Available online at www.sciencedirect.com
SCIENCE DIRECT®
Environmental Modelling & Software 19 (2004) 875–879
Environmental Modelling & Software
www.elsevier.com/locate/envsoft

Short communication

ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps

Xiaoyong Zhan [a,*], Min-Lang Huang [b]

[a] Kansas Geological Survey, The University of Kansas, Lawrence, KS 66047, USA
[b] Disaster Prevention and Research Center, National Cheng-Kung University, Taiwan, People's Republic of China

Received 16 February 2004; received in revised form 16 March 2004; accepted 29 March 2004

Abstract

The development and the application of ArcCN-Runoff tool, an extension of ESRI@ ArcGIS software, are reported. This tool can be applied to determine curve numbers and to calculate runoff or infiltration for a rainfall event in a watershed. Implementation of GIS techniques such as dissolving, intersecting, and a curve-number reference table improve efficiency. Technical processing time may be reduced from days, if not weeks, to hours for producing spatially varied curve number and runoff maps. An application example for a watershed in Lyon County and Osage County, Kansas, USA, is presented.

Keywords: Curve number; Runoff; Watershed; Modeling; Hydrology; GIS

Software availability

Name of software	ArcCN-Runoff
Developers	Xiaoyong Zhan and Min-Lang Huang
Contact address	Kansas Geological Survey, The University of Kansas, 1930 Constant Ave., Lawrence, KS 66047, USA
Tel.:	+1-785-864-2173
Fax	+1-785-864-5317
E-mail	xyz@ku.edu
Availability	http://arcscripts.esri.com/details.asp?dbid=13311

1. Introduction

In hydrology a curve number (CN) is used to determine how much rainfall infiltrates into soil or an aquifer and how much rainfall becomes surface runoff. A high curve number means high runoff and low infiltration (urban areas), whereas a low curve number means low runoff and high infiltration (dry soil). The curve number is a function of landuse and hydrologic soil group. The Soil Conservation Service (SCS; now Natural Resources Conservation Service (NRCS)) curve-number method is the most common method for predicting storm runoff volume. Many watershed models such as AGNPS (Young et al., 1987), EPIC (Williams, 1995), SWAT (Arnold et al., 1996), and WMS (http://www.ems-i.com/WMS/WMS_Overview/wms_overview.html) use this method to determine runoff. Sediment and nutrient transports are then calculated based on the runoff. Some applications of this method with watershed models in Kansas were reported recently (Bhuyan et al., 2002, 2003; Tsou and Zhan, 2004; Misgna et al., 2004).

Traditionally, an area weighted average curve number for the entire watershed is used to study the runoff of a watershed. The details of the spatial variation in the watershed are often lost. An ArcGIS tool, named ArcCN-Runoff, is therefore developed to facilitate watershed-modeling work. Unlike raster mode, ArcCN-Runoff is designed for any shape of polygon in order to keep irregular boundaries unaltered. Application of dissolving techniques reduces processing time significantly. The curve-number database implemented provides a flexible way to use a reference table for the

* Corresponding author. Tel.: +1-785-864-2173; fax: +1-785-864-5317.
E-mail address: xyz@ku.edu (X. Zhan).

1364-8152/$ - see front matter
doi:10.1016/j.envsoft.2004.03.001

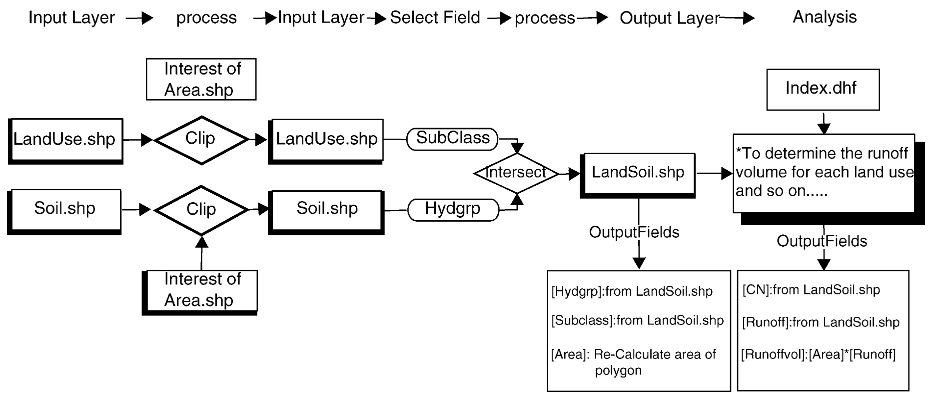

Fig. 1. Flow chart of ArcCN-Runoff.

curve number based on soil and landuse information. Users can also develop their own database as simply as to editing an Excel file. The tool can be used to design and manage hydraulic structures and projects, to estimate future discharges, and to predict watershed response associated with changes in topography, soil, landuse, and landcover (e.g. urbanization).

This paper documents the development of the ArcCN-Runoff and its application to a watershed in Lyon and Osage counties, Kansas, for the estimation of runoff depth and volume based on the spatially varying information on soil and landuse. The following sections are organized in a step-by-step procedure through a field example to explain the development and application of ArcCN-Runoff. Fig. 1 shows the flow chart for this software. The software was developed with Visual Basic 6 on an ArcGIS 8.3 platform and its structure includes one clipping tool, one intersecting tool, one working panel, and one curve-number database.

2. Processing data

Soil and landuse data are needed as inputs. In the USA, these data are usually available on the internet. The following procedures, as an example, explain how to prepare data before using the ArcCN-Runoff tool.

Soil data of two counties, Lyon and Osage, Kansas, were downloaded from http://www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo/. These coverages were projected from CGS_North_American_1983 to NAD83 using ArcInfo. After adding these coverages into ArcMap, a table called "comp" in soil data, which contains the attribute hydrogroup, is linked to the coverage for each country individually. These two coverages for two counties were then merged with Geoprocessing wizard.

The landuse data of these counties were downloaded from http://mapster.kgs.ku.edu/dasc/catalog/coredata.html. First, the land coverage was added into ArcMap, exported as a shapefile with appropriate projection, and then added into ArcMap again. The Kansas GAP Analysis Land Cover database includes 43 land-cover classes for the state of Kansas. The attributes "covername" in the landuse data is used.

After loading the ArcCN-Runoff tool in .dll file format into ArcMap, soil and land data were processed through the following three steps: (1) To focus on an interesting area or a watershed, the soil and land data for the watershed were clipped using a polygon feature from the overlay layer such as a watershed-boundary layer. (2) To reduce processing time, the soil and landuse layers were dissolved before intersection, based on the attributes "hydrogroup" in soil and "covername" in landuse. For this example, the number of polygons for soil was reduced from 611 to 4 and for landuse from 4330 to 17 after being dissolved. Figs. 2 and 3 are the dissolved soil and landuse layers, respectively. (3) Soil and landuse layers were intersected to generate new and smaller polygons associated with soil hydrogroup and landuse covername. This step keeps all the

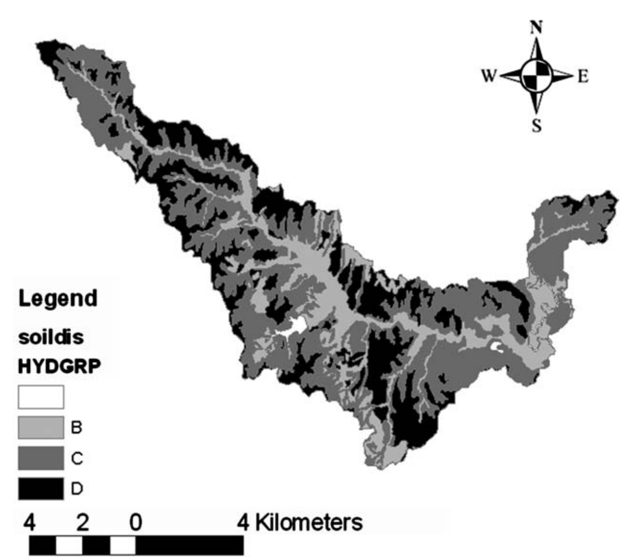

Fig. 2. Soil data.

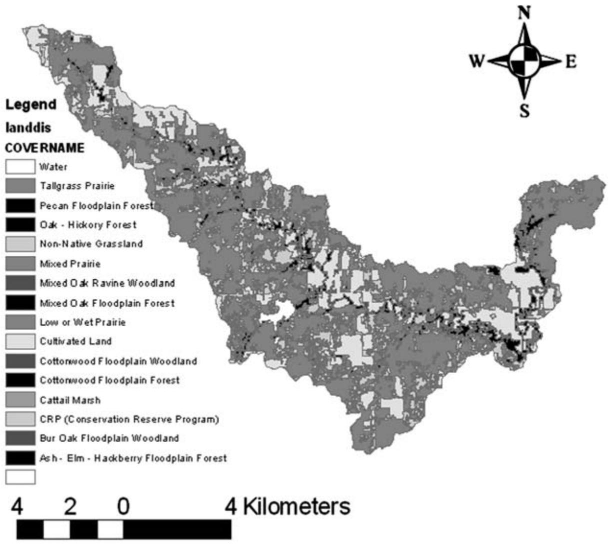

Fig. 3. Landuse data.

details of the spatial variation of soil and landuse, and therefore it is considered more accurate than using raster grid to calculate runoff or any average or dominant methods to determine curve number.

3. Determining curve numbers

The curve number for each polygon was determined from the soil and landuse information. All input and output are stored in the newly generated layer after intersection and the operation was performed through the following panel (Fig. 4). An important step is to match the covername of landuse to the landuse of index table in the curve-number database. The curve-number database was built based on the similar curve-number databases of AnnAGNPS, Basins, and other watershed models. For real field application, the curve-number database should be developed based on the local field data if possible. Users can prepare this database easily by editing an Excel file and then exporting it in .dbf format. The map showing spatial variation of the curve number (Fig. 5) is generated automatically after clicking on the button called “finish match” on the working panel, Fig. 5. Using the statistics functions in ArcMap, users can report immediately some statistical results of the curve number for the watershed.

4. Calculating runoff

The runoff is calculated based on the SCS curve-number-runoff method. The SCS curve-number method assumes that, for a rainfall storm event, the ratio of actual retention of soil after runoff begins to the potential maximum retention of soil is equal to the ratio of direct runoff to rainfall. This simplified assumption (Ponce and Hawkins, 1996) results in the following runoff equation where the curve number

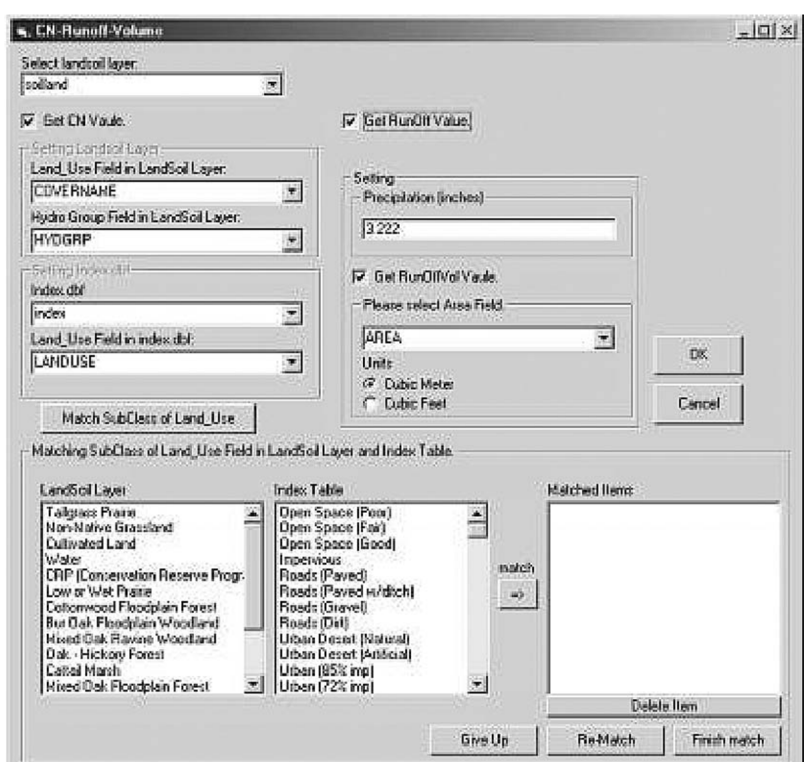

Fig. 4. Working panel.

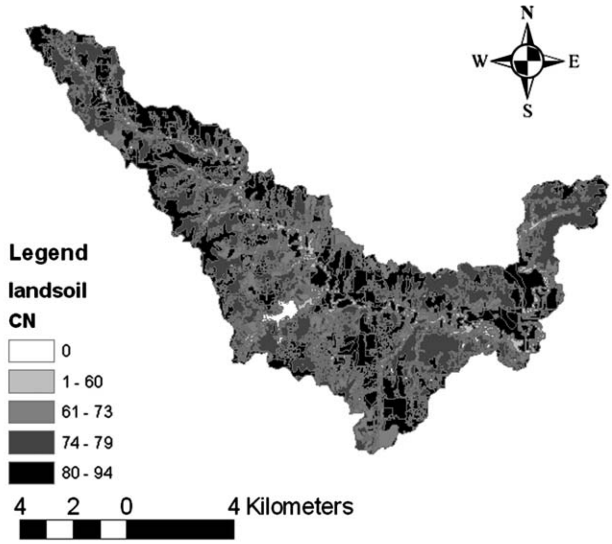

Fig. 5. Curve number generated.

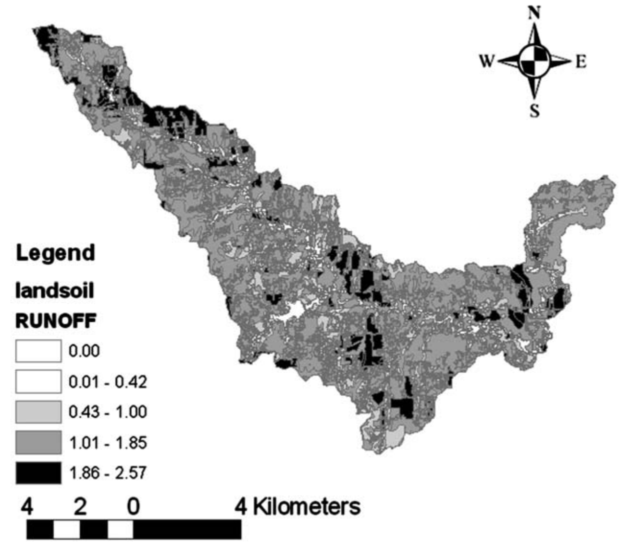

Fig. 6. Runoff calculated.

($0 \leq \mathrm{CN} \leq 100$) represents a convenient representation of the potential maximum soil retention (S):

$$\begin{aligned} &\text{runoff} = \frac{(\text{rainfall} - 0.2S)^2}{(\text{rainfall} + 0.8S)} && \text{if rainfall} > 0.2S \\ &\text{runoff} = 0 && \text{if rainfall} <= 0.2S \end{aligned} \quad (1)$$

where $S = (1000/\mathrm{CN}) - 10$ in inches and $S = (25\,400/\mathrm{CN}) - 254$ in mm, SI units.

Data provided by the Kansas Agriculture Statistics Service (Policy Research Institute of The University of Kansas, 2003) show that the average annual precipitation from 1961 to 1990 for Lyon County is 38.66 in (980 mm). The precipitation used for this example is 3.222 in = 38.66 in/12 months. It can be interpreted as the averaged monthly value or a single rainfall event by assuming there are about 12 relative large rainfalls annually. In short, it is a hypothetical precipitation event for this example. Apparently, daily and event-based runoff can be calculated in a similar way.

Fig. 6 shows the runoff in depth, responding to the specified precipitation event. The runoff in volume is area multiplied by runoff depth. The total area of the watershed is 10^8 m^2 and the total runoff in volume is 3 708 338 m^3 for the whole watershed.

5. Final remarks

The newly developed ArcCN-Runoff tool and its application to a watershed are reported to introduce this tool to the research community for protection of water resources and water quality in watersheds. Improvements may be made through implementing precipitation time series and considering additional factors, such as dry and wet antecedent moisture conditions, affecting the determinations of curve number and runoff. They will be the main efforts for the future version of this software.

Acknowledgements

Appreciation is expressed to Dave Young for matching the covername in landuse in the watershed and those in the database. XYZ appreciates the computer support of the Chinese Academy of Sciences (Innovation Project No. KZCX3-SW-428). The review comments from Harry He, Department of Natural Resources, New South Wales, Australia; Ming-Shu Tsou, Hydrologic Inc., USA; and Li Zheng, Chinese Academy of Sciences, were helpful in improving the clarity of this manuscript. The authors would like to thank Ms. Marla Adkins-Heljeson for helping to edit this paper.

References

Arnold, J.G., Williams, J.R., Srinivasan, R., King, K.W., 1996. SWAT: Soil and Water Assessment Tool. USDA-ARS, Grassland, Soil and Water Research Laboratory, Temple, TX.

Bhuyan, S.J., Kalita, P.K., Janssen, K.A., Barnes, P.L., 2002. Soil loss predictions with three erosion simulation models. Environmental Modelling & Software 17 (2), 135–144, (http://www.sciencedirect.com/science/article/B6VHC-44NM3X4-3/2/b3c5b71bd1e8163ce823fda8327db976).

Bhuyan, S.J., Koelliker, J.K., Marzen, L.J., Harrington, Jr., ., J.A., 2003. An integrated approach for water quality assessment of a Kansas watershed. Environmental Modelling & Software 18 (5), 473–484, (http://www.sciencedirect.com/science/article/B6VHC-48CNX6P-2/2/9feb312b1de00f2201ef52325e7ade0c).

Misgna, G., Tsou, M., Zhan, X., 2004. Integrated GIS-AnnAGNPS modeling system for watershed assessment. Journal of Hydrologic Engineering (in review).

Policy Research Institute of The University of Kansas, 2003. The Thirty-Seventh Edition of the Kansas Statistical Abstract 2002. Available from http://www.ku.edu/pri/ksdata/ksah/.

Ponce, V.M., Hawkins, R.H., 1996. Runoff curve number: has it reached maturity? Journal of Hydrologic Engineering 1 (1), 11–19.

Tsou, M., Zhan, X., 2004. Estimation of runoff and sediment yield in the Redrock Creek Watershed using AnnAGNPS and GIS. Journal of Environmental Sciences 16 (6).

Williams, J.R., 1995. The EPIC model. In: Singh, V.P. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, Highlands Ranch, CO, pp. 909–1000.

Young, R.A., Onstad, C.A., Bosch, D.D., Anderson, W.P., 1987. AGNPS, Agricultural Non-Point Source Pollution Model: A Watershed Analysis Tool. USDA Conservation Report 35. USDA-ARS, Washington, DC.