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Curve number method for surface runoff estimation in Lam Takhoong River Basin, Thailand.

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Abstract

Curve Number (CN) is a popular method for analyzing of rainfall-runoff relationship. The CN value is a combination of land use and hydrological soil type. Corrected CN values would result in accurate runoff prediction. Since the Curve Number method was originated from the Department of Agriculture of the US (USDA), therefore we matched the Thai soil series to the hydrological soil groups classified by USDA then the CN values of Lam Takhong watershed were evaluated as a case study. The Lam ta khoong River is a tributary of the Mun River. It covers a watershed area of 1,560 km^2 which is divided into 2 sub-watersheds in this study. In both sub-watersheds consis of 6 land use types i.e. paddy field, forest, upland crop, residential, tree bush, and water body. There are 22 CN values for the upper sub-watershed and 24 values for the lower one, the average values are 70.42 and 75.40 respectively. These CN values were applied for rainfall-runoff simulations using the historical data collection from rain stations Buriram 436401, Nang rong 436201 and inflow data flowing into the Lam Takhoong reservoir, during 2008-2012 and given resonable results.

Keywords: Curve Number, Soil Series, Lam Takhoong, Thailand

1 Introduction

Surface runoff affects many aspects of environmental, hydrological, and ecological conditions, such as flood hazard, reservoir operation, and soil erosion control. It is definitely necessary to estimating surface runoff in order to managing or mitigating flood hazard, soil erosion, and water resource operation (Vojtek and Vojtekova, 2016). Surface runoff, the consequence of rainfall, is controlled by soil characteristics, land use, and topography of the area, therefore it must be assessed from rainfall together with soil, land use and topographic condition. One of the most popular methods for estimating surface runoff is the Curve Number method (SCS-CN) which belongs to the Natural Resources Conservation Service (NRCS) of the US Department of Agriculture (USDA). The NRCS replaced the older office called the Soil Conservation Service (SCS), that's why the method named SCS-CN.

The SCS-CN method being originated in the US is now being used all over the world. The method is to transform the depth of rainfall into depth of runoff by considering soil characteristics, land use, and antecedent soil moisture (Hawkins et al, 2009). It is quite simple, but neither simplest nor inaccurate, because only one parameter is required namely curve number (CN) which is the combination of soil type and land use group. Since this method was created in the US therefore soil types are US soils. It is necessary to match Thai soils with US soil. We experimented this using Lam Takhoong River in Northeastern Thailand as case study.

Lam Takhoong (ลำตะโคง) is an important river in Burirum Province Northeast, Thailand which is not the same river as the Lam Takhong (ลำตะคอง) in Nakhon Ratchasima Province. Lam Takhoong is a very important water resource for Burirum Province and surrounding areas. Although very significant river, no research has been carried on but one on flood study by (Chawangsuk 2003). It was our objective to study surface runoff estimation of Lam Takhoong using SCS-CN method which included matching the US soils characteristics to Thai soils.

2. Study Area

Lam Takhoong, a subbasin of the Mun basin, is in between 14°41' 54" to 15° 17' 51" latitude and 102° 56' 15" to 103° 17' 15" longitude with the area of 1,560 km^2 covering total area of Buriram Province. In general, the Lam Takhoong River Basin is relatively flat and it flows northward to the Mun River (Figure 1).

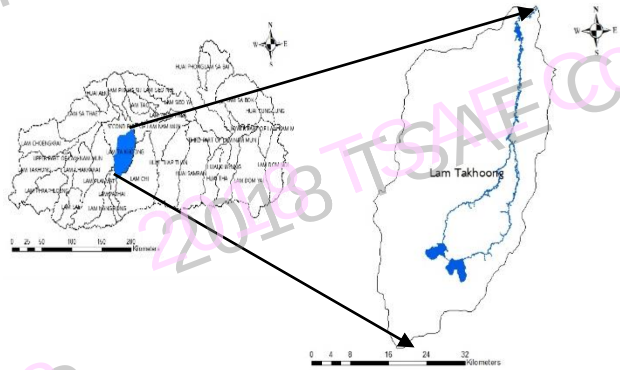

Figure 1 Illustration of Mun River Basin (left) and Lam Takhoong basin (right).

The climate of Lam Takhoong Basin is the typical climate of the Northeast, Thailand which is tropical monsoon with wet and dry seasons share each half of the year. The wet season starts from the middle of May to the middle of October and the rest is the dry season (Takahashi and Yasunari, 2008). About 90 % of rainfall is during the rainy season and normally the rainfall peak is in September. Average monthly rainfall of Burirum station is shown in Figure 2.

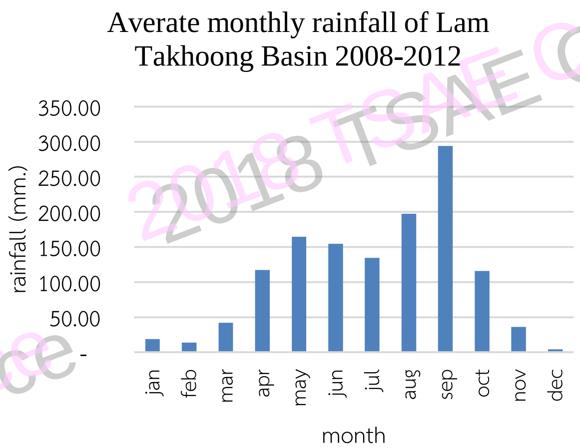

Figure 2. Averate monthly rainfall of Lam Takhoong Basin

3. Materials and Methods

3.1 Rainfall data

Acurate rainfall data is basically neeed for rainfall- runoff simulation (Beven, 2012) . Meteorological stations around the study area are of two stations: at Buriram and Nangrong, their details are in Table 1. Daily rainfall data of the years 2008 to 2012 were used in this study.

Table 1 Details of rainfall stations

Rain station	Name station	Lat	Long	During
436201	Burirum	15°1'6.56"	103°12'57.02"	2008 - 2012
436401	Nang Rong	14°37'36.17"	102°47'39.92"	

3.2 Hydrological soil group

SCS- CN method classifies soils into four categories (A, B, C and D) called hydrological soil groups basically based on infiltration potential (USDA, 1986). Soils of hydrological class A are characterized with very high infiltration rate and low surface runoff Whereas hydrological soils of group D have mostly a high clay content with high runoff potential. The soils of groups B and C are in between (Hawkins et al, 2009). We identified hydrological soil groups from their textures, thichnesses, and percolation capacities of the Thai soil series. We used the digitalized soil map of the Department of Land Development (DLD).

3.3 Land use and land cover data

Land use/land cover (LULC) characteristics are an important factor for deriving spatial CN of the river basin. We also used the 2012 land use/land cover map of DLD to specify LULC of the Lam Takhoong basin.

3.4 Observed runoff data

Observed runoff data are essential input parameters in hydrological studies for the purpose of testing the applicability of a given hydrological model and for undertaking basic calibration processes (Beven, 2012; Herschy, 1995). In this study, we used inflow data flowing into the Lam Takhoong reservoir as shown in Figure 3.

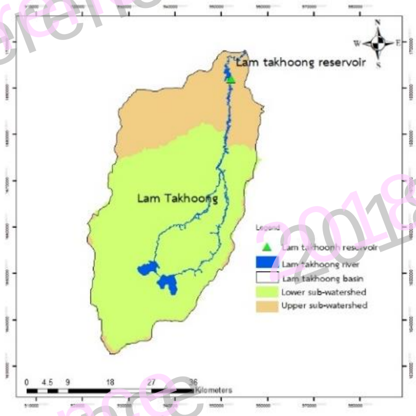

Figure 3 Observed runoff in Lam Takhoong

4 Surface runoff estimation using the Curve Number method

The SCS-CN method was developed from several empirical analyses of runoff events from series of rainfall and the resulting runoff with observing soil types and LULC of the basin. The SCS-CN method assume there is some initial loss of rainfall (I_a) and some storage in the soil (S). which is a function of CN. Then (Hawkins et al. 2002) demonstrated the relationship of surface runoff (Q) with rainfall (P) as in Eq (1)

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \tag{1}$$

where, Q is the actual direct runoff or rainfall excess in mm, and P is the total rainfall mm, I_a is initial abstraction, S is the maximum potential soil water retention (the watershed storage) in mm. I_a and S can be related as $I_a = 0.2S$ in original SCS-CN model. However, this assumption has often been criticized for its rationality and applicability, invoking a critical examination of the I_a- S relationship for practical applications, and suggested on need of modification and local determination of its actual value. (Baltas, Dervos, & Mimikou, 2007; Ponce & Hawkins, 1996). In this study, a value of 0.2 was taken to verify if it works for watersheds outside USA, especially for Lam Takhoong as shown Eq. (2).

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{2}$$

for P>0.2S otherwise Q=0

Potential storage (S) can be obtained from CN:as shown in Eq. (3).

$$S = \frac{25400}{CN} - 254 \tag{3}$$

where S is in mm, and CN is the curve number (dimensionless). The values of CN range from 5 (minimum runoff) to 100 (maximum runoff) which normally depends on the hydrologic soil group, land cover type and treatment, and antecedent moisture condition (USDA, 1986). The value of CN from the table is usually the moderate soil moisture called CN2 whereas CN1 and CN3 are antecedent low and high moisture content, respectively. We calculate CN1 and CN3 from CN2 as (Hawkins et al, 2009)

$$CN1 = (4.2CN2)/(10-0.058CN2) \tag{4}$$

and

$$CN3 = (23CN2)/(10+0.13CN2) \tag{5}$$

The conditions to determine CN1 and CN3 in this study are from 2-day antecedent rainfall. CN1 is to be applied when antecedent rainfall is less than 5 mm, CN3 is when antecedent rainfall higher than 50 mm.

4. Results and Discussion

4.1 Hydrological soil group

ArcGIS 10.3 was used for the spatial extent analysis of the hydrological soil group from the soil texture and infiltration rate raster file of the basin. The area and percentage of soil hydrological group for the basin was computed as shown in Table 2 and Figure 4.

Table 2 Classification of hydrological soil group

Hydrological soil group	Area	Precentage of Area
HSG-A	128.21	8.22
HSG-B	201.23	12.90
HSG-C	604.75	38.77
HSG-D	625.84	40.12
Sum	1,560.03	100

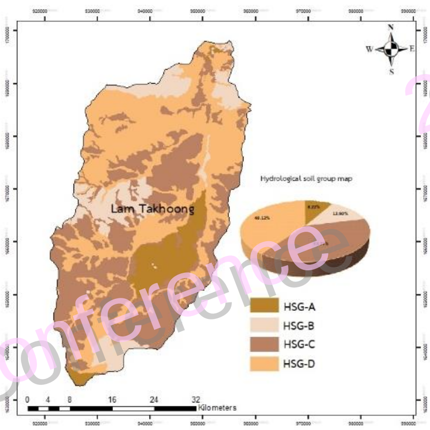

Figure 4. Hydrological soil groups of Lam Takhoong Basin.

4.2 Land use / land cover

Land use/land cover of Lam Takhoong Basin in this study was determined using ArcGIS 10.3 to calculate from LDL land use map. The results consis of 6 land use types i.e. paddy field, forest, upland crop, residential, tree bush, and water body as shown in

Table 3,4 and Figure 5 for upstream and downstream sub-basin, respectively.

Table 3 Details of parameters for downstream sub-basin.

Land use	HSG	CN	Area (Km^2)	Precentage of Area %
tree bush	A	30	0.79	0.0007
	D	55	0.43	0.00
forest	A	30	22.58	0.02
	B	55	10.48	0.01
	C	70	37.91	0.03
	D	77	34.09	0.03
upland crop	A	62	2.80	0.00
	B	71	13.47	0.01
	C	78	78.19	0.07
	D	81	58.44	0.05
resident	A	77	18.73	0.02
	B	85	5.87	0.01
	C	90	42.60	0.04
	D	92	28.34	0.03
paddy field	A	59	71.58	0.06
	B	70	89.61	0.08
	C	78	357.73	0.32
	D	81	208.05	0.19
water body	A	100	4.47	0.00
	B	100	1.36	0.00
	C	100	22.35	0.02
	D	100	8.35	0.01

Table 4 Detail parameters for upstream sub-basin

Landuse	HSG	CN	Area (Km)	Precentage of Area %
tree bush	A	30	0.04	0.00
	B	55	20.61	0.05
	C	70	1.27	0.00
	D	77	9.39	0.02
forest	A	30	0.82	0.00
	B	55	29.38	0.07
	C	70	8.21	0.02
	D	77	58.74	0.14
upland crop	A	62	0.84	0.00
	B	71	15.64	0.04
	C	78	26.28	0.06
	D	81	120.63	0.28
resident	A	77	0.81	0.00
	B	85	2.62	0.01
	C	90	2.97	0.01
	D	92	10.30	0.02
paddy field	A	59	3.58	0.01
	B	70	6.56	0.02
	C	78	22.11	0.05
	D	81	83.27	0.19
water body	A	100	0.13	0.00
	B	100	0.27	0.00
	C	100	0.89	0.00
	D	100	3.11	0.01

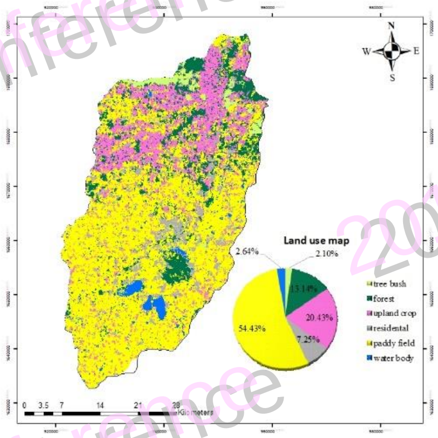

Figure 5 Land use/land cover of Lam Takhoong Basin

4.3 Observated and estimated surface runoff comparisons

The daily observation data of surface runoff was obtained from the Royal Irrigation Department by measuring the inflow into the Lam Takhoong reservoir. The daily observed runoff and the estimated runoff are compared to daily actual rainfall during the years 2008 to 2012. The daily data were sum up to be monthly data for comparison only for the very wet year, 2008, and very dry year, 2012, in Figure 6. Annually data comparison is in Figure 7.

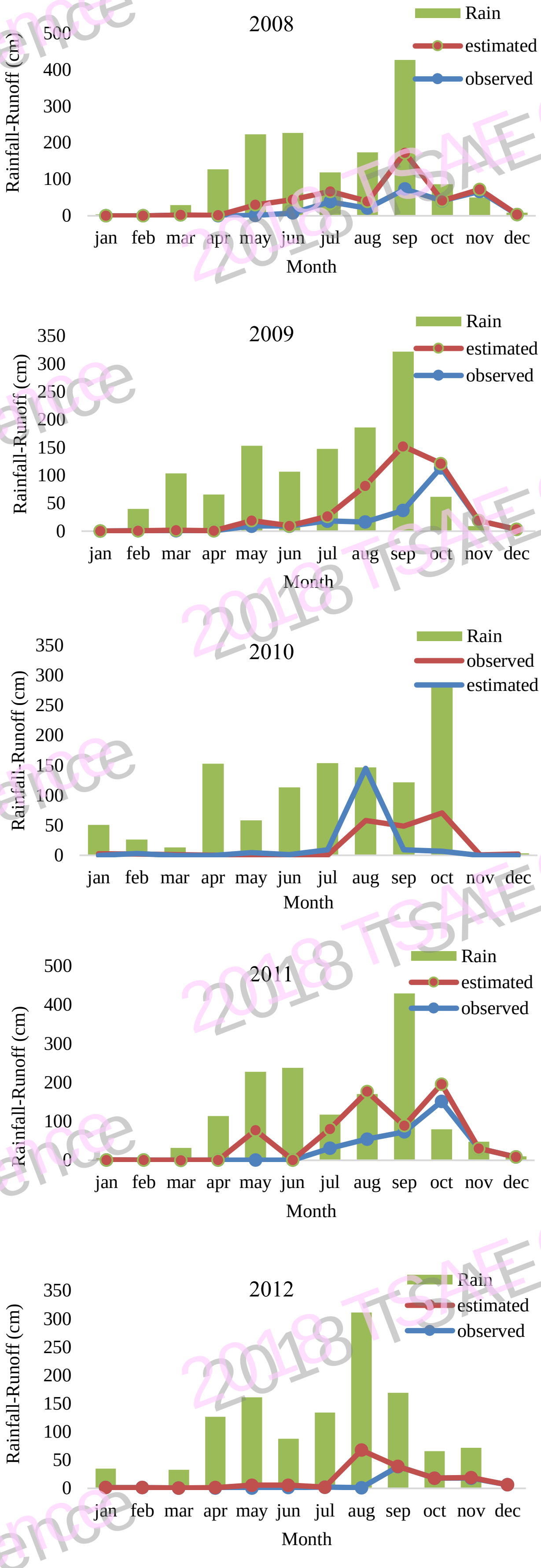

Figure 6 Comparison of monthly observed and estimated runoff with rainfall for 2008 and 2012

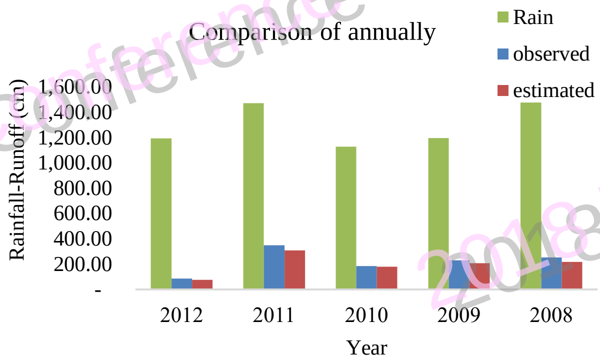

Figure 7 Comparison of annually observed and estimated runoff with rainfall.

The data of five years of this study, Figure 7 shows two years of wet years, 2008 and 2011, and 3 of dry years 2009, 2010, and 2012. The yearly comparison between the observed and the estimated in Figure 7 are quite agreeable. All of the estimated runoffs, however, are less than the observed ones. The reson for this is that the flow into the Lam Takhoong reservoir is not only surface runoff but also the base flow component. The SCS-CN method calculates only the surface runoff (Hawkins et al, 2009).

For monthly comparison in Figure 6, the observed and the estimated runoff are not quite compatible. Although the estimated runoff follows the actual rainfall quite well but the observed value does not. For example, of the 2008 result during November the observed value is higher than the rainfall value which is not realistic.

5. Conclusions

This study was founded that the estimat runoff using by Curve number method results were satisfactory. Most of the Lam takhoong are rice fields with an area of 50 Precentage of area and Hydrological soil group is 40.12 Precentage of area. So, the CN value of Lum takhoong is 72.91. The estimate runoff Values are more than observations. But less than rain data. The runoff estimates Maximum value of 2009 in September and Maximum value of 2012 in August. But the runoff observ Maximum value of 2009 in October and Maximum value of 2012 in September. Therefore, the runoff observ value next lag of one month in as much have cumulative runoff from upstream to downstream. In 2008 and 2011 were the maximum value in the same month. However, the CN method is also positive alternative used to analyzing of rainfall- runoff relationship.

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