



AGRICULTURAL POLICY RESEARCH TO SUPPORT NATURAL RESOURCE MANAGEMENT IN INDONESIA'S UPLAND LANDSCAPES (INDOGREEN)

THE IMPACTS OF CLIMATE CHANGES, LAND USE DAN SOIL CONSERVATION ON SEDIMENTATION AND LIFE SPAN OF SAGULING RESERVOIR

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Introduction

- Changes in land use and climate change are among other factors that affect many changes in the hydrological function of the watershed, which also affect various hydrological problems that arise, such as landslides, floods, and droughts.
- The Saguling Reservoir, as the main outlet of the upstream Citarum watershed, is currently facing threats as a result of the high rates of erosion and sedimentation that occur in the area and the reservoir.
- Therefore, a process-based hydrological and erosion-sedimentation modeling is urgently needed to identify the causes of hydrological problems and erosion-sedimentation in the upstream Citarum watershed and to recommend efforts to address them.
- This paper aims to analyze the impacts of climate changes, land use and soil conservation practices on sedimentation rates and lifespan of Saguling reservoir.



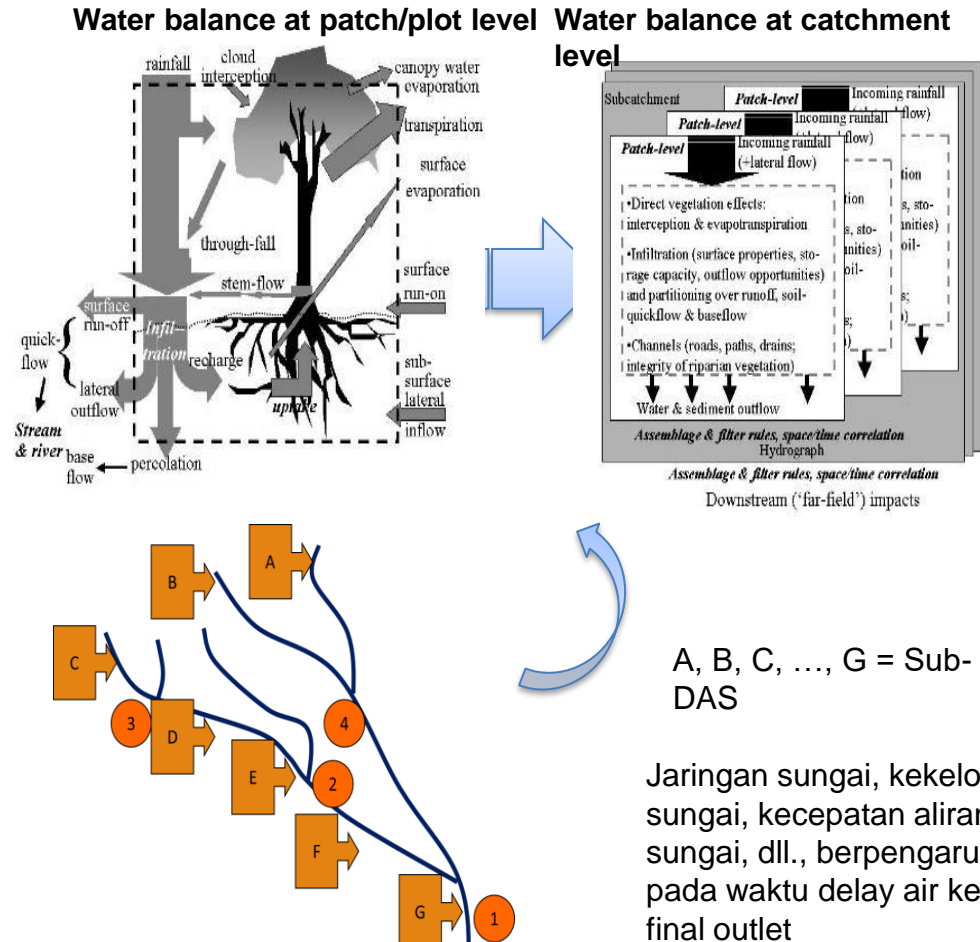
Research Methods

- Hydrological modeling is an effective and efficient method for assessing the condition of watersheds.
- This research uses a processed-based hydrological and erosion-sedimentation model.
- Specifically, it uses GenRiver 3.0 as a modification of GenRiver 2.0.



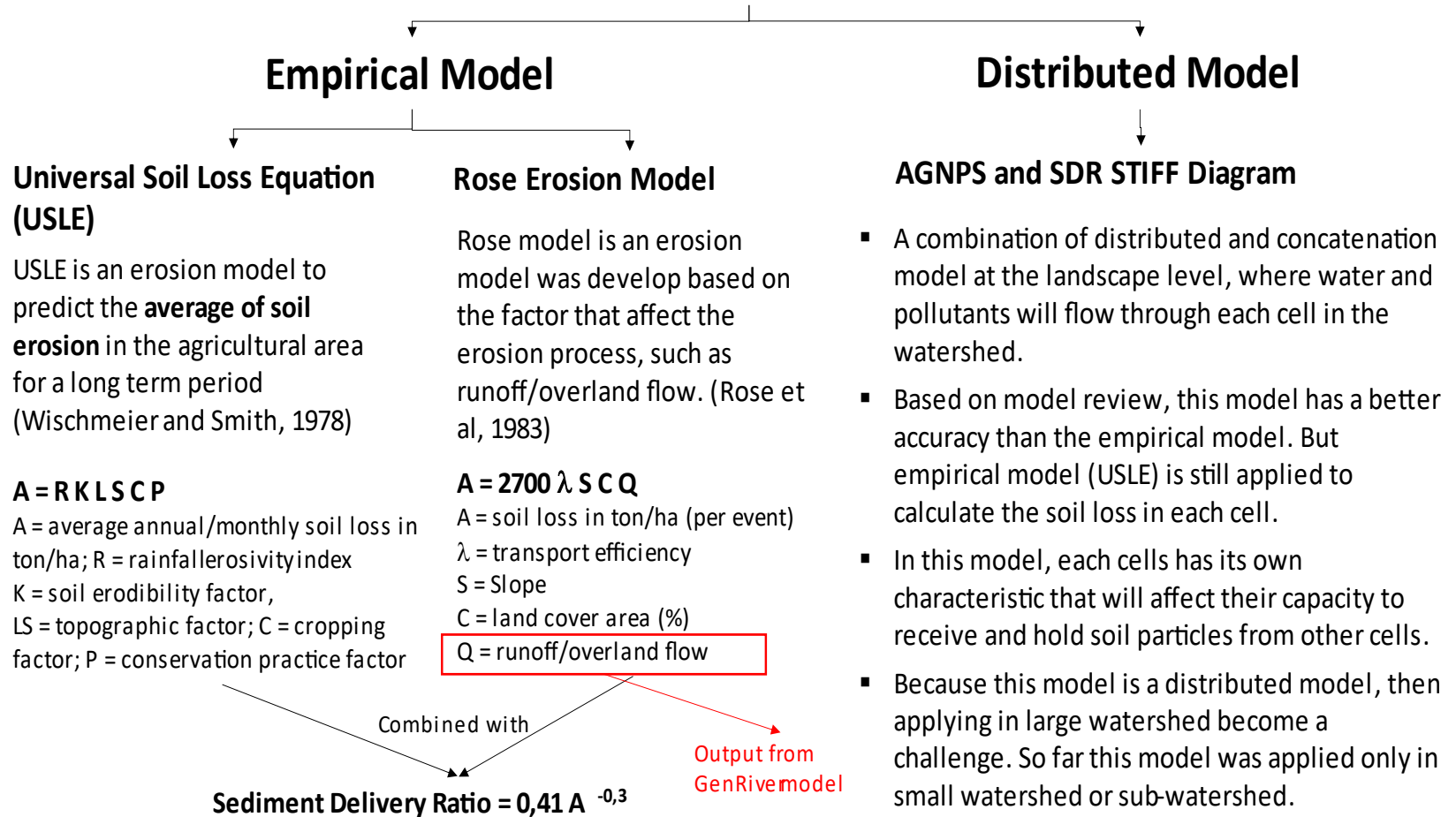
Generic River Flow Model (GenRiver)

- GenRiver 2.0 is a semi-distributed conceptual hydrological model which converts the water balance at the plot level to the landscape level through a river network.
- It simulates a daily water balance driven by changes in rainfall, land cover, and soil type
- By adding erosion and sedimentation modules, GenRiver 3.0 can predict the impacts of climate change, land cover, and soil conservation practices on daily water balance, erosion in the upstream Citarum, and sedimentation in the Reservoir.



Soil Erosion

General Soil Erosion Model



Erosion-sedimentation in GenRiver

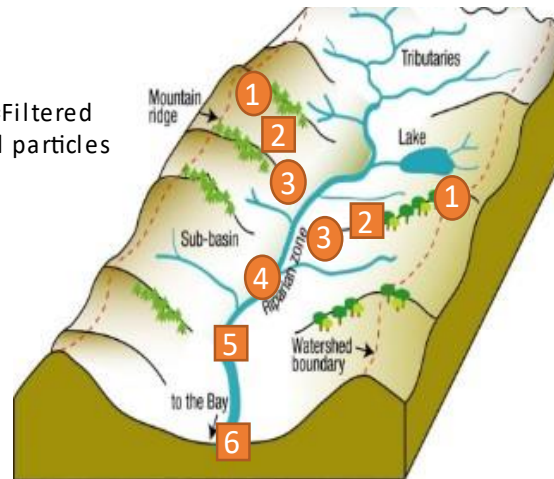
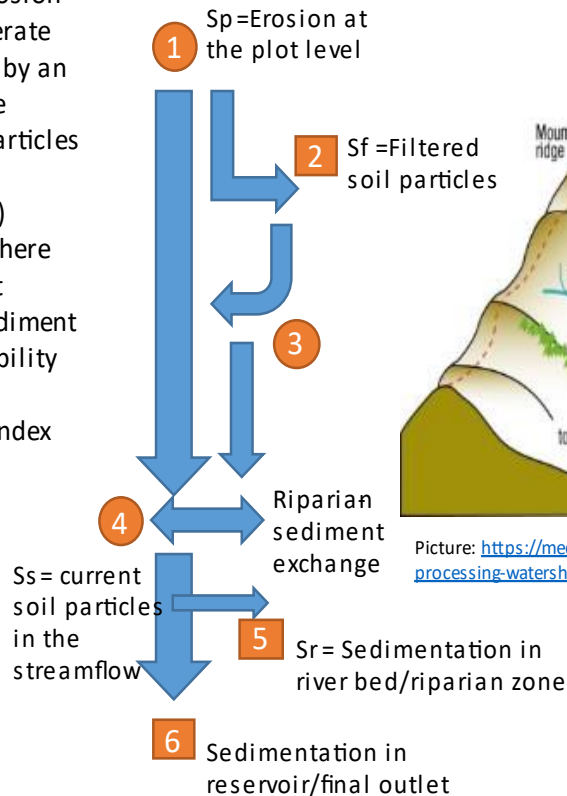
Erosion-Sediment Model in GenRiver Model

Semi-distributed model

1. Soil particles in the soil profiles throughout the landscape; erosion linked to conditions that generate overland flow and controlled by an 'entrainment' factor (see Rose equation) will transfer soil particles

2. Soil particles (temporarily) trapped in 'filter' locations where overland flow loses sediment and/or infiltrates, leaving sediment at the surface -> vegetation ability to filter the soil particles, conservation actions, slope index

3. if the filter function is affected and/or the overland flow arriving in the filter locations exceeds what its vegetation can cope with, soil particles can be transferred to stream



Picture: <https://medium.com/@dhairya.vavada/intuitive-image-processing-watershed-segmentation-50a66ed2352e>

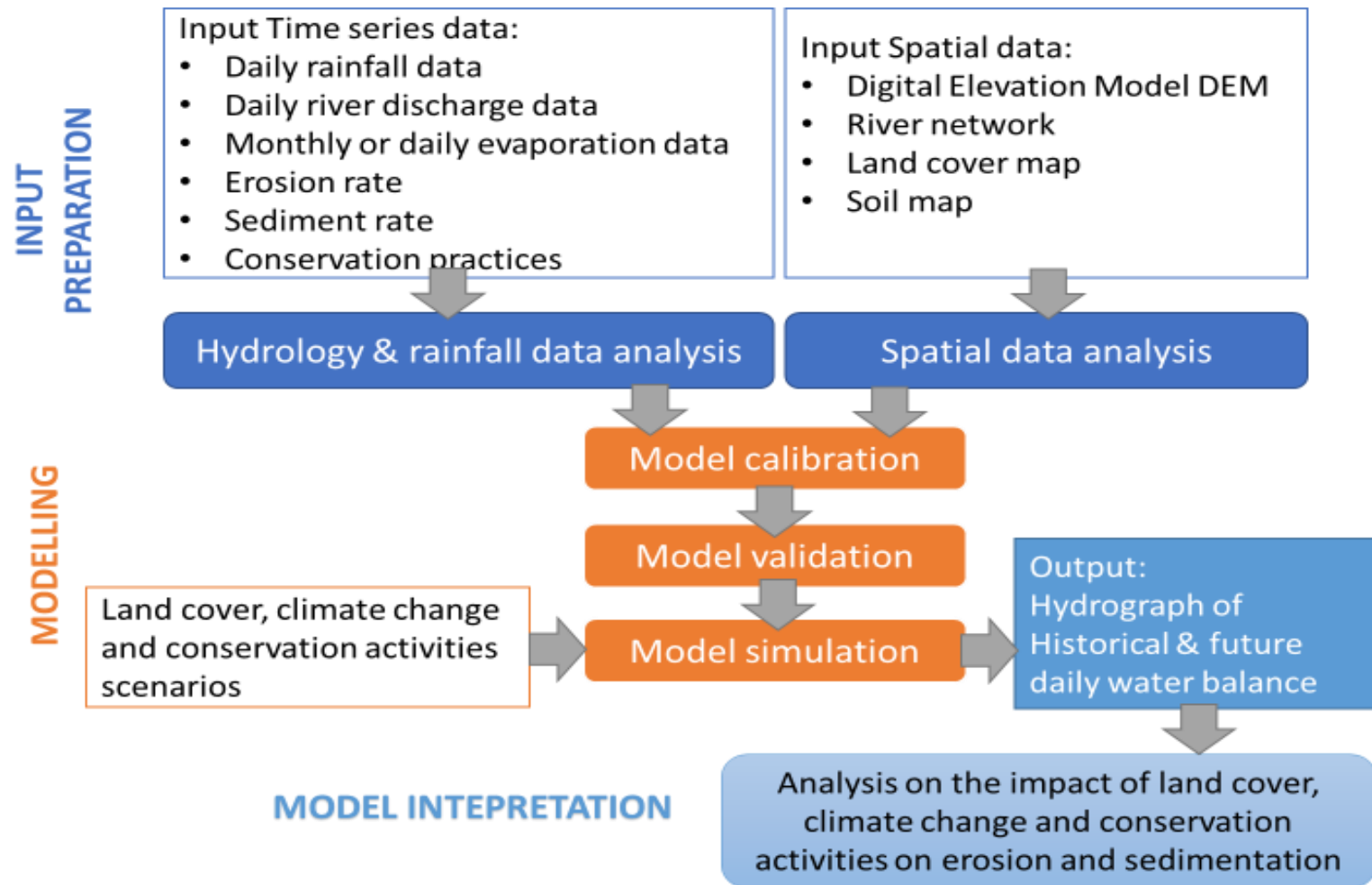
4. Soil particles in current streamflow, derived from S_p and/or S_f in two-way exchange with S_r , or trapped in S_l -> sediment transport capacity and flow velocity

5. Soil particles (temporarily) deposited in the riparian zone and/or river bed, in a two-way exchange with S_s -> stream formation (flow velocity, river bend)

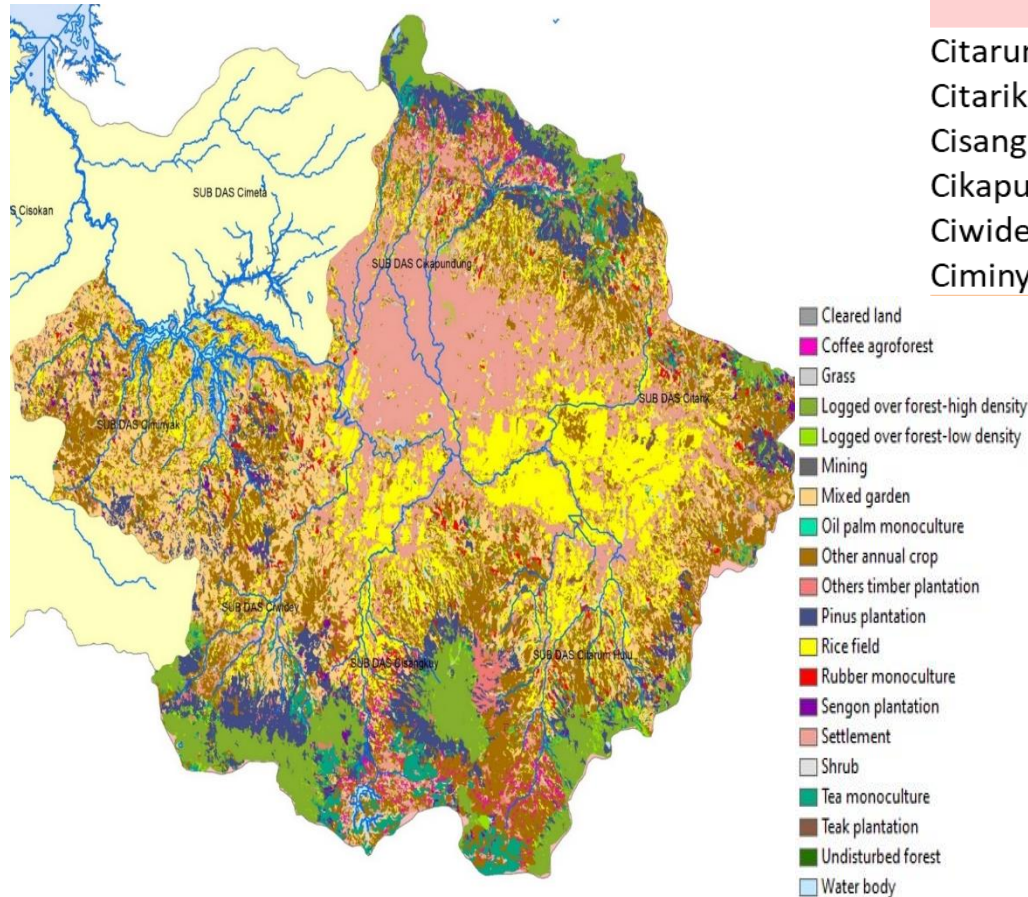
6. Soil particles (semi)permanently deposited in reservoirs or lakes (unless dredged or affected by dam-breaks)



Modeling Input-output and Proses of Genriver 3.0



Upstream Citarum Watershed



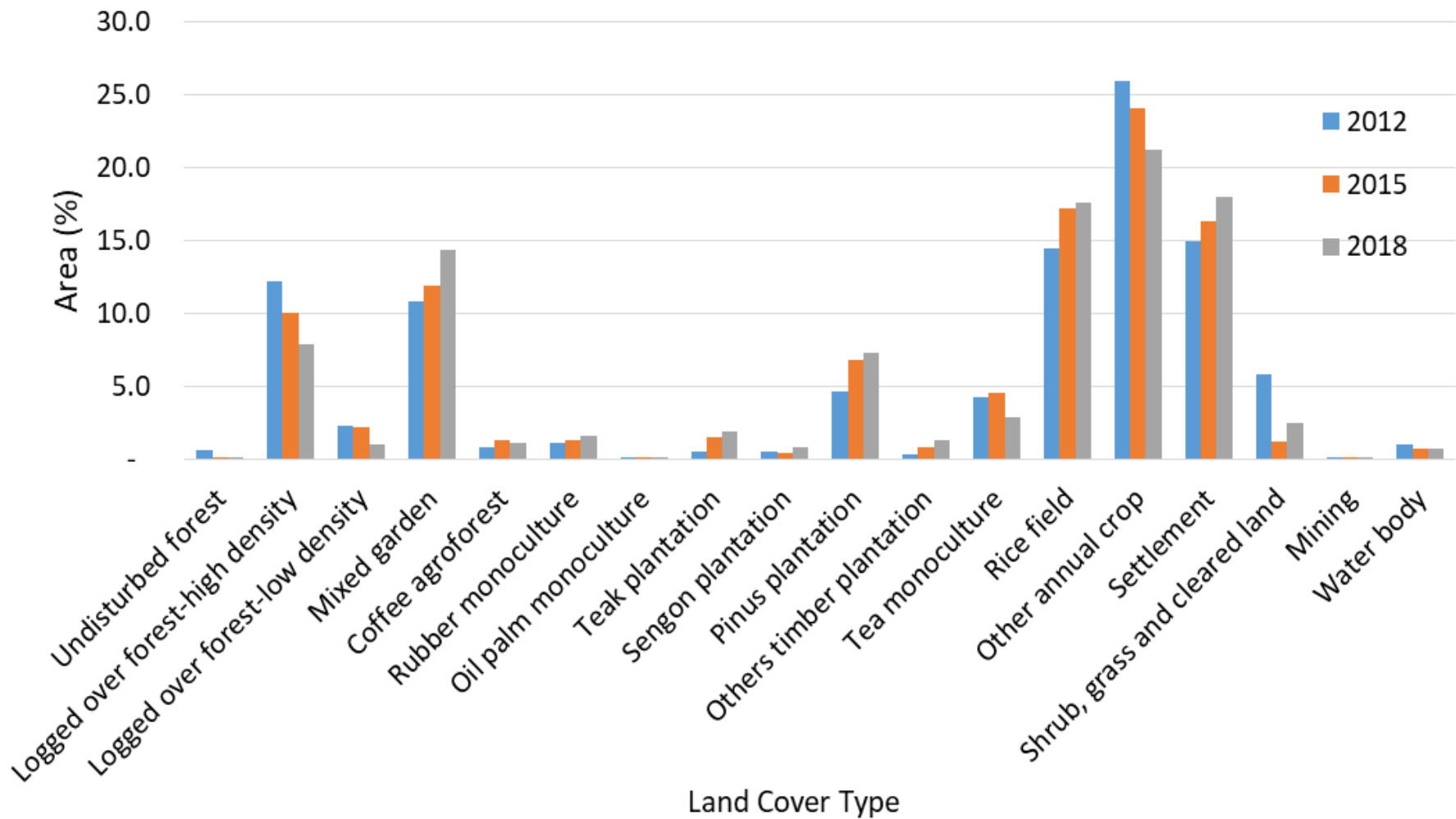
Sub-DAS	Area (km ²)	Jarak ke Saguling
Citarum Hulu	375	88.5
Citarik	459	78
Cisangkuy	305	78.3
Cikapundung	400	72.3
Ciwidey	270	59.8
Ciminyak	322	5

Upstream Citarum river with its outlet of Saguling riservoir:

1. Cirasea
2. Citarik
3. Cisangkui
4. Cikapundung
5. Ciwidey
6. Ciminyak

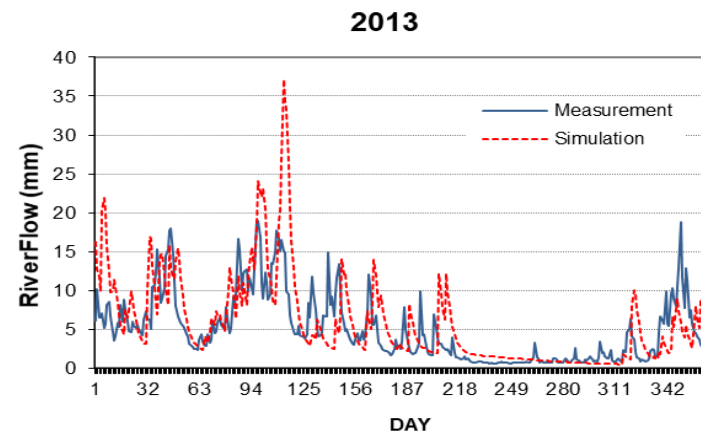
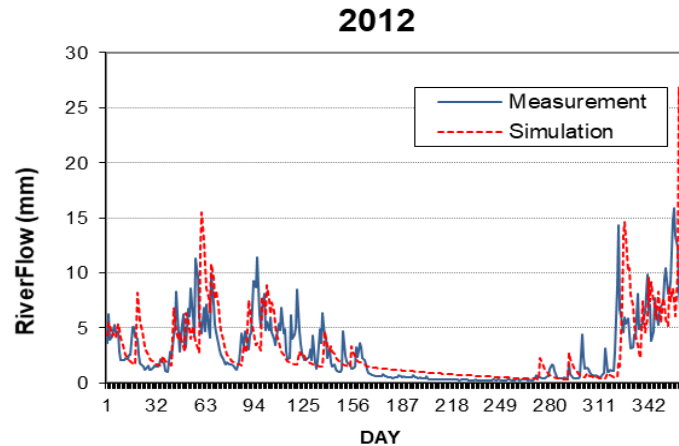


Land Use Changes in Upstream Citarum



Calibration and Validation – Water Balance

Calibration and validation use discharge data from Nanjung station and rainfall data from Cicalengka, Bojong Soang and Hantap Stations.



Year	n	Biased (%)	NSE	r	Biased (%)	NSE
2012	12	9.14	0.84	0.94	Very good	very good
2013	12	17.52	0.56	0.91	satisfactory	satisfactory
2014	12	-11.46	0.82	0.96	good	very good
2015	12	51.59	-0.34	0.67	unsatisfactory	unsatisfactory
2016	12	0.42	-0.65	0.25	Very good	unsatisfactory
2017	12	-21.40	0.62	0.81	satisfactory	satisfactory

(MSE: mean square error, and the related normalization, NSE: Nash-Sutcliffe Efficiency)



Soil Conservation Parameter

No	Types of conservation activities		Censervation value
1	Terraces	Good condition/quality	0.04
		Moderate condition/quality	0.15
		Poor condition/quality	0.35
2	Traditional terraces		0.4
3	Strip grass	Good condition/quality	0.04
		Poor condition/quality	0.4
4	Contour line planting	Slope 0-8%	0.5
		Slope 9-20%	0.75
		Slope >20%	0.9
5	Mulching	6 ton/ha/tahun	0.3
		3 ton/ha/tahun	0.5
		1 ton/ha/tahun	0.8
6	Permanent vegetation cover	High density	0.1
		Moderate density	0.5
7	Revegetation		0.3
8	Without soil conservation actions		1.0

Source: FAO and Soil Research Institute, IAARD, Bogor. 1978



Calibration and Validation–Erosion & Sedimentation

Erosion calibration and validation at the sub-watershed level refers to research from A Chadar, L Soekarno, A Wiyono et al, 2017

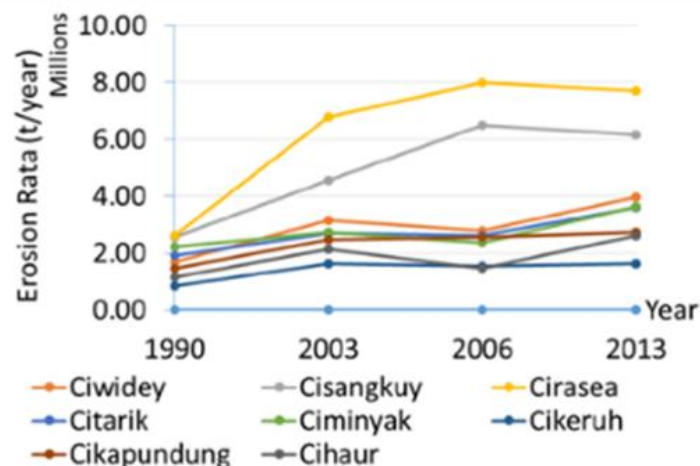
Data 2016

Tabel 4.8. Laju Sedimentasi Waduk Saguling

No.	TMA	Laju Sedimentasi (Juta m ³ / tahun)
1	643	7,83
2	623	4,89
3	616	3,42

Average: 5.38 juta m³/year

GenRiver Simulation, total sediment 2016 in Saguling was 5,363,827 m³/year



CIRASEA	7,530,109
CITARIK	19,432,845
CISANGKUY	5,441,289
CIKAPUNDUNG	6,813,951
CIWIDEY	3,982,947
CIMINYAK	5,262,495

Genriver's Simulation Soil loss to River (Ton/tahun) - 2012



Estimated Erosion Rates (2012 – 2018)

- The Citarik and Cirasea sub-watersheds are the largest contributors to erosion. Based on their land cover, the two sub-watersheds have the highest area of seasonal crops and paddy fields compared to other sub-DAS.
- The Ciwidey sub-watershed is the least contributor to erosion because it has the largest area of secondary forest and mixed gardens compared to other sub-watersheds
- Conservation activities can reduce erosion rates by 7-13% in 2012 – 2018, assuming less than 50% of the area applies soil conservation with poor to moderate conservation quality.



Estimated Sedimentation 2012 - 2018

Sedimentation per year and cumulative Sediment in the Saguling Reservoir

YEAR	Curah Hujan (mm)	Sediment (m3/tahun)	Cumulative Sediment (m3)	Note
2007	No data available	4,500,000	88,644,877	From data (PT Indonesia Power)
2008		4,500,000	93,144,877	Assumption
2009		4,500,000	97,644,877	Assumption
2010		4,500,000	102,144,877	Assumption
2011		4,500,000	106,644,877	Assumption
2012	1851	4,165,407	110,810,284	GenRiver simulation
2013	2891	5,923,403	116,733,687	GenRiver simulation
2014	2034	4,170,365	120,904,052	GenRiver simulation
2015	1671	3,600,511	124,504,563	GenRiver simulation
2016*	3076	5,363,827	129,868,390	GenRiver simulation
2017	1939	3,796,447	133,664,838	GenRiver simulation
2018	2151	4,509,464	138,174,302	GenRiver simulation

* Year of validation based on data from Saguling



Simulation Scenarios 2018-2028

Climate Changes (Rainfall Intensity):

- Low (20 mm/sec); Med (25 mm/sec); High (30 mm/sec).

Land Cover/Land Use (settlement area and water body constant):

- S1: The government carries out a seasonal crop development program (rice, secondary crops, and vegetables) => by reducing the use of other commodities that are less priority.
- S2: Coffee agroforestry development program by reducing forest land and other wood crops, while rice and other seasonal crops remain constant (as the base year)
- S3: Reforestation program in the state forests by reducing mix garden and coffee agroforest.

Soil Conservation:

- S1: <50% of areas implement soil conservation activities
- S2: >50% of areas implement soil conservation activities



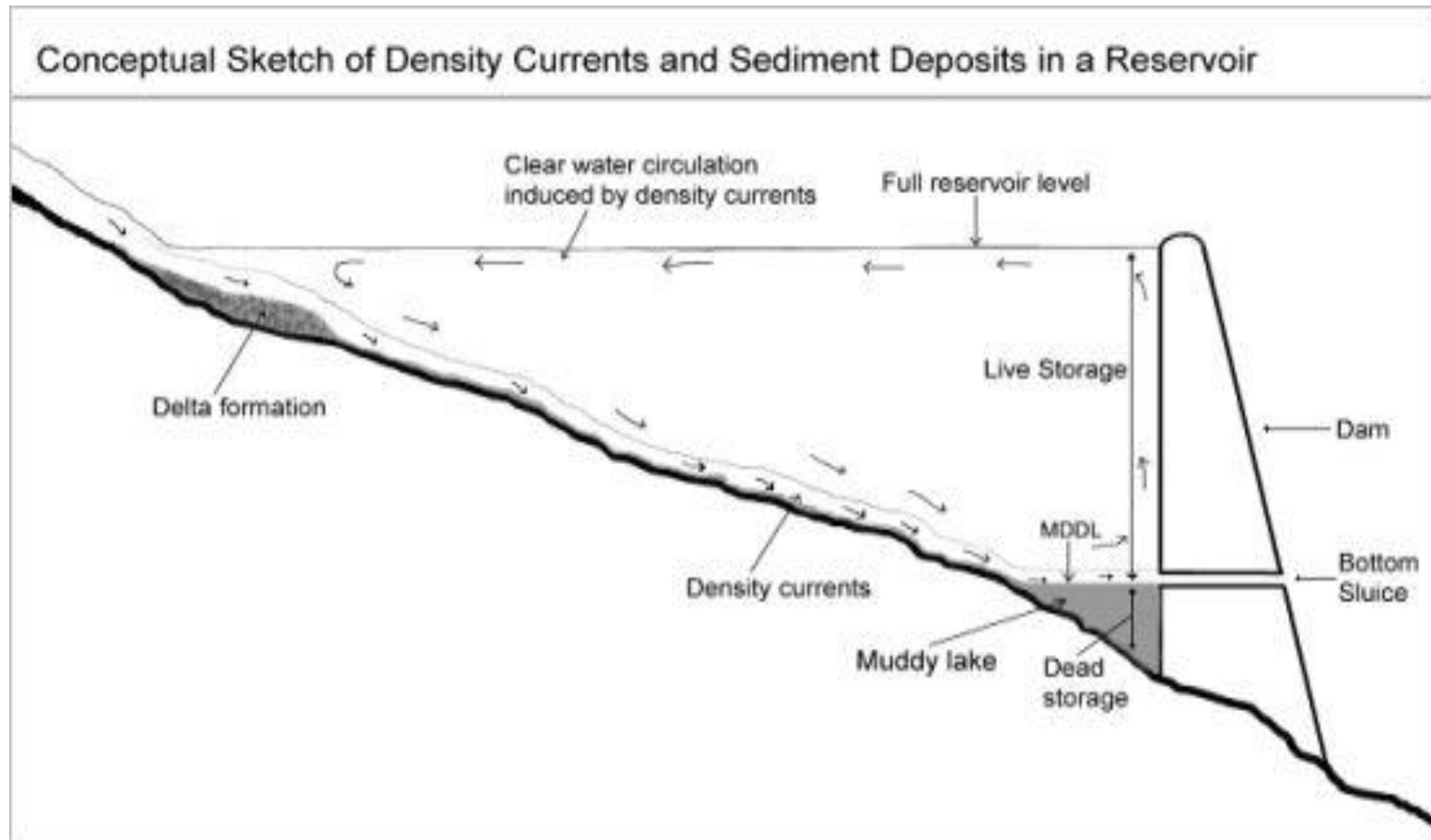
Simulation Scenarios And Results:

(% Increase Of Sedimentation)

Scenario areas that apply soil conservation	Scenario of land cover	Climate change scenario		
		Low rainfall intensity (I = 20 mm/second)	Moderate and actual rainfall intensity (I = 25 mm/second)	High rainfall intensity (I = 30 mm/second)
<50% of areas implement soil conservation activities	Scenario 1	28.51%	29.44%	30.07%
	Scenario 2	28.31%	29.39%	30.04%
	Scenario 3	28.09%	29.05%	29.72%
>50% of areas implement soil conservation activities	Scenario 1	27.18%	28.00%	28.55%
	Scenario 2	26.97%	27.95%	28.55%
	Scenario 3	26.79%	27.65%	28.26%



Conceptual Sketch of Dead Storage Level of Sediment



Dead Storage: 167.6 juta m³



Estimated Sedimentation in Saguling Reservoir

Estimated cumulative sedimentation (million m³) in the Saguling Reservoir 2018-2028

Year	More than half (>50%) areas implement soil conservation								
	Scenario 1			Scenario 2			Scenario 3		
	I = 20	I = 25	I = 30	I = 20	I = 25	I = 30	I = 20	I = 25	I = 30
2018	136.59	138.17	139.35	136.59	138.17	139.34	136.59	138.17	139.35
2019	140.05	141.84	143.10	139.91	141.69	142.95	139.91	141.69	142.95
2020	144.15	146.11	147.50	143.66	145.57	146.95	143.66	145.57	146.94
2021	148.40	150.54	152.13	147.41	149.47	151.00	147.38	149.43	150.96
2022	152.86	155.36	157.19	151.17	153.48	155.18	151.08	153.39	155.07
2023	156.49	159.22	161.25	154.26	156.73	158.55	154.14	156.60	158.41
2024	160.34	163.35	165.56	157.39	160.02	161.95	157.24	159.85	161.75
2025	165.37	168.75	171.18	161.14	163.96	166.00	160.85	163.66	165.67
2026	171.87	175.74	178.46	165.52	168.59	170.79	165.05	168.11	170.25
2027	175.36	179.43	182.36	168.31	171.46	173.75	167.79	170.92	173.15
2028	181.50	185.89	189.04	172.25	175.50	177.87	171.53	174.73	177.02

Dead Storage sediment: 167.6 million m³



Conclusion and Recommendation (1)

- The simulation results show that expansion of food and seasonal crop farming (scenario-1) increases sedimentation faster than other scenarios of expanding mixed garden and agroforestry and reforestation of the state forest areas.
- The state forest restoration program, combined with better conservation practices in the agriculture and plantation area, reduces erosion in the upstream Citarum and the sedimentation rates in the reservoir.
- In addition to land cover management in the Upstream Citarum areas, management of riverbanks with more trees can help reduce soil entering rivers and the sedimentation rates in the reservoir.



Conclusion and Recommendation (2)

- The limited data and parameters make the model validation process inaccurate, which may result in overestimation or underestimation of erosion and sedimentation rates.
- Therefore, measuring erosion rates at several outlets and the sedimentation rates in the reservoir needs to be carried out towards sustainable land management and farming practices in the upstream Citarum watershed and sustaining the reservoir's lifespan.



THANK YOU

