第II部門　A **method to downscale upslope contributing area for solving scale effects on surface flow hydrology**

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INTRODUCTION

It is found that basin hydrological response in relations with the drainage basin dominating geomorphological parameters is directly influenced by the scale of DEM resolution. A Scale Invariant model for the topographic index distribution (Pradhan *et al.*, 2004) has fulfilled a part of this gap. A scale independent relationship in flood routing models in a distributed hydrological model is yet to be developed. To overcome this problem, scale laws that govern the relation in digital elevation data resolution on upslope contributing area has been analyzed and a mathematical formulation has been derived that successfully downscaled the upslope contributing area from coarse resolution DEM to target fine resolution DEM. The method to downscale the upslope contributing area is used to obtain the similar distribution of depth, cross-section and kinematic wave celerity from different DEM resolutions in Kamishiiba catchment (210 km^2). The downscaled flow variables are then used in Muskingum-Cunge routing method to develop a Scale Invariant Muskingum-Cunge routing method.

PROBLEM ANALYSIS

In surface flow hydrology, wave characteristics constitute the hydraulics of flow routing or propagation and are greatly affected by the geometric characteristics of channels. The flow variables whose propagation characteristics are of interest are discharge, velocity, depth, cross-section, volume and duration. In catchment hill slope channel routing these flow variables is a function of upslope contributing area. Figure 1 shows how the smaller contributing area (less than a km^2) that appears in more than 95% of the all contributing area at 50m DEM resolution is lost when 1000 m DEM resolution is used. Thus higher frequency up-slope contributing area

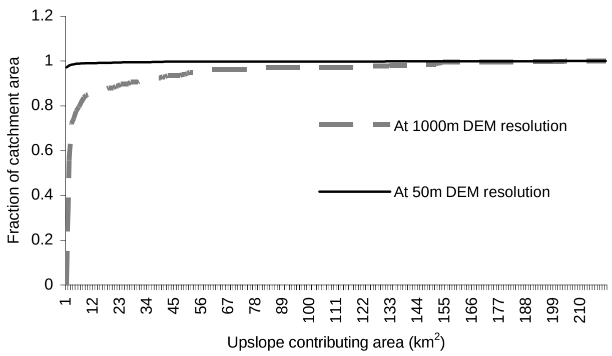

Fig. 1 Comparison of the distribution of upslope contributing area obtained from different DEM resolution in Kamishiiba catchment (210 km^2).

information contained in finer DEM resolution is lost as the larger sampling dimensions of the grids in a coarse resolution act as filter. This scale effect leads identified catchment channel routing effective parameters values to be dependent on DEM resolution. This makes difficult to use model parameter values identified with different resolution model. Moreover, a model may be physically based in theory but not consistent with observations. This results primarily from the mismatch in scales between the scale at which the parameters are identified and the scale of application.

METHOD TO DOWNSCALE UPSLOPE CONTRIBUTING AREA

In fact, the smallest contributing area derived from a DEM resolution is a single grid of the DEM at that resolution. Thus area smaller than this grid resolution is completely lost as the larger sampling dimensions of the grids act as filter. But as we use finer resolution DEM, the smaller contributing area - that is the area of finer grid resolution is achieved. From this point of view, we introduced N_s, number of target resolution grids that adds up to make a coarse resolution grid, to derive scaled upslope contributing area as shown by Equation 1.

$$C_{i\,scaled} = \left(\frac{C_i}{N_s I_f} \right) \qquad (1)$$

where $C_{iscaled}$ is the scaled upslope contributing area at a point i, I_f is a influence factor. N_s is the total number of subgrids within a coarse resolution grid. i is a location in a catchment. The influence of N_s in equation (1) should reduce gradually as the distribution of upslope contributing area given by coarse and fine resolution DEM at the points downstream becomes closer. For this reason we introduced influence factor I_f in Equation (1) and I_f is described as;

$$I_f = e^{\left\{ \frac{(1-N_i)H}{N_o} \right\}} \qquad (2)$$

where, N_i is the number of the coarse resolution grids contained in the contributing area at a location i in the catchment, N_0 is the number of the coarse resolution grids contained in the contributing area at the outlet of the catchment. Considering the contributing area given by coarse DEM resolution and fine DEM resolution is equal at the out let of the catchment, H in Equation (2) is introduced as harmony factor whose value is obtained from Equation (3).

$$N_s e^{-H} = 1 \qquad (3)$$

Finally, we developed a Scale Invariant model for the upslope contributing area as;

$$C_{i\,scaled} = \left(\frac{C_i}{N_s e^{\left\{ \frac{(1-N_i)H}{N_o} \right\}}} \right) \qquad (4)$$

RESULTS AND DISCUSSION

Using Equation (4), the upslope contributing area is downscaled from 1000m DEM resolution to 50m DEM resolution. In contrast to Figure 1, Figure 2 shows the similar distribution of upslope contributing area from 50m DEM resolution and downscaled from 1000m DEM resolution to 50m DEM resolution.

The method to downscale the upslope contributing area is used to obtain the similar distribution of velocity, depth, cross-section from different DEM resolutions in Kamishiiba catchment (210 km^2) and to develop a Scale Invariant model in the surface flow hydrology. The propagation speed or celerity of a flood wave is one of the main properties of the flood-wave propagation and is related directly to the wave deformation and attenuation. The scaled wave celerity derived from the scaled upslope contributing area and scaled slope (Pradhan *et al.*, 2004) is then used to adjust the time of propagation of a given discharge alone a reach length in Muskingum-Cunge routing method. It is shown that the simulated runoff from the scale independent Muskingum-Cunge routing method applied at 1000m grid resolution DEM, with the same effective parameter value (Manning's roughness coefficient) derived from 50m grid resolution DEM, has matched with the simulated runoff at the50m DEM resolution without recalibration.

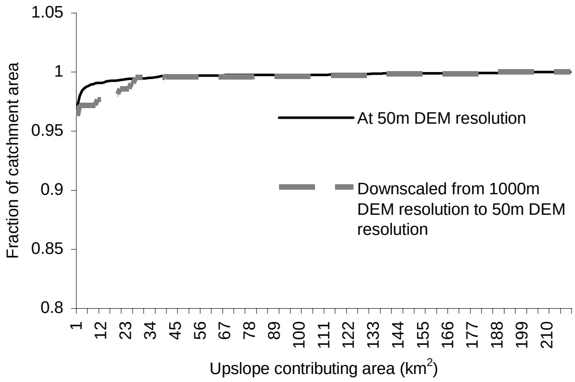

Fig. 1 Comparison of the distribution of upslope contributing area from 50m DEM resolution and scaled from 1000m to 50m DEM resolution in Kamishiiba catchment (210 km^2).

CONCLUSION

In this research, we show that the method to down scale upslope contributing area can be used to acquire parameter consistency in hydrological geomorphology. It is hoped that the research finding seeks its applicability as a tool to a wider range of boundary as per the scale problems in hydrology and solution approach is concerned.

REFERENCES

1) Pradhan N. R., Tachikawa Y., and Takara K., A scale invariance model for spatial downscaling of topographic index in TOPMODEL, *Annual Journal of Hydraulic Engineering, JSCE*, vol. 48, 2004.