**(Supplement)**

### The Rainfall-Runoff-Inundation Model

This study uses the RRI model developed by the authors (Sayama et al. 2012). It is a two-dimensional model, which can simulate both rainfall-runoff and flood inundation simultaneously. It is a grid-cell based model which distinguishes slope cells and river channel cells. For river channel cells, the model assumes that a river channel is positioned at the centerline of a slope. For both the slope and river channel cells, the model computes rainfall-runoff based on the Equation (1). After computing the rainfall-runoff using the two-dimensional diffusive equation, the model simulates the interaction of the slope and river water using different over topping formulae based on the relationship between the river and slope water levels as well as levee height for each grid-cell and time step. The overtopping formulae allows the stream flow to be flooded; thus, the model can compute water from rainfall-runoff and overtopping without separate treatment. This two-dimensional diffusive wave structure has an advantage, especially when flood inundation influences the streamflow or the conditions of the downstream water level affect the upstream water level due to a gentle topography, which is difficult to be simulated by typical distributed rainfall-runoff models based on the kinematic approximation. The model uses an adaptive time step Runge-Kutta algorithm (Cash and Karp 1990) to solve the set of ordinary differential equations efficiently while maintaining computational stability for simulating large areas from mountains to plain areas.

To compute the lateral flow on a slope grid-cell, the RRI model combines a mass balance equation and the following water depth and discharge relationship. The equation can solve lateral flow based on unsaturated and saturated subsurface and surface flow using a single variable of water depth *h* at each grid-cell (Sayama and McDonnell 2009; Tachikawa et al. 2004).

(1)

where *qx* is the discharge in the *x*-direction from one grid-cell to another adjacent grid-cell; *H* is the water level; sgn is the signum function; *n* is the Manning’s roughness; *ka* and *km* are the lateral saturated and unsaturated hydraulic conductivities; and *da* and *dm* are the maximum water depths of flowing as saturated subsurface flow and unsaturated subsurface flow, respectively. ** represents the reduction of unsaturated hydraulic conductivity with reducing *h*. By assuming the continuity of the discharge and depth relationship, *km* can be estimated as *ka* /**without taking *km* as an extra parameter. Note that by neglecting the effect of the unsaturated flow component (*dm* = 0), the above equation can be simplified as a combination of the Darcy’s saturated subsurface flow and the Manning’s overland flow.