Simulation of flood hazard using GIS-based cellular automata (Case study: Chirchir Catchment)

Somaiyeh Khaleghi
Assistant Professor, Department of Physical Geography, Earth Science Faculty, Shahid Beheshti University, Iran
Leila Malekani*
Assistant Professor, Department of Civil Engineering, Faculty of Technical and Engineering of Marand, University of Tabriz, Iran

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Extended Abstract

Introduction

Flood is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which not only damages the lives, natural resources and environment, but it also causes the loss of economy and health. Thus, estimation and prediction of flood hazard is very important spatially in the watersheds without measurement stations. There are many models in the water and environmental studies for investigation about the runoff and flood in the watersheds without measurement stations. One of the newest is cellular automata model that has been combined well with the GIS for simulation of runoff and flood hazard. Cellular automata as a tool for modeling and simulation of processes taking place in the real world are now increasingly used, as evidenced by their use not only as a tool for creating simulations, but also by their use in the areas of crisis management. Using GIS knowledge, it is possible to create cellular automata appropriately and authentically reflect the water flow on the Earth's surface. Cellular automata tool (CA) is a mathematical model that can be used for computation and simulation of the systems. In this method, the basin is defined with a network of the rectangular cells, and the interactions between the cells together with the geographic rules that govern the area result in the runoff modeling. This model relies on the GIS and satellite images. Cellular automata model uses various data such as Digital Elevation Model (DEM), landuse, hydrologic soil groups, rainfall, slope and etc. for runoff estimation. In the present study, the runoff of the Chirchir catchment in East Azarbaijan province, Iran, has been modeled by means of the GIS-based cellular Automata.

* E-mail: lmalekani@tabrizu.ac.ir Tel: +98 9141907477

Materials and Methods

In this study, GIS-based cellular automata were used to simulate flood in the Chirchir catchment in the northwest part of Iran. CA models use several primary components including the cells arranged in a regular mosaic pattern (raster, grid), transition rules determining the changes in cell properties, neighborhood of the cell, and boundary conditions. These components affect the status of each individual cell in a network in a given time span. In this research, Chirchir catchment in East Azerbaijan province is modeled using cellular automata. First, SCS formula is used to predict the runoff in each cell. Map of hydrological soil groups of Chirchir catchment is determined by means of soil texture map, then land use and SHG maps are prepared for calculating the runoff curve number (CN) map for the normal conditions. Since the soil has dry moisture condition and the slope is greater than 5%, adjusted CN is calculated for dry antecedent moisture condition and catchment slope using the common relationship. After reading the rainfall and the CN map for dry antecedent moisture condition, the runoff was calculated using the SCS equation. Then Kinematic wave model is used for flow depth in the cells and runoff production within each cell is simulated by determining the cell state (water surface elevation) that included both the cell altitude and the water depth. The distribution of water flow among the cells was determined by applying CA transition rules based on conservation of energy and continuity equations. D8 algorithm is used to simulate flow direction during the calculation of the surface convergence. The procedures for channel network delineation are based on the D8 model for flow over a terrain surface represented by a grid DEM. In this model, a single flow direction in the direction of steepest slope towards one of the eight (cardinal and diagonal) grid cells neighboring is used to represent the flow field. Also for calculating flood hydrograph, travel time is calculated using flow length and flow velocity. So roughness coefficient and flow depth is used for flow velocity and then travel time map is obtained. Finally, Python programming language is used to estimating flow hydrograph due to simplicity, powerful and object-oriented programming language and supported by GIS.

Results and Discussion

Results show that the most areas of the Chirchir catchment have pasture and type D of hydrological soil group. Therefore, it has very low permeability which means that a large amount of rainfall is converted into runoff. Runoff depth is high in east and southeast of the Chirchir catchment due to physical characteristics and rainfall of the catchment but among these parameters, the slope was the most important parameter in the runoff generation. Also, map of the flood hazard shows that downstream river has high potential in flood hazard due to receiving water from upstream. Then, for simulation of flood hydrograph, travel time was calculated using ratio between flow lengths to flow velocity. Flood hydrograph estimated for two events, June 17, 2009 and June 02, 2007. The computational runoff is very adapted to observational runoff. The correlation coefficient for the two events (0.82 and 0.70) indicates the good accuracy of the model. Low error rates also indicated that the cellular automata model has the high efficiency to predict the flood peak and the time of its occurrence in the Chirchir catchment. The results of this study are consistent with the results of researchers such as Aboudagga (2005), Rinaldi et al. (2012) and Cirbus and Podhoranyi (2013). They stated that the use of cellular automata model compared to the conventional methods by GIS, has higher accuracy and capable to estimate

flood hydrograph. Therefore, the use of cellular automata with GIS, not only accelerates the calculation of runoff, but also increases the accuracy of the results.

Conclusion

Comparison of the results with the observation proved that the results are well accurate. Besides the advantages of this method in simplicity and implementation of the realistic rules, this method is good at gaining the runoff data at any point of the basin except the exit point. Good agreement between the model output and the empirical measurements revealed that a CA approach can provide realistic results for a complex natural process like flood.

Keywords：cellular automata, Chirchir catchment, flood hazard, GIS.