International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-5 Issue-1, March 2015

Development of a Soft Tool for Estimating Direct Runoff from Watersheds

V. S. Malunjkar, M. G. Shinde, R. D. Bansod, A. A. Atre

Abstract— Natural Resources Conservation Services-Curve Number (NRCS-CN) model is the most commonly used hydrological model for runoff estimation. This paper introduces about the interface developed to estimate curve number and runoff depth for hydrologic evaluations. The programming syntax was developed in Visual Basic 10.0 for its simplicity. The developed tool is easy to handle and can be useful for academicians, scientists and decision makes involved in watershed planning and development.

Index Terms— Antecedent moisture condition, curve number NRCS-CN method, runoff, watershed.

I. INTRODUCTION

The actual physical processes that convert rainfall to runoff are both complex and highly variable. As such, these processes cannot be replicated mathematically with exact certainty. However, through the use of simplifying assumptions and empirical data, there are several mathematical models and equations that can estimate and simulate these processes and predict resultant runoff volumes and rates with acceptable accuracy.

In general, runoff can be described as a by-product of rainfall's interaction with the land. This interaction is one of several processes that the earth's water may go through as it continually cycles between the land and the atmosphere. The phenomenon of runoff is studied and modeled by various scientists. Natural Resources Conservation Services-Curve Number (NRCS-CN), formerly Soil Conservation Services-Curve Number (SCS-CN) model is widely used to estimate direct runoff, water recharge, stream flow, infiltration and soil moisture content from rainfall data [1], and subsequently was selected for the purposes of the present study. This method is popular among hydrology software developers and users because of its simplicity and accuracy [2]. This method is described in detail in the National Engineering Handbook Section 4: Hydrology (NEH-4) from the United States Department of Agriculture [3], [4]. Its applications have been discussed and reported in the recent literature [5], [6], [7], [8], [9], [10].

Manuscript Received on February 16, 2015.

Er. V.S. Malunjkar, Department of Soil and Water Conservation Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri [MH], India.

Dr. M.G. Shinde, Department of Soil and Water Conservation Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri [MH], India.

Dr. R.D. Bansod, Department of Soil and Water Conservation Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri [MH], India.

Dr. A.A. Atre, Department of Soil and Water Conservation Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri [MH], India.

II. NRCS-CN HYDROLOGICAL MODEL

The standard SCS-CN model [3] is a simple method, widely recognized and commonly used to estimate the total runoff or depth of runoff, over an entire basin in a 24-hour storm event. The model balances precipitation, the initial abstraction, and the potential water retention after runoff begins. The empirical model that combines these parameters is as follows,

$$\frac{(P-I_a)^2}{(P-I_a+S)} \quad P > Ia \tag{1}$$

Where, P is the total rainfall (mm), I_a is the initial abstraction (mm), Q is the direct runoff (mm), S is the potential maximum retention (mm).

Based on several studies, the NRCS determined that there was a linear relationship between I_a and S, resulting in empirical solution of $I_a = 0.2S$ [3]. The S parameter value depends on the soil capacity for water runoff or infiltration. Therefore, it is possible to estimate the value as described below using the CN, an empirical parameter based on the hydrologic soil groups (HSG), land use, treatment and hydrologic conditions [3], [11]. Also, the initial abstraction coefficient ($\lambda = Ia / S$) is dependent on regional climatic or geologic conditions, ranging from 0.1 to 0.3 [12].

$$S = \frac{25400}{CN} - CN \tag{2}$$

The CN is dimensionless ranging from 0 when S tends to infinity, up to 100 when S = 0. Both conditions represent the extremes between total infiltration (runoff = 0) and totally impervious watersheds (rainfall = runoff). However, many of the computations use 30 as the lowest value, even when lower values could be detected.

To estimate CN values, the NRCS has provided runoff curve number tables for different cover types (agricultural, arid and semiarid rangelands and urban areas), hydrologic conditions (poor, fair and good) and the HSG. The HSG is a standard soil classification (groups A, B, C, D) that depends on soil texture and infiltration rates. The A group includes well-drained soils with a high rate of infiltration, whereas D soils are poorly drained with a permanently high water table [3]. The NRCS introduced the AMC concept to determine soil moisture before a storm event, the condition of which could affect the calculation of runoff. There are three conditions for dry (AMC I), normal (AMC II) and saturated soils (AMC III) that are assigned as a function of the five day antecedent rainfall. The moisture condition could affect runoff estimates because it modifies the CN whose standard values are set to the AMC II by default.

The option of selecting a soil condition is included in the interface, and users must be aware of soil conditions to select the correct AMC. After selecting the AMC, the standard CN values are derived from the National Engineering Handbook; Section 4 (NEH-4) tables and, if necessary, converted to AMC I or AMC III using the following functions [4],

$$CN_I = \frac{4.2CN_{II}}{10 - 0.058CN_{II}} \tag{3}$$

$$CN_{III} = \frac{23CN_{II}}{10 - 0.13CN_{II}} \tag{4}$$

III. INTERFACE DESCRIPTION

The NRCS-CN model described above is integrated and programmed in Visual Basic 2010 (VB10 .NET 4.5), a programming language that can create .dll and .exe files. Visual Basic is mainly used to develop user friendly windows based applications.

Once a .dll file installed, user is allowed to select the different options of land use pattern (single or multiple), hydrologic soil groups and hydrologic condition, watershed area, AMC condition, precipitation input, I_a values and finally getting the output in the form of CN values and runoff depth for the study area (Figure 1).

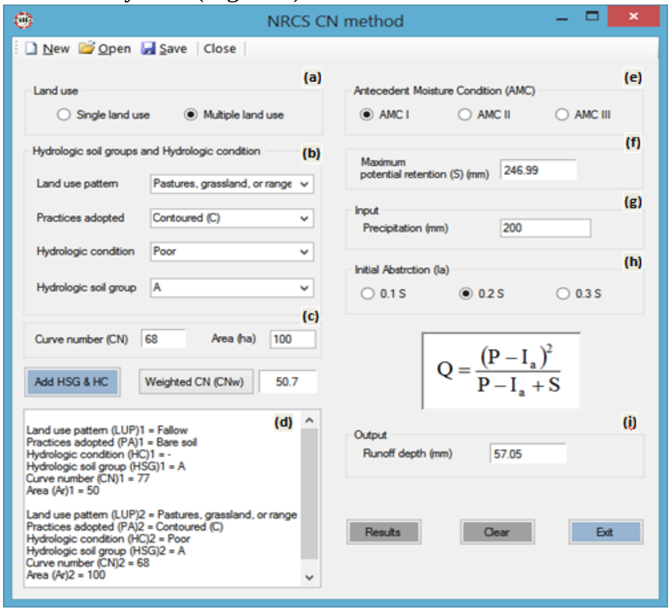

Figure 1. Main screen of developed interface to access curve number and runoff depth with different inputs and conditions. (a) Land use pattern selection. (b) Hydrologic soil groups and hydrologic condition selection. (c) CN output and input of area. (d) Selected inputs. (e) AMC selection. (f) Maximum potential retention output. (g) Precipitation input. (h) Initial abstraction selection. (i) Runoff depth output.

When all required fields are filled, the developed tool first assigns CN standard values to the selected hydrologic soil groups and condition, taking the AMC II by default. Following this different scenario can be modeled, adapting them if necessary to AMC I and AMC III conditions according to the procedure described by the USDA [4]. Finally after putting precipitation input, the tool can gives output of direct runoff in the form of runoff depth.

IV. CONCLUSION

The developed soft tool helps to extend the possibility of using NRCS-CN method in which it is possible to introduce different configurations and adaptations according to local conditions. Additionally, tool will be useful for students, research scholars, department of agriculture and decision makers involved in watershed management development and planning.

ACKNOWLEDGMENT

This study is based on work supported by Department of Science and Technology (DST-INSPIRE), Government of India. Also technical guidance from the Department of Soil and Water Conservation Engineering, MPKV, Rahuri has made this project possible.

REFERENCES

1. M. J. Mack, "HER-Hydrologic evaluation of runoff; The Soil Conservation Service Curve Number technique as an interactive computer model". *Comput. Geosci.* 1995, 21, p. 929-935.
2. S. Shadeed and M. Almasri, "Application of GIS based SCS-CN method in West bank catchments, Palestine." *WSE-3*, 2010, p. 1-13.
3. USDA, "Urban hydrology for small watersheds". United States Department of Agriculture. Natural Resources Conservation Service. Conservation Engineering Division. *Tech. Release* 55. 2nd ed. Washington, DC. 1986. P. 164.
4. USDA, "Estimation of direct runoff from storm rainfall". Part 630. Hydrology National Engineering Handbook. Ch. 10. United States Department of Agriculture. Natural Resources Conservation Service. Washington, DC. 2004. P. 22.
5. S. K. Mishra and V. P. Singh. "Long-term hydrological simulation based on the Soil Conservation Service curve number". *Hydrol. Process.* 2004. 18. p. 1291-1313.
6. S. K. Mishra and V. P. Singh. "A relook at NEH-4 curve number data and antecedent moisture condition criteria". *Hydrol. Process.* 2006. 20. p. 2755-2768.
7. S. K. Mishra, M. K. Jain, R. P. Pandey and V. P. Singh. "Catchment area-based evaluation of the AMC-dependent SCS-CN-based rainfall-runoff models". *Hydrol. Process.* 2005. 19. p. 2701-2718.
8. N. W. Kim and J. Lee. "Temporally weighted average curve number method for daily runoff simulation" *Hydrol. Process.* 2008. 22. p. 4936-4948.
9. R. K. Sahu, S. K. Mishra and T. I. Eldoh. "An improved AMC-coupled runoff curve number model". *Hydrol. Process.* 2010. 24. p. 2834-2839.
10. H. Cao, R. W. Vervoort, and S. M. Dabney. "Variation in curve numbers derived from plot runoff data for New South Wales (Australia)". *Hydrol. Process.* 2011. 25. p. 3774-3789.
11. V. M. Ponce and R. H. Hawkins. "Runoff curve number: has it reached maturity?" *J. Hydrol. Eng.* 1996. 1. p. 11-19.
12. J. P. Patil, A. Sarangi, O. P. Singh, A. K. Singh and T. Ahmed. "Development of a GIS interface for estimation of runoff from

AUTHORS PROFILE

Er. Vaibhav S. Malunjkar, Ph.D. Scholar, MPKV Rahuri and INSPIRE fellow (DST-GOI)

Dr. M.G. Shinde, Associate professor, Department of Soil and Water Conservation Engineering, MPKV, Rahuri.

Dr. R. D. Bansod, Professor and Head, Department of Soil and Water Conservation Engineering, MPKV, Rahuri.

Dr. A.A. Atre, Associate professor, Department of Soil and Water Conservation Engineering, MPKV, Rahuri.