

Using the Method of soil conservation service Curve Number (SCS-CN) Combined with the Geographic information system (GIS) to estimate the surface runoff on the Co To Island, North Vietnam

Bui Xuan Thong¹, Nguyen Van Dan², Nguyen ManhTrinh³, Nguyen Ngoc Ha³

¹ Institute of Oceanography and Environment, Viet Nam

² Institute of Resources and Environmental Water, Viet Nam

³ National Center for Water Resources Planning and Investigation, Viet Nam

*Correspondence email: buixuanthonghunre@gmail.com

Abstract— Co To Island in the north of Vietnam is about 22 km² in area (including Big and Small Co To Islands), of which about 51% of mountainous and hilly areas, about 49% of cultivated land. On the island, there is only the meteorological observation station, no hydrological station. Because of the demand for water resources management, rainwater harvesting and storage needs initial hydrological parameters, this study first published the results of surface flow from rainwater on Big Co To Island.

The authors used the Soil Conservation Services Curves Number method (SCS - CN) in conjunction with the Geographic Information System (GIS) to estimate surface flow parameters on Big Co To Island. Two types of rainfall monitoring data that have been exploited in this study are the average annual rainfall (Rainfall Event 1) and the amount of rainfall during the storms (Rainfall Events 2-4). Estimated results of Qo discharge flow rate reach 0.39 m³/s based on the 30-year rain monitoring data series with error less than 29%.

The result of estimating the total surface water (Wo) generated from rain in event 1 was 13.1 x 10⁶ m³, meanwhile, during the rainy event 2 these values reached 10.2 x 10⁶ m³. This result confirms the potential of exploiting rainwater resources from storms on the island. SCS - CN method combined with GIS for determining exact areas, soil properties, land use ... has allowed the implementation of other calculations on the distribution of hydrological parameters at 14 sub-basins with different rain events.

In the absence of any official statements about the hydrographic parameters of Big Co To Island, the findings of this study will be good references for other research and calculations involved.

The SCS - CN method combined with GIS is an effective and convenient tool to evaluate the hydrological parameters of water resources on the island, especially where there is no permanent hydrological monitoring station.

Keywords— Storm Rainfall, Surface flow, SCS - CN, GIS, Co To Island.

I. INTRODUCTION

Forecasting the surface runoff for a basin is very important in research and exploitation of water resources. There are quite a number of approaches to estimating surface flow, SCS - CN method that is one of the most widely used because of their simplicity and ease of use for practical. For each event, rainfall generates a certain amount of surface flow after loss of water surface and underground. Evaluation of surface water losses using

traditional and latest methods combined with GIS has been mentioned in the works of Abhijit M. Zedel et al (2014), Geena GB et al (2011), Eljakeen M et al (2009) and Ningaraju et al (2016). Curve number (CN) is proportional to the surface flow quantity and inversely proportional to the permeability index of the soil. Curve number is a function of land use and hydrologic soil group (HSG). As such, the curvature index changes with the change in land use of the catchment area. Describing the properties of

curve number as well as its variability with land use change has been mentioned by authors like Gandalia M et al (2014), Jeffry Swingly et al (2012) and in many another monographs.

In recent years, traditional SCS - CN method has been significantly enhanced with the development of satellite monitoring technology and geographic information systems. Data on soil properties and land use status have been evaluated for each group of hydrologic soil group (HSG). Therefore, the curve number (CN) is quantified and the results of surface flow estimates for each rainfall events are more accurate than other methods. Recent researches have confirmed that the SCS - CN method combined with GIS is highly effective in surface flow estimation, particularly for basins without a hydrological monitoring station. Modern GIS technologies have allowed to assess in detail the dimensions and angles of the basins, whether large or small. The geographical information system can retrieve and process the soil type and land use shapefiles and a new intersection shape file can be created as another data file for the curve number calculation. These types of studies have been mentioned by authors like Matej Vojtek et al (2016), Noah Kimeli et al (2017), Ningaraju H.J. et al (2016), Sameed Shadeed et al (2010).

Several other research teams use SCS - CN to evaluate the loss of rain for the SWAT and other model that calculates the potential for flooding from heavy rainfall events in the design of water protection projects. In the study of Sameed Shadeed (2010) also mentioned some other authors when simulate SWAT model used SCS -SN method to determine surface runoff as input for their model.

Improving the quality of SCS-CN calculation techniques is continuing to improve. Directions that enhance the accuracy of the SCS-CN method mainly take into account the distribution of CN in specified spatial regions, using a set of rainfall survey data in storms and surface runoff observations. Other authors have exploited the infiltration data and the soil moisture to correct the CN curve. Some other works focus on determining the correlation relationship between potential surface flow depth (S) with initial abstraction value. Studies using SCS -CN methods apply to different rainfall events in the basins with surface flow monitoring data and to basins where no hydrological monitoring stations have been mentioned in the works of Chow, V.T at al (1988), Jaehak Jeong et al (2010), Manoharan A (2012), H.J. Ningaraju et al (2016), Noah Kimeli (2017), Soulic K.X (2012) and Sameed Shadeed et al (2010).

The traditional method of SCS-CN in combination with GIS is still being exploited and researched to enhance the accuracy of the curve number (CN). Author Tomasz Kowalik et al (2015) used asymptotic function to evaluate CN. From the author's point of view, it is necessary to create many CN values as a function of rainfall depth and rainfall abundance. In this study, the authors studied CN value distribution in 3 scenarios: scenario 1 is very large industrial value and very small depth of rain and concludes that CN value changes very little. The second scenario is when rainfall increases and the value of CN is unstable. The third scenario is that with many different depths of rain, the value of CN does not change unless the depth of rain is very small and the value of CN increases suddenly. The results of this study show that it can accept constant CN value for small basins.

Determining the coefficient λ in the formula point out the relationship between maximum potential water depth S (mm) and initial loss depth Ia depends very much on local conditions. However, in most related studies, the method of determining the coefficient λ is not indicated and selecting initial abstraction coefficient λ is only approximate.

The research direction of SCS -CN application in Vietnam is not much, however, it must mention the research works of Son Nguyen Thanh (2005) and An Ngo Le at al (2016), , in which they used surface runoff estimated by the SCS -CN method as input for SWAT model.

Before we started applying the SCS -CN method in combination with GIS on Big Co To Island conditions, we had a lot of difficulties. In addition to the limitations of the SCS -CN method as other authors mentioned above, estimating the surface flow value on Big Co To Island by SCS - CN method has its own difficulties. This has been confirmed by researchers on water resources in Viet Nam as well as in the study of Thong Bui Xuan et al (2017), Dan Nguyen Van, Thong Bui Xuan et al (2019).

Most of the islands in Viet Nam do not have hydrological stations, small areas, steep slopes, geological structure as well as terrain conditions are different, rivers and streams are very little so the determination of surface flow is very complex. So far, there has been almost no published information on surface flow in the islands including Co To Island. On Co To Island, there is a meteorological observation station currently exploiting daily rainfall data. However, there is no hydrological monitoring station on the island, so it is difficult to check the calculation results of the hydrological parameters. While the need to provide initial data on surface flow, total precipitation and other parameters of groundwater

recharge on Big Co To Island is very urgent. We have chosen the simplest approach to apply the traditional SCS - CN method on the basis of fairly accurate assessments of land and land use in Big Co To Island to provide a set of parameters on water resources on the island.

Rainfall monitoring data on Co To Island with a continuous length of over 30 years is a reliable source to ensure the calculation of rainfall regime on the island. In this study, we have exploited two series of monitoring data of water flow in some streams on the island in September and October 2012 (Dan Nguyen Van, Thong Bui Xuan et al, 2019). This is a rare source of data that has been allowed to use in this study to evaluate the calculation error of the water flow value of Q_0 according to the SCS - CN method combining GIS with monitoring data at the same period.

One thing to emphasize in this study is that in the last 10 years GIS technology has been implemented very effectively in land use management and land classification on Co To Island. Due to the accurate GIS results, 14 sub-basins of Co To Island have been classified according to the actual use of land. Taking advantage of the results of GIS we exploited rain events corresponding to the average

rainfall of 30 years (Rainfall event 1) and storm rainfall (Storm rainfall events) to calculate hydrological parameters for 14 basins of Big Co To Island.

As we are aware, the determination of Q_0 value of flow rate depends very much on the GIS results in accurately determining the area of sub-basins, slope, and types of land use. The value of Q_0 will be checked through the actual measurement results along with the allowable errors. If the value of Q_0 is evaluated with the permissible level, the other hydrological parameters will have a level of security.

RESEARCH AREA

Big Co To Island is one of the largest islands in the Co To archipelago and geographically locates at $21^{\circ}00'$ N latitude and $107^{\circ}15'$ E longitude covering an area of 16.31 km^2 . The population of Big Co To Island is estimated at 4,110 people in 2016 (Year Book, Quang Ninh, 2013, 2016). Co To Island is low hills and mudflats. Mountainous areas cover about 51%. In the dense vegetation, natural forests and plantation forests cover the peaks and slopes. The cultivated land area occupies 49% of the natural area (Fig. 1).

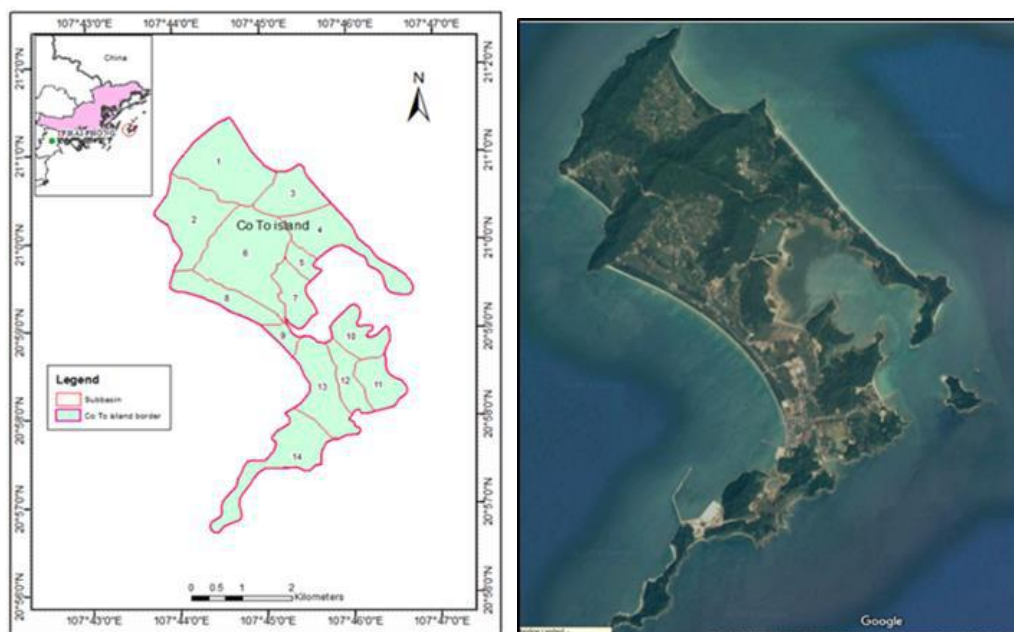


Fig.1: Location of Co To Island and sub-basins

Due to its small island nature, the potential for water resources is limited, while Co To is a tourist destination which attracts over 300,000 visitors every year. Therefore, the demand for water on the island is very high. In recent years, the situation has deteriorated due to the increase of salinity intrusion, pollution and exhaustion of surface water. Thus, the quantification of

water resources with the objective of stability and economic development is a very necessary. Determining the characteristics of the total amount of water, groundwater or other features of the island water resources need to be appropriately formulated on the basis of available literature.

On the Co To Island there is the only one marine meteorological station with long observation data from 1958 up to now. The CoToMarine Meteorological Station is 160 m above sea level and has coordinates at 20° 59' N latitude and 107° 46' E longitude. The meteorological station belongs to the network of national monitoring stations should ensure the reliability used data in calculating water resources for whole CoTo Island. The Co To Island is located in the monsoon tropics with basic climatic characteristics as following.

- Temperature: The average annual air temperature on the island was about 23°C, the lowest air temperature was 15°C in January and February, the highest average temperature in July was 28.6°C. Generally the temperature is typical of marine climate, the amplitude of fluctuation is not large.

- Rainfall: The average annual rainfall is not high compared to many inland areas, the average rainfall was 1776 mm. The highest rainfall in 2013 was 2936 mm, the least rain in 1977 was 884 mm. The highest rainfall was from July to September and the least rainfall was from December to January.

- Wind: northeastward, prevailing from September to April. East wind from May to August, July alone South wind. Average wind speed was 4.2 m/s.

Winter wind is stronger than summer. In about 100 years from 1895 to 1995, on average, 1-2 storms a year. Storm season from June to September, mainly from July to September.

- Average humidity was 84%, the lowest was about 23%.

- Evaporation: The average amount of evaporation was 954 mm. The months most evaporated from July to November, at least in February to March (Year Book, Quang Ninh, 2013, 2016). The climatic characteristics of Co To Island are summarized in Table 1.

- Co To island surface water resources: The aquatic ability on Co To island is quite large, but the ability to hold water is very poor due to the sloping topography, the water drains quickly to the sea, so the streams on the island are few. Water flow of streams depends on rainfall, there is no regular flow. The streams on the island have temporary water: the Hong Van streams, Nam Dong stream, Nam Ha stream, Hai Tien stream ... The Island has no natural lake but only artificial water reservoirs. The local government invested in building 6 freshwater lakes, of which Truong Xuan and C4 lakes supplied water to the town, the remaining lakes supplied water to agriculture.

Table 1. Climate characteristics of Co To Island in the period of 1977 -2016

Month/ Element	January	February	March	April	May	June	July	August	September	October	November	December	Yearly
Rainfall (mm)	32.7	24.1	45.7	74.9	144.6	217.0	335.9	382.9	337.4	108.4	44.1	28.0	1776
Evaporation (mm)	70.4	45.1	46.9	51.2	66.5	73.4	86.6	77.0	91.0	122.0	116.2	107.5	954
Humidity (%)	83	88	90	90	88	87	85	86	82	78	76	78	84
Temperature (°C)	15.1	15.2	18	22.1	26.2	28	28.6	28.3	27.4	25.1	21.4	17.5	23

II. MATERIAL AND METHOD

It can be said that the Soil Conservation Service (SCS) method originated in the early 1950s in United States of America. The original goal of this method is to evaluate the volume of direct runoff from rainfall.

Later, many improvements appeared to enhance the accuracy of determining the number of CN curves and from that method CN SCS is often applied to small basins in agricultural production. Until 1992, the CN SCS method was still considered the traditional method of determining the relationship between rainfall and surface flow. The method of SCS - CN has a long time of development and is widely applied in the world due to its simplicity and ease of application. GIS technology has strongly developed, soil properties, land use status,

accuracy of land area with complicated angles has been quickly implemented by GIS with absolute accuracy. In general, SCS - CN method combined with GIS is the current method. Representatives for traditional SCS groups must include authors such as Chow, VT, Maidment, DR, and Mayse W (1988), Sheridan JM, and Marshall LK (2007), Professor Patel, United States Department of Agriculture (1986) and Varsha Mane, YB Katpatal, KR Aher (2014).

According to these authors, the SCS-CN method is based on the following principle. During a rainfall, the effective rainfall depth or the direct flow depth (Pe) never exceeds the rainfall depth (P). Similarly, after the flow of rainwater begins, the water depth is held in the basin,

Continuous permeability depth (F_a) is always less than or equal to a certain depth of maximum potential water (S).

At the same time there is a loss of the initial loss depth (I_a) before runoff begins. Therefore, there is a potential flow of $P - I_a$. In the SCS method, assume that the ratio between the two real numbers P_e and F_a is equal to the ratio between the two potential quantities $P - I_a$ and S , which means:

$$\frac{F_a}{S} = \frac{P_e}{P - I_a} \quad (1)$$

From the principle of continuous leading to the expression of total depth of rainfall P as follows:

$$P = P_e + I_a + F_a \quad (2)$$

From (1) and (2) the effective rainfall depth P_e :

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \quad (3)$$

In particular, P is the total depth of rainfall (mm), P_e is the effective rainfall depth (mm), F_a is the continuous permeability depth (mm), S is the maximum potential water depth (mm), I_a is the initial loss depth (mm). In the works of Sammeer SHADEED (2010), Ningaraju H.J. et al (2016), have shown that for the dry and semi-dried basins the value of $I_a = 0.2S$. So from (3) P_e is rewritten as follows:

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (4)$$

Plotting relationships between P and P_e using data from multiple basins has found their standardized CN curves. CN is a dimensionless integer, taking a value in the range $0 \leq CN \leq 100$. A CN of 100 represents a limiting condition of a perfectly impermeable catchment with zero

retention, in which all rainfall becomes runoff. For natural basins, $CN < 100$. The curve number CN is estimated using antecedent moisture condition (AMC) and hydrological soil group (HSG).

The variable S , which varies with antecedent soil moisture and other variables, can be estimated as

$$S = 25.4 \left(\frac{1000}{CN} - 10 \right) \quad (5)$$

Where S is the spatial variation of the soil according to changes in soil properties, land use and management, slope and time.

The CN is calculated based on the weighted average of the land use types present in the basin:

$$CN = \frac{(CN_1 \cdot A_1) + (CN_2 \cdot A_2) + (CN_3 \cdot A_3) + \dots + (CN_n \cdot A_n)}{\sum_{i=1}^n A_i} \quad (6)$$

Where $A_1, A_2, A_3 \dots A_n$ is the area of land types in the basin with $CN_1, CN_2, CN_3, \dots, CN_n$ respectively. A_i is the total area of the basin. Table 2 summarizes the HSG characteristics. The conditions for moisture classification according to SCS are shown in Table 3.

The combination of GIS in SCS-CN method is described as follows. Land use and soil type shapefiles were first obtained and compiled in a GIS Data base. Soil properties and land use themes were intersected using GIS techniques, to generate new and smaller polygons associated with hydrological soil group (HSG_s) and land use cover names. At the same time the curve number database was built based on the intersected land soil layer and its related common table. All the field calculator combined with GIS techniques were presented on methodology scheme 2 below.

Table 2. Classification of hydraulic conductivity of soil group (HSG) according to SCS

Soil group	Lowest permeability rate (mm/hour)	Description
A (High infiltration)	7.62÷11.43	Types of soil with high sand and gravel. Low erosion potential
B (Moderate infiltration)	3.81÷7.62	Soils with fine and coarse grains are balanced
C (Low infiltration)	1.27÷3.81	Soil types have a lot of fine grains. High erosion potential
D (Very low infiltration)	0 ÷ 1.27	Soil types with very high clay content, static groundwater levels are often high, that is, valley and clay soil near the surface. Very high erosion potential.

Table 3. AMC moisture conditions for determination of CN

Antecedent Moisture Condition		Conversion of CN from AMC II to I and III	Total Rain in Previous 5 Days (mm)	
Description	AMC		Dormant Season (mm)	Growing Season (mm)
I	Dry conditions	$CN(I) = \frac{4.2CN(II)}{10 - 0.0568CN(II)}$	< 13	< 36

II	Normal moisture conditions		13÷28	36÷53
III	Wet conditions	$CN(I) = \frac{23CN(II)}{10 + 0,13CN(II)}$	> 28	> 53

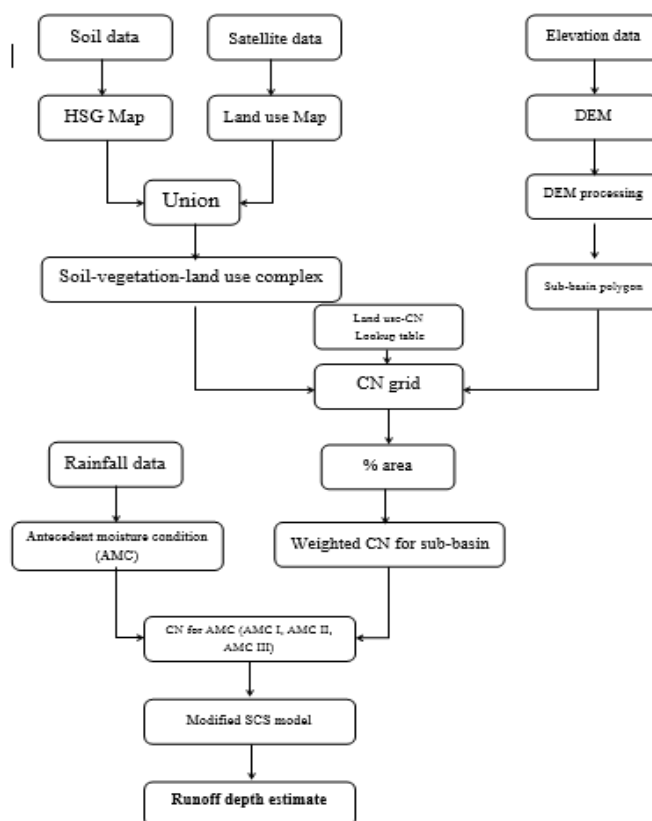


Fig.2: Scheme of surface runoff estimation by SCS - CN method combined with GIS

III. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Data used

Data on land and land use of BigCo To Island are presented in Table 4 and Table 5 and on Figures 4. Data on topography and slope of the island are shown in Figure 3 below.

+ 1/10,000 scale topographic map is digitized into 30 m x 30 m digital elevation map (DEM). From the topographic map, it is possible to determine the slope of the Big Co To Island topography. Grading of slopes in the range of <10%, 10-20%, > 20% shows that the topographic area is <10% (has the nature of the delta) occupying more than 60% of the total area.

+ The land map was extracted from the national atlas of 2000. According to FAO land classification, the whole land on Big Co To Island is ferrallitic gray soil corresponding to land type B according to the HSG classification (Table 2).

+ Land use map extracted from the results of interpretation from Landsat 7 satellite imagery taken in 2015. The results of the classification according to different types of land use showed that there are 8 main land use categories, of which land grassland occupies the highest rate of 48.5%, followed by bare mountain land accounts for 24.6%.

Table 4. Summary of spatial data of Big Co To Island

Number	Type of data	Amount	Source	Year
1	Topographic map of the scale of 1 / 10,000	Whole island	Department of Surveying and Mapping - Ministry of Natural Resources and Environment https://earthexplorer.usgs.gov/	2009
2	Landuse map	Whole island	Landsat 7 ETM + C1 Higher-Level	2015
3	Soil map	Whole island	Atlas	2000

Table 5. Total area of land use types of BigCo To Island

Number	Type of land use	Land code (According to FAO 74)	Area (ha)	Area (%)	CN (Land type B, AMC II)
1	Residential land	URBN	86.2	5.3	85
2	Land Stone bald	BARR	401.3	24.6	86
3	Grassland	GRAS	790.8	48.5	79
4	Land for planting fruit trees and perennial trees	ORCD	6.0	0.4	65
5	Flooded land	WATR	171.7	10.5	100
6	Forest land planted	FRST	70.7	4.3	66
7	Fixed upland fields	AGRL	29.4	1.8	75
8	Land Planting rice	RICE	74.5	4.6	78
Total			1631	100	

The series of continuous rainfall monitoring data (Rainfall event 1) in the period of 1977 -2016 and 4 storm rainfall events (Storm rainfall events 2,3, 4 and 5) in the period 2013-2016 were collected to calculate surface flow and other hydrological parameters on the Big Co To Island. Four storm events with corresponding type III moisture conditions (with the preceding 5-day precipitation greater than 53 mm), thereby determining the CN III value. Table 6 below summarizes the characteristics of 4 storm rainfall events.

Table 6.Characteristics of storm rainfall events on Big Co To Island

Storm rainfall Event	Time period	Amount of rainfall (mm)	Number of hours	Average rainfall intensity (mm/h)	Five-day antecedent rainfall (mm)	AMC
2	3-5/9/2013	652.4	72	9.06	109.6	III
3	20-21/8/2014	227.3	48	4.74	182.6	III
4	2-4/9/2015	287	72	3.99	86.7	III
5	5-6/7/2016	313.6	48	6.53	78.1	III

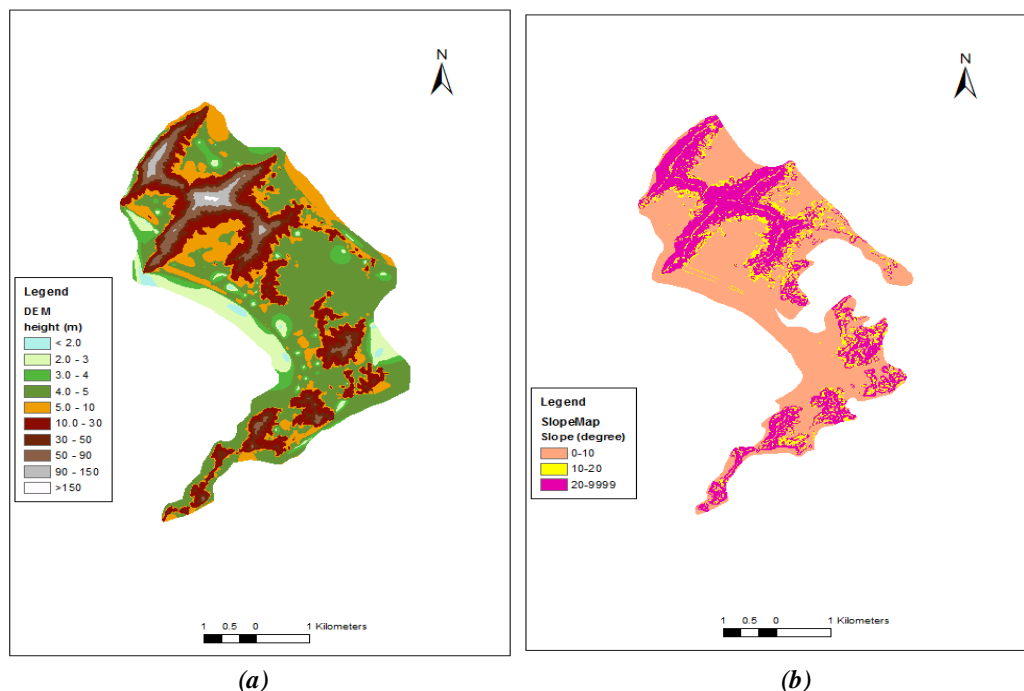


Fig.3: Topographic map (a) and slope (b) of Big Co To Island

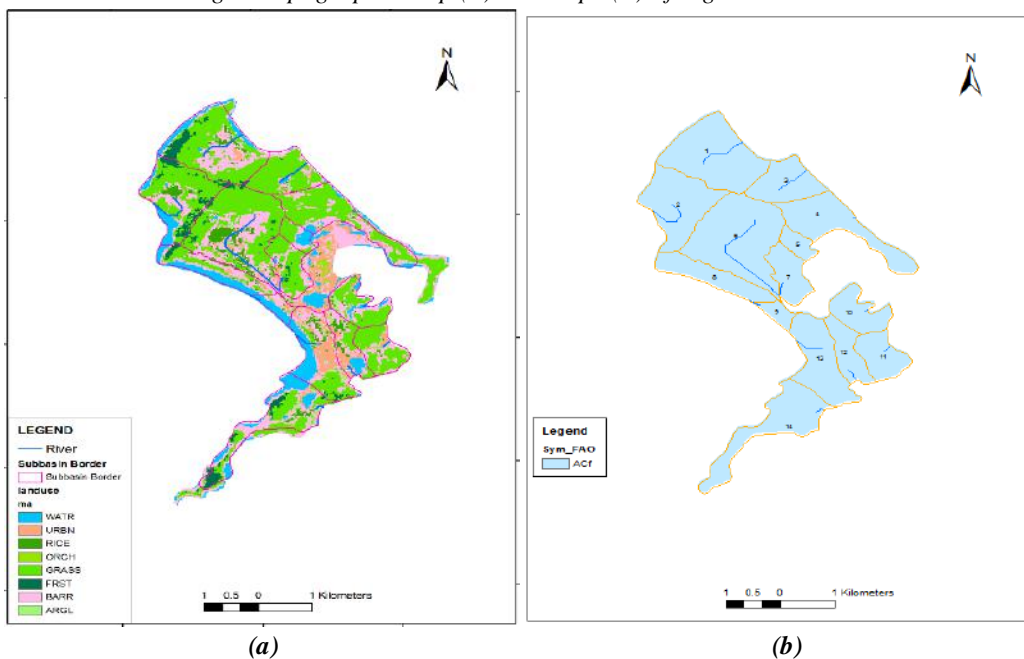


Fig. 4: Map of land use status (a) and soil properties (b) of Big Co To Island

3.1.2. Sub-basins

From topographic map combined with the existing river and stream network on the island, the Big Co To Island is divided into 14 sub-basins according to independent water sources to evaluate water resources parameters (Dan Nguyen Van, Thong Bui Xuan et al

2019). Combined with the land use map to determine the area of land use types in the sub-basins. The coastal sub-basins are mostly small areas and are watery lagoons. The results of determining soil types of 14 sub-basins are shown in Table 7.

Table 7. Area of land types in sub-basins of Big CoTo Island

Sub -basins	Type of land use								Total F (km ²)
	BARR	WATR	GRASS	FRST	URBN	ARGL	RICE	ORCH	
1	0.58	0.19	1.11	0.17	0.04	0.01	0.08	0.00	2.18
2	0.27	0.18	0.93	0.20	0.01	0.01	0.08	0.00	1.68
3	0.12	0.02	0.80	0.01	0.03	0.01	0.01	0.00	1.00
4	0.35	0.08	0.96	0.00	0.04	0.01	0.01	0.01	1.46
5	0.07	0.08	0.15	0.00	0.00	0.00	0.00	0.00	0.31
6	0.81	0.01	1.42	0.09	0.08	0.03	0.29	0.01	2.74
7	0.17	0.01	0.47	0.02	0.03	0.00	0.01	0.00	0.71
8	0.28	0.27	0.21	0.04	0.03	0.01	0.04	0.00	0.88
9	0.07	0.12	0.01	0.00	0.02	0.01	0.00	0.00	0.23
10	0.21	0.06	0.42	0.00	0.02	0.04	0.02	0.01	0.77
11	0.16	0.00	0.50	0.00	0.04	0.03	0.01	0.01	0.74
12	0.19	0.08	0.14	0.00	0.15	0.03	0.07	0.00	0.65
13	0.33	0.30	0.31	0.03	0.33	0.06	0.08	0.01	1.44
14	0.42	0.32	0.46	0.16	0.04	0.05	0.05	0.01	1.52
Total F (km ²)	4.01	1.72	7.91	0.71	0.86	0.29	0.74	0.06	16.31

3.1.3. Determine the average CN value of sub-basins

The average CN value of the basin is determined by weighted average according to the area of different types of land use in the basin. Based on the land use classification table of each basin (Table 7) and CN II value (Table 5), the average CNII value of sub-basins is determined as shown in Table 8. The values of CN I and CN III are converted from CNII according to the formula mentioned above. In Table 8 we can see that in the coastal sub-basins, the CN curve number is often very high (Sub-basin 9).

Table 8. Average CN values of each sub-basin by three moisture content (AMC)

AMC/Sub- basins	I	II	III
1	65.2	81.7	91.1
2	63.9	80.8	90.7
3	63.1	80.3	90.3
4	65.4	81.8	91.2
5	72.1	86.0	93.4
6	63.7	80.7	90.6
7	63.9	80.8	90.6
8	74.2	87.2	94.0
9	83.7	92.4	96.6
10	66.4	82.4	91.5
11	63.4	80.5	90.5
12	69.7	84.5	92.6
13	71.8	85.9	93.3
14	68.5	83.8	92.3
Average	68.2	83.5	92.1

3.1.4. Determine moisture conditions

Based on the total rain in previous 5 days and the AMC classification table (Table 3), the corresponding moisture conditions of categories I, II and III (AMCI, AMCI and AMCI) were determined. The growing

season on Co To Island was chosen as the rainy season and that starts from May to October.

3.1.5. Determine CN value corresponding to moisture conditions

The value of the CN curve corresponding to the humid conditions I, II and III (CN I, CN II, and CN III)

was determined corresponding to the previous 5 day humidity conditions. The results of estimating CN curve values were presented in Table 8.

3.1.6. Determine the value of maximum potential water depth S (mm) and initial water loss depth I_a (mm)

Based on CN values according to the corresponding moisture conditions, determine S value according to formula (5). From S value, I_a parameter was determined. In some studies of applying SCS method in Vietnam to coastal areas with high mountainous terrain such as the authors of An Ngo Le et al (2016), Son Nguyen Thanh (2005) used $I_a = 0.1S$. Considering that on Co To Island, there were similar terrain conditions, we selected $I_a = 0.1S$.

3.1.7. Results of calculation of surface runoff characteristics according to selected rainfall events

The relationship between the average annual rainfall and the average depth of the annual flow in the period of 1977-2016 was shown by the correlation coefficient R^2 and this coefficient reaches the value of 0.94. This result showed very good relationship between total rainfall and flow depth of the same period. The years with high rainfall will have a high flow depth and vice versa (Fig. 6 and Fig. 9).

+ At rainy event 1, conduct calculations with the entire series of rainfall data from 1977-2016 to identify P_e , W_0 , Q_0 , C_0 values. The calculation results were

presented in Table 9. In addition, the monthly distribution results of the flow depth P_e of the sub basins are shown in Table 10.

+ At storm rainfall events 2, 3, 4 and 5, calculations were done according to storm parameters as shown in Table 6 above. Four storm rainfall events were selected in the last 4 years from 2013-2016.

Results calculated values of S (mm), I_a (mm), P_e (mm) and W_0 ($\times 10^6 \text{ m}^3$) of 4 storm rainfall events are presented in Table 11 below. In these storm rainfall wet conditions were determined under AMC III moisture conditions.

+ Value Q_0 cannot be calculated for storm rainfall events.

A summary of the results of estimating water resource parameters corresponding to the rain events was presented in Table 12 below. In section 4.8 below we will try to analyze the calculated results.

3.1.8. Spatial and temporal distribution of hydrological parameters on Big Co To Island

The results of estimating number of CN curves in different moisture conditions were shown in Tables 8 and Table 9 and Figure 5. The average value of CN II corresponding to rainfall event 1 was 83.5 (Table 8 and Table 9). The average value CN III corresponds to rainfall event 2 as 92.1 (Table 8).

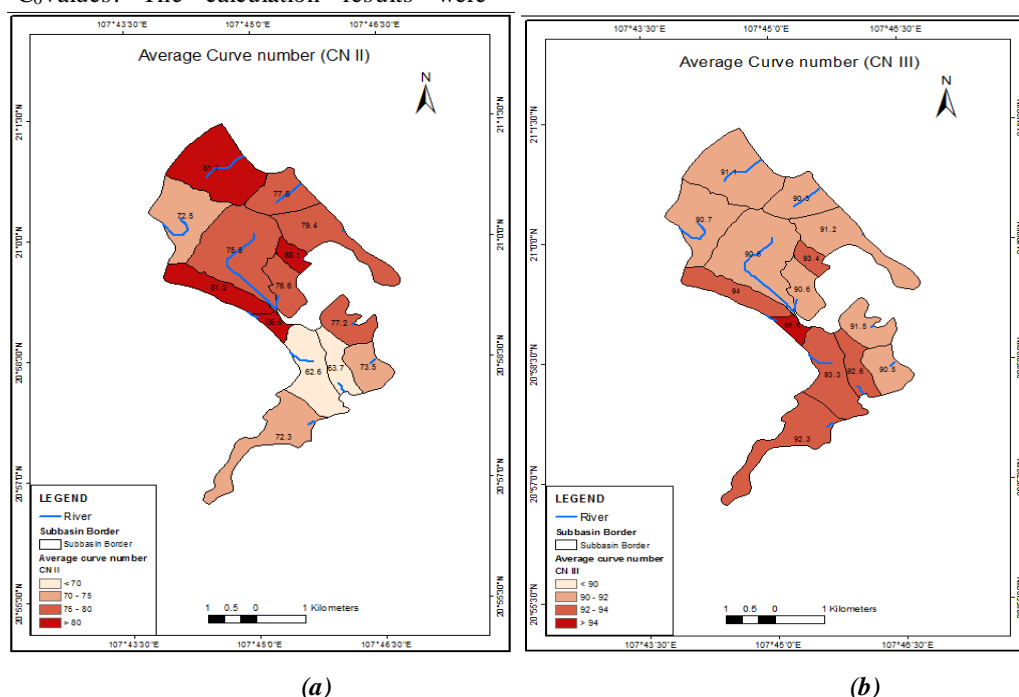


Fig.5: Average number of curves CN II (a) and CN III (b) on sub-basins

Here are some comparative remarks between the hydrological parameters of the average annual rainfall event and the storm rainfall events. Storm rainfall event 2 had the highest flow coefficient of 0.96 and the highest

intensity of rain was 9.06 mm/hour and of course the maximum flow was $10.2 \times 10^6 \text{ m}^3$ (Table 6, Tables 11 and 12). The heavy rain event number 3 had the lowest rainfall intensity of only 3.99 mm / hour, the flow

coefficient reached the value of 0.94 and so the total flow was only the lowest value of $3.3 \times 10^6 \text{ m}^3$. What needs to be emphasized here is that with heavy rain events such as rain event 2, the total flow is quite large at $10.40 \times 10^6 \text{ m}^3$ while at the rainy event 1 from the average annual rainfall gave a total flow of only $13.1 \times 10^6 \text{ m}^3$. However,

the potential maximum depth S (mm) of the storm rainfall event 2 was very low compared to this value of the rainfall event 1. This conclusion is in our opinion very complementary to the management of water resources on the island. The results of rainfall and surface flow were shown in Figure 6 and Figure 9.

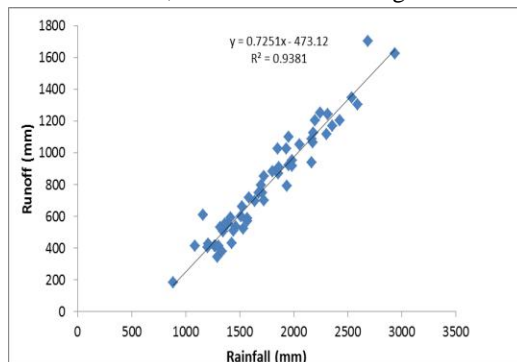


Fig. 6: Runoff- rainfall relationship for Co To Island

Total annual flow generated from rainfall event 1 in sub-basins 1, 2, 4, 6, 13 and 14 were higher than that of other sub-basins, of which the total surface water volume in the sub-basin 6 was the highest with a value of $2.07 \times 10^6 \text{ m}^3$ /year and total surface water reached the lowest value in sub-basin 9 with a value of only $0.26 \times 10^6 \text{ m}^3$ / year (Table 9). For storm rainfall events the distribution of volume water surfaces in the space of 14 sub-basins also shows the similarity of rainfall event 1.

Sub-basin 6 was a place with very low permeability coefficient and the lowest number of CN (CN II was 80.7, CN III was 90.6), so in this basin, the value of surface water volume obtained from rainwater W_o in both rainfall event 1 and storm rainfall event 2 were of the highest value (W_o of rainfall event 1 was 2.07×10^6

m^3 and storm rainfall event 2 is worth $1.75 \times 10^6 \text{ m}^3$ (Table 9 and 10).

In contrast, sub-basin 9 is the basin bordering the tidal flood waters and here the CN II and CN III were very high, so the total surface water received from rain water W_o reaches the lowest value among 14 sub-basins.

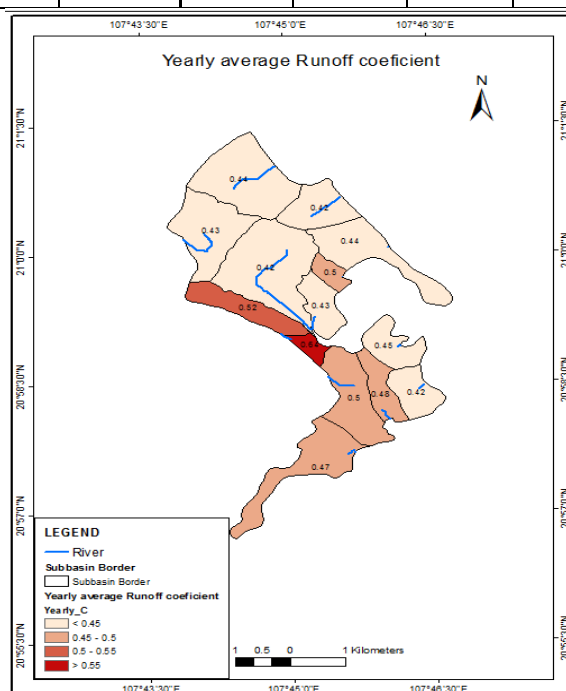
A conclusion can be drawn as follows. The distribution of the hydrological parameters on the island in the rain events shows the general hydrological rule of small basins with different water permeability. During storm events even though the total volume of surface water from rainwater reaches a high value, the maximum potential water depth is not higher than the maximum potential depth of the average annual rainfall event.

Table 9. Distribution of water resources characteristics according to the rainfall event 1 in the Co To sub-basins

Sub -basins	P (mm)	Pe (mm)	CNII	Qo (m^3/s)	Wo (10^6 m^3)	Co=Pe/P
1	1776	777.2	81.7	0.05	1.69	0.44
2	1776	757.0	80.8	0.04	1.26	0.43
3	1776	743.7	80.3	0.02	0.75	0.42
4	1776	780.6	81.8	0.03	1.14	0.44
5	1776	893	86.0	0.01	0.27	0.50
6	1776	753.3	80.7	0.06	2.07	0.42
7	1776	756.1	80.8	0.02	0.53	0.43
8	1776	931	87.2	0.02	0.82	0.52
9	1776	1128	92.4	0.01	0.26	0.64
10	1776	796	82.4	0.02	0.61	0.45
11	1776	749	80.5	0.02	0.56	0.42
12	1776	851	84.5	0.02	0.56	0.48
13	1776	888	85.9	0.04	1.28	0.50
14	1776	832	83.8	0.04	1.26	0.47
Average	1776	831.1	83.5	0.03		0.47
Total				0.39	13.1	

Table 10. Results of calculation of surface flow characteristics according to 4 storm rainfall events on the sub-basins of Co To Island

Sub-basin	CNIII	S(mm)	Ia(mm)	Event /Pe (mm)				Event/Wo x 10 ⁶ m ³			
				2	3	4	5	2	3	4	5
1	91.1	24.8	2.5	637.8	213.1	273.1	299.2	1.39	0.46	0.59	0.65
2	90.7	26.2	2.6	637.0	212.3	272.3	298.4	1.06	0.35	0.45	0.50
3	90.3	27.2	2.7	636.4	211.8	271.7	297.9	0.64	0.21	0.27	0.30
4	91.2	24.5	2.5	637.9	213.2	273.2	299.4	0.93	0.31	0.40	0.44
5	93.4	18.0	1.8	641.8	216.9	276.9	303.1	0.20	0.07	0.08	0.09
6	90.6	26.4	2.6	636.8	212.2	272.1	298.3	1.75	0.58	0.75	0.82
7	90.6	26.2	2.6	636.9	212.3	272.2	298.4	0.45	0.15	0.19	0.21
8	94.0	16.2	1.6	642.8	217.9	277.9	304.1	0.57	0.19	0.25	0.27
9	96.6	9.0	0.9	647.0	222.0	282.0	308.2	0.15	0.05	0.07	0.07
10	91.5	23.5	2.4	638.5	213.8	273.8	299.9	0.49	0.16	0.21	0.23
11	90.5	26.7	2.7	636.6	212.0	272.0	298.1	0.47	0.16	0.20	0.22
12	92.6	20.2	2.0	640.4	215.6	275.6	301.8	0.42	0.14	0.18	0.20
13	93.3	18.2	1.8	641.6	216.7	276.8	302.9	0.92	0.31	0.40	0.44
14	92.3	21.3	2.1	639.8	215.0	275.0	301.2	0.97	0.33	0.42	0.46
Average	92.1	22.0	2.2	639.4	214.6	274.6	300.8				
Total								10.4	3.5	4.5	4.9

Fig.7: Annual mean flow coefficient C_0 of sub-basins

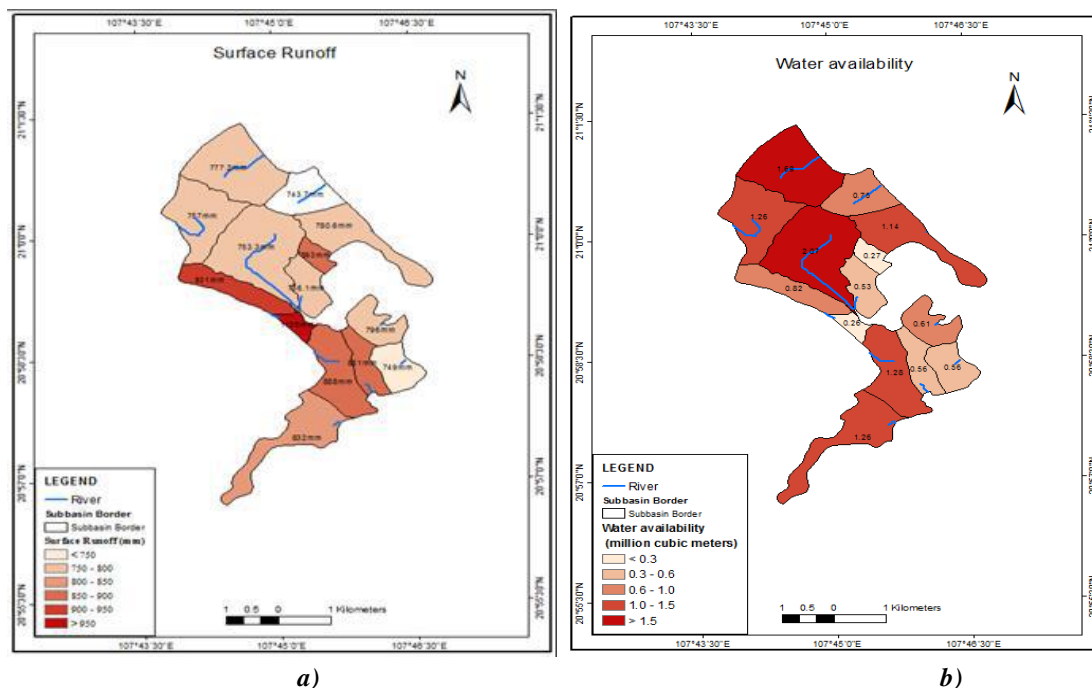


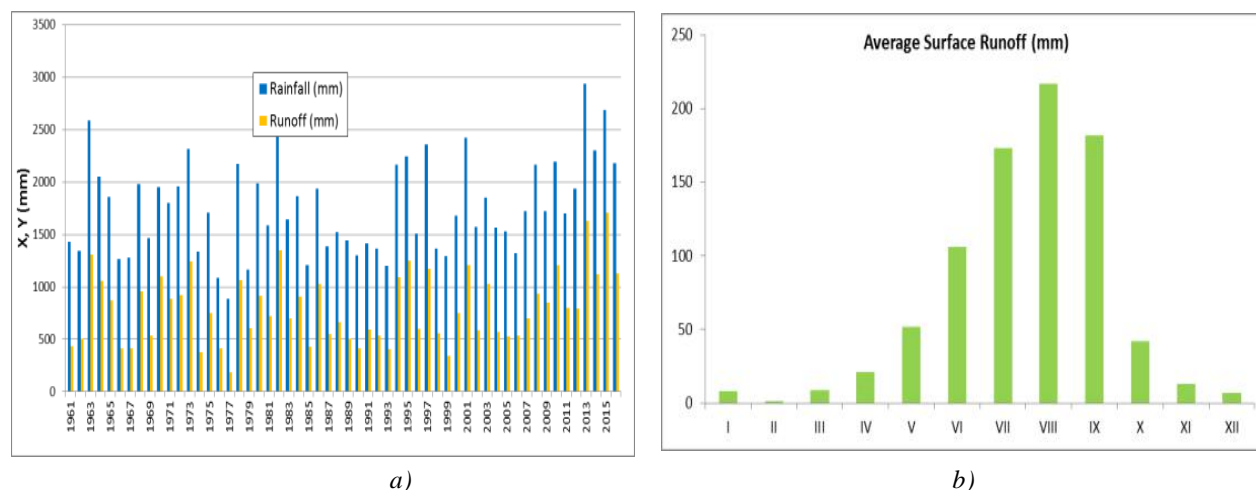
Fig.8: Surface runoff (a) and total annual average water volume (b) on sub-basins

In the first rain event with 30-year rainfall data we made calculations of the discharge flow value Q_0 (m^3/s) and distributed the average flow depth layers Pe (mm) of months (Table 9 and Table 11).

Table 11. Monthly distribution of the depth of the flow layer Pe (mm) in the sub-regions of the rainfall event 1

Month/ Sub- basins	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Pe (mm)
1	7.2	1.2	7.8	18.7	46.4	98.7	164.0	205.1	172.1	38.7	11.5	5.9	777
2	6.9	1.1	7.5	17.8	44.5	95.9	160.5	200.5	168.3	37.5	10.9	5.6	757
3	6.8	1.0	7.3	17.3	43.3	94.0	158.1	197.5	165.7	36.7	10.6	5.4	744
4	7.2	1.2	7.9	18.8	46.7	99.1	164.6	205.9	172.7	38.9	11.6	5.9	781
5	8.6	1.9	9.9	23.9	57.2	114.8	183.9	231.0	193.4	46.0	14.8	7.8	893
6	6.9	1.1	7.5	17.7	44.2	95.4	159.8	199.7	167.6	37.3	10.8	5.5	753
7	6.9	1.1	7.5	17.8	44.5	95.8	160.3	200.3	168.1	37.4	10.9	5.6	756
8	9.1	2.1	10.6	25.6	60.7	120.0	190.2	239.1	200.1	48.4	15.9	8.5	931
9	12.1	4.1	14.8	35.6	80.1	147.7	222.3	280.2	233.9	62.1	22.6	12.4	1128
10	7.4	1.3	8.2	19.5	48.1	101.2	167.2	209.4	175.5	39.8	12.0	6.2	796
11	6.8	1.0	7.4	17.5	43.8	94.8	159.1	198.7	166.8	37.0	10.7	5.5	749
12	8.1	1.6	9.1	21.9	53.1	108.9	176.7	221.6	185.7	43.3	13.5	7.1	851
13	8.6	1.8	9.8	23.6	56.7	114.2	183.1	230.0	192.6	45.7	14.7	7.7	888
14	7.8	1.5	8.8	21.1	51.4	106.2	173.5	217.5	182.2	42.1	13.0	6.7	832
Average	7.9	1.6	8.9	21.2	51.5	106.2	173.1	216.9	181.8	42.2	13.1	6.8	831.1

In the rainfall event 1, the results of the distribution of the average monthly flow in the whole island showed that the flow layer began to increase from May, the highest in August every year and gradually decreased in October (Table 11, Figure 9).



a)

b)

Fig. 9: Annual rainfall (a) and monthly distribution of surface runoff (b) in the period of 1977-2016 on Co To Island

As mentioned above, sub-basin 9 is a coastal marsh, small area, the CN II curve coefficient was quite high, so here the depth of the flow layer P_e (mm) always reached the highest value compared with in the months of the year (Table 11).

Table 12. Summary of water resource calculation results corresponding to rainfall events

Event	P (mm)	CN _{ave.}	S (mm)	I _a (mm)	P _e (mm)	W _{ox} 10 ⁶ m ³	C ₀ =P _e /P
1	1776	83.5	50.2	5.0	831.1	13.1	0.47
2	652.4	92.1	22	2.2	626.7	10.4	0.96
3	227.3	91.5	24	2.4	213.8	3.5	0.94
4	287.4	91.5	24	2.4	273.8	4.5	0.95
5	313.6	91.5	24	2.4	299.9	4.9	0.96

Table 13. Estimated results of Q_0 by SCS - CN method and observed data Q_0 in sub-basins 1, 2, 3, 4, 6 and 12 on Co To Island in September, October

Basin	Area (km ²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Q ₀ (m ³ /s)	Observed in Sep (m ³ /s)	Observed in Oct (m ³ /s)
1	2.17	0.01	0	0.01	0.01	0.01	0.09	0.1535	0.184	0.083	0.06	0.01	0	0.05	0.065	0.07
2	1.67	0	0	0	0.01	0.03	0.13	0.186	0.12	0.014	0.0126	0.01	0	0.04	0.01	0.01
3	1	0	0	0	0.01	0.02	0.03	0.08	0.07	0.04	0.01	0	0	0.02	0.03	0.01
4	1.46	0	0	0	0.01	0.02	0.05	0.04	0.11	0.09	0.0116	0.01	0	0.03	0.07	0.01
5	0.31	0	0	0	0	0.01	0.01	0.06	0.03	0.02	0.01	0	0	0.01	-	-
6	2.74	0.01	0	0.01	0.02	0.08	0.05	0.1	0.4	0.026	0.0094	0.01	0.01	0.06	0.02	0.01
7	0.71	0	0	0	0	0.01	0.02	0.06	0.05	0.04	0.01	0	0	0.02	-	-
8	0.88	0	0	0	0.01	0.02	0.04	0.06	0.08	0.06	0.02	0	0	0.02		
9	0.23	0	0	0	0	0.01	0.01	0.06	0.02	0.02	0.01	0	0	0.01		
10	0.77	0	0	0	0.01	0.01	0.03	0.06	0.06	0.05	0.01	0	0	0.02		
11	0.74	0	0	0	0	0.01	0.02	0.06	0.05	0.04	0.01	0	0	0.02		
12	0.65	0	0	0	0	0.01	0.02	0.06	0.05	0.04	0.04	0	0	0.02	0.04	0.032
13	1.44	0	0	0.01	0.01	0.03	0.06	0.06	0.12	0.1	0.02	0.01	0	0.04		
14	1.52	0	0	0	0.01	0.03	0.06	0.06	0.12	0.1	0.02	0.01	0	0.04		
Total	16.31	0.04	0.01	0.05	0.11	0.28	0.58	0.06	1.23	1	0.24	0.07	0.04	0.39		

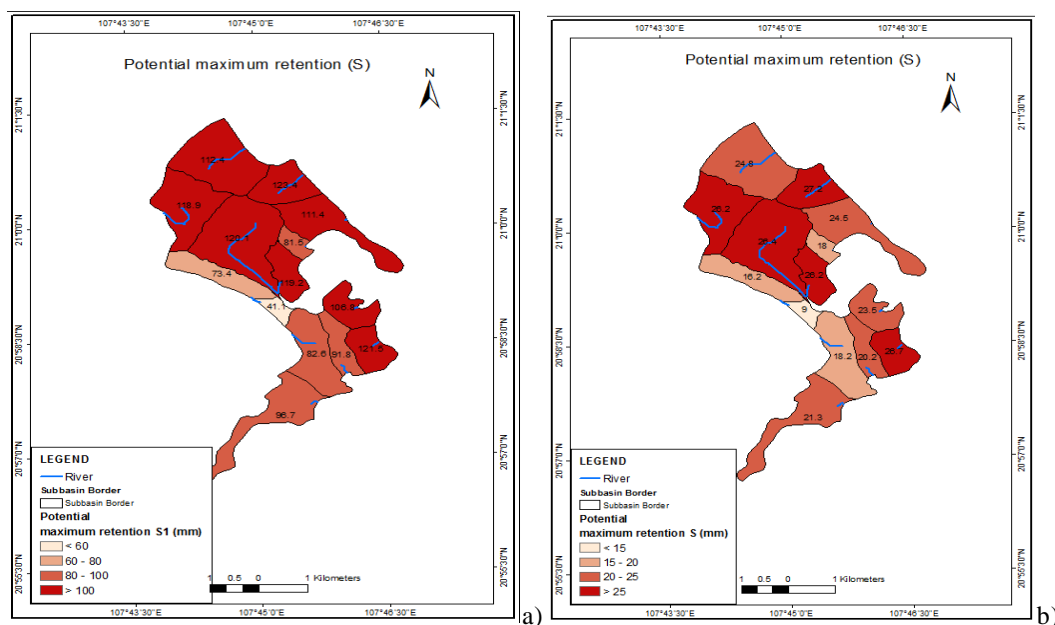


Fig.10: Maximum potential water storage (S) on the Co To sub-basinsat rainfall event 1 (a) and in storm rainfall events 2, 3,4,5 (b).

The calculation error of September ranged from 20 to 29%, while this value in October was lower, only fluctuated between 6 - 21%

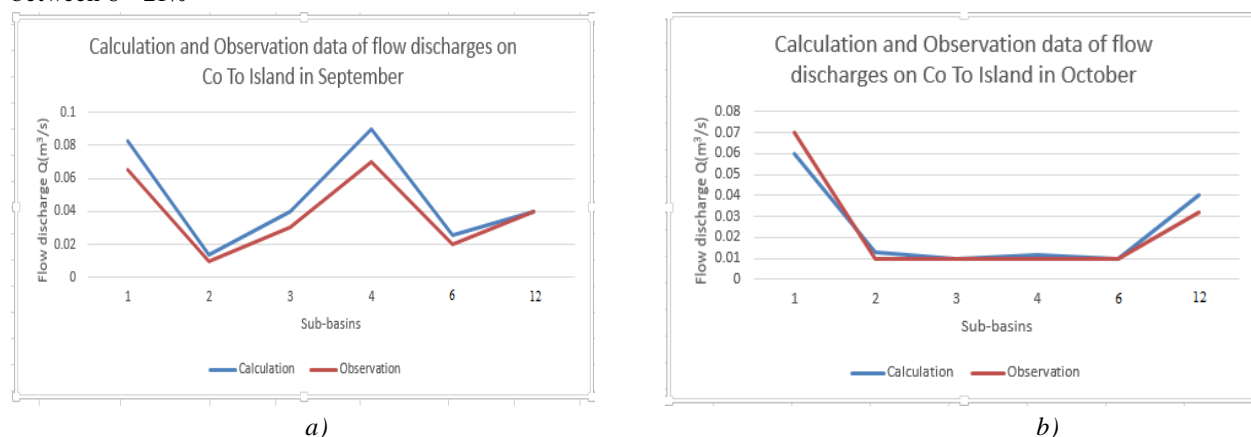


Fig. 11: Comparison of estimated results Q_0 by SCS – CN method combining GIS with observed data on Co To Island. a) For September, b) For October

3.2. Discussion

Research on island hydrology is a very new issue in Vietnam. Published documents on water resources in general and hydrological parameters on the island are very limited. On the island, there are no fixed stations for hydrological monitoring, and the discharge monitoring data are also very rare. In such difficult conditions, the need to provide information for water exploitation management on the island is very urgent, in this study we want to confirm that our calculation results are based on scientific basis.

1. SCS - CN method combined with GIS has advantages and disadvantages when applied to island conditions. Traditional SCS - CN method and today with

the support of GIS technology has been confirmed as a convenient method to identify water resources parameters of small basins with different geological structures and terrain. However, almost no research has applied the SCS - CN method for island conditions. There are very few studies applying SCS - CN method combined with GIS for coastal basins, where hilly and mountainous terrain and part plain. We believe that with the results of applying SCS - CN method in such basins, it will be suitable with the climate and terrain conditions of the island.

2. We followed closely the guidelines of using SCS –CN method combined with GIS technology to estimate the hydrological parameters of Co To Island. The reasonable distribution of hydrological parameters in the

14 sub-basins with accurate data on soil type, land use, slope as well as permeability of each sub-basin has shown the calculation results is a scientific basis. The results of applying SCS - CN method combined GIS for rainfall event 1 and storm rainfall events (Storm rainfall event 2) showed a reasonable distribution of hydrological parameters of Co To Island condition. The value of the discharge rate Q_0 calculated for September and October has been verified by observed data at 6 sub-basins showing that the error was not more than 29%. The calculated Q_0 value was always higher than the actual observed value. The Q_0 error assessment results allow us to believe that other hydrological parameters can be used for other research purposes on water resources on Co To Island.

3. The set of 30-year continuous rainfall monitoring data at the island's meteorological observation station and the latest data on soil quality, land use and detailed terrain for 14 sub-basins were assessed with the high precision. This has increased the accuracy of the calculation results of the hydrological parameters on the island.

4. In the study of water resources of Co To Island, we have experimented to exploit SWAT model, but the results are still very limited. Due to the lack of long-term observing of the flow discharge on the island, the application of the Soil Water Assessment Tool (SWAT) to evaluate water resources parameters on the island is also difficult. The process of using a basin similar to Co To Island to calculate the hydrological parameters on the island was a major limitation that reduces the accuracy of the actual hydrological parameters of the island. It is for this reason that we have decided in the long run to use the SCS - CN method that incorporates GIS technology to be the only effective solution to assess the parameters of water resources on the island. This conclusion has set out a task to strengthen research on the SCS-CN method to further improve the accuracy of the island's hydrological parameters. At the same time, it is necessary to add monitoring data on flow, surface runoff and other hydrological parameters to verify and calibration of calculation results according to model types.

IV. CONCLUSION

This is the first time we have published the hydrological parameters of Co To Island. This set of parameters is the result of applying SCS - CN model combined with GIS techniques based on exploiting the series of 30-year rain monitoring data along with accurate data on land and land use of the island.

The results included: total surface water from rainfall $W_0 = 13.6 \times 10^6 \text{ m}^3/\text{year}$, surface flow depth (Pe)

and maximum potential storage depth was estimated with values of 831.5 mm and 50.2 mm. At the same time other hydrological parameters such as flow rate Q_0 , surface flow coefficient C_0 were determined to be $0.39 \text{ m}^3/\text{s}$ and $0.47 \text{ m}^3/\text{s}$ respectively. These are necessary results on the water resources parameters on Co To Island.

SCS - CN method combined with GIS is also applied to storm events, this estimation result also show that the surface potential water from storm on the island is very large despite the maximum potential water depth S of storm rainfall events are not large, even less than half of the maximum potential water depth S of rainfall event 1. This conclusion allows us to apply for a permanent rainwater storage solution and water rain occurs in the storm.

The application of SCS - CN method combined with GIS is also implemented for 14 sub-basins of Co To Island. The results of the distribution of hydrological parameters on sub-basins with permeability conditions, topography, land use area and different soil quality have shown the reasonableness of the general hydrological law.

In this study, we performed the calculation of Q_0 value and this value was verified by monitoring data in September and October 2012. Thus, the Q_0 value was determined by the average of the set of the 30-year precipitation over the Big Co To island is $0.39 \text{ m}^3/\text{s}$, which can be used as a reference for other models such as SWAT as well as for designing rainwater storage techniques on the island.

The calculation results of this study once again confirm the superiority of traditional SCS - CN method when combined with GIS will be a main tool to estimate hydrological parameters on the island.

ACKNOWLEDGEMENT

This study belongs to the topic KC 09 04/16 20 funded by the Ministry of Science and Technology of Vietnam. This financial support is gratefully acknowledged. The Project code: KC 09 04/16 – 20 namely “Estimation of potential and variation of surface, underground water resources and proposed appropriate measures for water resource management to support economical – social development on some important islands”.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The founding sponsor had no role in the design of the study, in the collection, analyzing, or interpretation of data, in the writing of the manuscript and in the decision to publish the results.

REFERENCES

- [1] Adornado H.A and Yoshida, M, 2010: GIS -based watershed analysis and surface runoff estimation using curve number (CN) value. *J. Environ. Hydrology* 18. pp 1-10.
- [2] Abhijit M.Zende1, Nagarajan R1, Atal K.R.,2014.Analysis of surface runoff from Yerala River Basin using SCSCN and GIS.*International Journal of Geomatics and Geosciences* Volume 4, No 3, pp 508 - 516.
- [3] An Ngo Le, Thu Phuong Trinh, Noi Doan Thi, Tung Thanh Hoang, 2016. Research for recommendation of designed flood calculation methods for transporation in the north – east region of Vietnam. *Journal of Water Resources & Environmental Engineering*, No. 53 (6/2016).
- [4] Chow V. T, Maidment D. R and Mayse W, 1988. *Applied Hydrology*. New York: McGrawHillan
- [5] Dan Nguyen Van, Thong Bui Xuan et al, 2019. Water resources potention on Co To Island and exploitation orientation to use. *Journal of Marine Science and Technology*, ISSN 1859-3097, No.4, 2019.
- [6] Eljakeen M and Paramicolao, A.N., 2009. Estimation of the sum off curve number via direct rainfall simulator measurement in the State of Iowa, USA. *Water Resource Management*, 23, pp 2455 -2473.
- [7] Gandalia M, M. Dhakia, 2014. Impact of monthly curve number on daily runoff estimation for Ozat catchment in India, *OJMH*, vol.4, No.4, pp 145 -155.
- [8] Geena G.B. and P.N. Ballukraya 2011.Estimation of runoff for Red hills watershed using SCS method and GIS. *Indian Journal of Science and technology*. Vol. 4, No. 8, pp. 899-904.
- [9] H.J.Ningaraju, Ganesh Kumar S B , Surendra H.J. Estimation of Runoff Using SCS-CN and GIS method in ungauged watershed: A case study of Kharadya mill watershed, India.*International Journal of Advanced Engineering Research and Science (IJAERS)*, Vol-3, Issue 5, May – 2016, pp 36-40.
- [10] Jeffry Swingly, Frans Sumarauwand, Koichiro Ohgushi. Analysis on Curve Number, Land Use and Land Cover Changes and the Impact to the Peak Flow in the Jobaru River Basin, Japan.*International Journal of Civil & Environmental Engineering IJCEE-IJENS* Vol: 12 No: 02. 2012.
- [11] Journal of Indian Water Resources Society. Procedure for determination of design runoff curve number for a watershed, Vol 34, No.3, July, 2014.
- [12] Manoharan A, Muragappan A, 2012.Estimation of Runoff in ungauged rural watershed, Tamilnadu.*India International journal of Engineering science&Technology* 2012 Vol. 4 No.02, pp 449-456.
- [13] Matej Vojtek, Jara Vojtejkova, 2016: GIS - based Approach to Estimate Surface Runoff in Small Catchment: A Case Study. *The Journal of Adam Mckiewicz. Quaestiones geographicae* 35 (3) – 2016, pp 99 – 101.
- [14] Noah Kimeli, Benson M. Okumu, Application of GIS for Estimation of Water Runoff Volume in Water Collection Sites Case Study: Northern Collector Water Tunnel. *American Journal of Geographic Information System* 2017, 6 (5): 169 – 177, pp 170 – 173.
- [15] SameedShadeed, MohammadAl Masri, 2010. Application of GIS - based SCS - CN method in West Bank catchments, Palestine. *Water Science and Engineering*, 010.3(1): 1-13.
- [16] Son Nguyen Thanh, 2004-2005. Application of mathematical model to calculate flood in the river basin Ve - Station An Chi. *Project of Hanoi National University*, Code QT 04–26.
- [17] Soulic K.X and J.D. Variantzas, 2012: SCS-CN parameter determination using rainfall- runoff data in heterogeneous watersheds- the two CN system approach Hydrology Earth syst. Science. 16, 2012. pp 1001 -1015.
- [18] SCS Runoff Curve Method. Professor Patel. United States Department of Agriculture (1986). [Urban hydrology for small watersheds](#) (PDF). Technical Release 55 (TR-55) (Seconded.). *Natural Resources Conservation Service, Conservation Engineering Division, Appendix A-1*.
- [19] Tomasz Kowalik and Andrzej Walega, 2015: Estimation of CN Parameter for Small Agricultural Watersheds Using Asymptotic Functions, *Water*, ISSN 2073 -4441. Online: www.mdpi.com/journal/water.
- [20] Thong Bui Xuan, Dat Le Tuan, Chau Truong Viet, 2017: Determination of some marine meteorological extreme values and its relation with distribution of surface water resources on the Ly Son Island (in Vietnamese). *Journal of Marine Science and Technology*, 4B (T.17), ISSN 1859 – 3097, pp 353-354.
- [21] Varsha Mane, Y B Katpatal, K R Aher (2014). Spatial verification of SCS methods in correlation to land use/land cover and Soil characteristics,.United States Department of Agriculture (1986). [Urban hydrology for small watersheds](#) (PDF). Technical Release 55 (TR-55) (Seconded.). *Natural Resources Conservation Service, Conservation Engineering Division, Appendix A-1*.
- [22] Year Book, Quang Ninh province, 2013 - 2016.
- [23] United States Department of Agriculture. *National Engineering Handbook- Part 630 – Hydrology*. Online: <https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21422>