Canopy Elevation Controls Soil Erosion under Natural and Simulated Rainfall: Field and Rainfall Simulator Evidence

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1. INTRODUCTION

Soil erosion on forested slopes depends on canopy-modified rainfall and soil resistance. Canopy interception alters throughfall amount, drop size, and kinetic energy, producing spatially variable erosion, while soil properties and experimental methods further affect responses. The independent effect of canopy elevation on event-scale soil loss remains unclear. This study quantifies soil loss across canopy elevations under natural and simulated rainfall and compares responses of decomposed granite (DG) and silica sand (SS) soils.

2. METHOD

Field and laboratory experiments at Ritsumeikan University (BKC) used identical sediment boxes filled with DG and SS to measure soil loss under same-species canopies at three elevations. Outdoor experiments covered 19 rainfall events, while indoor tests included 32 rainfall-simulator runs at a constant 100 mm rainfall depth and four intensities; sediment export was collected separately by soil type and elevation.

3. RESULT

In both outdoor and indoor experiments, soil loss increased with canopy elevation. Under natural rainfall, DG generally produced higher event scale and rainfall-normalized losses than SS, with the DG–SS contrast strengthening from low to high elevation. Under simulated rainfall, erosion also increased with canopy distance, but SS typically showed higher and more variable losses than DG, especially at high elevation. Normalized soil loss (g/mm) showed a clear elevation effect in both datasets, but the dominant soil type differed between field and simulator conditions.

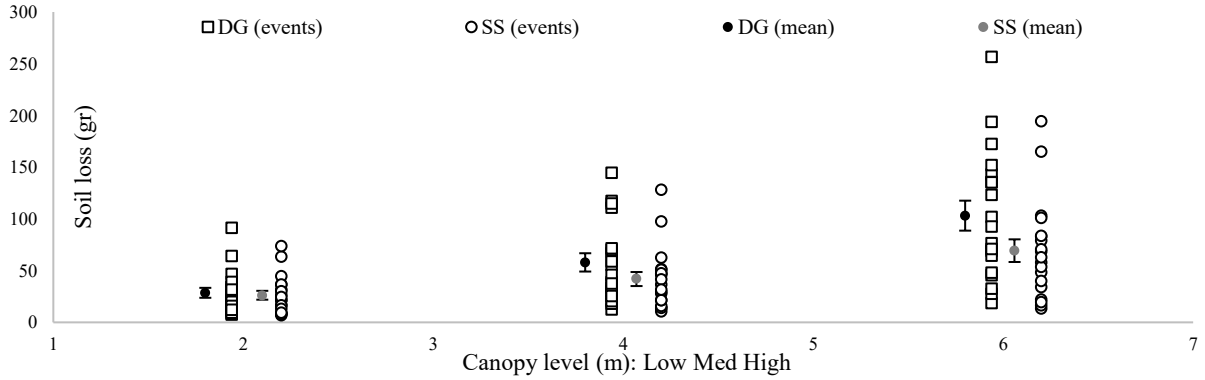
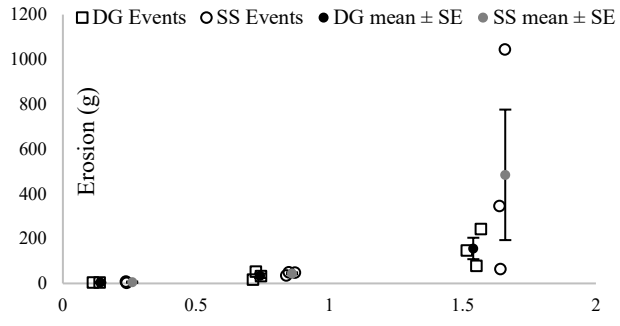
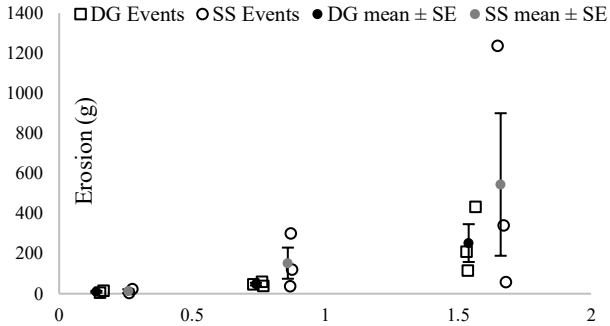


Fig. 1 Event scale soil loss under natural rainfall at canopy elevations of 2, 4, and 6 m for DG and SS. Each open marker represents one rainfall event (n = 19 per elevation). Filled markers indicate the mean, and vertical error bars show the standard error (SE).



(a) Indoor sim, 50mm: canopy height (m)



(b) Indoor sim, 100 mm: canopy height (m)

Fig. 2 (a–b) Indoor rainfall-simulator soil loss at three elevations under two rainfall totals: (a) 50 mm and (b) 100 mm. Open symbols indicate individual runs, filled symbols the mean, and error bars ±SE for DG and SS.

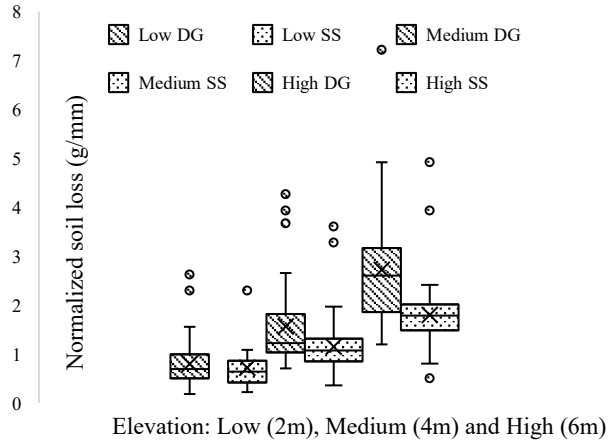


Fig. 3 Outdoor boxplots of rainfall-normalized soil loss (g/mm) for DG and SS across low, medium, and high canopy elevation classes.

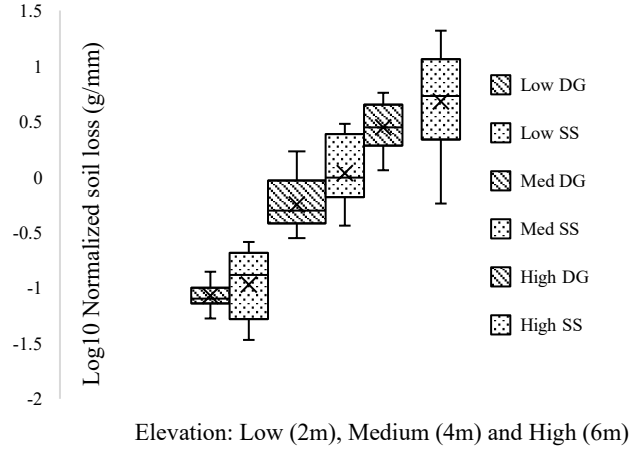


Fig. 4 Boxplots of log10 rainfall-normalized indoor soil loss (g/mm) for DG and SS across low, medium, and high canopy elevations.

4. DISCUSSION

Higher canopy elevation likely increased erosion by enhancing drip drop size, velocity, and throughfall concentration, which increased impact energy and localized detachment. Field results showed greater DG losses, likely due to easier detachment of finer particles, whereas simulator runs often showed larger and more variable SS losses due to granular transport sensitivity and differences between simulated and natural rainfall. Canopy elevation increased soil loss per unit rainfall, so rainfall alone cannot explain erosion risk.

5. CONCLUSIONS

Canopy elevation consistently increased soil loss under both natural and simulated rainfall. DG dominated outdoors, whereas SS was generally higher and more variable indoors, indicating that soil ranking depends on rainfall generation. Normalized results showed greater erosion per unit rainfall at higher elevations, and maximum losses did not always occur during the largest storms. Models should therefore include canopy vertical structure and soil type.

Keywords: canopy elevation, soil erosion, decomposed granite and silica sand