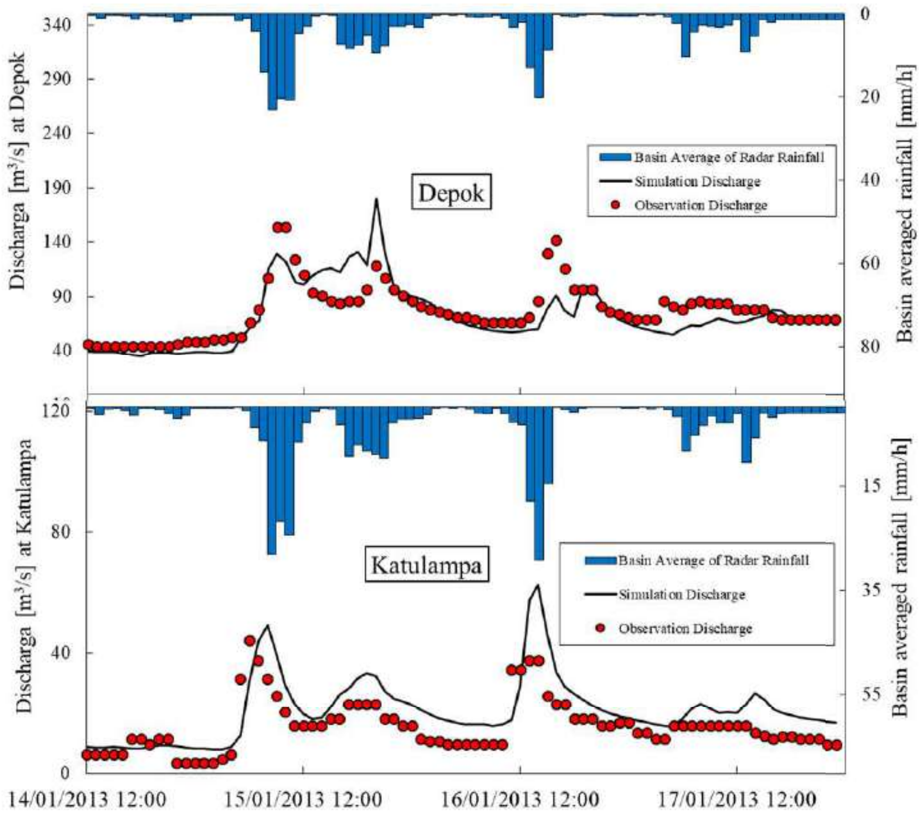
Distribution of manning's roughness coefficients for the rivers

Calibrated parameters of rainfall runoff model

	Urban	Forest	Cropland	Paddy Field
Soil depth [cm]	0.5	20	15	5
Saturated hydraulic conductivity [mm/h]	5	270	170	50
Effective porosity	0.1	0.5	0.4	0.2
Surface roughness	0.1	0.6	0.3	0.2
Runoff coefficients	0.8	0.4	0.5	0.6

- Soil parameters were determined as shown in Table.
- Manning's roughness coefficients for the riverbeds were set from 0.02 to 0.4 m-1/3s for river sections as shown in left figure,
- Manning's roughness coefficients for land surface were set to 0.1 m-1/3s for all floodplains.
- These parameters were determined by trial and error to obtain a good flood inundation results.

Model Application to 2013 event



Flood event from 14 January until 17 January 2013 was selected as calibration event

Radar rainfall was use as input

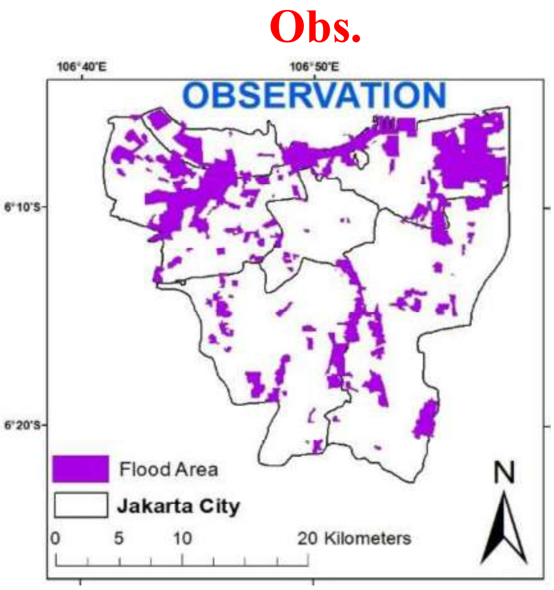
Simulation results reasonably matched well with the observation.

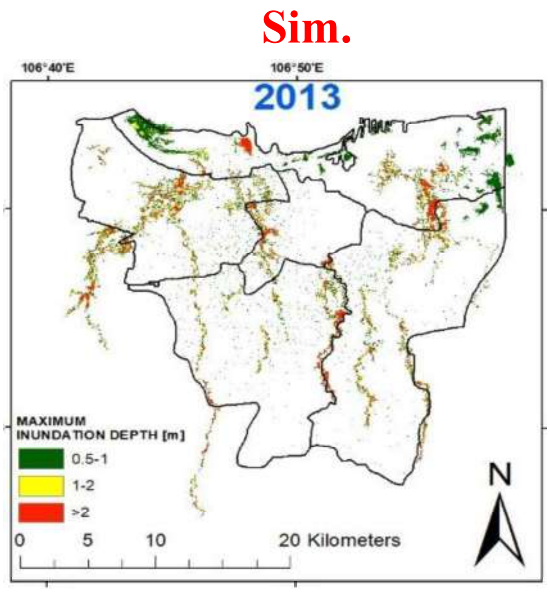
High Nash Index of 0.75 and 0.95 at Depok and Katulampa stations and correlation coefficients of 0.8 and 0.81, respectively, were simulated

Time series of observed and simulated discharge at Katulampa and Depok stations for 2013

Model Application to 2013 event

Model Application to 2013 event

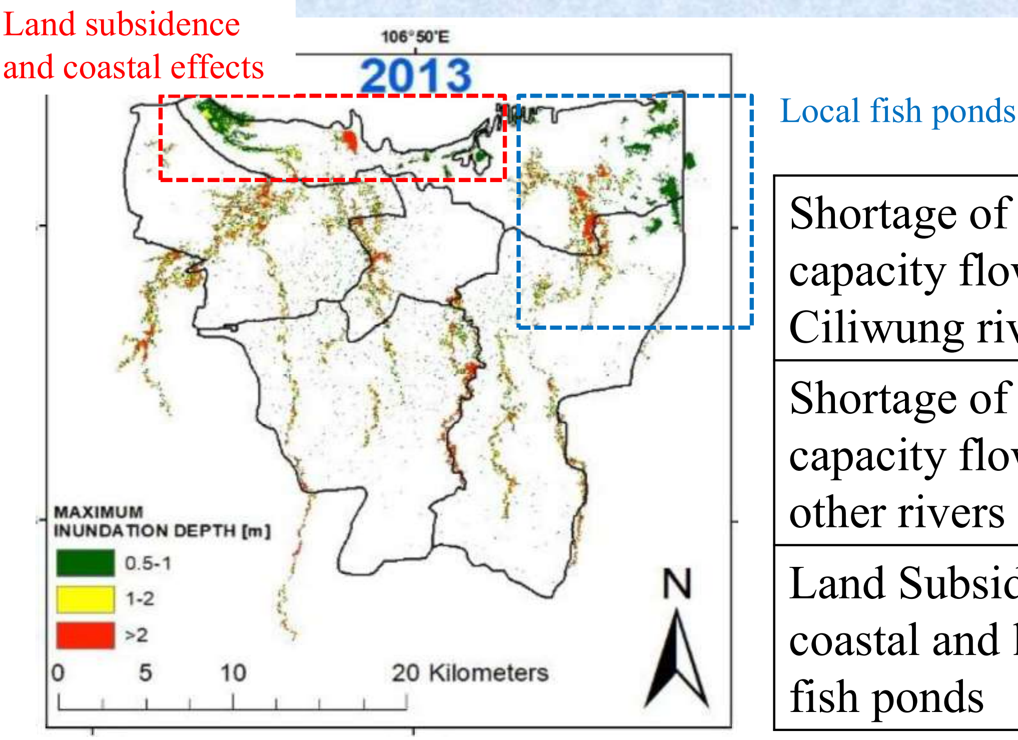




Comparisons between the simulated (right) and observed (left) inundation areas

Visual-graph comparisons between the simulated flood inundation distribution and the observed inundation map indicated an acceptable agreement.
The differences are because of observation error and local elevation of fish ponds coastal areas.

Flood mechanism in Jakarta

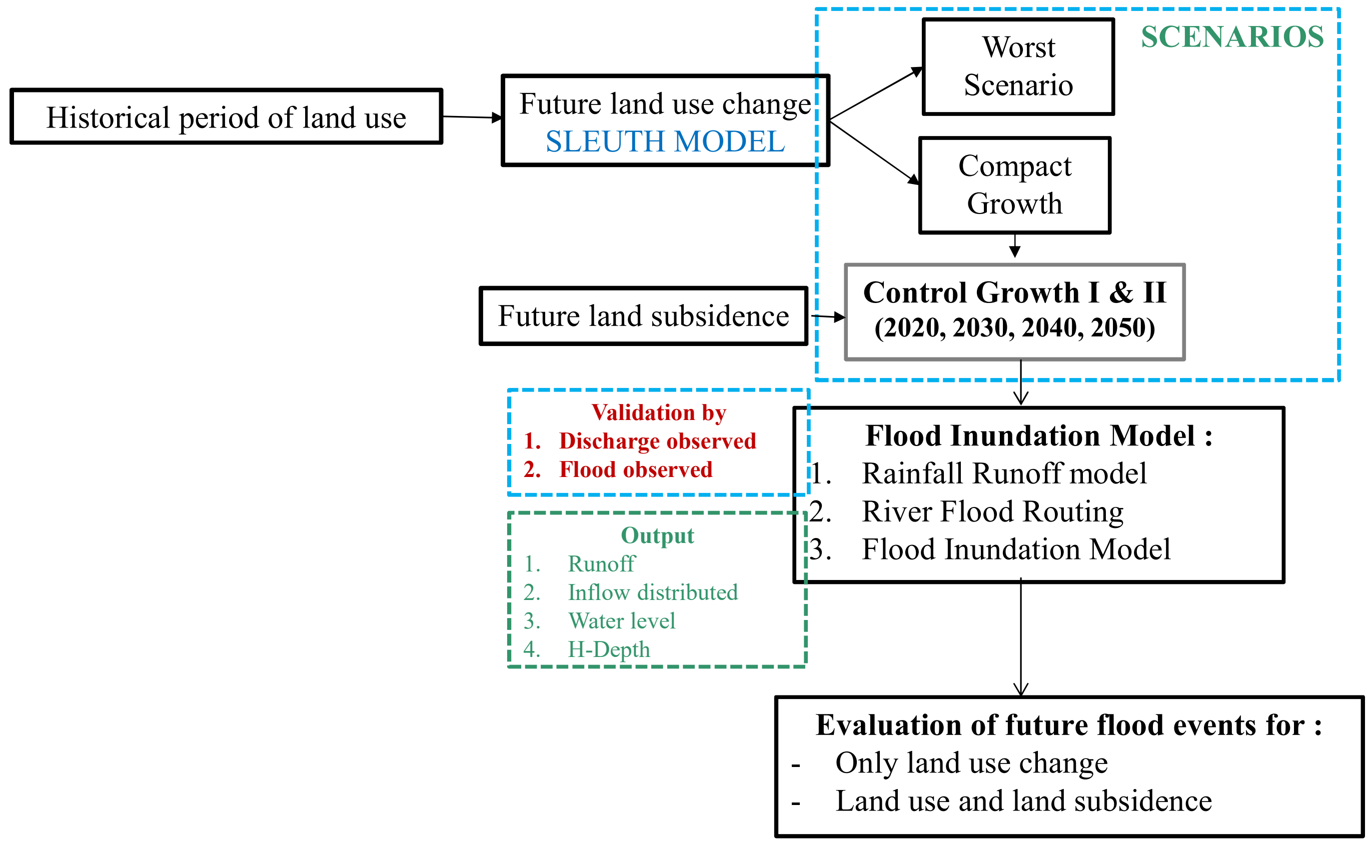


Shortage of capacity flow in the Ciliwung river	10.3%
Shortage of capacity flow in other rivers	53.2%
Land Subsidence, coastal and local fish ponds	36.5%

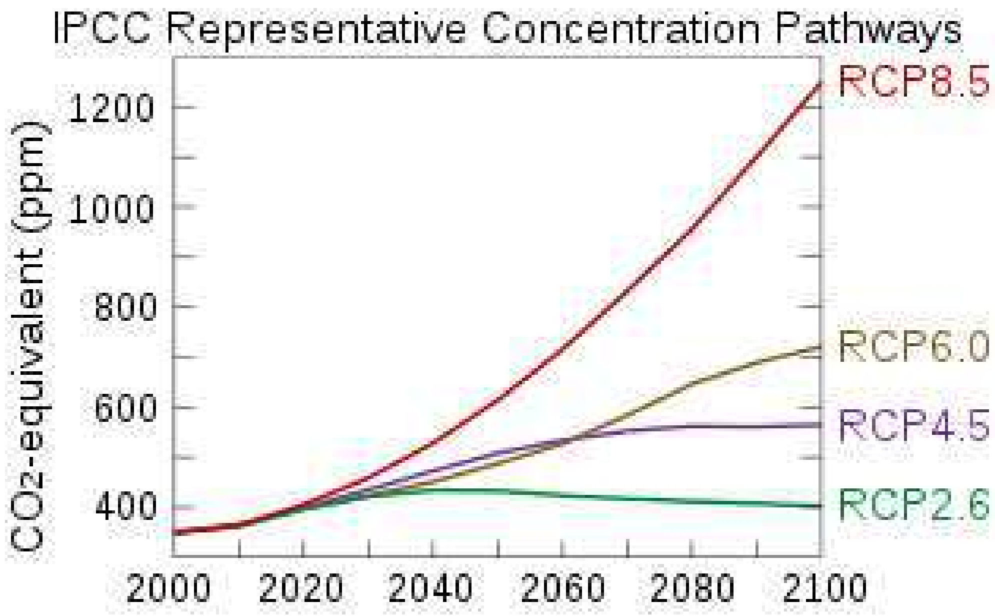
From application model, we concluded the percentage of the original sources of the flood inundations (shown in Table). Our simulation could not capture the local pond effects and coastal elevation effects.

Chapter 4 : Effects of Land Use/Cover Change and Land Subsidence

Methodology



Representative Concentration Pathways



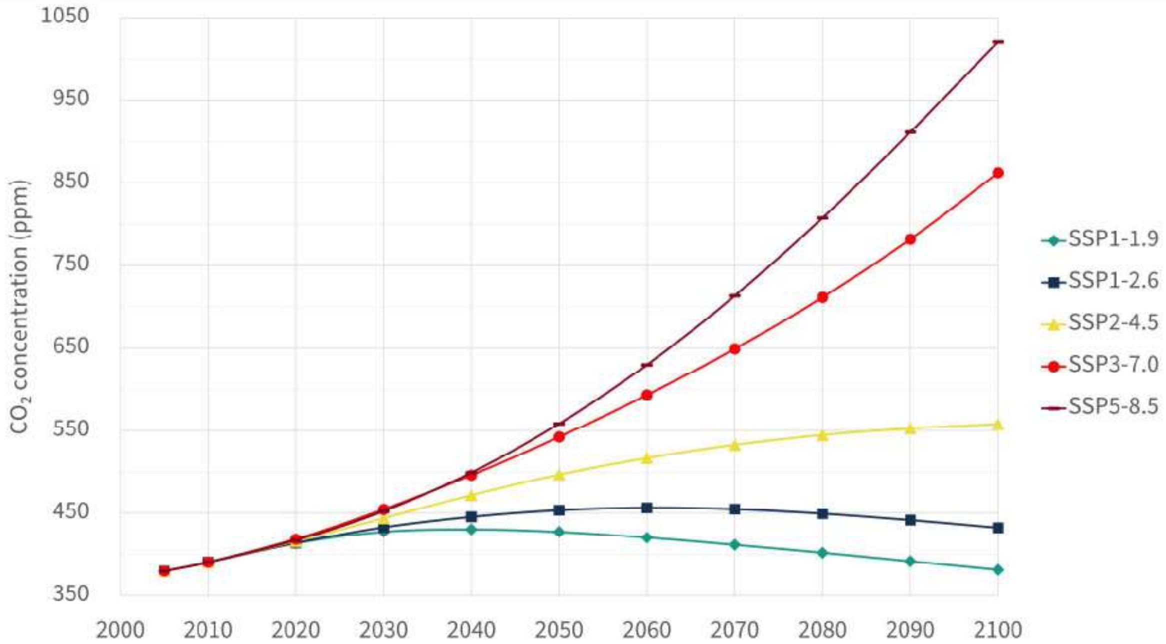
This figure shows yearly time series for future period, and shows connectivity between CO_2 and RCP's scenarios. The **lowest scenario is RCP2.6 and highest is RCP8.5** based on the CO_2 conditions for the future period (IPCC, 2007)

Shared Socioeconomic Pathways (SSPs)

SSPs is Shared Socioeconomic Pathways (SSPs) which represent five different futures with widely varying challenges to mitigation and adaptation (IPCC, 2007). There are :

- **SSP 1 is sustainability** (low challenges to mitigation and low challenges to adaptation),
- SSP 2 is population growth stabilizes toward the end of the century,
- **SSP 3 is population growth continues with high growth in developing countries,**
- SSP 4 is population growth stabilizes toward the end of the century,
- SSP 5 is emphasis on economic growth and technological progress and lack of environmental awareness.

Relationship between SSP and RCP



This figure shows yearly time series for future period, and shows connectivity between CO_2 and SSP's scenarios. It was related with the climate policies. (IPCC, 2007)

In this study, **RCP2.6-SSP1 was treated as compact growth scenario** and **RCP8.5-SSP3 was treated as the worst case** (BaU case)

SLEUTH Model

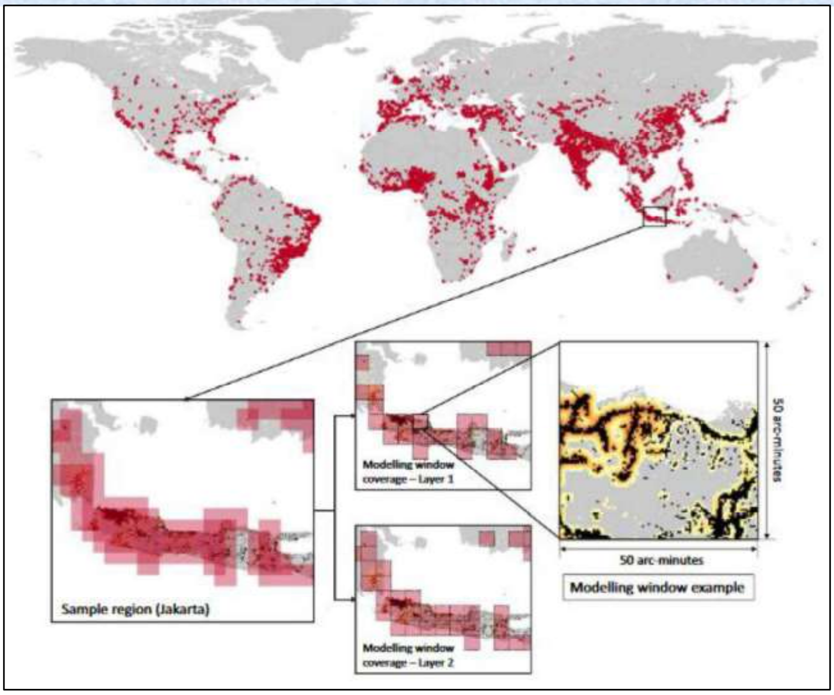
SLEUTH Model is a model for future land use prediction which it was estimates urban growth based on historical slopes, land use, exclusion, urban growth, transportation, and hill-shade data. These information data is used as a necessary input for this model.

However, this model was excluded region, where urban growth is restricted (e.g. water bodies, parks).

SLEUTH Model is a model to determine future distribution of urban parameters.

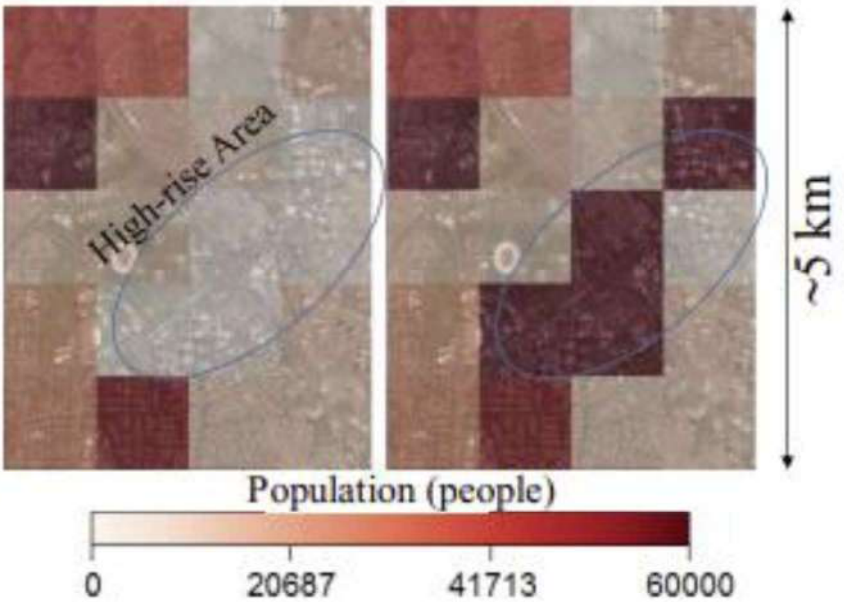
The Urban parameters was representing buildings in weather models such as Average building height [H_{avg} (m)], and planar area index. Also the SLEUTH is projecting urbanization with certain regional/global scenarios, such as those that can be derived from representative concentration pathways (RCP) and shared socio-economic pathway (SSP).

SLEUTH Model



Global coverage of the GUGPS modelling framework and an example of modelling window area. The coordinates refer to WGS 84. The modelling window size is 50 arc-minutes by 50 arc-minutes, and the grid cell in each modelling window is 30 arc-seconds (approximately 1 km at the equator). The example locates on the east of Jakarta, Indonesia (Zhou et al, 2019)

SLEUTH Model



- This figure show the Comparisons between LandScan population dataset before (Left) and (Right) after adjustment in Jakarta,
- Highlights an example showing the effect of adjustment,
- Estimation for new population density adjusted by nighttime lights (PDNL) by replacing the DMSP-OLS products with the Version 1 Nighttime VIRRS Day/Night Band

SLEUTH Model

$$\beta_{Havg} = -2\,x\,10 - 12\,x\,\text{GDP}_{\text{city}} + 9.18$$ (1a)

$$\alpha_{Havg} = \quad 2\,x\,1011 \quad x\,\text{GDP}_{\text{city}} + 9.80$$ (1b)

$$H_{avg} = \quad \alpha_{Havg}\,x\left(\frac{\text{PDNL}}{\text{PDNL}_{\text{max}}}\right) + \beta_{Havg}$$ (1c)

where PDNL (population density adjusted by nighttime lights) $_{max}$ represents the maximum gridded PDNL value within the area of the city. $GDP_{city,}$ or the city-level GDP, was estimated from the sum of individual grid population density within the city's administrative boundary (PD_{city}) and that of the country ($PD_{country}$), and the country-level $GDP_{country}$ (1d).

$$\text{GDP}_{\text{city}} = \quad \text{GDP}_{\text{country}}\,x\left(\frac{\text{PD}_{\text{city}}}{\text{PD}_{\text{country}}}\right)$$ (1d)

SLEUTH Model

Input Layer	Source	Note
Slope	DEM	Slope > 21% can not be urbanized
Land use /Land Cover	Landsat 5,7,8	2 layers : 1989, 2014
Excluded	Landsat 8 OLI &. OSM	Ocean/Lake, waterways, Airport, National Parks, Square are resistant to urbanization
Urban	Landsat 5,7,8	4 layers : Input : 1989, and Validation : 1994, 2001, 2014
Transportation	Open Street Map (OSM)	2 layers : 1992, 2001 Road influenced urban growth
Hillshade	DEM	1 layer

SLEUTH Model

Future urban expansion was estimated using the SLEUTH model, which is an evolutionary product of the Clarke Urban Growth Model that uses cellular automata, terrain mapping and land cover deltatron to estimate horizontal urban growth.

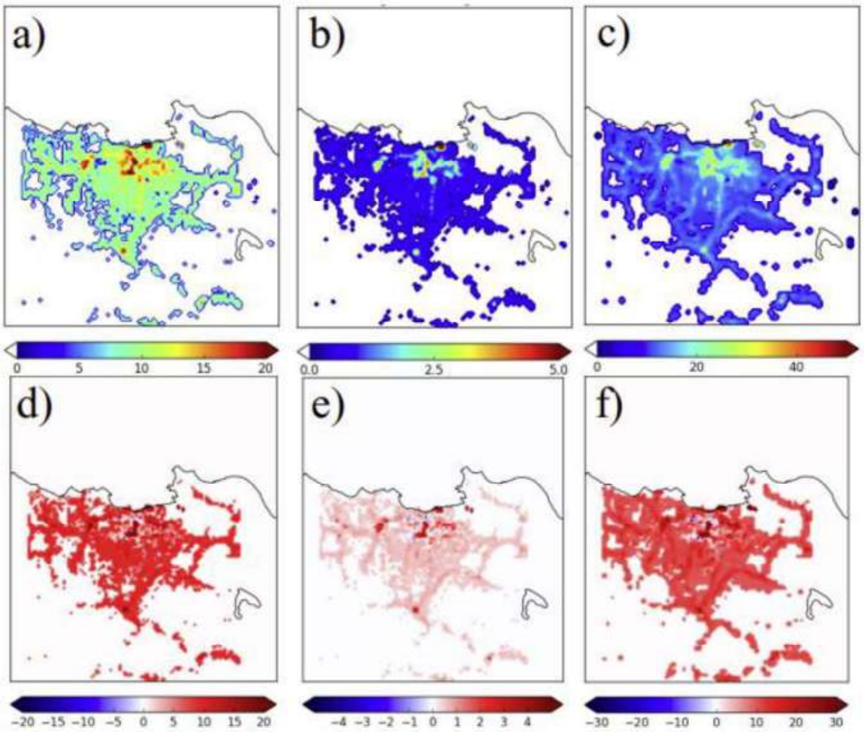
The necessary inputs (whose initial letter corresponds to the name SLEUTH) are slope, land cover, excluded region, urban cover, transportation, and hill shade.

- ❑ Hill shade and slope were estimated from the globally available topography dataset, ASTER GDEM by NASA.
- ❑ Land and urban cover were estimated from a supervised landuse classification of Landsat imagery taken on clear days for the years 1972, 1994, 2001, and 2014.
- ❑ Transportation networks were acquired from the year 1992 and 2001.
- ❑ Exclude region, means areas where urban growth is restricted (e.g. water bodies, parks).

SLEUTH Model

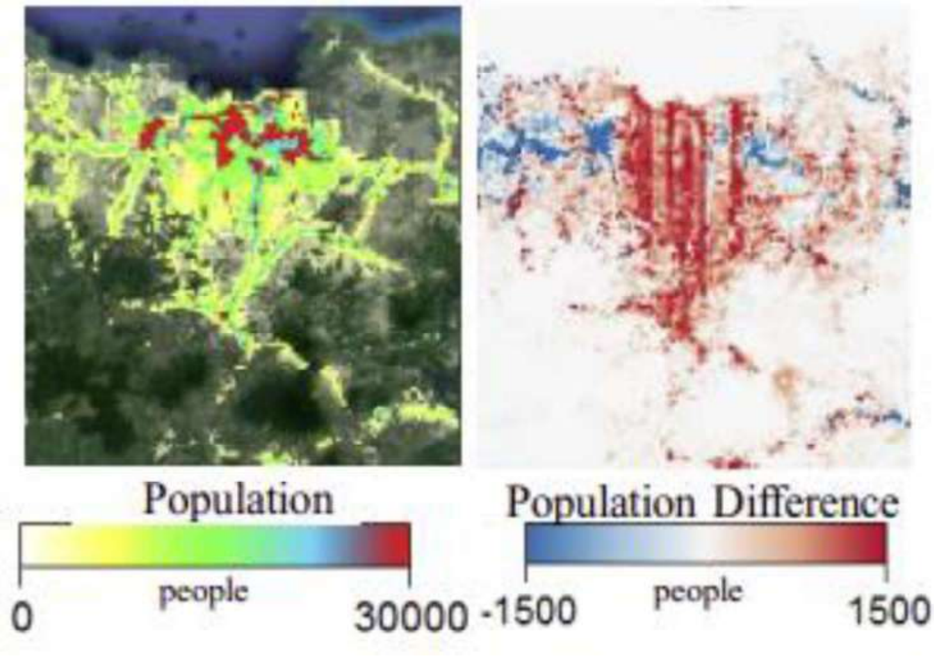
- ❑ From the inputs, SLEUTH model finaly calibrates the necessary growth coefficients (dispersion=1, breed=14, spread=89, slope=65, and road=28) for urban growth using 1000 iterations of the Monte Carlo Simulation.
- ❑ Worst scenario (RCP8.5-SSP3) in the future if no adaption and low mitigation strategies are implemented. In the worst scenario growth coefficient of spread = 89.
- ❑ Compact growth (RCP2.6-SSP1) scenario in the future if high mitigation /or to limit urban expansion (SSP)1 and reductions in the coefficient of spread = 22.

SLEUTH Model



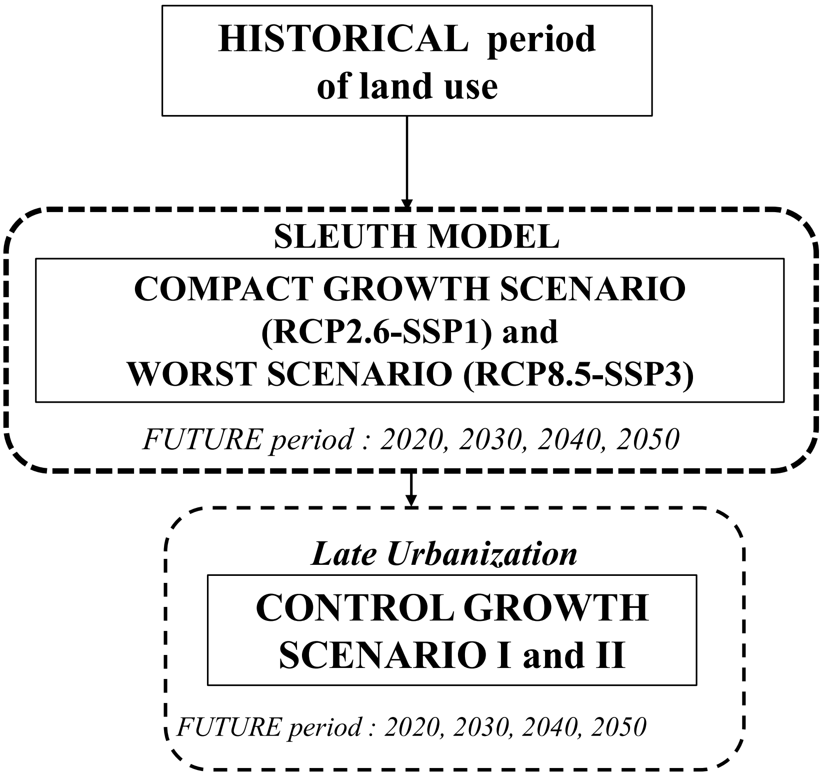
Assumed average (a) building height, (b) $Z_{0,}$ and (c) d representing 2050s urbanization and their corresponding increase compared with the present urban condition. (c), (d), (e) are for building height, $Z_{0,}$ and d, respectively. All units are in m.

SLEUTH Model



Projected population in 2050 (left) under the SSP3 scenario. Difference of projected population in 2050 between SSP3 and SSP1 (Right). Positive value means projected population under the SSP3 are larger than that of SSP1.

SLEUTH model with Scenarios



Land use map under the compact growth and worst scenarios were developed by SLEUTH. However, **Land use map under the control growth was developed based on the land use map of compact growth.** Several sub basins in compact growth were changed from urban area to forest in the control growth.

New Scenarios (control growth)

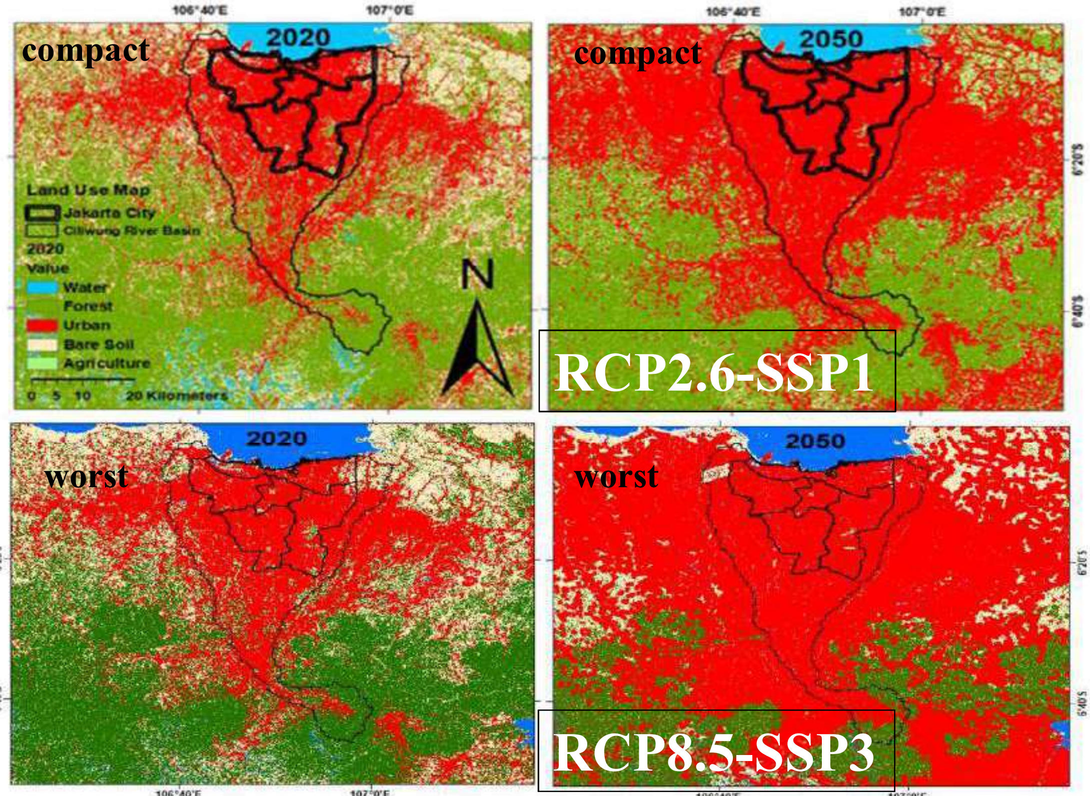
Varquez et al (2017) applied SLEUTH to Jakarta under the RCP2.6-SSP1 (compact growth) and RCP8.5-SSP3 (Worst Scenario)

- **Worst scenario** (RCP8.5-SSP3) in the future if no adaption and low mitigation strategies are implemented.
- **Compact growth** (RCP2.6-SSP1) scenario in the future if high mitigation /or to limit urban expansion.

In this study, the following two scenarios are newly considered;

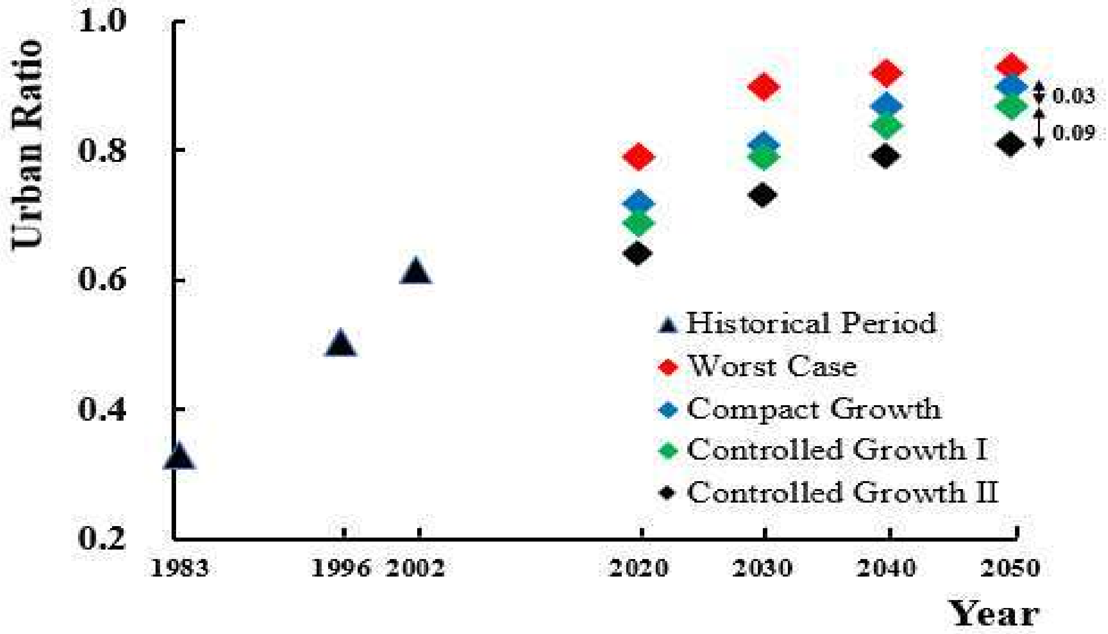
- **Control growth** scenario in the future if it reduced the total urbanization ratio. Land-uses in sub-basins were changed from urban to forest in the future period.
- **Control Growth I** was set the constant difference ratio (0.03) between the compact growth and control growth I at each year
- **Control growth II** was set the constant difference ratio (0.09) between the compact growth and control growth II at each year

Projected land-use map



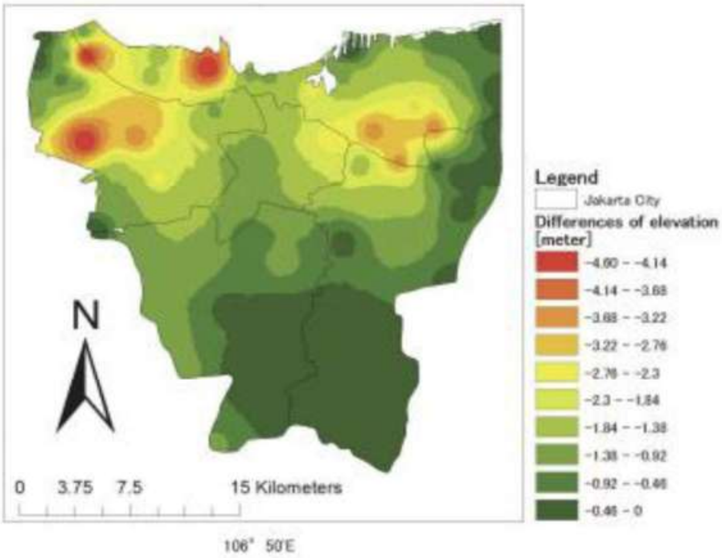
These figures show the future projection of land-use/cover map for 2020 and 2050, for compact (top) and worst (bottom). It is clear that **the worst conditions (RCP8.5-SSP3) have more urbanized area (red color) than compact growth**.

Projected Urban Ratio



This figure shows time series of the total urban ratio of each scenario in the historical and future periods. It is clear that the **worst case has the highest urbanization ratio and the Controlled Growth II is the lowest urbanization.**

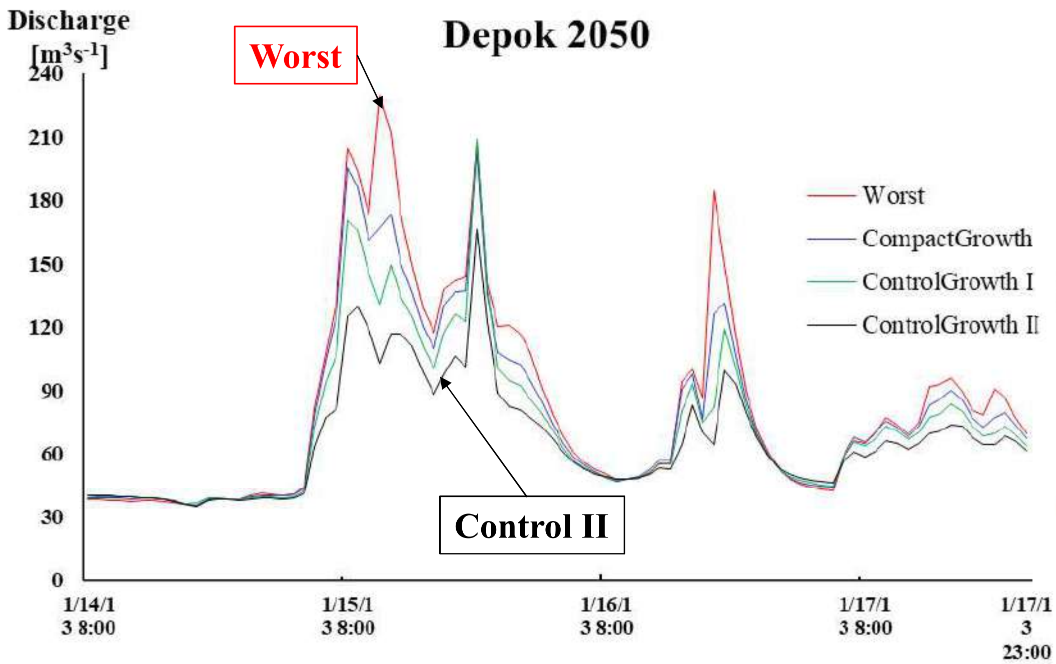
Projected Land Subsidence (LS)

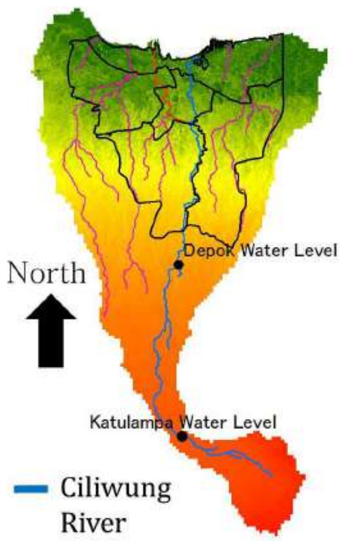


Projected land subsidence situation in Jakarta in 2050 compared to 2009.

Land subsidence situations were also projected toward the future based on a linear interpolation of the historical LS trend. This LS was also evaluated during the flood simulations with and with out LU (land use change).

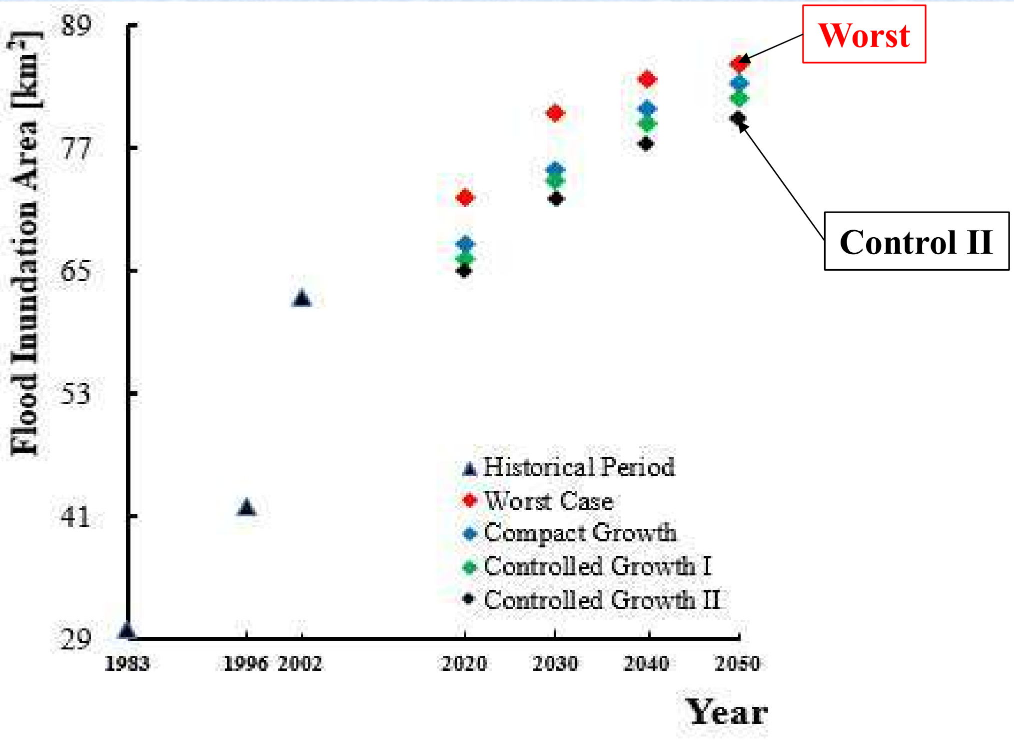
Hydrograph Comparisons for 2050 (Only LU)





Simulated hydrograph on Depok for 2020 based on four scenarios were presented. **The worst scenario shows highest discharge and control growth II is the lowest.** It means the control growth reduced the flood flow.

Effects of Land Use Change (LU)



Time series of flood inundation areas under 4 scenarios are shown. As the same as the urbanization ratio and the river flood discharge, **the worst scenario shows highest flood inundation and control growth II is the lowest.**

Effects of both LU and LS

Table. Percentages [%] of the flood inundation volume increase compared to the original 2013 flood. (LU: only land-use change, LS: only land subsidence, and LU+LS: land-use change with land subsidence)

Year	LS	Worst Case		Compact Growth		Controlled Growth I		Controlled Growth II	
		LU	LU+LS	LU	LU+LS	LU	LU+LS	LU	LU+LS
2020	1	7	12	-1	1	-2	1	-4	-1
2030	2	18	25	9	17	9	15	6	12
2040	5	20	31	15	26	13	24	10	20
2050	7	20	35	18	31	15	29	13	25

Only LS　Only LU　LU& LS

Worst 35%　Control II 25%

LU and LS in 2050 would **increase the flood inundation volume by 35% in the worst and 25% in the controlled-growth-II** compared to the flood inundation in 2013. **The combination of LU and LS significantly increased flood inundation.**

Conclusions of this chapter

- ❑Four land use change scenarios in the future were evaluated by the flood inundation simulations [page 48, 49].
- ❑Increase of urban ratios in upstream region contributed to increase of the flood inundation in Jakarta [page 48].
- ❑Land use change and land subsidence in 2050 would increase the flood inundation volume by **35%** in the worst case and **25%** in the controlled-growth-II compared to the flood inundation in 2013 [page 49].

However, climate change was not considered in this chapter. **The next chapter will focus on the climate change and heat island** effects associated with the urban development.

Chapter 5 : Evaluation of Counter Measures

Methodology

Adaptation Scenarios

- Countermeasures 1 (CM1)

Improve flow capacity by increasing river bank height 1 m to all river

- Countermeasures 2 (CM2)

CM1 with dredging bed level 1 m all river

Damage Cost Estimation (Fajar et al. 2018)

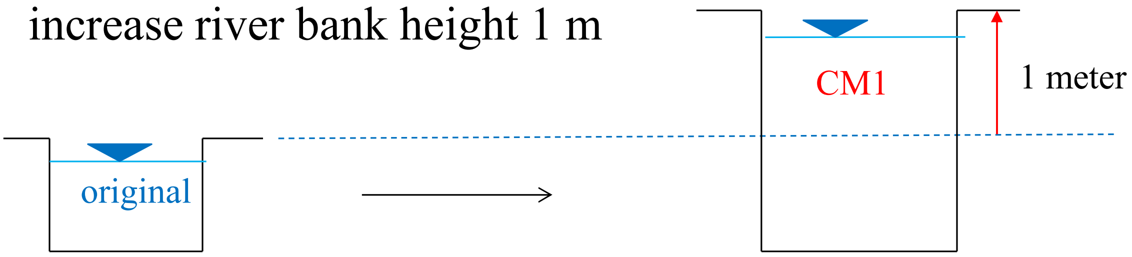
Expected Annual Damage Costs (EADC) were calculated based on return period rainfall and land use classification..

Future Scenarios

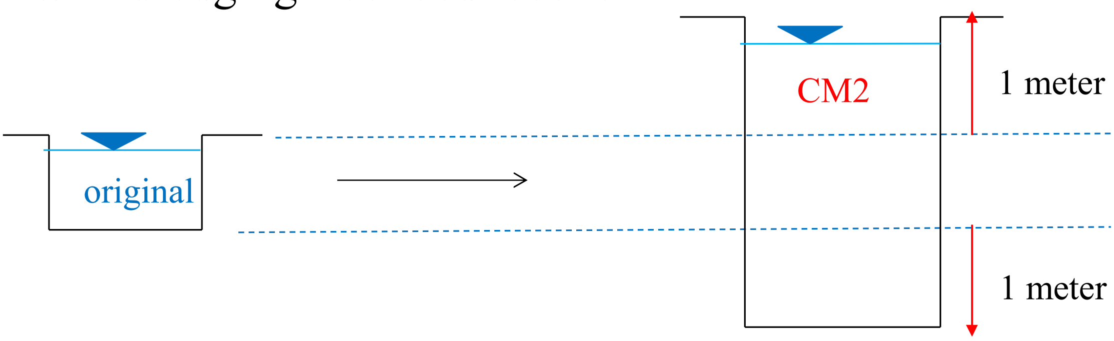
RCP8.5-SSP3 in near future (2050) and far future (2100)

Adaptation scenarios

CM1
increase river bank height 1 m

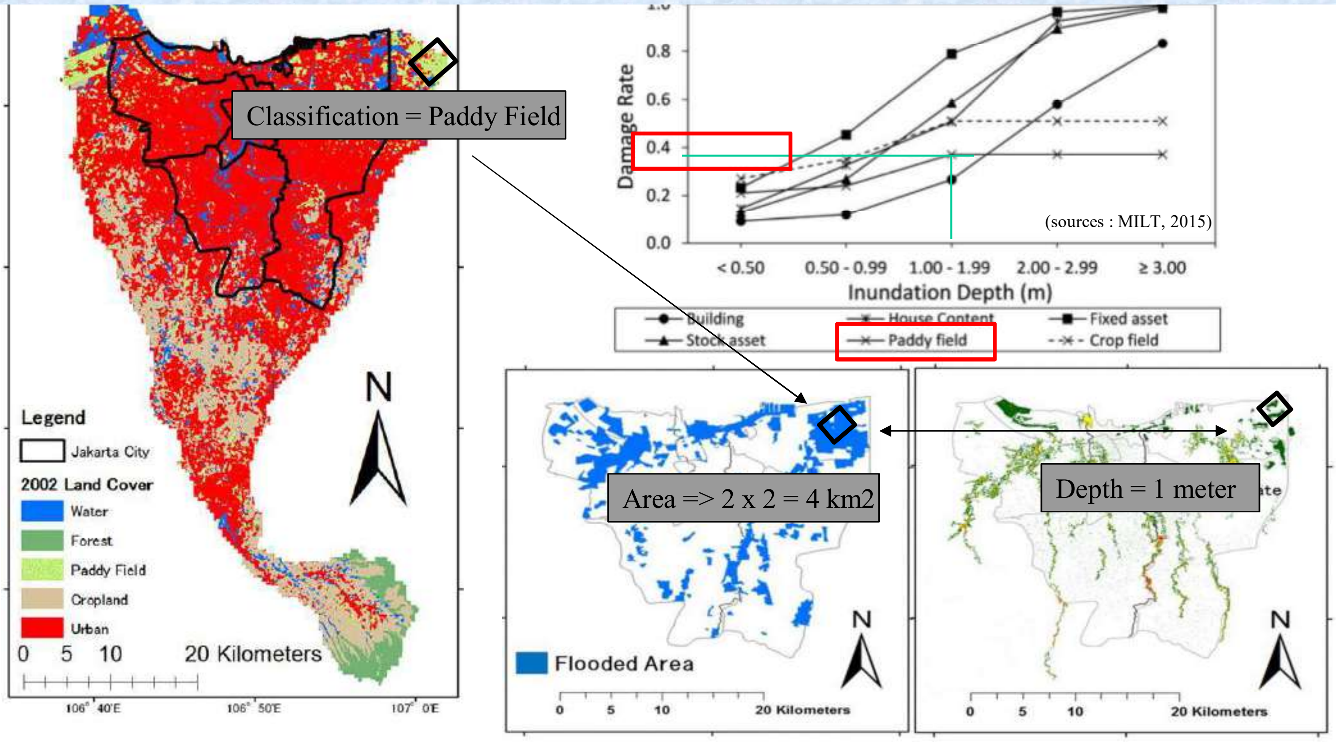


CM2
CM1 with dredging river bed level of 1 m



Purpose of the CM1 and 2 is to increase the flood flow capacity in the river

Damage Cost Estimation (example)



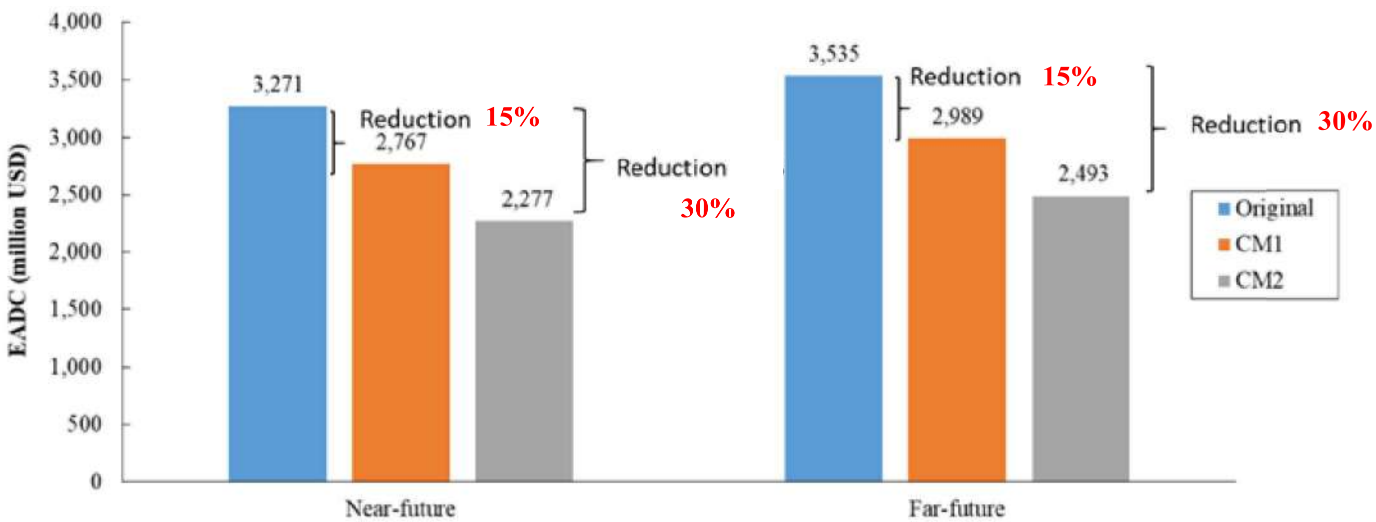
Paddy Field : $DC_p = 564 \times 266 \times A \times DR_p$,

564 is average rice productivity (ton/km^2), 266 is the average rice price (USD/Ton)

= 564 x 266 x 4 x 0.38 = 228,036.48 USD

DCs were numerical integrated by return periods to convert Expected Annual Damage (EAD)

Results



Comparisons between original, CM1 and CM2 in the near and far future.

CM1 will reduce EADC by 15% and CM2 will reduce EACD by 30%.

Cost and Benefit/Cost (CM1)

	Original	CM1
EADC (Near-future):	3,271	2,767
EADC (Far-future):	3,535	2,989

A. Compute **Benefit** : Benefit for near-future : 3,271 – 2,767 = 504 million USD

Benefit for far-future : 3,535 – 2,989 = 546 million USD

B. Compute **Cost** :

Total Length of whole rivers is 434,596 m

According to the reference ‘ NCICD ‘ :

For the length 2,200 m, the cost is 418,381,000,000 IDR,

So, for the countermeasures number 1 are :

For the length 434,596 m, the cost is 82,648,504,125,455 IDR or 5,772,047,429 USD;

But it is only for the one side, if two side (right and left) the **total cost is 11,544,094,858 USD**;

C. Compute **B/C**: B/C for near-future is 504,000,000/11,544,094,858 = 0.044

B/C for far-future is 546,000,000/11,544,094,858 = 0.047

D. Compute **B - C**: B-C for near-future is 504,000,000 – 11,544,094,858 = -11,040,094,858 USD

B-C for far-future is (546,000,000 – 11,544,094,858) = -10,998,094,858 USD

Cost and Benefit/Cost (CM2)

	Original	CM3
EADC (Near-future):	3,271	2,277
EADC (Far-future):	3,535	2,493

A. Compute **Benefit** : Benefit for near-future : 3,271 – 2,277 = 944 million USD

Benefit for far-future : 3,535 – 2,493 = 1,042 million USD

B. Compute **Cost** :

Dredging 1m bed level to all rivers:

1. Total length of whole rivers : 434,596 m
2. Assume width of rivers (average) is 7.5 m
3. Total volume of dredging is 1 m x 434,596 m x 7.5 m = 3,259,470 m^3
4. Cost for dredging 1 m^3 is 250,000 IDR

then total cost is 3,259,470 m^3 x 250,000 IDR = 814,867,500,000 IDR (= 113,818,245 USD)

CM1+cost of dredging bed level = **11,544,094,858 $ +227,636,491 $ = 11,771,731,349 $**

C. Compute **B/C**: B/C for near-future is 944,000,000/11,771,731,349 = 0.082

B/C for far-future is 1,042,000,000/11,771,731,349 = 0.090

D. Compute **B - C**: B-C for near-future is 944,000,000 – 11,544,094,858) = -10,600,094,858 $

B-C for far-future is 1,042,000,000 – 11,544,094,858) = -10,502,094,858 $

Discussion

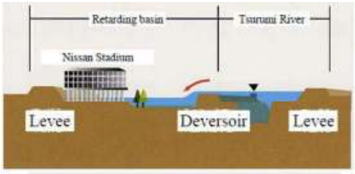
Benefit-Cost Ratio (B/C)

Adaptation measures	Benefit/Cost Ratio (BCR)
CM1	0.047
CM2	0.088

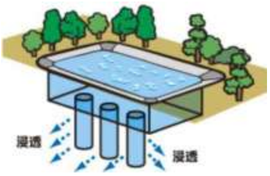
Adaptation measures	Benefit-Cost Ratio (BCR)
RPPs	2.193
RWs	9.076
SWP	0.045
GI	0.004

(sources: Fajar et al, 2020)

RRPs:
Recharge and Retention Ponds
RWs: Recharge Wells
SWP: Seawall Protection
GI: Green Infrastructure



RRPs


RWs


SWP


GI

B/Cs of CM1 and CM2 were compared with those of counter measures proposed by Fajar et al. (2020). It is clear that CM1 and CM2 are not good from the view point of B/C. Best counter measure is RWs (Recharge wells) due to its low cost.

Especially in Jakarta, low cost measures would be required for the implementation

Conclusions

Two counter measures were evaluated and compared with those in the previous study [page 67, 60].

CM1 and CM2 successively reduced the EADC compared with the present situations [page 69-72].

However, CM1 (increase of the bank embankment height) and CM2 (dredging) cost too much, so that other non structural counter measure should be evaluated [page 70-71].

The next chapter will focus on the **non structural counter measures, it is because the structural countermeasures was expensive and difficult to implement in Jakarta**.

Chapter 6 :
Flood Prediction as a Nonstructural Counter Measure

Possible nonstructural counter measures

Other counter measures suitable for Jakarta may be:

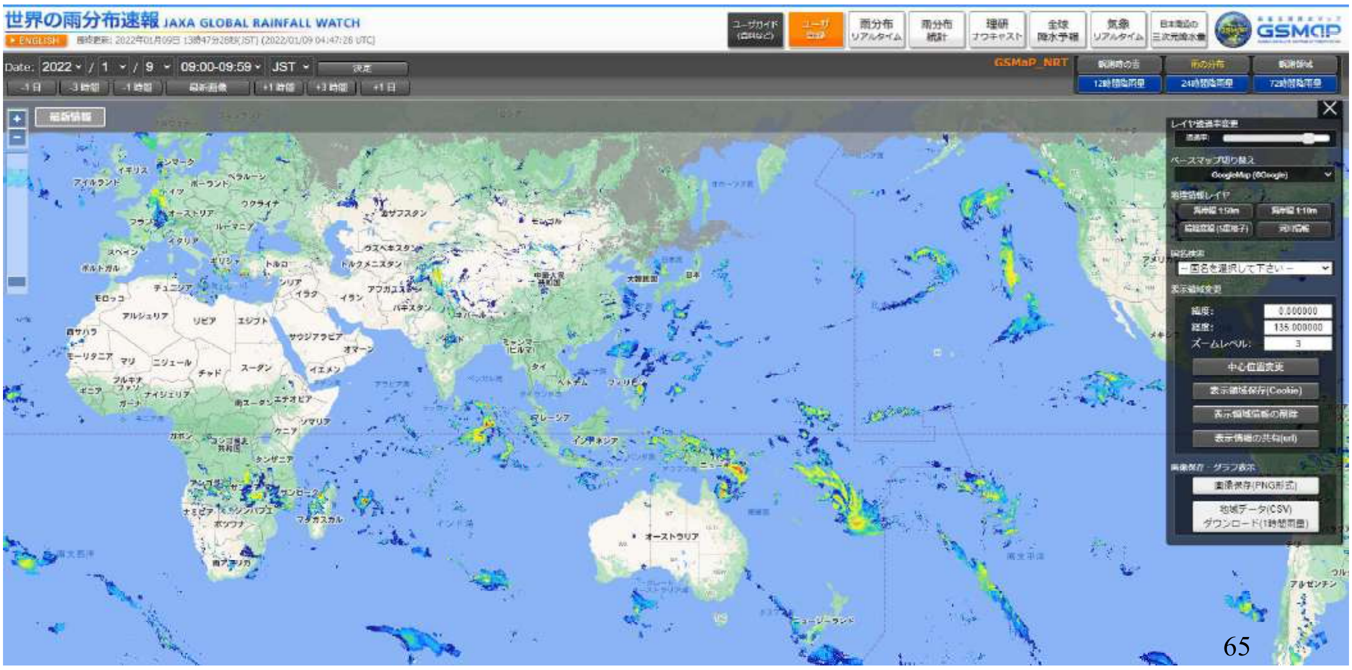
1. Flood early warning system
2. Development of flood hazard map with campaign and evacuation drill
3. Land use control such as
   forestation and stop urbanization in upstream region,
   and stop groundwater extraction in lowland area

etc.

Here, a possibility of flood prediction based on satellite data was examined as a non structural counter measure.

Satellite rainfall data (GSMaP)

Global satellite mapping of precipitation (GSMaP) was used.
It provides hourly rainfall data (mm/h) with the coverage 60^0N - 60^0S.
High spatial (10km) and temporal (1hour) resolutions are suitable for flood simulations in highly urbanized areas.



https://sharaku.eorc.jaxa.jp/GSMaP/index_j.htm

Target flood events

Summary of historical flood event

Year	Averaged rainfall (mm/day)	Maximum water level (cm) at Manggarai	Flood area (km^2)	Death Person	Main damage	Damage Cost (IDR)
1996	421	970	-	10	529 houses were highly damaged	6.4 Trillion
2002	464	1050	160	32	Electrical System Shutdown	9.9 Trillion
2007	340	1060	397	80	Electrical System Shutdown	8.8 Trillion
2013	168	1020	132	41	Embankment failure	1.5 Trillion
2014	581	830	201	26	134,662 persons were affected	5 Trillion
2015	310	890	196	5	Electrical System Shutdown	1.5 Trillion
2016	275	580	152	2	-	3 Trillion
2017	322	700	139	6	1,178 houses were inundated	147 Billion
2018	346	775	79	1	42 houses were highly damaged	150 Billion
2019	154	890	84	2	-	100 Billion
2020	196	965	150	67	Electrical System Shutdown	1 Trillion

Target flood events

Six yearly largest flood events from 2015 to 2020 were selected as the target because both GSMaP NRT and GSMaP Gauge data are available for these flood events.

Methodology

Satellite rainfall products

- ✓ **GSMaP NRT** (real-time flood-forecasting system)
- ✓ **GSMaP Gauge** (reconstructing past flood events)

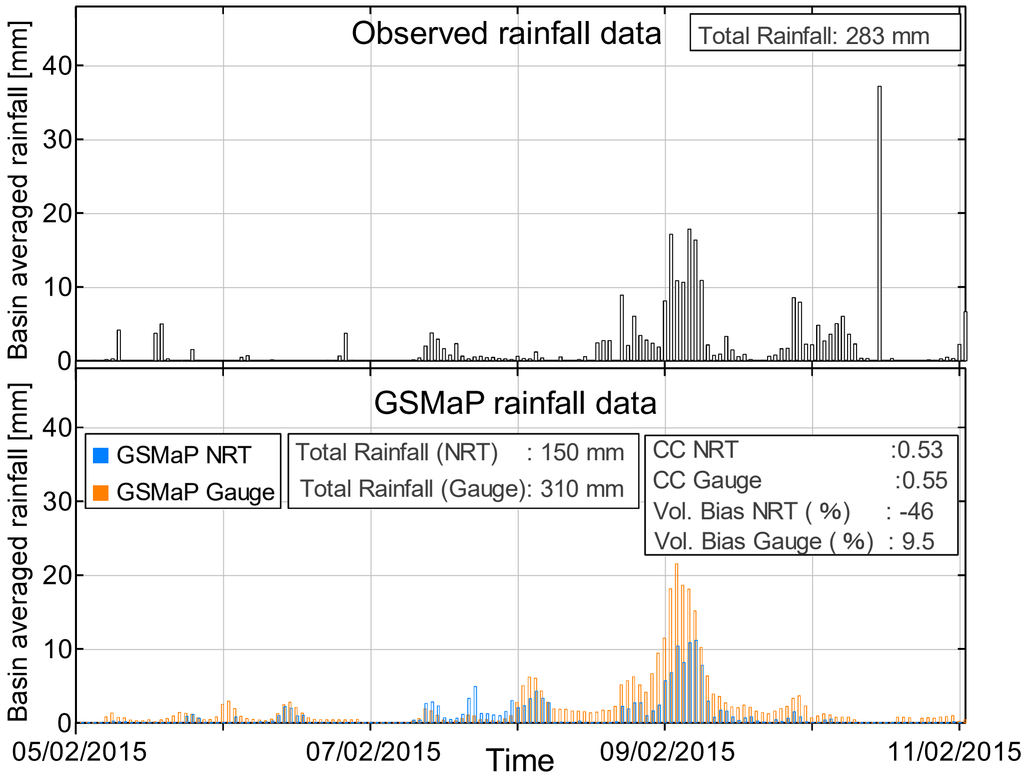
Validated by **Ground rainfall data**

Flood simulations based on GSMaP

- ✓ Root Mean Square Error (RMSE)
- ✓ Correlation Coefficients (CCs)
- ✓ Volume Bias (%)
- ✓ Nash–Sutcliffe efficiency index (NSE)

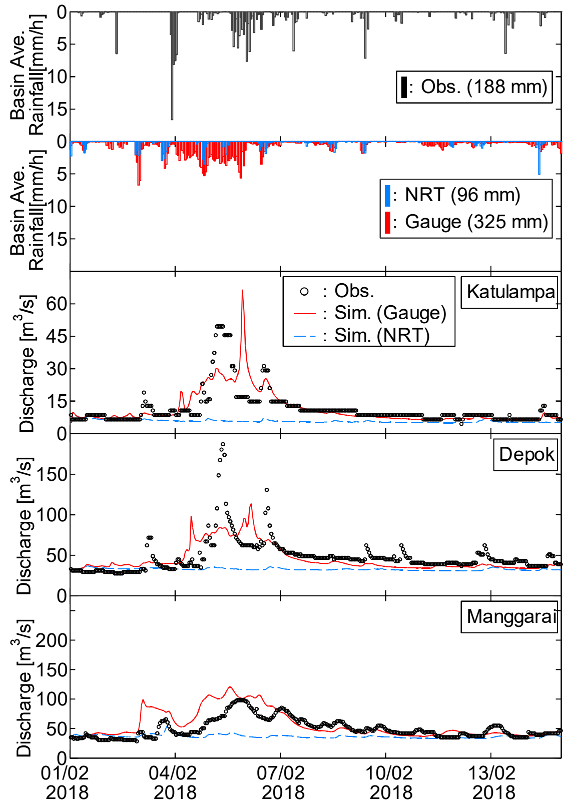
Evaluation based on observed river discharge and flood inundation map

Best rainfall comparisons



Hourly and daily rainfall comparisons at 2015 event show good correlation between rainfall satellite data and observation. However, **NRT (blue)** shows under estimation.

Best Hydrograph Comparisons



Hydrograph comparisons at 2018 event show good correlation between simulated and observed. Especially, **Gauge (red)** shows high performance but **NRT (blue)** shows under estimation.

hydrograph comparisons

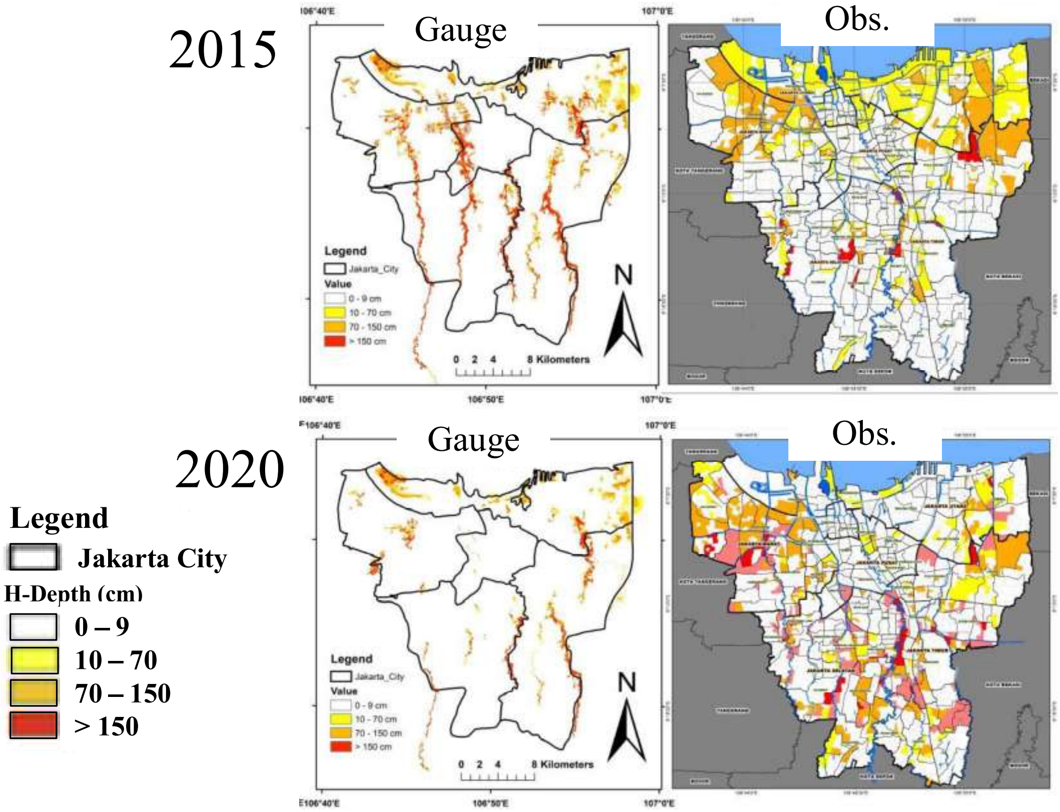
Summary of discharge hydrograph comparisons (GSMaP gauge)

Relatively Okay

Period	GSMaP gauge Correlation coefficients (CCs)	Nash Index	RMSE (m^3/s)
Event 2015	0.52	-1.15	3.97
	0.63	-0.80	15.02
	0.72	-2.39	28.92
Event 2016	0.03	0.44	3.86
	0.24	-0.40	11.92
	0.52	-5.18	22.32
Event 2017	0.42	0.67	4.04
	0.39	-0.44	11.48
	0.39	-0.94	17.61
Event 2018	0.69	0.39	6.41
	0.64	0.38	16.75
	0.73	-0.18	17.76
Event 2019	0.60	0.69	3.96
	0.60	0.43	10.49
	0.49	-0.06	9.67
Event 2020	0.68	0.54	4.37
	0.60	0.15	19.25
	0.62	-0.61	23.11

Correlation coefficients (CCs) of hydrograph comparisons show relatively acceptable values as a flood prediction.

Best Flood Inundation Comparisons



Flood inundation comparisons at 2015 and 2020 events show good correlation between simulated (Gauge) and observed. From these, we concluded GSMaP gauge may be used as flood prediction in Jakarta.

Conclusions

- GSMaP Gauge showed **acceptable** agreement in simulating the flood hydrograph and inundation of Jakarta, so that a flood prediction system based on GSMaP is possible [page 81].

- However, Gauge data are unavailable in real time, so we need some bias correction method for NRT data [page 80], which provided **near real-time rainfall data**.

- Also, other possible forecasting system should be analyzed and evaluated.

Other possible forecasting

Other possible forecasting system to be suitable for Jakarta are based on:

1. Radar rainfall system
2. Regional climate model simulation
3. Deep learning prediction with the real time observation data (rainfall, water level etc.)
4. Ensemble prediction of above

These also need to be checked and analyzed in the further study.

Chapter 7 : Summary and Recommendations

Summary

○ Rainfall runoff and flood inundation model was developed and applied to 2013 flood event in Jakarta, and it reasonably well reproduced flood inundation in Jakarta

○ Jakarta's flood inundation volume at future period would increase compared with the present situation due to:

- Only land subsidence by 7 %
- Only land use change by 18% (SSP1) and 20 % (SSP3)
- Land use change and land subsidence by 37% (SSP3)
- Climate change by 14% (RCP2.6) and 24% (RCP8.5)
- Heat island by 4 % (SSP1) and 8% (SSP3)

Summary

○ Urban development was clearly seen to increase not only the rainfall intensity and volume in future but also runoff from basin, river flow discharges, and flood inundations, due to the combination of land use change and increased rainfall.

○ Effects of urban development on both the atmosphere and runoff processes should be considered in climate change studies in cities.

○ Structural countermeasures were expensive and difficult to implement in Jakarta

○ GSMaP NRT product, which provided near real-time rainfall data, is suitable for real-time flood forecasting but some bias correction would required.

Recommendations

The government should prepare following matters for mitigation and adaptation to the climate crisis:

◯ Land use control such as forestation and prevent urbanization in the upstream and ground water pumping in the lowland area.

◯ Non structural counter measures such as the flood prediction system and hazard map with the evacuation drills.

◯ Mitigation plan for the heat island such as green infrastructure, update air conditioner as high energy efficiency.

◯ Further research support for mitigation and adaptation for the climate crisis and urban development in Jakarta

Thank you very much for your kind attention.

I owe special gratitude to the late Prof. Akira Mano, Tohoku University, Japan. Prof. Mano made me to come to Japan and his support made this work possible. His kindness and passion were a gift to the scientific community of Indonesia and Japan, and he will be sorely missed.

2024

Pengembangan Peta Bahaya Banjir di Pulau Kalimantan

Oleh:

Idham Riyando Moe, Ph.D

PUPR
SIGAP MEMBANGUN NEGERI

Outline Kegiatan:

- Introduction Kegiatan;
- Sistem Sungai DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil;
- Penyebab Banjir DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil;
- Pembangungan Model Banjir Genagan dan Hasil Simulasi;
- Evaluasi Banjir pada Kecamatan yang Mungkin Terdampak Banjir
- Hujan Kala Ulang-Banjir Kala Ulang dalam Persiapan Early Warning System WS Mentaya Katingan.
- Klasifikasi Peta Bahaya Banjir Berdasarkan BNPB
- Kesimpulan

Introduction Kegiatan

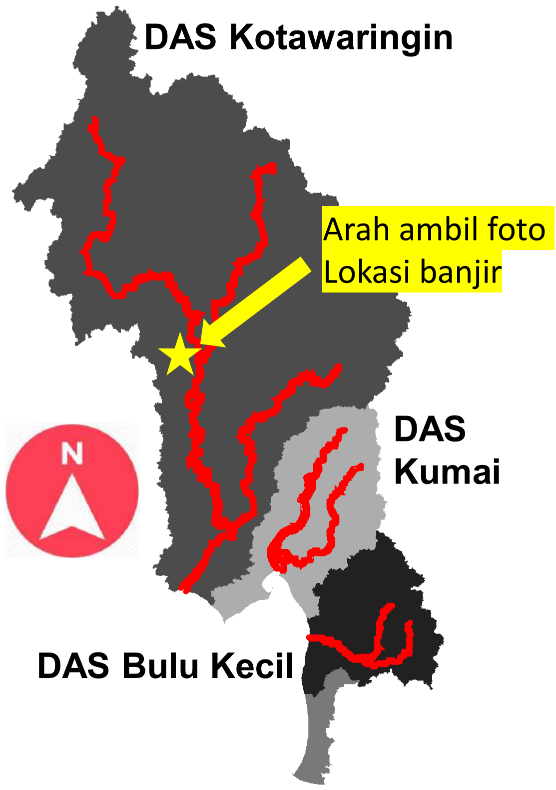
- Latar Belakang Kegiatan
- Lokasi DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil dalam WS Jelai-Kendawangan
- Tujuan Kegiatan

Latar Belakang Kegiatan (1)

Sumber: Pemkab Lamandau

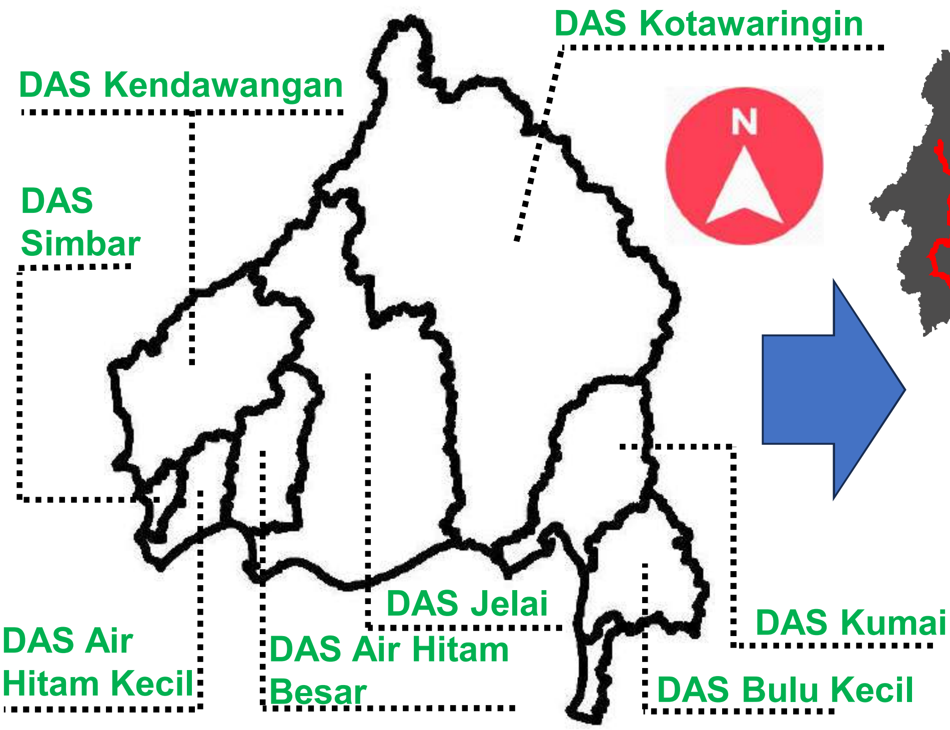
- Gambar diatas adalah kejadian Banjir Sungai di Kabupaten Lamandau.
- Banjir sering terjadi pada musim/periode hujan deras.

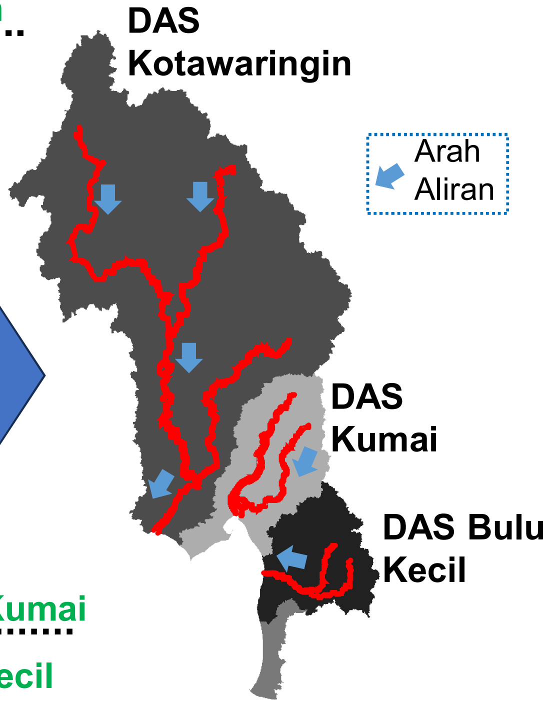
Latar Belakang Kegiatan (2)



- Diatas adalah perbandingan gambar flood dan no flood. Gambar a dan Gambar b Lokasi sangat identik.
- Salah satu informasi lain kejadian banjir, daerah JL Batu Batanggui (Kecamatan Bulik, Kabupaten Lamandau) sering terjadi banjir pada periode hujan deras. Kejadian banjir dapat terlihat seperti pada Gambar di atas pada Sep, 2020.
- Kejadian ini masih kerap terjadi pada musim hujan deras.

DAS yang di Evaluasi





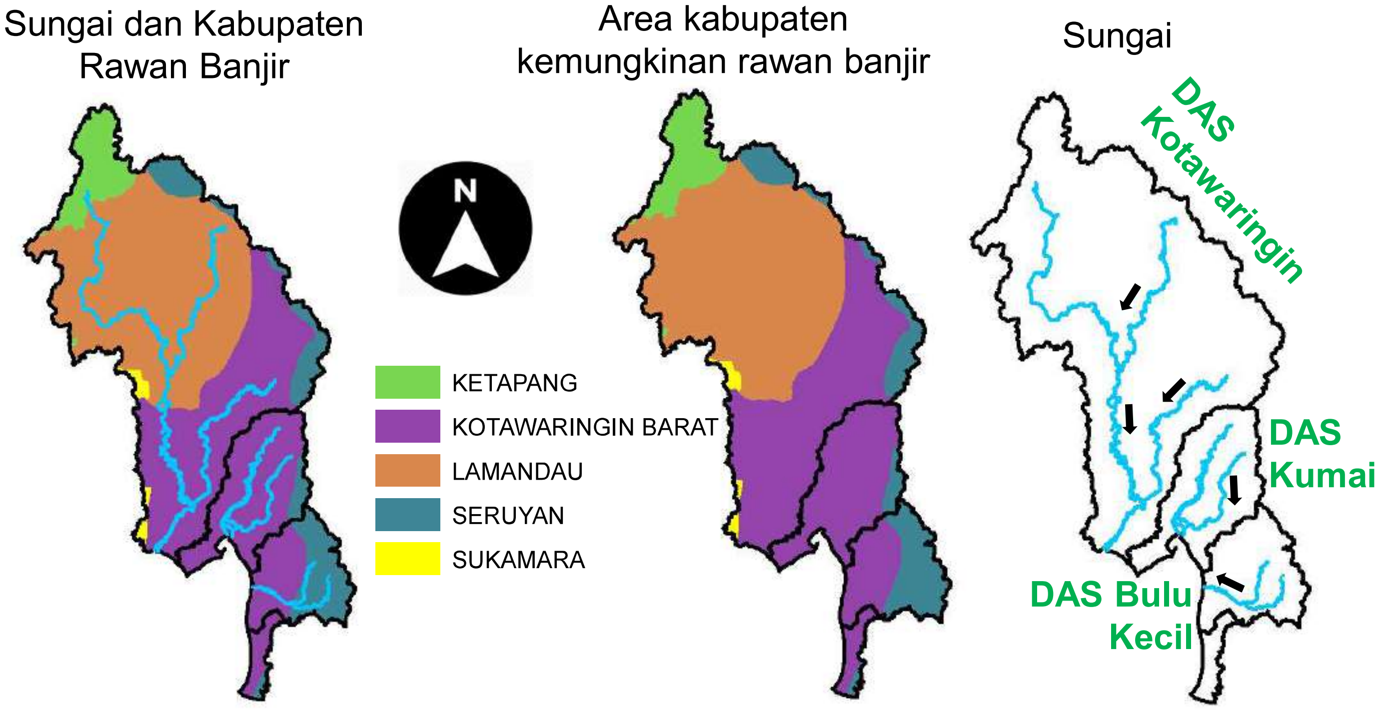
WS Jelai Kendawangan:

1. Kendawangan
2. Simbar
3. Air Hitam Kecil
4. Air Hitam Besar
5. Jelai
6. Bulu Kecil
7. Kumai
8. Kotawaringin

DAS di evaluasi:

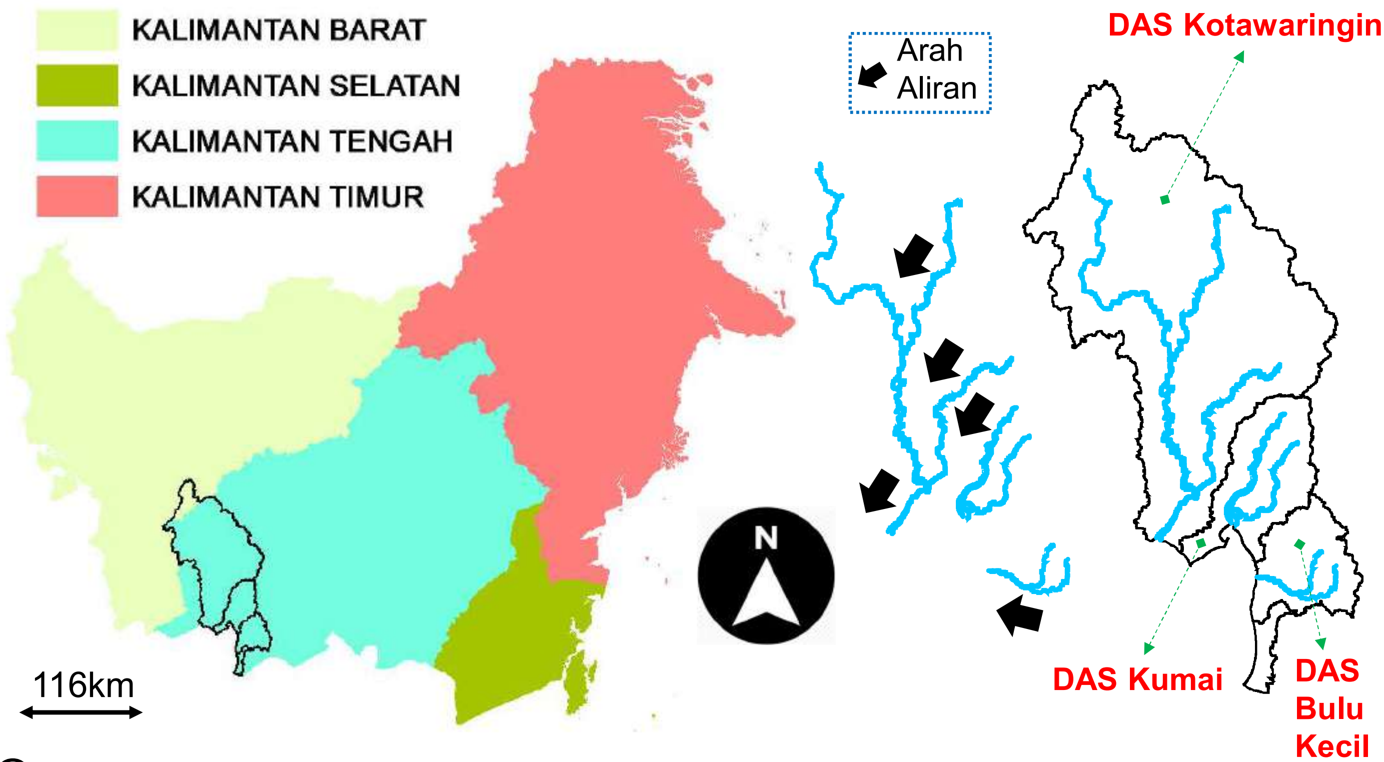
1. Kotawaringin
2. Kumai
3. Bulu Kecil

Kabupaten Sering/Rawan Banjir



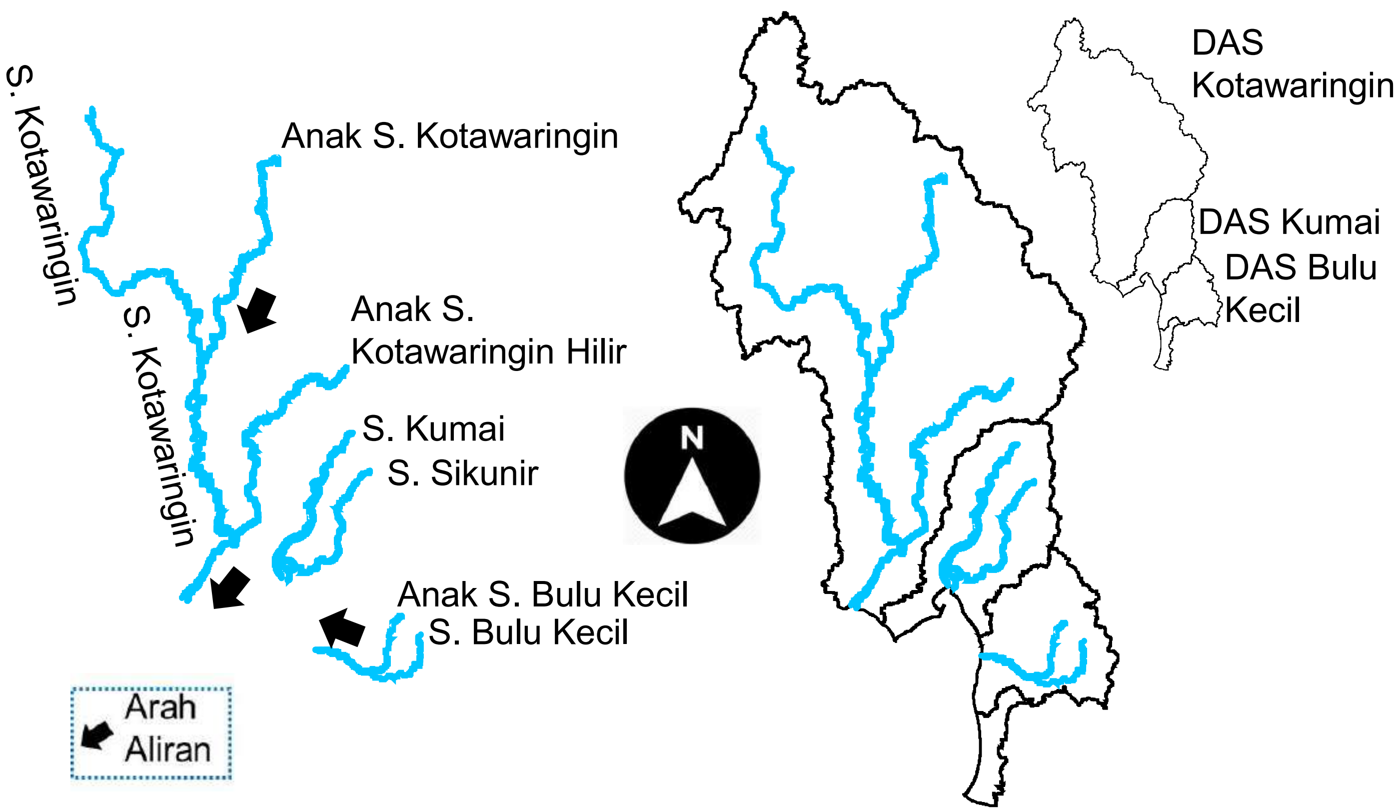
Berdasarkan laporan/informasi sekunder yang di dapat dari rekap banjir BWS Kalimantan II dari tahun 2020 hingga 2023, disimpulkan terdapat 5 Kabupaten yang mungkin kerap terkena banjir beberapa kali dalam rentang waktu tersebut. Area Rawan banjir (gambar kiri dan tengah) terlihat sangat kasar area banjir nya akibat di plot berdasarkan batas **kabupaten**. Observasi dari BWS Kalimantan II ini dapat di jadikan pemikiran dasar pada wilayah yang sering terdampak banjir.

Target Area Kegiatan



- DAS Kotawaringin berada diantara Kalimantan Barat dan Kalimantan Tengah.
- DAS Bulu Kecil dan DAS Kumai berada di Kalimantan Tengah
- Luas DAS Bulu Kecil= 1867.16 km^2, DAS Kotawaringin= 13996.5 km^2 dan DAS Kumai= 2456.29 km^2

Nama-Sungai dalam DAS Kotawaringin, Kumai dan Bulu Kecil



Sungai yang berada di dalam DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil dapat terlihat pada Gambar diatas.

Literature Review

- **Brian L. Djumaty dan Nina Putri Hayam Dey (2023)** menyatakan bahwa telah banyak adaptasi perubahan iklim yang telah dilakukan oleh Masyarakat di Kabupaten Kotawaringin Barat. Evaluasi ini dilakukan secara kualitatif melalui Forum Discussion Group.
- **Ivan Agusta Farizkha, dkk (2022)** mengatakan bahwa memerlukan jaringan drainase untuk menjangkau seluruh perumahan guna mengurangi potensi banjir di Kabupaten Kotawaringin Barat. Pendekatan yang di lakukan adalah melakukan overlaying hasil simulasi banjir terhadap areal perumahan.
- **E. Usman dan Imelda R. Silalahi (2012)** melakukan evaluasi sedimen di Teluk Kumai, dimana sedimentasi yang terjadi di Teluk Kumai sangat berpengaruh pada muka air laut dan debit Sungai Kumai. Sedimen ini membentuk endapan pasir Pantai.

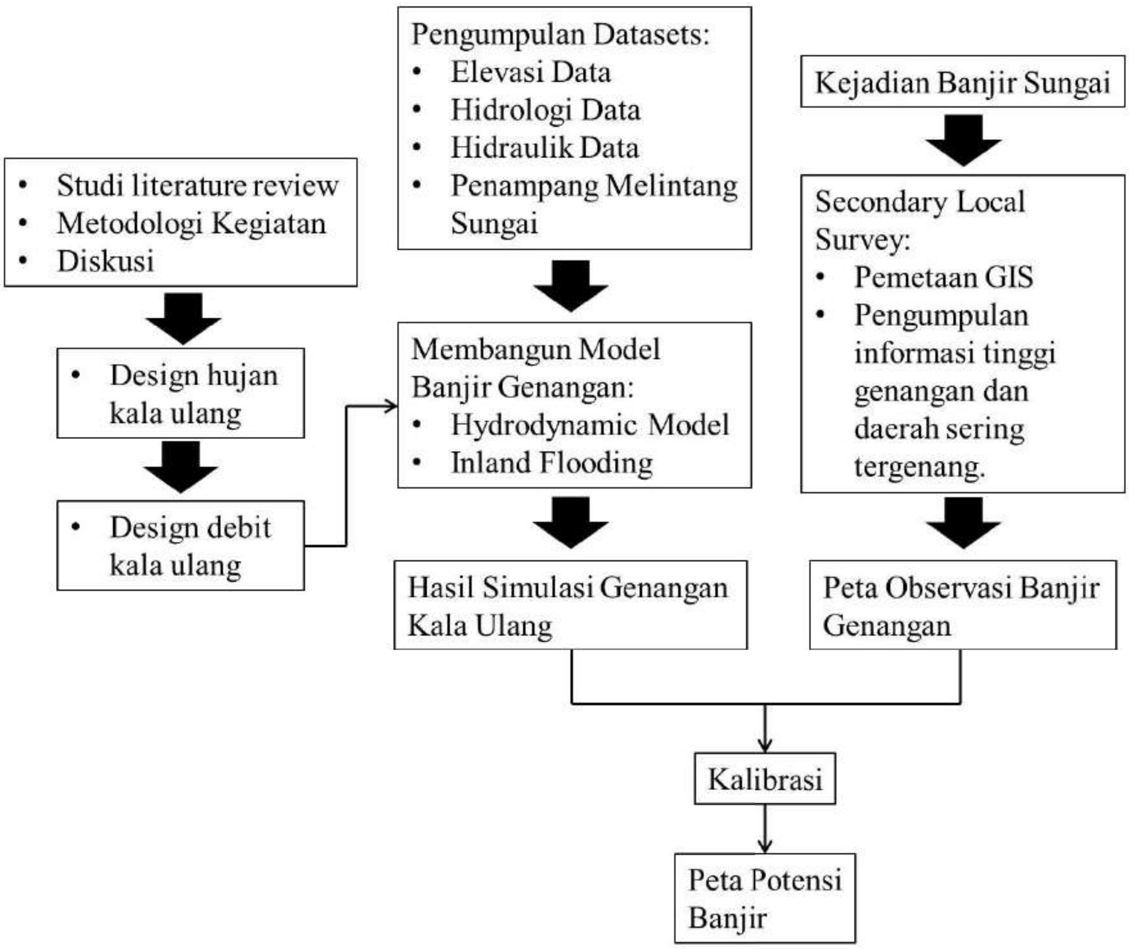
Kesimpulan Literature Review:

- Belum di dapat kegiatan yang meng-evaluasi pemanfaatan data hidrologi terhadap pos hujan yang terpasang di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil
- Sangat banyak upaya pengembangan area bahaya banjir di DAS dalam WS Jelai Kendawangan khususnya DAS Kotawaringin dan sekitarnya, namun, belum ditemukan pemanfaatan data hidrologi hingga sampai dikembangkan nya area bahaya banjir secara Spasial menggunakan model numerik (matematis).

Tujuan

- Melakukan Analisa hidrologi guna memanfaatkan data hidrologi yang telah banyak terpasang di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil;
- Membangun distribusi hujan kala ulang spasial dan debit rancangan yang ada di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil;
- Membangun model hidrologi dan hidraulik DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil
- Memanfaatkan dan melakukan Analisa data hidrologi yang ada untuk memetakan bahaya banjir di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil secara spasial menggunakan model 1D-2D hydrodinamik.

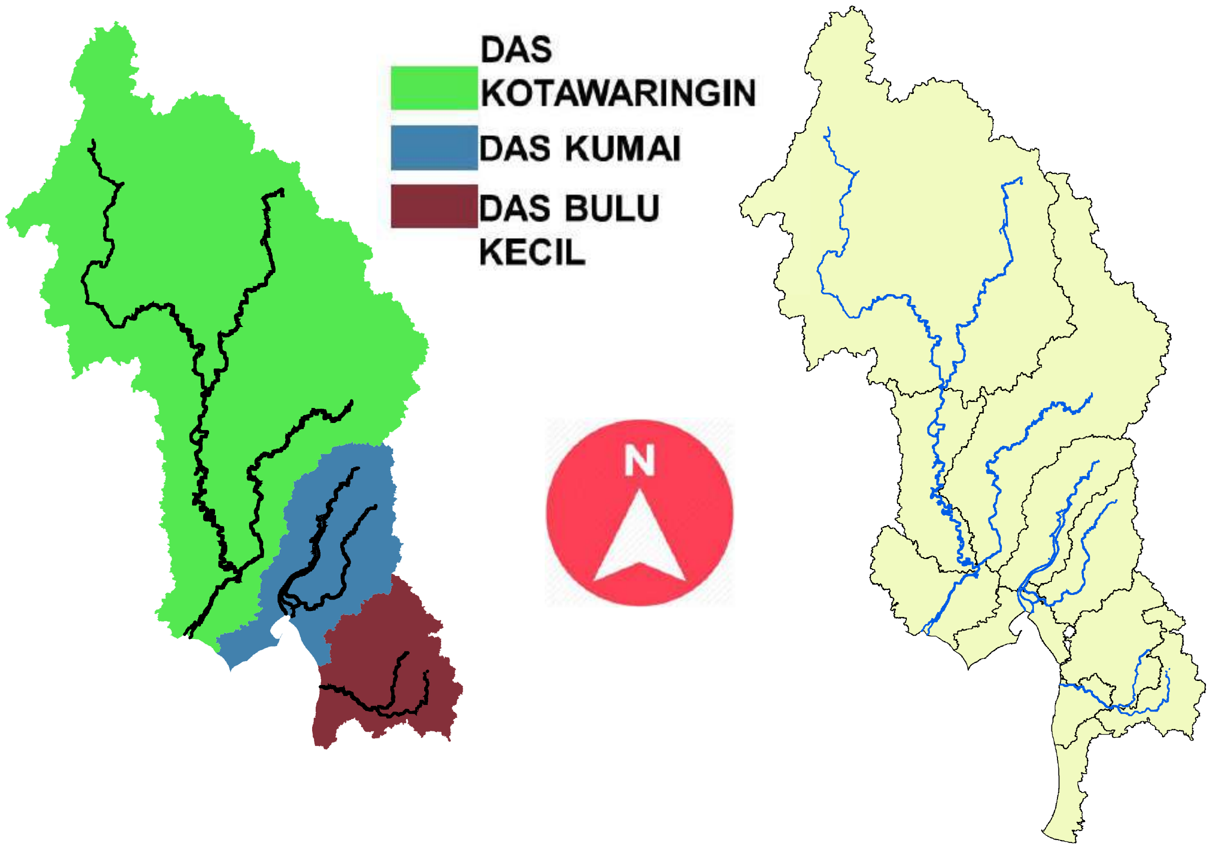
Metodologi Kegiatan



Sistem Sungai pada DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

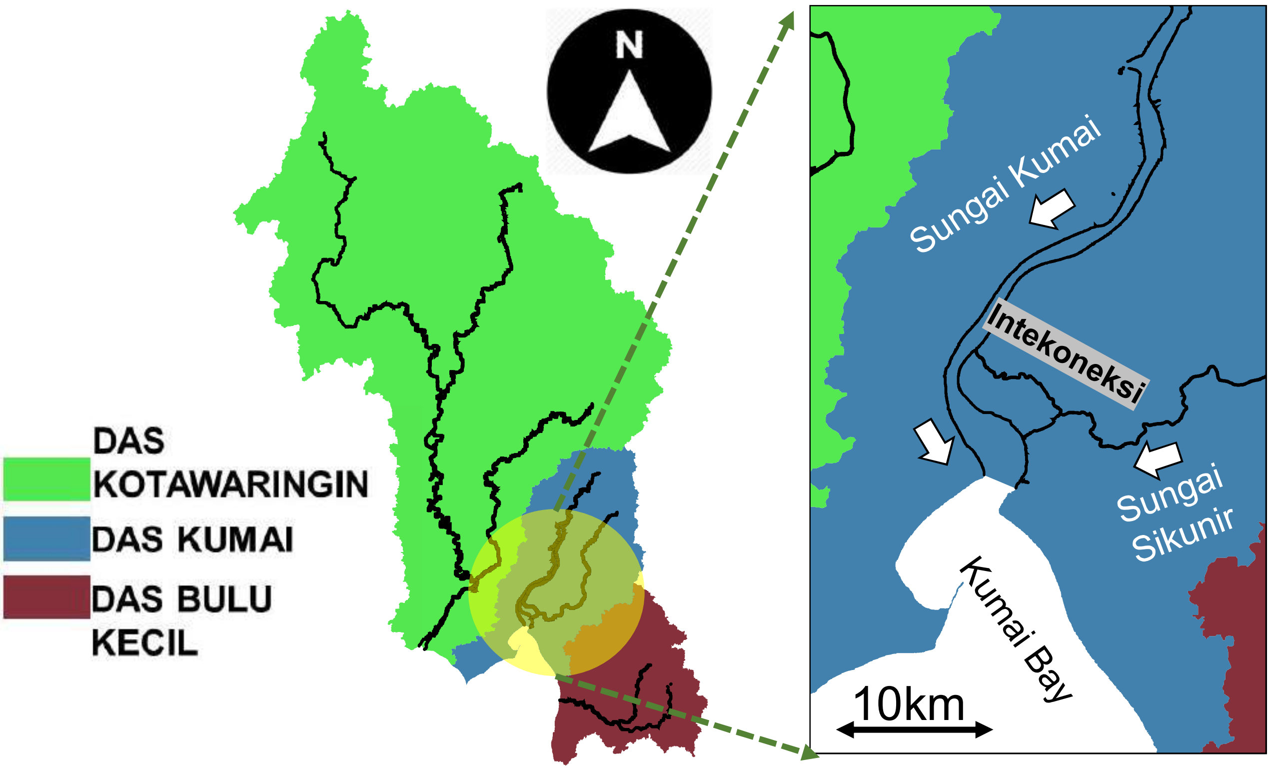
- Sistem Sungai
- Interkoneksi Sistem Sungai di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

Sistem Sungai DAS Kotawaringin, Kumai dan Batu Kecil



Sungai yang ada di dalam DAS Kotawaringin, DAS Kumai dan DAS Batu Kecil adalah target evaluasinya. Pada DAS Kumai terdapat interkoneksi antara kedua Sungai di dalam DAS Kumai tersebut. Pada DAS Kotawaringin dan DAS Batu Kecil tidak terdapat interkoneksi.

Interkoneksi Sistem Sungai pada DAS Kumai

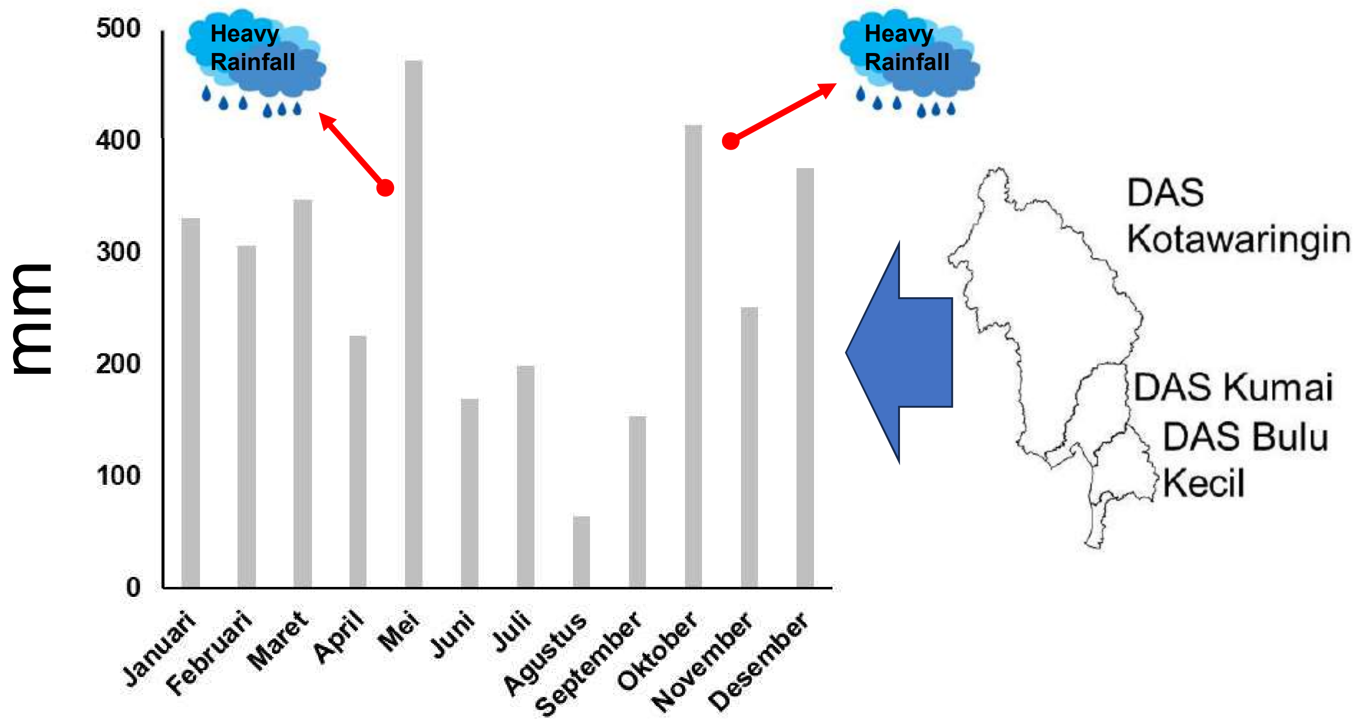


Dapat terlihat pada Gambar diatas Inter-Koneksi terdapat pada DAS Kumai. Sungai interkoneksi ini terjadi antara pertemuan Sungai Kumai dan Sungai Sikunir pada bagian hilir DAS Kumai. Sungai interkoneksi ini menjadi penting karena akan menjadi suplesi dari/untuk kedua Sungai tersebut. Sungai interkoneksi ini harus di input ke dalam model hidraulik.

Penyebab Banjir DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

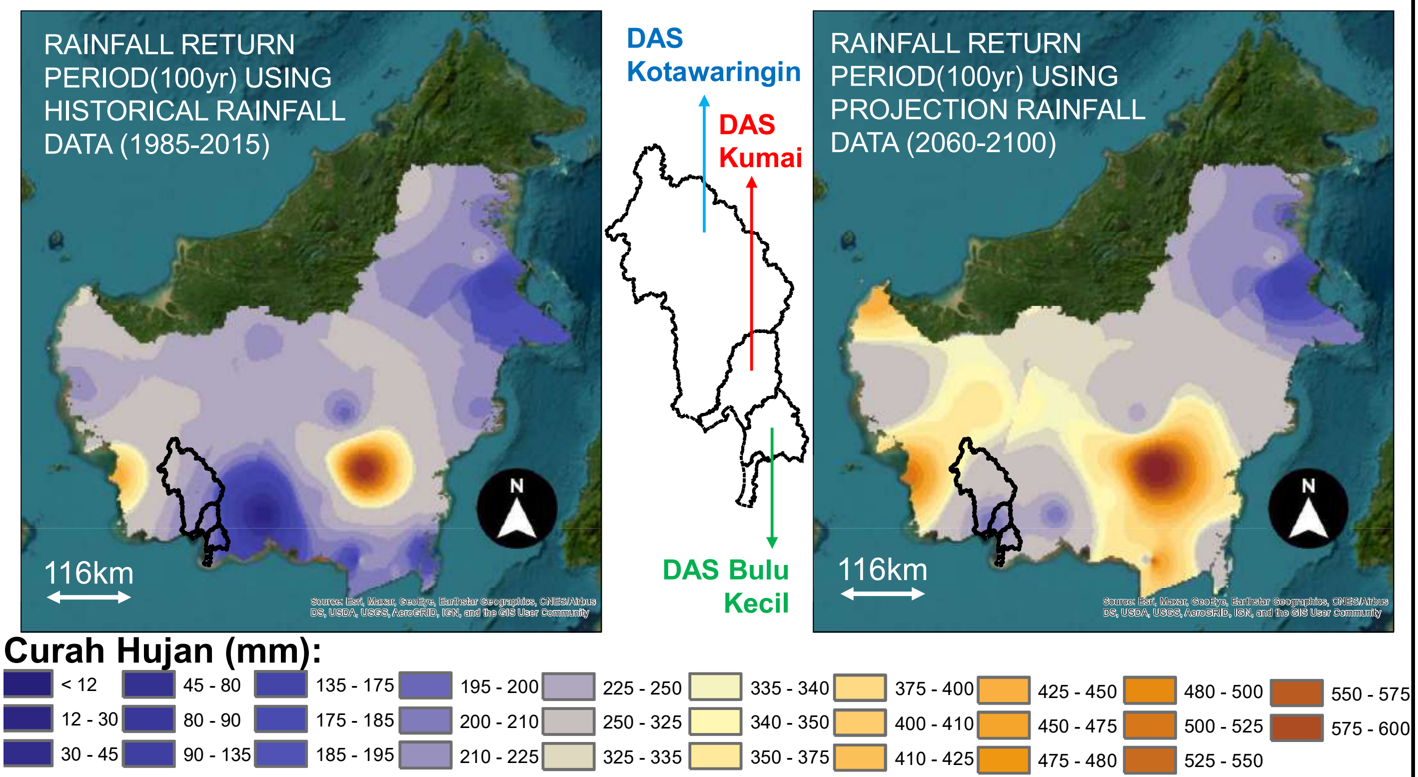
- Informasi Hujan Bulanan
- *Climate Change*
- Perubahan Tata Guna Lahan
- Permukiman, Pertanian dan Tambang dalam DAS Kotawaringin dan Sekitarnya

Hujan Rata-Rata Bulanan DAS Kotawaringin, Kumai, Bulu Kecil



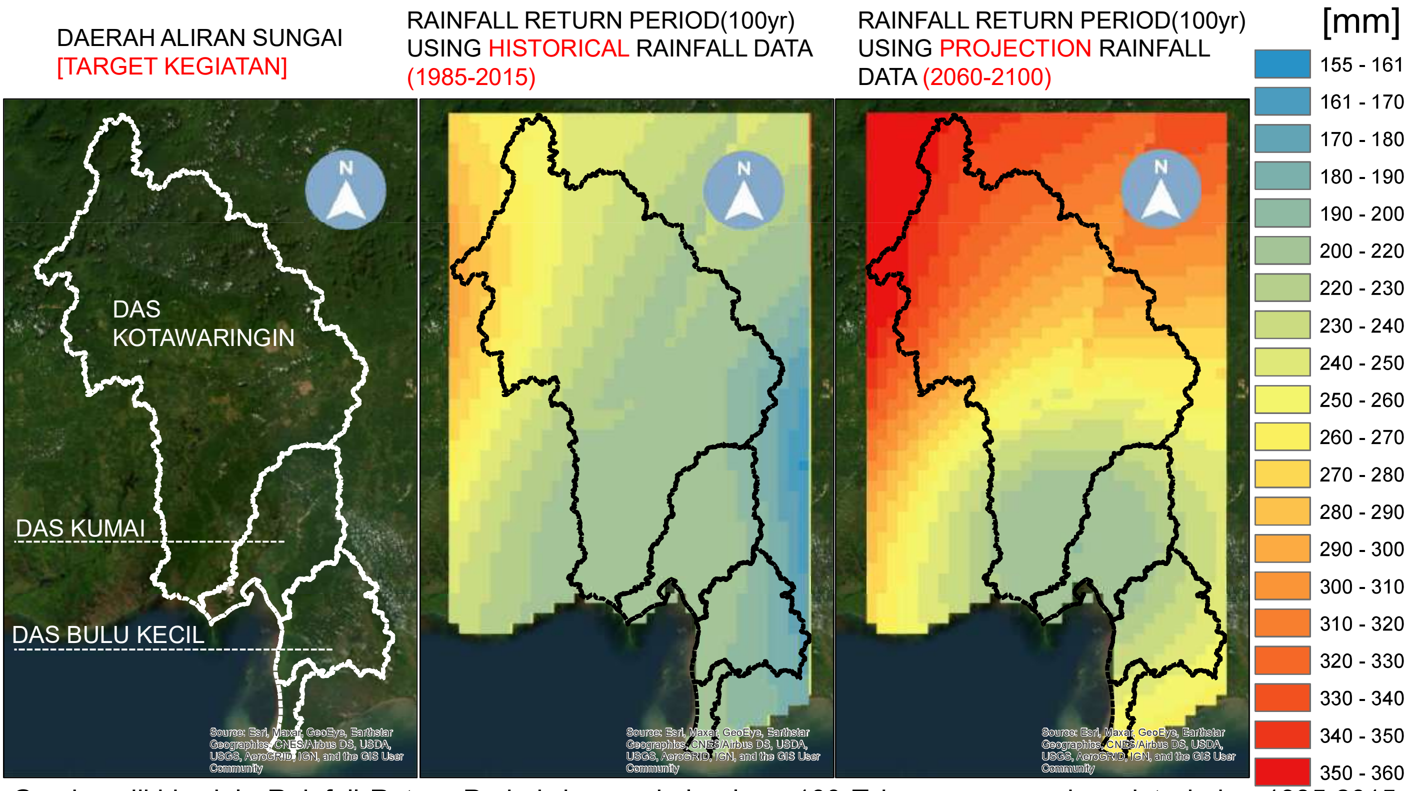
Hujan deras menjadi salah satu trigger yang menyebabkan banjir di Kotawaringin, DAS Kumai dan DAS Bulu Kecil. Gambar diatas adalah rata-rata hujan bulanan di ketiga DAS Tersebut. Dapat terlihat pada Gambar diatas bahwa rata-rata hujan dalam jumlah besar terjadi di Oktober hingga Mei. Sumber Data adalah dari BMKG.

Perubahan Iklim di Pulau Kalimantan (SDA, 2018)



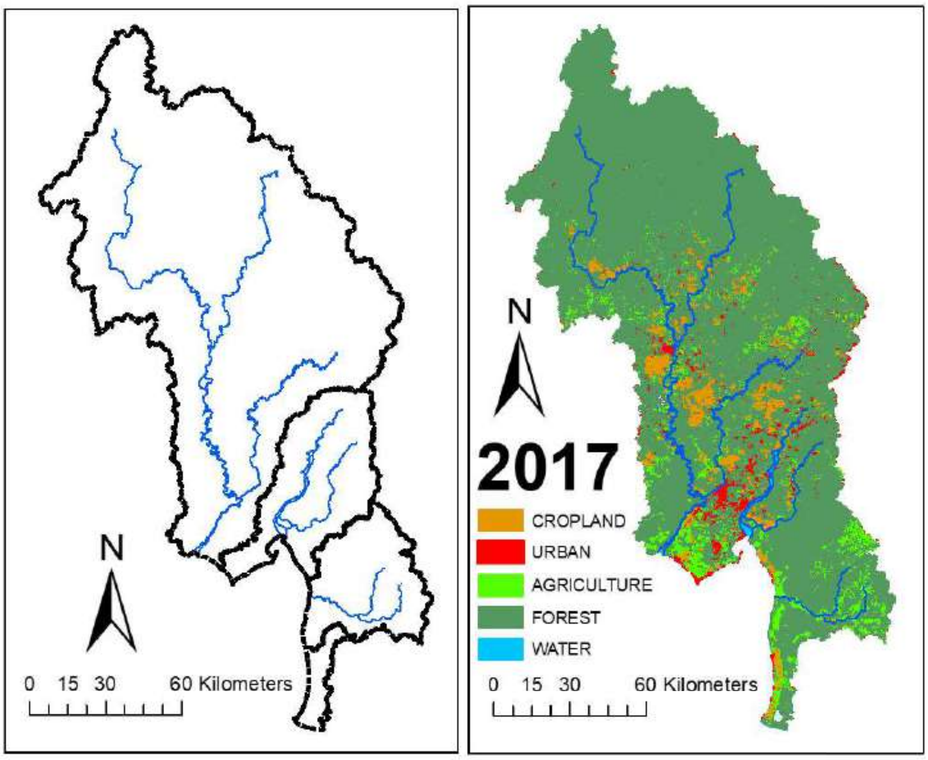
Diatas ialah spasial distribusi hujan antara historical (kiri) dan proyeksi (kanan) dibawah scenario climate change (Sumber: BPSDA-PUPR, 2018). Pada kala ulang 100yr, dapat terlihat bahwa terdapat kenaikan hujan di tahun 2060-2100 di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil. Dari historical ke masa depan, curah hujan meningkat 31.4% (dari 223mm→293mm). Ini merupakan trigger banjir yang mungkin akan terjadi di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil.

Perubahan Iklim di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil (SDA, 2018)



Gambar dikiri adala Rainfall Return Period dengan kala ulang 100 Tahun menggunakan data hujan 1985-2015. Dengan kala ulang yang sama, hujan proyeksi 100yr kedepan dapat terlihat meningkat khususnya terlihat pada khususunya bagian hulu DAS Kotawaringin, dan DAS Bulu Kecil. Hasil ini meng-indikasikan akan adanya potensi bahaya debit dan mungkin banjir di masa-masa yang akan datang pada DAS tersebut. Akibat situasi tersebut dapat dijelaskan bahwa DAS Kotawaringin bagian hulu naik dari 255mm→355mm (±39.22%), DAS Kumai bagin hulu naik dari 195mm→225mm (±15.38%) dan DAS Bulu Kecil naik 175mm→255mm (±45.71%).

Tata Guna Lahan DAS Kotawaringin, Kumai, Bulu Kecil



[km^2]

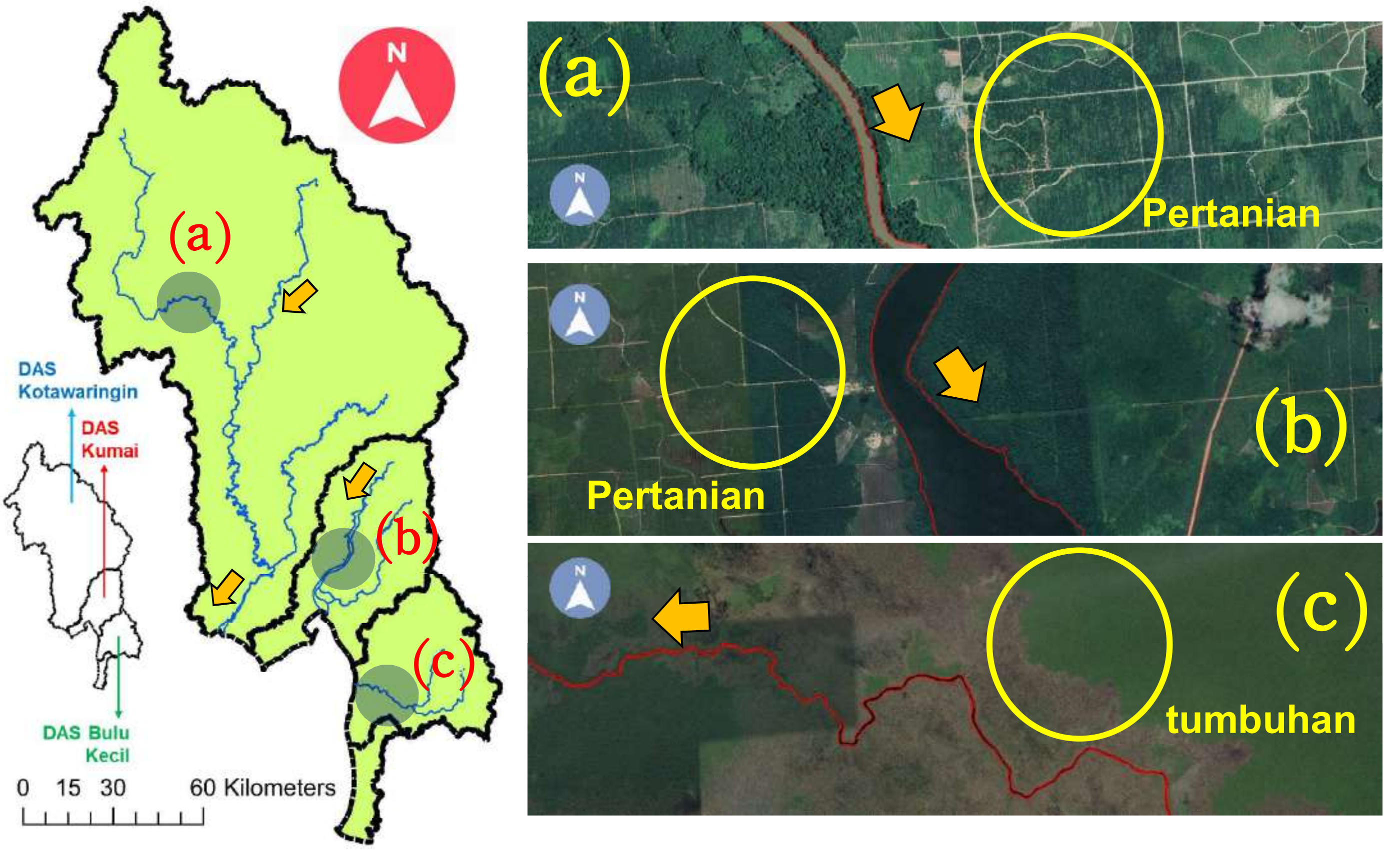
No	Penggunaan Lahan	DAS Kotawaringin
1	Crop	650.9
2	Urban	133.1
3	Agriculture	654.4
4	Forest	12484.1
5	Water	73.9

No	Penggunaan Lahan	DAS Kumai
1	Crop	182.6
2	Urban	91.7
3	Agriculture	203.6
4	Forest	1918.6
5	Water	59.9

No	Penggunaan Lahan	DAS Bulu Kecil
1	Crop	0.8
2	Urban	0.1
3	Agriculture	325.9
4	Forest	1537.2
5	Water	3.2

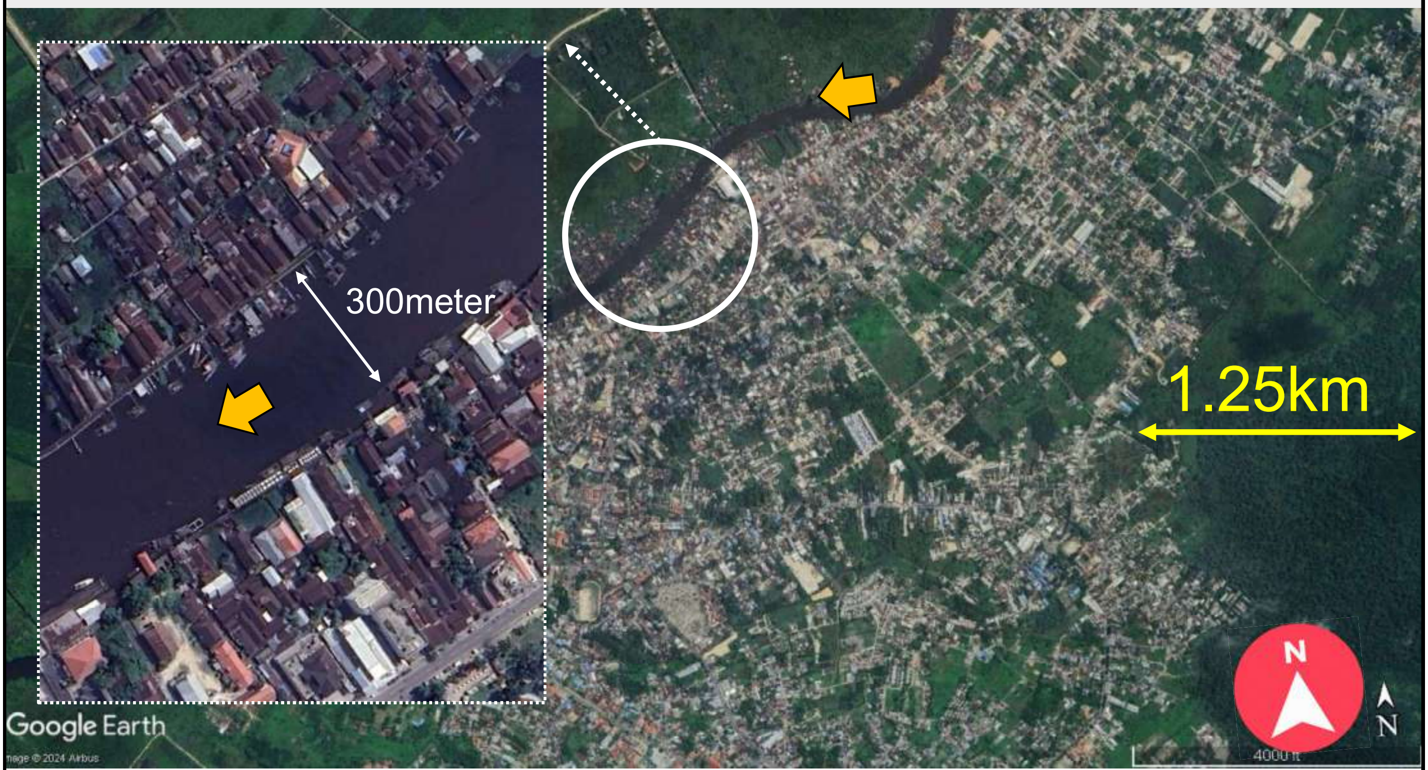
Dapat terlihat pada Gambar diatas penggunaan land use pada DAS Kotawaringin, Kumai dan Bulu Kecil Thn 2017. Data tata guna lahan ini berasal dari Sentinel-2 (ESRI). Tahun 2017, Forest area cukup mendominasi tutupan lahan seperti yang telihat pada Gambar diatas.

Spot Penggunaan Lahan di DAS Kotawaringin, Kumai dan Bulu Kecil



Dapat terlihat pada gambar diatas situasi DAS Kotawaringin, Kumai dan Bulu Kecil. Pada sekitaran Sungai banyak dimanfaatkan area pertanian, situasi ini hamper serupa pada seluruh DAS yang menjadi target evaluasi.

Permukiman Pinggiran Sungai Kotawaringin



Banyak nya perumahan yang terletak di pinggir ataupun di area basah anak sungai Kotawaringin. Hal ini menjadikan kapasitas sungai DAS Kotawaringin mungkin menjadi relative lebih sempit atau kapasitas sungai nya kecil, khususnya pada area banyak nya pemukiman tersebut. Hal ini juga menjadi trigger kejadian banjir DAS Kotawaringin dll.

Permukiman Pinggiran Sungai Kumai

Gambar diatas adalah area hilir Sungai Kumai di DAS Kumai. Dapat terlihat bahwa hilir Sungai Kumai di penuhi dengan area perkotaan. Pada saat musim hujan deras, luapan air sungai mungkin akan menggenangi area perumahan. Hal ini menjadikan kemungkinan banjir di Sungai Kumai ini semakin tinggi.

Permukiman Pinggiran Sungai Bulu Kecil

Diatas adalah hilir Sungai bulu kecil, sesuai dengan Namanya, lebar Sungai di DAS Bulu Kecil relative sangat kecil. Terlihat melalui Google earth, lebar Sungai di DAS Bulu Kecil adalah 0.02 km hingga 0.05 km. DAS ini juga tidak banyak di tempati area urban. Dengan Sungai yang kecil, kemungkinan air meluap sangat lah besar. Ini mungkin menjadi trigger banjir di DAS Bulu Kecil.

Pembangunan Model Banjir WS Mentaya Katingan

- *Rainfall-Runoff di* Daerah Aliran Sungai*:* Nakayasu
- *Flood routing* di Sungai
- *Flood Inundation Simulation* di *Flood Plain*

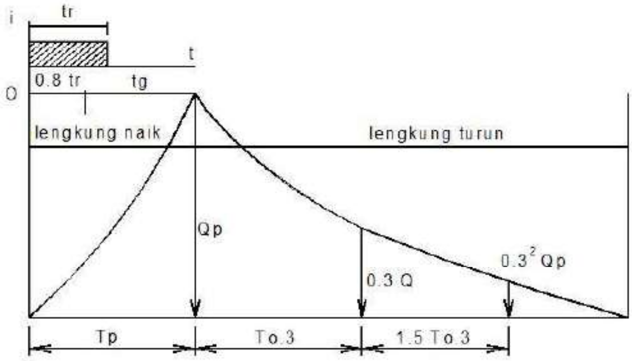
Model Banjir Genangan

Model banjir genangan terdiri dari:

- Rainfall Runoff Process: Nakayasu
- Flood Routing: One dimensional unsteady flow
- Flood Inundation Model: Two dimensional unsteady flow

Metode diatas adalah sangat umum digunakan guna membangun model banjir genangan. Metode diatas merupakan fisikal based flood model. Proses hidrologi dan hidraulik dipakai guna mengevaluasi banjir di Sungai Mentaya dan Katingan secara quantitative.

Rainfall Runoff: Nakayasu



Persamaan Hidrograf Satuan Sintetik Nakayasu:

$$Qp = \frac{A.Re}{3{,}6(\,0{,}3\ Tp + T0{,}3)}$$

Dengan :

- Qp = debit puncak banjir (m3/detik)
- Re = curah hujan efektif (mm)
- Tp = tenggang waktu (time log) dari permulaan hujan sampai puncak banjir (jam)
- T0,3 = waktu yang di perlukan oleh penurunan debit, dari debit puncak sampai 30% dari debit puncak (jam)

Sebagai catatan, metode Nakayasu adalah model linier dalam mendapat kan debit di setiap sub catchment pada DAS Mentaya dan DAS Katingan (masing-masingnya)

Flood Routing & Flood Inundation Simulation

✓ Flood Routing in Rivers and drainage system

Continuous equation

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_1$$

Momentum Equation

$$\frac{\partial Q}{\partial t} + \frac{\partial (uQ)}{\partial x} = gA\frac{\partial (h)}{\partial x} - \frac{gn^2|Q|Q}{R^{4/3}A}$$

A = area of cross section

Q = discharge

q_1 = lateral inflow

u = velocity

h = water depth

✓ Flood Inundation Simulation

$$\frac{\partial h}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0$$ **Mass Equation**

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{C^2 \cdot h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial x}(h\tau_{xy})\right] = 0$$ **Conservation momentum for X**

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gq\sqrt{p^2+q^2}}{C^2 \cdot h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] = 0$$ **Conservation momentum for Y**

The following symbols are used in the equations:

$C(x,y)$ is the Chézy resistance ($m^{1/2}\ s^{-1}$),

ρ_w is the density of water ($kg\ m^{-3}$),

ζ (x,y,t) is the water elevation (m),

τ_{xx}, τ_{xy}, and τ_{yy} are the components of effective shear stress ($kg\ m^{-1}\ s^{-2}$),

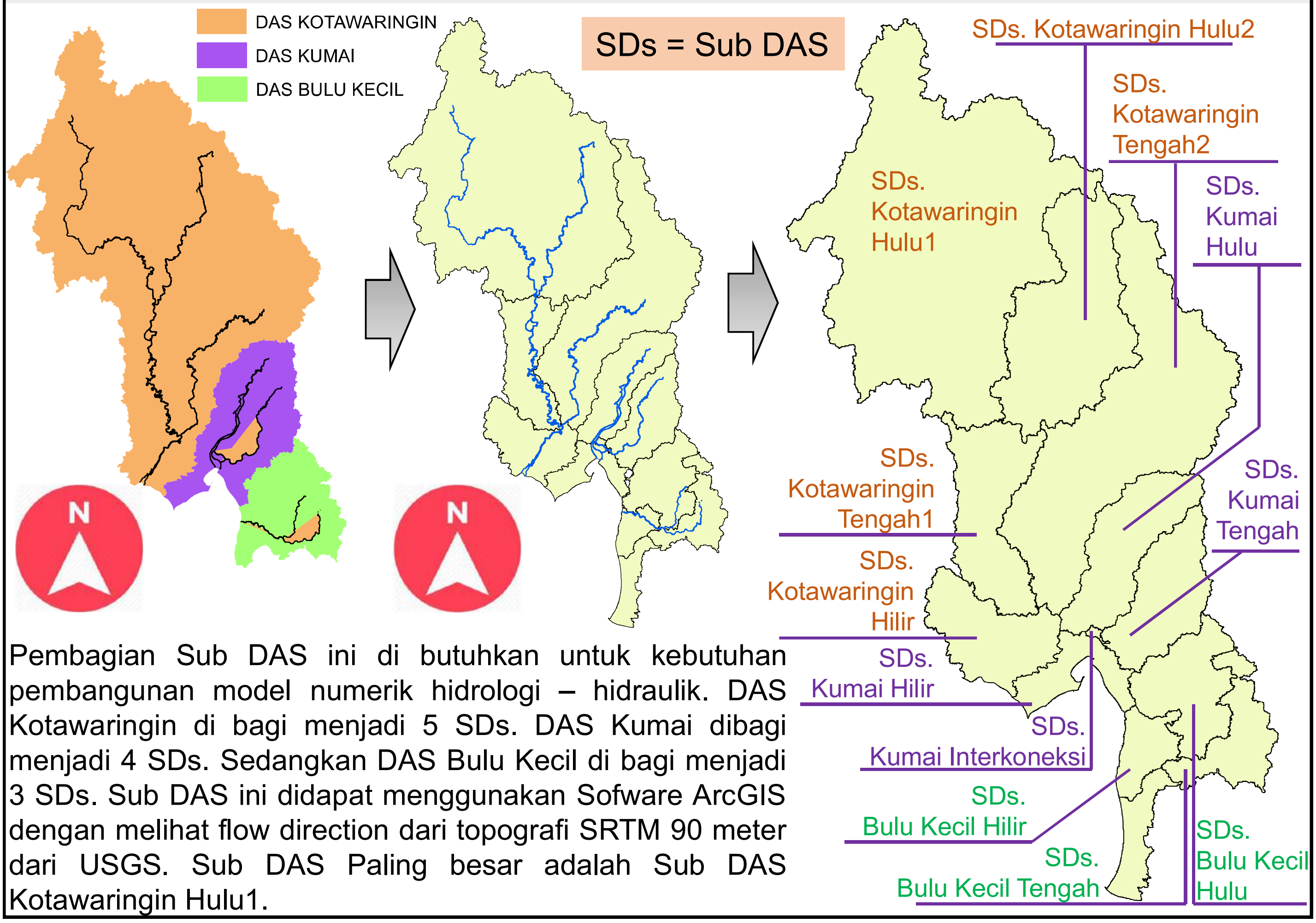
p(x,y,t), q(x,y,t) are the flux densities ($m^3\ s^{-1}\ m^{-1}$) in the x- and y-directions,

h(x,y,t) is the water depth (m). g is the acceleration of gravity ($m\ s^{-2}$).

Datasets untuk Evaluasi Banjir DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

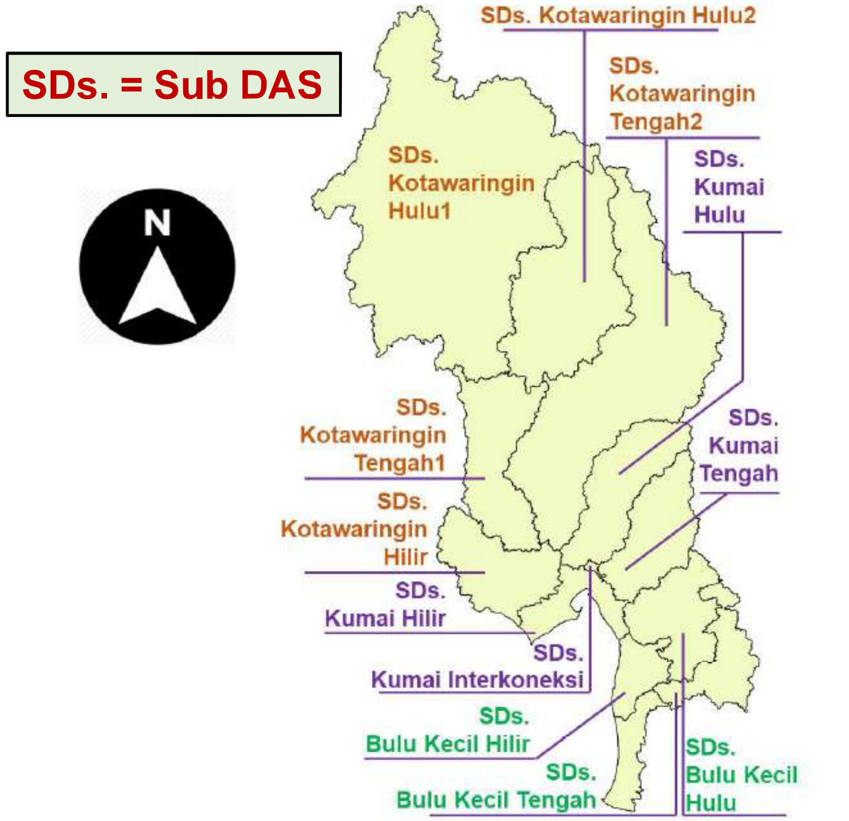
- Sub DAS Kotawaringin, Kumai dan Bulu Kecil
- Pos Curah Hujan dan Seleksi Pos Curah Hujan
- DEM
- Tata Guna Lahan 2017 dan 2023
- Pasang-Surut

Pembagian Sub DAS Kotawaringin, DAS Kumai, DAS Bulu Kecil



Pembagian Sub DAS ini di butuhkan untuk kebutuhan pembangunan model numerik hidrologi – hidraulik. DAS Kotawaringin di bagi menjadi 5 SDs. DAS Kumai dibagi menjadi 4 SDs. Sedangkan DAS Bulu Kecil di bagi menjadi 3 SDs. Sub DAS ini didapat menggunakan Sofware ArcGIS dengan melihat flow direction dari topografi SRTM 90 meter dari USGS. Sub DAS Paling besar adalah Sub DAS Kotawaringin Hulu1.

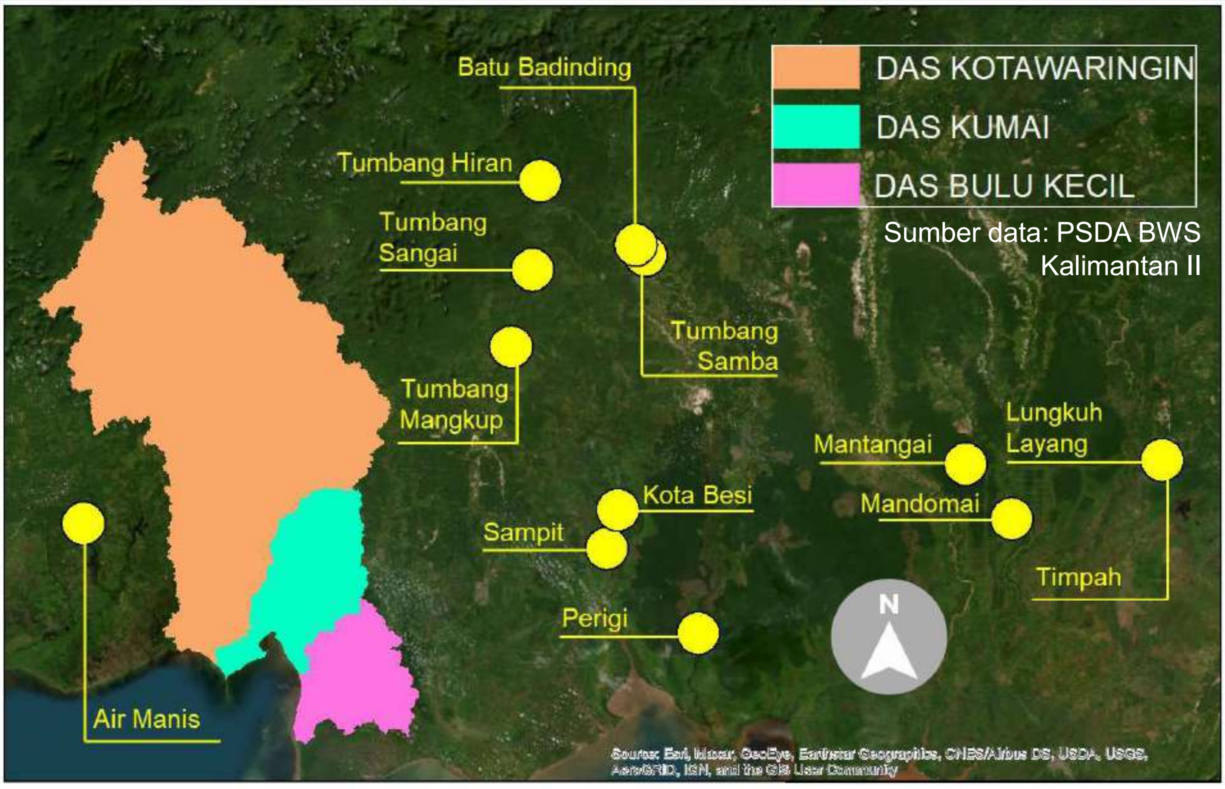
Luasan Sub DAS di DAS Kotawaringin, DAS Kumai, DAS Bulu Kecil



NAMA SUB DAS	(AREA) Km^2
SDs KOTAWARINGIN HULU2	2137.5
SDs KOTAWARINGIN HULU1	6387.2
SDs KOTAWARINGIN TENGAH1	1207.7
SDs KOTAWARINGIN TENGAH2	3572.2
SDs KOTAWARINGIN HILIR	935.3
SDs KUMAI HULU	1041.0
SDs KUMAI TENGAH	943.1
SDs KUMAI INTERKONEKSI	16.2
SDs KUMAI HILIR	448.4
SDs BULU KECIL TENGAH	641.4
SDs BULU KECIL HULU	862.1
SDs BULU KECIL HILIR	365.0

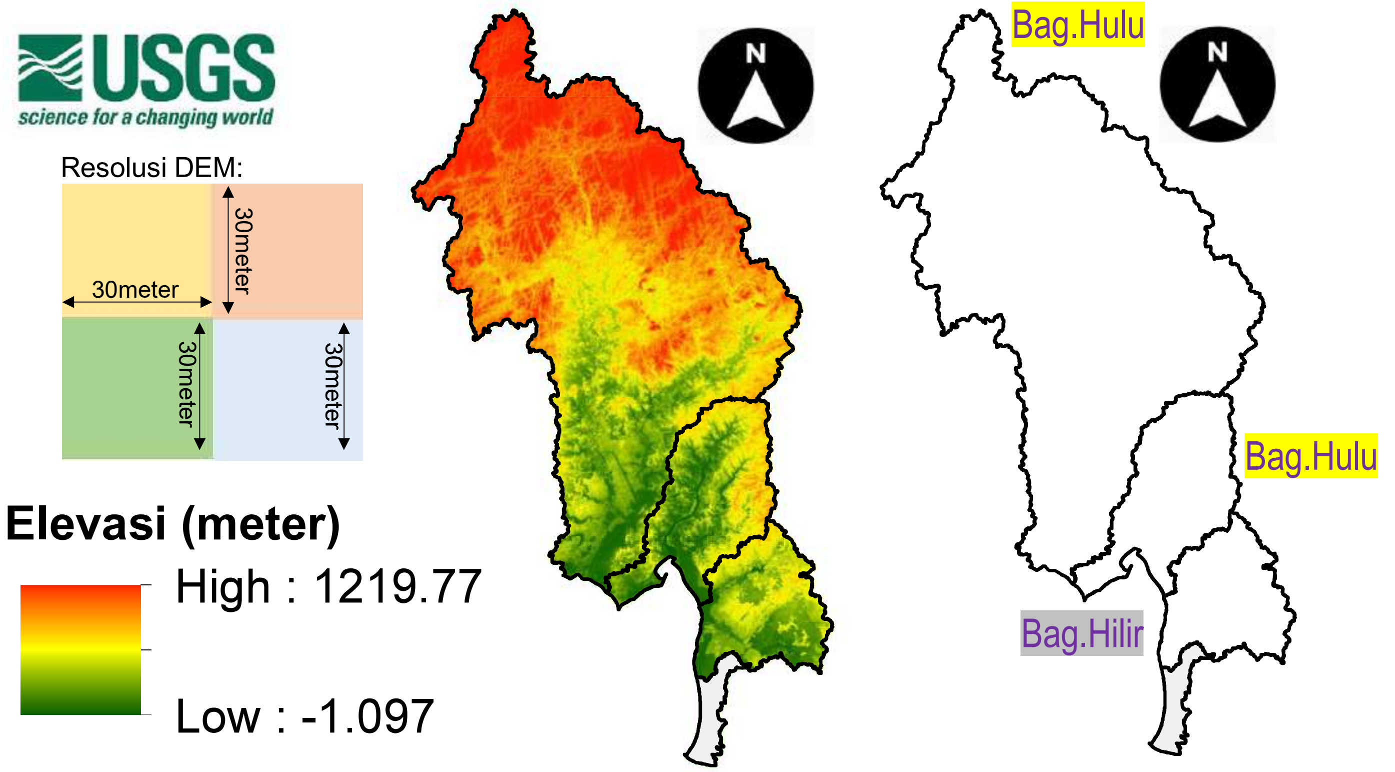
Diatas adalah luasan sub DAS di dalam DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil. Penamaan Sub DAS tersebut dilakukan dalam rangka mudah memahami dan memahami Sub DAS pembentuk dalam ketiga DAS tersebut. Dari informasi table diatas dapat terlihat Sub DAS paling besar adalah Sub DAS Kotawaringin Hulu1.

Ketersediaan Informasi Pos Curah Hujan (PCH)



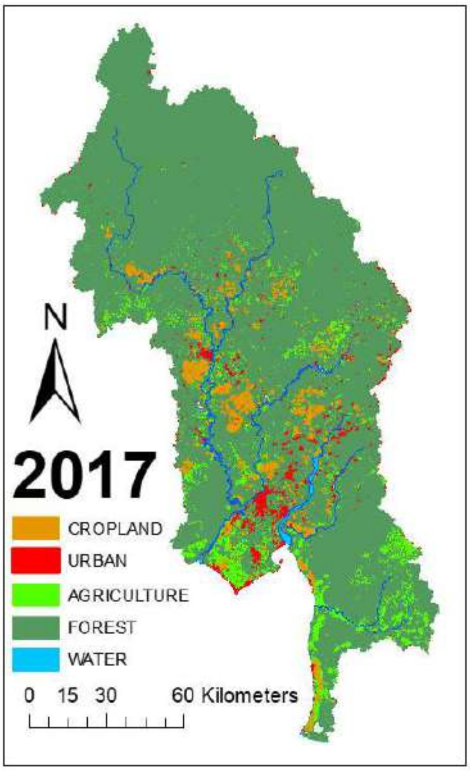
Terdapat 13 Pos Curah Hujan (CH) yang tersedia pada evaluasi target seperti yang terlihat pada Gambar diatas. Nama PCH juga tercantum pada Gambar diatas. Seluruh Lokasi pos Curah hujan tidak berada di dalam DAS Target. Saat ini pemanfaatan data hidrologi (curah hujan) akan memanfaatkan data-data yang tersedia tersebut. Karena kurang nya pos hidrologi (CH) di daerah DAS target, maka seluruh pos terdekat harus dimanfaatkan.

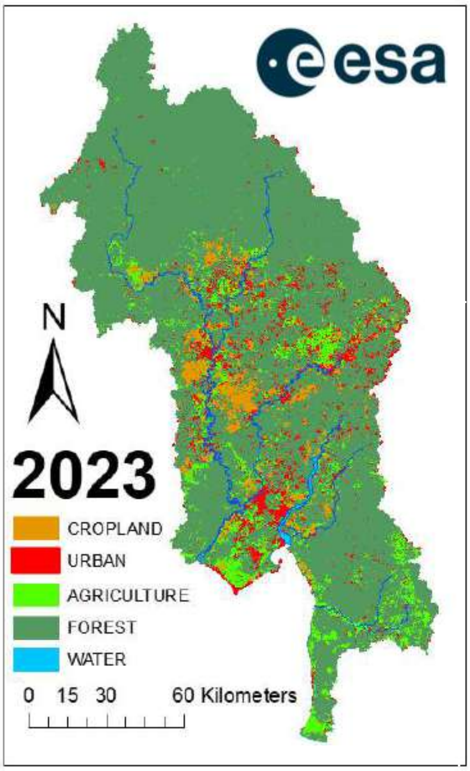
Digital Elevation Model (DEM)



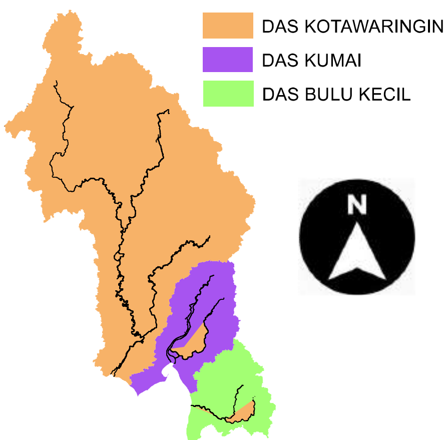
Diatas adalah gambar digital elevation model dari USGS (USA) untuk model domain DAS Kotawaringin, Kumai dan Bulu Kecil. Bagian hulu tertinggi adalah 1219 m di DAS Kotawaringin dan bagian hilir adalah -1 meter dari atas permukaan air laut pada ketiga DAS. Daerah hilir merupakan area rawa. Resolusi diatas adalah 30 meter.

Perubahan Tata Guna Lahan Ke-3 DAS Target



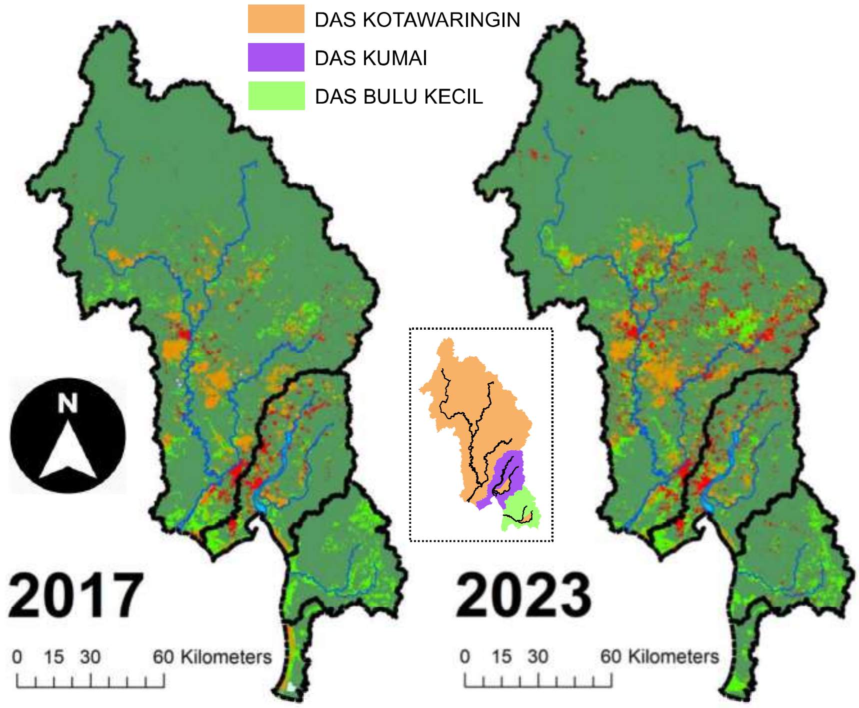


No	Penggunaan Lahan	DAS Kotawaringin, DAS Kumai, DAS Bulu Kecil	
		2017	2023
1	Crop	834.4	974.1
2	Urban	224.9	441.0
3	Agriculture	1184.0	1540.6
4	Forest	15939.8	15235.5
5	Water	137.0	128.7



Di 2017 dan 2023, dapat terlihat bahwa *area cropland* meningkat dari 834.4 km^2 (2017) menjadi 974.1 km^2 (2023). Dalam waktu 6 Tahun naik hamper 16.74%. Urban area naik dari 224.9 km2 (2017) menjadi 441 km2, persentase meningkat hingga 96.09%. Moe et al (2015) menyatakan bahwa debit meningkat denga meningkat nya area urban pada tata guna lahan. Sumber data landuse dari European Space Agency (ESA).

Perubahan Tata Guna Lahan DAS Kotawaringin, Kumai dan Bulu Kecil



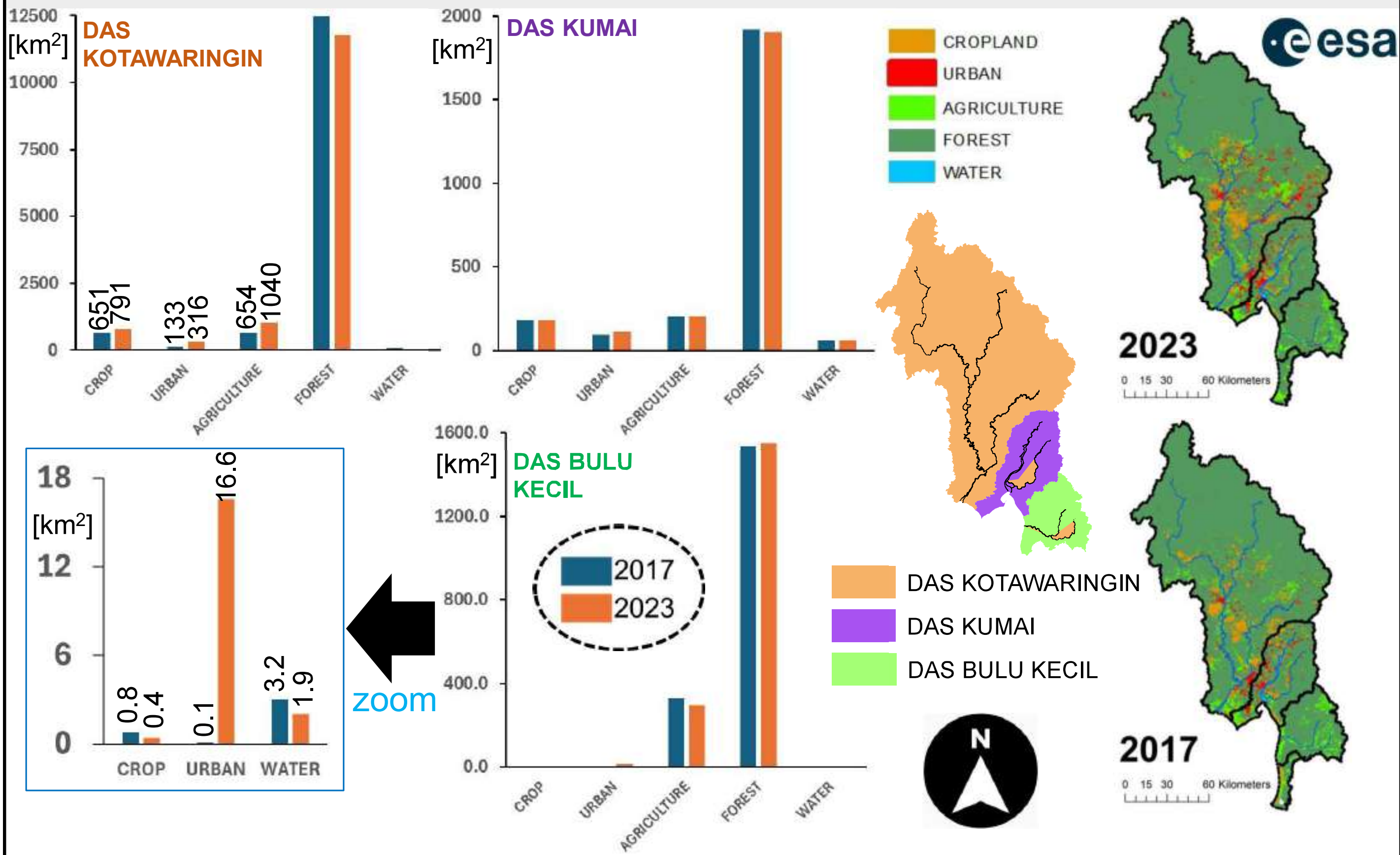
No	Penggunaan Lahan	DAS Kotawaringin	
		2017	2023
1	Crop	650.9	791.0
2	Urban	133.1	315.9
3	Agriculture	654.4	1040.3
4	Forest	12484.1	11782.3
5	Water	73.9	66.8

No	Penggunaan Lahan	DAS Kumai	
		2017	2023
1	Crop	182.6	182.6
2	Urban	91.7	108.5
3	Agriculture	203.6	203.6
4	Forest	1918.6	1901.6
5	Water	59.9	59.9

No	Penggunaan Lahan	DAS Bulu Kecil	
		2017	2023
1	Crop	0.8	0.4
2	Urban	0.1	16.6
3	Agriculture	325.9	296.7
4	Forest	1537.2	1551.6
5	Water	3.2	1.9

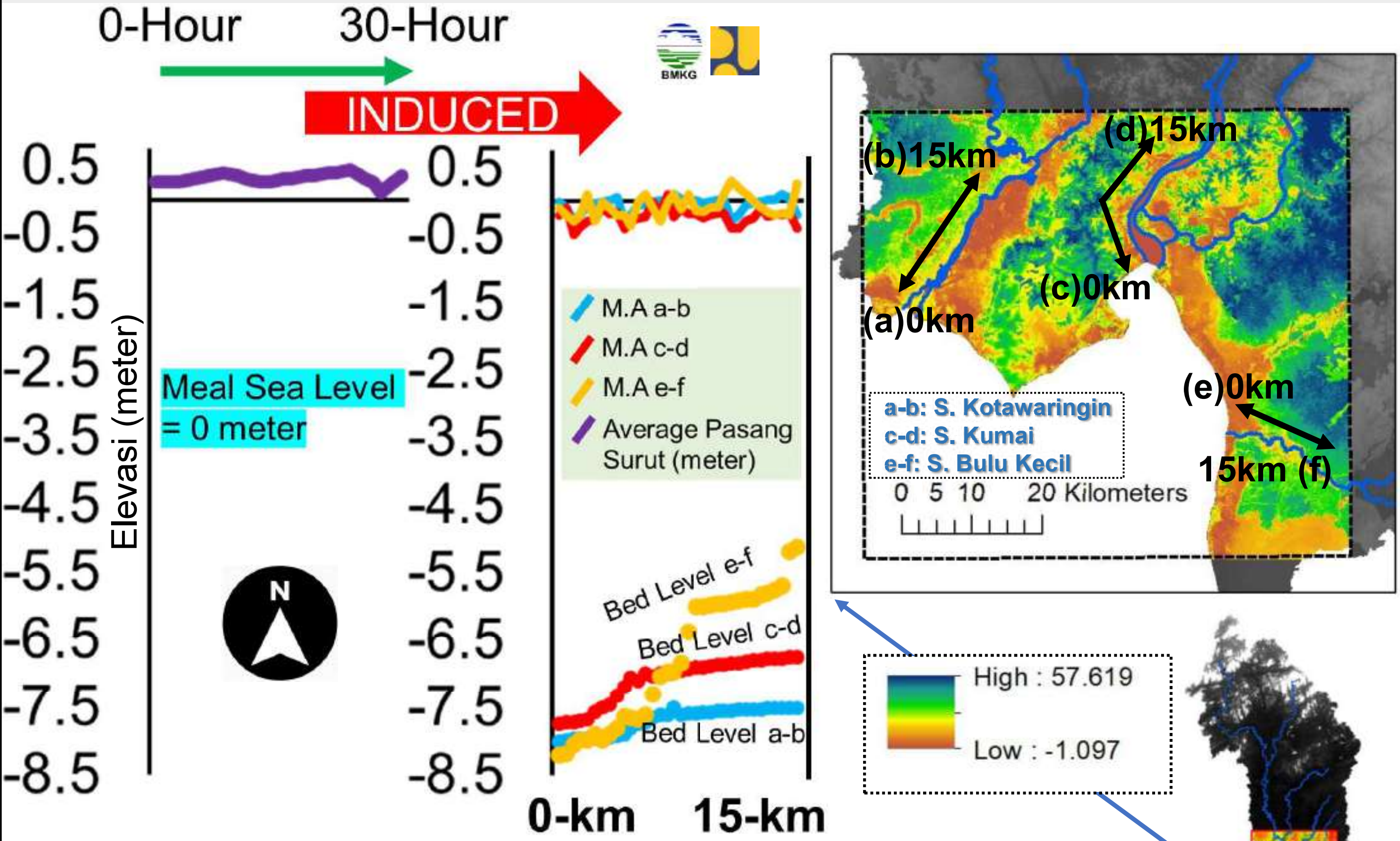
Antara 2017 dan 2023, dapat terlihat dalam kurun waktu 6 tahun, bahwa: pada **DAS Kotawaringin**, area urban naik 137.4%. Sedangkan cropland dan agriculture meningkat 21.5% dan 58.97%, masing-masingnya. Pada **DAS Kumai**, area urban naik 18.32%, sedangkan cropland dan agriculture relative tetap. Pada **DAS Bulu Kecil**, area urban tahun 2023 adalah 16x nya area urban tahun 2017, sedangkan area cropland dan agriculture turun 50% dan 8.96%, masing-masingnya. Area cropland dan agriculture umumnya digunakan untuk pertanian. Chen, dkk (2013, *National Taipei University of Technology*) menyampaikan bahwa paddy field memiliki daya infiltrasi yang sangat rendah dari beberapa pertanian tumbuh lainnya. Sehingga situasi ini rentan terhadap banjir yang lama dan panjang.

Perubahan Tata Guna Lahan DAS Kotawaringin, Kumai dan Bulu Kecil



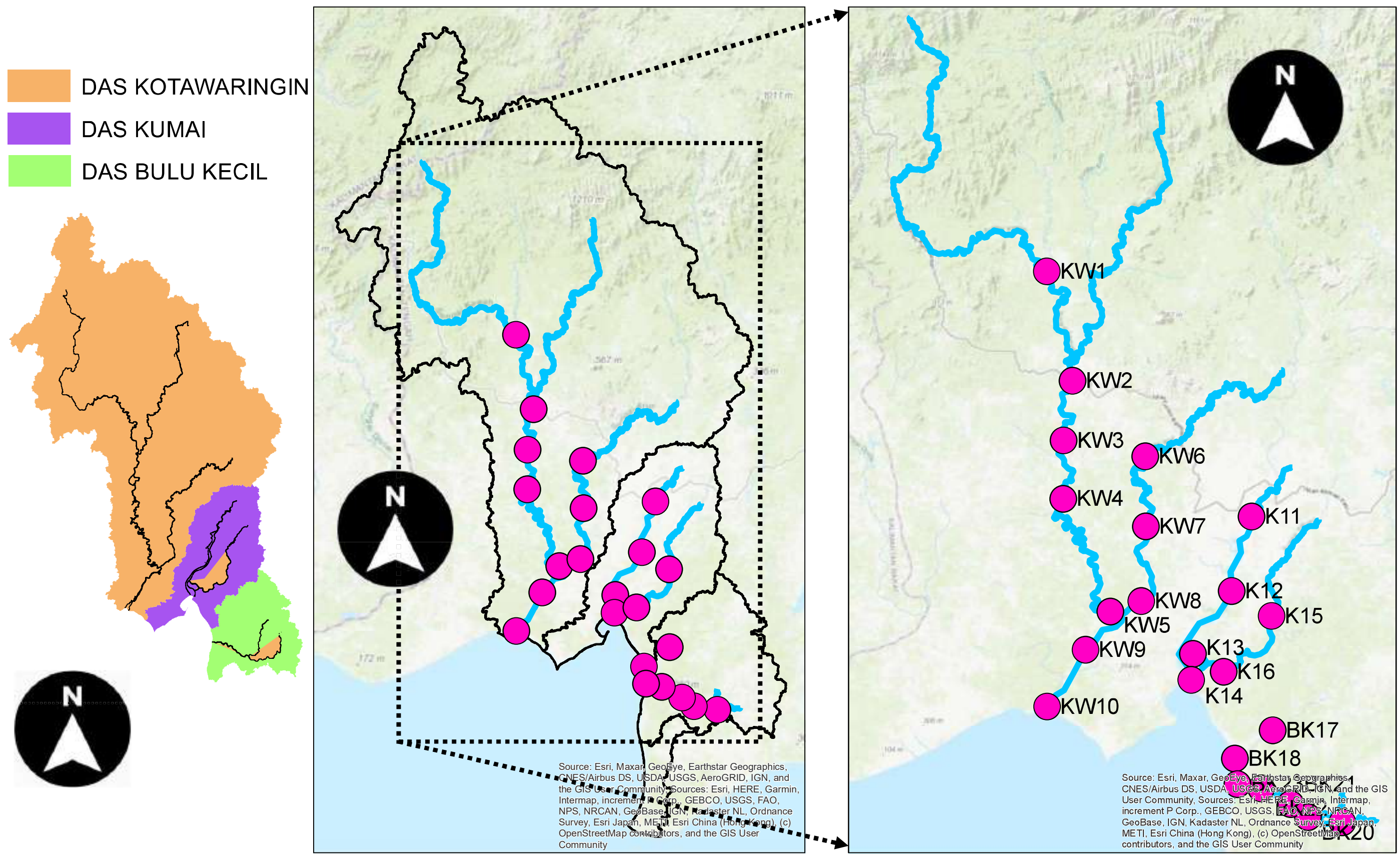
Dapat terlihat pada Gambar diatas perubahan land use masing-masing kategori pada masing-masing DAS antara Thn 2017 dan Thn 2023. Dapat terlihat pada gambar diatas, umumnya, pada DAS Kotawaringin , DAS Kumai dan DAS Bulu Kecil di dominasi oleh areal forest (hutan).

Pasang-Surut



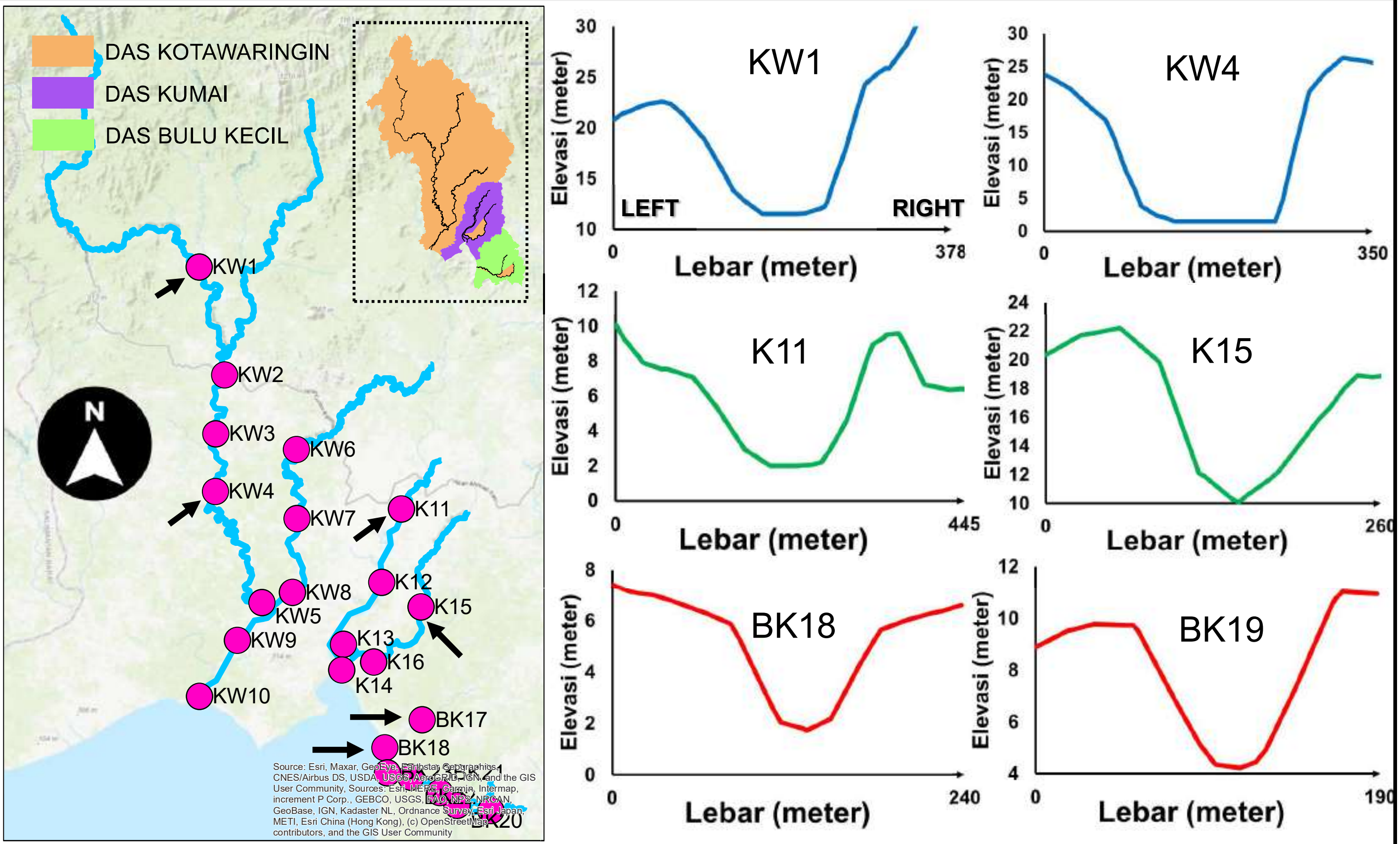
Diatas menunjukkan M.A di Sungai Kotawaringin, Kumai dan Bulu Kecil. Dapat terlihat M.A di Sungai di bawah elevasi nya di bandingkan dengan pasang surut yang datang dari laut. Situasi seperti ini dapat menjadi trigger (pemicu) situasi banjir di area hilir.

Lokasi Penampang Melintang



Terdapat 23 point cross section yang di gunakan pada Lokasi studi diatas. Dapat terlihat titik cross section tersebar pada ketiga DAS Kotawaringin (Kode Cross Section: KW), DAS Kumai (Kode Cross Section: K) dan DAS Bulu Kecil (Kode Cross Section: BK)

Penampang Melintang DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

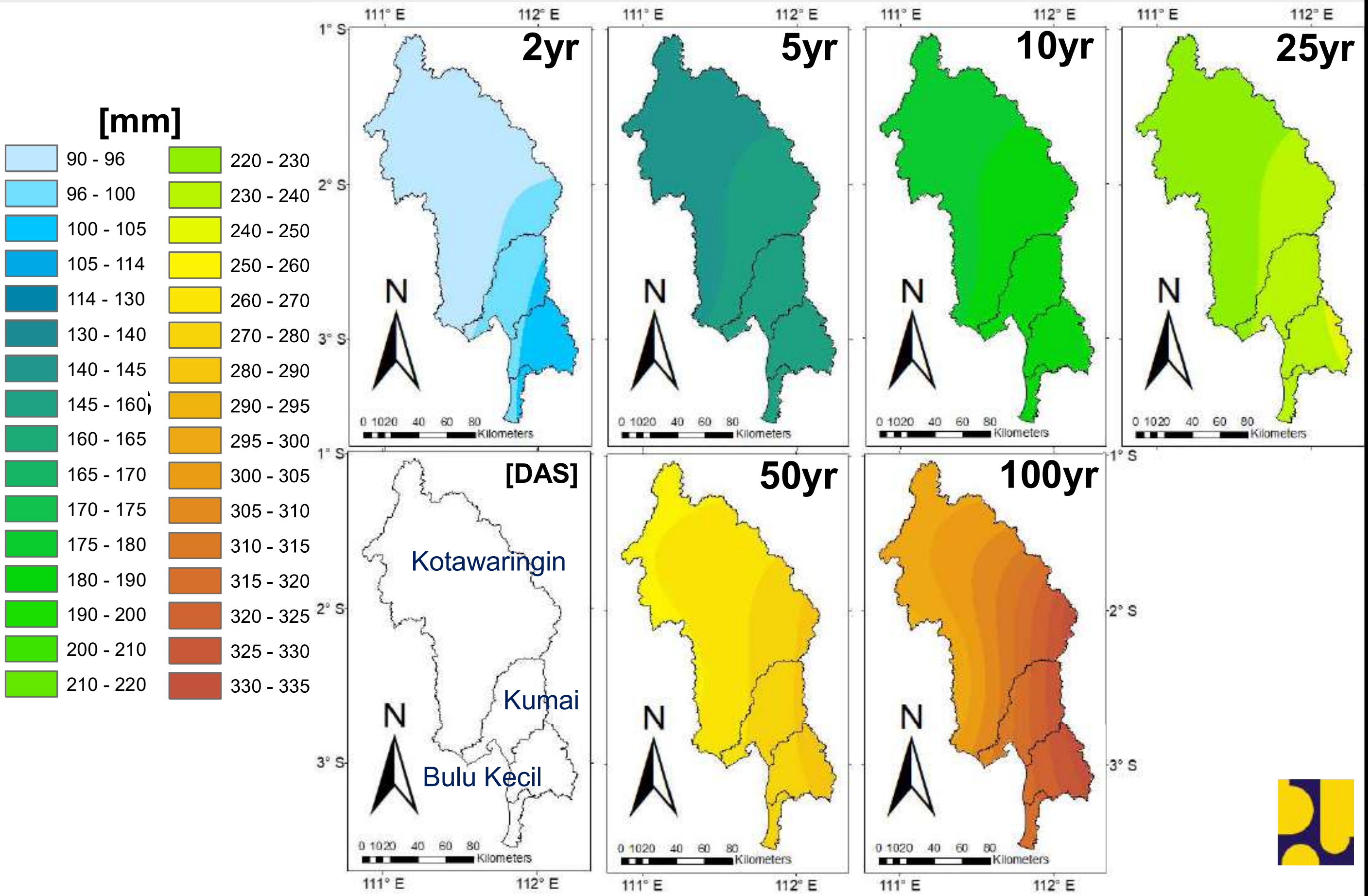


Pada point-point cross section yang digunakan bersumber data DEM dapat digunakan untuk mengisi point cross tersebut. Data cross section dapat terlihat pada gambar kanan di atas. Data cross sintetis yang di bangun menggunakan interpolasi linier. Data menunjukkan kan bahwa cross section di DAS Kotawaringin, Kumai dan Bulu Kecil terdistribusi lebar nya dari 190-380 meter. Lebar sungai sangat besar untuk mengairkan air dari hulu.

Hasil Simulasi Banjir DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

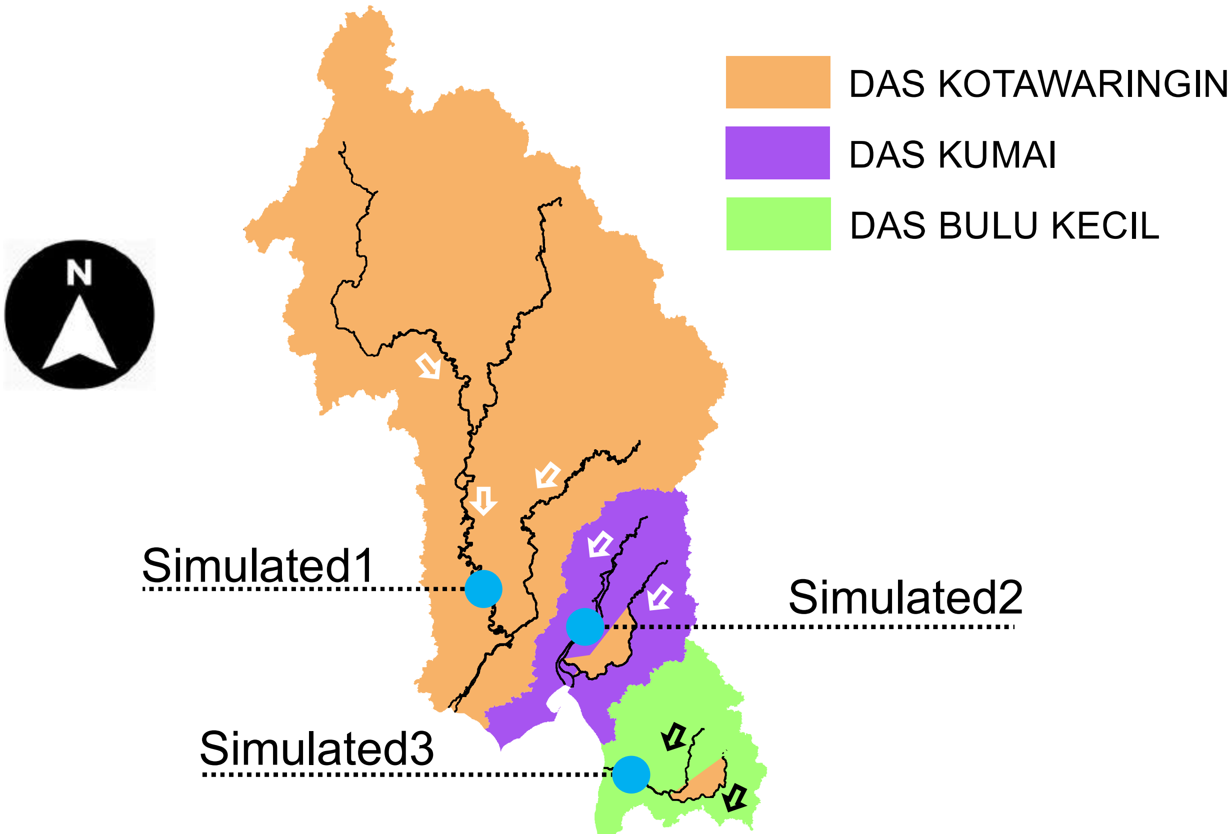
- Hujan Kala Ulang
- Debit Kala Ulang
- Banjir Kala Ulang
- Komparasi Simulasi Banjir dan Observasi Banjir

Hujan Kala Ulang DAS Kotawaringin, DAS Kumai, DAS Bulu Kecil(dalam mm)



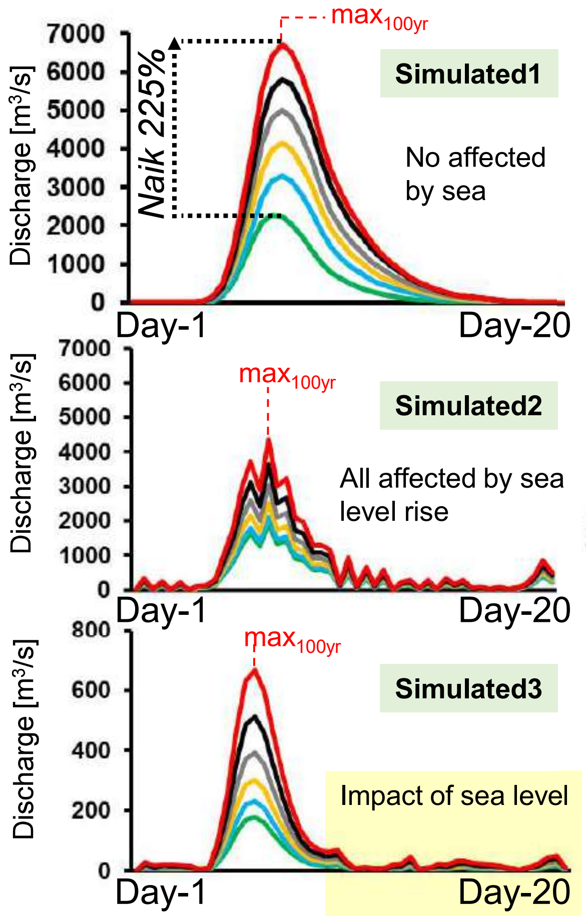
Hujan kala ulang DAS Kumai dan Buu Kecil lebih tinggi di bandingkan dengan DAS Kotawaringin. Pada seluruh DAS Kotawaringin, Kumai dan Bulu Kecil memiliki hujan kala ulang yang lebih rendah pada area hilirnya jika di banding kan pada daerah hulu nya pada masing-masing DAS.

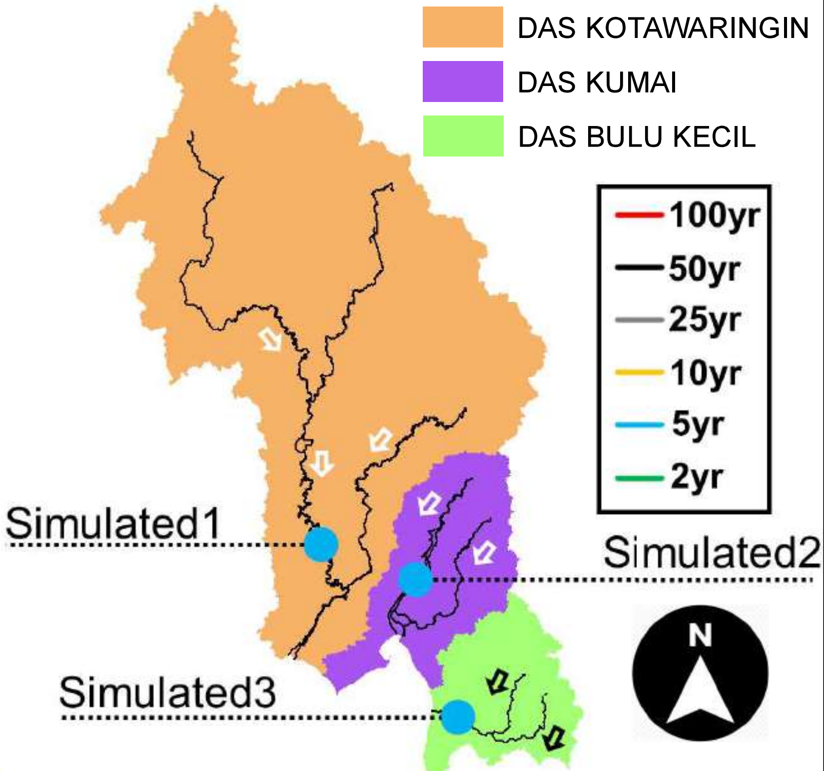
1-D simulation beberapa titik



Gambar diatas adalah lokasi titik simulasi debit banjir setiap kala ulang. Point simulasi banjir di pilih dapat dilihat pada point Simulated1 (DAS Kotawaringin), Simulated1 (DAS Kumai), dan DAS Bulu Kecil (DAS Bulu Kecil).

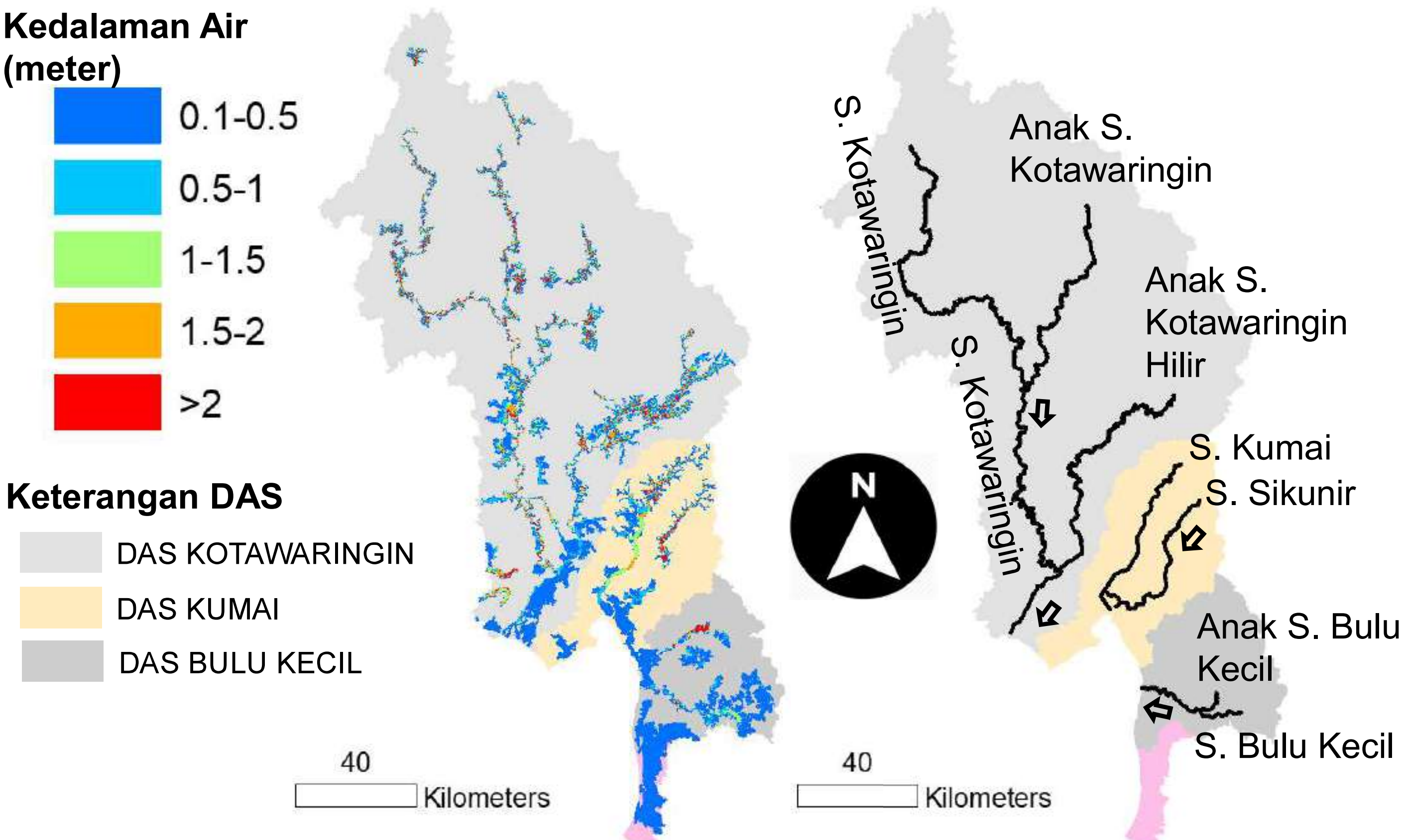
1-D simulation (Result)





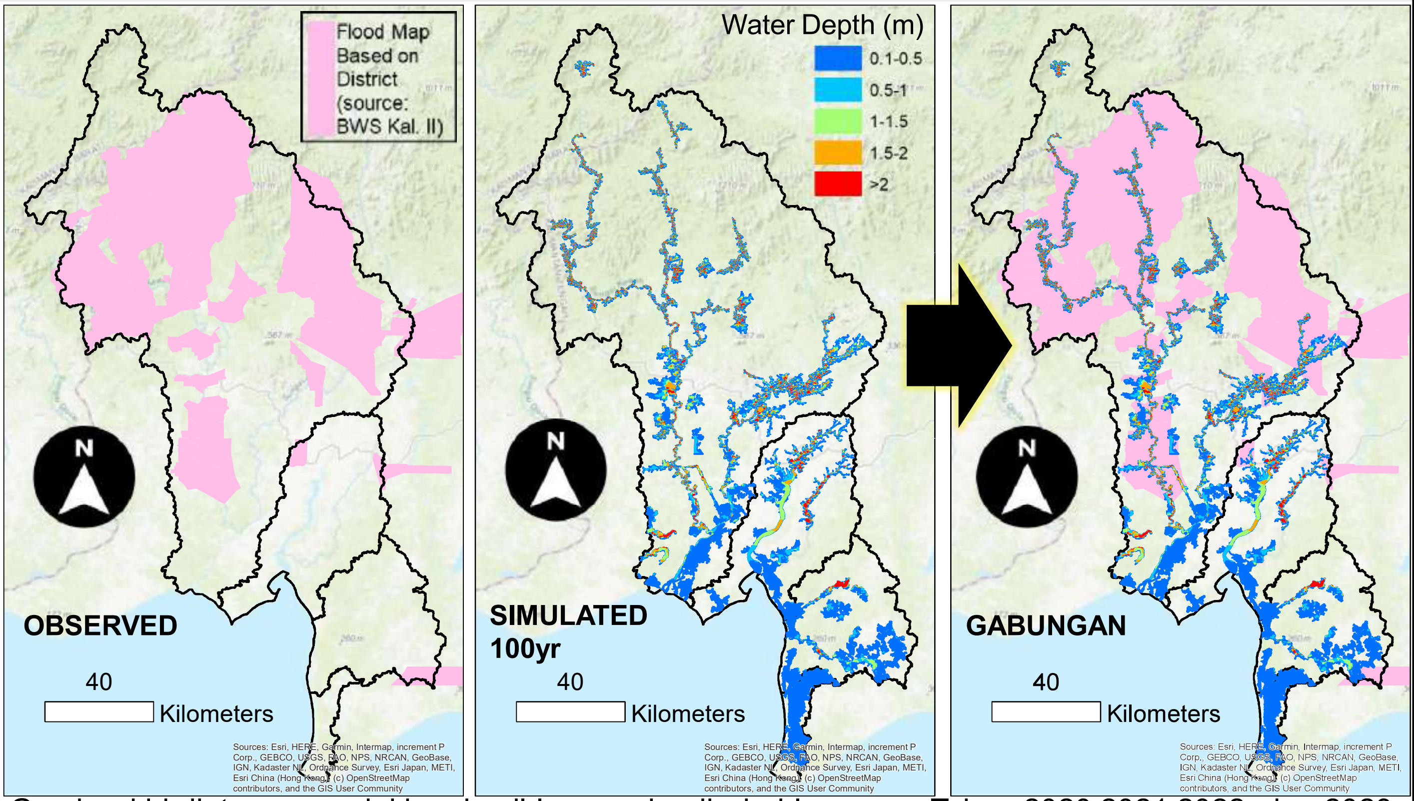
○ Dapat terlihat bahawa DAS kumai dan DAS Bulu Kecil sangat terpengaruh oleh muka air laut. Pada DAS Kotawaringin, pada titik yang terpilih, menunjukkan belum ada nya pengaruh muka air laut. Hal ini mungkin di sebabkan adanya debit hulu yang sangat tinggi di bandingkan dengan DAS lainnya.

Banjir Kala Ulang 100 Tahun (Simulasi)



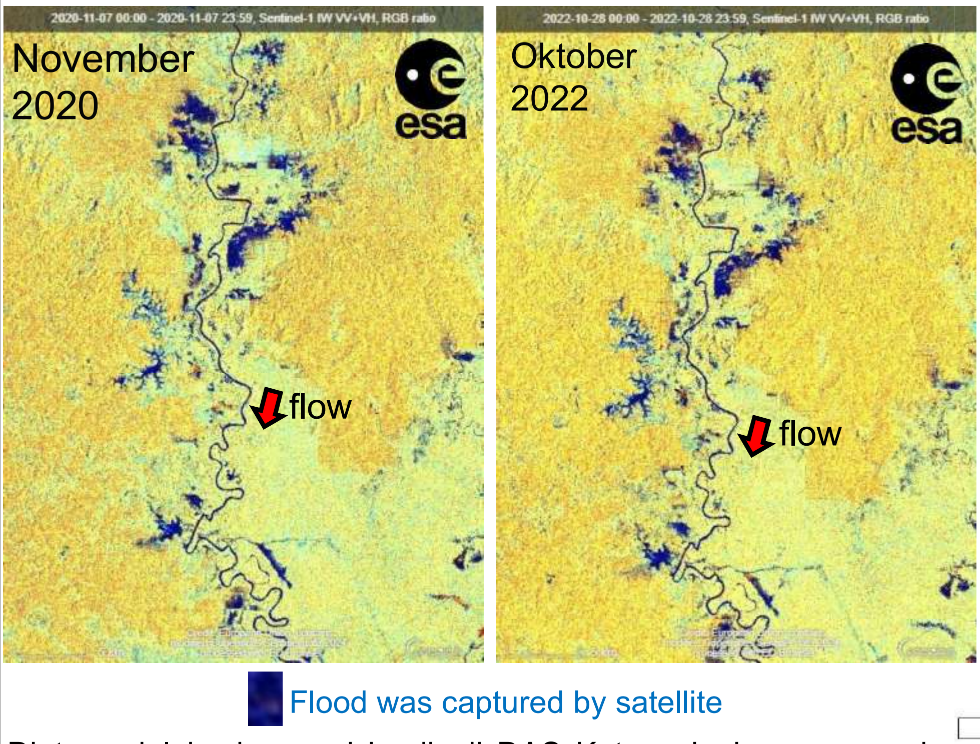
Gambar diatas adalah simulasi banjir kala ulang 100 Tahun DAS Kotawaringin, Kumai dan Bulu Kecil. Banjir diatas adalah *flood simulated* maksimum event untuk RT 100 Tahun. Dapat terlihat banjir terjadi di bagian hulu dan hilir pada Ketiga DAS tersebut. Area genangan maksimum 100yr adalah 12.93 x 10^4 Ha.

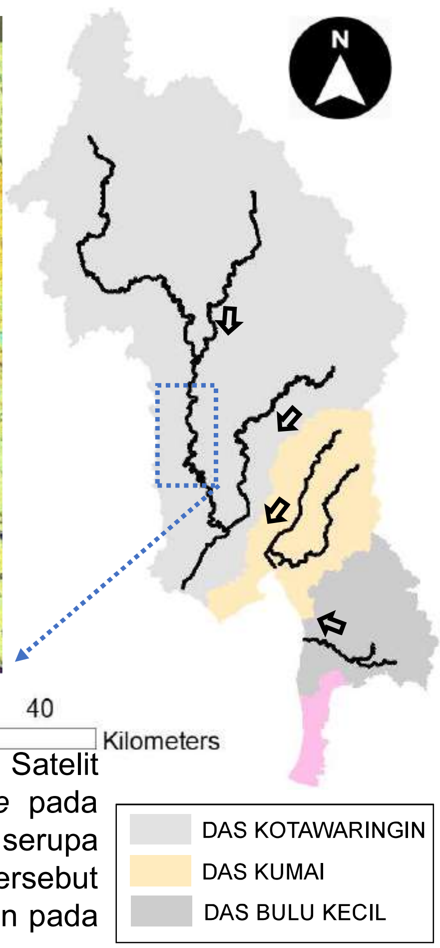
Perbandingan Observasi (Lapangan) dan Simulasi Floos (Spasial)



Gambar kiri diatas menunjukkan hasil laporan banjir dari lapangan Tahun 2020,2021,2022, dan 2023. Gambar Kiri adalah peta observasi banjir yang di dapat berdasarkan peta distrik yang terlapor banjir. Gambar Tengah dan Kanan: Hasil simulasi 100yr Flood dan Overlay keduanya. Hasil overlay menunjukkan Hubungan yang sangat kuat antara observasi Lapangan dan Simulasi yang telah dilakukan namun masih terdapat beberapa daerah yang belum ter-klarifikasi area banjir nya. Namun, untuk tahap ini simulasi ini dapat dikatakan cukup mendekati.

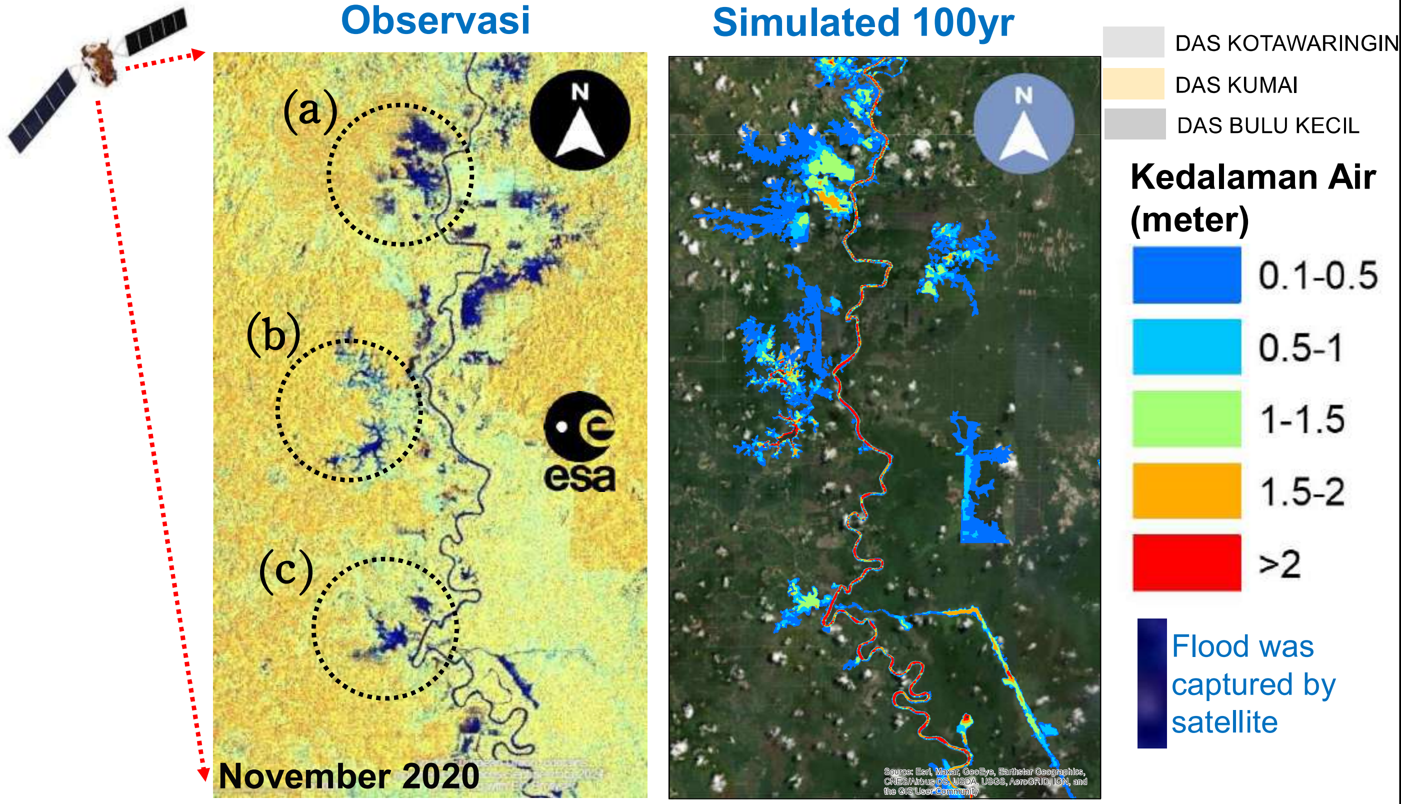
Observasi (**Satelit**)





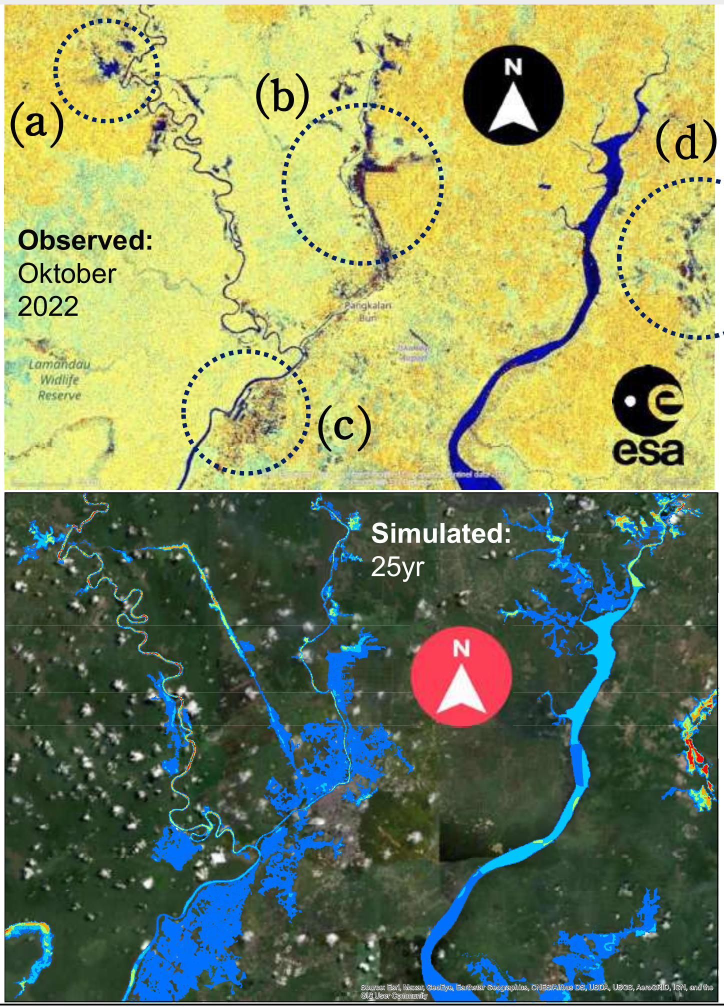
Diatas adalah observasi banjir di DAS Kotawaringin menggunakan Satelit Sentinel 1 dari European Space Agency (ESA). Data di *capture* pada November 2020 dan Oktober 2022. Terdapat kejadian banjir yang serupa pada dua tahun pengambilan peta observasi banjir tersebut. Peta tersebut dapat di jadikan komparasi dan kalibrasi model banjir yang di bangun pada kegiatan kali ini.

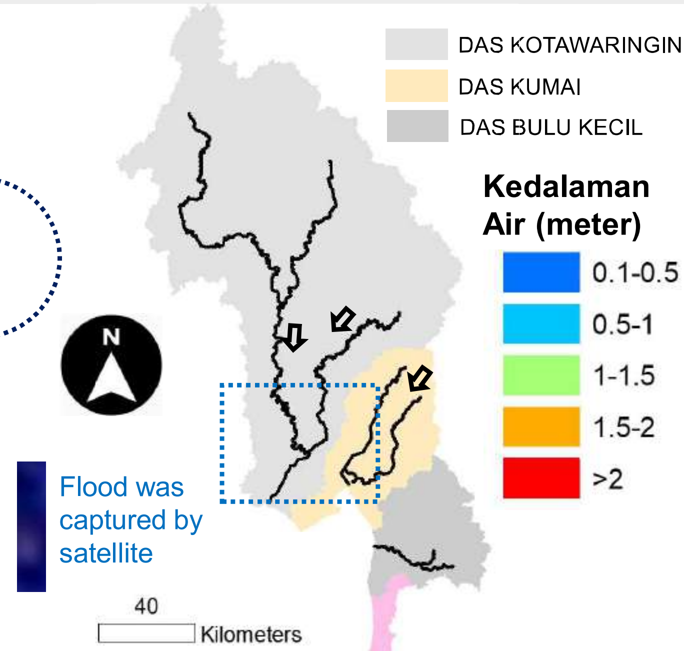
Perbandingan Observasi (**Satelit**) dan Simulasi Flood (Spasial)



Dapat terlihat pada Gambar Kiri diatas adalah observasi banjir Satelit Sentinel 1-A di DAS Kotawaringin. Gambar kanan adalah hasil maximum simulasi 1-2 Dimensional banjir. Dapat terlihat pada Gambar diatas bahwa hubungan sangat erat antara observasi dan simulasi (seperti area (a), (b) dan (c)). Artinya, model ini dapat digunakan untuk menghasilkan banjir genangan kala ulang pada tahun lainnya.

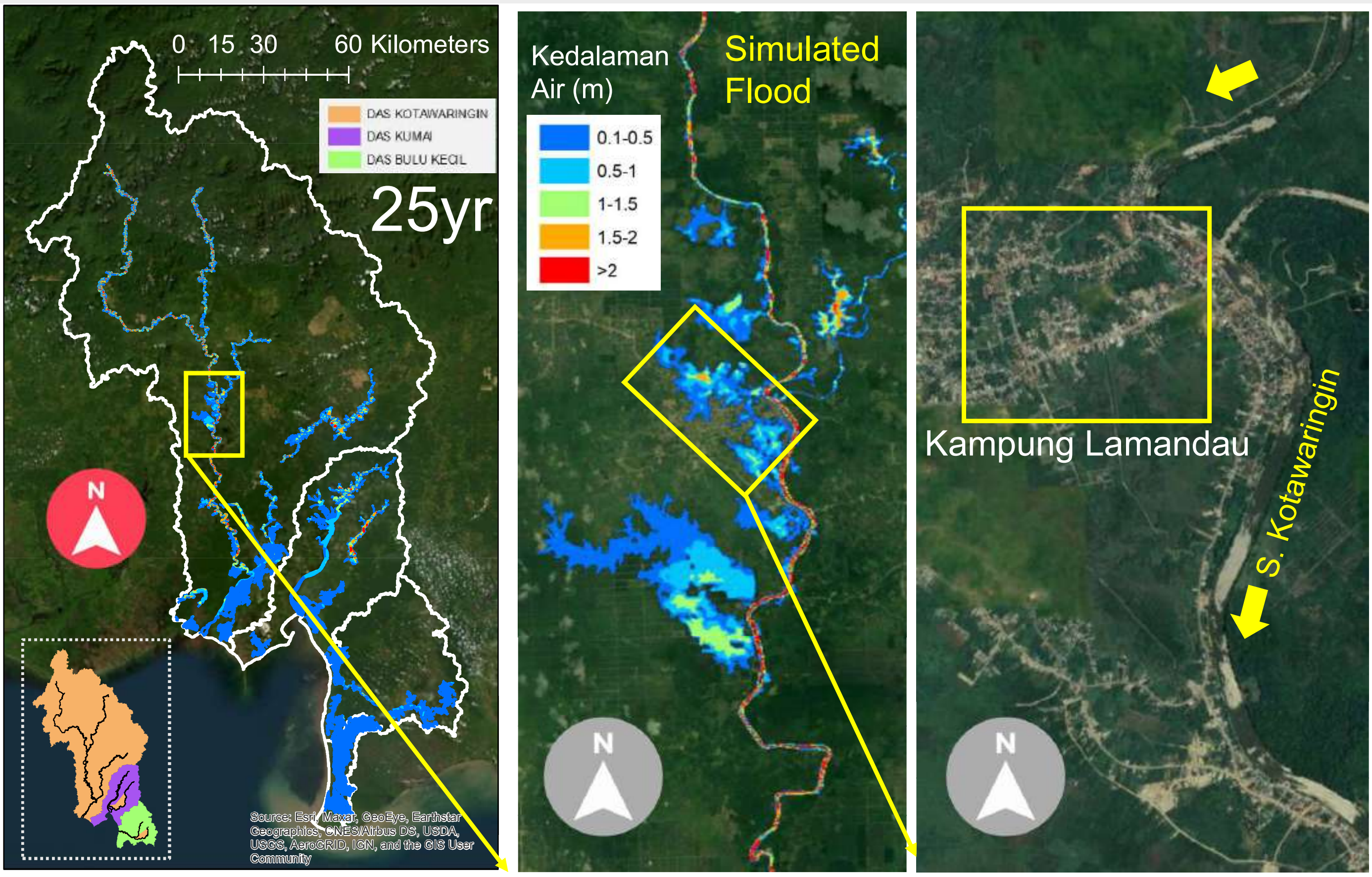
Perbandingan Observasi (**Satelit**) dan Simulasi Flood (Spasial)





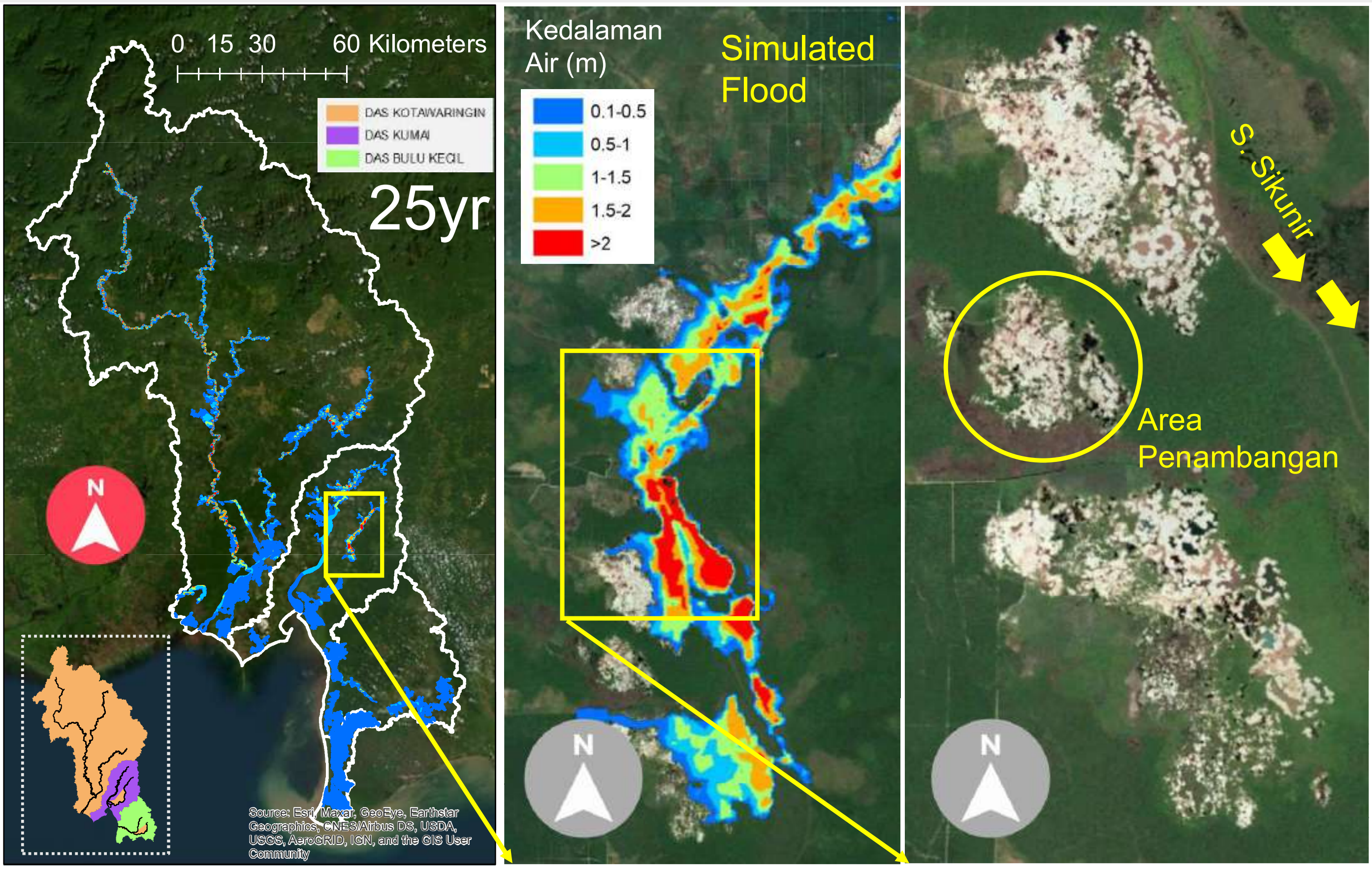
Pada area komparasi lainnya, dapat terlihat pada Gambar Kiri diatas adalah observasi banjir Satelit Sentinel 1-A di DAS Kotawaringin dan Kumai. Gambar bawah adalah hasil maximum simulasi 1-2 Dimensional banjir. Dapat terlihat pada Gambar diatas bahwa hubungan sangat erat antara observasi dan simulasi (seperti area (a), (b), (c) dan (d)). Artinya, model ini dapat digunakan untuk menghasilkan banjir genangan kala ulang pada tahun lainnya.

Situasi Aktual Banjir DAS Kotawaringin



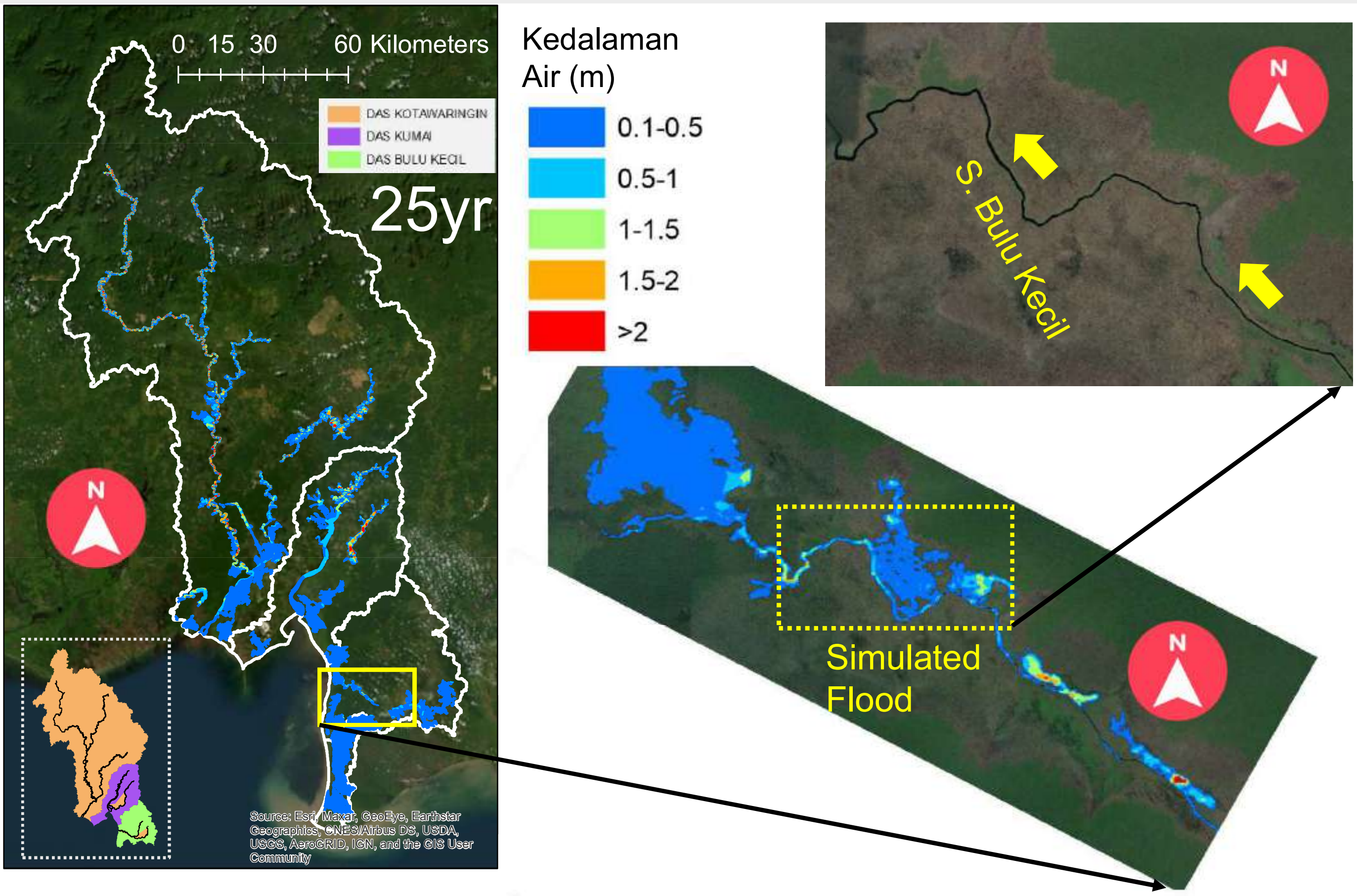
Pada area hulu, area banjir menunjukkan area yang tergenang di Lamandau (DAS Kotawaringin). Dapat terlihat banyak perumahan yang terdampak banjir saat hujan deras. Sebagai catatan, area yang tergenang tersebut diatas di overlay dengan Banjir Kala Ulang 25 Tahun.

Situasi Aktual Banjir DAS Kumai



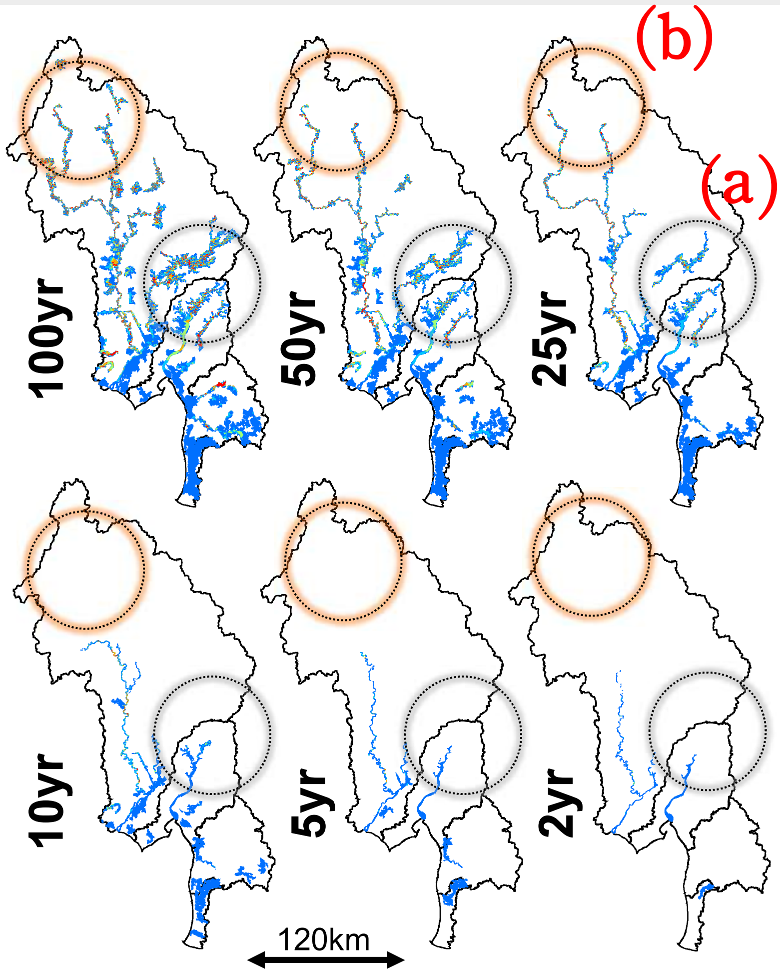
Pada area hulu DAS Kumai, area banjir menunjukkan area yang tergenang area pertambangan (DAS Kumai). Sebagai catatan, area yang tergenang tersebut diatas di overlay dengan Banjir Kala Ulang 25 Tahun.

Situasi Aktual Banjir DAS Bulu Kecil



Pada area hulu DAS Bulu Kecil, area banjir menunjukkan area yang tergenang area hutan dan rawa. Belum banyak pelaksanaan Pembangunan fisik di DAS ini. Sungai masih berupa natural river. Area yang tergenang tersebut diatas di overlay dengan Banjir Kala Ulang 25 Tahun.

Simulasi Banjir Beberapa Kala Ulang



(a) Hal yang dapat dilihat dari perbedaan kala ulang banjir spasial disamping adalah sebagai berikut:

1. Pada area (a)-area hilir dapat terlihat bahwa semakin tinggi kala ulang banjir maka dapat terlihat bahwa tinggi genangan semakin tinggi pula genangannya. Pada area (a) dapat terlihat kala ulang 5yr-tinggi genangan 0.1-0.5 meter dan kala ulang 100yr-tinggi genangan ada yang capai >2 meter.
2. Area (b) hulu disamping menunjukkan genangan banjir bertambah area genangan nya pada kala ulang 100yr bila di bandingkan dengan 2yr. Artinya, banjir genangan spasial kala ulang memiliki hubungan yang sangat kuat dengan meningkatnya hujan kala ulang.
3. Peta banjir setiap kala ulang di atas di gunakan untuk mengevaluasi area terdampak banjir yang mungkin terjadi di masa yang akan datang.

Hasil Analisa Banjir Setiap Kala Ulang DAS Kotawaringin, Kumai, Bulu Kecil (dalam angka/table)

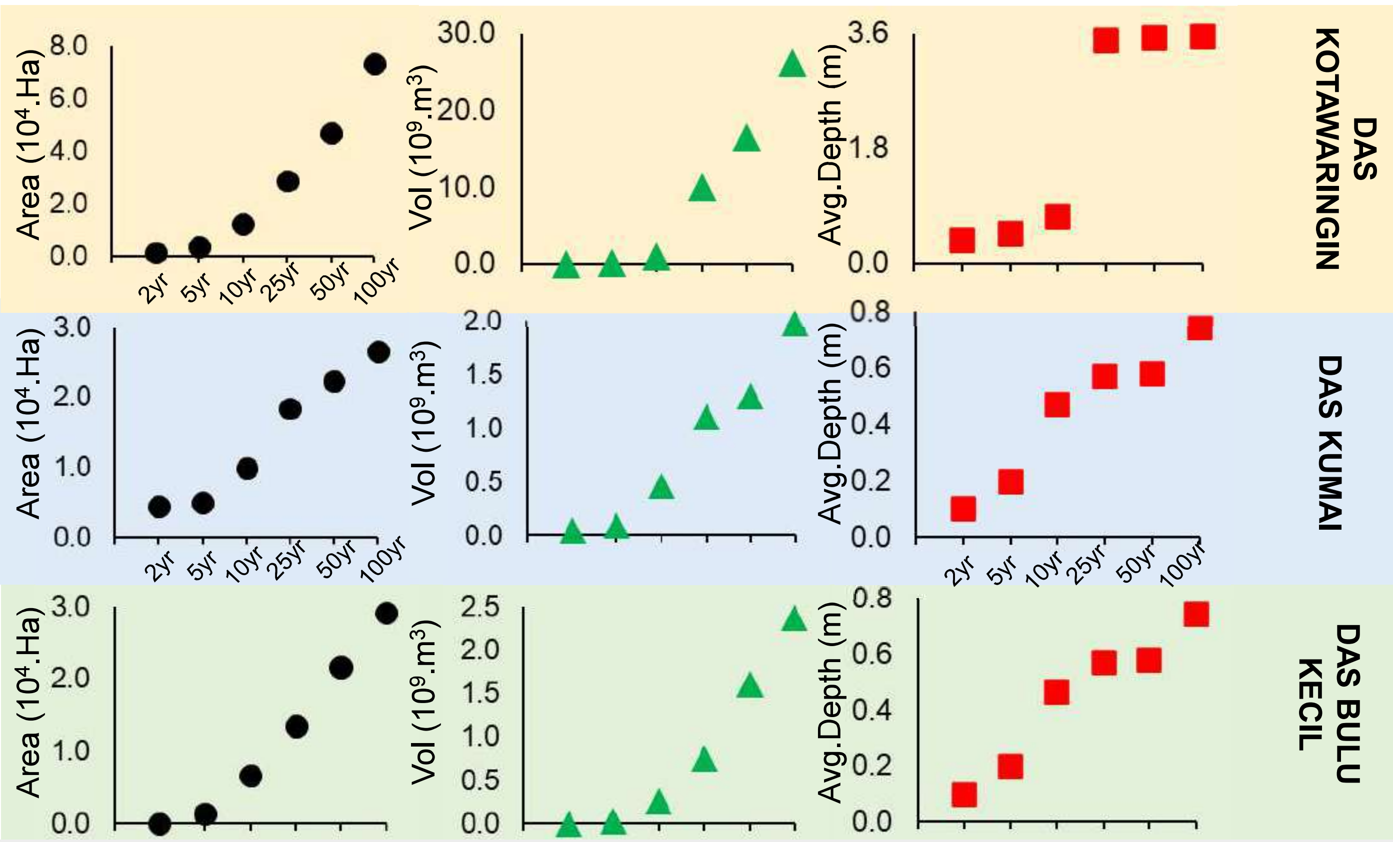
KALA ULANG	FLOOD AT DAS KOTAWARINGIN, KUMAI, BULU KECIL		AVG.DEPTH (m)
	LUAS (10^4.Ha)	VOLUME (10^9.m3)	
2yr	0.5832 Naik	0.0946 Naik	0.1623
5yr	0.9972 5 x	0.3045 18.2 x	0.3053
10yr	2.9053	1.6409	0.5648
25yr	6.0566 Naik	11.8522 Naik	1.9569
50yr	9.0762 2.13 x	19.4626 2.58 x	2.1443
100yr	12.9318	30.5385	2.3615

Dari hasil simulasi dihasilkan area genangan banjir, volume genangan banjir dan tinggi rata-rata maksimum di setiap banjir kala ulang. Dapat terlihat bahwa banjir terjadi meningkat dengan meningkatnya banjir kala ulang di DAS Kotawaringin. DAS Kumai dan DAS Bulu Kecil. Hal tersebut dapat terlihat seperti pada Table diatas.

Hasil Analisa Banjir di DAS Kotawaringin, Kumai dan Bulu Kecil (Total) menunjukkan:

- *Area* Banjir meningkat 5 x nya dari kala ulang 2yr ke 10yr, dan meningkat 2.13 x nya dari kala ulang 25yr menjadi 100yr.
- *Volume* Banjir meningkat 18.2 x nya dari kala ulang 2yr ke 10yr, dan meningkat 2.58 x nya dari kala ulang 25yr menjadi 100yr.

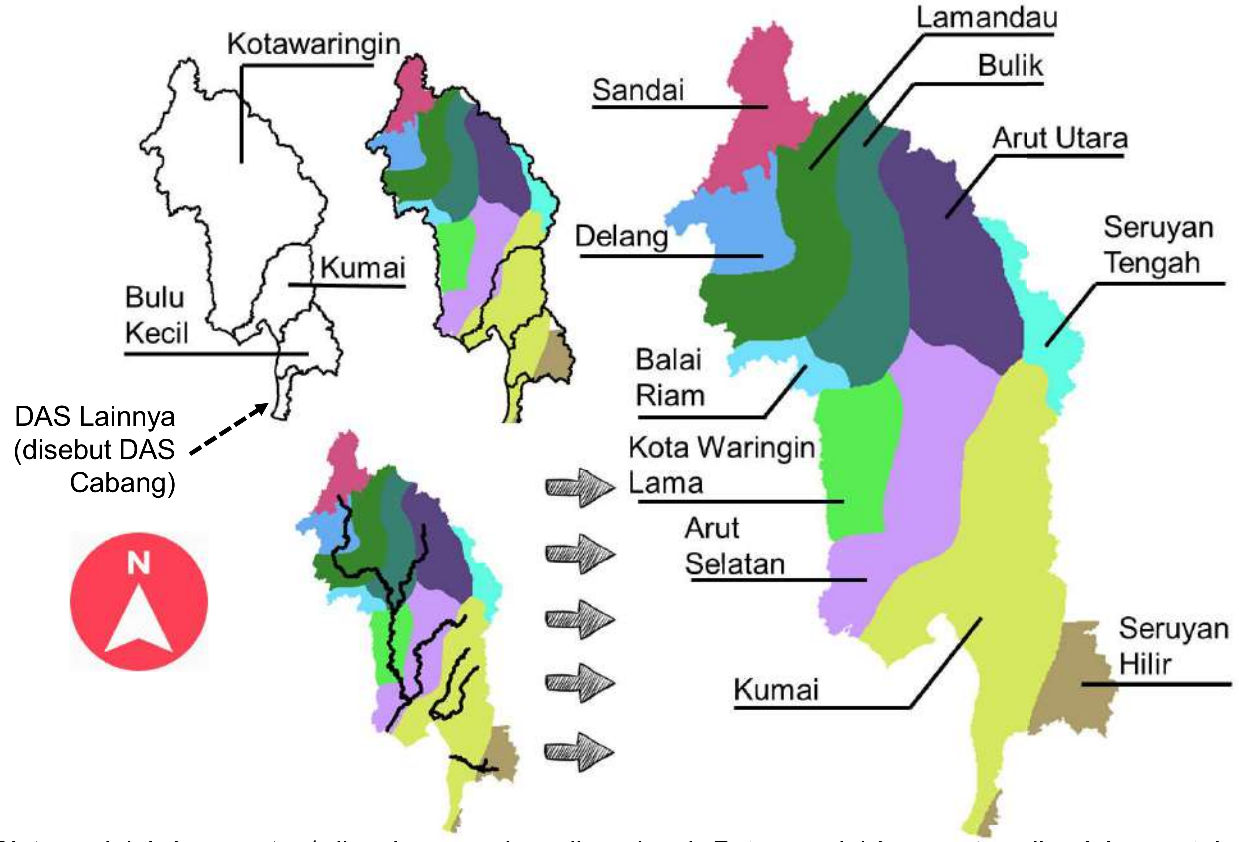
Hasil Analisa Banjir Setiap Kala Ulang DAS Kotawaringin, Kumai dan Bulu Kecil



Diatas adalah banjir genangan baik Area, Volume dan kedalaman rata-rata kedalaman genangan di masing-masing DAS dan pada setiap kala ulang. Dapat terlihat bahwa DAS Kotawaringin memiliki dampak paling besar pada area dan volume genangan banjir yang mungkin terjadi pada setiap kala ulang. Pada DAS Kotawaringin, kala ulang >25yr memiliki kedalaman rata-rata yang sangat tinggi di bandingkan pada kala ulang lain nya di DAS Kumai dan DAS Bulu Kecil.

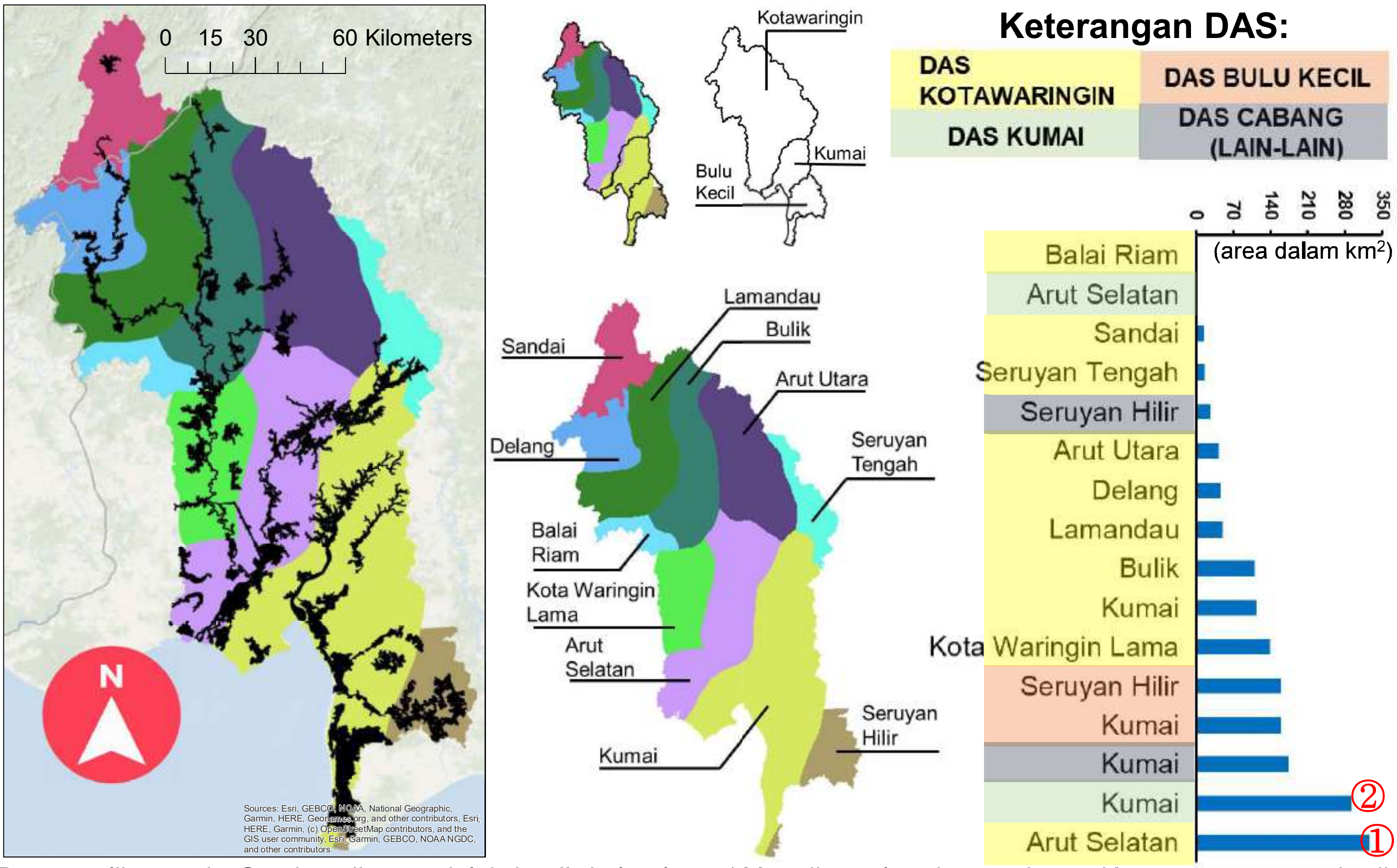
Evaluasi Banjir Pada Kecamatan Yang Mungkin Terdampak Kala Ulang

Batas Kecamatan Dalam DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil



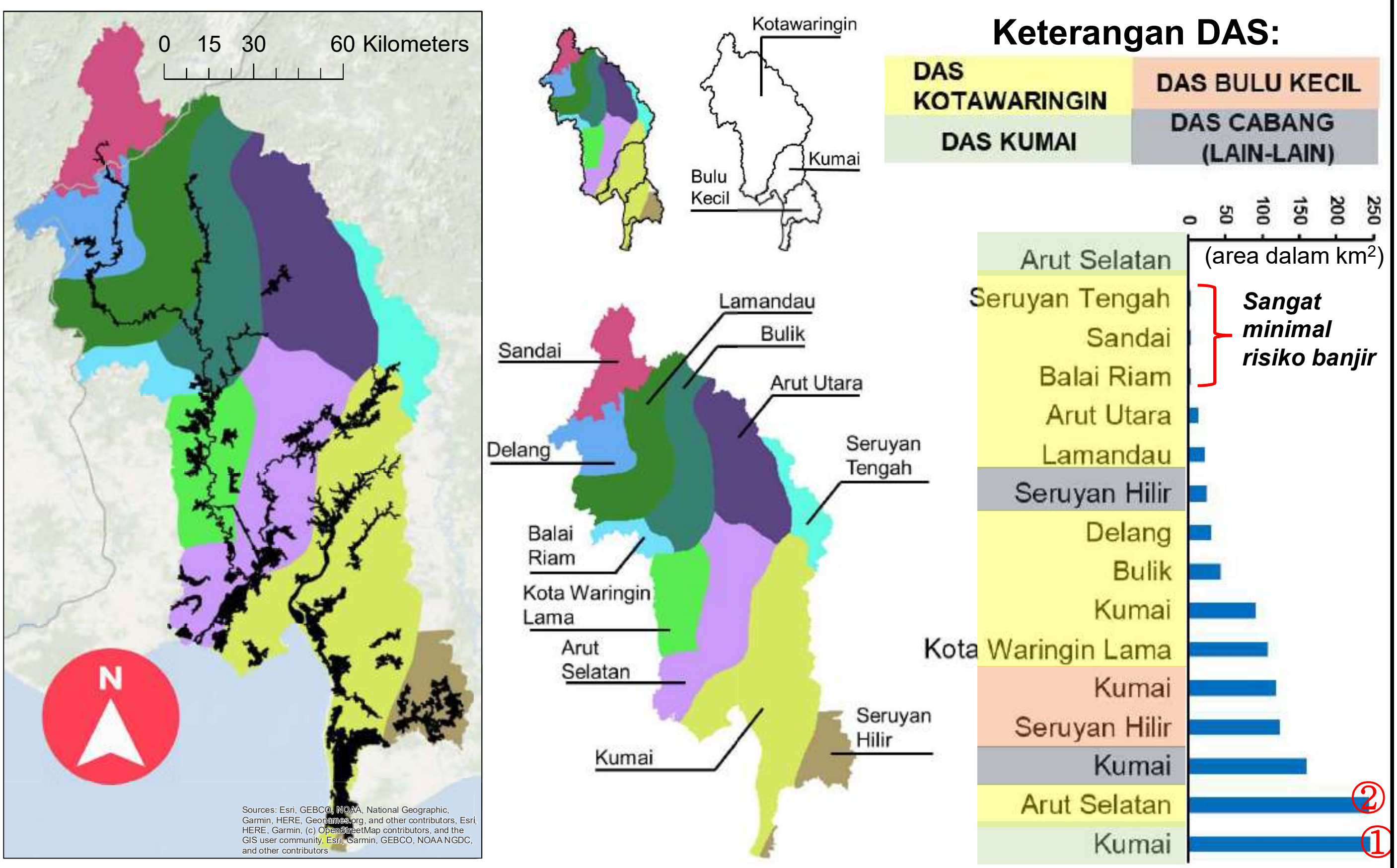
Diatas adalah kecamatan/wilayah yang akan di evaluasi. Peta spasial kecamatan diperlukan untuk mengetahui besaran banjir setiap kala ulang yang mungkin terdampak pada setiap Kecamatan sehingga BWS dapat merencanakan adaptasi dan mitigasi banjir di masa yang akan datang di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil. Satu Kecamatan memiliki potensi banjir diakibatkan tiga Daerah Aliran Sungai, seperti contoh, Kecamatan Kumai, berada di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil

Kecamatan Terdampak Banjir Kala Ulang 100yr



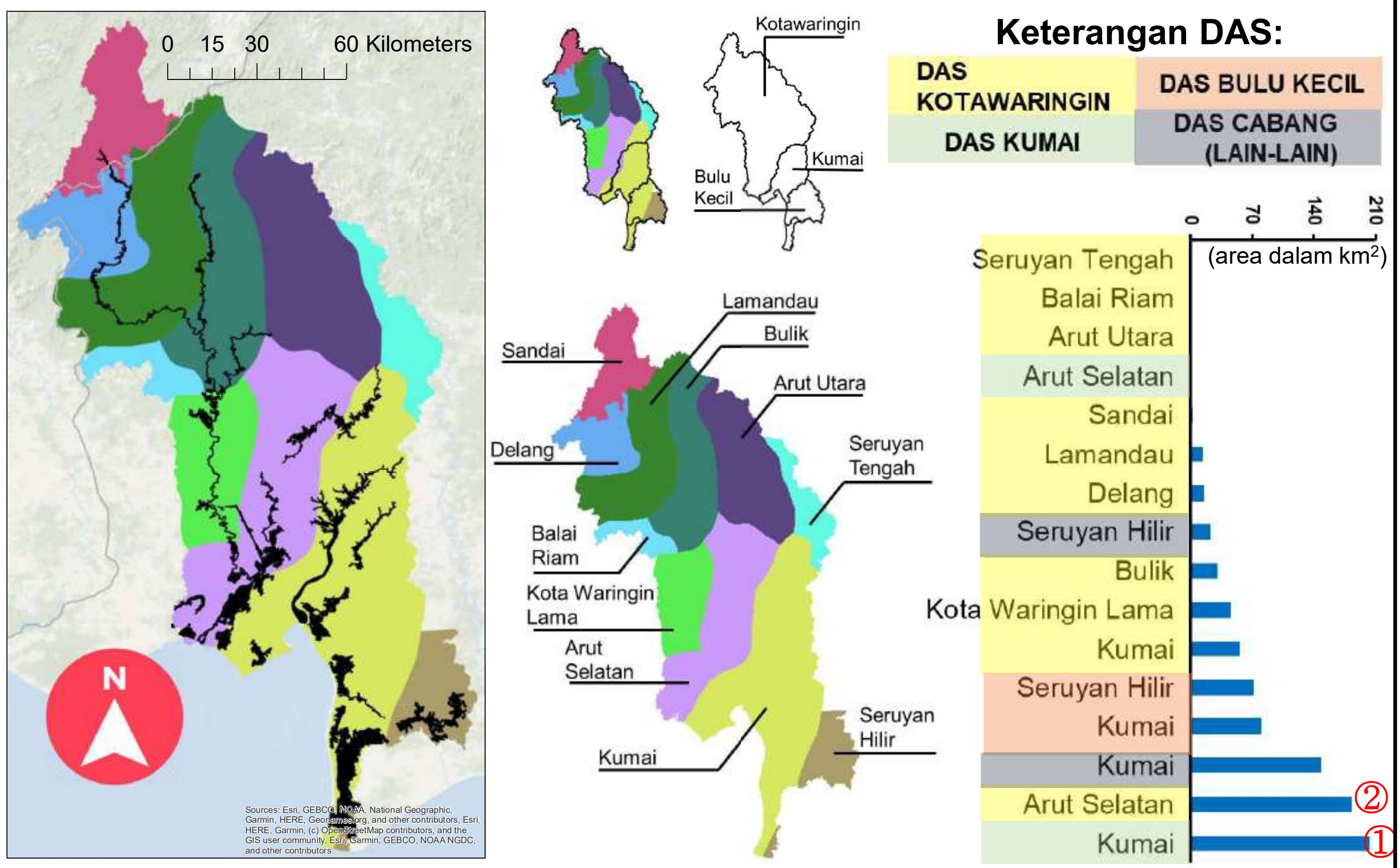
Dapat terlihat pada Gambar diatas adalah banjir kala ulang 100yr di overlay dengan batas Kecamatan yang ada di atas nya. Kecamatan Arut Selatan (DAS Kotawaringin), Kecamatan Kumai (DAS Kumai) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 19.4% dan 17.3% dari area total tergenang di simulasi banjir kala ulang 100 Tahun.

Kecamatan Terdampak Banjir Kala Ulang 50yr



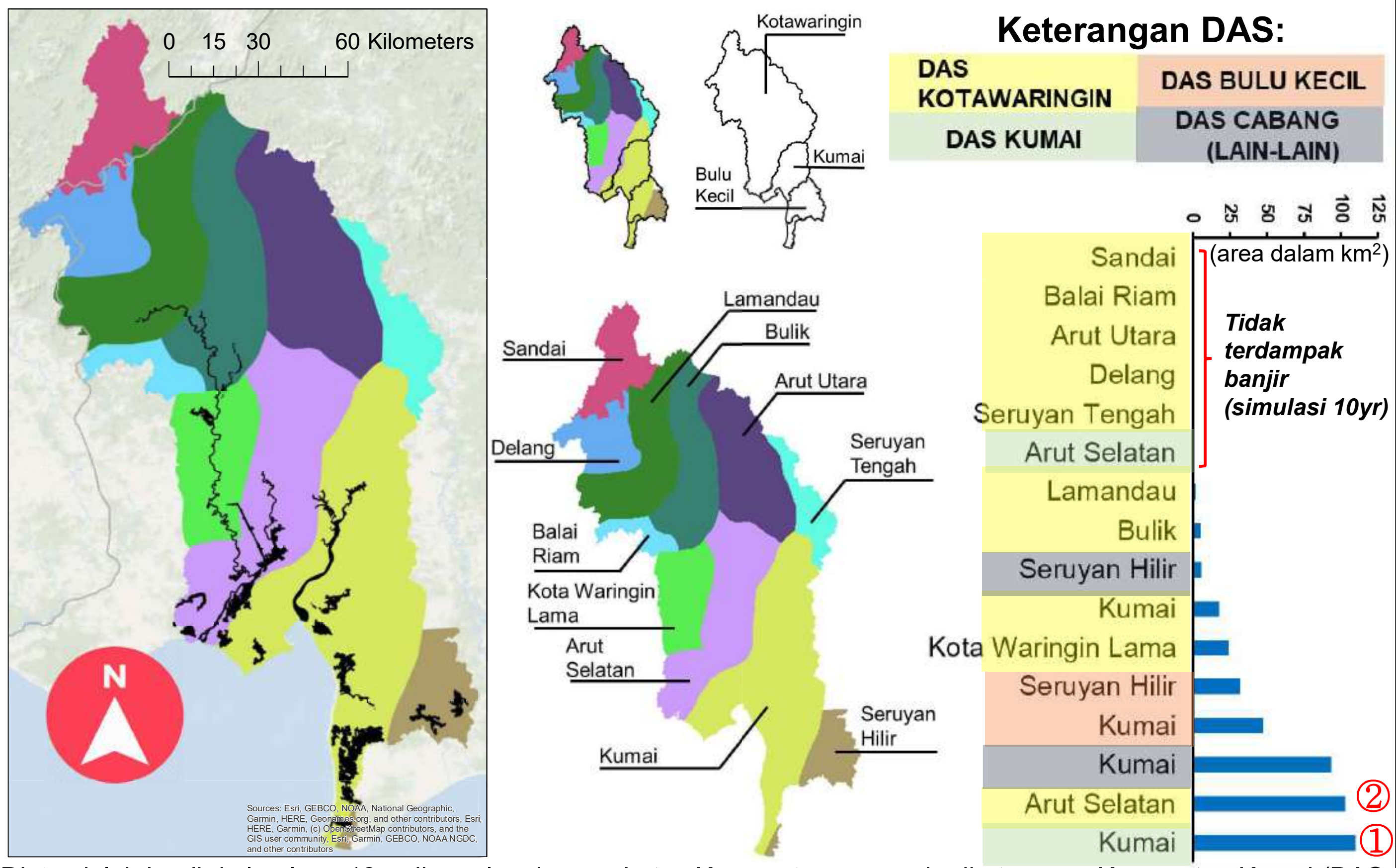
Gambar diatas adalah banjir kala ulang 50yr di overlay dengan batas Kecamatan yang ada di atas nya. Kecamatan Kumai (DAS Kumai), Kecamatan Arut Selatan (DAS Kotawaringin) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 20.0% dan 19.8% dari area total tergenang di simulasi banjir kala ulang 50 Tahun. Kecamatan Seruyan Tengah, Sandai dan Balai Riam di DAS Kotawaringin memiliki (very) minimal risiko banjir.

Kecamatan Terdampak Banjir Kala Ulang 25yr



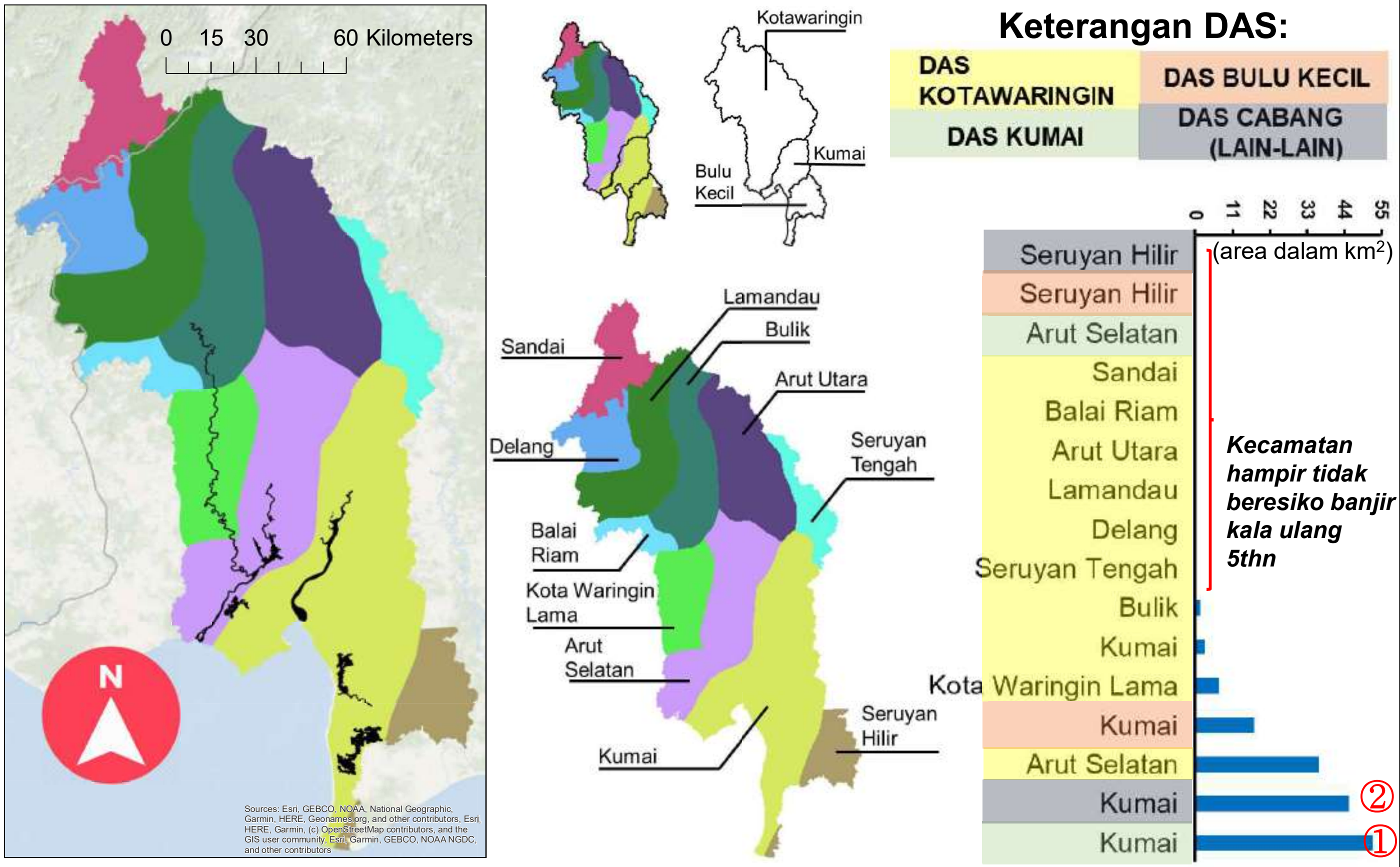
Diatas ialah banjir kala ulang 25yr di overlay dengan batas Kecamatan yang ada di atas nya. Kecamatan Kumai (DAS Kumai), Kecamatan Arut Selatan (DAS Kotawaringin) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 23.3% dan 20.9% dari area total tergenang di simulasi banjir kala ulang 25 Tahun. Kecamatan Seruyan Tengah, Balai Riam, Arut Utara, Sandai (DAS Kotawaringin) memiliki minimal risiko banjir.

Kecamatan Terdampak Banjir Kala Ulang 10yr



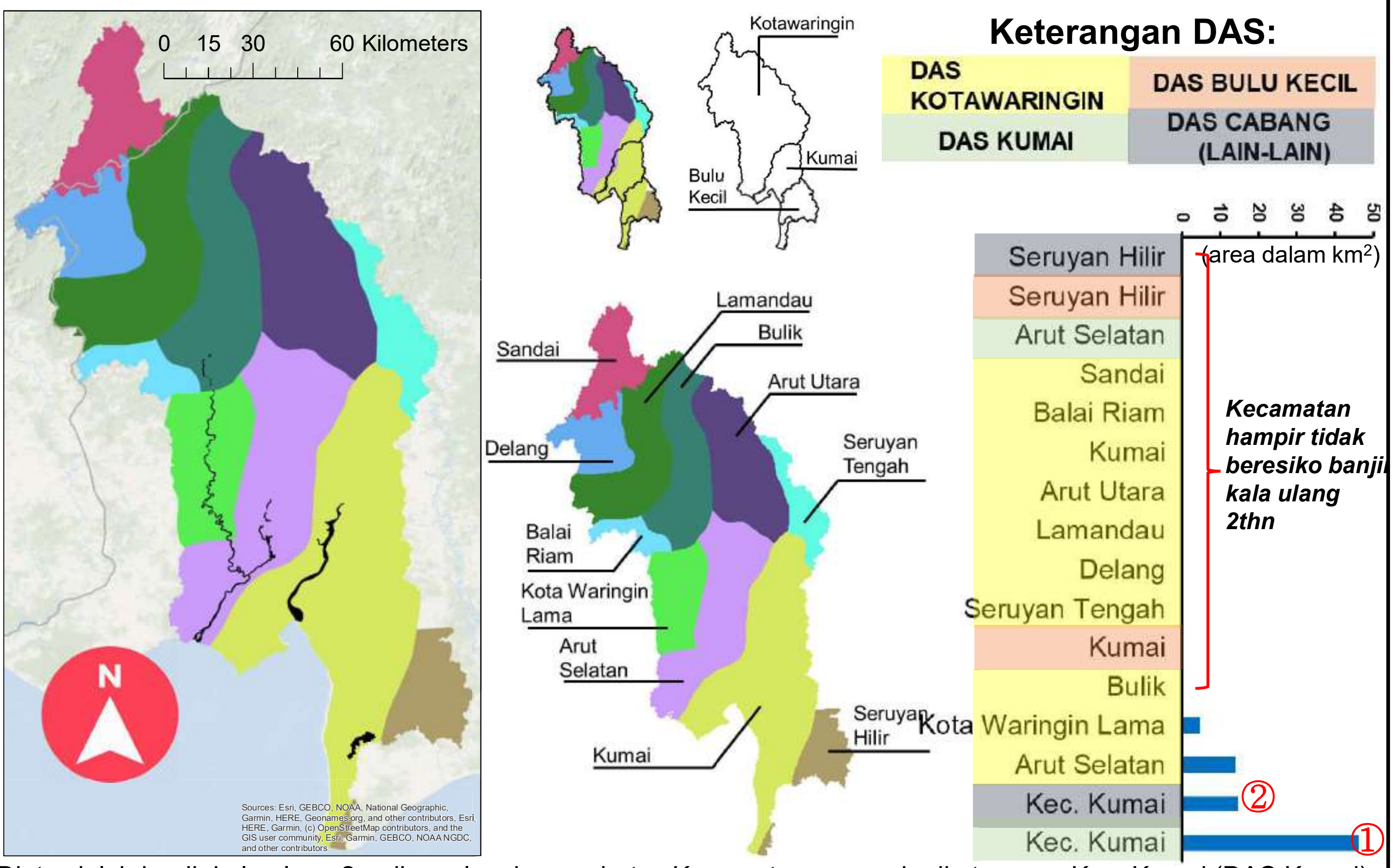
Diatas ialah banjir kala ulang 10yr di overlay dengan batas Kecamatan yang ada di atas nya. Kecamatan Kumai (DAS Kumai), Kecamatan Arut Selatan (DAS Kotawaringin) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 25.1% dan 23.4% dari area total tergenang di simulasi banjir kala ulang 10 Tahun. Kecamatan Sandai, Balai Riam, Arut Utara, Seruyan Tengah (DAS Kotawaringin) belum memiliki risiko banjir kala ulang 10thn.

Kecamatan Terdampak Banjir Kala Ulang 5yr



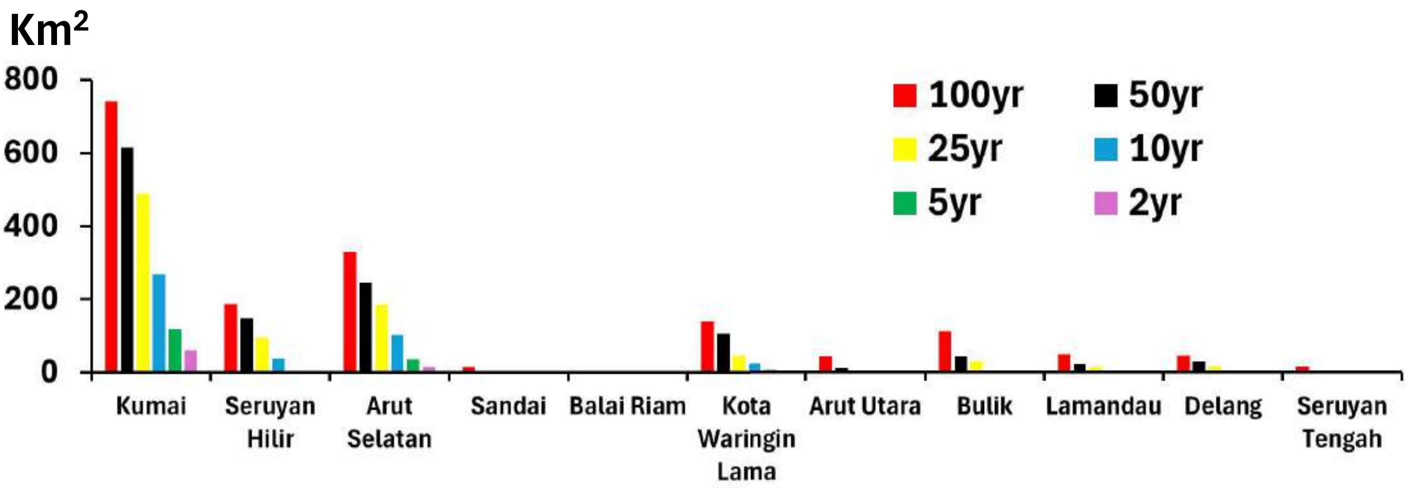
Diatas ialah banjir kala ulang 5yr di overlay dengan batas Kecamatan yang ada di atas nya. Kec. Kumai (DAS Kumai), Kec. Kumai juga di DAS Lainnya (DAS Cabang) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 32.1% dan 27.7% dari area total tergenang di simulasi banjir kala ulang 5 Tahun. Di DAS Kotawaringin, Kec. Kotawaringin Lama dan Kec Kumai yang memiliki potensi bencana banjir kala ulang 5 thn.

Kecamatan Terdampak Banjir Kala Ulang 2yr



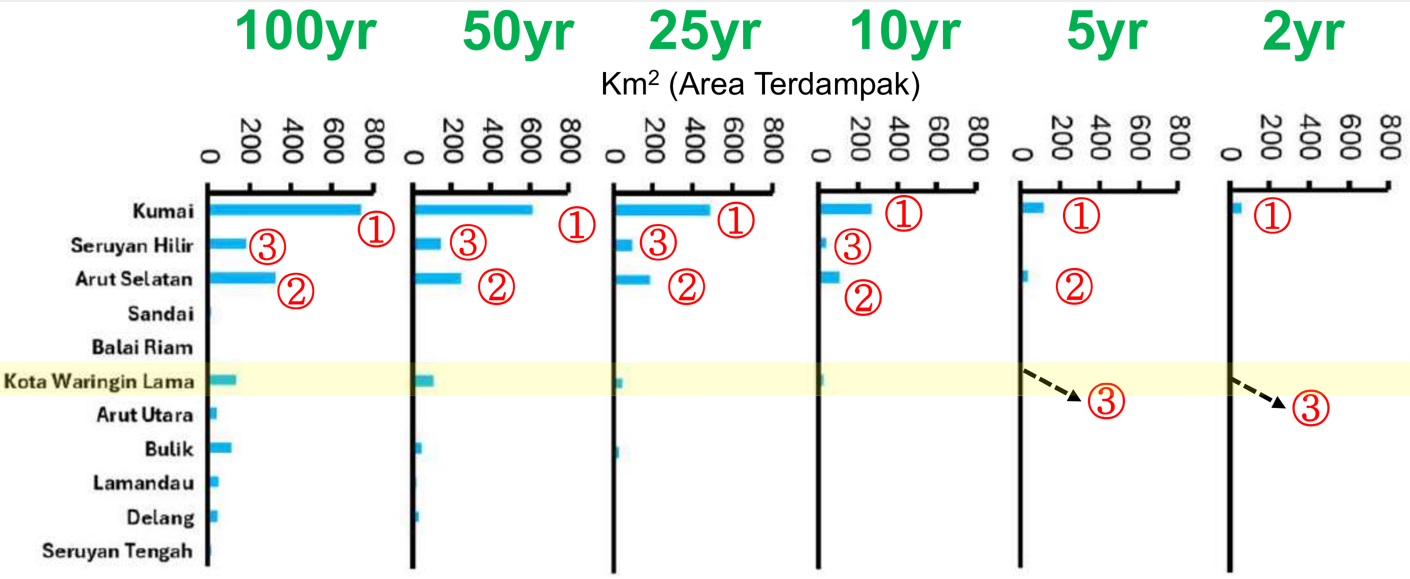
Diatas ialah banjir kala ulang 2yr di overlay dengan batas Kecamatan yang ada di atas nya. Kec. Kumai (DAS Kumai), Kec. Kumai juga di DAS Lainnya (DAS Cabang) memiliki kemungkinan terdampak banjir paling besar no 1 dan 2 dengan presentase: 57.8% dan 18.3% dari area total tergenang di simulasi banjir kala ulang 2 Tahun. Pada kala ulang 2 Tahun ini: hanya Kecamatan Kumai, Kecamatan Arut Selatan dan Kota Waringin Lama yang memiliki risiko banjir.

Kecamatan Terdampak Banjir (dalam Grafik)



Gambar diatas menunjukkan area terdampak banjir setiap Kecamatan pada setiap kala ulang. Grafik batang diatas hanya menunjukkan kecamatan yang terdampak banjir saja secara total (area dalam km²). Dari hasil simulasi banjir setiap kala ulang, dapat terlihat Kecamatan Kumai mengalami kemungkinan terdampak paling besar pada setiap kala ulang. Perlu di catat bahwa kemungkinan kecamatan Kumai banjir bisa di akibatkan oleh banjir di DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil dan Lainnya. Kecamatan Sandai dan Balai Riam memiliki potensi bahaya banjir yang sangat kecil di bandingkan dengan lainnya.

Peringkat Bahaya Banjir Kecamatan Terdampak Banjir



Dapat terlihat pada grafik diatas ranking/peringkat kecamatan terdampak banjir oleh DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil terdistribusi dari beberapa kecamatan. Perlu dicatat bahwa peringkat 1,2 dan 3 selalu di dominasi oleh Kec. Kumai, Arut Selatan dan Seruyan Hilir untuk kala ulang diatas 10yr. Namun untuk kala ulang dibawah 5yr, kecamatan yang berpotensi banjir besar adalah Kec. Kumai, Kec Arut Selatan dan Kota Waringin Lama.

Kecamatan Terdampak Banjir (Tinggi ke Rendah)

Peringkat Kecamatan Terdampak	Return Period					
	2yr	5yr	10yr	25yr	50yr	100yr
1	Kumai	Kumai	Kumai	Kumai	Kumai	Kumai
2	Arut Selatan	Arut Selatan	Arut Selatan	Arut Selatan	Arut Selatan	Arut Selatan
3	Kota Waringin Lama	Kota Waringin Lama	Seruyan Hilir	Seruyan Hilir	Seruyan Hilir	Seruyan Hilir
4	Bulik	Bulik	Kota Waringin Lama	Kota Waringin Lama	Kota Waringin Lama	Kota Waringin Lama
5	Seruyan Hilir	Seruyan Hilir	Bulik	Bulik	Bulik	Bulik
6	Sandai	Sandai	Lamandau	Delang	Delang	Lamandau
7	Balai Riam	Balai Riam	Sandai	Lamandau	Lamandau	Delang
8	Arut Utara	Arut Utara	Balai Riam	Sandai	Arut Utara	Arut Utara
9	Lamandau	Lamandau	Arut Utara	Arut Utara	Balai Riam	Seruyan Tengah
10	Delang	Delang	Delang	Balai Riam	Sandai	Sandai
11	Seruyan Tengah	Seruyan Tengah	Seruyan Tengah	Seruyan Tengah	Seruyan Tengah	Balai Riam

Dapat terlihat pada table diatas beberapa catatan penting: **(1)** Kec. Kumai dan Kec. Arut Selatan selalu menjadi kec paling berpotensi terdampak banjir pada setiap kala ulang. **(2)** Kota Waringin Lama memiliki Tingkat resiko banjir lebih tinggi di Kala Ulang 2yr dan 5yr jika di bandingkan dengan diatas kala ulang 10yr. **(3)** Kec. Seruyan Hilir umumnya tidak memiliki risiko bahaya banjir di seluruh kala ulang.

Area Terdampak Banjir Kala Ulang dalam Angka Pada Ke Tiga DAS (Table)

Return Period of 100yr

No	KECAMATAN	100yr
1	Kumai	740.0
2	Seruyan Hilir	185.8
3	Arut Selatan	330.1
4	Sandai	14.3
5	Balai Riam	4.1
6	Kota Waringin Lama	139.0
7	Arut Utara	42.6
8	Bulik	111.2
9	Lamandau	49.4
10	Delang	45.8
11	Seruyan Tengah	15.6

Area (km^2)

Return Period of 10yr

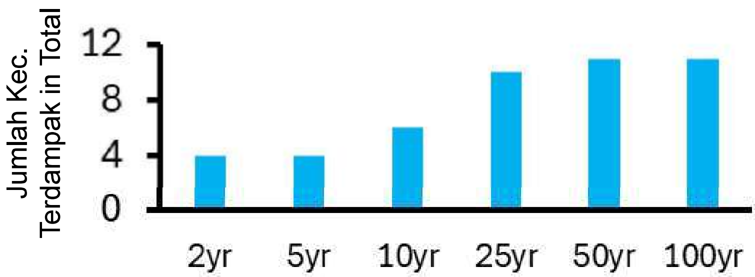
No	KECAMATAN	10yr
1	Kumai	267.7
2	Seruyan Hilir	37.5
3	Arut Selatan	103.1
4	Kota Waringin Lama	23.7
5	Bulik	5.1
6	Lamandau	1.6

Area (km^2)

Return Period of 2yr

No	KECAMATAN	2yr
1	Kumai	61.1
2	Arut Selatan	14.0
3	Kota Waringin Lama	4.7
4	Bulik	0.2

Area (km^2)



- Pada simulasi banjir Kala ulang 100 yr terdapat 11 Kecamatan berpotensi terdampak banjir dan pada kala ulang 2yr terdapat 4 Kecamatan berpotensi terdampak banjir. Penurunan jumlah kecamatan terdampak turun 63.64% dari kala ulang 100yr ke 2yr.

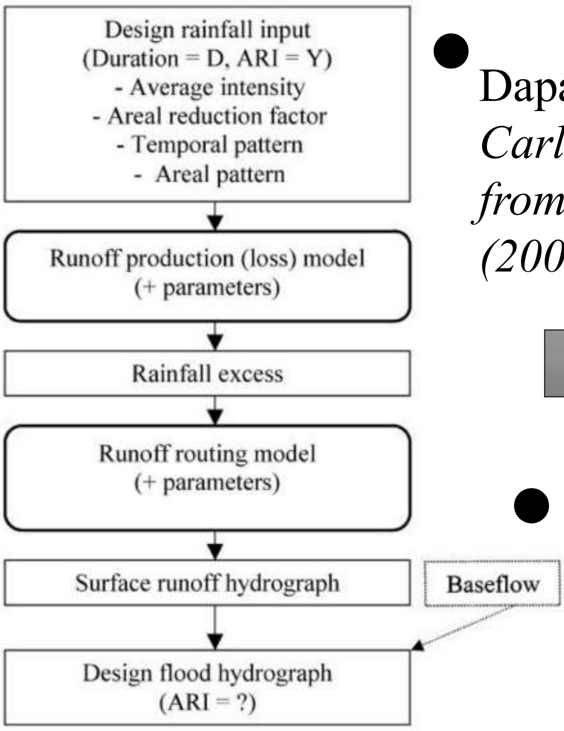
Imajinasi

Luas Prov. DKI Jakarta 660 Km^2

- Total luas potensi banjir 100yr= 1677.98 Km^2 (atau sekitar 2.5 kali luas Prov Jakarta area banjir nya).
- Total luas potensi banjir 2yr= 79.94 Km^2 (atau sekitar 1/10 total Luas Prov. DKI Jakarta.

Pemanfaatan Data Hidrologi Lainnya: Preliminary Early Warning System

Hujan~Banjir Kala Ulang



- Dapat melihat paper dengan judul: *Monte Carlo simulation of flood frequency curves from rainfall. Journal of Hydrology, 256 (2002) 196-210*

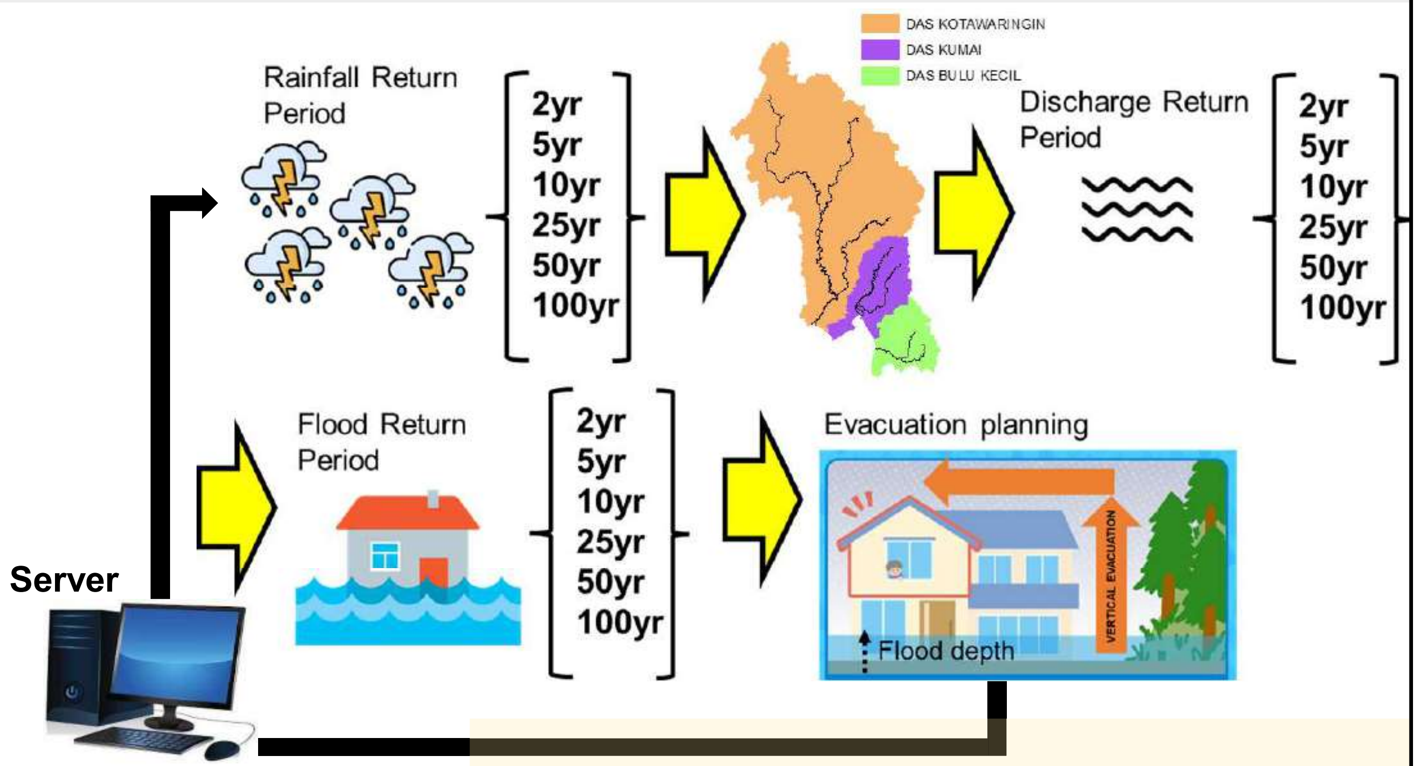
$$\text{Rainfall } TR_n \equiv \text{Flood } FR_n$$

n= 2,5,10,25,50,100

- Curah hujan kala design kala ulang -n- ekuivalen dengan banjir design kala ulang -n-.

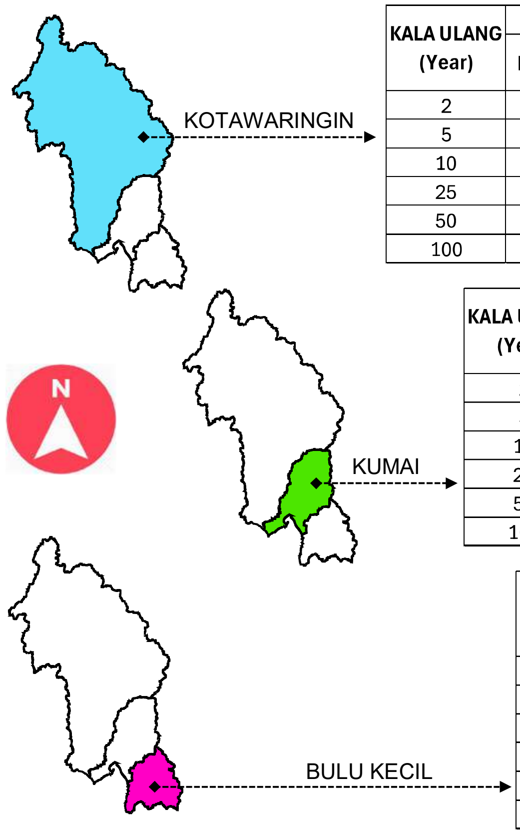
- Rahman et al (2002) menyampaikan dalam teori teknik banjir praktis, return period dari hujan dan debit dianggap ekuivalen. Design flood secara umum dihasilkan dari design rainfall.

Persiapan *Early Warning System* DAS Kotawaringin, Kumai dan Bulu Kecil



Gambar diatas menunjukkan hubungan Hujan-Banjir kala ulang yang di persiapkan untuk membangun Early Warning System di DAS Kotawaringin, Kumai dan Bulu Kecil. Skema dasar Hujan yang datang di DAS akan di evaluasi pada banjir setiap kala ulang. Banjir setiap kala ulang ini dapat di jadikan dasar dalam menentukan evakuasi saat terjadi hujan kala ulang tertentu di Das Tersebut diatas.

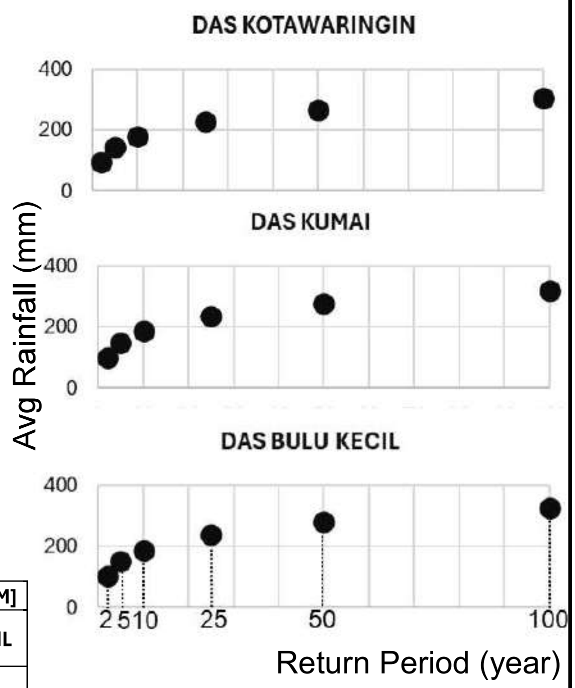
Hujan Kala Ulang DAS Kotawaringin, Kumai dan Bulu Kecil



KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2

KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8

KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9

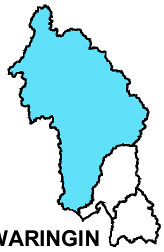


Gambar diatas menunjukkan average hujan kala ulang (2, 5,10,25, 50 dan100) pada setiap masing-masing DAS. Informasi Kala ulang ini dapat digunakan pada tahap awal dalam menentukan early warning system di DAS Kotawaringin, Kumai dan Bulu Kecil.

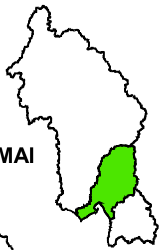
Hujan Kala Ulang Tr_{2yr}~Banjir Kala Ulang Fr_{2yr}

Rainfall — Flood

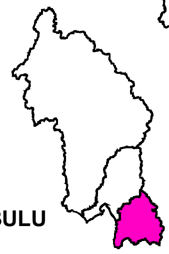
Rainfall T_{2y} = Flood F_{2y}



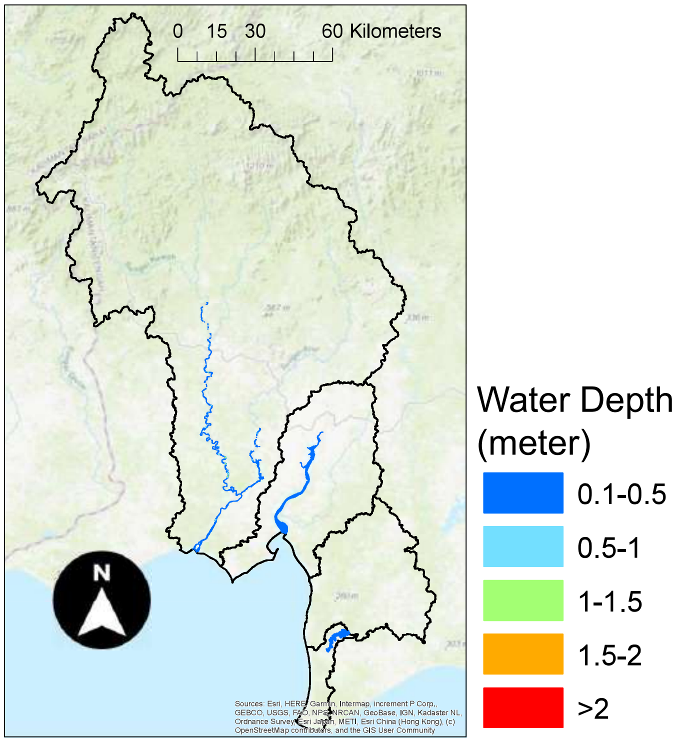
KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9

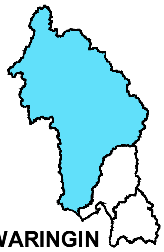


Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **94 mm**, DAS Kumai **98.5 mm** dan DAS Bulu Kecil adalah **101.4 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat menjadikan informasi tersebut sebagai inisial awal akan terjadi nya banjir seperti Gambar Kanan diatas.

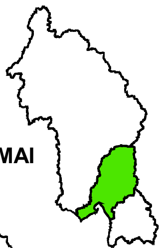
Hujan Kala Ulang Tr_{5yr}~Banjir Kala Ulang Fr_{5yr}

Rainfall — Flood

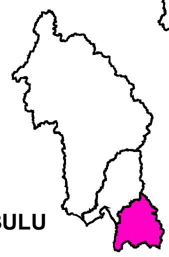
Rainfall T_{5y} = Flood F_{5y}



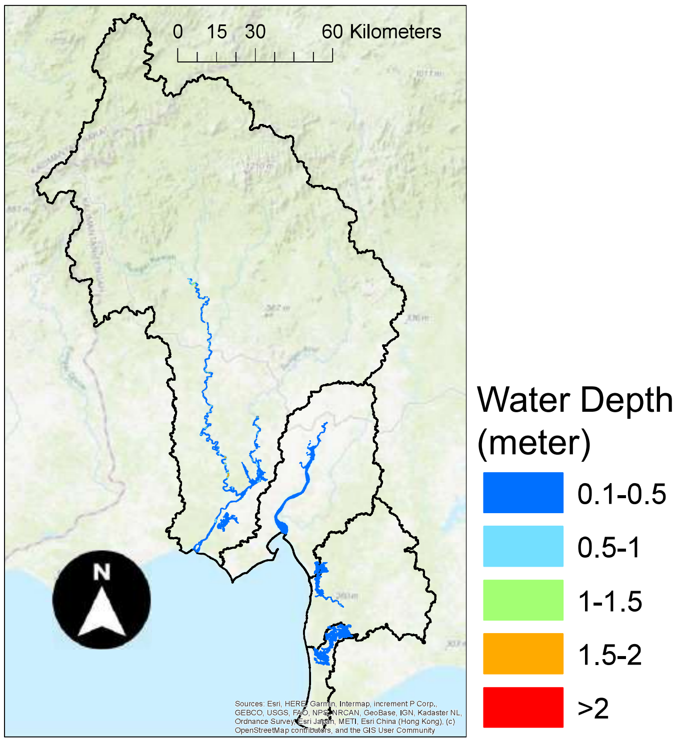
KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9

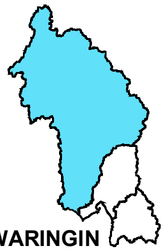


Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **144 mm**, DAS Kumai **148 mm** dan DAS Bulu Kecil adalah **151 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat menjadikan informasi tersebut sebagai inisial awal akan terjadi nya banjir seperti Gambar Kanan diatas.

Hujan Kala Ulang Tr_{10yr}~Banjir Kala Ulang Fr_{10yr}

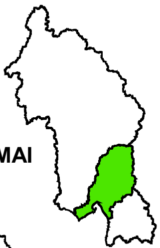
Rainfall — Flood

Rainfall T_{10y} = Flood F_{10y}



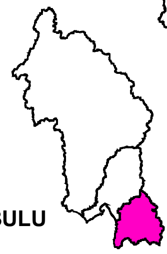
DAS KOTAWARINGIN

KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



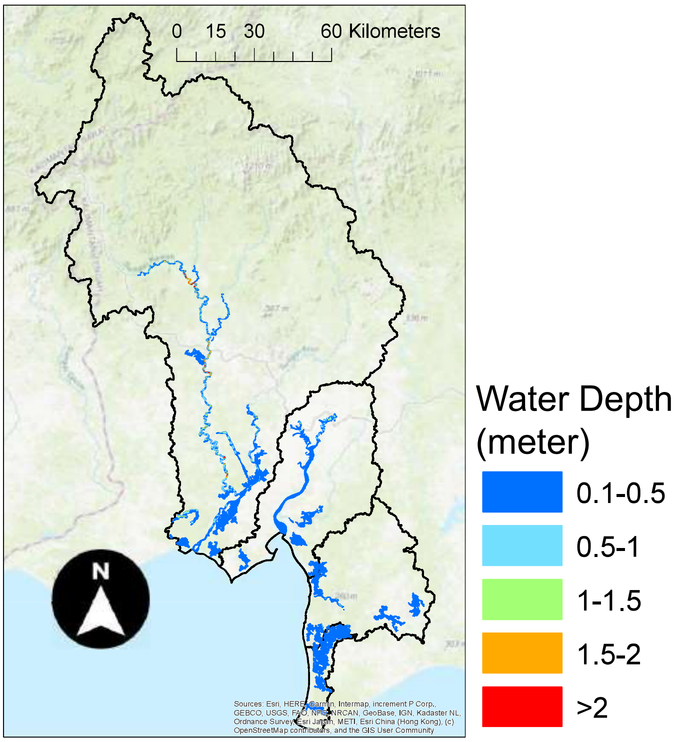
DAS KUMAI

KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



DAS BULU KECIL

KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9

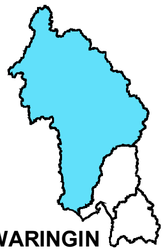


Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **179 mm**, DAS Kumai **184 mm** dan DAS Bulu Kecil adalah **187 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat menjadikan informasi tersebut sebagai inisial awal akan terjadi nya banjir seperti Gambar Kanan diatas.

Hujan Kala Ulang Tr_{25yr}~Banjir Kala Ulang Fr_{25yr}

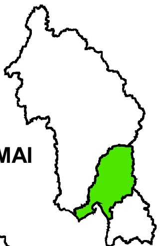
Rainfall — Flood

Rainfall T_{25y} = Flood F_{25y}



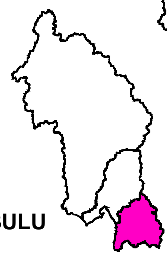
DAS KOTAWARINGIN

KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



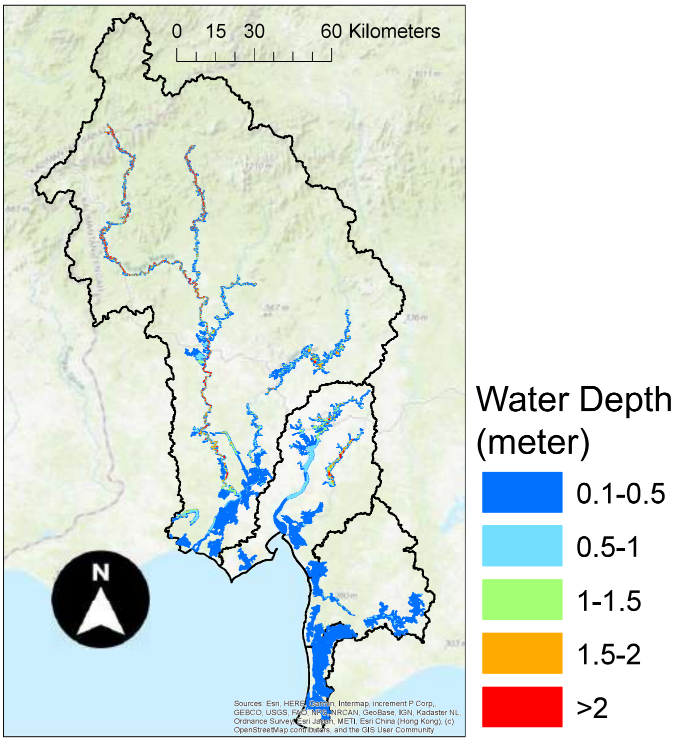
DAS KUMAI

KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



DAS BULU KECIL

KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9



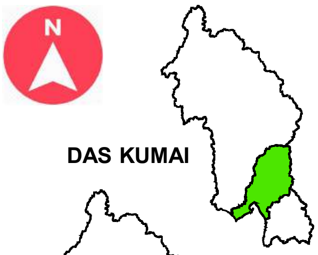
Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **227 mm**, DAS Kumai **234 mm** dan DAS Bulu Kecil adalah **237 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat menjadikan informasi tersebut sebagai inisial awal akan terjadi nya banjir seperti Gambar Kanan diatas.

Hujan Kala Ulang Tr_{50yr}~Banjir Kala Ulang Fr_{50yr}

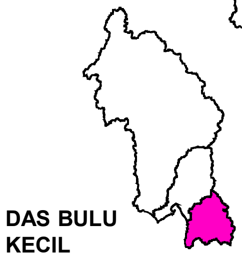
Rainfall → Flood

Rainfall T_{50y} = Flood F_{50y}

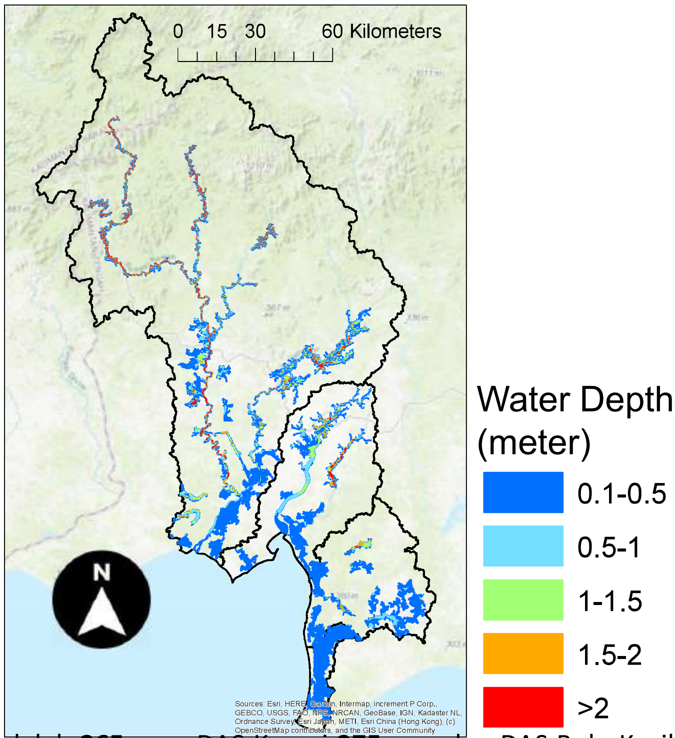
KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9



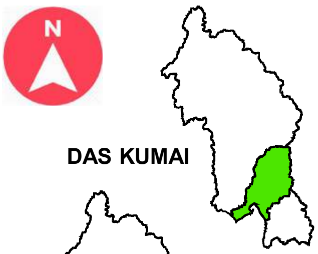
Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **265 mm**, DAS Kumai **275 mm** dan DAS Bulu Kecil adalah **279 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat memberikan inisial informasi hujan seperti tersebut diatas sebagai adanya perkiraan banjir yang mungkin terjadi di ketiga DAS tersebut.

Hujan Kala Ulang Tr_{100yr}~Banjir Kala Ulang Fr_{100yr}

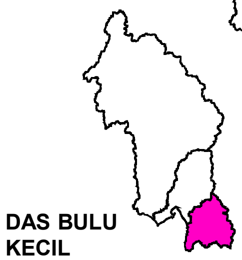
Rainfall → Flood

Rainfall T_{100y} = Flood F_{100y}

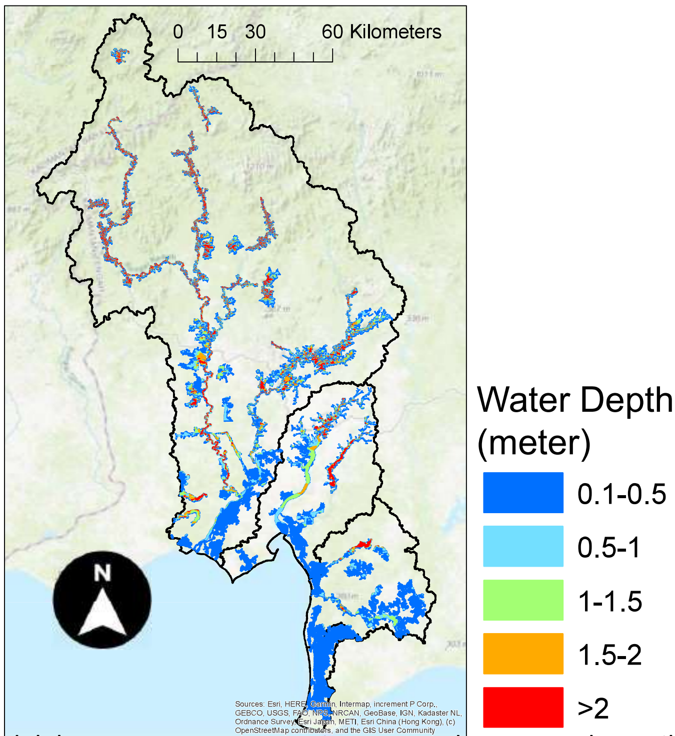
KALA ULANG (Year)	AVG. HUJAN [MM] DAS KOTAWARINGIN
2	94.3
5	144.7
10	179.9
25	227.4
50	265.4
100	306.2



KALA ULANG (Year)	AVG. HUJAN [MM] DAS KUMAI
2	98.5
5	148.8
10	184.8
25	234.4
50	275.2
100	319.8



KALA ULANG (Year)	AVG. HUJAN [MM] DAS BULU KECIL
2	101.4
5	151.2
10	187.3
25	237.7
50	279.6
100	325.9



Dengan Average Hujan Kala Ulang pada DAS Kotawaringin adalah **306 mm**, DAS Kumai **319 mm** dan DAS Bulu Kecil adalah **325 mm** dapat ditunjukkan bahwa banjir yang terjadi seperti di sebelah kanan pada gambar diatas. BWS dapat memberikan inisial informasi hujan seperti tersebut diatas sebagai adanya perkiraan banjir yang mungkin terjadi di ketiga DAS tersebut.

Klasifikasi Peta Bahaya Banjir Berdasarkan BNPB.

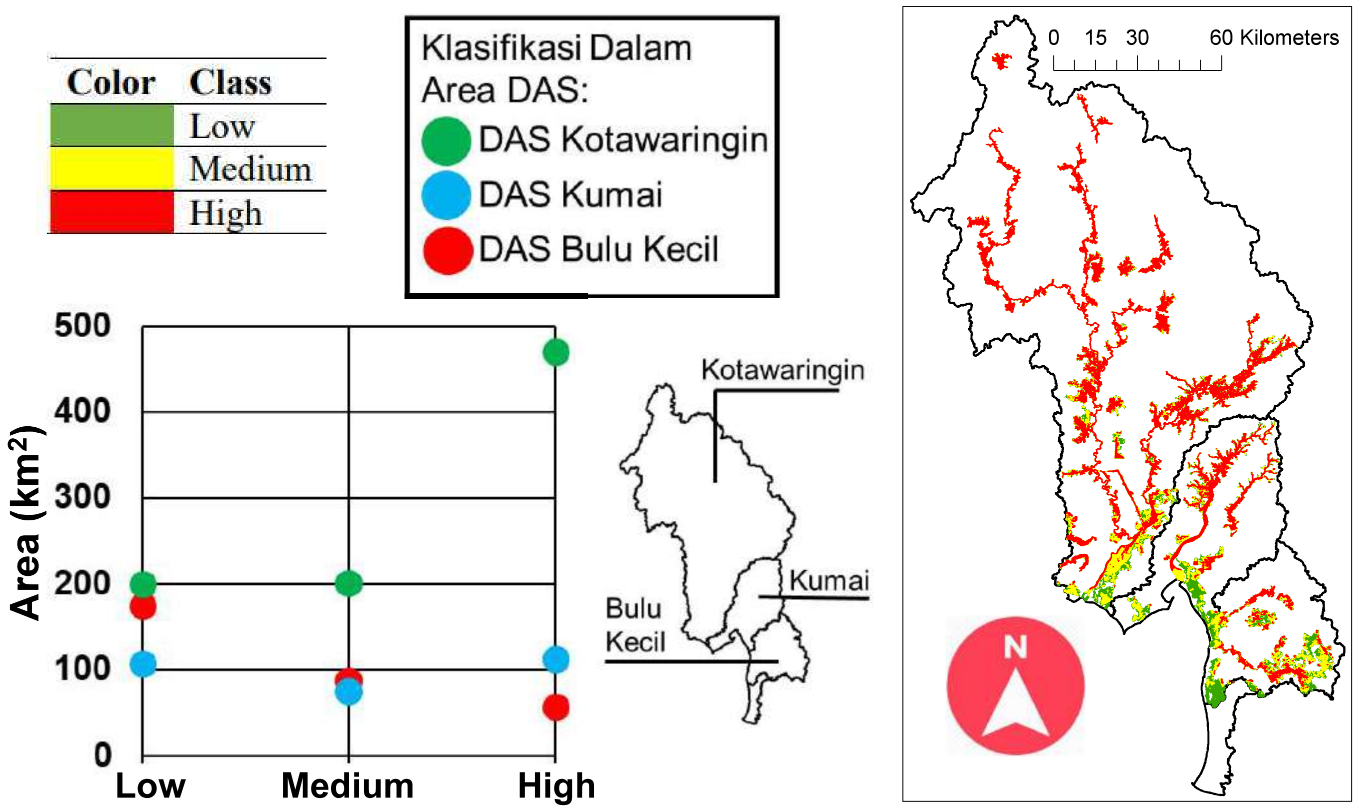
Klasifikasi Bahaya Banjir

Color	Class	Range of Flood Depth (m)				Ratio of Index Class		
	Low	0	-	0.75	→	0	-	1/3
	Medium	0.75	-	1.5	→	1/3	-	2/3
	High	1.5	-	Max Value	→	2/3	-	1

Badan National Penanggulangan Bencana di Tahun 2012 mengeluarkan klasifikasi/kelas bahaya banjir yang dapat digunakan sebagai standar bahaya banjir. Kelas tersebut di bagi menjadi 3 (tiga) yakni: Kelas Low, Kelas Medium dan Kelas High.

Peraturan Kepala Badan Nasional Penanggulangan Bencana Nomor 02 Tahun 2012 tentang Pedoman Umum Pengkajian Risiko Bencana

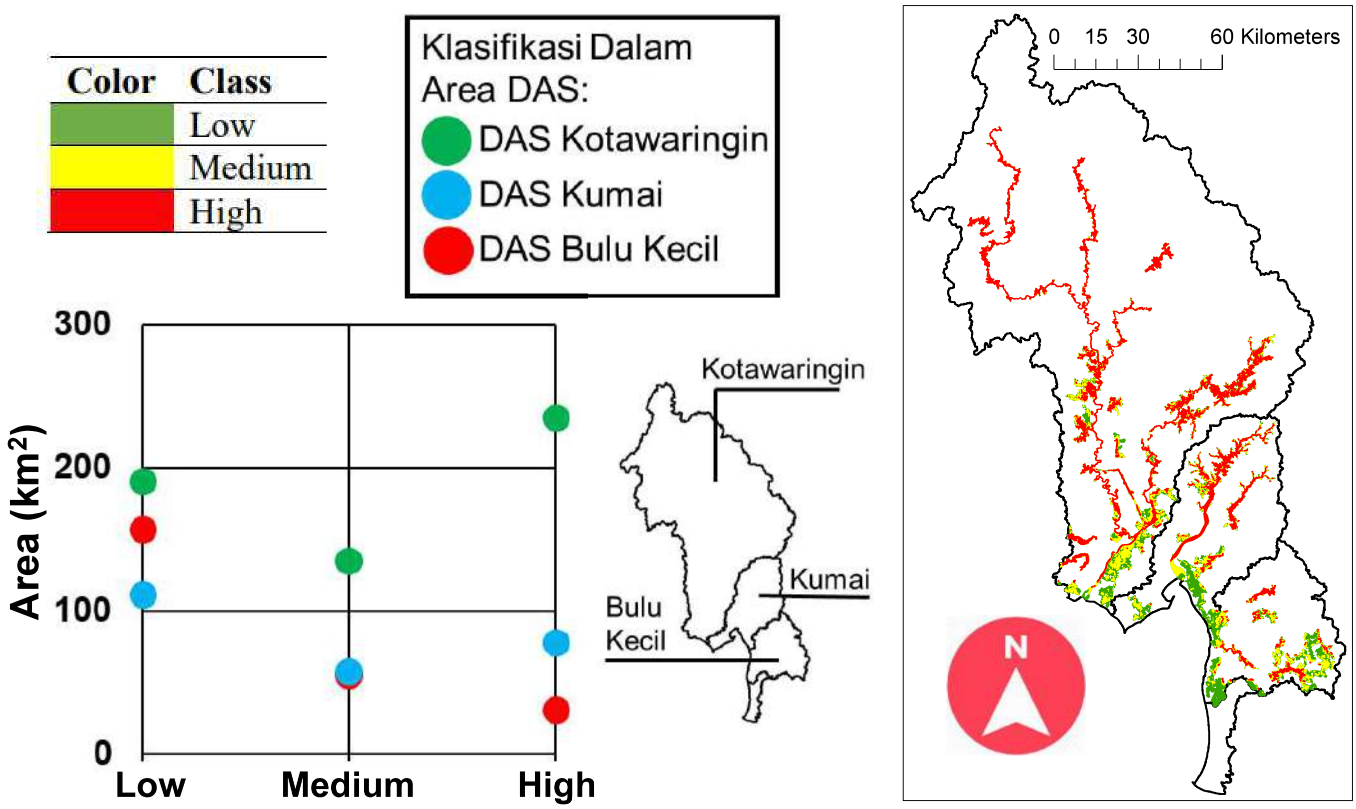
Klasifikasi Bahaya Banjir Kala Ulang 100yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 100thn,

- Pada DAS Kotawaringin, kelas bahaya high mendominasi jika di bandingkan dengan kelas low dan medium. Kelas low dan medium umumnya tersebar di daerah hilir.
- Pada DAS Kumai, Kelas Low, Medium dan High tersebar merata dalam ukuran area (km^2).
- Pada DAS Bulu Kecil, kelas high sangat rendah area nya jika dibandingkan dengan low dan medium.

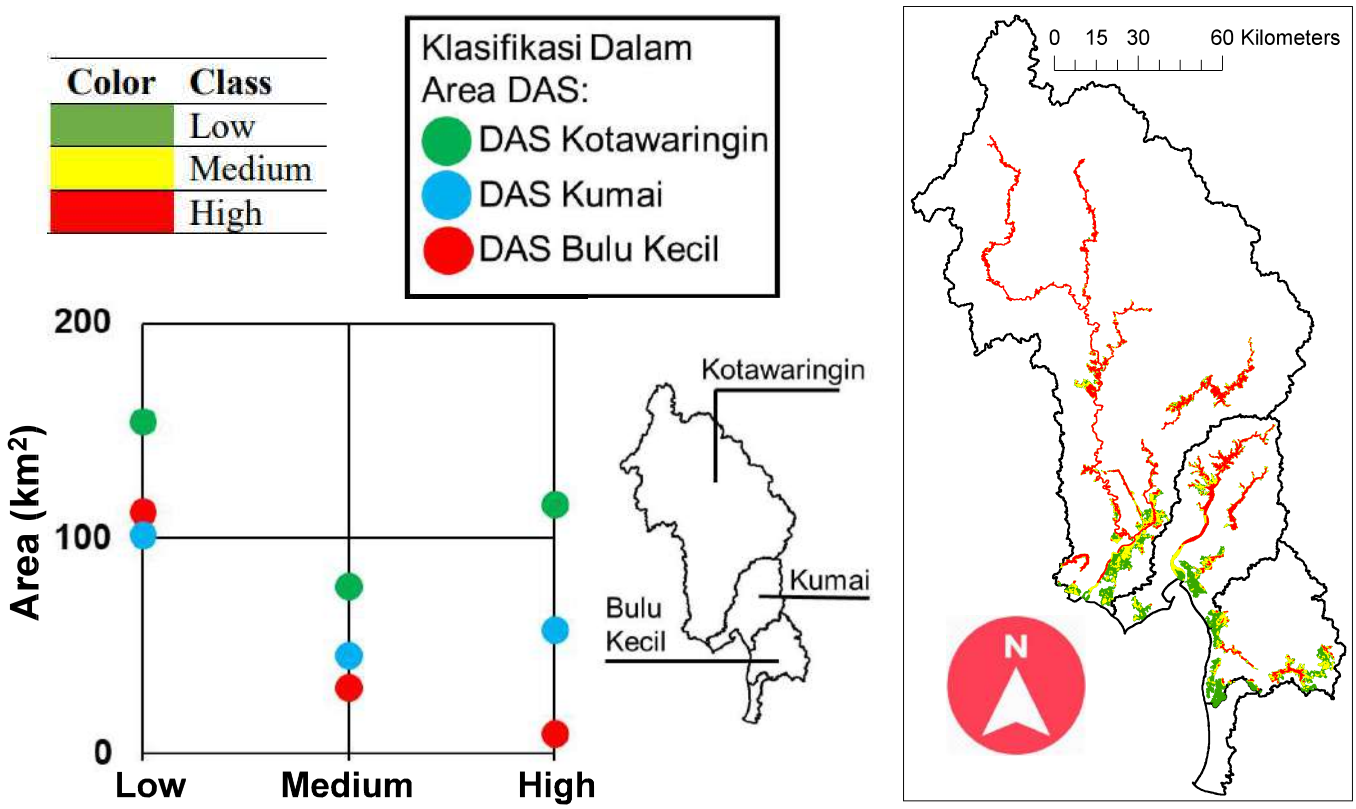
Klasifikasi Bahaya Banjir Kala Ulang 50yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 50thn,

- Pada DAS Kotawaringin, kelas bahaya high sedikit lebih banyak terpapar jika di bandingkan dengan Low dan medium.
- DAS Kumai, Kelas Low, Medium dan High tersebar merata dalam ukuran area (km^2).
- DAS Bulu Kecil, kelas high dan medium sangat rendah area terpaparnya jika dibandingkan dengan low class.

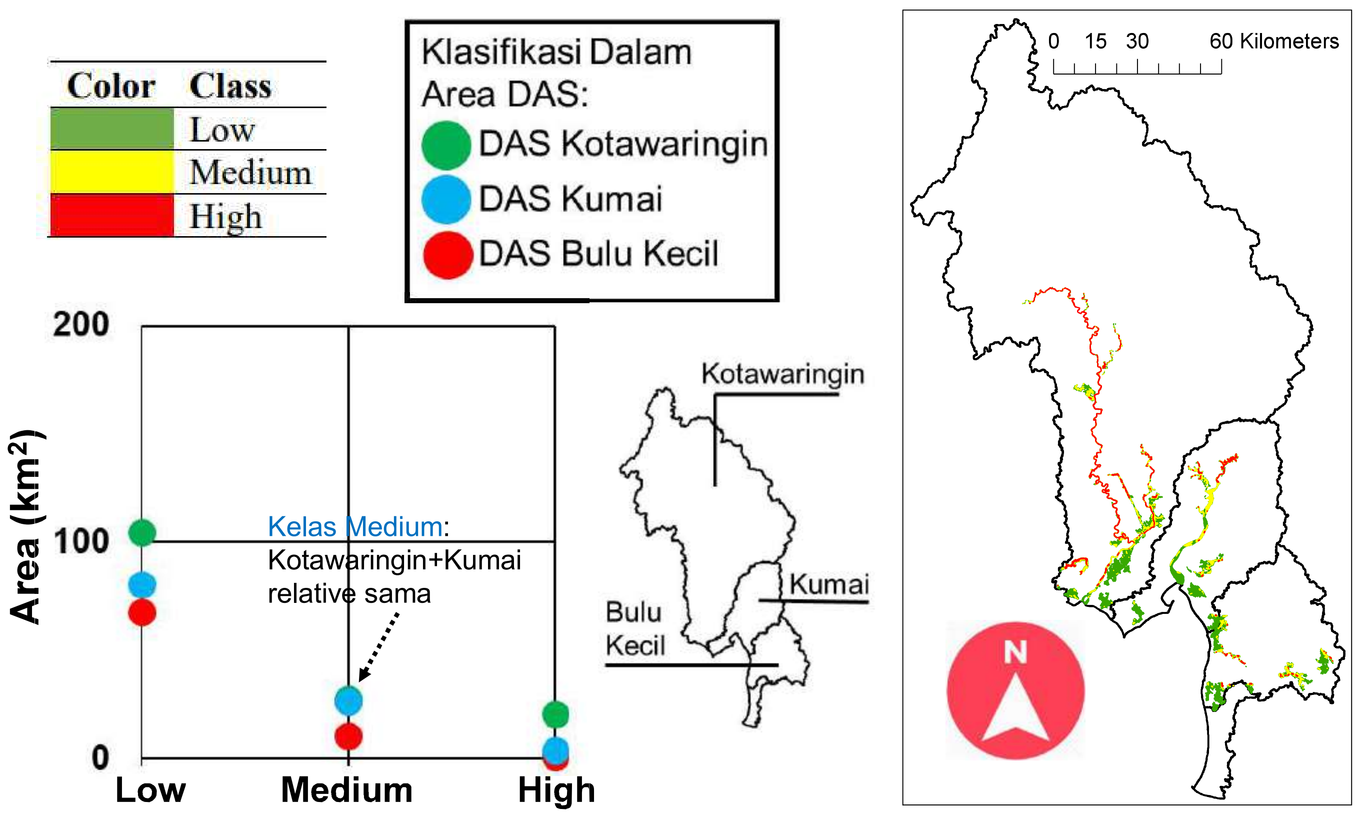
Klasifikasi Bahaya Banjir Kala Ulang 25yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 25 thn,

- Pada DAS Kotawaringin, kelas bahaya high masih di bawah kelas risiko low. Artinya pada kala ulang 25yr banyak area yang memiliki risiko low.
- Pada DAS Kumai, Kelas Low memiliki potensi lebih besar dibandingkan kelas lain nya.
- Pada DAS Bulu Kecil, kelas high dan medium sangat rendah area nya jika dibandingkan dengan high class.

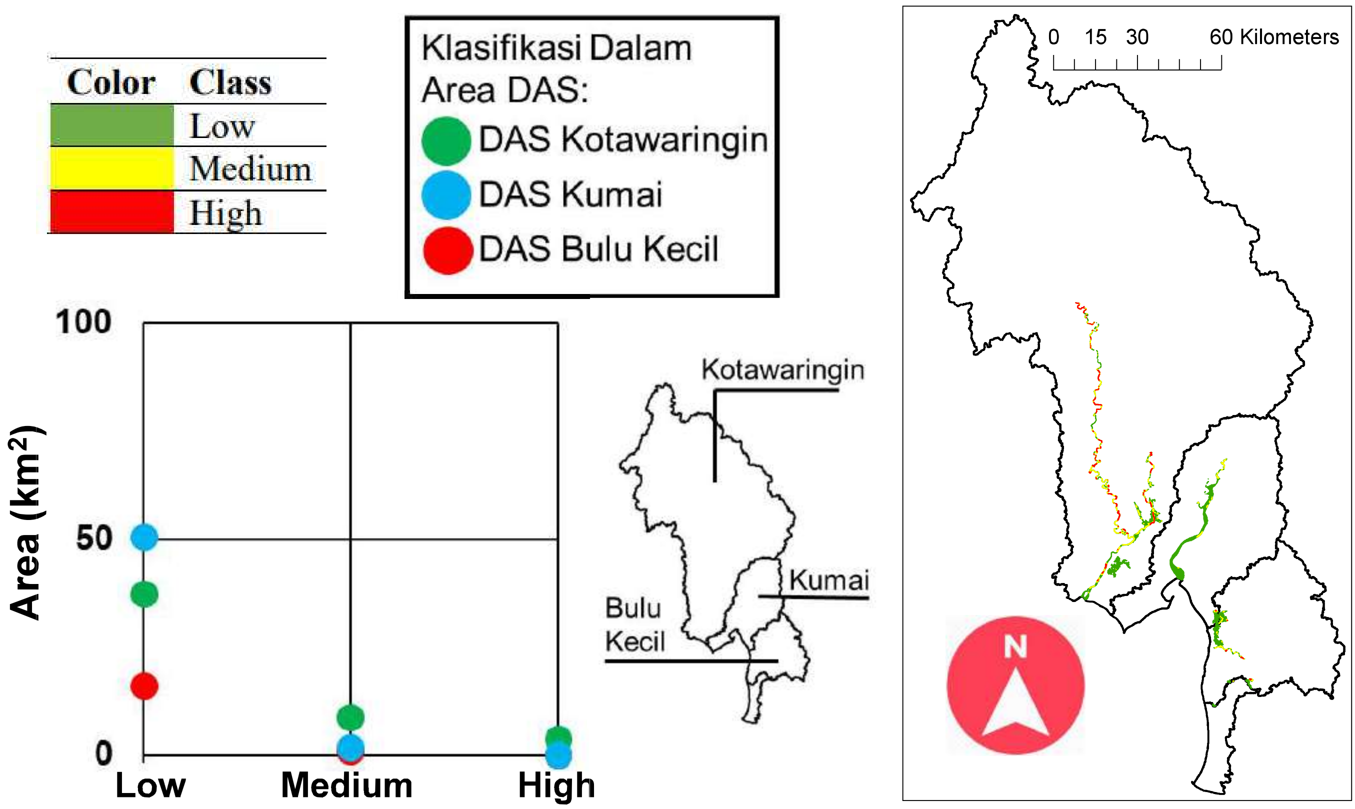
Klasifikasi Bahaya Banjir Kala Ulang 10yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 10thn,

- Pada DAS Kotawaringin, kelas bahaya low mendominasi jika di bandingkan dengan kelas low dan medium. Kelas low dan medium umumnya tersebar di daerah hilir.
- Pada DAS Kumai, Kelas Low, Medium dan High tersebar merata dalam area (km^2).
- Pada DAS Bulu Kecil, kelas high dan medium sangat rendah area nya jika dibandingkan dengan low class.

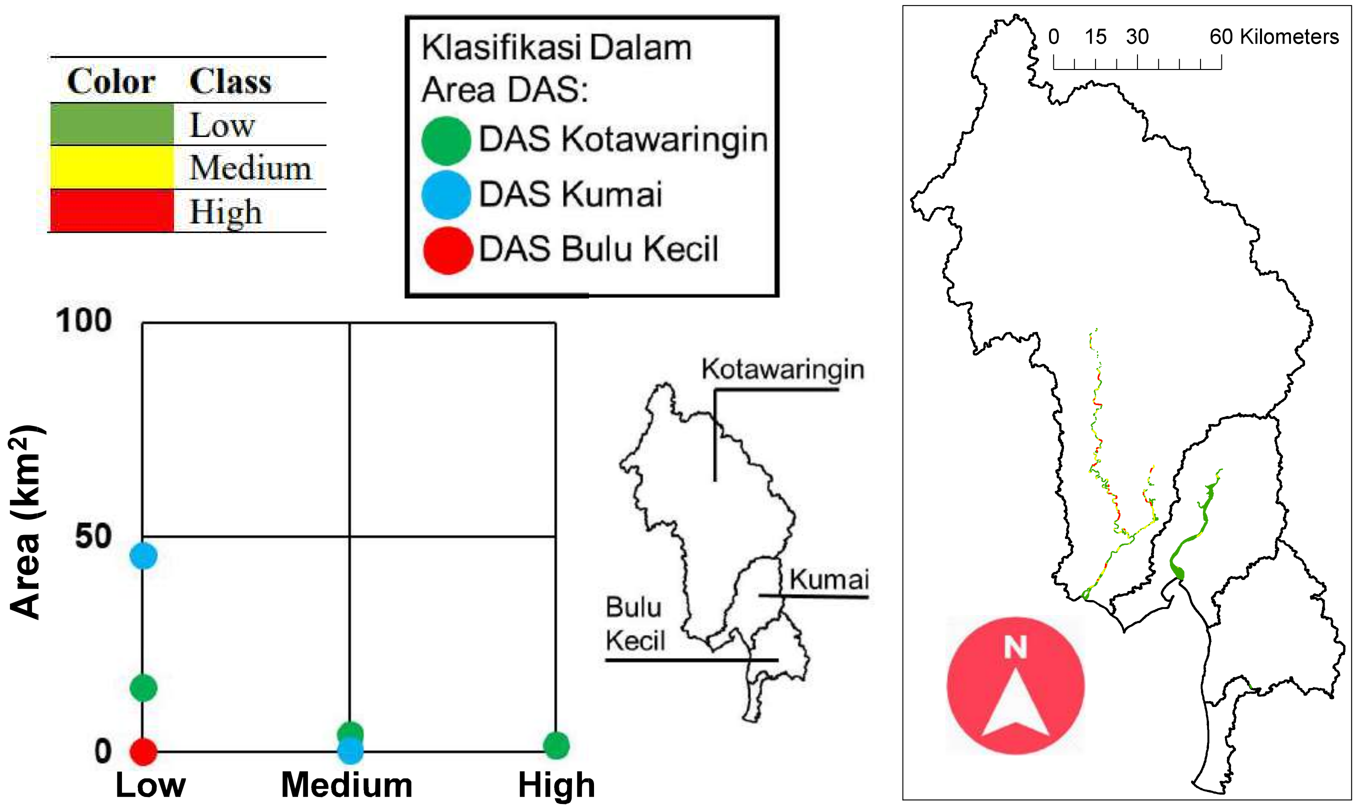
Klasifikasi Bahaya Banjir Kala Ulang 5yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 5thn,

- Pada DAS Kotawaringin, kelas bahaya low mendominasi jika di bandingkan dengan kelas low dan medium. Kelas low dan medium umumnya tersebar di daerah hilir.
- Pada DAS Kumai, Kelas Low, Medium dan High tersebar merata dalam area (km^2).
- Pada DAS Bulu Kecil, kelas high dan medium sangat rendah area nya jika dibandingkan dengan low class.

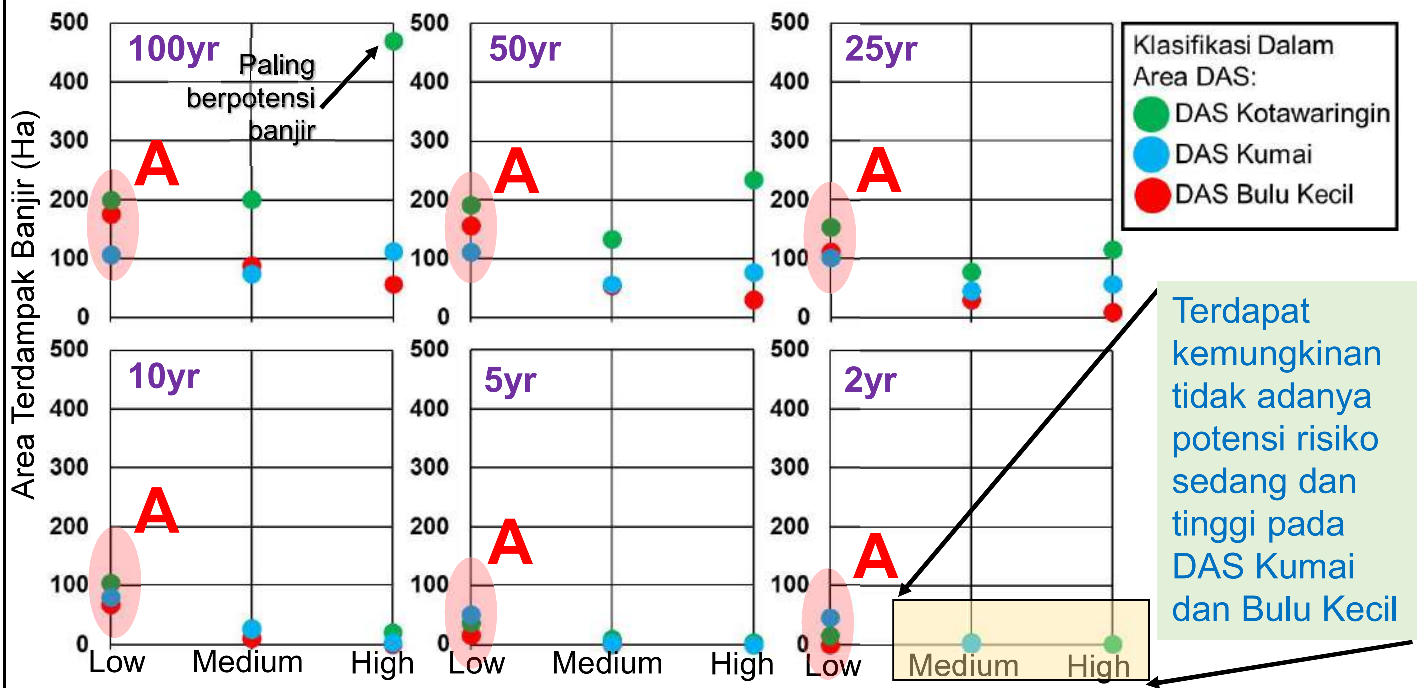
Klasifikasi Bahaya Banjir Kala Ulang 2yr



Dengan menggunakan klasifikasi bahaya banjir dari BNPB, pada kala ulang 2thn,

- Pada DAS Kotawaringin, kelas bahaya low memiliki potensi paling tinggi di bandingkan dengan kelas lainnya.
- Pada DAS Kumai, Kelas Low dan Medium mendominasi. Das Kumai tidak memiliki potensi kelas high pada kala ulang 2thn.
- Pada DAS Bulu Kecil, di kala ulang 2thn, hanya memiliki kelas kala ulang 2thn.

Klasifikasi Bahaya Banjir Dalam Graph



- Dapat terlihat pada kelas risiko banjir **Low** (lihat A) di setiap kala ulang. Dimana Setiap Kala Ulang memiliki potensi risiko bahaya banjir kelas low di seluruh DAS Kotawaringin, DAS Kumai, dan DAS Bulu Kecil.
- Pada DAS Bulu Kecil: di kala ulang 2yr tidak ada risiko kelas sedang dan tinggi seluruhnya dalam risiko rendah. Pada DAS Kumai: di kala ulang 2yr Tidak ada risiko potensi pada Kelas Tinggi.
- Risiko potensi banjir paling tinggi terdapat pada kala ulang 100yr di DAS Kotawaringin dengan kelas high.

Kesimpulan

Kesimpulan

- DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil menjadi target pada kegiatan ini.

- Telah di bangun model rainfall-runoff, flood routing dan inland flooding yang dilakukan pada DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil. Model mempertimbangkan situasi perubahan muka air laut di area paling hilir pada ketiga DAS Tersebut. Sebagai catatan, ketiga DAS tersebut bersebelahan antar satu dan lainnya.

- Telah evaluasi quantitative terhadap penyebab banjir di ketiga DAS Tersebut. Beberapa hal yaitu: curah hujan yang mungkin semakin meningkat dengan hasil evaluasi:
  1. DAS Kotawaringin bagian hulu naik dari 255mm→355mm (±39.22%),
  2. DAS Kumai bagin hulu naik dari 195mm→225mm (±15.38%) dan
  3. DAS Bulu Kecil naik 175mm→255mm (±45.71%).
- Tata guna lahan juga meningkat pada DAS Kotawaringin, DAS Kumai dan DAS Bulu Kecil dengan catatan sebagai berikut dari Tahun 2017 hingga 2023 (6 Tahun):
  1. area cropland meningkat dari 834.4 km^2 (2017) menjadi 974.1 km^2 (2023). naik hampir 16.74%.
  2. Urban area naik dari 224.9 km2 (2017) menjadi 441 km2, persentase meningkat hingga 96.09%.

- Dari hasil Analisa, bagian DAS Kotawaringin memiliki potensi **suplesi debit yang cukup tinggi** terhadap banjir pada periode hujan deras.. Debit di DAS Kotawaringin naik 225% dari kala ulang 2yr menjadi 100yr.

Kesimpulan

- Hasil Analisa Banjir di DAS Kotawaringin, Kumai dan Bulu Kecil (Total) menunjukkan:
  1. *Area* Banjir meningkat 5 x nya dari kala ulang 2yr ke 10yr, dan meningkat 2.13 x nya dari kala ulang 25yr menjadi 100yr.
  2. *Volume* Banjir meningkat 18.2 x nya dari kala ulang 2yr ke 10yr, dan meningkat 2.58 x nya dari kala ulang 25yr menjadi 100yr.

- Pada simulasi banjir Kala ulang :
  A. 11 Kecamatan berpotensi terdampak simulasi banjir pada kala ulang 100yr
  B. 4 Kecamatan berdan pada simulasi banjir kala ulang 2yr

  Penurunan jumlah kecamatan terdampak turun 63.64% dari kala ulang 100yr ke 2yr.

- Telah juga di kembangkan persiapan Early Warning System pada DAS Kotawaringin, Das Kumai dan. Assessment awal ini dapat di gunakan untuk melakukan peramalan pada kemungkinan area terbanjiri pada DAS-DAS tersebut pada setiap dan kala ulang yang telah di sajikan pada studi ini.

- Telah di lakukan klasifikasi terhadap bahaya banjir berdasarkan Peraturan Kepala Badan Nasional Penanggulangan Bencana Nomor 02 Tahun 2012 tentang Pedoman Umum Pengkajian Risiko Bencana. BWS dapat memanfaatkan tersebut sebagai masukan pengembangan Lokasi bahaya bencana banjir di masa depan.

Kesimpulan

- Kec. Kumai, Kec. Arut Selatan dan Kota Waringin Lama selalu menjadi kec paling berpotensi terdampak banjir pada setiap kala ulang. Kecamatan Seruyan Hilir umumnya tidak memiliki risiko bahaya banjir di seluruh kala ulang.

Terima Kasih

Assessment of Future Water Stress in the New Capital City of Indonesia under Climate Change Scenarios

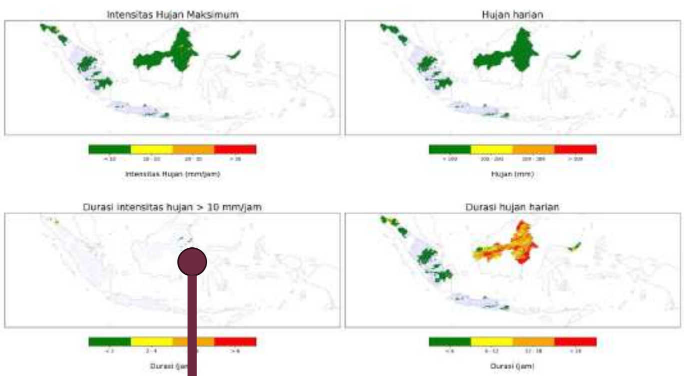
Nurul Fajar Januriyadi

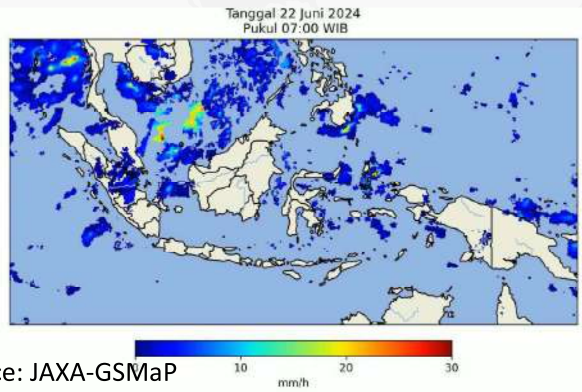
Symposium toward Success of Relocation and Revival of the Capital City in Indonesia: Hydrologic Flood Modeling and Local Adaptation to Climate Change

Auditorium in the Griya Legita, Universitas Pertamina

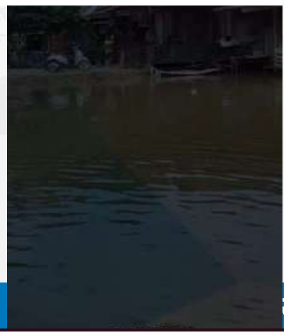
Water-Related Disaster Risk Management for Whole Indonesia

- Determining Regional Vulnerability
- Local Scale water related disaster risk assessment
- Water-related Disaster risk reduction for whole Indonesia





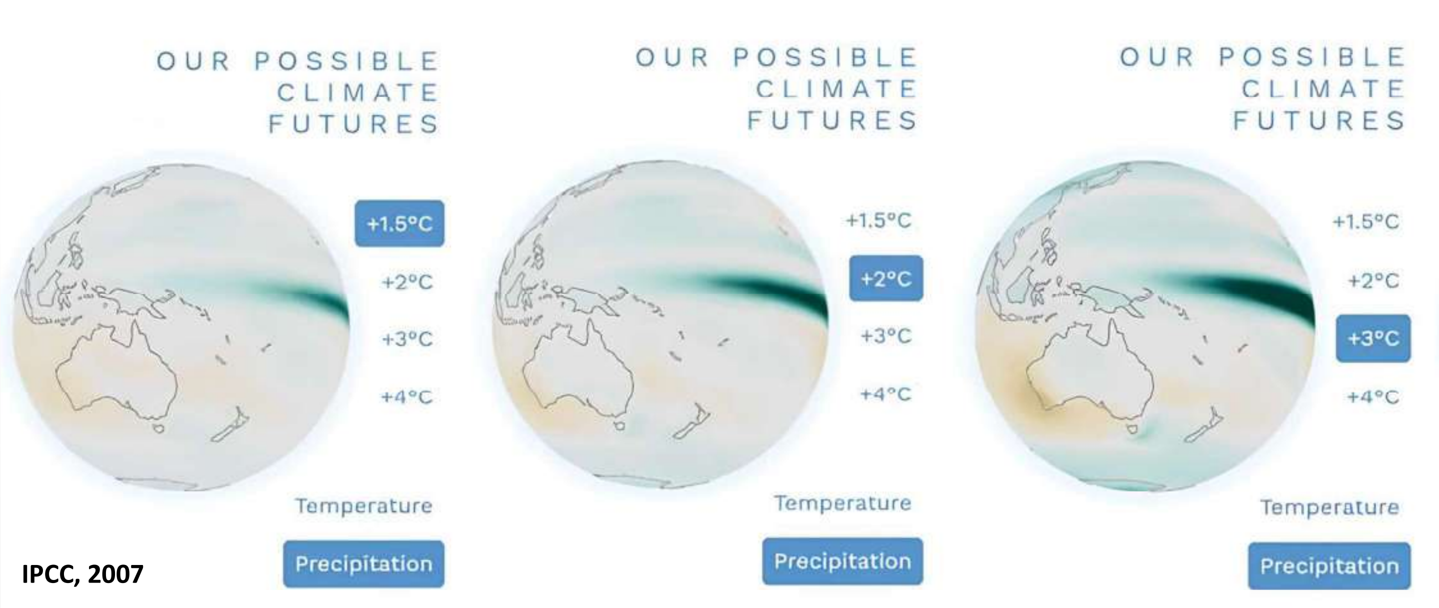
Source: JAXA-GSMaP



Contents

Introduction

Introduction



IPCC, 2007

Warmer climate is projected to increase extreme rainfall, especially over India, Southeast Asia, and **Indonesia**. (Scoccimarro, et al 2013)

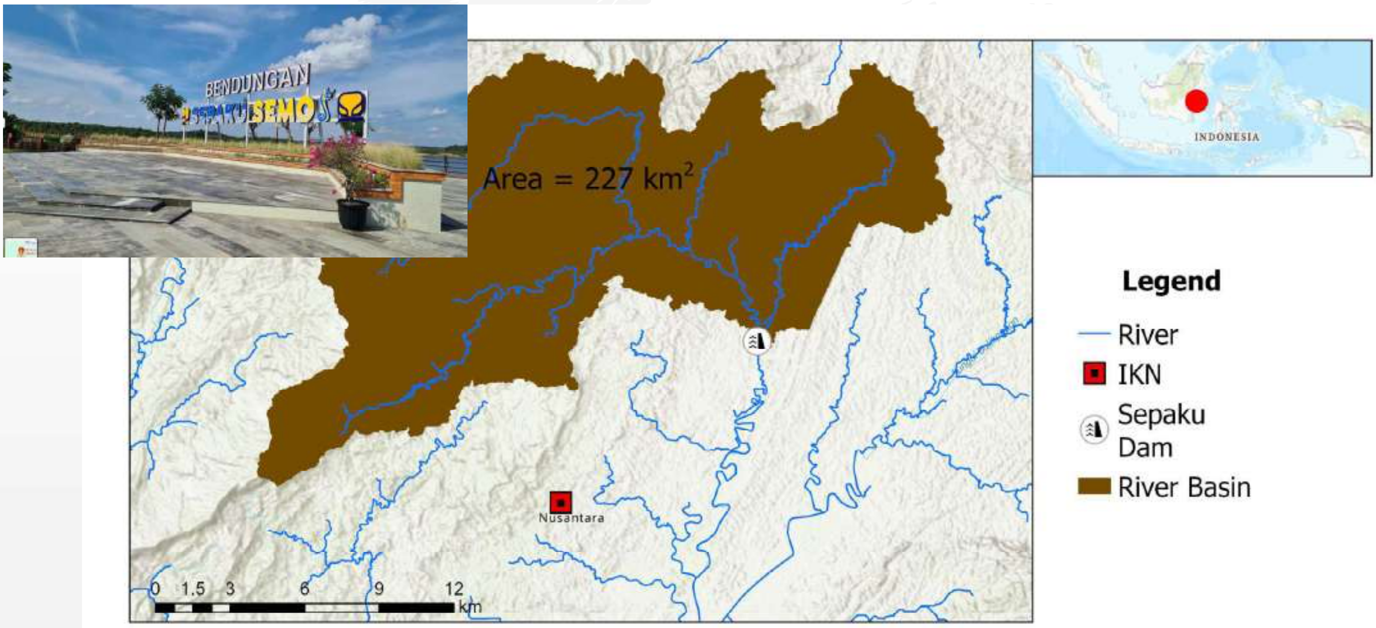
Introduction

- The government has decided to relocate the capital, replacing Jakarta.
- The new capital will see a population surge and greater water demand.
- Climate change may impact the new capital's water supply.
- **This study examines water supply in the new capital considering climate change.**

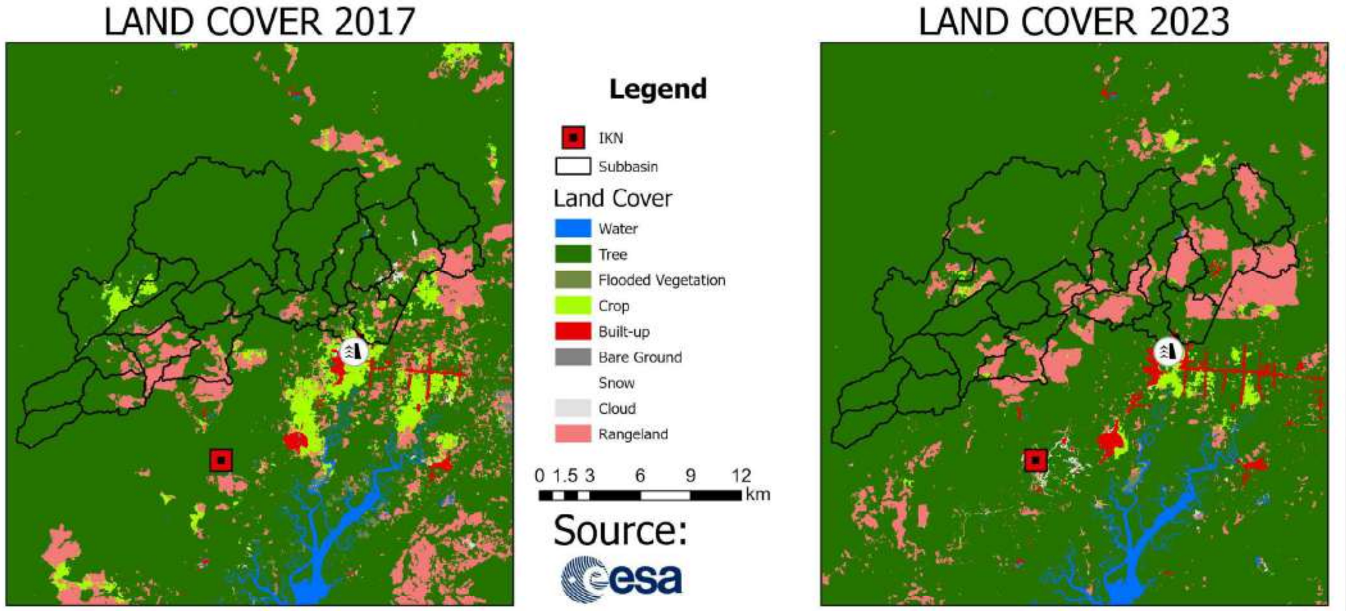
Jokowi: Pemindahan Ibu Kota Bagian Transformasi Indonesia

Study Site

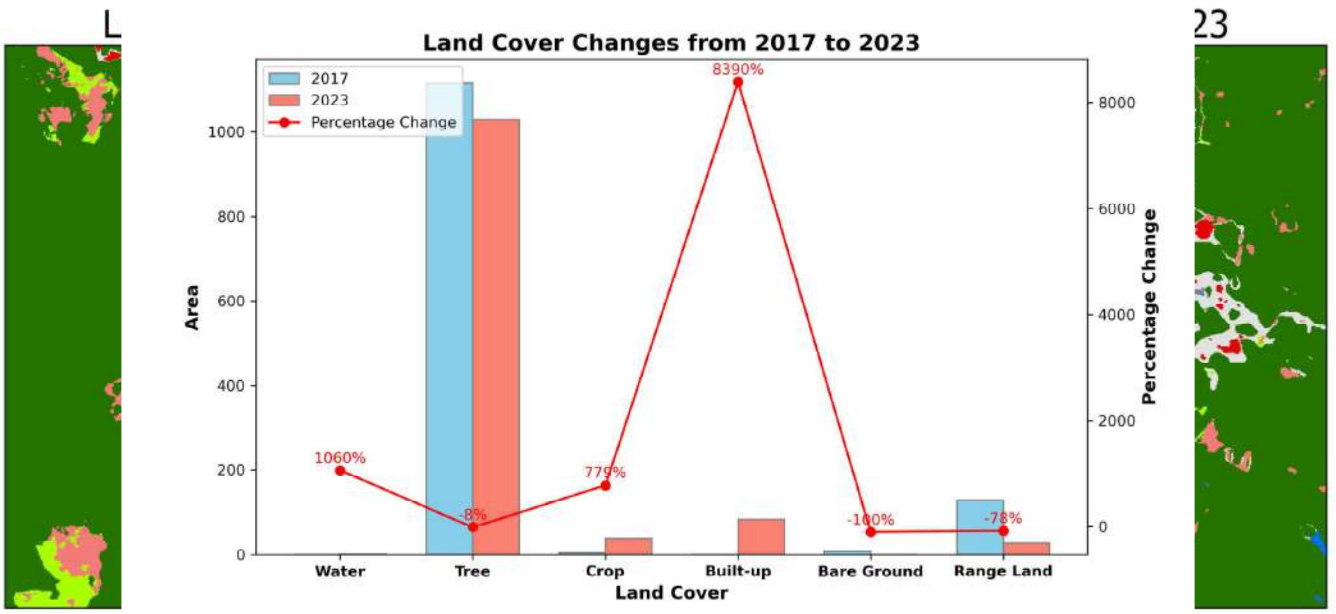
Study Site



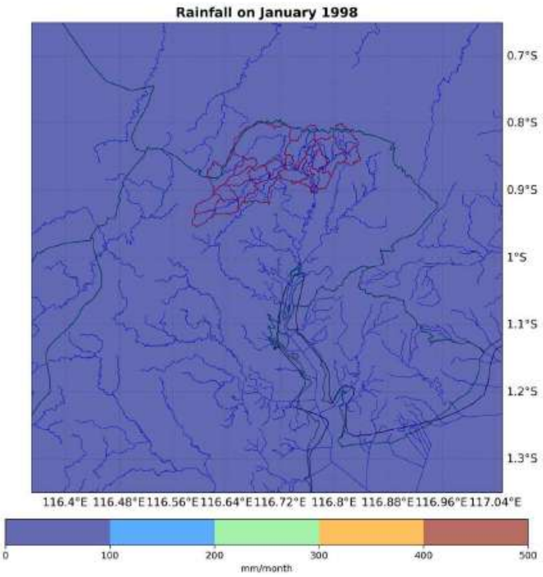
Land Cover

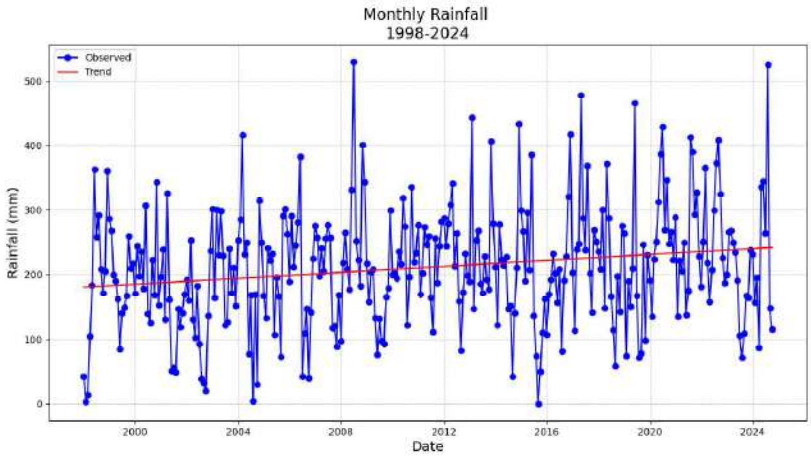


Land Cover



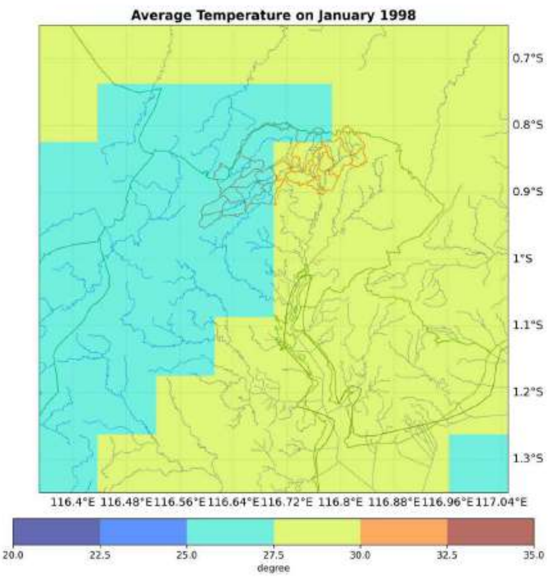
Characteristic of Rainfall

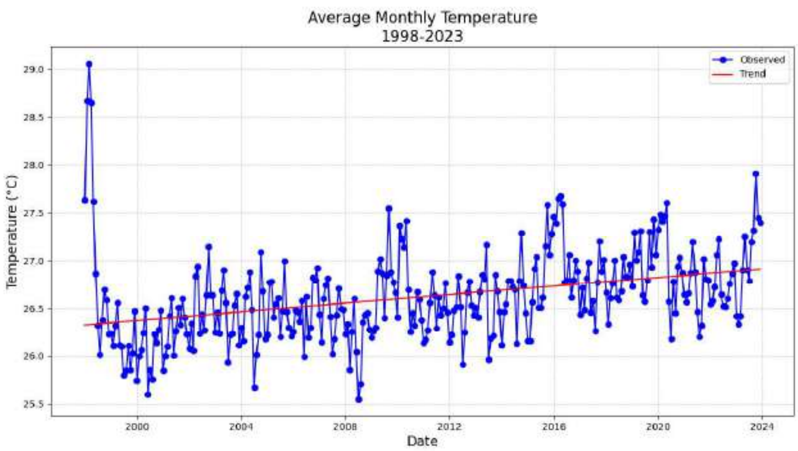




Source: JAXA-GSMaP

Characteristic of Temperature

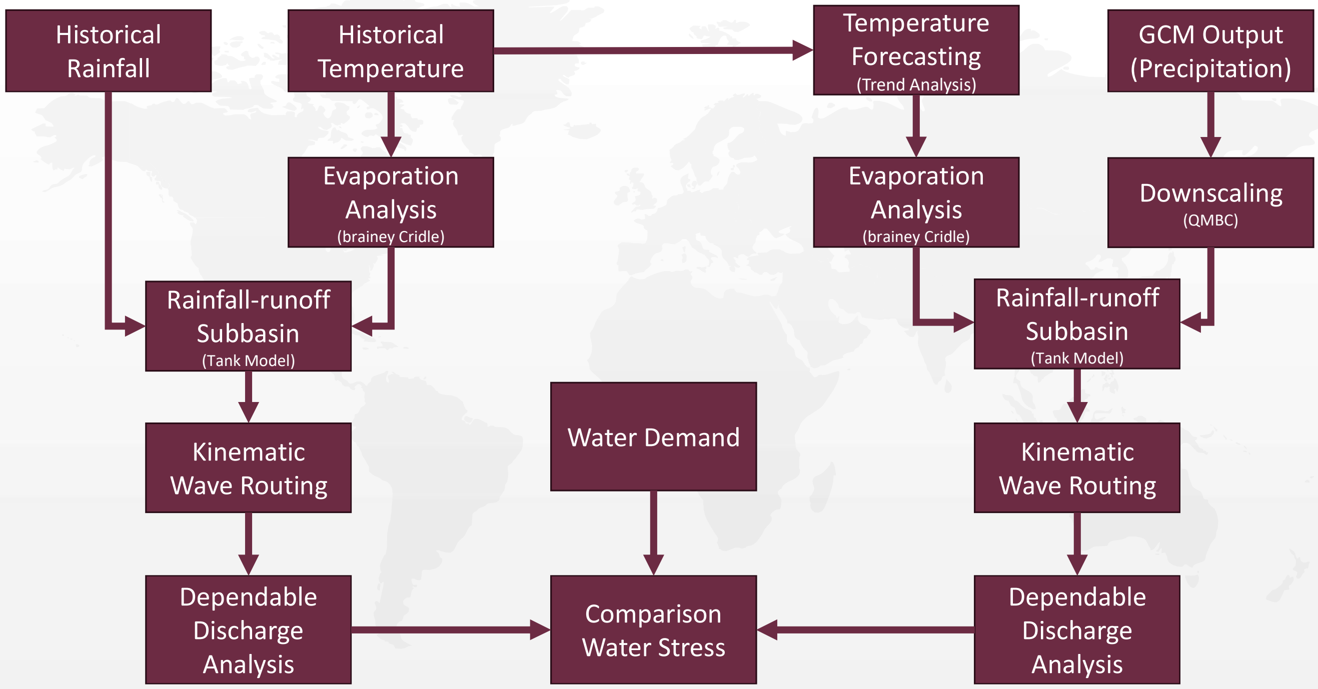




Source: ERA5 Reanalysis

Methodology

Methodology

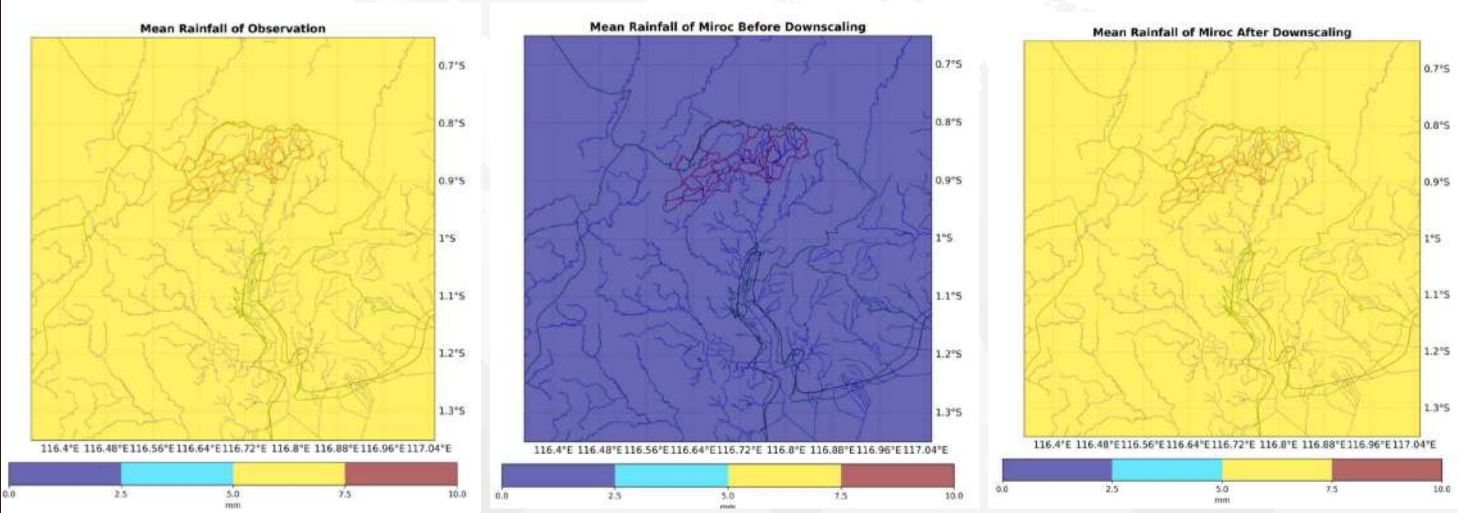


Dataset

- DEMNAS
- Sentinel Land-Cover 2023
- GSMaP Ver 8 Historical rainfall 1998 – 2023
- ERA5 Reanalysis temperature 1998 – 2023
- GCM CMIP6: 4 Models (ACCESS-CM2, BCC-CSM2-MR, MIROC6, and MPI-ESM1-2-HR) and 3 SSP Scenarios (SSP126, SSP245, and SSP 585)

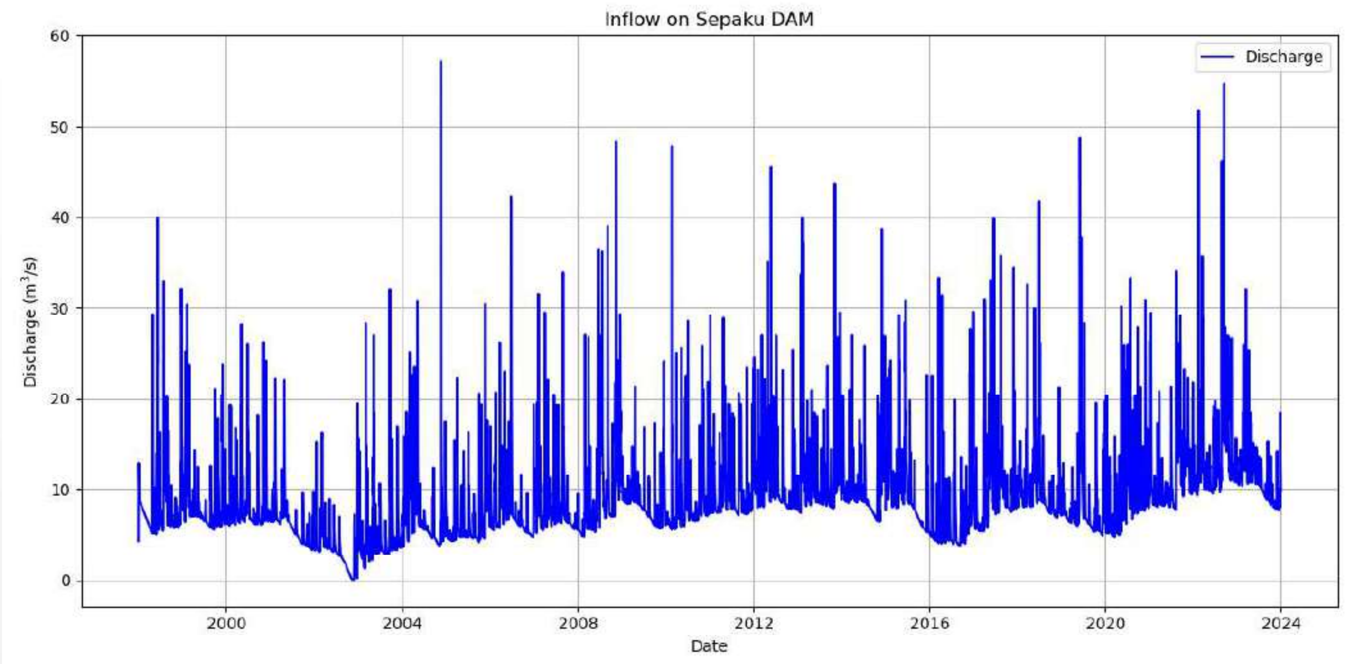
Results and Discussion

Downscaling

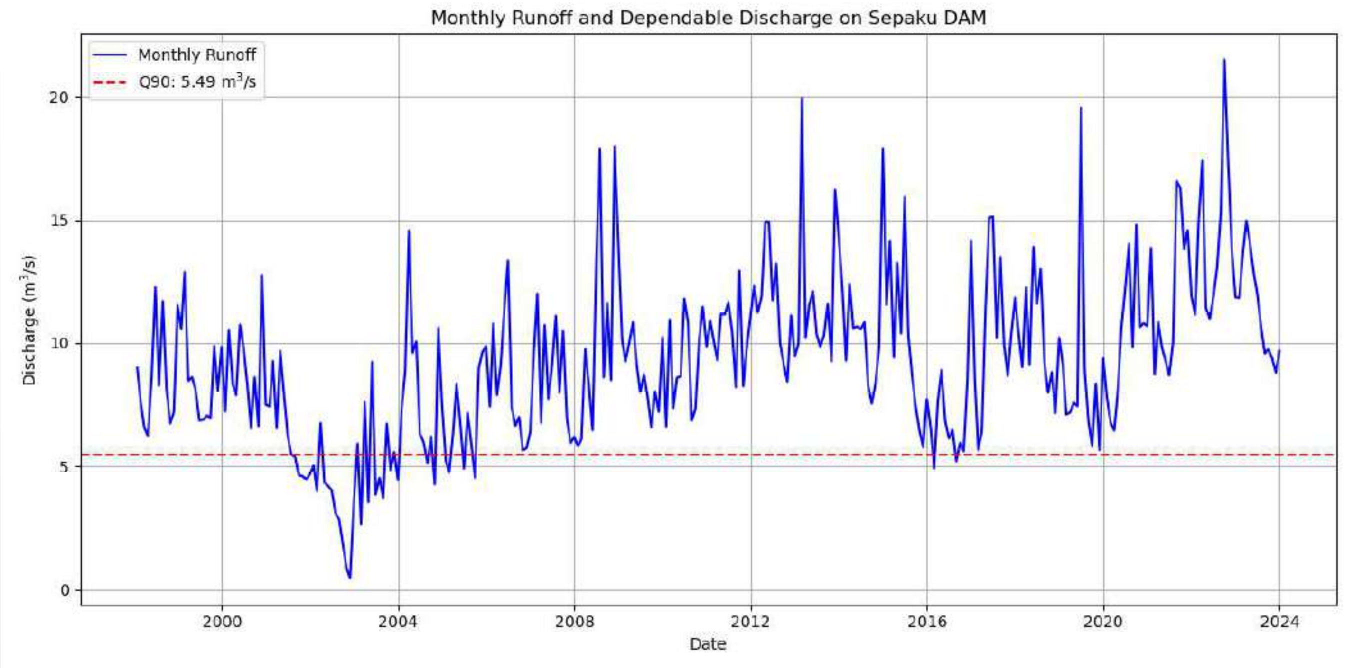


Average rainfall from 1998 to 2014 was observed at **6.644 mm**. After bias correction, the MIROC 6 model closely matched this observation at **6.643 mm**, a significant improvement from the pre-correction value of **0.224 mm**.

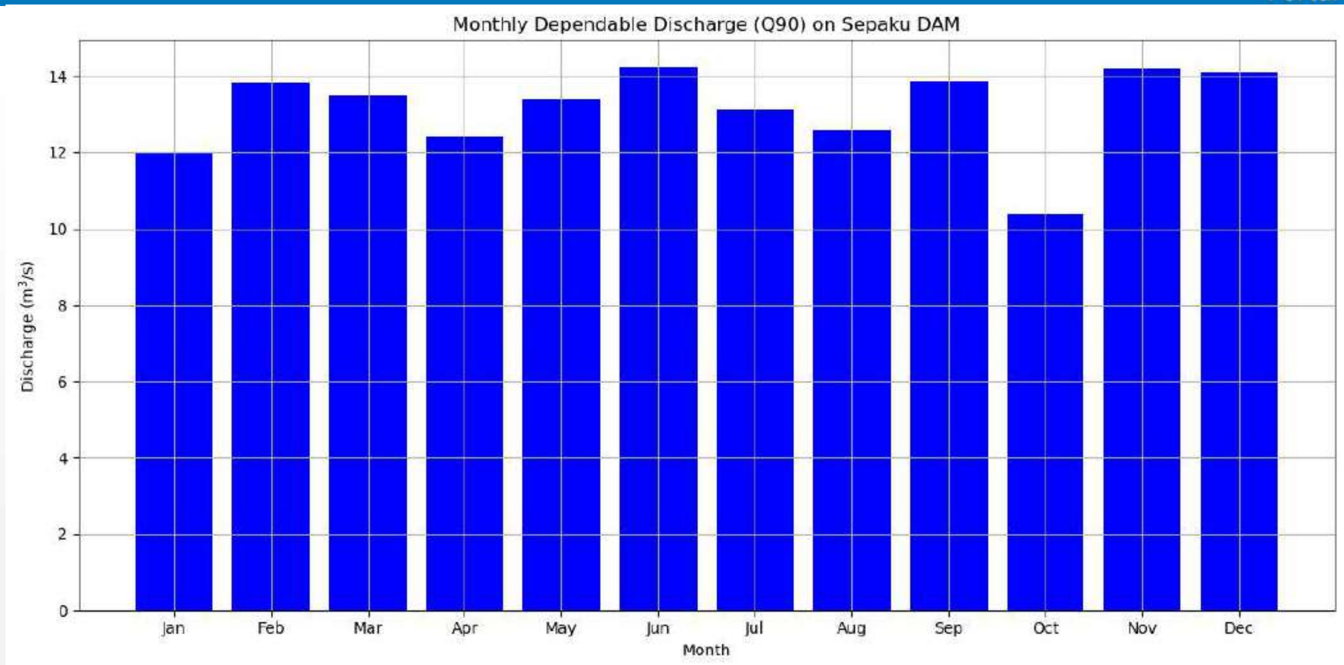
Historical Discharge Simulation



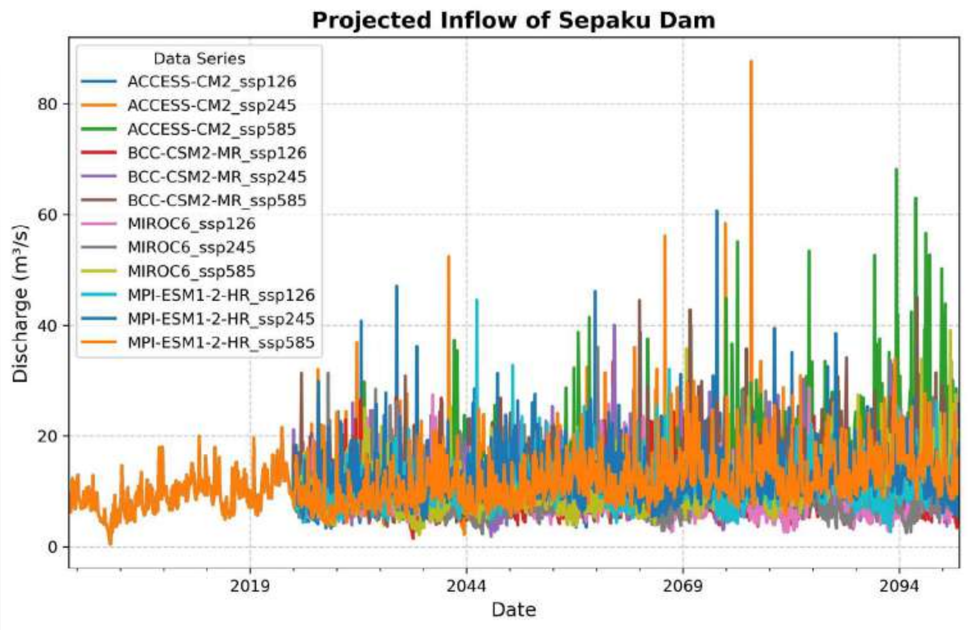
Historical Discharge Simulation



Historical Discharge Simulation

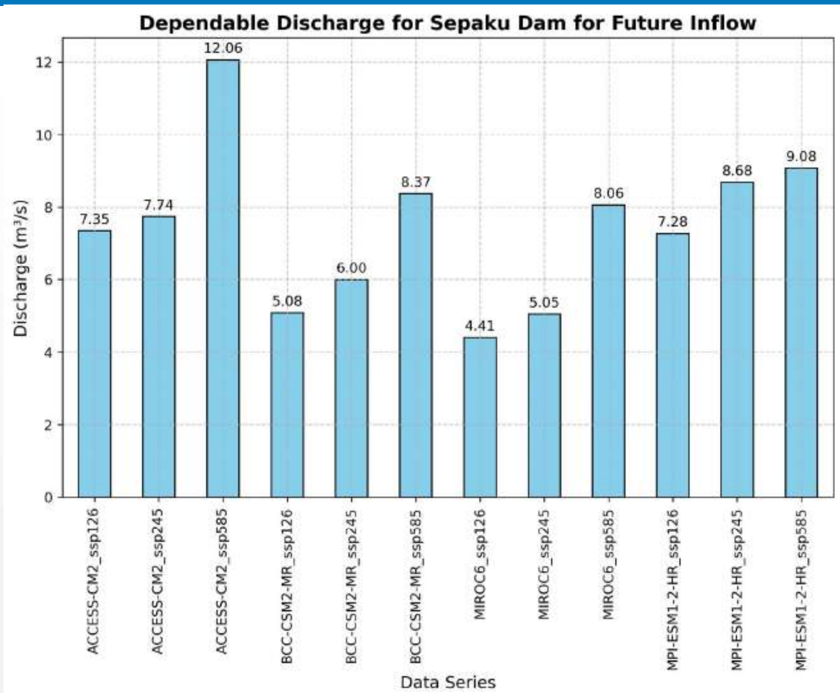


Future Monthly Inflow



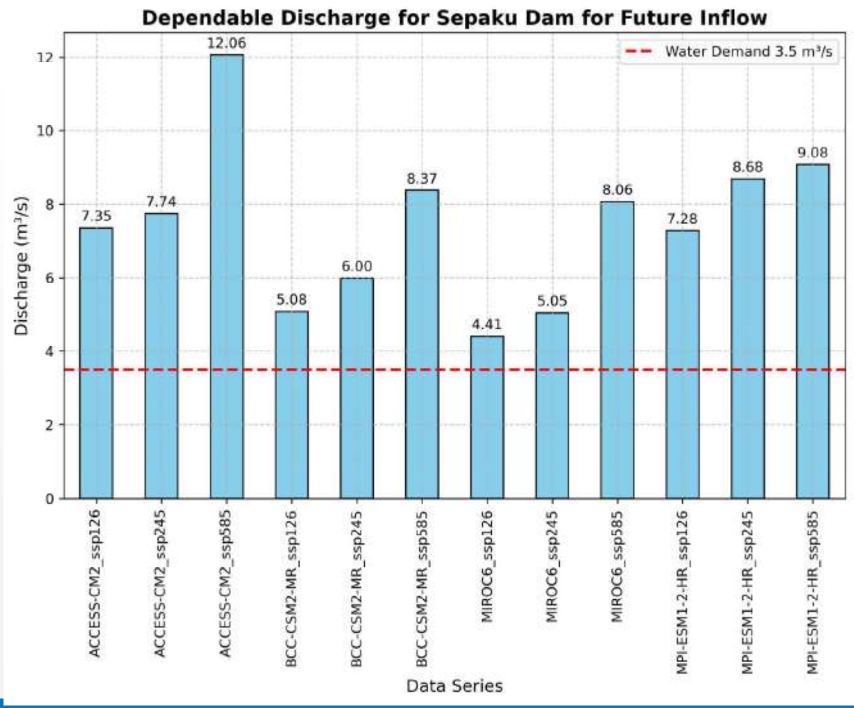
Based on inflow simulations, the projected discharge tends to **significantly increase for maximum inflow**, while it shows a **slight decrease** or remains almost similar for **minimum inflow** when compared to historical simulation.

Future Dependable Discharge



Most GCM models predict an increase in dependable discharge over the next 25 years in the new capital. However, some models (BCC-CSM2-MR SSP585, MIROC6 SSP126, SSP245) show a slight decrease.

Water Stress Assessment



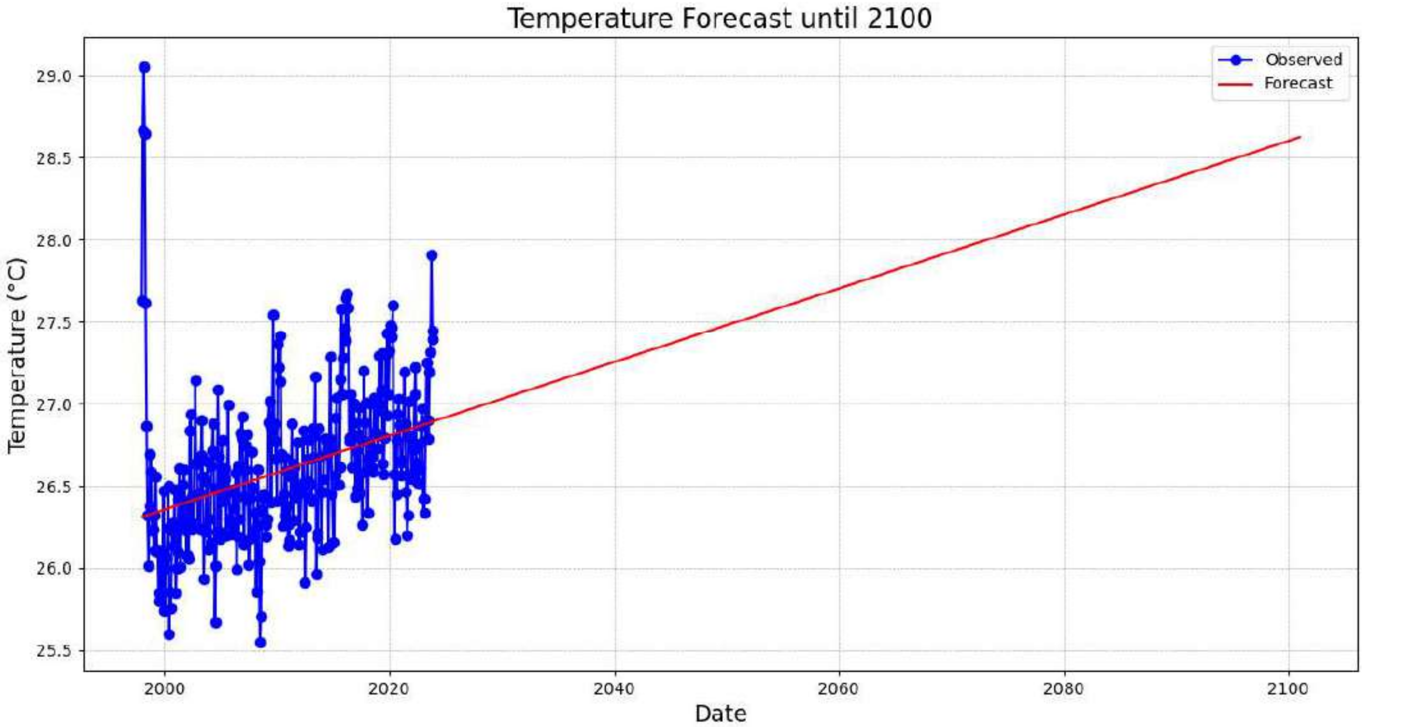
The new capital will have a population of 2 million people, with an average daily water demand of 150 liters per person. GCM Model indicate that there will be sufficient water supply until the end of the century

Conclusions

Conclusions

1. The Research utilized 12 combinations of GCM-SSP scenarios to project inflow discharge at Sepaku Dam.
2. The analysis results indicate that climate change does not affect water supply fulfillment in the new capital, as water demand remains lower than the reliable discharge for each scenario.
3. The findings of this study suggest that the new Indonesian capital is more prone to flooding rather than drought or water stress.

Terima kasih


Temperature Forecast until 2100
Observed
Forecast
Temperature (°C)
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
2000
2020
2040
2060
2080
2100
Date

Assessing Climate and Hydrological Conditions in Indonesia's New Capital City

Integrating Future Climate Projections, Land Use Change, and GIS-Based Analysis

By I Gede Putu Indra Aditya
1st Year Master's Course Student
Toyama Prefectural University

Discussion Contents

Discussion Contents

Why Indonesia Need a New Capital City

TRAFFIC CONGESTION

Image Source @CNN Indonesia

POPULATION DENSITY

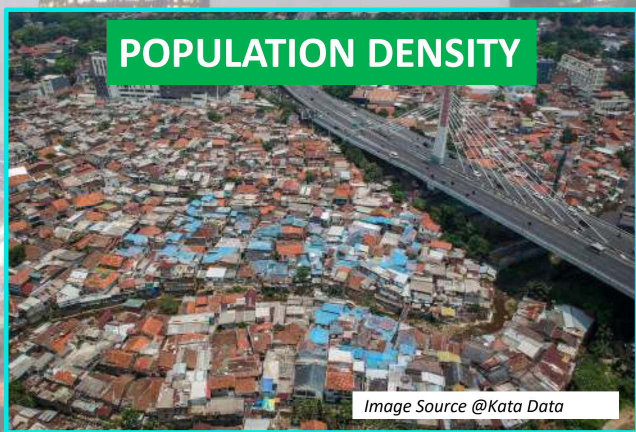


Image Source @Kata Data

30 **World Rank 2023**

For travel 10 km distance in 2023

23 min **20** s

40 s more than in 2022

Source TomTom.com

Travel Time

(Yearly)

225 h for total

117 h due to congestion

Total Population by 2023

10,672,100 People

Population Density by 2023

16,146 people/km^2

Source BPS DKI Jakarta

Why Indonesia Need a New Capital City

ECONOMY CONCETRATION

Image Source @Marble Guide

Contribution Toward National GDP **17-18%**

FLOOD PRONE

Image Source @Bloomberg Technoz

Flood in 2024

February 2nd , 2024	April 5th , 2024
March 3rd , 2024	July 6th , 2024

Image Source @wikipedia

Why Indonesia Need a New Capital City

Why is it moved to East Kalimantan ???

High Accessibility
Close to two big cities (Balikpapan and Samarinda)

Strategic Defense Area

Available Necessary Infrastructures
Balikpapan-Samarinda Highway and Trans Kalimantan

Strategic for trade ship track
Makassar Strait

Wide area
Productive and Agriculture Forest Status

Abundant Water Resources

Airport and Harbour
At Balikpapan and Samarinda City

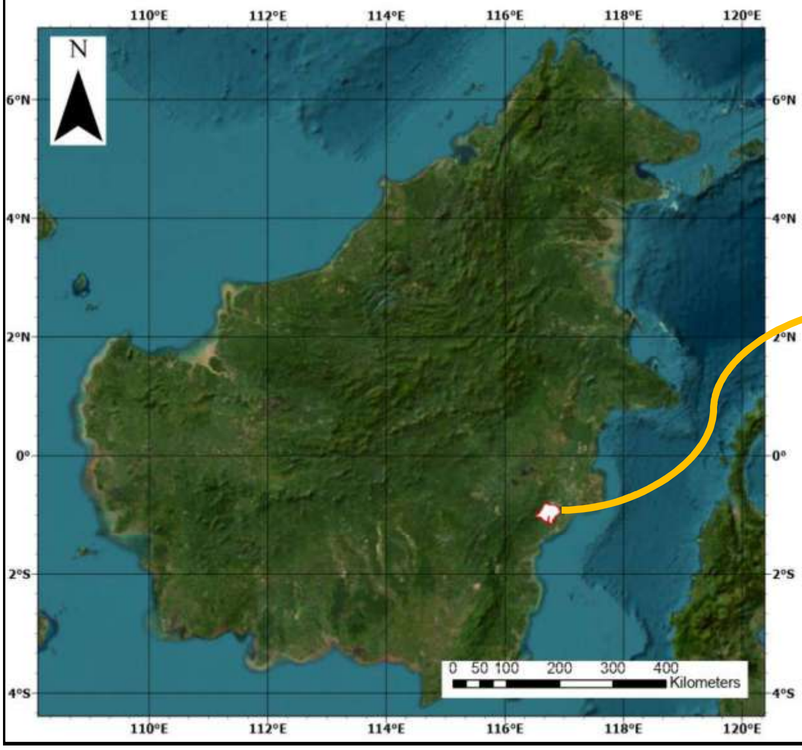
Nusantara Construction Phase

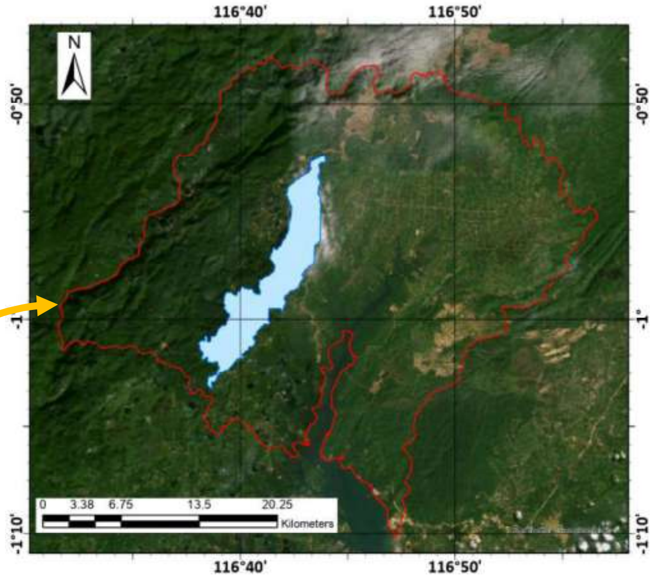
1. **Early Stage Transition** [2022 – 2024]
2. **Building New Capital City as Core Resilience City** [2025 – 2029]
3. **Progressively Continuing Construction of New Capital City** [2030 – 2034]
4. **Building All Infrastructure and Three Cities Ecosystem to Accelerate Kalimantan's Development** [2035 – 2039]
5. **Bolestring Reputation as "World City for All"** [2040 – 2045]

IKN National Strategic Area (KSN)	Indonesia's GDP Target by 2045	Estimated Workforce Number by 2045
252.660 ha	**USD 180 Billion**	**4.811.000**
IKN Development Zone	The IKN Area	Main Governmental Zone
196.501 ha	**56.159 ha**	**6.671 ha**

Image Source @wikipedia

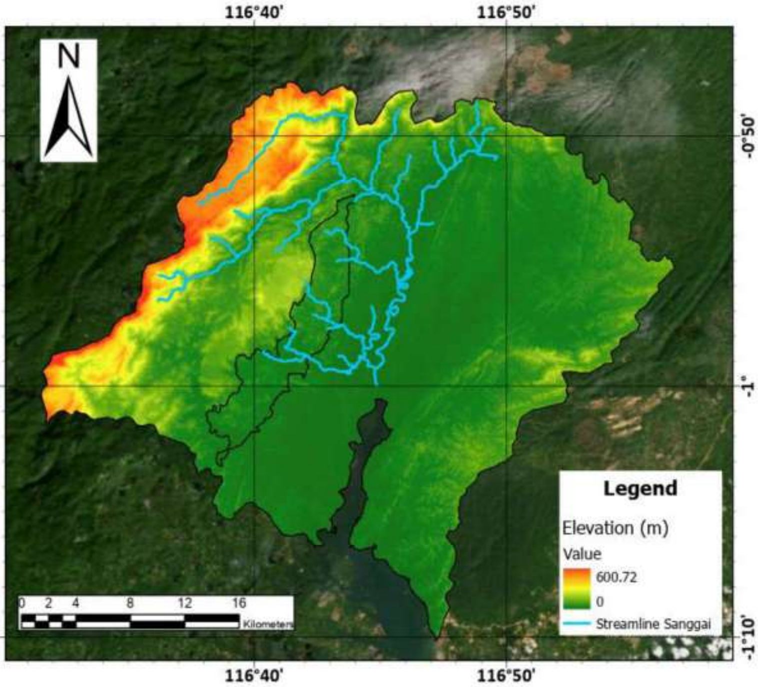
Topography of New Capital City Watershed

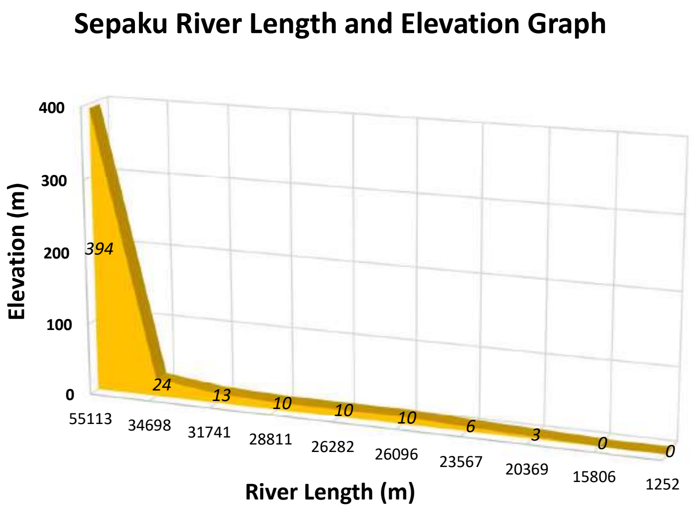




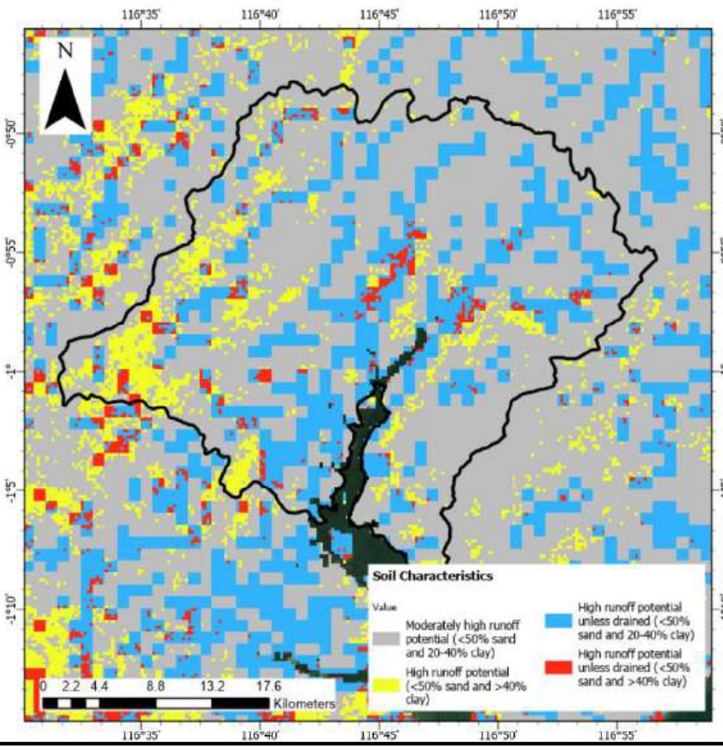
- Sanggai Watershed
- Central of New Capital City Area

Topography of New Capital City Watershed





Soil Characteristics



Global Hydrologic Soil Groups (HYSOGs250m)

Pixel values	Description
1	HSG-A: low runoff potential (>90% sand and <10% clay)
2	HSG-B: moderately low runoff potential (50-90% sand and 10-20% clay)
3	HSG-C: moderately high runoff potential (<50% sand and 20-40% clay)
4	HSG-D: high runoff potential (<50% sand and >40% clay)
11	HSG-A/D: high runoff potential unless drained (>90% sand and <10% clay)
12	HSG-B/D: high runoff potential unless drained (50-90% sand and 10-20% clay)
13	HSG-C/D: high runoff potential unless drained (<50% sand and 20-40% clay)
14	HSG-D/D: high runoff potential unless drained (<50% sand and >40% clay)

Recorded Flood Events

Monday 24th June, 2024

RT 01, RT 02, dan RT 03, Kelurahan Sepaku, Kecamatan Sepaku, Kabupaten Penajam Paser Utara (PPU), Kalimantan Timur
https://ikn.kompas.com/read/2024/06/24/124847287/banjir-di-sepaku-cepat-surut-pembangunan-ikn-tak-terganggu

Monday 30th September, 2024

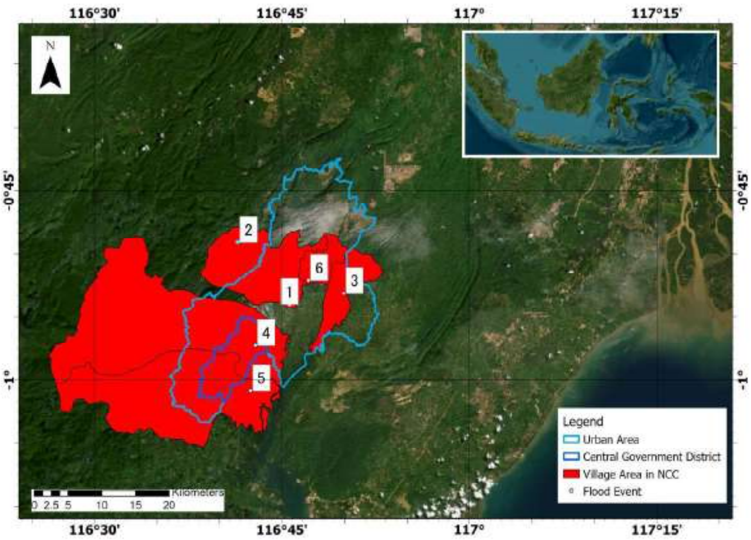
Desa Sukaraja, yakni RT 04 , RT 07, RT 24, dan RT 25. Selain itu, ada 2 RT di Kelurahan Sepaku, yaitu RT 01 dan RT 02., Kecamatan Sepaku, Kabupaten Penajam Paser Utara (PPU), Kalimantan Timur
https://kaltimpost.jawapos.com/penajam/2385146895/hujan-deras-bikin-sungai-sepaku-meluap-dua-desa-di-wilayah-ikn-tergenang-banjir

Recorded Flood Events

1) Kelurahan Sepaku, RT 04-07
Inundation duration: 6-24 hours
Flood intensity: 2 times per year
Causes: contraction due to crossing infrastructure

2) Karang Jinawi village
Inundation duration: 3-12 hours
Flood intensity: 2-3 times per year
Causes: river's meandering conditions

3) Tengin Baru village
Inundation duration: 3-12 hours
Flood intensity: 1-2 times per year
Causes: contraction due to crossing infrastructure and building nearby



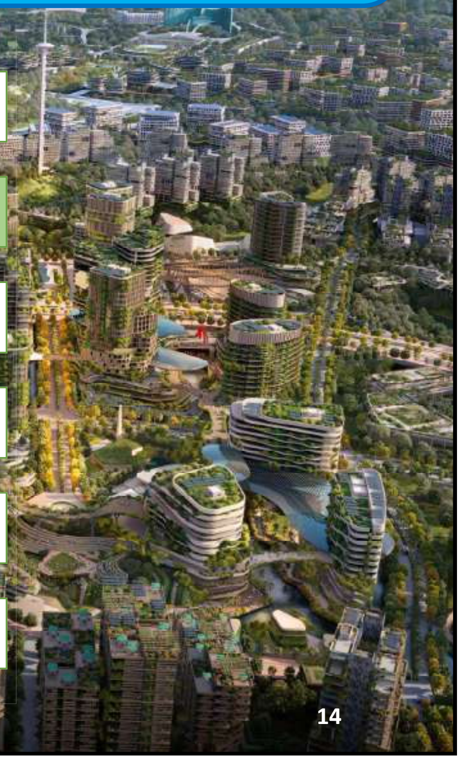
4) Bumi Harapan village
Inundation duration: 3-12 hours
Flood intensity: 1-2 times per year
Causes: rainfall intensity and tidal conditions

5) Kelurahan Pemaluan
Inundation duration: 2 hours – 2 days
Flood intensity: 2-3 times per year
Causes: high rainfall intensity and tidal conditions

6) Suka Raja village
Inundation duration: 6-24 hours
Flood intensity: 2 times per year
Causes: river's meandering conditions

New Capital City of Indonesia

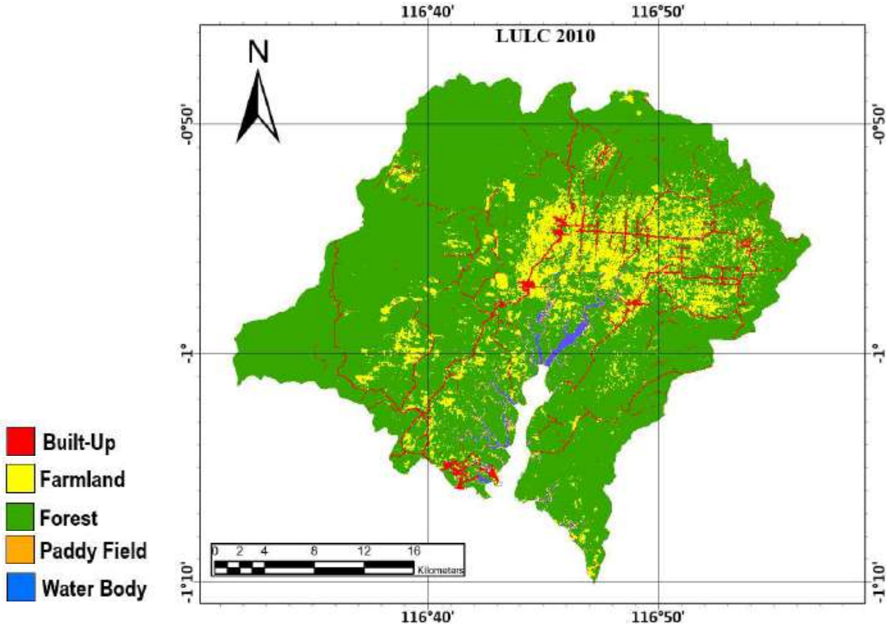
Discussion Contents



Land Use and Land Cover Distribution

Historical Land Use and Land Cover Changes 2010

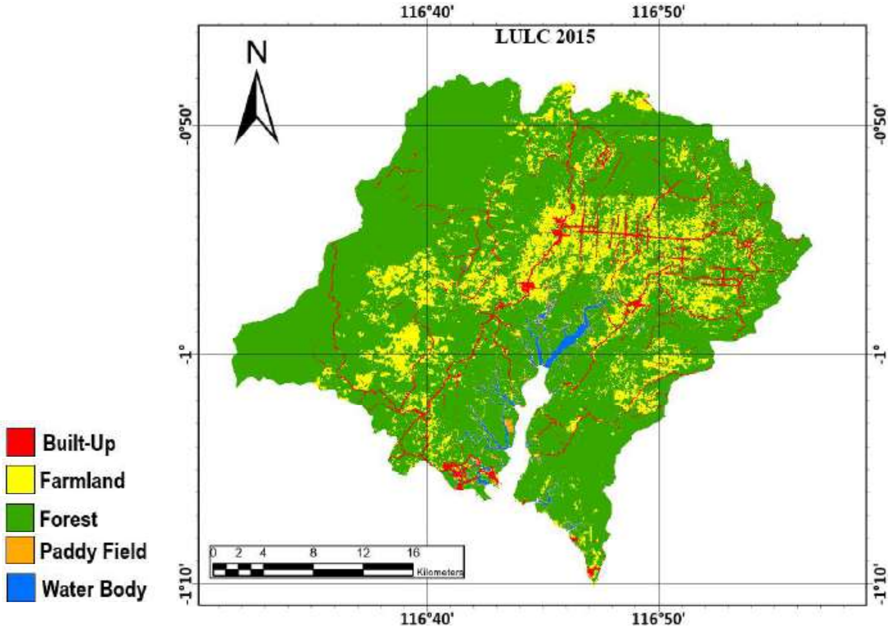
Global Land Analysis and Discovery



Land Use and Land Cover Distribution

Historical Land Use and Land Cover Changes 2015

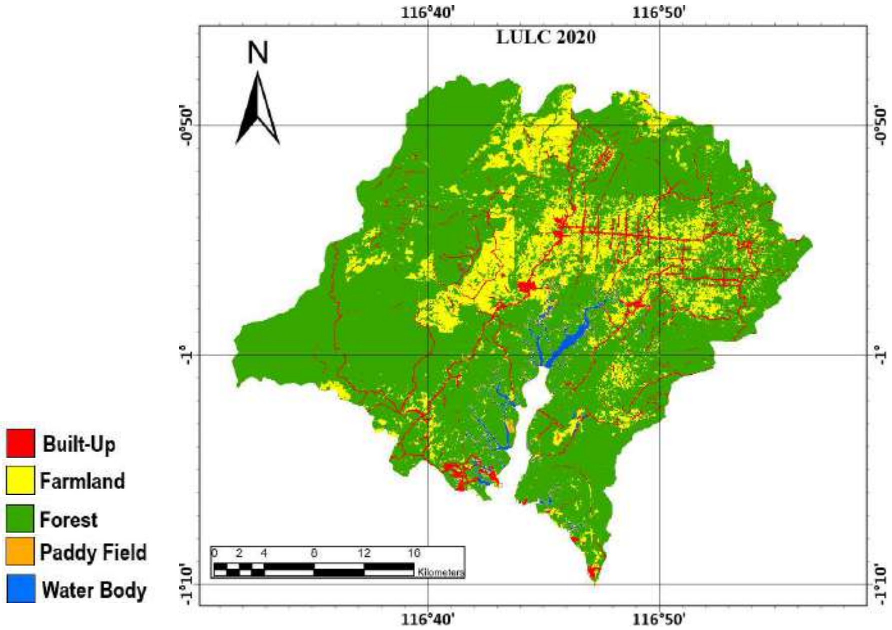
Global Land Analysis and Discovery



Land Use and Land Cover Distribution

Historical Land Use and Land Cover Changes 2020

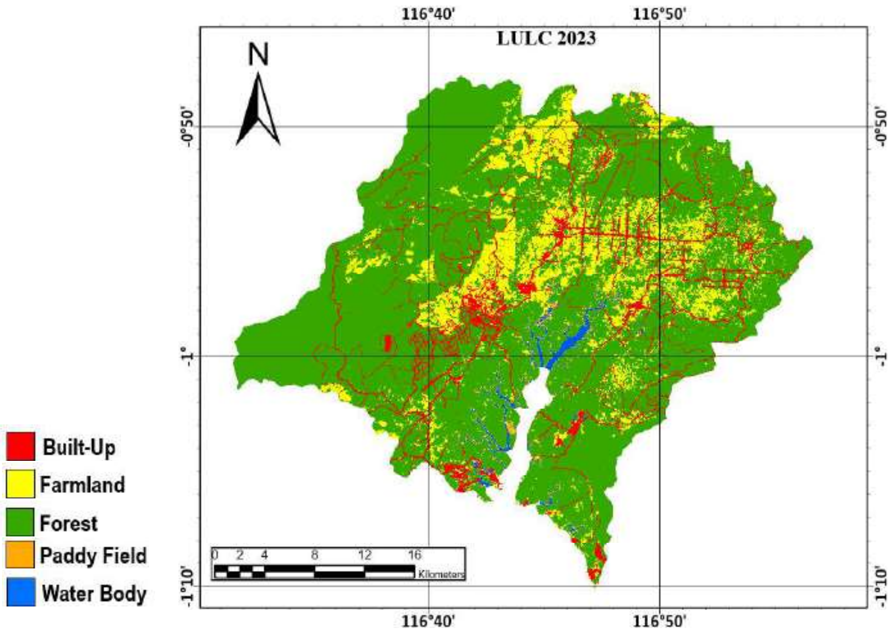
Global Land Analysis and Discovery



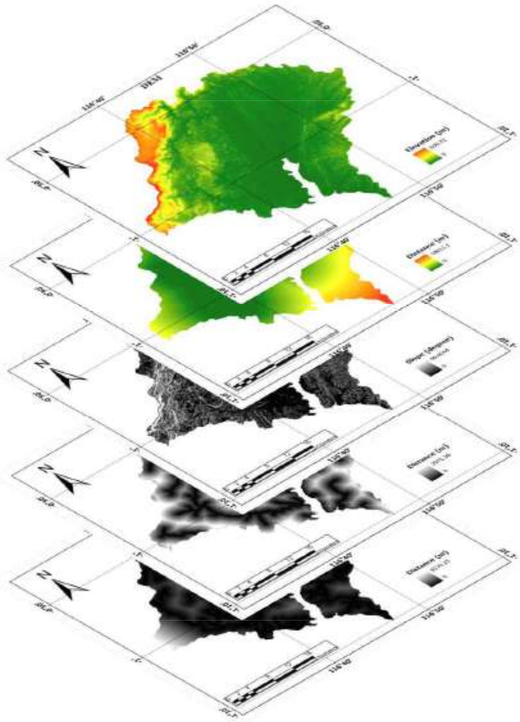
Land Use and Land Cover Distribution

Historical Land Use and Land Cover Changes 2023

Global Land Analysis and Discovery



Future Land Use and Land Cover Projection

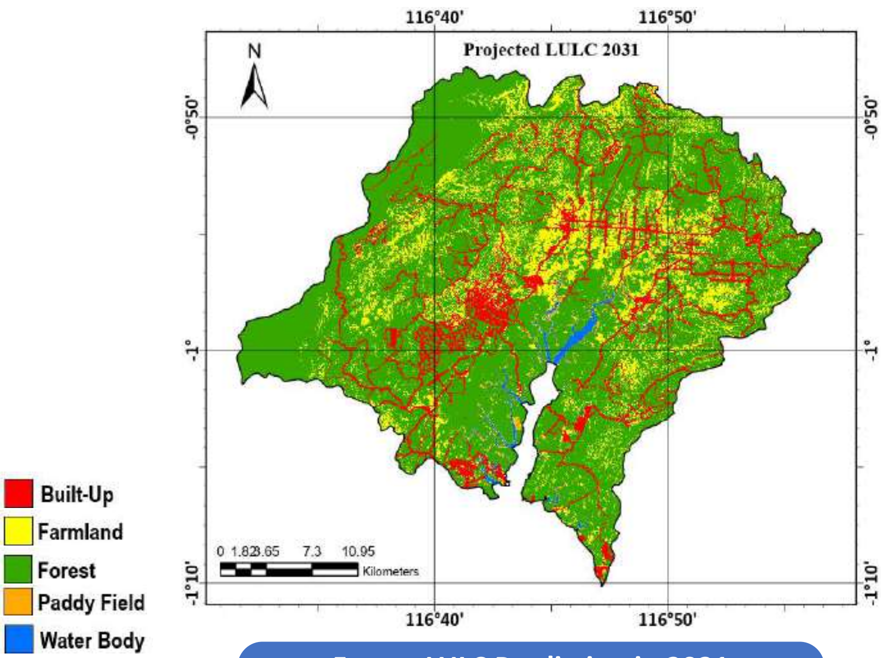


- DEM
- Distance From NCC
- Slope
- Distance From River
- Distance From Road

→ **ANN** (Artificial Neural Network) →

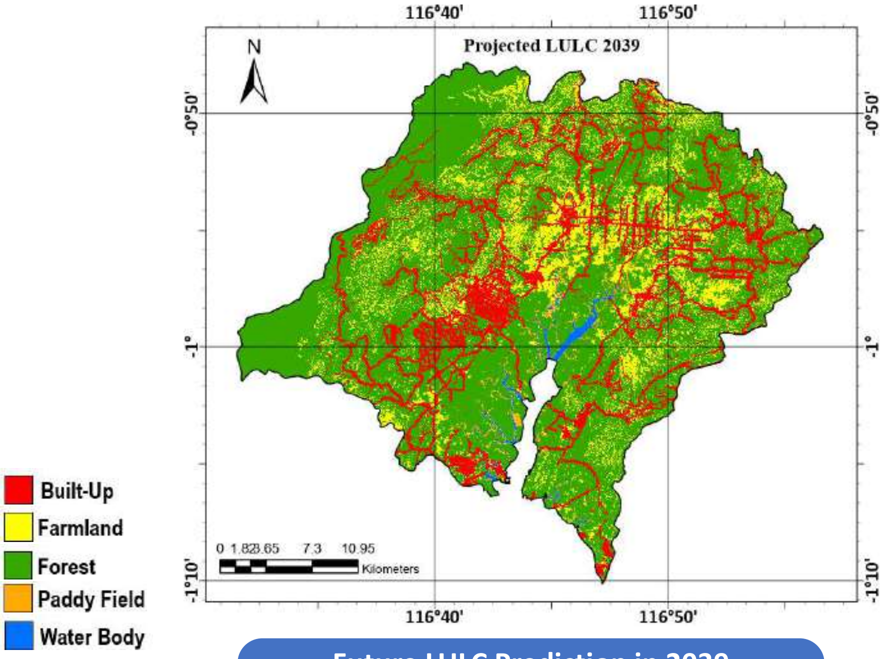
- 2031
- 2039
- 2047
- 2055

Future Land Use and Land Cover Projection



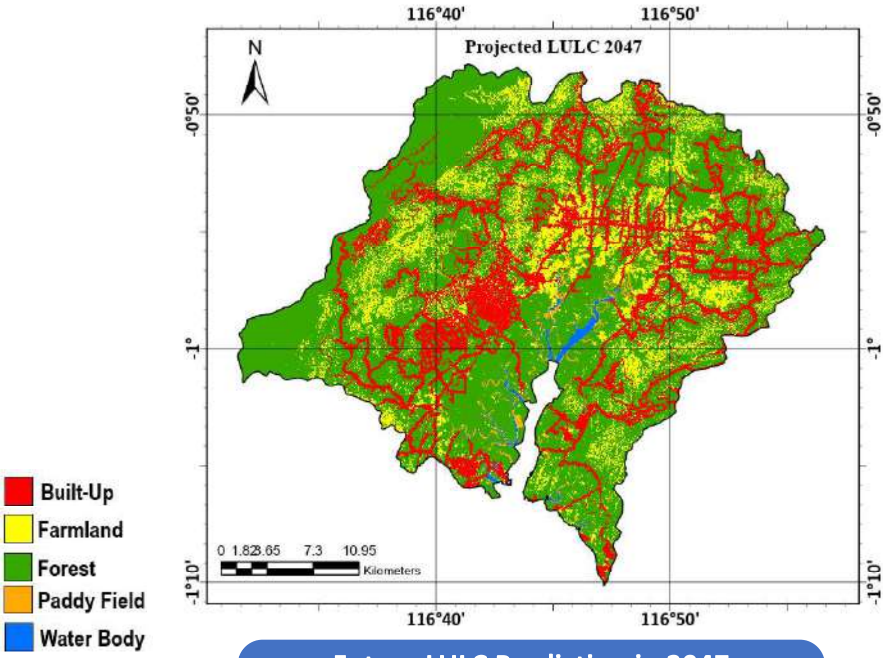
Future LULC Prediction in 2031

Future Land Use and Land Cover Projection



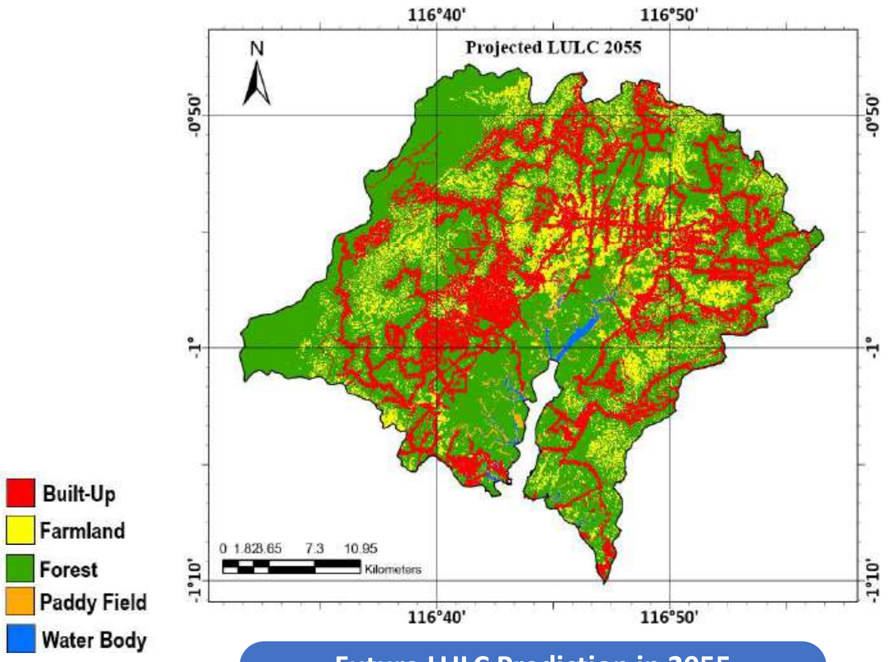
Future LULC Prediction in 2039

Future Land Use and Land Cover Projection



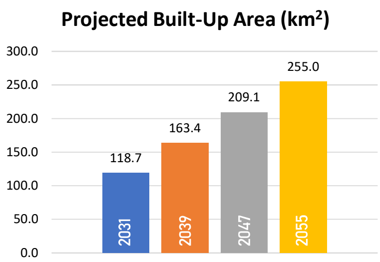
Future LULC Prediction in 2047

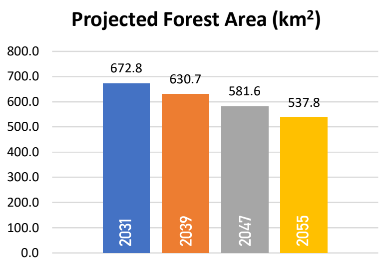
Future Land Use and Land Cover Projection

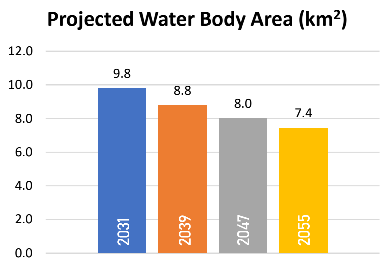


Future LULC Prediction in 2055

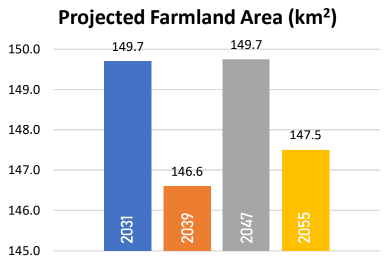
Future Land Use and Land Cover Projection

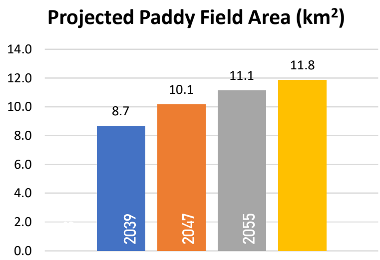






2031 2039 2047 2055

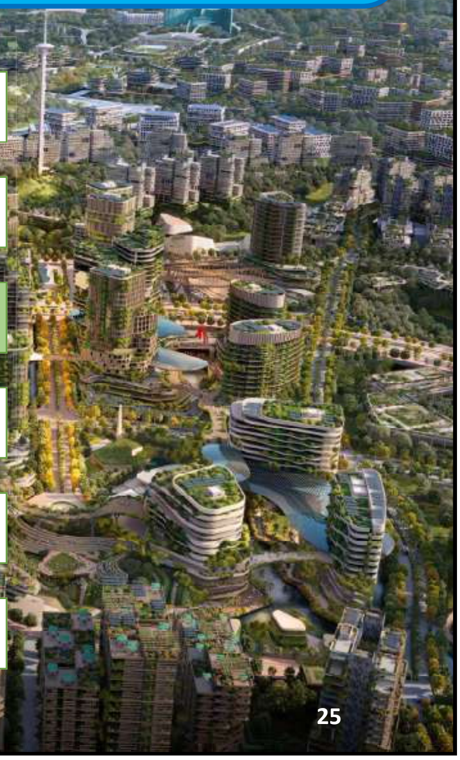




Validation Results

- % of Correctness → 79.46%
- Kappa (Overall) → 0.68
- Kappa (Histo) → 0.86
- Kappa (Loc) → 0.80

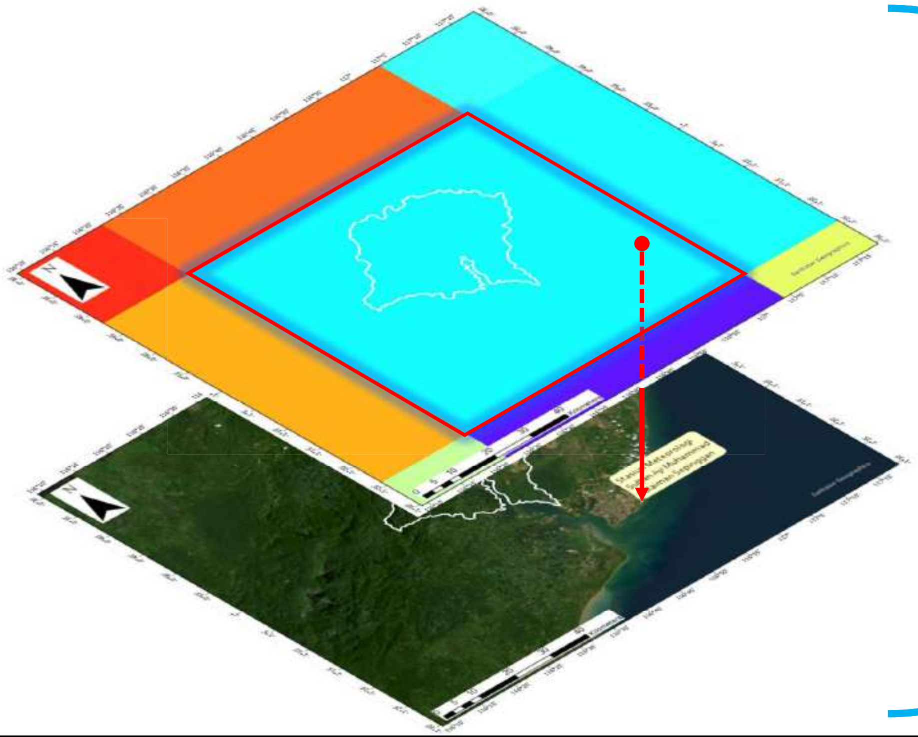
Discussion Contents



Statistical Downscaling of Global Climate Data

EC-Earth3	EC-Earth3-Veg	EC-Earth3-Veg-LR	INM-CM4-8	MPI-ESM1-2-HR	MRI-ESM2-0
SSP1-2.6	SSP1-2.6	SSP1-2.6	SSP1-2.6	SSP1-2.6	SSP1-2.6
SSP2-4.5	SSP2-4.5	SSP2-4.5	SSP2-4.5	SSP2-4.5	SSP2-4.5
SSP3-7.0	SSP3-7.0	SSP3-7.0	SSP3-7.0	SSP3-7.0	SSP3-7.0
SSP4-6.0	SSP4-6.0				SSP4-6.0
SSP5-8.5	SSP5-8.5	SSP5-8.5	SSP5-8.5	SSP5-8.5	SSP5-8.5

Statistical Downscaling of Global Climate Data



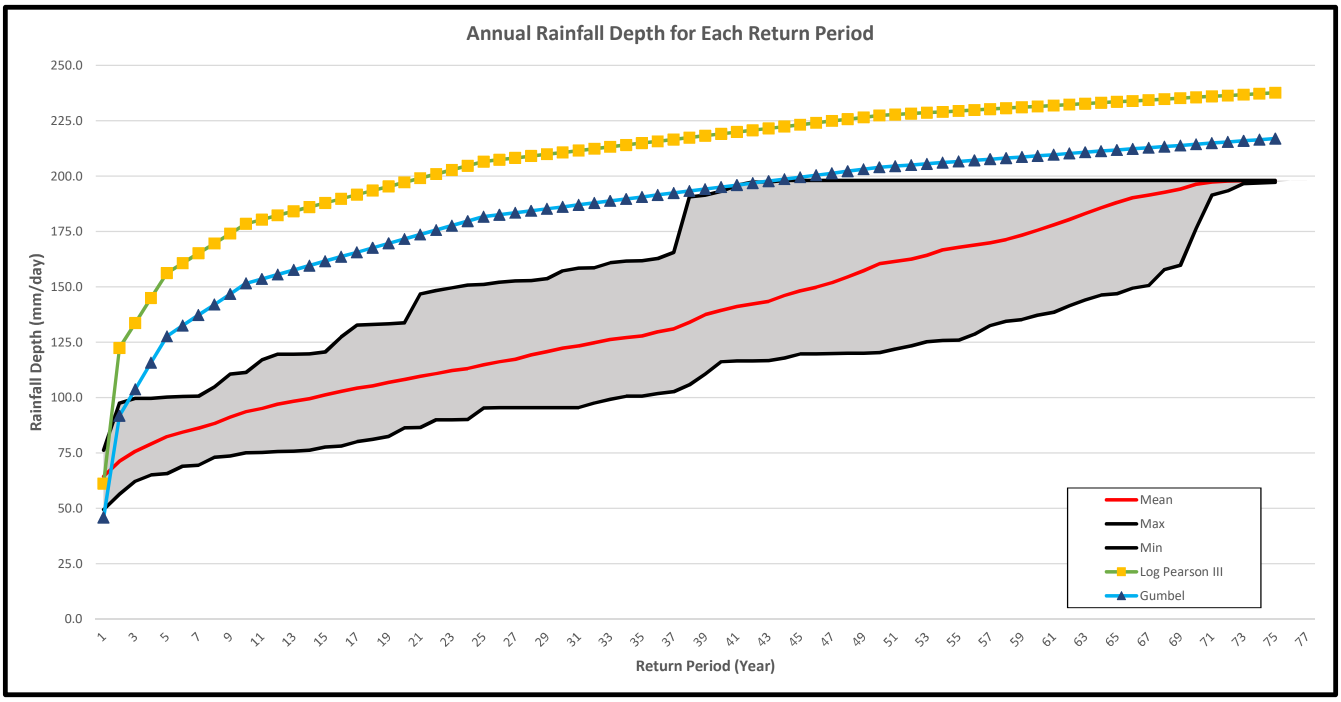
Quantile Mapping (QM)

$$\widetilde{x_m}(t) = F_{o.h}^{-1}\left(F_{m,h}[x_m\,(t)]\right)$$

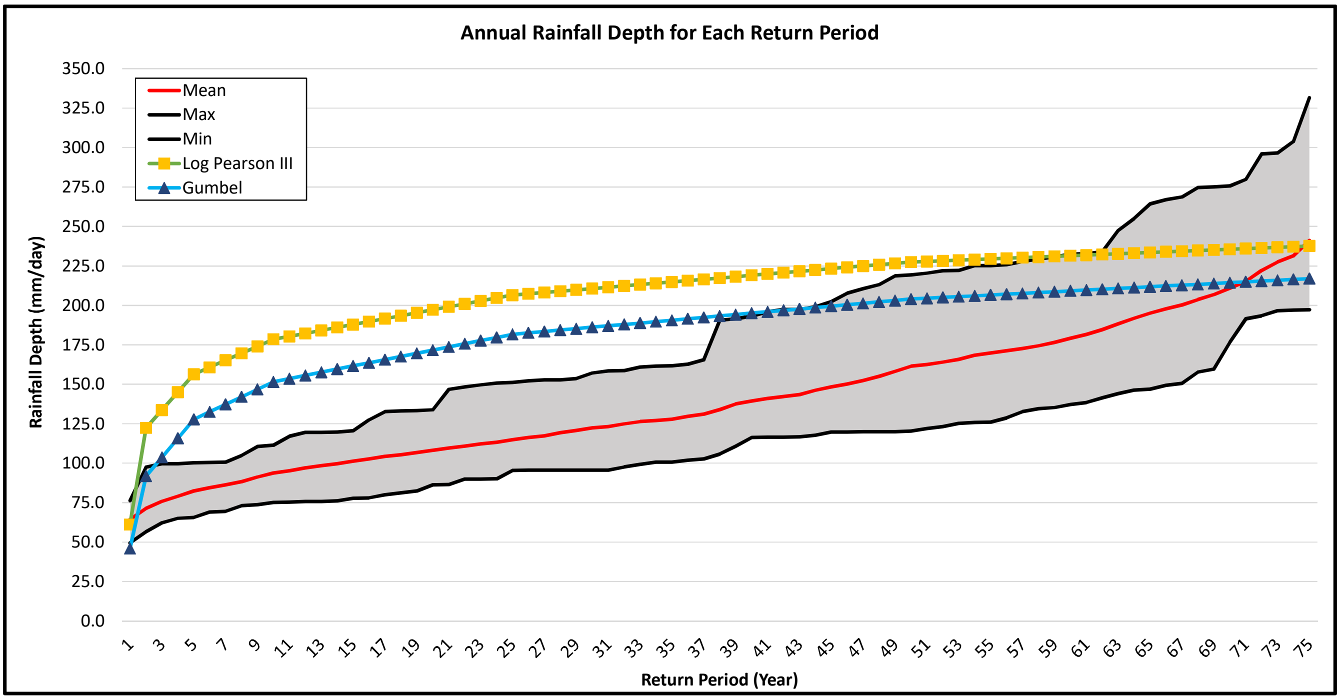
Quantile Delta Mapping (QDM)

$$\widetilde{x_m}(t) = F_{o.h}^{-1}[Prob_m(t)]\Delta_m(t)$$

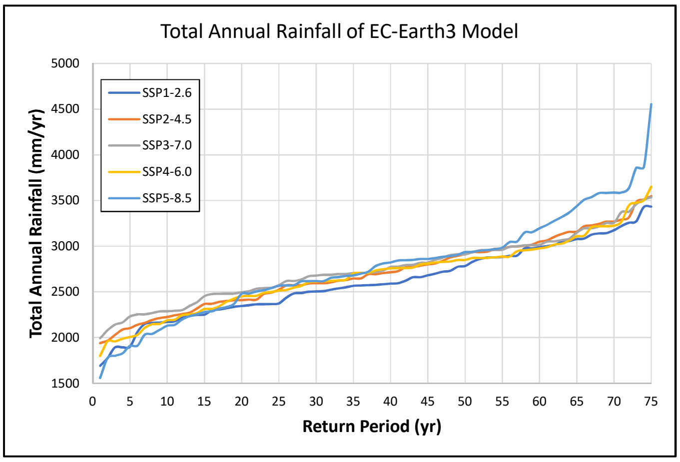
Statistical Downscaling of Global Climate Data – Quantile Mapping

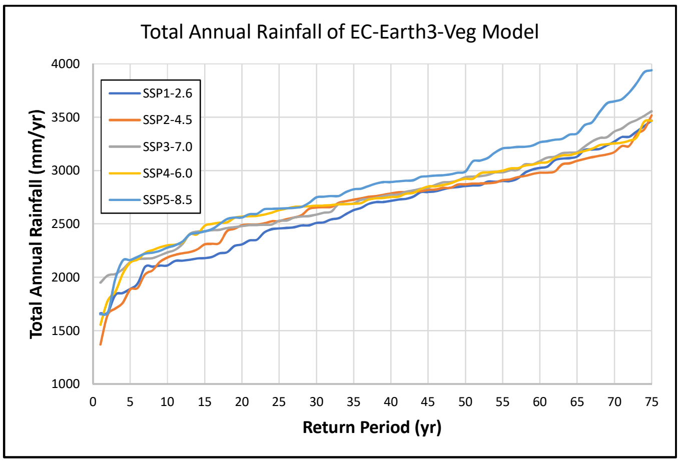


Statistical Downscaling of Global Climate Data – Quantile Delta Mapping

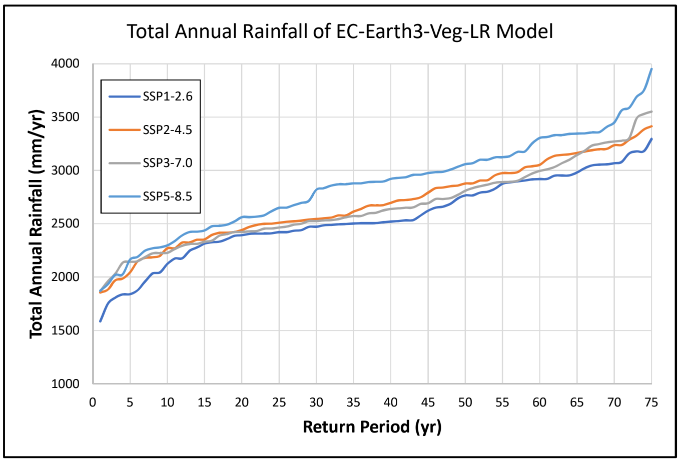


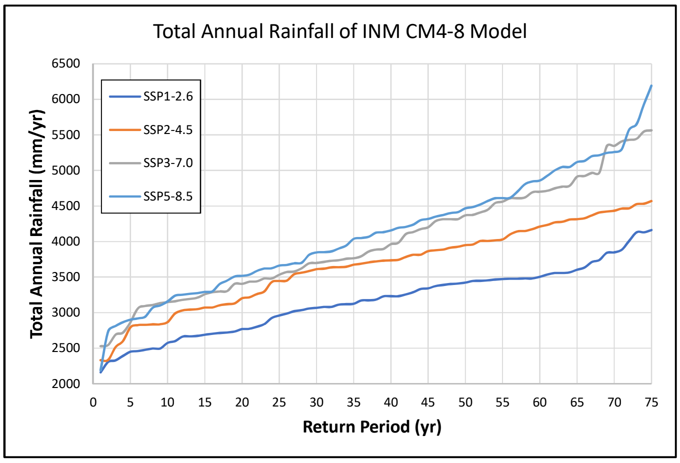
GIS-Based Water Availability Analysis



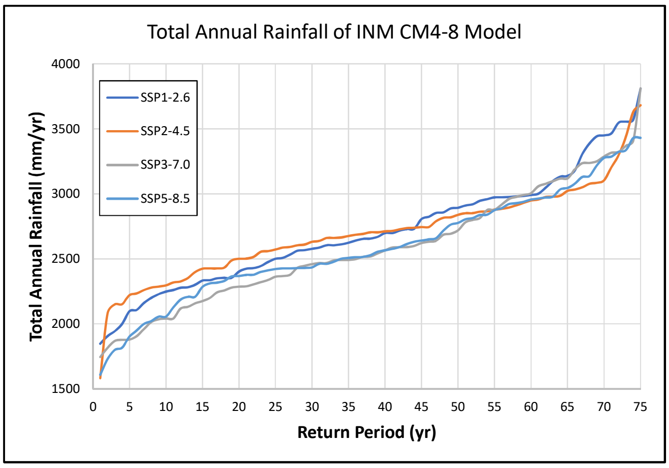


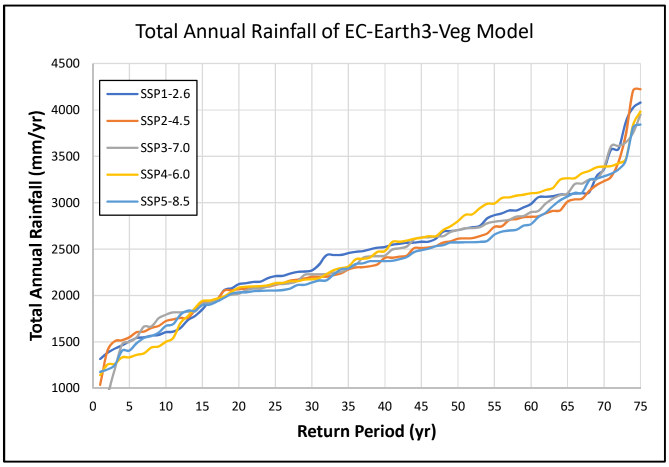
GIS-Based Water Availability Analysis





GIS-Based Water Availability Analysis

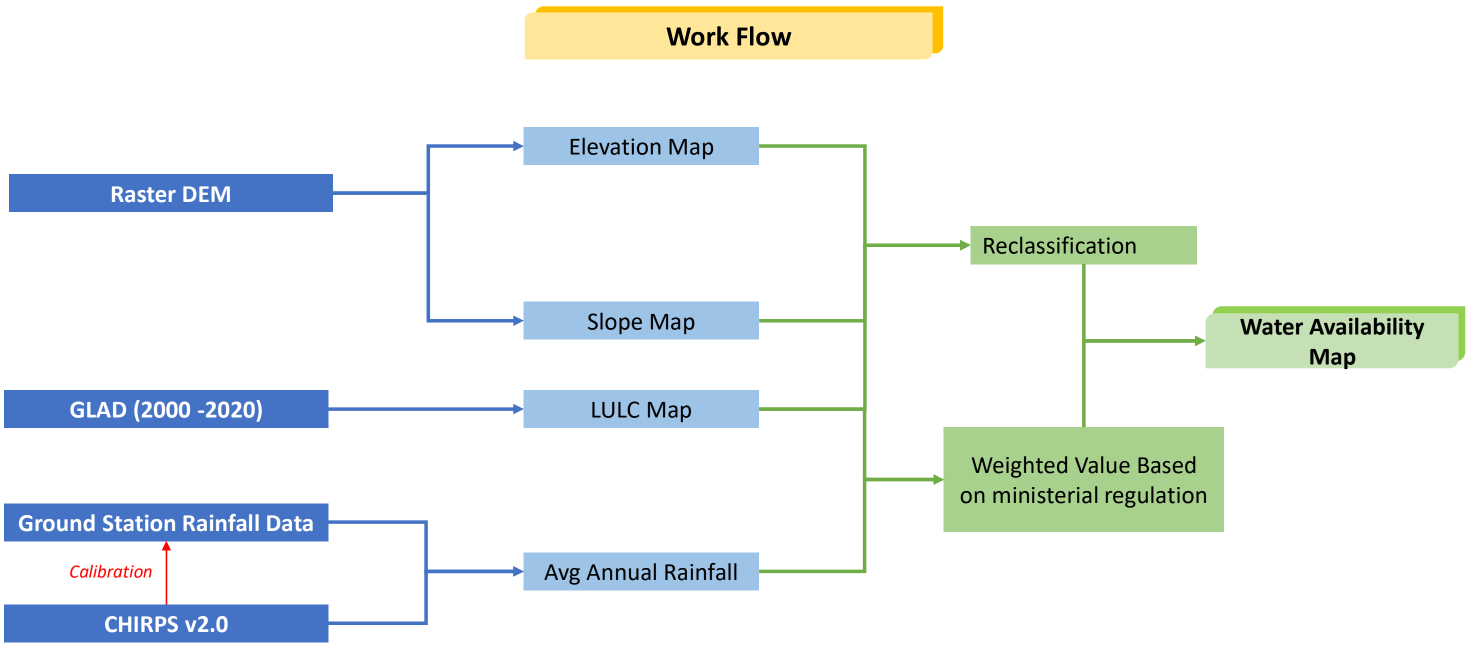




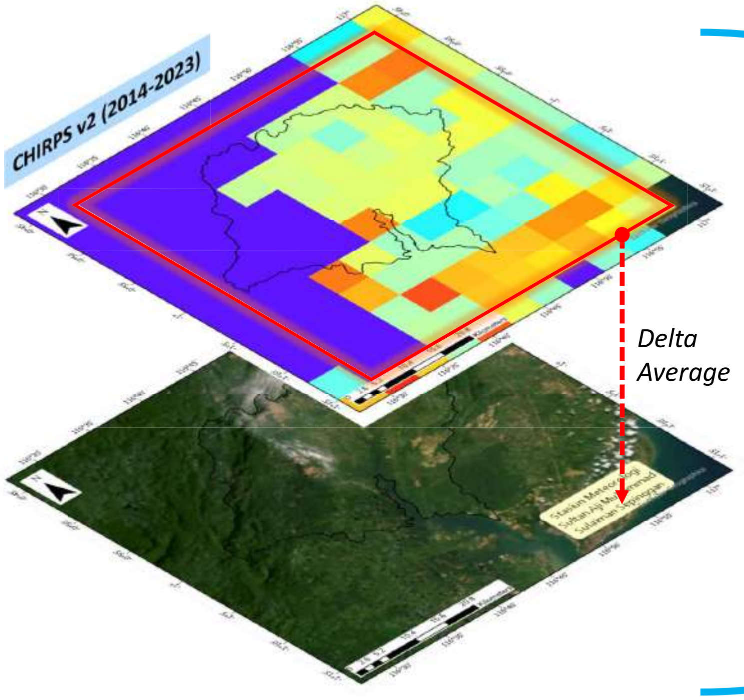
Discussion Contents

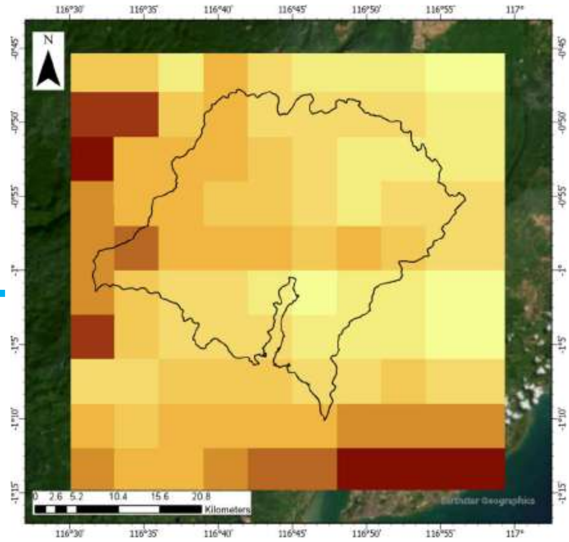
1. New Capital City Overview
2. Land Use and Land Cover Analysis
3. Spatial-Temporal Precipitation Analysis
4. **GIS-Based Water Availability Analysis**
5. GIS-Based Flood Hazard Analysis
6. Conclusion

GIS-Based Water Availability Analysis



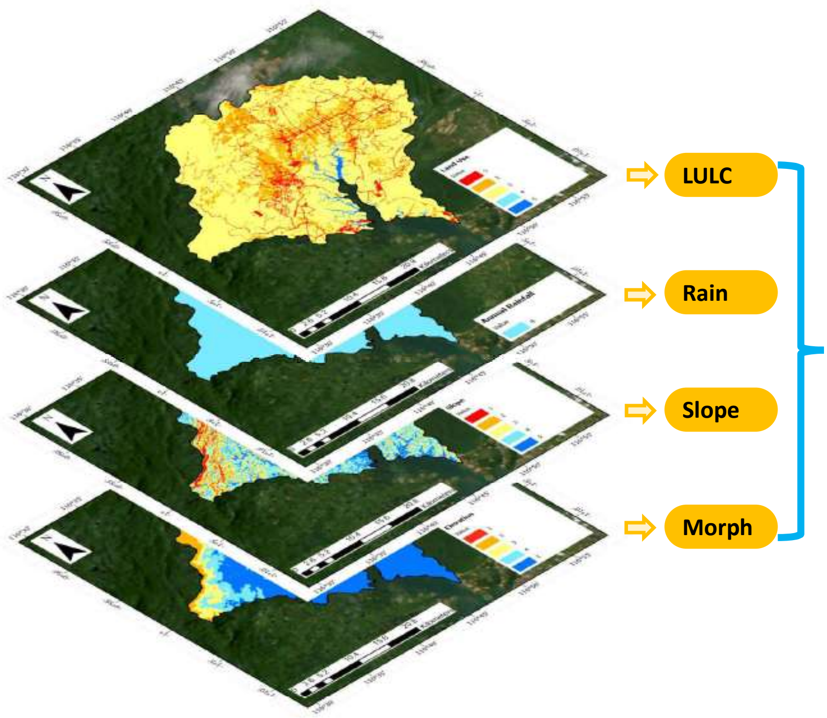
CHRIPS v.2 Rainfall Calibration





Calibrated Rainfall

GIS-Based Water Availability Analysis



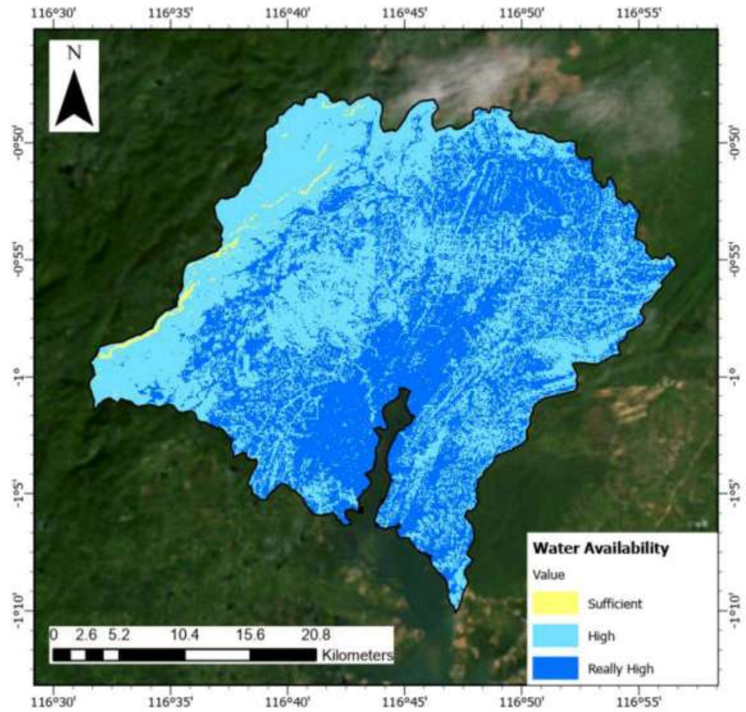
Raster Calculation

Morphology	Total Annual Rainfall	Slope	Land Use	Water Availability (SKL)	Value
Mountain	<1500 mm/yr	>40%	Urban	Very Low	1
Mountain-Hill	1500 – 2000 mm/yr	25 – 40%	Farmland	Low	2
Hill	2000 – 2500 mm/yr	15 – 25%	Forest	Sufficient	3
Low Land	2500 – 3000 mm/yr	2 – 15%	Wetland	High	4
Low Land	> 3000 mm/yr	0 – 2%	Water Body	Very High	5

Source: Peraturan Menteri PU No. 20/PRT/M/2007 (minstrial regulation)

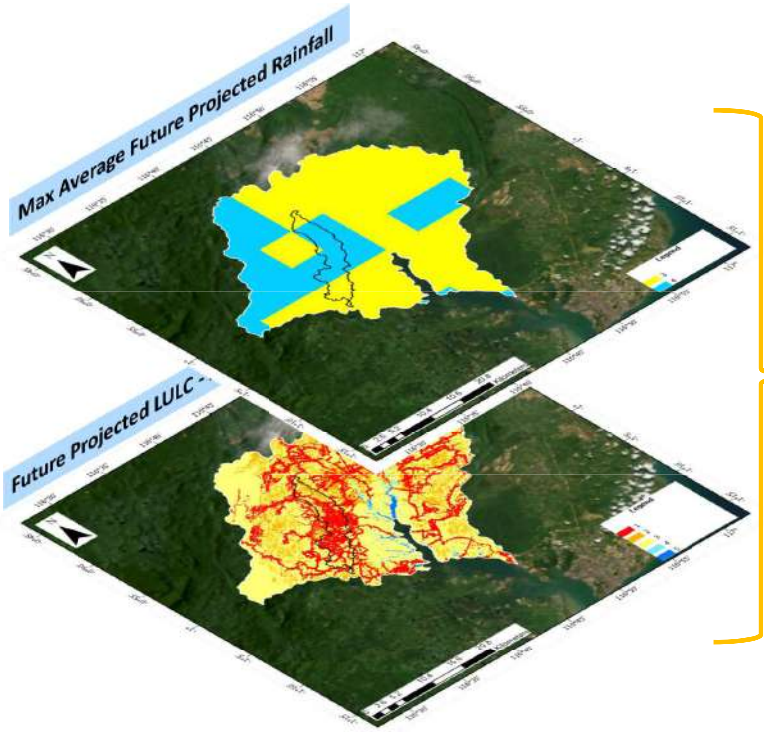
GIS-Based Water Availability Analysis

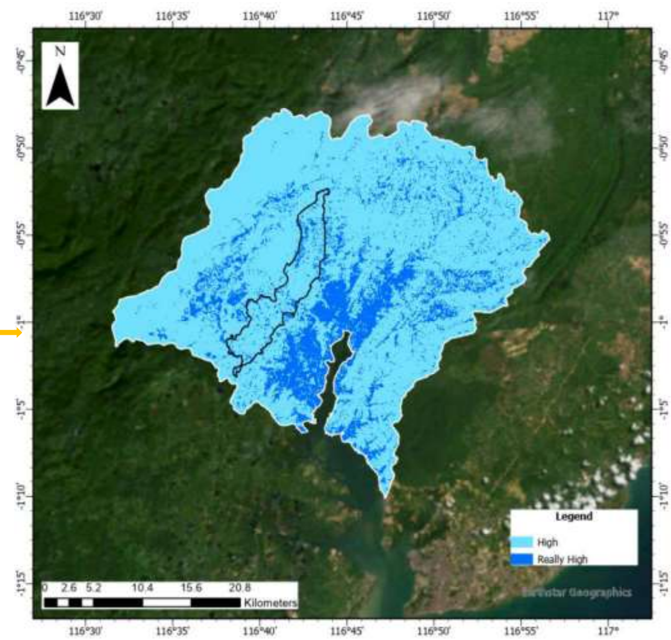
We Have A Resilience Water Availability Area



Too Much Water?

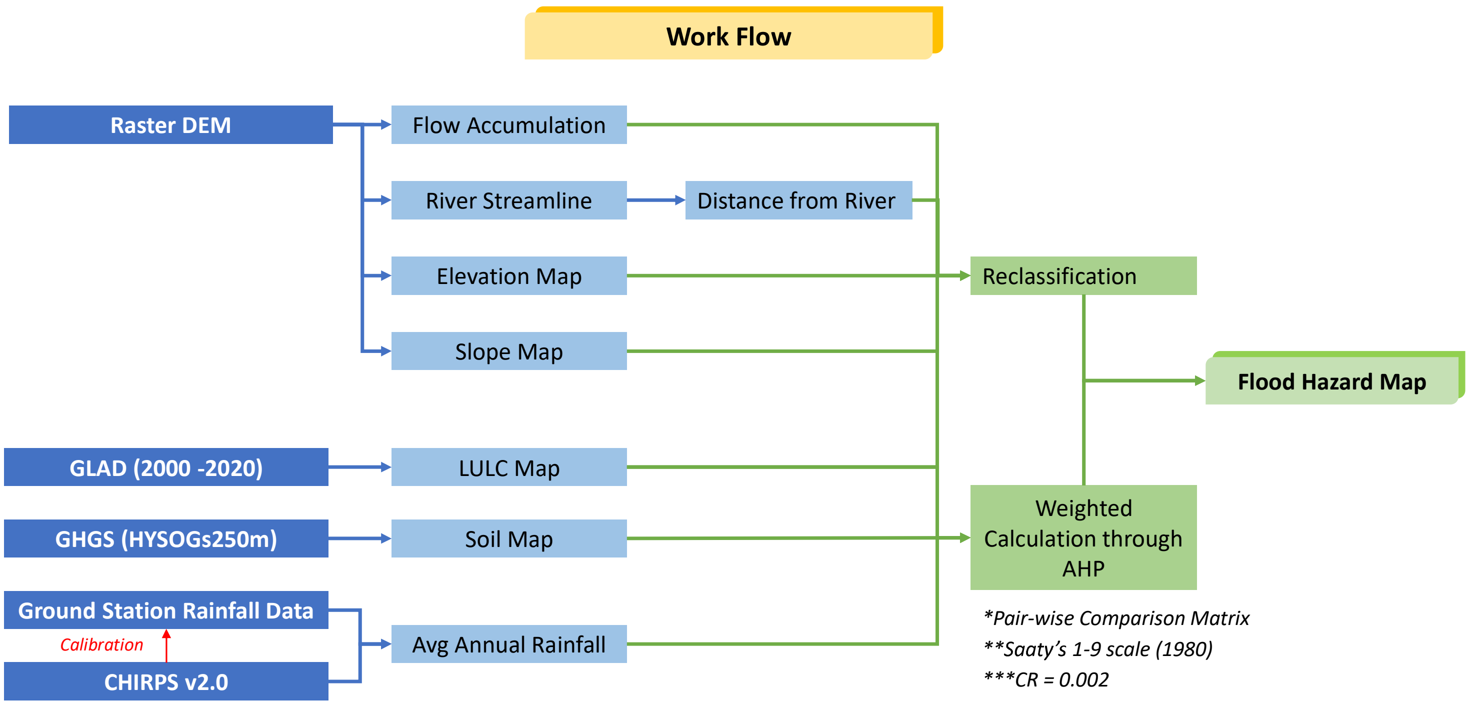
GIS-Based Water Availability Analysis



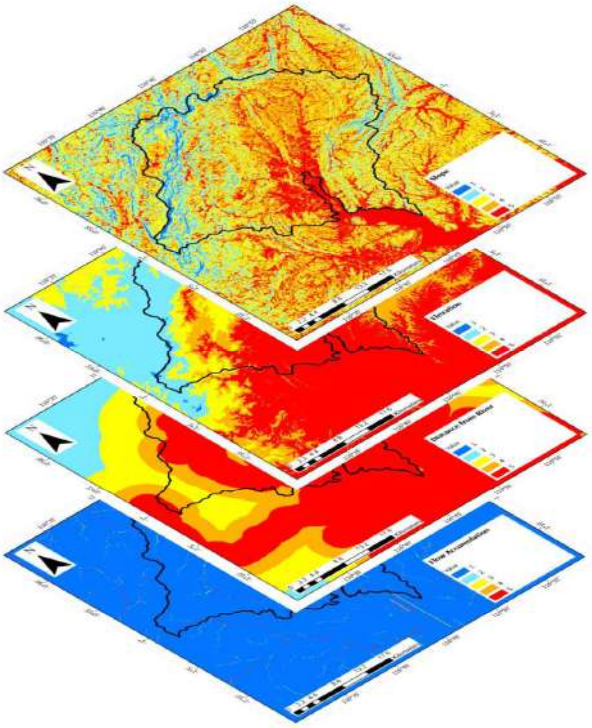


Discussion Contents

GIS-Based Flood Hazard Risk Analysis

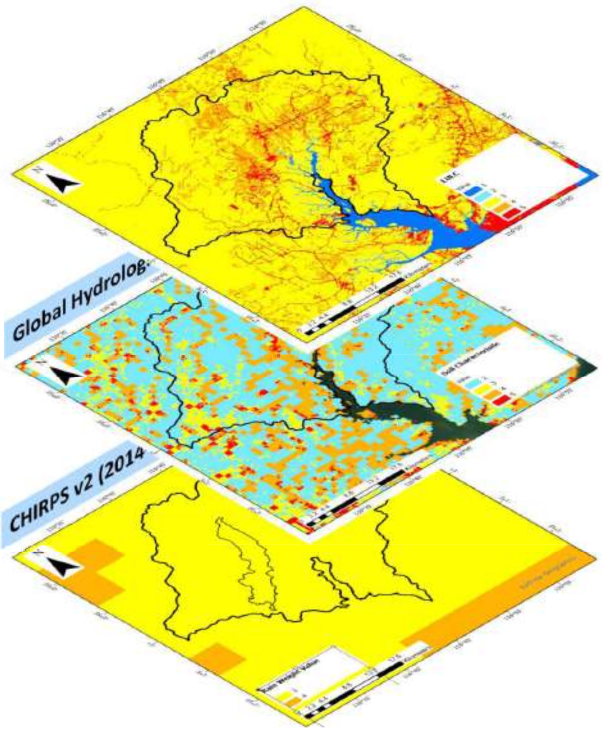


GIS-Based Flood Hazard Risk Analysis



		Weight Value
Slope	=	0.221
Elevation	=	0.220
Distance from River	=	0.134
Flow Accumulation	=	0.207

GIS-Based Flood Hazard Risk Analysis

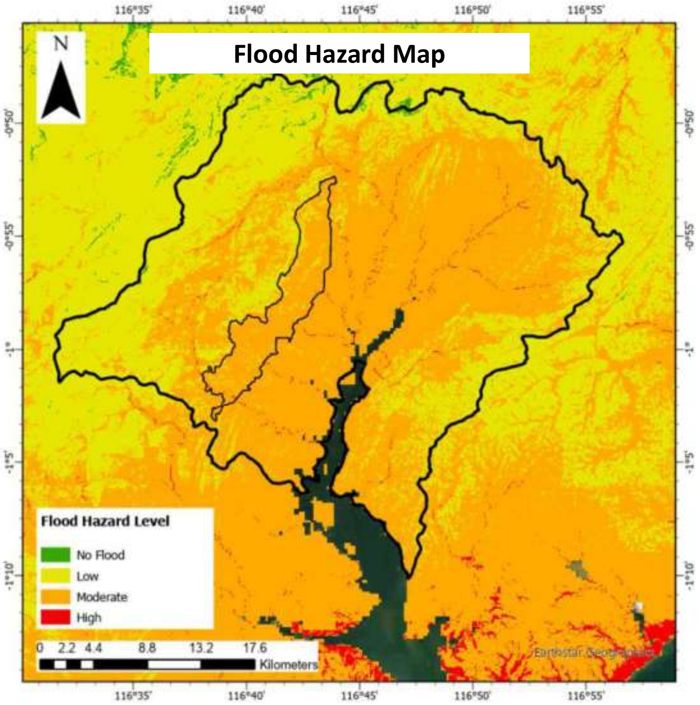


		Weight Value
LULC	=	0.050
Soil	=	0.030
Total Annual Rainfall	=	0.138

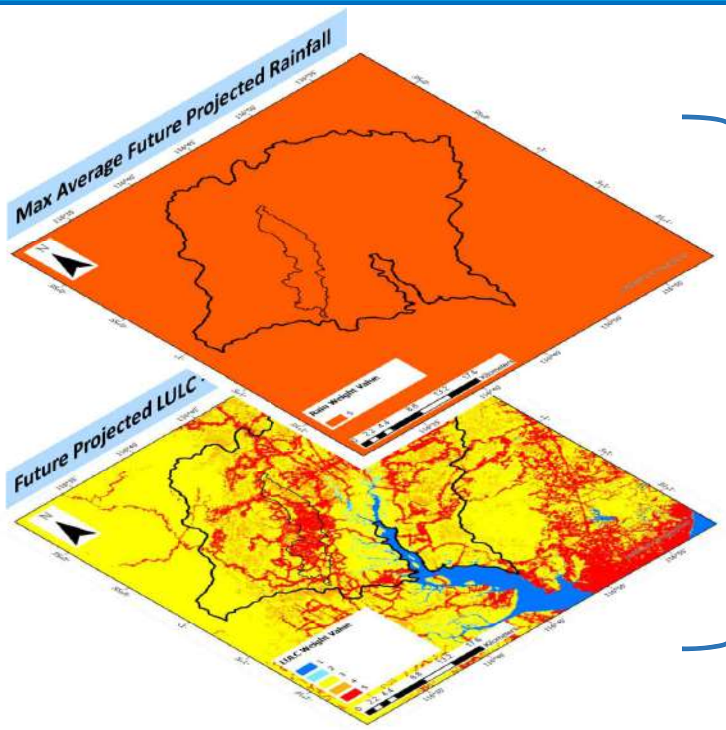
GIS-Based Flood Hazard Risk Analysis

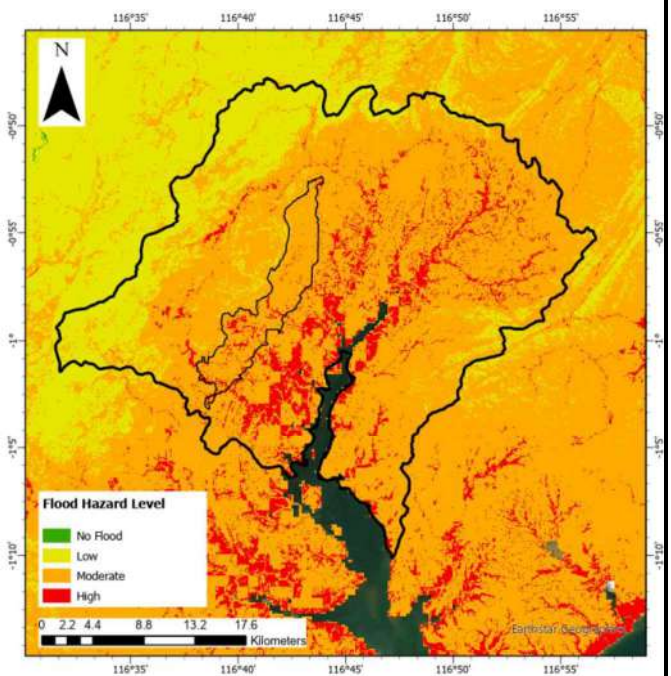
- Slope
- Elevation
- Distance from River
- Flow Accumulation
- LULC
- Soil
- Total Annual Rainfall

Raster Calculation



GIS-Based Flood Hazard Risk Analysis





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Conclusion

1 Sanggai watershed where the New Capital City is built will experience rapid growth or urban areas.

2 Under the current condition of LULC and historically recorded rainfall data, Sanggai watershed is considered as a high-resilience water availability area.

3 Under the current condition of LULC and historically recorded rainfall data, the vast majority of areas in Sanggai watershed, have a moderate level of flood risk. Hence, further analysis by using hydrological and hydrodynamic models is important.

4 This study contributes to the preliminary analysis of water availability and flood hazard risk in Sanggai River where the NCC has been constructed.

Recommendation for Current Urgencies

1. More Rainfall Station for IKN with hourly record abilities.
2. More Accurate and Finer Topographical Data.
3. Downscaled Global Climate Data (Dynamical Downscaling)

Recommendation for Current Urgencies

1. River Geometry and Hydrology Measurement .
2. River Discharge Observation.
3. More Comprehensive Disaster Simulation and Analysis for Flood, Erosion, Landslide, Sea Level Rise or Even Tsunami
4. Evaluation of Adaptation Counter Measures Towards Each Disaster Possibility

Assessing the Efficacy of Flood Adaptation Measures for Future Flooding in the Upper Citarum River Basin, Indonesia

〇Akbar **Rizaldi**
(PhD candidate, Toyama Prefectural University)
Shuichi **Kure**
(Professor, Toyama Prefectural University)

TOYAMA Prefectural University

Outline

- Introduction and aim
- Study location
- Data and methods
- Result
- Summary

Introduction

In 2023, the maximum average air temperature broke the record. ECMWF projections show a 1.76℃ increase in surface temperatures for November 2023.

A 1℃ (1.8 °F) rise in air temperature increases the atmosphere's water-holding capacity by about 7% (IPCC, 2007), leading to higher potential for heavy rainfall and floods.

The Upper Citarum Basin (UCRB) in Indonesia faces persistent flooding issues due to landscape conditions, urbanization, deforestation, sedimentation, subsidence, and poor drainage. Despite mitigation efforts, annual flooding persists, requiring anticipatory and adaptive measures.

Aim

To evaluate the efficacy of several countermeasures in tackling future flood condition in the Upper Citarum River Basin.

Study location

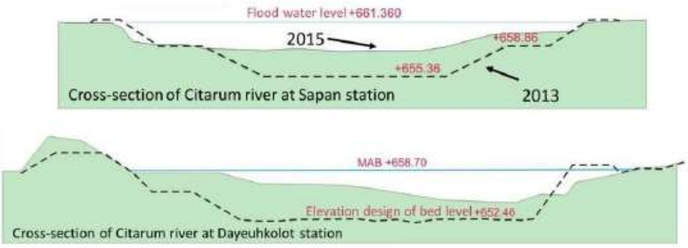
Study location

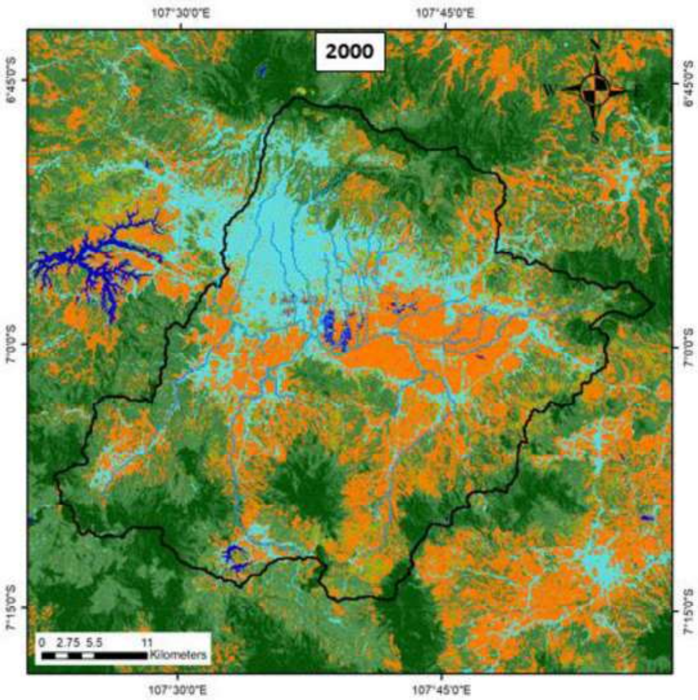
The Upper Citarum River Basin (UCRB) is located in West Java, Indonesia, covering a total area of 1,738.4 km^2.

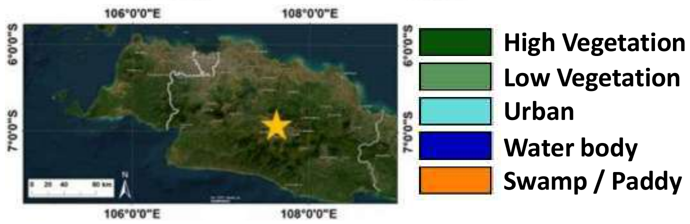
Flowing through Bandung city, the capital city of West Java, and being the longest river in the province, the Citarum river holds strategic importance as one of Indonesia's key watersheds.

The Citarum basin faces various water-related challenges, including floods. Several factors that attributed floods are:

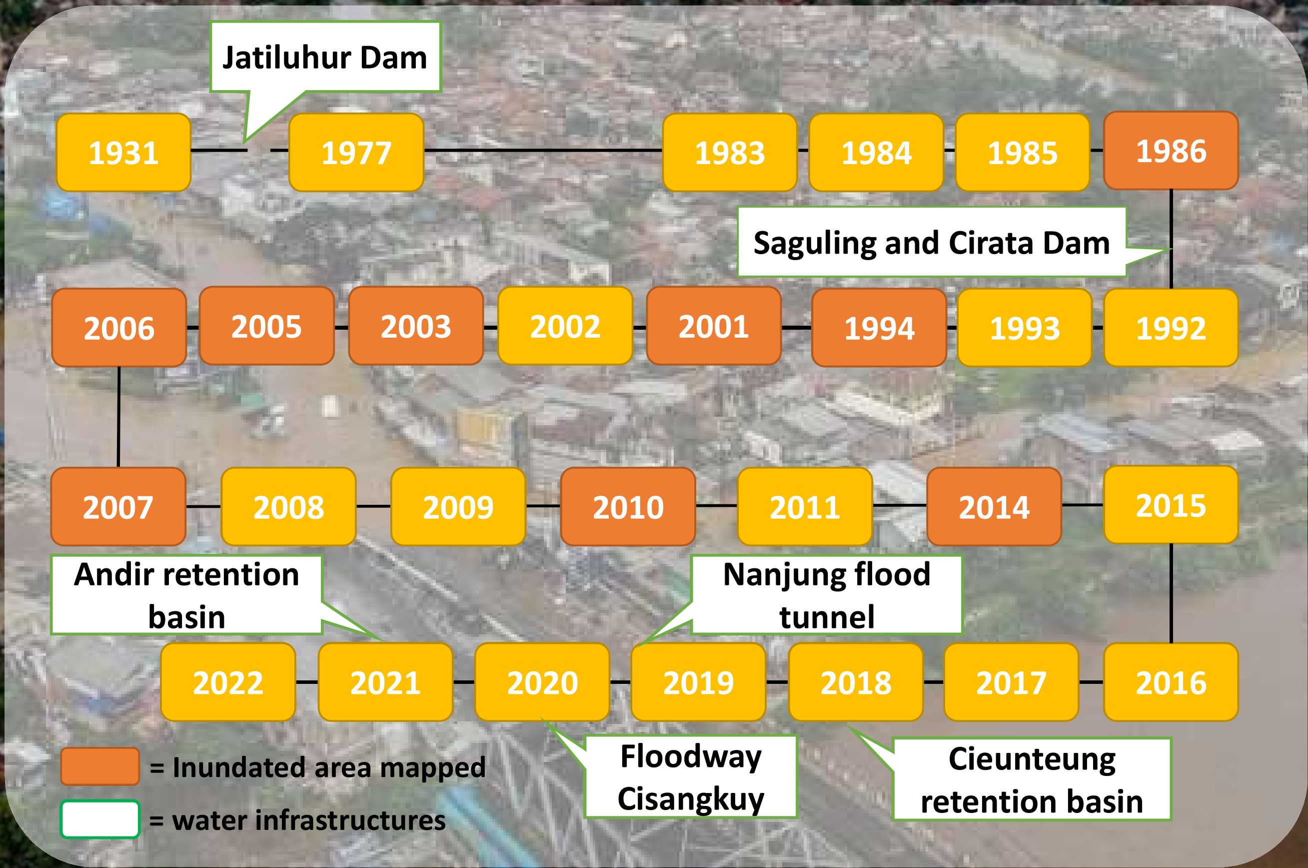
- High rainfall
- Land subsidence
- Land-use change
- Sedimentation
- Climate change





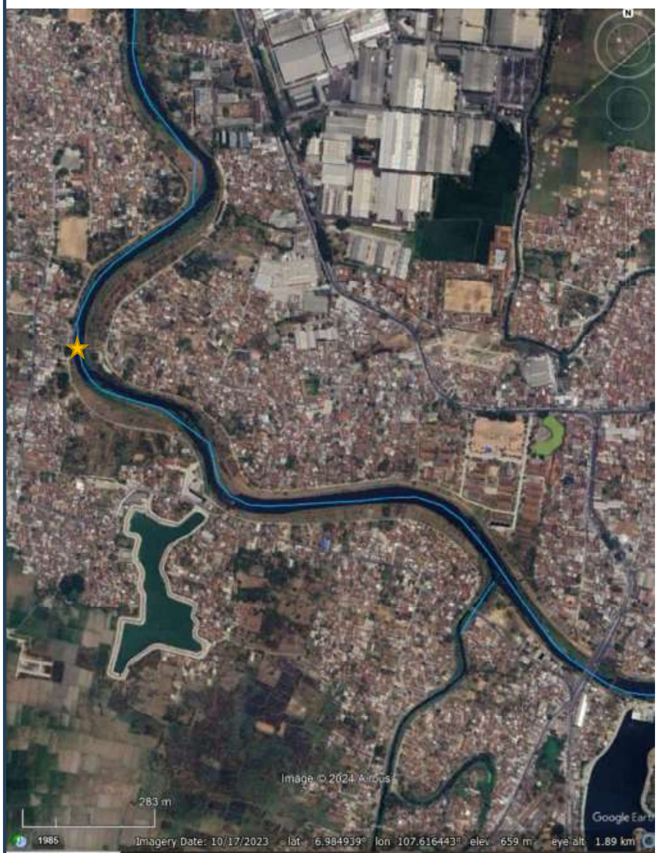


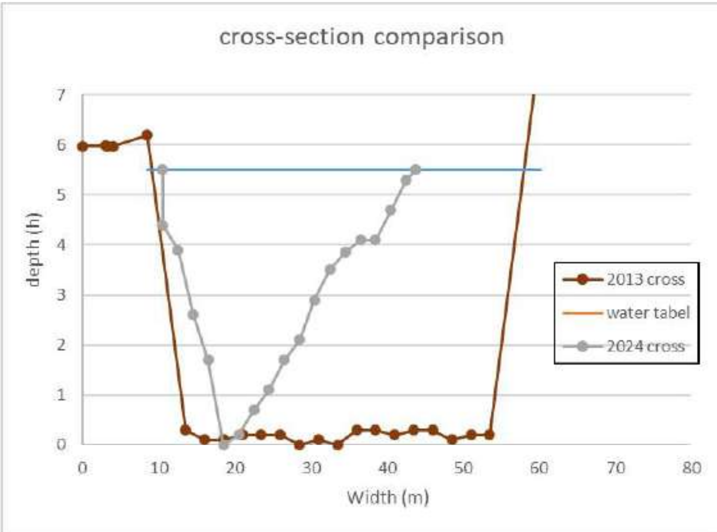
Flood event in Citarum basin



Source: news.detik.com (Flood May 25th , 2021)

Sedimentation condition

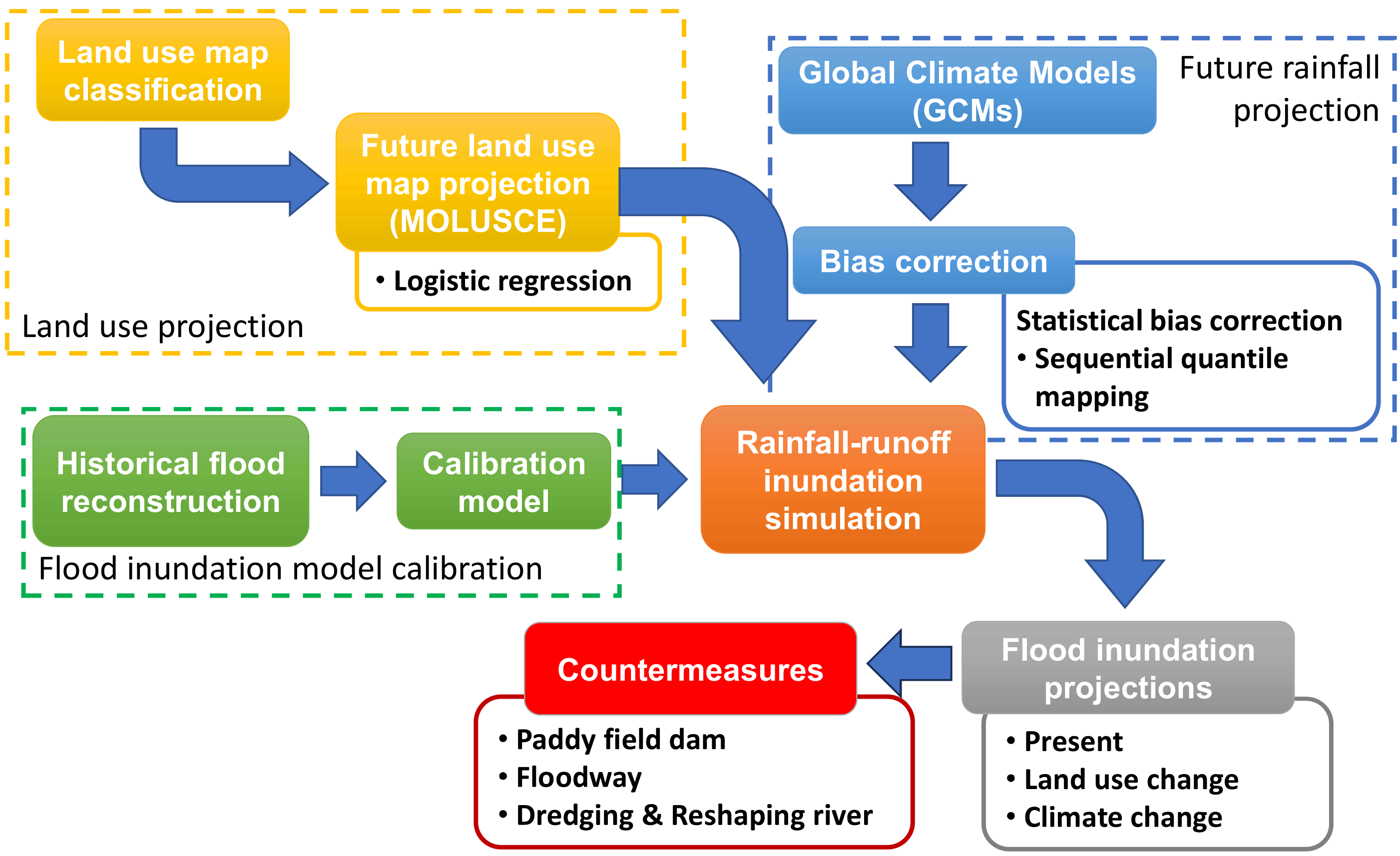




- Flow area in 2013: 243.656 m^2
- Flow area in 2024: 92.13 m^2

The flow area has been reduced to be only 41.2% of its original capacity due to sedimentation during 2013-2024.

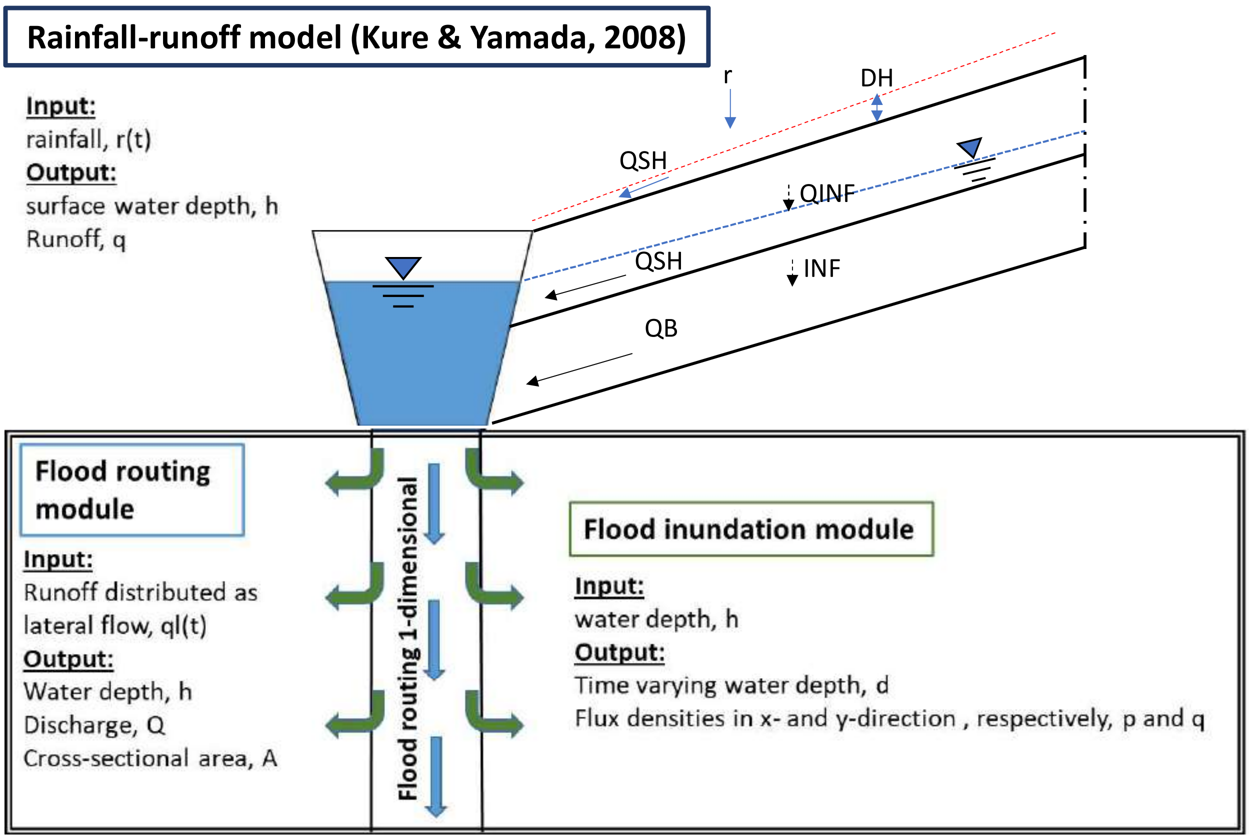
Data and Methods



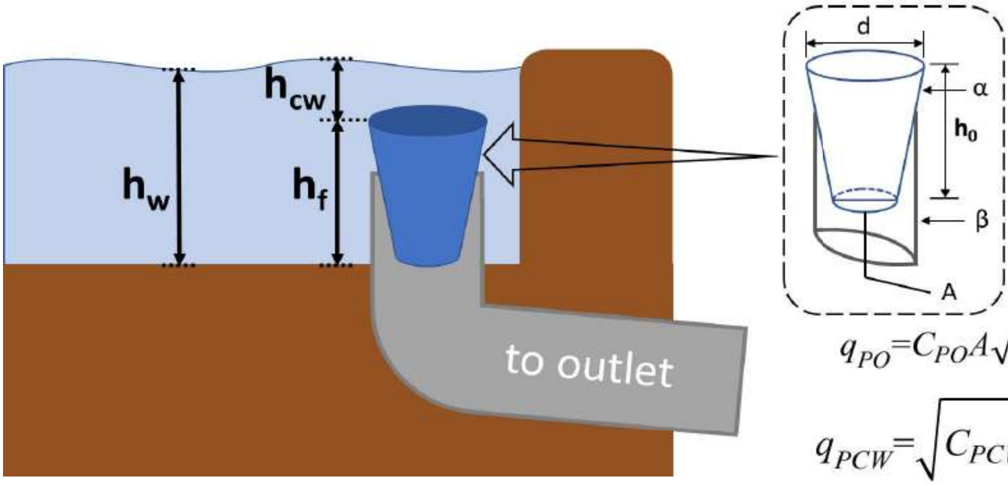
Data used

Category	Data source	Specifications
Surface elevation model	FABDEM	resolution 30 meters
Cross-section	BBWS Citarum	based on measurement in 2013
Rainfall and water level	BBWS Citarum & Dinas SDA Provinsi Jabar	hourly, daily (2003-2020)
Satellite rainfall	Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)	Spatial resolution 0.05° (2003-2014)
Land cover data	The Global Land Analysis and Discovery (GLAD)	based on LANDSAT satellite analysis Spatial resolution 30 meters
Future rainfall	World Climate Research Programme (WCRP) CMIP6	6 models GCM under RCP8.5-SSP5 scenario. Spatial resolution 100-250 km

Rainfall-runoff and flood inundation modeling schemes



Paddy field dam



$$q_{PO}=C_{PO}A\sqrt{2g(h_{CW}+h_O)}$$

$$q_{PCW}=\sqrt{C_{PCW}gd^5(h_{cw}/d)^3}$$

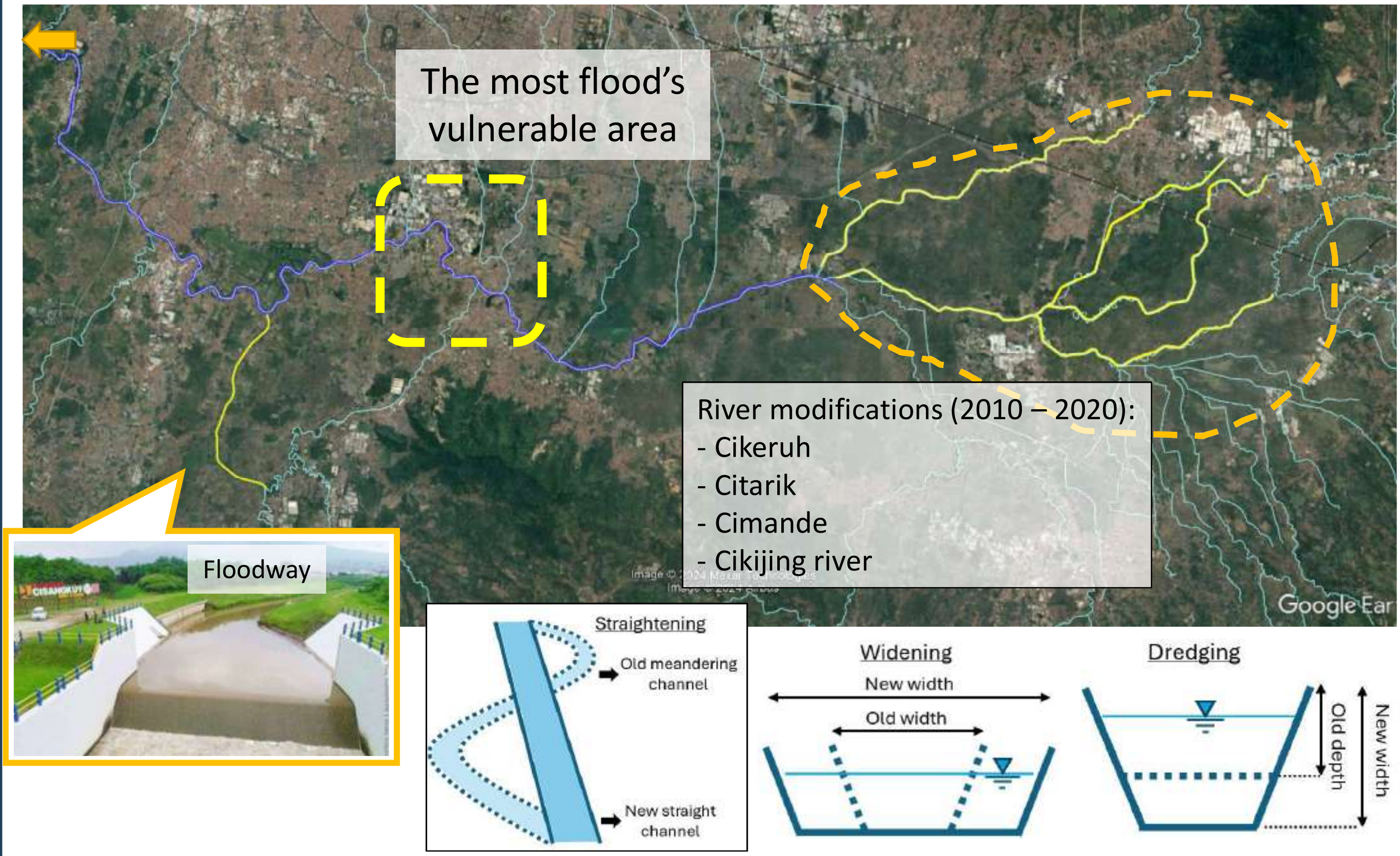
The water level (h_W) of the paddy field is:

$$\frac{dh_w}{dt}=-\frac{Q}{A_P}+R-L$$

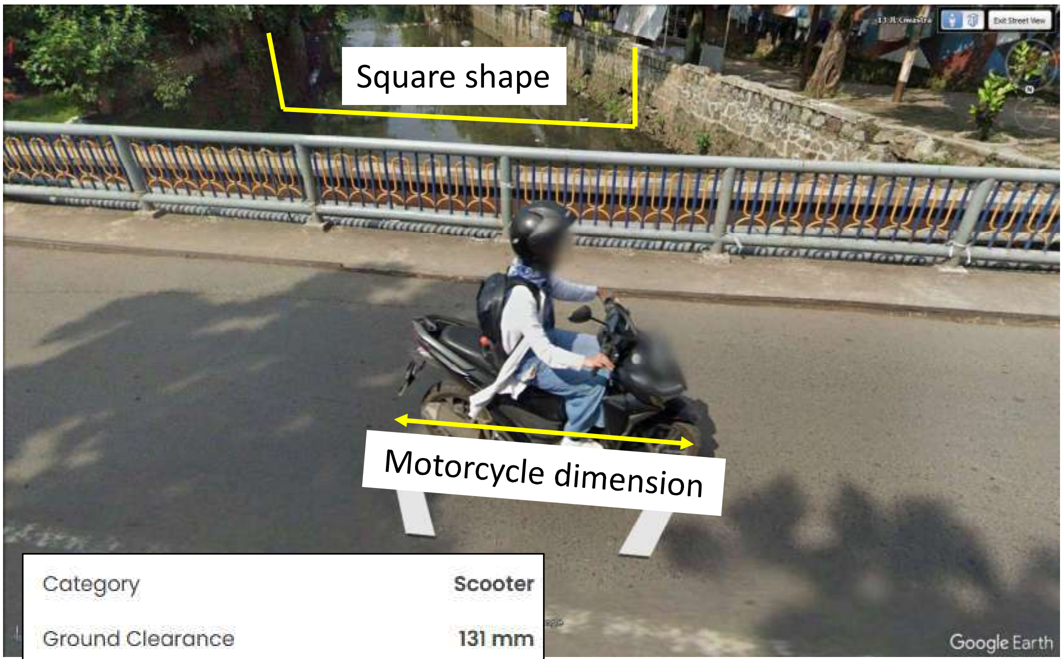
Where:

C_{PO} = coefficient of orifice
C_{PCW} = flow coefficient of cylindrical weir
h_{CW} = height from hole to water level
h_O = height of orifice
d = diameter of hole
A = area of hole
g = gravitational acceleration
q_{PO} = outflow from paddy field
A_P = area of paddy field
R = rainfall
L = sum of infiltration and evapotranspiration

Countermeasures



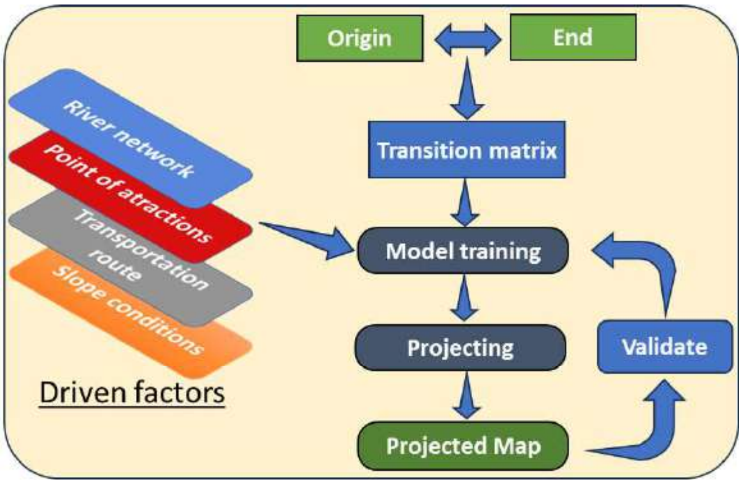
How to estimate the cross-section

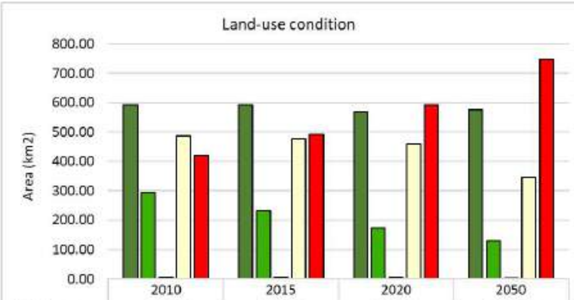


Category	Scooter
Ground Clearance	131 mm
Seating Capacity	2 Seats
Length	1918 mm
Width	679 mm

Result

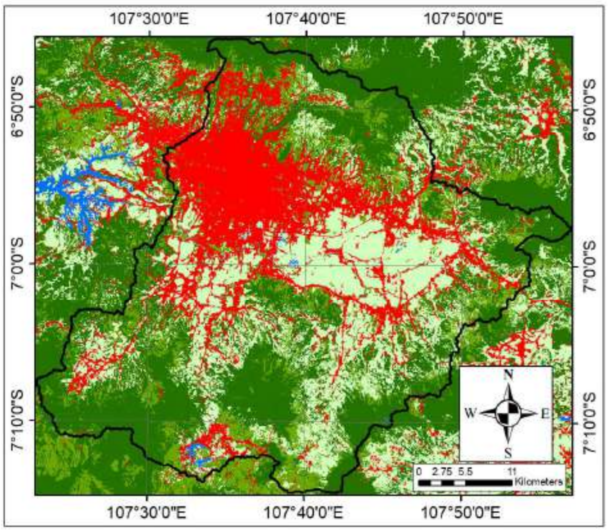
Land use projection





	2010	2015	2020	2050
Forest	592.15	593.51	568.42	576.97
Crop land	293.32	232.18	174.24	128.56
Water	4.91	4.76	4.71	1.96
Paddy field	487.27	477.08	459.28	344.75
Built area	421.27	491.38	592.27	746.68

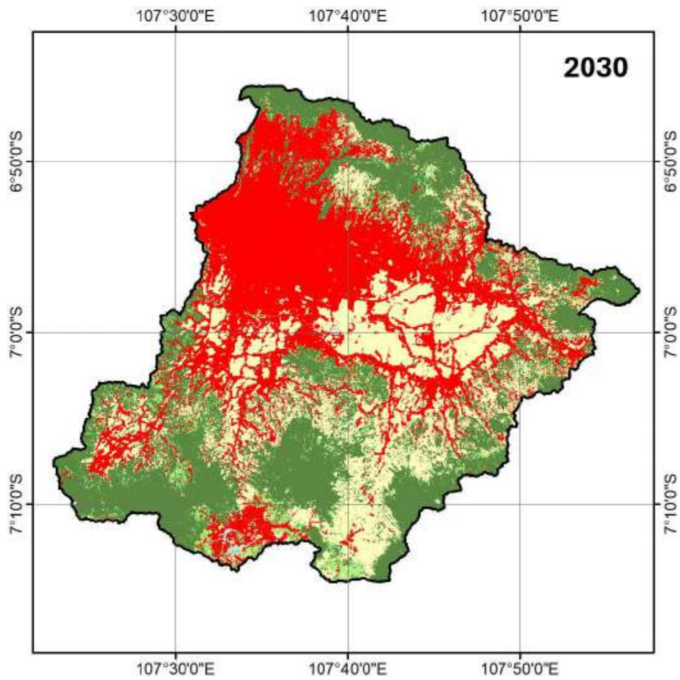
2010



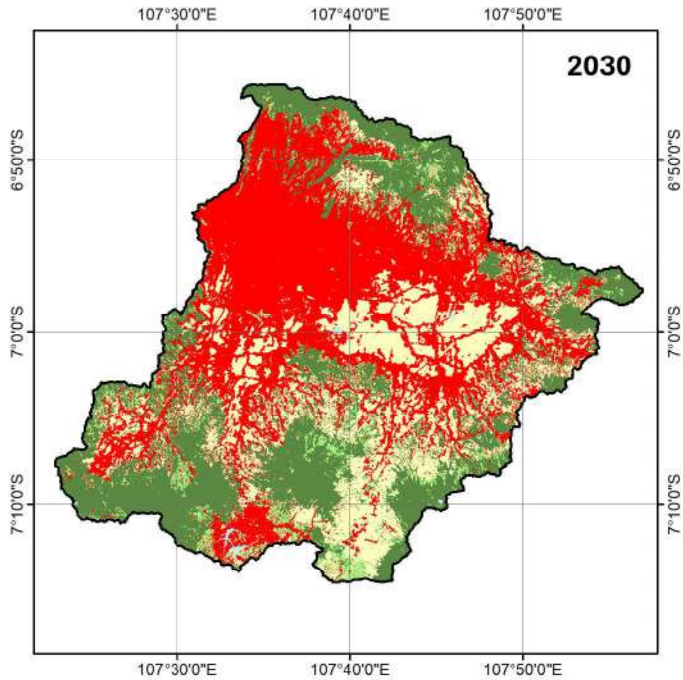
Categories	(2010-2015)	(2015-2020)	(2020-2050)
Forest	0.08%	-1.4%	0.5%
Crop	-3.4%	-3.2%	-2.5%
Water	-0.008%	-0.003%	-0.15%
Paddy	-0.6%	-1%	-6.4%
Urban	3.9%	5.6%	8.6%

Land use projection (logistic regression)

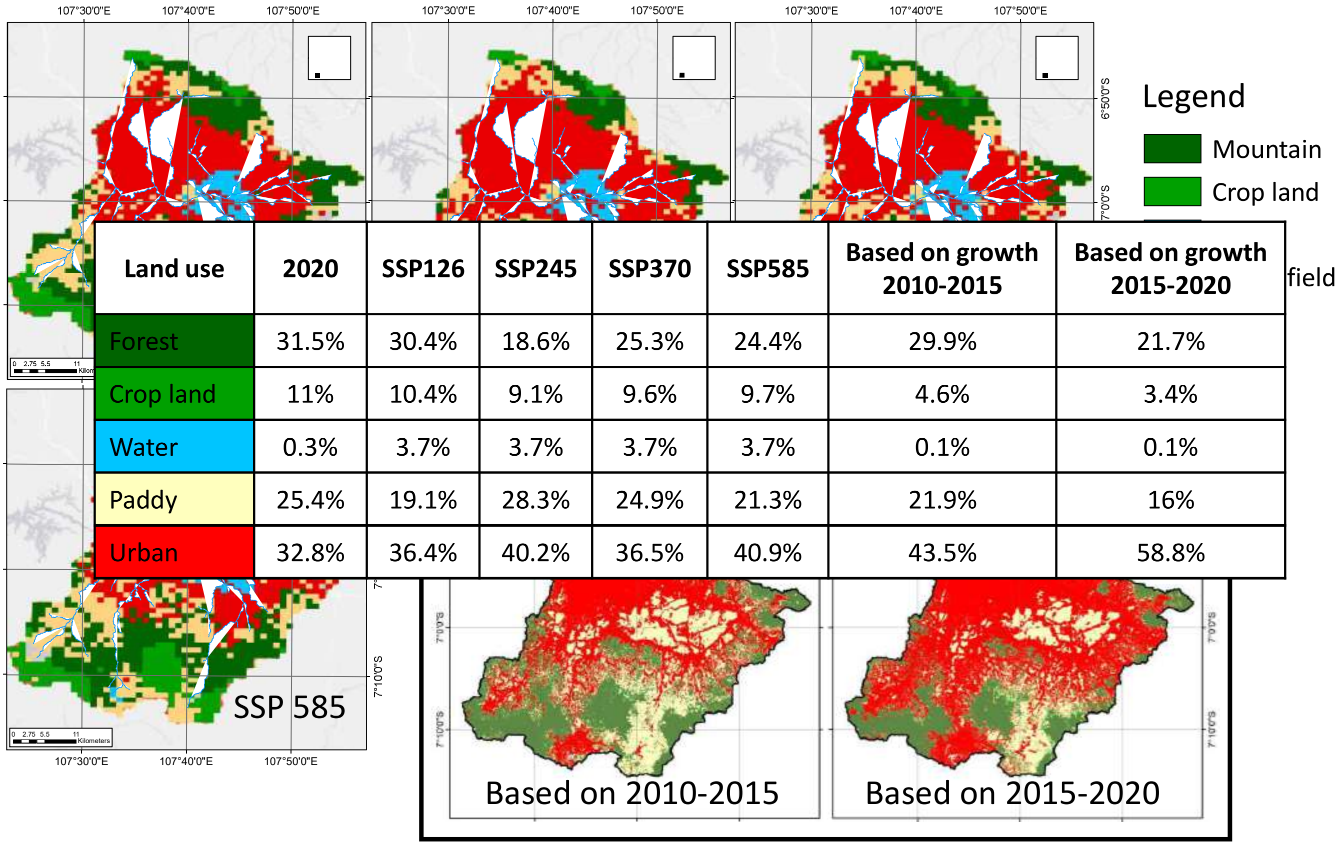
Based on 2010-2015



Based on 2015-2020

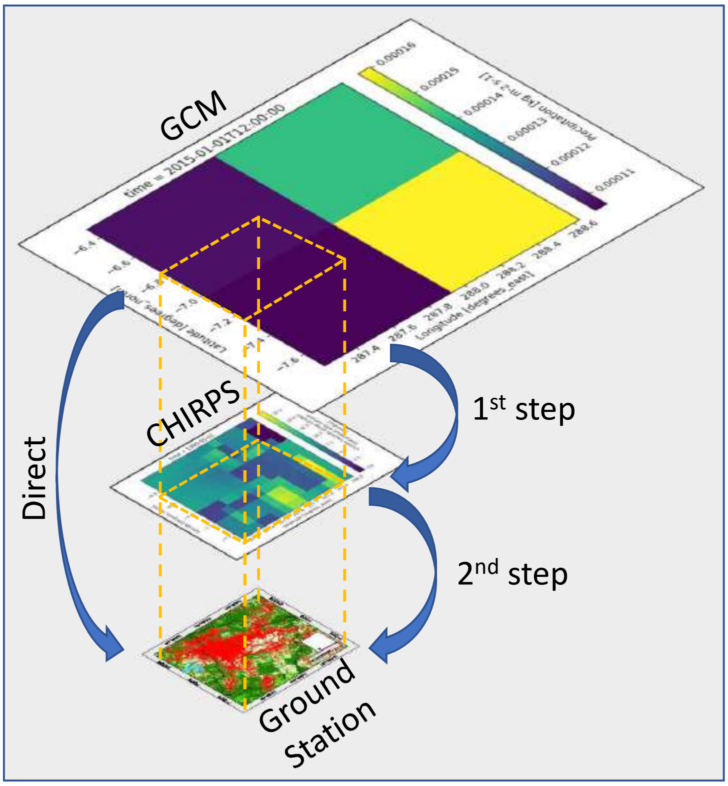


Comparison land use projection 2050 with other scenarios



Land use	2020	SSP126	SSP245	SSP370	SSP585	Based on growth 2010-2015	Based on growth 2015-2020
Forest	31.5%	30.4%	18.6%	25.3%	24.4%	29.9%	21.7%
Crop land	11%	10.4%	9.1%	9.6%	9.7%	4.6%	3.4%
Water	0.3%	3.7%	3.7%	3.7%	3.7%	0.1%	0.1%
Paddy	25.4%	19.1%	28.3%	24.9%	21.3%	21.9%	16%
Urban	32.8%	36.4%	40.2%	36.5%	40.9%	43.5%	58.8%

GCMs statistical bias correction



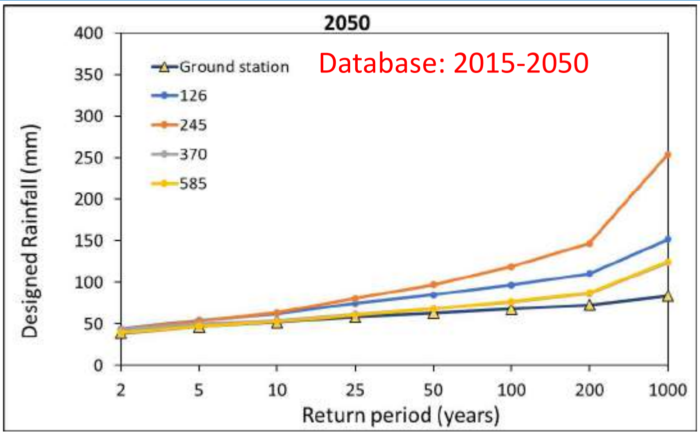
GCMs	Resolution
EC-Earth3	100 km
EC-Earth3-Veg	250 km
EC-Earth3-Veg-LR	100 km
MPI-ESM1-2-HR	100 km
MRI-ESM2-0	100 km
INM-CM4-8	100 km

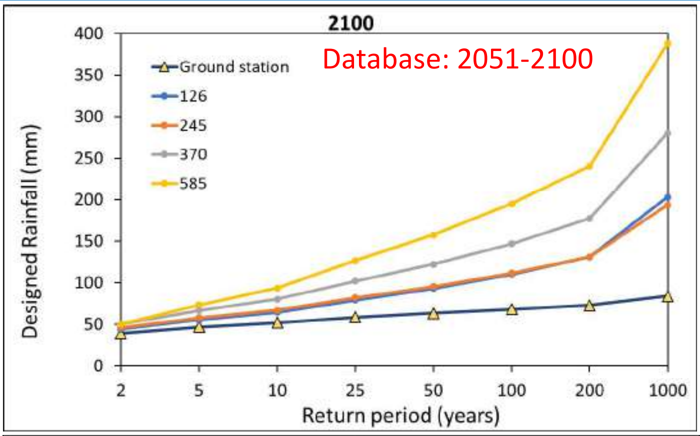
Bias correction

GCMs model	Original	QM
MRI-ESM2-0	0.777	0.995
MPI-ESM1-2-HR	0.808	0.996
INM-CM4-8	0.833	0.996
EC-Earth3-Veg-LR	0.823	0.999
EC-Earth3-Veg	0.793	0.998
EC-Earth3	0.798	0.997

Six global climate models (GCMs) are selected to represent the future rainfall conditions. The six GCMs were chosen due to their performance that have been assessed by Zulfaqar et al. in 2022. Every GCM is under scenario of RCP 8.5 SSP 5.

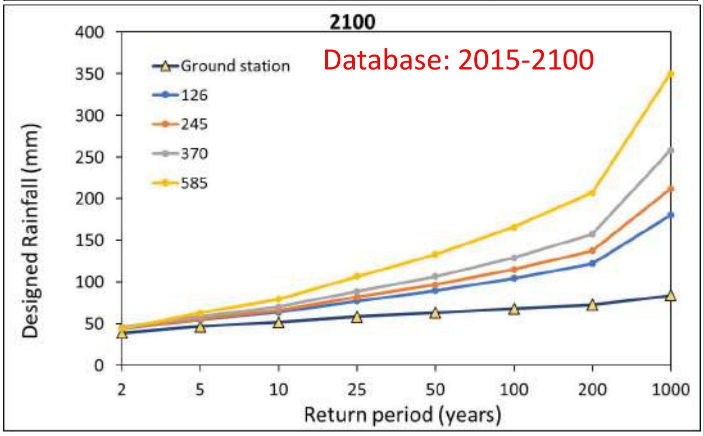
Return periods rainfall projection 21



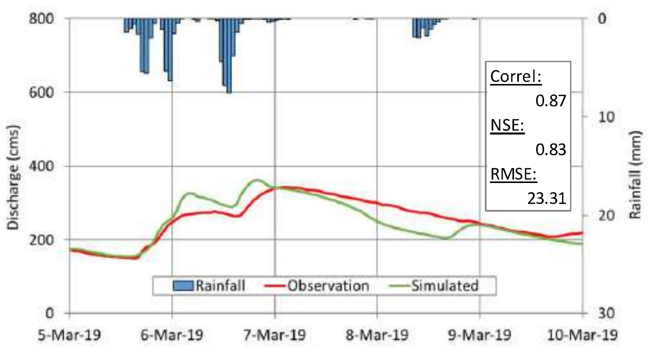


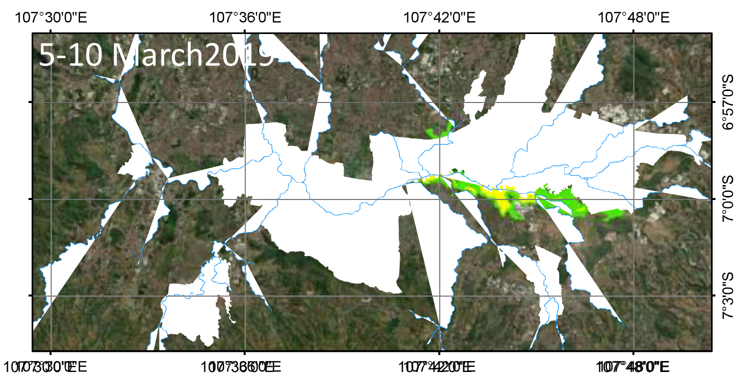
Return Period (years)	Ground station	Projection 2050	Projection 2100
2	38.94	39.92	44.20
5	46.75	47.02	59.31
10	51.92	52.37	74.18
25	58.45	60.40	101.43
50	63.29	67.68	130.61
100	68.10	76.46	170.79

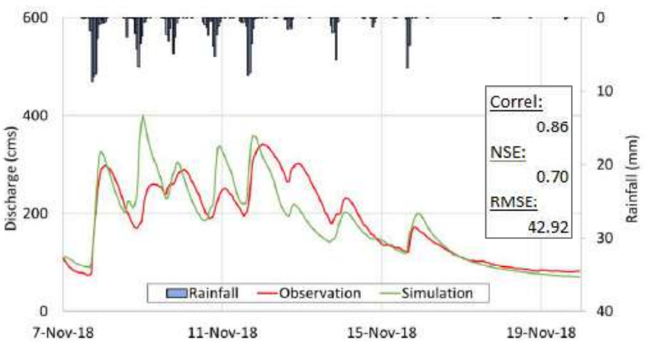
*Return period's rainfall is in mm.

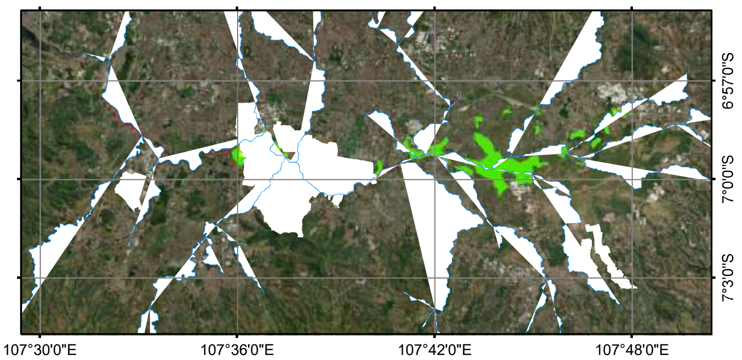


Calibration and verification model 22



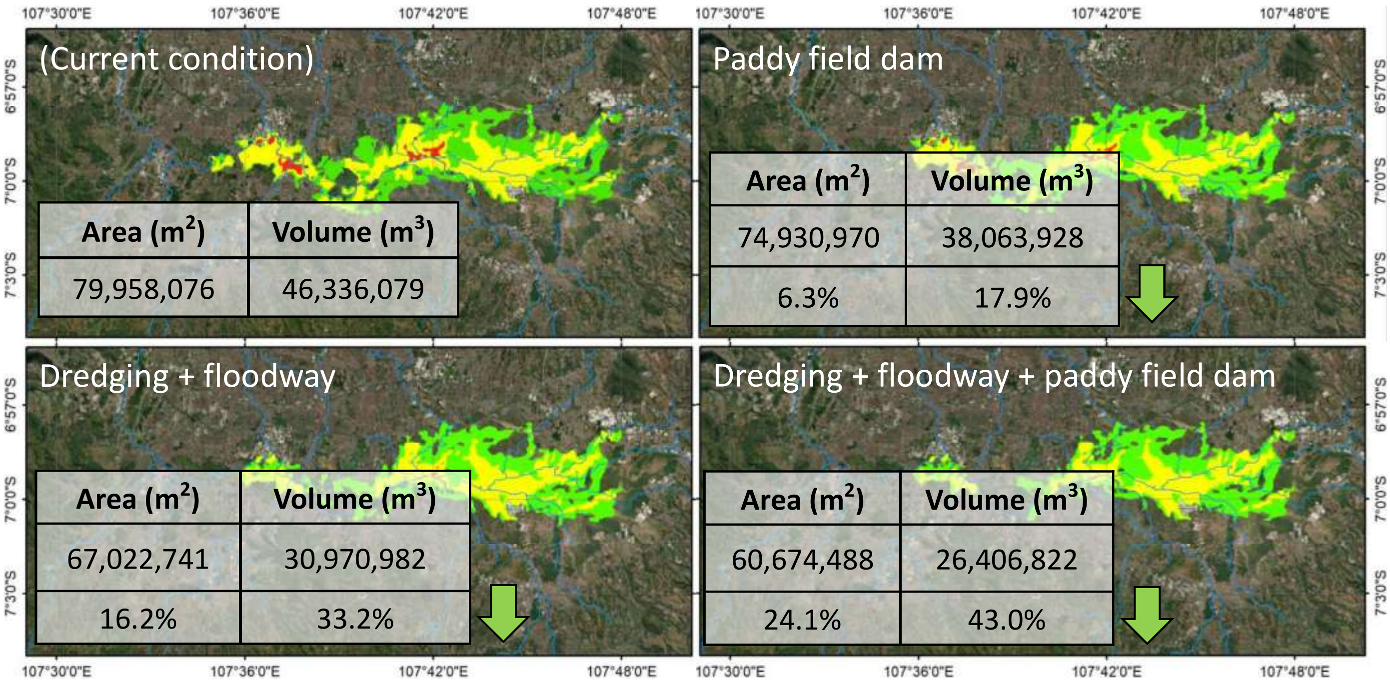






Legend: 0.1m < h < 0.5m 0.5m < h < 1.5m 1.5m < h

Flood conditions (March 2019)



(Current condition)

Area (m²)	Volume (m³)
79,958,076	46,336,079

Paddy field dam

Area (m²)	Volume (m³)
74,930,970	38,063,928
6.3%	17.9%

Dredging + floodway

Area (m²)	Volume (m³)
67,022,741	30,970,982
16.2%	33.2%

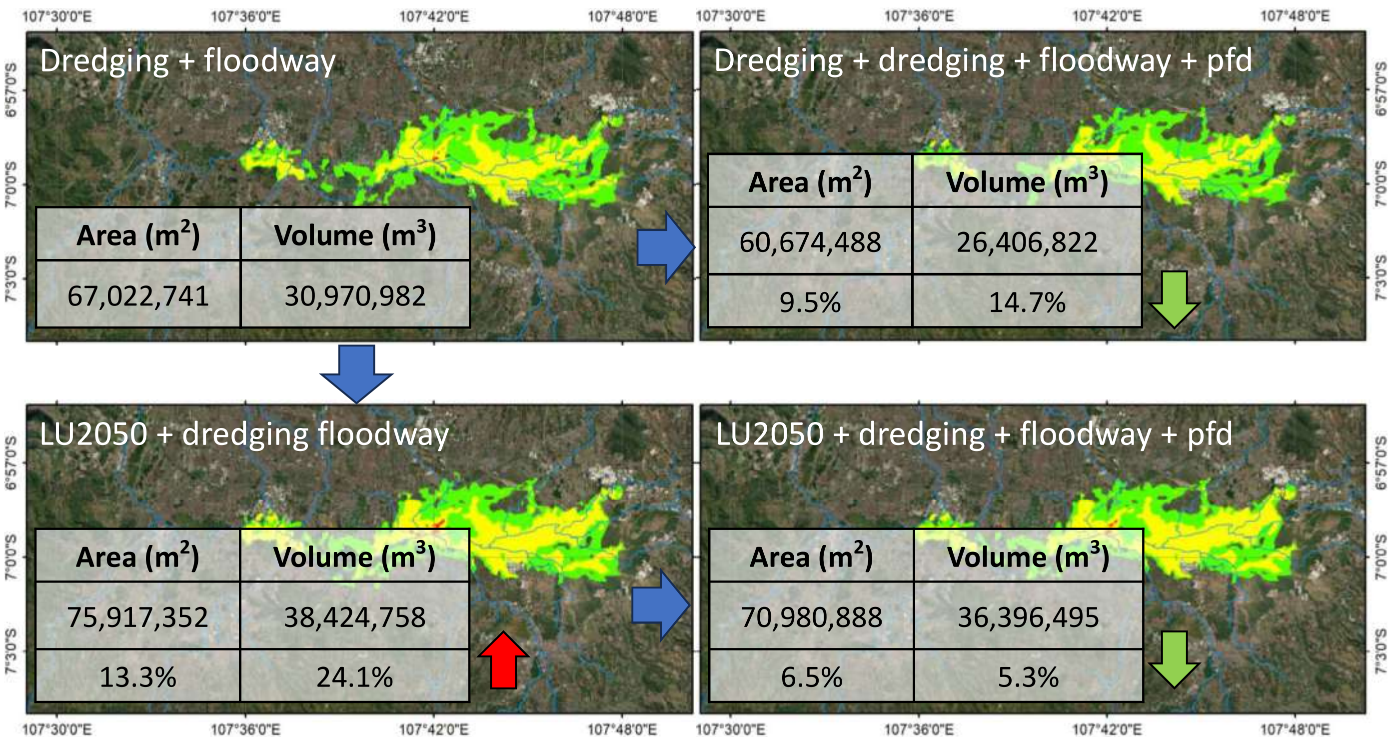
Dredging + floodway + paddy field dam

Area (m²)	Volume (m³)
60,674,488	26,406,822
24.1%	43.0%

Legend:

0.1m < h < 0.5m **0.5m < h < 1.5m** **1.5m < h**

Impact of land use change (March 2019)



Dredging + floodway

Area (m²)	Volume (m³)
67,022,741	30,970,982

Dredging + dredging + floodway + pfd

Area (m²)	Volume (m³)
60,674,488	26,406,822
9.5%	14.7%

LU2050 + dredging floodway

Area (m²)	Volume (m³)
75,917,352	38,424,758
13.3%	24.1%

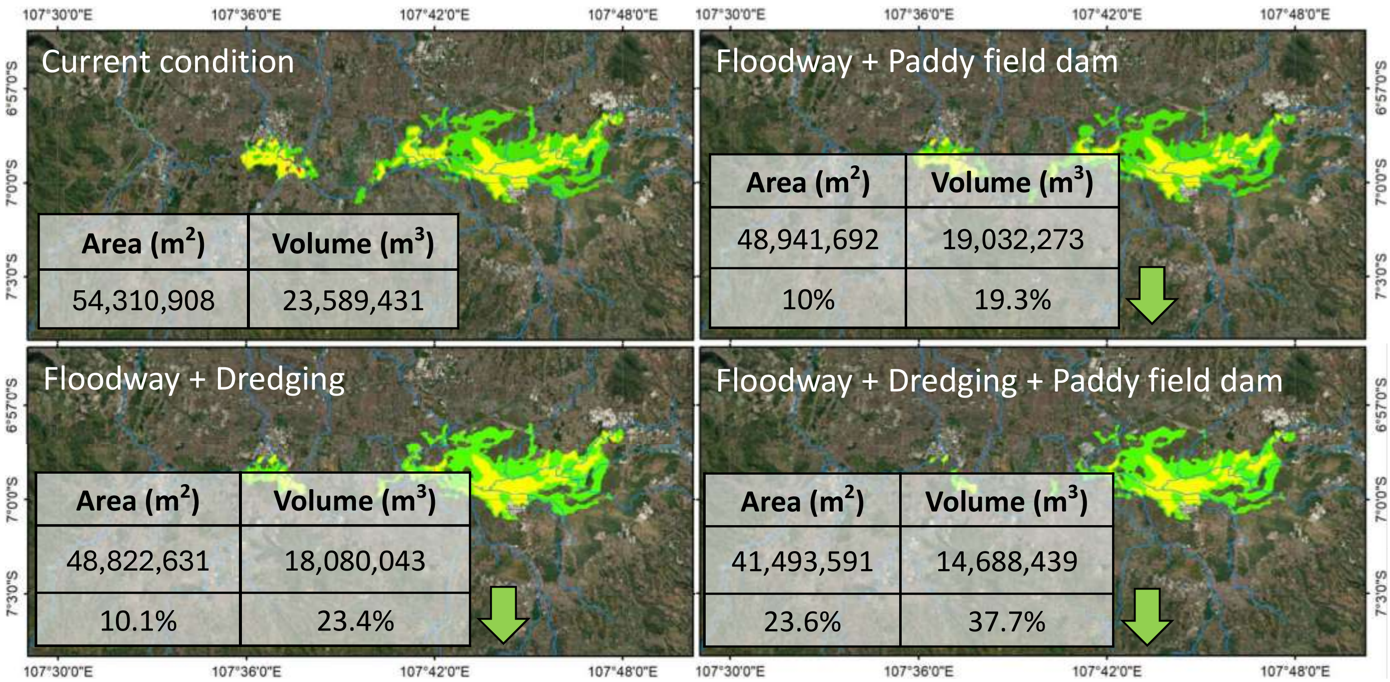
LU2050 + dredging + floodway + pfd

Area (m²)	Volume (m³)
70,980,888	36,396,495
6.5%	5.3%

Legend:

0.1m < h < 0.5m **0.5m < h < 1.5m** **1.5m < h**

Land use and climate changes 2050 (return period 2 years)



Current condition

Area (m²)	Volume (m³)
54,310,908	23,589,431

Floodway + Paddy field dam

Area (m²)	Volume (m³)
48,941,692	19,032,273
10%	19.3%

Floodway + Dredging

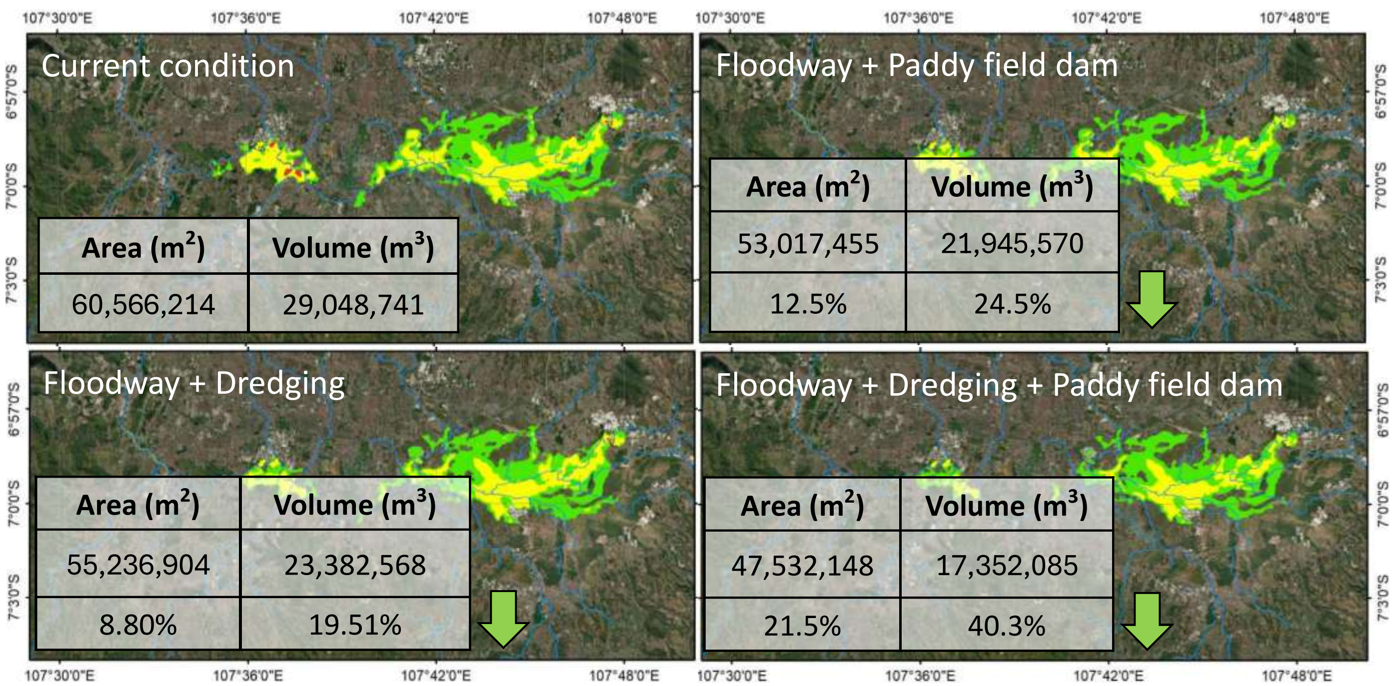
Area (m²)	Volume (m³)
48,822,631	18,080,043
10.1%	23.4%

Floodway + Dredging + Paddy field dam

Area (m²)	Volume (m³)
41,493,591	14,688,439
23.6%	37.7%

Legend:
- 0.1m < h < 0.5m
- 0.5m < h < 1.5m
- 1.5m < h

Land use and climate changes 2050 (return period 5 years)



Current condition

Area (m²)	Volume (m³)
60,566,214	29,048,741

Floodway + Paddy field dam

Area (m²)	Volume (m³)
53,017,455	21,945,570
12.5%	24.5%

Floodway + Dredging

Area (m²)	Volume (m³)
55,236,904	23,382,568
8.80%	19.51%

Floodway + Dredging + Paddy field dam

Area (m²)	Volume (m³)
47,532,148	17,352,085
21.5%	40.3%

Legend:
- 0.1m < h < 0.5m
- 0.5m < h < 1.5m
- 1.5m < h

Summary

- **The most effective adaptation measure is dredging of Citarum river. It could decrease the inundation volume about 33%.**
- **The combination of all countermeasures could decrease the flood volume around 43%**
- **The paddy field dam efficacy in reducing flood volume is dramatically decreasing along with the change in land cover in 2050, from 14.7 % to 5.3%.**
- **The implementation of river modifications (diverting, enlarging, dredging)* and paddy field dam are not sufficient to encounter the flood discharge under the future conditions****

*2022's conditions
**RCP8.5 SSP5 and land-use 2050

Thank you

Summary Report: Toward the Success of the Relocation and Revival of the Capital City in Indonesia

Introduction

In a transformative and highly ambitious decision, the Indonesian government has resolved to relocate the nation's capital from Jakarta, on the island of Java, to a new site in East Kalimantan, Borneo. This move, though discussed since Indonesia's independence in 1945, is now imperative, driven by the environmental and urban crises that threaten Jakarta's sustainability. The relocation seeks to address a twofold challenge: the sinking and increasingly flood-prone nature of Jakarta and the need to balance Indonesia's economic and infrastructural development across its vast archipelago.

Jakarta, one of the world's fastest sinking cities, faces a range of threats caused by excessive groundwater extraction, rapid urbanization, and climate change. The northern areas of the city are sinking at alarming rates, up to 25 cm per year, and it is estimated that much of the city could be submerged by 2050. Flooding, already a chronic issue, is expected to worsen with climate change, further threatening Jakarta's future as a viable capital. In addition, Indonesia's economic activity has long been concentrated in Java, leaving other islands underdeveloped. Moving the capital to East Kalimantan is expected to redistribute economic activity and development across the country.

However, the relocation also poses new challenges and potential exposure to future water-related disasters, such as floods and water shortages. Therefore, thoughtful planning and risk mitigation strategies are needed. These concerns formed the basis for an important discussion among stakeholders, experts, and policymakers.

Preliminary Presentations

Before initiating the discussion, participants were provided with comprehensive presentations to outline the challenges and risks associated with both the current situation in Jakarta and the new capital. The presentations covered:

- **Flood risks in Jakarta**: Detailing the dire future projections if the city continues to sink at its current rate, exacerbated by climate change and uncontrolled urbanization.
- **Environmental impact of new capital development**: A warning that large-scale construction in East Kalimantan could lead to deforestation, land cover changes, and increased vulnerability to water-related disasters.

- **Climate-induced flood risks near the new capital**: Projections that highlight potential future flooding in the surrounding areas due to changing weather patterns.
- **Water stress concerns the new capital**: A discussion of the potential for water shortages despite initial indications that the water balance in the region may be manageable.

Discussion Focus

The central question that guided the discussion was: What measures should be taken to ensure the successful relocation and revival of Indonesia's capital while minimizing the environmental and water-related risks that could threaten the new city and its surrounding areas?

Key Outcomes and Recommendations

Several recommendations emerged during the discussion, each addressing different aspects of ensuring the success of the new capital while mitigating potential risks:

1. Ongoing Scientific Research and International Collaboration

- Scientific collaboration is essential to understand the long-term environmental impacts of the relocation and to mitigate risks associated with water-related disasters.
- Programs such as SATREPS (Science and Technology Research Partnership for Sustainable Development) and E-ASIA were highlighted as successful models for conducting joint research projects, particularly with Japan and other countries, to address water-related risks. These projects provide valuable insights into hydrology, urban planning, and climate adaptation, offering tools to make the new capital more resilient to environmental threats.
- Continued partnerships with international experts will ensure Indonesia remains at the forefront of disaster management strategies and innovative solutions in urban planning and climate adaptation.

2. Improvement in Hydrological Monitoring and Data Collection

- Accurate and real-time hydrological data is crucial for planning and disaster management. It was proposed that Indonesia invest heavily in upgrading its meteorological and hydrological observation infrastructure, through the implementation radar systems and development of mini radars to gather more accurate and localized weather data.

- Improving data collection by increasing the number of hourly rain gauge stations and river water level stations to provide up-to-date information on rainfall and water levels, allowing for quicker responses to flood events.
- The development of fine-resolution Digital Elevation Models (DEMs) for better understanding of the region's topography, helping to model potential flood scenarios more accurately.
- Utilization of satellite imagery to monitor land use changes, deforestation, and water levels, providing critical data for both long-term planning and emergency responses.

3. Advanced Analytical Tools and Technological Solutions

- Analytical tools such as dynamical downscaling was recommended to improve the accuracy of future climate and disaster projections. By refining large-scale climate models to better reflect local conditions, Indonesia can develop more reliable forecasts and identify regions most at risk from future flooding and other water-related hazards.
- The development of flood hazard maps and a flood early warning system will enable better preparation and faster responses to flood events, reducing the potential for loss of life and property damage.
- The development of rainfall runoff inundation models will help simulate flood scenarios based on rainfall patterns, enabling authorities to plan flood defenses more effectively.
- Both structural adaptation measures (such as dams, reservoirs, and water treatment systems) and non-structural measures (including policies, community preparedness programs, and emergency response planning) were identified as necessary to reduce flood risks.

4. Environmental Management and Land Use Control

- Participants highlighted the importance of careful land use management to prevent the uncontrolled expansion of urban areas around the new capital, which could lead to environmental degradation, increased flood risks, and loss of biodiversity.
- Conducting rigorous environmental assessments before any large-scale development will help prevent deforestation, soil erosion, and other adverse environmental impacts.
- Proper management of natural resources, particularly water, will be crucial in ensuring the new capital does not face water shortages as it grows. Balancing the

needs of urban development with the preservation of forests and water sources was identified as a key concern.

5. Political and Economic Stability

- Governance and Policy Continuity: Political stability and clear governance frameworks were recognized as essential for the success of the relocation project. Participants noted that maintaining political stability would help ensure that long-term planning and implementation remain consistent.

- A stable economy will be necessary to sustain the long-term infrastructure development required for the new capital. Economic planning should account for the potential influx of residents and businesses to East Kalimantan and provide adequate infrastructure and services.

Conclusion

The relocation of Indonesia's capital city from Jakarta to East Kalimantan represents a bold and transformative initiative. The move is driven not only by the urgency of Jakarta's environmental challenges but also by the broader goal of equitable national development. However, the move also brings significant risks, particularly related to environmental sustainability and water-related disasters.

Through continued scientific research, international collaboration, technological advancements, and careful environmental management, Indonesia can mitigate these risks and ensure the success of its new capital. By addressing these challenges proactively, the relocation of Indonesia's capital can become a model of sustainable development and climate adaptation in the 21st century.