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APPLICATION OF REMOTE SENSING AND GIS FOR DETERMINING CURVE NUMBER IN ESTIMATING RIVER BASIN SURFACE FLOWS

Trinh Thi Hoai Thu, Bui Thi Thuy Dao

Hanoi University of Natural Resources and Environment, Vietnam

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Abstract

Water discharge is valuable information for strategies on exploitation management, erosion control, determination of flow trends, flood forecasting and assessing the impact of climate change on water flows. Hydrological models were developed in response to the need for tractable techniques that could simplify the relationships between rainfall and runoff. The runoff curve number so called a curve number is an empirical parameter used for forecasting and quantifying runoff. This study aims to estimate the curve number index based on remote sensing and GIS (geographic information system) in the Vu Gia - Thu Bon river basin.

Keywords: Curve number; GIS; Remote Sensing; River Basin.

Corresponding author. Email: bttdao@hunre.edu.vn

1. Introduction

Watershed models are widely utilized to evaluate hydrological processes and to simulate basin at different spatial and temporal scales. Nowadays, various hydrological models have been developed based on the relationship between the rainfall and the flow. The hydrological models usually require input information related to precipitation, soil properties, geography, vegetation, temperature and other physical parameters. Numerous methods have been developed for estimating rainfall - runoff for instance Rational method, Green-Ampt method and Curve number (CN) method. The CN method has been widely applied because of the basic, simple implementation and dependable in results. Therefore, the CN determination is a significant task for the simulation of runoff. The CN estimation for a basin requires information on landuse/landcover, soil and antecedent soil moisture condition. The integration of remote sensing techniques and GIS is a reliable solution to prepare most of the input data required to compute the CN.

The numerical curve is an important parameter for the flow simulation. The surface runoff depends on a number of parameters such as soil types, land use, land cover, surface structures and previous moisture conditions. Information on these factors is input data to calculate a CN parameter of a river basin (Nayak et al., 2012) [1]. In National Engineering

Handbook (NEH) developed by USDA, soil types are classified in four groups A, B, C and D based upon the infiltration and other characteristics, where the A group and the D group has the highest and lowest infiltration rate, respectively. Ibrahim-Baths & Ahmed (2016) [2] successfully determined the CN coefficients for specific land-use types in the Doddahalla basin to provide necessary information about rain, flow characteristics, flow velocities, flow peaks and their respective times.

Gajbhiye et al (2012) [3] used the curve number method for selected storm events in a basin to estimate the flow depth and to determine the influence of slope on CN values and the flow depth. The study showed that remote sensing and GIS is very reliable techniques for preparation of input data required by curve number model.

Remote sensing techniques provides most of the input data required by the numerical curve method, while GIS has been used to develop algorithms for determining CN (Anubha & Vaishya, 2015; Rawat & Singh, 2017) [4, 5]. The combination of remote sensing techniques and GIS has improved the accuracy for the flow estimation, besides it can also provide auxiliary to fill the gap of lacking gauge data.

This study aims to determine the CN coefficient of the Vu Gia - Thu Bon basin based on the land cover data and the soil data in which, the land covers are extracted from satellite data and soil parameters are achieved from historical maps.

2. Study area

The Vu Gia - Thu Bon river basin is located in the center of Vietnam with an area of 10,350 km^2 covering 14 districts and towns of Quang Nam province, Da Nang city and a part of Dak Glei district (Kon Tum province). The basin is formed by a complex river system including many large hydropower reservoirs upstream such as A Vuong, Tranh 2 and Bung. Suffering the tropical weather with extreme precipitation in the summer and characterizing by a short and steep slope, especially the western mountainous area with an altitude of 2000 m, the basis is usually flooded in a short time but water recedes slowly.

3. Data used and methods

3.1. Data used

a. Land use/ land cover data

In the study, the supervised classification was performed based on Landsat 8 data obtained in May in 2014 on the Google Earth Engine platform. The classification approach used the Random Forest with Kappa index of 0.7. The land use/ land cover data was determined consisting of 11 classes which are shown in Table 1.

Table 1. Description of land use/ land cover types and the curver number values

LU Value	Code	Description	CN_{II}			
			A	B	C	D
1	URMD	Residential - medium density	57	72	81	86
2	WATR	Water	100	100	100	100
3	URLD	Residential - Low density	46	65	77	82
4	UIDU	Industrial	81	88	91	93
5	FRSE	Forest - evergreen	30	55	70	77

LU Value	Code	Description	CN_{II}			
			A	B	C	D
6	RICE	Rice	63	75	83	87
7	UCOM	Commercial	89	92	94	95
8	SWRN	Bare land	77	86	91	94
9	AGRR	Argicultrual land - rowcrops	64	75	82	85
10	ORCD	Land annual crop	57	73	82	86
11	FRST	Forest - mixed	43	65	76	79

b. Soil data

Soil data is extracted in soil paper maps established by the Ministry of Agriculture in 2005. Soil data was digitalized using ArcGIS and georeferenced in the projection WGS 84 zone 48N. According to National Engineering Handbook developed by the USDA, soils are classified into four hydrologic soil groups (HSG) based on the penetration of water and other characteristics. The four hydrologic soil groups are A, B, C and D.

Group A has a high rate of water transmission.

Group B has a moderately low runoff, potential to moderate infiltration rate.

Group C has moderately high drainage potential and low infiltration rates.

Group D has high flow potential and very low infiltration rates.

The soil categories are shown in Table 2.

Table 2. Description of soil types

No	Soil type name	HSG	No	Soil type name	HSG
1	Plinthic ferralsols	D	13	Orthic acrisols	D
2	Dystric fluvisols	C	14	Mollic solonchaks	D
3	Eutric anofluvic fluvisol	D	15	Acric ferralsols	C
4	Luvic arenosols	B	16	Dystric gleysols	C
5	Haplic arenosols	B	17	EndoProto-thionic Gleysols	D
6	Gleyic solonchaks	C	18	Arenic phaeozems	D
7	Haplic nitisols	C	19	Luvic phaeozems	D
8	Gleyic fluvisols	C	20	Ferralic acrisols	C
9	Stagni dystric fluvisols	C	21	Calcic luvisols	C
10	Haplic solonchaks	D	22	Plinthic hluvisols	B
11	Dystric fluvisols	D	23	Surface water	D
12	Albic acrisols	C			

c. DEM

The elevation data used in the study is Shuttle Radar Topography Mission (SRTM) DEM 30 data that provides worldwide coverage of terrain elevation at 1 arcsecond (30 meters) resolution.

3.2. Methodology

The CN method was originally developed by the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) and is one of the traditional methods for estimating direct runoff in watersheds.

$$CN = \frac{25400}{S + 254} \quad (1)$$

$$I_a = 0,2S$$

where: I_a is the initial abstraction (mm) and S is the potenital maximum retention (mm)

CN is the curve number in the range from 0 to 100 depending on soil, land use data annotated according to the NRCS. Land use data, soil data according to four hydrological soil groups are the input data for estimate the CN coefficient. The CN has been modified for larger watershed. Thus, the CN can be applied for watersheds larger than 15 km^2 by weighing CN with regards to the land use/land cover areas of the watershed. The weighted CN equation is shown as follows:

$$CN_w = \frac{\sum CN_i A_i}{\sum A_i} \quad (1)$$

where: CN_w is the weighted curve number, CN_i is the curve number I and A_i is the area with CN_i

4. Results

The composite CN curve for the Vu Gia - Thu Bon basin is generated based on the DEM, land use/ land cover, soil data and a CN lookup table which are analyzed using intersection tools in ArcGIS software. Values of CN are ranged from 55 to 100 which indicate the relative good flow formation in the study area. The CN value of 70 occupies the largest area with 40.4 % of the total basin while the lowest CN value (55) appears in only 0.01 % of the total. The CN map and corresponded areas of the Vu Gia - Thu Bon basin are shown in Figure 1 and Table 3, respectively. The weighted CN value for each soil hydrologic group and corresponding land cover/ land use class are presented in Table 4. The lowest weighted CN was 71.7 in forest - evergreen land and the highest weighted curve number was found to be 93.5 in commercial land except for water. These values show that Vu Gia - Thu Bon basin generates more runoff for a given rainfall in areas having greater CN values.

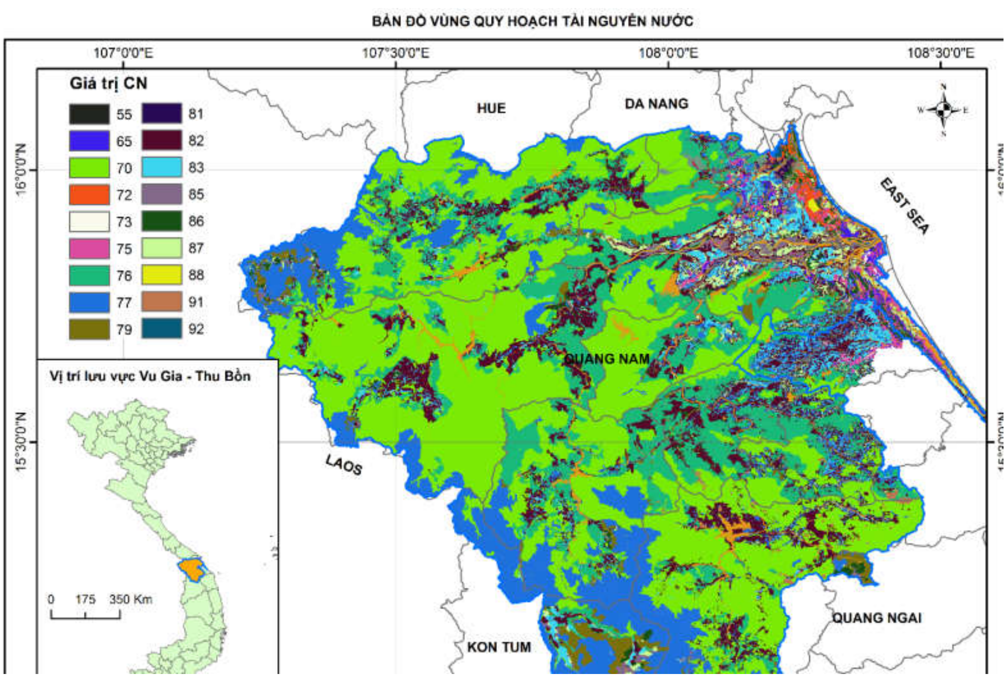

Figure 1: CN map of Vu Gia - Thu Bon basin

Table 3. Results of determining CN for the whole Vu Gia - Thu Bon basin

CN	Area (ha)	Area (%)	CN	Area (ha)	Area (%)
55	69,479	0,007	83	34419,666	3,309
65	5681,783	0,546	85	12501,017	1,202
70	419786,264	40,356	86	18367,023	1,766
72	3649,570	0,351	87	18424,663	1,771
73	1408,287	0,135	88	607,041	0,058
75	9499,237	0,913	91	6881,853	0,662
76	183406,699	17,632	92	618,774	0,059
77	153927,080	14,798	93	61,890	0,006
79	22258,941	2,140	94	4646,561	0,447
81	2320,201	0,223	95	115,849	0,011
82	110522,220	10,625	100	31040,362	2,984

Table 4. Calculation of weighted curve number for Vu Gia - Thu Bon basin

No	Land use cover	CN	Area (ha)	Weighted CN
1	Residential - medium density	72	3651.73	78.1
		81	2314.52	
		86	1948.36	
2	Residential - low density	65	5592.12	76.9
		77	22668.88	
		82	12326.87	
3	Industrial	88	607.53	89.6
		91	528.53	
		93	63.11	
4	Forest-evergreen	55	72.63	71.7
		70	419500.59	
		77	131468.29	
5	Rice	75	4730.90	83.6
		83	34520.84	
		87	18398.58	
6	Commercial	92	617.00	93.5
		94	1363.30	
		95	116.40	
7	Bare land	86	5347.48	89.9
		91	6406.81	
		94	3337.95	
8	Argicultrual land- rowcrops	75	4727.33	82.1
		82	19135.43	
		85	12522.48	
9	Land annual crop	73	1418.31	82.3
		82	78870.37	
		86	11077.44	
10	Forest- mixed	65	94.30	76.3
		76	183056.42	
		79	22260.54	
11	Water	100	31479.66	100

5. Conclusion

Vu Gia - Thu Bon is a huge and complicated river basin which is frequently flooded due to the extreme precipitation, steep slope. The study demonstrates that application of remote sensing and GIS is the effective tool to investigate CN values. The method can significantly assist in the effective management of Vu Gia - Thu Bon basin and water resources. The map of CN is calculated in Vu Gia - Thu Bon from the soil type and land use/land cover and class combinations in ArcGIS. The basin has weighted CN values between 71.7 and 100. The largest area belongs to the weighted CN value of 71.7 which concentrates in the area with the elevation value range 465 m to 937 m. The weighted CN is shown in Table 1 which indicated that a significant area of the watershed, about 40.4 % is covered by forest - evergreen land that leads to soil hydrologic groups B, C and D. Most of the land use categories have high weighted CN values in the study and the commercial land has weighted CN value of 93.5 that is the highest value excluding water. The values denote the higher the values of CN, the more flow is generated.

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