2D-FEM モデルによる低平水田域の洪水防止機能

Flood Prevention Roles of Paddies in Low-lying Areas by a 2D-FEM Flood Model

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1. Introduction

A unique feature of the flow in and around Tonle Sap Lake and its environs in the Mekong River system is the existence of reverse flows into the lake from the Mekong River. This natural mechanism provides a unique and important balance to the Mekong River downstream of the lake and ensures a fresh water flow into the Mekong Delta in Vietnam during the dry season, protecting the rich agricultural lands of the delta from salt water intrusion from the South China Sea. In order to assess this unique feature of flooding processes, a two-dimensional finite element method (FEM) simulation model was developed using full terms of depth-averaged shallow water motion equations. Such models are capable of addressing the geometric complexity usually found in topography as well as at the boundaries of the study area. The results of the model simulation and land-use data were used to evaluate the flood prevention function of paddies in Tonle Sap Lake and its environs. That is, the volume of flooded water on paddies was estimated in order to evaluate the impact of non-irrigated paddies on floods and water use.

2. Model description

The model has been described in detail by P. T. Hai *et al.* (2006), so only a brief description is given here. The model is based on 100m grid-sized DEM topographic data of the study area. And refined unstructured-triangular FEM meshes of 62,965 nodes and 124,997 elements were generated. Bed elevations of grids in the DEM data are used to interpolate elevations of FEM nodes in the flood plain domain, while more precise and new updated sound-bathymetry data of the main rivers as bed elevations are utilized to interpolate FEM nodes' elevations in the main rivers' domain. The weighted-residual of the standard Galerkin FEM is applied to the 2D shallow water equations for spatial discretization, and the selective lumping two-step explicit FEM is employed for numerical integration in time. Observed (or calculated) discharges of 12 tributaries around Tonle Sap Lake are set up at ever-wet nodes which located in water-edge of the Lake in dry season, as inflow-boundaries. Measured water levels as a function of time at Kratie water level gauge are specified for the inflow of upstream conditions, while those at Tan Chau and Chau Doc water level

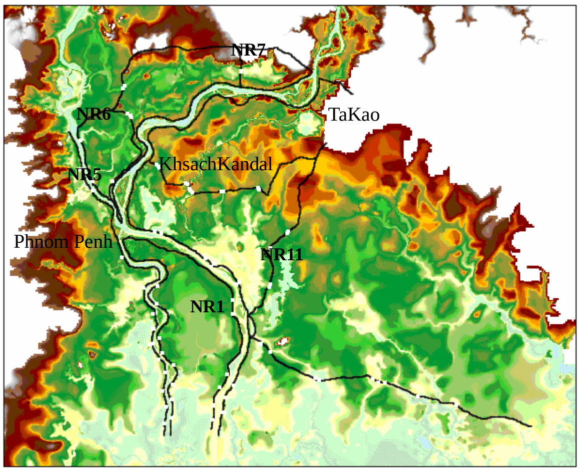

Fig.1 Selected roads, dikes and road-opening works in the model simulation

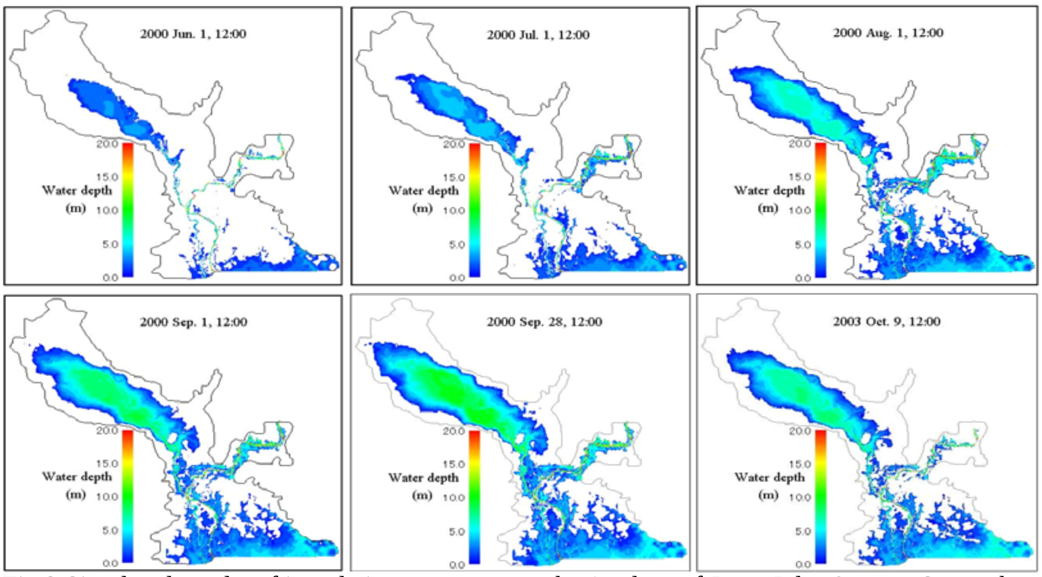

Fig.2 Simulated results of inundation processes on the 1st days of June, July, August, September 2000, and maximum flood extent on Sep. 28th of year 2000 and Oct. 9th of year 2003.

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gauges are specified as for the outflow of downstream conditions. Moving boundary problem was treated by applying a threshold technique, where a thin water depth is reset in dry nodes of all moving boundary elements every time.

3. Assigning elevations of main roads, dikes and road-opening works to FEM nodes

We selected National-roads NR1 from Phnom Penh to Vietnam border, NR5, NR6, NR7, local road on left side bank of Mekong River from Khsach Kandal to the junction with NR11 at Takeo; dikes on both sides of Mekong River from KomPong Cham to near Tan Chau, dikes of Tonle Sap river from Phnom Penh to Prek Dam, dikes on both sides of Bassac river from Phnom Penh to near Chau Doc; and main road opening-works which located on the selected roads and dikes, in order to assign their elevations to FEM nodes in the model simulation (Fig. 1). These construction works were considered that have significant influence on flow regimes in the study area. Tools of ArcGIS are used to convert poly-line-shape data of the selected roads, dikes and road-opening works to points data. Coordinates of these points are used to find FEM nodes which are closest to the points, then found FEM nodes are assigned elevations of the selected roads, dikes and road-opening works.

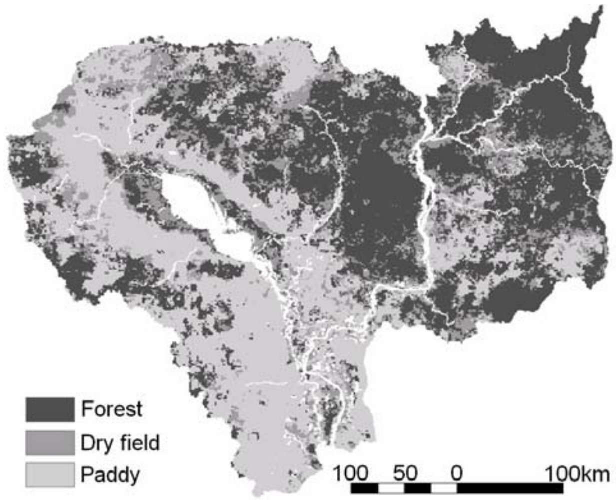

Fig.3 Land use in and around Tonle Sap Lake (Source: USGS).

4. Application for Evaluating Flood Prevention Roles of Paddies

(1) Simulation results: After applying the methods and parameters mentioned above, the following simulation results were obtained. Simulated results of water depth and flood extents of year 2000 and on 9 October 2003 are shown in Fig. 4. The simulated results reproduced the inundation processes occurring during the year: At the beginning of wet season (June), water was flowing only in the main rivers; at the onset of the flood (July), flood water spilled out gradually to adjacent areas, expanding the flood plain on both sides of the main rivers. Simulated water levels were compared with observed hydrographs at five points and maximum flood extents. The calculated water levels were a little bit lower than the observed ones.

(2) Estimation of flooded water on paddies:

a) Agricultural lands in Cambodia: Agricultural land use in and around Tonle Sap Lake is classified roughly as paddies and dry fields. Fig. 3 shows land use in Cambodia with the simple classifications of forest, dry fields, and paddies. The grid size of the digital map is 1 km. Areas in and around Tonle Sap Lake are used in particular for rice that is planted as the flood waters recede.

b) Estimation of inundation volume on paddies: In order to evaluate the role of agricultural lands in flood protection and agricultural water use, we estimated the volume of flooded water on paddies. The estimation was carried out by summing the height of floods (Fig. 2 shows one example) in accordance with all grid-cells of paddies and dry fields (Fig. 3). Fig. 2 shows the maximum inundated area and water depth in years 2000 and 2003, respectively. The years 2000 and 2003 are representative of the most significant recent flood and drought years, respectively. Table 1 shows the calculated results for the flooded area of paddies, the flooded volume in the paddies, and the ratio of the flooded volume in the paddies to the total flooded volume. Using the year 2000 flood as an example, about 42% (12,249 km^2/29,280 km^2) of paddies in Cambodia were affected, and it was estimated that paddies apparently stored 22.4% of the entire flooded volume in and around Tonle Sap Lake and environs. Even for the recent smallest flood (in 2003), the flooded volume on the paddies accounts for 15.1% of total storage (based on apparent value at the peak). In total, the ratio of flooded areas to the total paddy area in Cambodia varied from 30% (2003) to 42% (2000). The ratio of the flooded volume on paddies to the total flood was about 19%. Hence, we can say that roughly one-fifth of the total flood volume was stored on paddies in and around Tonle Sap Lake.

Table 1 Estimated flood inundation area and volume for years 2000 and 2003.

Year	Flooded area of paddies (km^2)	Flooded volume in paddies (10^9 m^3)	Ratio of flooded volume in paddies to the total (%)
2000 as a recent largest flood year	12,249	21.914	22.4
2003 as a recent drought year	5,527	8.171	15.1

Reference:

1) Pham T. HAI, T. MASUMOTO, K.SHIMIZU.(2006). *Evaluation of Flood Regulation Roles of Paddies in the Low-lying Mekong River Basin Using a 2D Flood Simulation Model*. Annual Journal of Hydraulic Engineering, JSCE, Vol.50: 73-78.