Understanding Future Urban Flood Risk Through Compound Environmental Drivers and Building-Level Damage Assessment

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INTRODUCTION

Rapid urban expansion and shifting hydrometeorological regimes in the Upper Citarum watershed have **critically aggravated flood vulnerability** in Bandung City. This research develops an integrated modeling framework to evaluate baseline (2025) and future (2045) flood hazard and risk through three core focuses:

- **Compound Driver Coupling:** Integrating historical and projected Land cover changes (2000–2045) from CA-Markov with bias-corrected CMIP6 extreme rainfall scenarios (SSP5-8.5) and dynamic terrain elevation adjusted for localized land subsidence.
- **2D Hydrodynamic Simulation:** Quantifying spatiotemporal inundation extent, depth, and hazard-class shifts across 5-, 25-, and 100-year return periods using HEC-RAS.
- **Building-Level Damage Assessment:** Overriding static vulnerability by intersecting hydrodynamic hazard outputs with 23,030 individual building footprints and empirical fragility curves to quantify structural damage ratios and potential economic losses.

Keywords: *Urban Flood Modeling, Land Cover Dynamics, HEC-RAS 2D, Building Vulnerability, Spatial Planning.*

RESULTS AND DISCUSSION

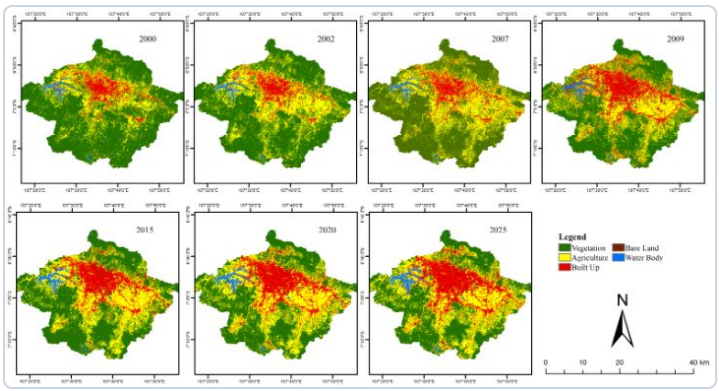


Figure 2. Land cover classification maps during 2000-2025

LAND COVER DYNAMICS: AREA AND CHANGE (2025-2045)

Land Cover	2025 AREA		2045 AREA		CHANGE (2025-2045)	
	km²	%	km²	%	km²	Percentage point
Vegetation	946,11	40,50	727,52	31,15	-218,60	-9,36
Agriculture	838,47	35,90	821,37	35,16	-17,10	-0,73
Built-up	458,22	19,62	677,64	29,01	219,43	9,39
Bare Land	41,85	1,79	53,92	2,31	12,07	0,52
Water Body	51,18	2,19	55,38	2,37	4,20	0,18

Red = Decrease, Blue = Increase

Figure 3. Future Land Cover Projection (2025–2045)

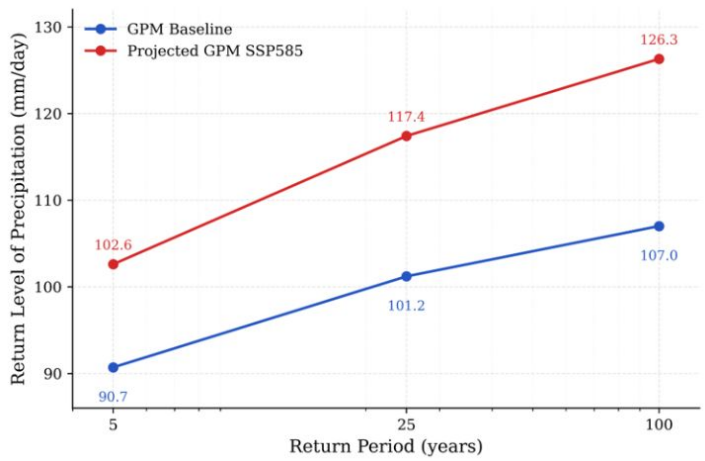


Figure 4. Daily design rainfall for the 5-, 25- and 100-year return periods under the bias-corrected IMERG baseline and the SSP5-8.5 projection

RESEARCH METHODS

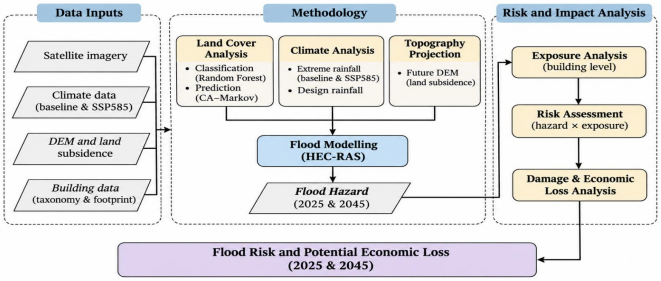
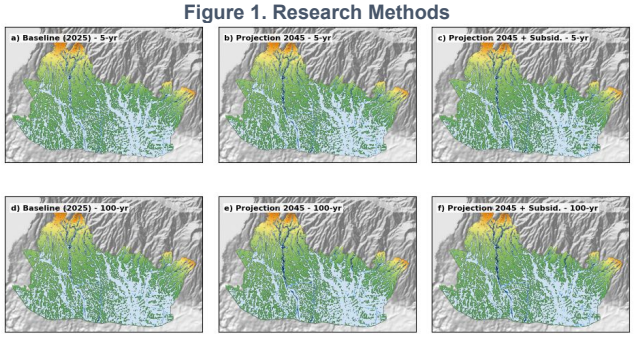


Figure 1. Research Methods



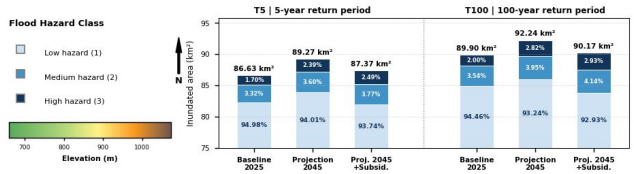


Figure 5. Flood Hazard Class

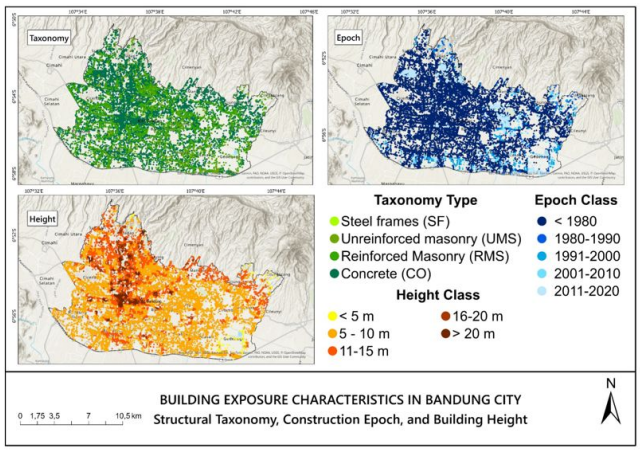


Figure 6. Spatial Heterogeneity of Building Structural Taxonomy, Construction Epoch, and Height Across Bandung City.

CONCLUSION

- **Land Cover Dynamics:** Vegetation cover decreased by 27.47% (2000–2025) and is projected to drop by 31.15% by 2045, while built-up areas will expand to 29.01%.
- **Future Flood Vulnerability:** Driven by SSP5-8.5 extreme rainfall and land cover shifts, total inundation will increase by 3.04% to 2.60%, with severe hazard zones surging ~44.5%.
- **Influence of Land Subsidence:** Subsidence causes a 2.13% to 2.24% decrease in total inundation, but high-hazard zones persist at elevated levels (+1.6% to 1.9%).
- **Primary Conclusion:** Assessing both total inundation extent and hazard severity is critical for robust urban flood mitigation and sustainable spatial planning.

LIMITATION AND FUTURE STUDY

- **Input data:** No independent land cover validation or socioeconomic drivers; subsidence validated at a single GNSS station. **Future work:** independent validation and socioeconomic drivers.
- **Modeling:** Ensemble-mean climate signal, daily rainfall, no drainage infrastructure, city-bounded domain. **Future work:** multi-model uncertainty, sub-daily rainfall, and a domain extended to the Citarum.
- **Risk:** Modeled building attributes, literature-based damage curves, direct losses only. Future work: local calibration and indirect losses.