AN OPEN SOURCE APPROACH TO AUTOMATED HYDROLOGICAL ANALYSIS OF UNGAUGED DRAINAGE BASINS IN SERBIA

Institute for the Development of Water Resources Jaroslav Černi, Serbia (Student Member) ○Nikola Zlatanović
ICHARM (Regular Member) Shigenobu Tanaka

INTRODUCTION

Drainage basins are for the most part ungauged or poorly gauged not only in Serbia but in most parts of the world, usually due to insufficient funds, but also the decommission of river gauges in upland catchments to focus on downstream areas which are more populated. Predictions in ungauged or poorly gauged catchments are not only highly uncertain but very data intensive. Hydrological analyses of these catchments usually require vast amounts of data such as landscape data, land use, various soil data, meteorological data, discharge measurements etc. Accurate data of this type is usually either scattered between different institutions, incomplete, or sometimes even non-existent, resulting in more time spent collecting and cataloging data than actual hydrological modelling.

This paper deals with the application of freely available datasets on the global, European and local level coupled with open source GIS (Geographic Information Systems) software in hydrological modelling, greatly improving cost and time effectiveness. The methods presented form a very cost-effective and solid basis for further hydrological analysis (e.g. effects of deforestation and urbanization, biodiversity resilience, flood control, pollutant transfer etc.).

METHODOLOGY

The method presented utilizes the Shuttle Radar Topography Mission digital elevation model (Rodriguez et al, 2005) (Figure 1b) with near-global coverage for landscape and terrain topography, CORINE (Coordination of Information on the Environment) Land Cover dataset (Bossard et al, 2000) with European coverage (Figure 1c) together with soil, meteorological and hydrological data, as input parameters for the NRCS (National Resources Conservation Service) method for estimating runoff predictions in ungauged basins.

The SCS (now NRCS) method of estimating direct runoff from storm rainfall was the method of choice for rainfall-runoff calculations in this paper. This method was developed by the Soil Conservation Service (now National Resources Conservation Service) as a procedure for estimating runoff in small, ungauged agricultural watersheds (SCS, 1985), and has since become one of the most popular methods for computing surface runoff for a given rainfall event in small to medium sized watersheds (Mishra and Singh 1999).

In order to obtain design effective rainfall the SCS Curve Number (CN) method was utilized. The CN is estimated by defining each and every hydrologic soil-cover complex in the watershed, and then weighting to get the watershed average, as described in the National Engineering Handbook (NRCS, 2002). The hydrologic soil groups (Figure 1d) were obtained from available soil maps, although more precise criteria for assignment of the four hydrologic soil groups are defined in the NEH.

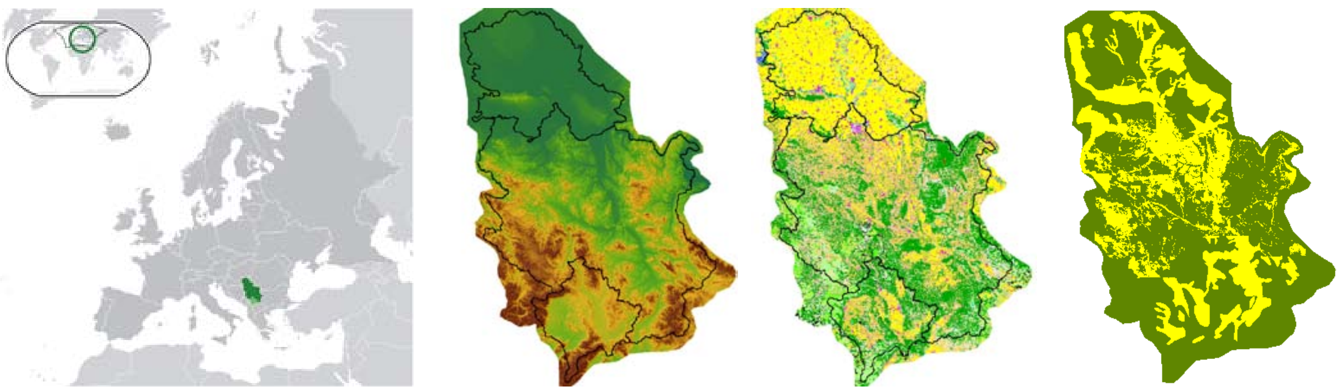
(a) (b) (c) (d)

Figure 1. Location and preview of implemented datasets: a) location b) Digital Elevation Model c) CORINE Land Cover d) Hydrologic Soil Groups

keywords: rainfall runoff, ungauged basins, open source gis

Effective rainfall is estimated using the following equation:

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \text{(Eq. 1)}$$

where P_e = total effective rainfall in mm, P = total amount of rainfall in mm, S = potential maximum retention or infiltration (in mm). The potential maximum retention is calculated using the Curve Number:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad \text{(Eq. 2)}$$

for obtaining S in millimeters.

The transformation of excess rainfall into direct runoff was simulated using a modified SCS dimensionless unit hydrograph. This dimensionless unit hydrograph (UH) expresses the UH discharge U_t, as a ratio to the UH peak discharge U_p, for any time t, a fraction of the time to UH peak T_p. Jovanović and Brajković (1989) suggested a modification of the SCS synthetic unit hydrograph based on a large number of observed watersheds in Serbia, and this method has since become the most widely used method in the region.

Morphological analysis was performed for every catchment in order to obtain necessary elements for the calculation of the unit hydrograph. The calculated morphological elements of catchments include catchment area and perimeter, mean elevation, longest flow path and slope, distance to catchment centroid etc.

The flowchart of the described methodology is presented in Figure 2. The software used for calculations was the open source programming language R coupled with the open source geographic information system SAGA GIS (System for Automated Geoscientific Analyses) using the module RSAGA.

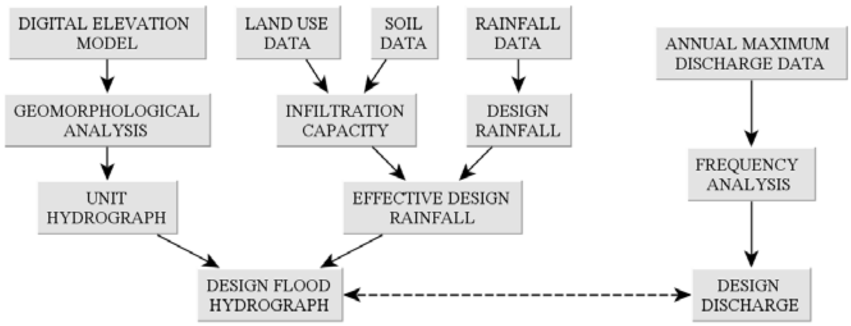

Figure 2. Methodology flowchart

RESULTS

The methodology described was implemented for 25 small to middle-sized catchments (drainage areas less than 500 km^2) throughout central Serbia. In Serbia, as in many other countries worldwide, design flood discharge is based on a defined return period. The results of the calculations were therefore compared to the results of frequency analyses of discharges measured on the same catchments. The frequency analyses included applying the Generalized Extreme Value probability distribution (using L-moments for parameter estimation) to series of measured annual maximum discharges.

CONCLUSION

The results show that the used open source datasets can be successfully used for hydrological analysis of ungauged catchments. The comparison between design discharges calculated by rainfall-runoff analysis and from frequency analysis yields very good resemblance, albeit with room for improvement. The type of automated analysis presented in this paper will enable a much quicker hydrologic analysis on multiple watersheds, as well as a platform for improving the methodology itself.

REFERENCES

BOSSARD M., FERANEC J., OTAHEL J., 2000: CORINE Land Cover Technical Guide - Addendum 2000. European Environment Agency, Copenhagen.

JOVANOVIĆ S., 1989: Hydrology (In Serbian). Građevinski tehničar III, p11-181. IRO Građevinska knjiga, Beograd.

MISHRA S.K., SINGH V.P., 1999: Another Look at SCS-CN Method. Journal of Hydrologic Engineering, 3, p257-265.

NRCS, 2002: National Engineering Handbook: Part 630 Hydrology. USDA, Washington, D.C.

RODRIGUEZ E. ET AL, 2005: An assessment of the SRTM topographic products (Technical Report JPL D-31639). Jet Propulsion Laboratory, Pasadena, California.

SOIL CONSERVATION SERVICE, 1985: National engineering handbook, Supplement A, Sect. 4, Chapter 10. US Department of Agriculture (USDA), Washington, D.C.