# Incision rate, riverbed slope and contributing area of an experimental drainage basin

*Imamura Akihiro[1], Noritaka Endo[1]

1. Kanazawa University

The stream power model is a traditional model that expresses the erosion rate due to rivers by the product of two power functions of the contributing area (proxy of discharge) and the riverbed slope. Combining this equation with an uplift term, the differential equation of the temporal change in the altitude of riverbed is constituted. When applying the model to a natural drainage basin, it is often the case that the equilibrium state between erosion and uplift is assumed, partially because the uplift rate is usually unknown. Under the assumption of equilibrium state, the stream power model is reduced to the relationship in which the riverbed slope is a power function of the contributing area, known as Flint’s law, which is the basis of slope-area analysis to determine the concavity (equivalent to the ratio of two power exponents in the stream power model). Usually the two power exponents in the stream power model are implicitly supposed to be constant if lithology, climate, and other factors are the same. It is difficult to verify the implicit postulation for natural fields, because the condition within a single drainage basin is not homogeneous and it is difficult to evaluate the incision rates comprehensively.

To examine the temporal change of the landform in terms of riverbed slope and contributing area, we conducted a laboratory experiment in a flume (ca. 90 ×180 cm), in which the substrate was composed of the uniform mixture of sand and clay, and fine mist was supplied as rainfall. The landform was measured by photogrammetry using several hundred photos taken during ceasing of rainfall for photographing. Uplift was realized by lowering a weir that was installed at the downstream end of the flume and determined the base level.

The initial landform was generated by exerting uniform and constant uplift (4.5 mm/h). Then, the run was started with setting the uplift rate at 6.0 mm/h, keeping the rainfall intensity constant. We continued the run until the landform became stable again, for ca 6 hours of run time. From the time series of topographic data, the power exponent, m, of contributing area, the power exponent, n, of riverbed slope, and coefficient k were determined by regression based on the stream power model directly using the values of incision rate without assuming equilibrium state or some relationship between slope and area.

Resultingly, the above three parameters in the stream power model did not seem constant. It is not surprising that the ratios m/n in non-equilibrium states differ from values obtained by the usual method of slope-area plot, because the slope-area analysis assumes a graded river. Nevertheless, the values of m/n obtained by the two methods became closer to each other in the equilibrium state, which is not trivial if m and n are not constant during the development of the basin landform. The approximation based on the slope-area analysis was not so good for both non-equilibrium and equilibrium state, and the correlation in the regression was comparable. The slope-area plots usually include wide deviation, as known for natural cases, presumably because the slope fluctuates very much, since the slope is a local variable expressed by the derivative of the riverbed altitude with respect to the distance along the stream. Therefore, to eliminate this kind of fluctuation and to take accounts of differential uplift rates, recently the integral method called chi plot is increasingly used, where an equilibrium state is expressed as a straight line in the chi-altitude space. Chi plot, however, needs the value of m/n, and the method to find m/n for natural landforms is still developing. When using the value obtained from the slope-area analysis in this study, the

line of chi plot was almost straight even for a non-equilibrium state that was drawn as a bent curve when employing the value of m/n determined by direct regression using the incision rate.
The stream power model includes the contributing area, but it is a surrogate of the water discharge, so the model is basically a local law of dynamics. It is not clear whether there is not any long-range interaction in terms of incision, i.e., the topographic effects such as channel network patterns, elongation or shortening of channel courses (change in distance from the base level point). Besides, widening (or narrowing) of valleys is another potential factor to modulate the stream power model. Although more examination should be conducted to refine the variability of the exponents in the stream power model, this preliminary result suggests that the river incision might not be a simple power law of riverbed slope and contributing area, especially when the drainage basin is not in an equilibrium state.

Keywords: stream power model, laboratory experiment, river incision, drainage basin, uplift, bedrock river