UNIVERSITI TEKNOLOGI MARA

# DEVELOPMENT AND APPLICATION OF AN IMPROVED INTERCEPTION LOSS MODEL INCORPORATING TEMPORAL RESOLUTION AND DEPTH OF STORAGE EFFECTS

**AZINOOR AZIDA BINTI ABU BAKAR**

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# ABSTRACT

In tropical forest ecosystems, the interception of rainfall by vegetation plays a crucial role in hydrological processes, significantly influencing the redistribution and availability of water resources. This study aims to enhance the accuracy of interception loss estimation by proposing a novel framework that integrates the temporal resolution of precipitation data with the depth of canopy storage, addressing existing deficiencies in interception models. The research encompasses theoretical model development, laboratory experiments, and field measurements, with findings validated against established interception models, including the Gash and modified Gash models. The theoretical aspect introduces an interception loss model that correlates annual rainfall with canopy storage depth, represented by the function $I_{L,0} = f(P, d)$, where $P$ denotes yearly precipitation, and d signifies canopy storage depth. This model is refined to incorporate the effects of temporal resolution (*TR*), utilizing a slope function that improves predictive accuracy across varying temporal scales of rainfall. Laboratory experiments conducted with broadleaf tropical plants, such as *Dracaena Sanderiana* and *Breynia Distincha*, reveal the significant influence of plant structure, canopy density, and rainfall intensity on interception loss. The results indicate a strong positive correlation ($r$ = 0.76) between precipitation and interception loss, with reduced Root Mean Square Error (RMSE) values when accounting for temporal resolution effects. Field measurements taken in Bukit Lagong Reserve Forest, Malaysia, provide insights into interception dynamics under real-world conditions, with data from two forest plots (Plot 11 and Plot 12) showing variations in interception loss influenced by canopy cover and rainfall intensity. Regression analysis yields $R^2$ values ranging from 0.31 to 0.65, demonstrating distinct relationships between interception loss and gross rainfall for each plot. Although the developed model slightly underestimates interception loss compared to field measurements, it offers improved estimates over the Gash and modified Gash models, which can overestimate interception loss by up to 45%. The focus on temporal resolution represents a significant advancement, as it is often overlooked in interception modeling. By utilizing high-resolution rainfall data, the model's accuracy is markedly improved, overcoming the limitations of previous models reliant on aggregated data. The incorporation of temporal resolution variability allows for more precise predictions, particularly in the dynamic rainfall regimes typical of tropical regions. Furthermore, this study explores the impact of plant species and canopy structure on interception loss, with results that have broad implications for enhancing rainfall partitioning models and promoting sustainable water resource management. The model's adaptability across various forest types is further validated through real-world data, establishing it as a versatile tool for hydrological studies, particularly concerning interception loss on a global scale. In conclusion, this research makes a significant contribution to the field of hydrology by addressing critical gaps in interception modeling. By incorporating canopy storage depth, temporal resolution effects, and validation through laboratory and field studies, the developed model provides a more accurate representation of interception loss. Its applications extend beyond academic research, offering practical solutions for water resource management and forest sustainability.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Research Background

Rainfall is a key input for all scientific studies dealing with the hydrological cycle. Rainfalls on the basin is first intercepted by vegetation before they reach the ground surface. Raindrops which are not intercepted but fall directly on the ground constituted the throughflow. Meanwhile, intercepted rainwater may still reach the ground level as stemflow. Intercepted rain water is usually lost through evaporation eventually. Meanwhile, rain water which ended on the ground level may undergoes soil infiltration to increase the soil moisture and groundwater recharge. The excess water flows away as surface runoff and is responsible for basin erosion process.

By definition, interception loss is the proportion of precipitation which retained by vegetation during and after a precipitation event and afterwards evaporates back to the atmosphere from the canopy surface (Crockford & Richardson, 2000). It is a significant process that impact the availability and dissemination of rainfall to other hydrological processes (He et al., 2014; Sajikumar and Remya, 2015; Zheng et al., 2019). The amount of rainfall that is lost to interception is influenced by the rainfall characteristics and the climate variables that regulate the evaporation rates both during and after rainfall events ((Muzylo et al., 2009) Rutter et al., 1975; Ward and Robinson, 2000; Dingman, 2002; Brutsaert, 2005).

Besides climatic factor, interception quantity is also dependent on the structure of the forest, including tree size, crown structure and bark morphology (Pflug et al., 2021). In general, forests with high canopy cover and tree species with a higher leaf area index (LAI) have higher rainfall interception rate (Yang et al., 2019). Carlyle-Moses (2004) found that the proportion of total rainfall that is lost due to interception in a rainfall event is around 13% in tropical rainforests. Interception loss values range from 10 to 50% of the annual or season-long total rainfall when it is measured over forested canopies (Carlyle-Moses and Gash, 2011). It accounts for 20,100 ± 9,800 $km^3$ of water annually on a global scale (Coenders-Gerrits et al., 2014).