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Limit of mountain growth in the development of experimental landforms

OUCHI, Shunji[1*]

[1]Faculty of Science and Engineering, Chuo University

A series of experiments with rainfall-erosion and uplift of various rates, in which a square (60×60 cm) mound of a mixture of fine sand and kaolinite is uplifted at a constant rate under the artificial mist-type rainfall, suggests the existence of threshold uplift rates. In the run with the uplift rate below the lower threshold, drainage networks develop as the surface is slowly uplifted. The erosion is exclusively fluvial and no high slope develops. When the uplift rate becomes higher than this lower threshold, uplift exceeds erosion on the divides of drainage basins, which developed with fluvial erosion, and hills grow and slope processes start working. The divides grow into low mountain ridges with the uplift and slope failures become dominant. When the relief grows high enough, large landslides occur concentratedly. The average height and relief lower with the landslides, but the ridges soon grow again with the uplift till the next concentration of large landslides, and this process proceeds repeatedly. Uplift and erosion seems to become balanced to keep average height and relief roughly constant and landscapes similar. Assuming the existence of the critical slope controlled by the strength of mound-forming material and the rainfall intensity, the experimental landform is considered to reach a dynamic equilibrium condition at a certain relief regardless of the uplift rate. However, when the uplift rate is in the range between the lower and the upper thresholds, both relief and average height become higher with the uplift at higher rate. A simple equilibrium or steady state seems difficult to be expected with the critical slope. Although the maximum slope in a 1 cm grid becomes higher than 80 degree in all runs, considering that the angle of repose of dried mound-forming material is about 34 degree, it is rather difficult to take this maximum slope as the critical slope. The observation of the experiment suggests that large landslides require triggering events to occur, and without triggering events slopes can grow higher. Large landslides often occur when the rainfall is resumed after halting the rainfall for the measurement. This resumption of rainfall can be the major triggering event in the experiment. The interval of measurement is not exactly constant but does not vary so much among runs. As far as the resumption of rainfall after the measurement is the major triggering event, hills can grow higher with the uplift at higher rate. Moreover, fluvial processes can work more with the uplift at lower rate to widen valleys and therefore increase the area of lower slope. Average slope, relief, maximum height, and average height all become lower. In this way experimental landforms can have average height and relief corresponding to the uplift rate. This condition may be called quasi steady state. When the uplift rate is higher than the upper threshold, on the other hand, relief grows to the limit determined by the width of deposition area. In this case further increase in uplift rate cannot increase the height or relief any more, and this condition apparently does not agree with the condition of equilibrium.

Erosion rate is considered to increase with average slope, and some people pointed out that the relation is nonlinear. In the experiments the average value of the highest slope in a 1 cm grid shows similar linear increase with relief regardless of the uplift rate, but they become to show no clear relationship after relief reaches about 60 mm when landslides become dominated in the landform change process. Erosion rate also increase linearly with average slope first, but it becomes almost constant after the dominance of large landslides in the process of landform development. The relation between erosion rate and average slope seems necessary to be reconsidered with taking uplift rate into account.

Keywords: rainfall-erosion experiment, limit of mountain growth, threshold uplift rate, critical slope, landslides