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RESOURCE COMMUNICATION

Variability in estimated runoff in a forested area based on different cartographic data sources

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Abstract

Aim of study: The goal of this study is to analyse variations in curve number (CN) values produced by different cartographic data sources in a forested watershed, and determine which of them best fit with measured runoff volumes.

Area of study: A forested watershed located in western Spain.

Material and methods: Four digital cartographic data sources were used to determine the runoff CN in the watershed.

Main results: None of the cartographic sources provided all the information necessary to determine properly the CN values. Our proposed methodology, focused on the tree canopy cover, improves the achieved results.

Research highlights: The estimation of the CN value in forested areas should be attained as a function of tree canopy cover and new calibrated tables should be implemented in a local scale.

Additional keywords: runoff estimation; Soil Conservation Service curve number; land use map; Geographic Information System; forested watershed; tree canopy cover factor.

Abbreviations used: CLC (Corine Land Cover); CN (Curve Number); E (Nash-Sutcliffe efficiency); PBIAS (Percent bias); RSR (RMSE-observations standard deviation ratio); SCLUM (Spanish Cultivation and Land Use Map); SCS (Soil Conservation Service); SFM (Spanish Forestry Map); SLOIS (Spanish Land Occupation Information System); TCCF (Tree Canopy Cover Factor).

Authors´ contributions Conception, data analysis and final approval of the version: LF, EQ and PDB. Experiments and drafting the article: LF. Critical revision: EQ and PD-B.

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Introduction

The hydrologic response of a watershed in a rainfall-runoff event depends largely on the runoff threshold, which represents the volume of water that can be absorbed by the ground before surface runoff begins. Therefore, it is an essential component of flood forecasting and warning systems (Carpenter *et al.,* 1999). Determining this value is one of the first steps in a hydrological analysis of a watershed, and it depends on several factors that are partially chosen by non-objective criteria, resulting in a corresponding uncertainty in the value.

Even though the Soil Conservation Service curve number (SCS-CN) method has been widely studied for decades (NRCS, 2009), there are not several works focused on the validation of this approach in forested watershed. In this way, Kim & Lee (2008) concluded that the SCS-CN lookup tables depicts inaccurate runoff estimation especially in forested watersheds. Ajmal *et al.* (2016) applied tabulated SCS-CN in forested areas and they confirmed that those tables were unreliable due to a runoff overestimation in all of their studied watersheds.

Works like Choi *et al.* (2016) have also studied the SCS-CN from several experimental forest catchments in order to modify SCS-CN runoff for forest lands in Korea. In particular, Tedela *et al.* (2011) evaluated the consistency of the CN method from forested-mountainous watersheds in the eastern United States and runoff estimated by tabulated CN were unreliable in most cases.

Free open access to different data sources leads to the question of choosing the best cartographic

Table 1. Summary of information provided by each cartographic source for decision-making with regard to land use or hydrologic condition.

Data source [1]	Agricultural areas		Prairies / Forest (scrub)		Forest (tree)	
	Land use (Definition of the crop type)	Hydrologic condition (Cultivation practices)	Land use	Hydrologic condition (Degree of land use)	Land use	Hydrologic condition (Canopy cover)
SCLUM	●	-	●	-	●	○
SFM	×	-	●	-	●	●
CLC	●	-	●	-	●	-
SLOIS	●	●	●	-	●	-

[1] SCLUM: Spanish Cultivation and Land Use Map; SFM: Spanish Forestry Map; CLC: Corine Land Cover; SLOIS: Spanish Land Occupation Information System. ●: adequate data definition. ○: acceptable data definition (requires user interpretation). ×: poor data definition. - : not provided data

sources for performing hydrological studies. However, the effects that the mapping information source exerts on the estimation of runoff have not been analysed in detail. Consequently, the main goals of this study were to analyse the effects of the use of different cartographic data sources on the CN values of a forested watershed and to determine which cartographic data source fit the measured runoff values in our studied area.

Material and methods

The SCS-CN method is based on the hypothesis of equivalence between the maximum volumes of retention and rainfall and the effective volumes of runoff and infiltration. This methodology was modified for its use in Spain by Témez (1987) who adapted the original table of the SCS-CN method. Similar to the original method, the estimation of runoff is based on parameters such as land use, slope gradient, hydrologic condition, and soil type. In this adaptation the considered land uses are as follows: cultivated areas, prairies, regular forest plantations, forests and rocks. In the case of forests, five levels of hydrologic condition are established (very clear, clear, average, thick, and very thick). However, in the case of forests, the classification proposed by Témez (1987) includes no objective criterion, because it does not indicate the vegetation cover density value for each level.

The study area was a watershed of the Jerte River in Cáceres province (Spain) that is covered by the following land uses: 59% of forest cover (40% of forest and 19% of scrubland forest), 17% of prairie, 23% of cultivated areas, and the remaining area corresponds to urban areas, roads and other minor uses. Rainfall volumes were obtained from two automatic weather stations belonging to the Spanish National Meteorological Agency. The baseflow was separated from observed total flow using the WHAT tool (Automated Web GIS Based Hydrograph Analysis Tool) described by Lim *et al.* (2005).

The cartographic sources used in this study were: Spanish Cultivation and Land Use Map (SLUM)[1] performed within 2000-2010 and Spanish Forestry Map (SFM)[2] performed within 1997-2006, both at a scale of 1:50,000; Corine Land Cover (CLC)[3] version published in 2000 at a scale of 1:100,000 and Spanish Land Occupation Information System (SLOIS)[4] published in 2005 at a scale of 1:25,000. The most remarkable characteristics of each cartographic source are shown in Table 1.

Estimation of runoff using different cartographic sources

Firstly, the estimation of land use and hydrologic condition, based on the available sources was achieved. In the cases that the used cartography did not provide the necessary data, fair hydrologic condition was assumed. Particularly, for forested areas, in the absence of objective criteria for establishing the hydrologic condition levels, we used a classification focused on

[1] http://www.mapama.gob.es/es/cartografia-y-sig/publicaciones/agricultura/mac_2000_2009.aspx
[2] http://www.mapama.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/mfe50.aspx
[3] http://centrodedescargas.cnig.es/CentroDescargas/catalogo.do?Serie=CAANE
[4] http://www.siose.es/

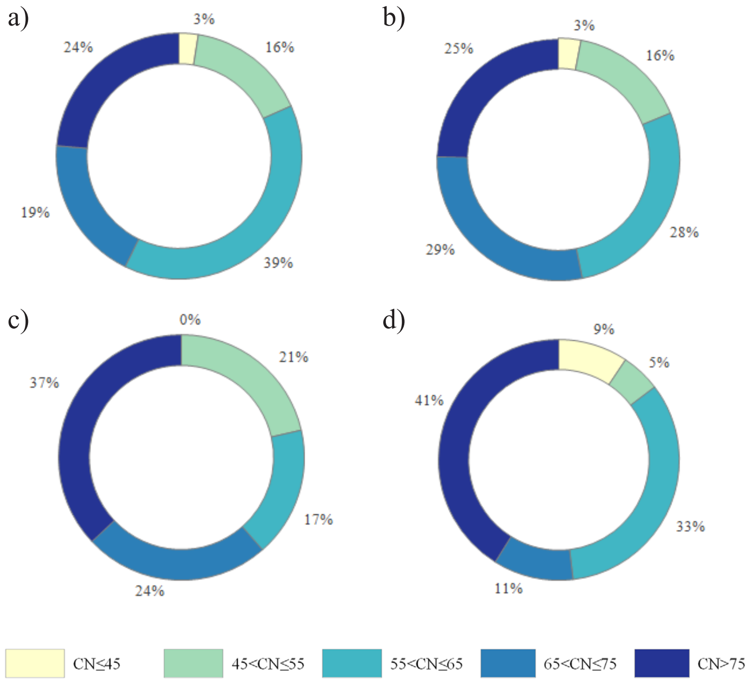

Figure 1. Fluctuations of obtained curve number (CN) values for each map: Spanish Cultivation and Land Use Map (SCLUM), (b) Spanish Forestry Map (SFM), (c) Corine Land Cover (CLC), (d) Spanish Land Occupation Information System (SLOIS).

Tree Canopy Cover Factor (TCCF). Our proposal for the assignment of hydrologic condition was: I-Very clear (< 20%), II-Clear (between 20 and 40%), III-Average (between 40 and 70%), IV-Thick (between 70 and 80%) and V-Very thick (> 80%).

Next, the slope was obtained from a Digital Elevation Model and the classification of soil groups was performed using the cartographic information developed by Ferrer i Juliá (2003), assigning soil group B throughout our studied area.

Finally, variations in CN values were analysed by comparing the four generated maps for land use and hydrologic condition.

Calibration

The observed runoff volumes (24 thunderous events from 2008 to 2014 period) were compared to the runoff volumes generated by each CN value obtained for each map. The comparison was attained by RMSE-observations standard deviation ratio (RSR), percent bias (PBIAS) and Nash-Sutcliffe efficiency (E) criteria.

Results and discussion

The estimation of CN value, as shown in Fig. 1, was dissimilar for each map. The range of CN values between 55 and 65 was the most variable: from 17% for the CLC up to 39% obtained for SCLUM. Those areas with CN value larger than 75, also presented significant fluctuations: from 24% for SCLUM to 41% for SLOIS. The most representative CN values for forest land use ranges from 55 to 65. These results are in substantial agreement with the outcomes attained in experimental forest catchments by Choi *et al*. (2016).

Otherwise, differences in CN spatial distribution (Fig. 2a) arranged from 1 (CN value coincidence in all maps) to 4 (none coincidence). The greatest differences (more than 15 points) in CN values (Fig. 2b) mostly corresponded with areas with no coincidence in CN

Table 2. Percent bias (PBIAS), Nash-Sutcliffe efficiency (E) criteria and RMSE-observations standard deviation ratio (RSR) values obtained from modelled volumes against the observed runoff volume.

Data source [1]	PBIAS	E criteria	RSR
SCLUM	-3.57	0.74	0.51
SFM	-2.04	0.74	0.51
CLC	4.41	0.71	0.54
SLOIS	15.58	0.62	0.61

[1] SCLUM: Spanish Cultivation and Land Use Map; SFM: Spanish Forestry Map; CLC: Corine Land Cover; SLOIS: Spanish Land Occupation Information System.

values. The highest variation in CN occurred in areas classified as scrubland forest and prairie, where none of the cartographic sources provided the TCCF values.

On average for the whole watershed, the CN obtained values were: 64.79 for SCLUM, 65.19 for SFM, 66.87 for CLC and 69.67 for SLOIS. Based on them, the runoff volumes associated to each thunderous event was calculated and compared with the observed runoff volume. The best results (Table 2) were attained by SCLUM and SFM based on RSR criterion. Comparing the PBIAS values, the best achievement was with the SFM map, with an overestimation of CLC and SLOIS. Similar results were obtained by Ajmal *et al.* (2016) in forested areas with a runoff overestimation using CN tabulated values. Finally, attending the E criteria, the best results (0.74) were obtained for SCLUM and SFM. It should be noted that this value was significantly better than those obtained in Tedela *et al.* (2011) in which the best of their forested basins showed a modest correlation (0.56).

Based on the performance rating proposed by Moriasi *et al.* (2007), a joint analysis reveals that the degree of suitability obtained in our CN estimation could be categorized as 'satisfactory' for SLOIS and 'good' for the rest of the maps, but being SCLUM and SFM located sorely close to the limit of 'very good'.

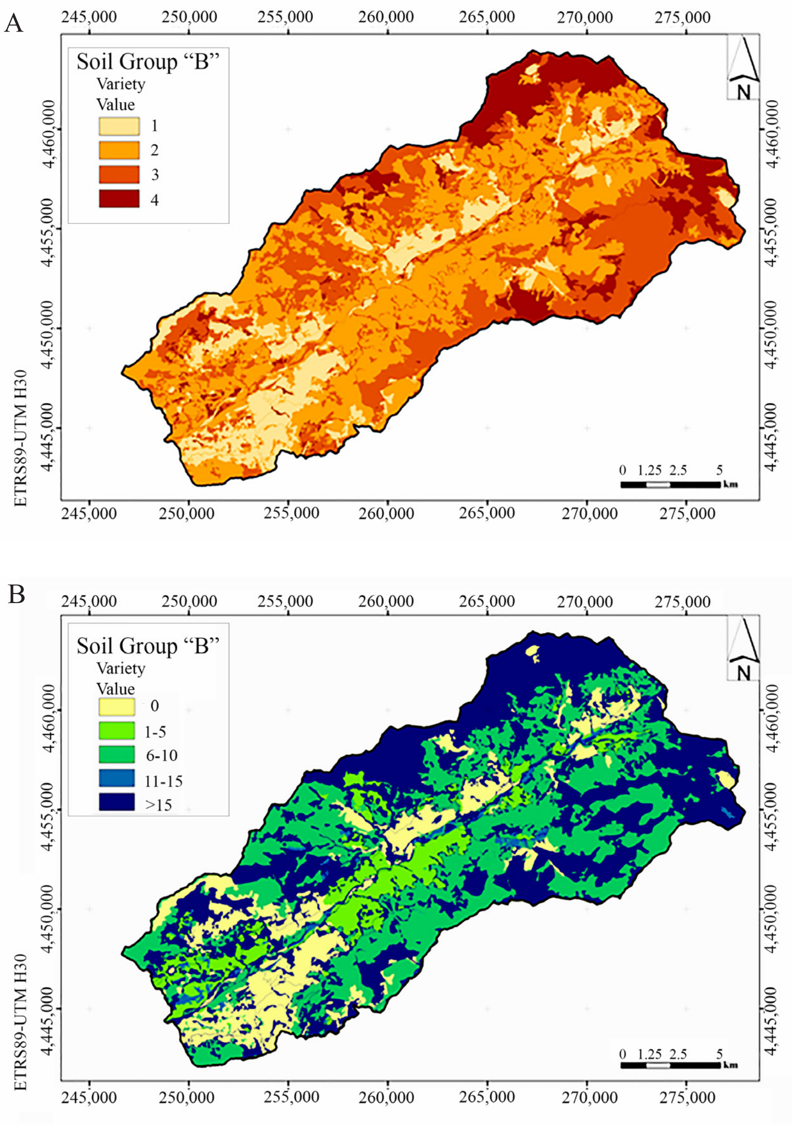

Figure 2. Results of variation in curve number (CN) for the four maps generated from each cartographic data source: (a) map of the variety in obtained CN values, (b) map of the range of variation in CN values.

In this work, the variation in CN, corresponding to the use of different cartographic data sources was studied. After the analysis of each of the data sources, it was observed that none of them provide all the information necessary to determine the land use and hydrologic condition. Based on the analysis of rainfall-runoff data in a forested watershed, the best cartographic data sources were the SCLUM and the SFM. Moreover, the ease to obtain the data of canopy cover from the SFM constitutes a distinct added value for this cartographic data source. Additionally, our proposed methodology for the assignation of the hydrologic conditions based on the TCCF, improves the achieved results, although the method could be validated over other cover ranges of forested watersheds. In short, we can conclude that the estimation of the CN in forested areas should be attained as a function of canopy cover and new calibrated tables should be implemented in a local scale.

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References

Amal M, Kim TW, Ahn JH, 2016. Stability assessment of the curve number methodology used to estimate excess rainfall in forest-dominated watersheds. Arab J Geosci 9 (5): 1-14. https://doi.org/10.1007/s12517-016-2421-y

Carpenter TM, Sperfslage JA, Georgakakos KP, Sweeney T, Fread DL, 1999. National threshold runoff estimation utilizing GIS in support of operational flash flood warning systems. J Hydrol 224 (1–2): 21-44. https://doi.org/10.1016/S0022-1694(99)00115-8

Choi HT, Kim J, Lim HG, 2016. Estimating the SCS runoff curve number in forest catchments of Korea. EGU General Assembly Conference Abstracts.

Ferrer i Juliá M, 2003. Análisis de nuevas fuentes de datos para la estimación del parámetro número de curva: perfiles de suelos y teledetección. CEDEX, Spain.

Kim NW, Lee J, 2008. Temporally weighted average curve number method for daily runoff simulation. Hydrol Proces 22 (25): 4936-4948. https://doi.org/10.1002/hyp.7116

Lim KJ, Engel BA, Tang Z, Choi J, Kim KS, Muthukrishnan S, Tripathy D, 2005. Automated Web GIS based Hydrograph Analysis Tool, WHAT. JAWRA 41 (6): 1407-1416. https://doi.org/10.1111/j.1752-1688.2005.tb03808.x

Moriasi DN, Arnold JG, Van Liew MW, Bingner RL, Harmel RD, Veith TL, 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. T ASABE 50 (3): 885-900. https://doi.org/10.13031/2013.23153

NRCS, 2009. National Engineering Handbook, section 4, Hydrology, version (1956, 1964, 1971, 1985, 1993, 2004, 2009). USDA, Washington, DC. Engineering Division

Tedela NH, McCutcheon SC, Rasmussen TC, Hawkins RH, Swank WT, Campbell JL, Adams MB, Jackson CR, Tollner EW, 2011. Runoff curve numbers for 10 small forested watersheds in the mountains of the Eastern United States. J Hydrol Eng 17 (11): 1188-1198. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000436

Témez JR, 1987. Cálculo hidrometereológico de caudales máximos en pequeñas cuencas naturales. MOPU, Spain.