EVALUATING THE EFFECTS OF CLIMATE CHANGE ON HYDRAULIC GRADIENT AND LANDSLIDE SUSCEPTIBILITY IN THE KEGALLE DISTRICT

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Landslides are considered one of the recurrent natural disasters spread worldwide, causing significant property damages and fatalities. Hydraulic gradient is one of the triggering factors affecting landslide hazards. Depending on the material, landslide bodies can hold a significant amount of groundwater. The effect of the hydraulic gradient is discussed in terms of decreasing suction head, rising groundwater table, groundwater exfiltration from bedrock, and hydraulic uplift pressure below the landslide. Furthermore, Climate change causes changes in rainfall regime and evapotranspiration, which reduces the amount of water recharge aquifers. As a result, the hydraulic gradient increases resulting in groundwater flowing faster and being depleted more quickly. This dynamic maturity of the hydraulic gradient and its spatial variation can be estimated using a groundwater simulation model.

Kegalle district in Sri Lanka is listed as one of the highly vulnerable areas for landslides by the National Building Research Organisation (NBRO), Sri Lanka. Heavy rainfall generally occurs in the area during the southwest monsoon season, causing variably saturated soil conditions and reducing the shear strength. This study simulated the spatial distribution of hydraulic gradient in an area covering 1,523 km^2 using the United States Geological Survey (USGS) modular finite-difference flow (MODFLOW) model. The study area was divided into 4,148 active square grids with an approximate 70 m × 55 m grid resolution coverage. The area was conceptualised as a single-layer aquifer with an average depth of 200 m. The model's upstream and downstream sides were considered constant head boundaries, and their magnitudes were estimated by drawing equipotential lines using groundwater level data at nine observation wells in the study area. Annual total rainfall during the 2007-2017 period at the Holombuwa rain gauge station was used to estimate the groundwater recharge. The model was run in a steady state and the hydraulic conductivity, groundwater recharge, and river conductance parameters were calibrated using observations at nine wells. When projecting future rainfall, outputs from the CNRM-CM6-1-HR Global Climate Model (GCM) for two shared socioeconomic pathways (SSP3-7.0 and SSP5-8.5) were downscaled using the quantile mapping method to the local scale for the near-term (2020-2050) and the long-term (2070-2100) periods. The increase in the annual average rainfall for each scenario was calculated and the same percentage of change was assumed for groundwater recharge in estimating hydraulic gradient in the future.

Past events in the study area categorised as landslides, slope failures, and cutting failures recorded by the NBRO were obtained for the 2016-2021 period. These observed events were compared and matched with simulated hydraulic gradient distributions in the study area. A 60% match for the present period was observed between the landslide observations and the range of hydraulic gradient identified as critical. Future projections indicate a 0.03-1.57% change in landslide-susceptible areas with the greatest changes estimated for the SSP5 scenario.

Keywords: Disaster Management, MODFLOW, Groundwater, GCM, Climate Scenarios

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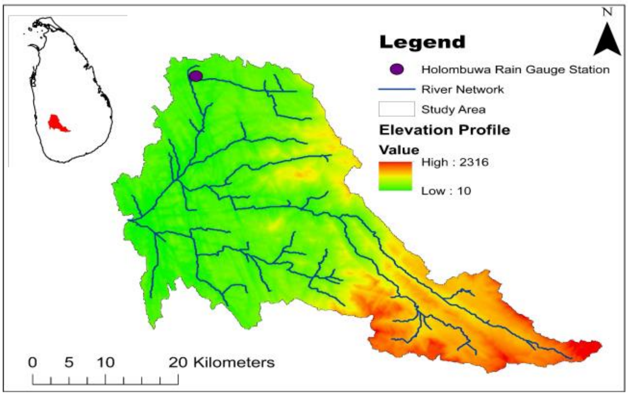

Figure 1: Study Area

Table 1: Rainfall Data

Period		Annual Mean Precipitation (mm)	Increase in Annual Total Rainfall (%)	Increase of Landslide Susceptible Area
Historical (1975 - 2014)		2,766	-	-
SSP 3-7.0	Near-Term Period (2020 - 2050)	2,843	3%	0.03%
	Long-Term Period (2070 - 2100)	3,104	12%	0.08%
SSP 5-8.5	Near-Term Period (2020 - 2050)	2,983	8%	0.05%
	Long-Term Period (2070 - 2100)	3,435	24%	1.57%

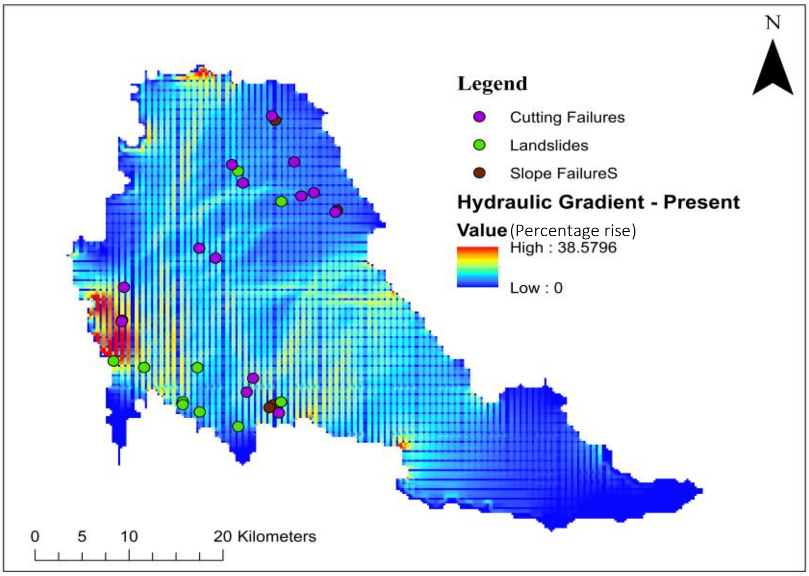

Figure 2: Relationship between Hydraulic Gradient and Landslide for the Base Line Period