Rainfall-Runoff-Inundation (RRI) model

Comparable to IFAS, the other key technology of ICHARM is the Rainfall-Runoff-Inundation (RRI) model developed by Dr. Takahiro Sayama, currently an Associate Professor at Kyoto University, during his tenure in ICHARM. This model simultaneously analyzes the hydrological processes from rainfall to runoff to flood inundation in a river basin, eliminating two-stage simulation employed in conventional flood analysis models in which a river channel runoff model first calculates the flow rate and then a flood inundation model uses it as the boundary condition for further calculation.

An event that had a great impact during the development of this model is the 2011 Thailand Flood along the Chao Phraya River. At that time, Japanese diplomatic missions and companies operating in Thailand tried to figure out the entire scale of the flood based on limited information. However, since satellite-based information was limited in its observation frequency, the temporal change of the flood was difficult to predict. Therefore, despite the strict time constraints, ICHARM hurried the development of the RRI model and developed a 1-2-km grid model for the Chao Phraya River basin. The flood movement was sequentially analyzed as emergency simulation, and the results were published in cooperation with the Ministry of Land, Infrastructure, Transport and Tourism (Figure 1).

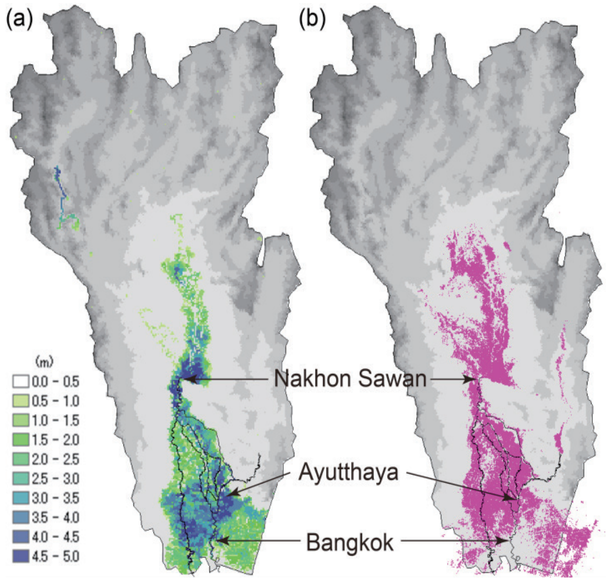

Figure 1 Results of emergency simulation for the Chao Phraya River (Left: (a) RRI, Right: (b) Satellite observation)

The development of the RRI model and provision of emergency information were highly appreciated, and the developer, Dr. Takahiro Sayama, was awarded by the Minister of Education, Culture, Sports, Science and Technology in the science and technology field in 2013 (Young Scientist Award), the Ministry of Land, Infrastructure, Transport and Tourism in 2013 (15th Infrastructure Technology Development Award), and the Japan Society of Civil Engineers in 2014 (Best Paper Award).

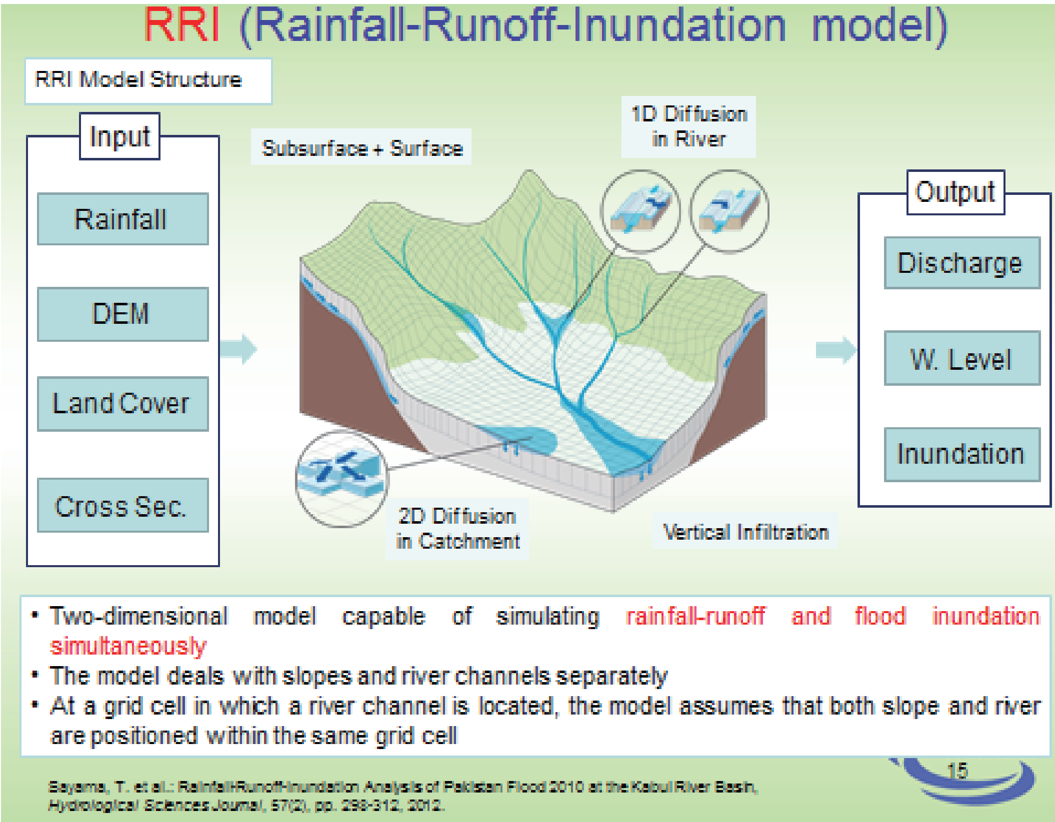

Figure 2 RRI model

The unique features of this model include: (1) flood simulation in lowlands by using a 2D diffusive wave approximation model; (2) simple expression of hydrological processes such as vertical infiltration flow in plains and lateral infiltration flow in mountains, evapotranspiration, and impacts of dams; and (3) high-speed and reliable numerical computation incorporating the Step Runge-Kutta Method, which automatically varies time steps and parallel algorithms using Open MP. This model, as well as IFAS, can use global data and satellite-based rainfall data (Figure 2).

The real-time flood forecasting system incorporating the RRI model was installed in the Royal Irrigation Department (RID) in Thailand in 2013, as part of JICA's flood management project in the Chao Phraya River after the 2011 floods.

The Indus-IFAS developed under a UNESCO Pakistan project also uses the RRI model for flood simulation over the lower Indus River. Thus, the Indus-IFAS becomes a coupling model taking advantages of the two powerful components: IFAS for high-speed simulation of runoff in upstream mountains and RRI for flood inundation simulation in downstream rivers.

RRI has been used in flash flood analysis in the Kabul River and in flood inundation analysis of the Chikusa River in Hyogo Prefecture as a verification tool for flood events. ICHARM also undertakes research to improve accuracy for forecasting the temporal development of a flood from rainfall to inundation by feeding the RRI model with ensemble information based on numerical weather forecasts targeting domestic river basins.

To further expand and disseminate the RRI model, ICHARM started the development of GUI in 2014 for easy input and output, and released it with an execution program on its website in 2016 (http://www.icharm.pwri.go.jp/research/rri/rri_top.html). The RRI-GUI is also used to learn the operation of flood simulation models in training held as part of the ADB project in Myanmar and also as part of the JAXA-SAFE project (2016) for the Kalu Ganga River basin in Sri Lanka.

ICHARM has also focused its support on training for the RRI model. The IFAS training by JICA in 2016 included the RRI training. Also, the training for Arab countries includes introduction and practice of the RRI model. With development of GUI, the base of RRI users is expected to expand further. In addition, to study adaptation measures against climate change and analyze the phenomena of extreme external force exceeding the design scale, the needs for flood simulation using the RRI model are expected to increase, including applications to small and medium-sized rivers in Japan. As mentioned earlier, the RRI model uses approximation of the diffusive wave to perform simulations efficiently; thus it is suitable for the analysis of low, flat land, but has limitations in the representation of complicated flood hydraulic phenomena such as those around building structures. Further studies are needed for the model to produce more accurate simulation results by reflecting detailed cross sections of rivers in simulation and considering combinations with sewerage/drainage networks and pump drainages in city areas. The model should also be verified for applicability to hydraulic phenomena not only in the Asian monsoon area but also in arid regions. RRI users are encouraged to use the model at their disposal, which should motivate further improvement in the future. ICHARM is fully open to active discussions with a wide variety of users to enhance the capacity of the RRI model. Currently ICHARM is also working on coupling the RRI model with WEB-DHM (water and energy budget-based distributed hydrological model) to include initial conditions of soil moisture in simulation.

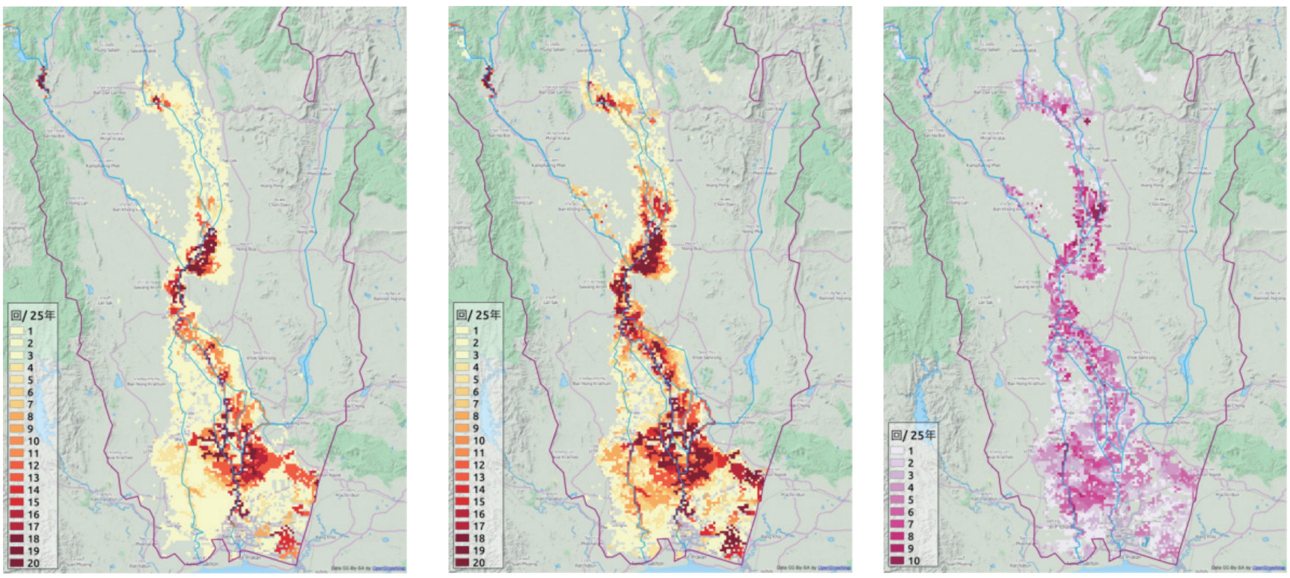

Figure 3 Inundation frequency analysis in Chao Phraya river basin for 25 years between present and future climate by using MRI-AGCM 3.2S
Left: Present(1979-2003), Center: Future(2075-2099), Right: Change (F–P)