INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 3, p. 218-223, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Investigation of factors in creation hydrological pits in geographic information system

Azadeh Kazemi*[1], Mohammad Reza Gili[2]

[1]*Department of Environment Sciences, Faculty of Agriculture and Natural Resources, Arak University, Arak, Iran*

[2]*Department of Environment, Faculty of Natural Resources and Environment, Malayer University, Hamedan, Iran*

Article published on March 31, 2017

Key words: DEM, Hydrology, Modeling, Pit.

Abstract

Digital Elevation Model (DEM) is an element for display earth topography. One of the most important applications of digital elevation model is in hydrological application. Moreover, in many hydrological processes such as infiltration, speed and direction of runoff, changes in height gradient in the region are important factors. The hydrologic analysis tools are designed to model the convergence of flow across a natural terrain surface. There is an assumption that the surface contains sufficient vertical relief that a flow path can be determined. The tools operate on the assumption that for any single cell, water can flow in from many adjacent cells but out through only one cell. Digital Elevation Model basin with cellular network structure is very important in the effective use of distribution models. Errors in DEMs are usually classified as either sinks or peaks. Sinks, being areas of internal drainage, prevent down slope flow routing of water. In this study, the effect of cell size and lack of data to create maps 1:25000 pits is studied. Interpolation with different cells in similar methods showed that increase in cell size and number of holes and water there is a strong relationship Cubic. The lack of hydrological data was studied on the effect of making holes in cell size of removing randomly. Results showed that the lack of data to evaluate the contours of the pits but a great effect on the effect of cell size to create more hydrological pits.

***Corresponding Author:** Azadeh Kazemi ✉ a_kazemi@ut.ac.ir

Introduction

There are good reasons to include modeling in hydrology education. First of all, models have become standard tools to address many types of practical hydrological questions and most hydrology students will be in contact with hydrological models in some way in their professional life. Therefore, it is important that hydrology students learn how to use models, get a general understanding of modeling concepts and realize possibilities as well as limitations of hydrological modeling (Seibert and Vis, 2012).

Sound prediction of flood runoff from a storm event is one of the challenges in hydrologic modeling. Prediction techniques such as the classical rational method have already been applied for this purpose at a scale of small river basins since long time. Another approach in estimation of flood runoff is on the basis of the soil moisture conditions and geophysical characteristics (Dickinson *et al.*, 1993).

However, as the size of the river basin of interest for hydrology modeling increases, lumped parameter models are not applicable because hydrologic parameters can vary widely in space and time. In such cases spatially distributed hydrologic models are appropriate. Distributed hydrologic rainfall-runoff models including hillslope overland flow and channel flow routing (Naden 1992; Troch *et al.*, 1994). Muzik (1996) presented a method for surface runoff routing by using a GIS-based distributed unit hydrograph. Schumann and Funke (1996) applied a two-dimensional instantaneous unit hydrograph within a GIS framework. Maidment *et al.* (1996) presented an elaborate grid-based model, in which the spatially distributed unit hydrograph is derived from a time-invariant flow velocity field.

Olivera & Maidment (1999) proposed a method for routing spatially distributed excess precipitation over a river basin using response functions derived from a digital terrain model.

Anurage (2000) has stated the factors in existence of hydrological pits:

- Lack of data for interpolation.
- Interpolation methods.
- Cell size limitations.
- Provided facts on The Earth's surface such as existed pits at areas of the calcareous

He considered them at the most important factor in the formation of pits and divided two sets of lack of data DEM errors into Resulting random and systematic errors. The lack of data error in the creation of DEM is the most significant factor in the formation of pits. By decreasing cell size, the number of pits cells in DEM increases. Preliminary studies indicate that approximately less than 5 percent of the cells of DEM depending on interpolation method and the size of cells can be pits. Therefore, in this work a spatially distributed hydrological model is presented that uses detailed basin characteristics to predict hydrological processes. At this stage of the work emphasis is given to the simulation of runoff by determining the effect of cell size in creation of pits in the maps of 1/ 25000 and the effect of the lack of data with cell size in creating digital pits.

Materials and methods

The study area

The study area is Ecbatana dam basin which Hamedan city is located in the northwest part of this basin. The highest point of the basin has the height of 3580 meters and outflow height as the lowest point is 1960 meters and the area is about 45/28 square kilometers, it is worth noting that the choice of this area was due to changes in topography of sub-watershed consists of flat, half flat and uneven areas. (Fig. 1)

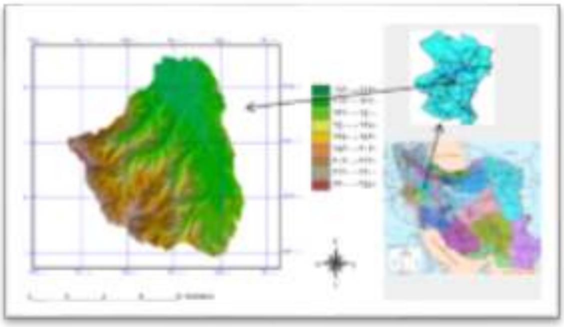

Fig. 1. Digital Elevation Model and hill shading of Ecbatana.

Edition of data

The topographic maps of the study area 1/25000, after preparation of the edition of maps with respect to the subject matter including Correction of non-elevation contours, correction of false elevations and correction of the connections between the contour lines of rivers, including seasonal and permanent. Over shoot and Undershoot Errors and discontinuous contours are also resolved.

Interpolation

By using contour lines of 1/25000 maps, elevation points and rivers with ANUDEM algorithm at ArcGIS9.3 software we have interpolated different cells size. ANUDEM algorithm is as one of the most complete algorithm of making digital elevation models with hydrological basis, which is commonly used nowadays.

Hydraulic pits fill-up

Hydrological pit is the cell that its height is less than of neighboring cells. The causes of them include lack of data for interpolation, the interpolation method and the key factor is cell size limitations that the cause of it is selecting the cell size smaller than the threshold and as the size is smaller in terms of more exaggerated increase in data, the height of a number of pits increase and hydrological models craters will caused lack of participation of upstream cells in the runoff and causes an error in the modeling process. D8 algorithm was used to remove the pit that this algorithm replaces the minimum height of neighboring cells to pit cells and causes removal of the pit.

The effect of cell size in the creation of digital pits

Cell size is as one of the criteria in the development of hydrological pits of various sizes that were made by using ANUDEM method in order to determine the extent of its impact. That causes creation of Digital pits, pixel size mismatch according to the scale and tilt of the region, and given the importance of pits in the small size pixels, in the interpolation the intervals of pixel has been selected as 1 meter which in this research the pixel sizes were examined in 1 to 20, 25.30, 35, 40, 45, 50, 55, 60 and 70. In table 1, the number of created digital pits in this cell size is represented.

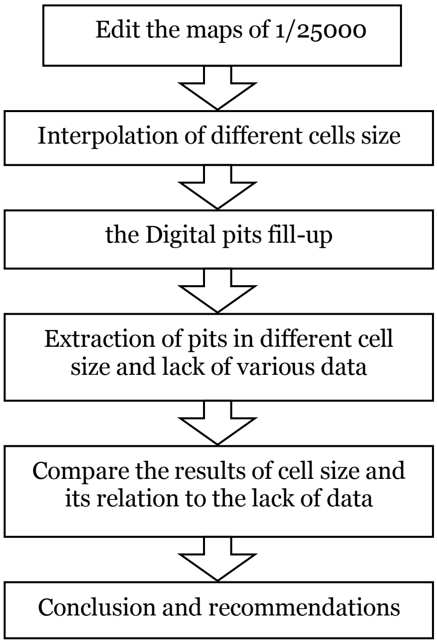

Fig. 2. Methodology of study.

Table 1. Number of created Digital pits in different cell size.

Cell size	Number of pits	Cell size	Number of pits	Cell size	Number of pits
2	185	11	9	20	9
3	121	12	12	25	11
4	85	13	14	30	16
5	64	14	14	40	9
6	51	15	11	50	3
7	36	16	21	60	2
8	22	17	10	70	2
9	29	18	12	80	0
10	21	19	4	90	0

The impact of the lack of data with cell size in creation of pits

The impact of lack of data on the production of hydrological pits was done in two ways.

1. Removal of Elevation contours of 1/25000 maps on a regular basis (interlaced)
2. Removal of adjacent contour lines and non-participation of contours in the interpolation

In both of the above methods, we have selected randomly a contour line and the rest of them were interpolated toward it cumulatively.

In order to determine the effect of the removal of contour lines in the digital elevation model, an average slope of each of them has been identified. In addition, the correlation of each of DEMs was calculated with the original DEM. The interpolation of each of the methods has been calculated in each of cell size 5, 10,15,20,25, 30.35 and 40 in order to determine the impact of the lack of data on different cell size in 1/ 25000 maps. In Table 1, the number of pits in different cell size with regular removal has been calculated and represented. In Table 2, the number of pits has been calculated in different cell size and the role of lack of data with irregular removal with the slope mean, standard deviation and correlation of basic DEM were interpolated and is represented.

Table 2. Calculated number of pits in different cell sizes and the role of lack of data with regular removal.

Cell size	5	10	15	20	25	30	35	40	Average slope	Standard deviation	DEM correlation with basic DEM
1	58	20	12	10	5	4	9	12	7.29	5.9	0.9999
2	65	23	12	10	5	4	9	12	7.39	5.97	0.9993
3	65	23	12	10	5	4	7	12	7.69	6.2	0.9995
4	43	10	6	5	3	4	7	5	7.99	6.33	0.9990
5	43	10	6	5	3	4	7	5	8.07	6.35	0.9930
Basis	64	21	11	9	11	16	12	9	8.08	5.9	1

Table 3. Number of calculated pits in different cell size and the role of lack of data by irregular removal.

Cell size	5	10	15	20	25	30	35	40	Average slope	Standard deviation	DEM correlation with basic DEM
1	60	404	180	104	66	49	39	29	8.08	6.32	0.9979
2	1618	409	188	108	70	49	39	29	8.57	6.27	0.9965
3	2154	808	130	146	144	69	41	38	8.69	6.27	0.9995
4	3509	1220	529	286	242	142	96	85	8.71	6.26	0.9887
5	64	1220	522	299	255	141	106	90	8.80	6.26	0.9868
Basis	64	21	11	9	11	16	12	9	8.80	5.9	1

Regression Analysis

If in consideration of the relationship between two variables, we consider estimation of one, of which (Dependent variable) using its relationship with other variables (independent variable) the regression function can be useful.

Function: $\hat{y} = E(y \mid x) = a + bx$

Where in:

$\hat{y}$: Estimated dependent variable y

$E(y \mid x)$: Mathematical expectation y given the x

a : Y-Intercept of the regression line

b : The slope of the regression line

The regression line y is on the x, we say that by so the variable amount of y is estimated.

To this end, we have arranged couples of $(x_1, y_1), \ldots, (x_n, y_n)$ in a coordinate system and to determine the amount of a and b we have fitted the function $E(y \mid x)$ that the sum of squares of differences between actual and estimated values of y with using regression equation become minimum. In other words:

Estimation error $y_i - \hat{y}_i = e_i$

$$\hat{y}_i - \hat{y}_i = e_i \Rightarrow \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 = Min \Rightarrow \begin{cases} b = \dfrac{\delta_{xy}}{\delta_x^2} \\ a_2\bar{y} - b\bar{x} \end{cases}$$

Where in:

e_i : Estimation error of y_i

$\hat{y}_i$: Estimation of y_i

δ_{xy} : The sample covariance between x and y

$\bar{y}$: Average y

$\bar{x}$: Average x

Results

Statistics and obtained results of lack of data and the size of individual cells was evaluated by the effect of cell size. Also the effects of cell size and lack of data in creating digital pits has been analyzed. The results will discuss in the following description.

After drawing Scatter Plot between two variables of Sink (dependent) and Cell (controlled), we realized that there is a strong non-linear relationship between two variables. As the Sink variable has Cubic relationship with inverse of $\left(\frac{1}{Cell}\right)$ Cell. In other words:

$$Sink = 1.846 + 66.603\left(\frac{1}{Cell}\right) + 1487.583\left(\frac{1}{Cell}\right)^2 - 1778.85\left(\frac{1}{Cell}\right)^3$$

By using this equation, we can estimate Sink using the cell size.

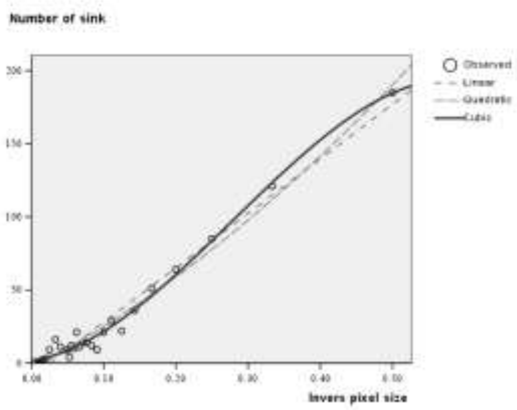

Fig. 3. The effect of cell size and lack of data in the creation of Digital pits.

Discussion

Among the most important errors are creating digital pits and areas with no slope or flat. These errors, which are caused by DEM, are among the major obstacles in the application of hydrological models. Because areas with pits or smooth surfaces prevent the flow of runoff in the actual direction and in addition taking into account the contribution of these areas in the basin of runoff, often cause disturbances in the process of simulation by the models. Mark (1988) knows the pits due to low estimation height for the cells of DEM. Garbrecht and Martz (1992) know the pits caused by the high and low height estimations for the cells that are caused by the input data. Jenson and Domingue (1988) and Garbrecht and Martz (1992) tried to develop algorithms that in these algorithms assume that the pits are caused by errors in the contained information in the DEM and our results show that The investigation of the effect of lack of data in creating hydrological pits by systematic random eliminating contour lines showed that the lack of data by eliminating most of the data increases the number of holes and the impact of lack of data in creating hydrological pits is higher than the cell size.

Conclusion

Derived maps of topographies of such as slope, Direction of dominant slope or flow direction to simulate the hydrologic runoff basins through hydrologic distribution models are needed. Some models are also used spatial curvature in longitudinal profile and the cumulative flow derived by certain operations of DEM. Extraction of these maps is subject to the provision and quality of DEM and quality of DEM is limited for use these models of digital pits that it is necessary to investigate the causes. The evaluations of impacts of lack of data and cell size in creating digital pits were considered in this study. The results showed that by reduction of cell size, the number of digital pits increase and a COUBIC relationship is between cell size and number of pits in the 1/25000map of this region.

References

Anurag S. 2000. Comparison of two algorithms for removing depression and delineating flow networks from grid digital elevation models, MSc thesis, Faculty of the Virginia Polytechnic Institute.

Chaplot V, Saleh A, Jaynes DB, Arnold J. 2004. Predicting water, sediment and NO−3 N loads under scenarios of land-use and management practices in a flat watershed. Water, Air, and Soil pollution **154,** 271–293.

Cuartero A, Felicísimo AM, Ariza J. 2004. Accuracy of DEM enervation from Terra-Aster stereo data. International Archives of Photogrammetry and Remote Sensing **35,** 559-563.

Dickinson RE, Henderson-Sellers A, Kennedy PJ. 1993. Biosphere-Atmosphere Transfer Scheme (BATS) Version 1e as coupled to the NCAR community climate model. NCAR Technical Note, National Center for Atmospheric Research, Boulder, Colorado, USA.

Garbrecht J, Martz M. 1997. The assignment of drainage direction over flat surfaces in raster digital elevation models. Journal of Hydrology **193,** 204-213.

Hutchinson MF, Dowling TI. 1991. A continental hydrological assessment of a new grid-based digital elevation model of Australia. Hydrological Processes **5,** 45-58.

Jenson SK, Domingue JO. 1998. Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. Photogrammetric Engineering and Remote Sensing **54,** 1593-1600.

Kenny F, Matthews B. 2005. A methodology for aligning raster flow direction data. Computers and Geosciences, **31,** 768–779.

Maidment DR, Olivera JF, Calver A, Eatherall A, Fraczek W. 1996. A unit hydrograph derived from a spatially distributed velocity field. Hydro. Processes **10,** 831-844.

Mark DM. 1988. Network models in geomorphology. Chapter 4 in Modeling in Geomorphological systems, Edited by M. G. Anderson, John Wiley, 73-97.

Michele Di. 2008. Correlation between channel and hill slope lengths and its effects on the hydrologic response. Journal of Hydrology **362,** 260-273.

Miller CL, Laflamme RA. 1958. The digital terrain model- theory and application. Photogrammetric Engineering, **24,** 433-442.

Muzik A. 1996. GIS-derived distributed unit hydrograph. In: Application of geographic information systems in hydrology and water resources. IAHS Publ **235,** 453-460.

Naden PS. 1992. Spatial variability in flood estimation for large catchment: The exploitation of channel network structure. Journal of Hydrology Sciences **37,** 53-71

Olivera F, Maidment DR. 1999. Geographic information systems (GIS)-based spatially distributed model for runoff routing. Water Resource Research **35,** 1155-1164.

Quinn PF. 1991. The prediction of hill slope flow paths for distributed hydrological modeling using digital terrain models. Hydrological Processes **5,** 59-79.

Rasmus S. 2007. Effects of DEM resolution on the calculation of topographical indices: TWI and its components. Journal of Hydrology **347,** 79-89

Reinfelds I, Cohen T, Batten P, Brierley G. 2004. Assessment of Downstream Trends in Channel Gradient, Total and Specific Stream Power: A GIS Approach, Geomorphology 60.

Schumann AH, Funke R. 1996. GIS-based components for rainfall runoff models. In: Application of geographic information systems in hydrology and water resources. IAHS Publ **235,** 477-484.

Sefercik UG. 2012. Performance Estimation of Aster Global DEM Depending upon the Terrain Inclination. Journal Indian Society of Remote Sensing **40,** 565–5761.

Seibert J, Vis MJ P. 2012. Teaching hydrological modeling with a ser- friendly catchment-runoff-model software package. Hydrology and Earth System Sciences **16,** 3315–3325.

Troch PA, Smith JA, Wood EF, De Troch FP. 1994. Hydrologic controls of large floods in a small basin. Journal Hydrology **156,** 285-309.