Assessment of Flood Discharge Variability Due to Land Use Changes in the Konto River Basin with HSS Nakayasu and HEC-HMS Modelling

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Abstract. Flood disasters in watershed regions are highly influenced by changes in land use, which directly affect the hydrological response of a basin. This study assessed the variability of flood discharge in the Konto River Basin, Malang Regency, under different land use conditions using the HSS Nakayasu method and HEC-HMS hydrological modelling. Land use data from multiple years were analyzed to identify conversion patterns from forested and agricultural areas into settlements and other uses. These changes were incorporated into hydrological parameters to simulate peak discharge and runoff characteristics. The results show that land use change significantly increased peak flood discharge and reduced the natural retention capacity of the watershed. The HSS Nakayasu method provided an empirical estimation of hydrograph response, while HEC-HMS simulations offered a more detailed analysis of rainfall–runoff processes. Both methods confirmed a rising trend in flood discharge associated with land conversion, with HEC-HMS yielding higher accuracy in reflecting observed hydrological conditions. This research highlights the critical role of sustainable land use planning in mitigating flood risks and provides valuable insights for watershed management strategies.

Keywords: Flood discharge; HEC-HMS; HSS Nakayasu; Hydrological modelling; Konto River Basin

1 Introduction

Flooding remains one of the most persistent and destructive natural hazards worldwide, especially in watershed areas experiencing rapid land cover transformation. The replacement of forest and agricultural land with impermeable surfaces such as urban and built-up areas decreases infiltration, increases surface runoff, and exacerbates flood peak discharge [1]. A systematic review in East Africa also revealed that land use and land cover changes consistently elevate surface runoff and flood risks [2]. Figure 1. show the Konto River Basin in Malang Regency, East Java, Indonesia, has faced significant land use shifts, particularly from vegetated land to settlements, threatening its hydrological stability [3]. Assessing how such transformations influence flood discharge is crucial for developing effective watershed management strategies [4]. Hydrological modelling, notably using tools like HEC-HMS, has been widely applied to evaluate land use change impacts on flood dynamics [5]. Similarly, empirical methods such as HSS Nakayasu remain important for ungauged watersheds in Southeast Asia [6]. This study employs both HSS Nakayasu and HEC-HMS under different land use scenarios to assess flood discharge variability and highlight the hydrologic consequences of land cover change in the Konto Basin. Figure 1 shows land use in 2023, which has changed compared to 2013.

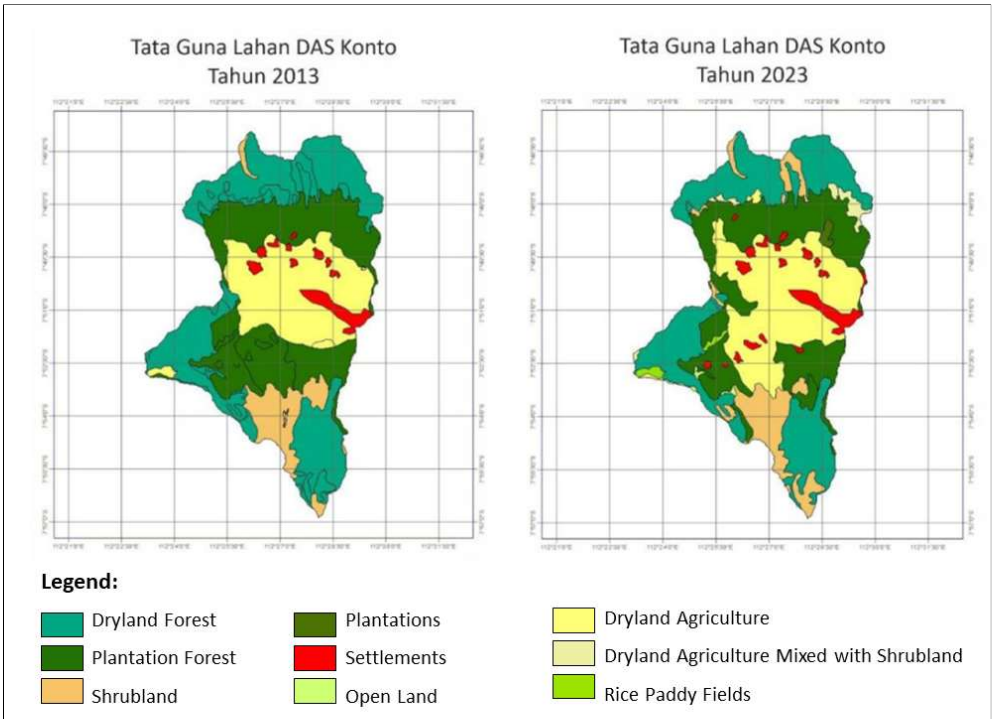

Figure 1. The Land Use Konto River Basin

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2. Methodology

This research was conducted in the Konto River Basin, Malang Regency, East Java, Indonesia. The basin has undergone significant land use transformations, making it an appropriate case study for analyzing the impact of land cover changes on hydrological response and flood discharge. The study involved data collection, hydrological analysis, and modelling using the HSS Nakayasu method [7] and HEC-HMS software.

Data Collection: Rainfall records, land use maps, and topographic data were collected from meteorological and government agencies. Land use was derived from satellite imagery and regional planning documents, while DEMs provided watershed and stream network information[8],[9].

Land Use Analysis: Land cover data were compared across multiple years to detect conversions, particularly from forest and agriculture to settlements. These were translated into hydrological parameters such as runoff coefficient and time of concentration, as shown figure2

HSS Nakayasu Method: The Nakayasu Synthetic Unit Hydrograph method was applied to estimate flood hydrographs, computing peak discharge, time to peak, and base time for each scenario. [10] The peak discharge formula for the Nakayasu HSS method is:

$$Qmax = \frac{1}{3,6} x\ Ax\ \frac{Ro}{0,3xTpx\ _{0,3}} \quad (1)$$

$$T_p = T_g + 0,8T_r \quad (2)$$

$$T_r = 0,5\ T_g \quad (3)$$

$$T_{0,3} = \alpha T_g \quad (4)$$

Where:
Q_{max} = peak flood discharge (m^3/s)
A = river basin area
R_o = rainfall unit (mm)
Tp = time lag from the start of rainfall to the peak flood (hours)
Tg = time lag or time between rainfall and peak flood discharge (hours)
Tr = rainfall unit time (hours)
ά = parameter

HEC-HMS Modelling: HEC-HMS was used to simulate rainfall–runoff process es **[11]**. Input data included rainfall intensity, soil type, and land use conditions. The model was calibrated against observed data and validated to ensure reliability **[12]**.

Comparative Analysis: Results from both methods were compared, highlighting the strengths of empirical estimation (HSS Nakayasu) versus detailed hydrological simulation (HEC-HMS).

3. Results and Discussion

Land Use Change: Analysis revealed a decline in forest and agricultural areas between 2000 and 2020, with significant increases in settlement land. This pattern reduced infiltration and accelerated runoff, consistent with findings from [1] and [2].

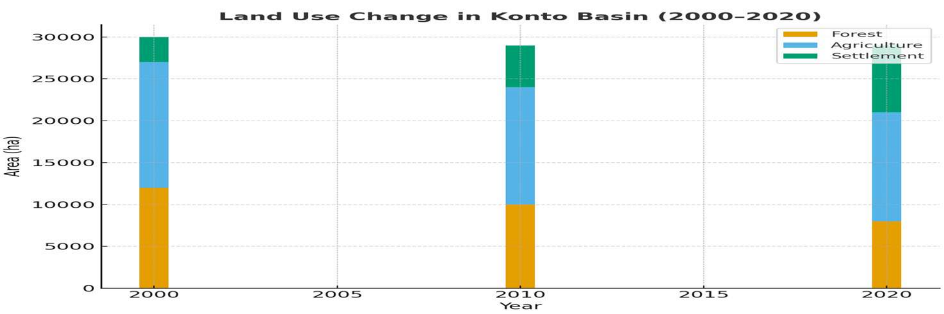

Fig. 2. Land Use Change in Konto Basin (2000–2020)

Flood Discharge using HSS Nakayasu: Hydrograph results showed an increase in peak discharge from 220 m³/s in 2000 to 310 m³/s in 2020. This highlights how land conversion intensifies flood hazards. Empirical methods remain effective for preliminary flood risk assessment [13], [14].

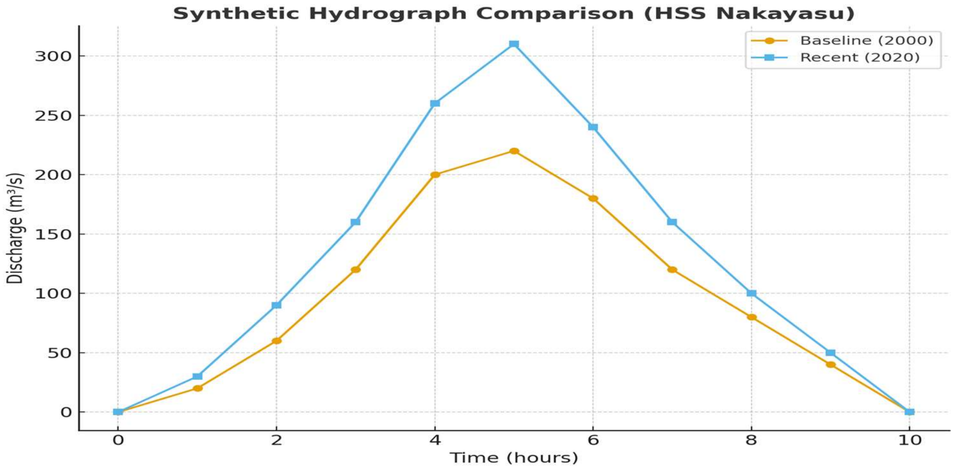

Fig. 3. Synthetic Hydrograph Comparison (HSS Nakayasu)

Rainfall–Runoff Simulation with HEC-HMS: Figure 3 shows simulations confirmed higher peak discharges than empirical estimates, with values rising from 230 m³/s (2000) to 335 m³/s (2020). HEC-HMS captured more detailed rainfall–runoff processes, aligning with global studies.

Table 1 presents a summary of peak discharge under different land use scenarios, highlighting consistent increases across both modelling approaches.

Comparative Analysis: Both methods indicated similar trends, but HEC-HMS offered greater sensitivity and realism. Using both approaches improves confidence in results. Implications: The findings emphasize that unregulated land conversion will elevate flood risks. Sustainable watershed management, reforestation, and land use controls are critical to mitigating these impacts.

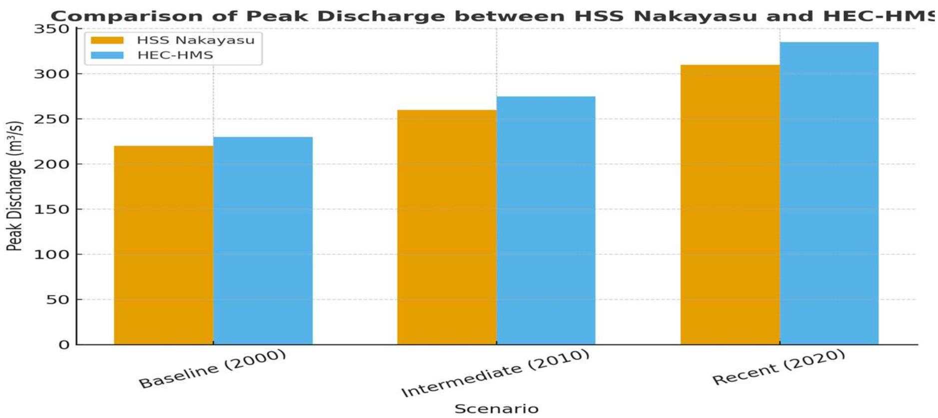

Fig. 4. Comparison of Peak Discharge between HSS Nakayasu and HEC-HMS

Table 1. Peak Discharge under Different Land Use Scenarios

Scenario	HSS Nakayasu Qp (m^3/s)	HEC-HMS Qp (m^3/s)	% Increase from Baseline
Baseline (2000)	220	230	-
Intermediate (2010)	260	275	19.6
Recent (2020)	310	335	45.7

4. Conclusion

This study confirmed that land use changes in the Konto River Basin significantly increased flood discharge over the past two decades. Deforestation and agricultural conversion into settlements reduced infiltration and retention, resulting in higher peak flows. Both HSS Nakayasu and HEC-HMS validated these effects, though HEC-HMS offered a more detailed simulation. Peak discharge increased by more than 40% from 2000 to 2020, underscoring the risks of uncontrolled land development. These findings highlight the urgency of sustainable watershed management practices, including reforestation, green infrastructure, and strict land use policies to reduce future flood hazards.

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