

Editorial

Soil Conservation Service Curve Number (SCS-CN) Method: Current Applications, Remaining Challenges, and Future Perspectives

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Predicting runoff in ungauged or poorly gauged watersheds is one of the key problems in applied hydrology. Thus, simple methods for runoff estimation are particularly important in hydrologic applications, such as flood design or water balance calculation models.

Probably, the most well-documented and at the same time simple conceptual method for predicting runoff depth from rainfall depth is the Soil Conservation Service Curve Number (SCS-CN) method. This method was originally developed by the U.S. Department of Agriculture, Soil Conservation Service (now known as Natural Resources Conservation Service—NRCS) to predict direct runoff volumes for given rainfall events and mainly for the evaluation of storm runoff in small agricultural watersheds. It was initially published in the late fifties and since then has been updated several times with the latest one being in 2004 [1]. Due to its simplicity and its extensive documentation, it soon became a ubiquitous technique that is used worldwide by many engineers and practitioners in numerous hydrological applications. The main reasons behind its impressive success are that it is a very simple but well-established method, it features easy to obtain and well-documented environmental inputs, and it accounts for many of the factors affecting runoff generation, incorporating them in a single parameter, the curve number (CN) [2].

Since its creation, the SCS-CN method has been adopted for various regions and for various land uses and climatic conditions, it has been applied to a wide variety of applications beyond its original scope including runoff estimation in large scale river basins and integration in long-term, daily time-step, hydrological models. It has been also the subject of numerous analyses on both practical and theoretical grounds and of several modifications, adaptation, and improvement attempts for over 60 years. Interestingly, after all these attempts, the original formulation of the method is mostly used up to now. Nevertheless, the constantly increasing attention that it receives in the hydrologic literature enhances the current understanding and highlights several critical issues, limitations, and areas for possible improvements, which are still remaining after many years of constant development and research [3].

Accordingly, the aim of this special issue is to present the latest developments in the SCS-CN methodology including but not limited to novel applications, theoretical and conceptual studies broadening the current understanding, studies extending the method's application in other geographical regions or other scientific fields, substantial evaluation studies, and ultimately key advancements towards addressing the key remaining challenges [3] such as:

- Improving the SCS-CN method runoff predictions without sacrificing its current level of simplicity [4–6].
- Moving towards a unique generally accepted procedure for CN determination from rainfall-runoff data considering the prevailing soil and land cover spatial variability in natural watersheds [7–10].



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- Improving the initial abstraction estimation and balancing the gains and the implications of altered initial abstraction ratios [11,12].
- Investigating the scale dependency of CN values and the compatibility of CN values obtained at different scales (plot scale, catchment scale, etc.).
- Investigating the integration of SCS-CN method in long-term continuous hydrological models and the implementation of various soil moisture accounting systems [4,13].
- Extending and adopting the existing CNs documentation in a broader range of regions, land uses and climatic conditions including emerging land uses such as roof gardens, solar farms, or porous pavements and considering the effect of gradual and abrupt land cover changes such as urbanization and wildfires [6,10,14–16].
- Utilizing novel modeling, geoinformation systems, and remote sensing techniques to improve the performance and the efficiency of the method [7].

This Special Issue of Water journal comprises eight papers covering many aspects of the above-mentioned challenges [4–7,10–12,14] and spreading in a wide range of different regions and conditions. Among them, two papers are proposing improvements on the SCS-CN method incorporating adjustments for the effects of slope [4,5], initial soil moisture, and storm duration [4]. The long-debated issue of the initial abstraction is investigated in three papers [5,11,12], while three additional papers investigate the application of the method in diverse geographical regions and conditions [6,10,14]. Finally, the utilization of the SCS-CN method along with earth observation for the assessment of the hydrological effect of gradual and abrupt land cover changes is also investigated in one more paper [7].

Specifically, Ajmal et al. [5] examined the initial abstraction ratio (λ) and the watershed slope factor effect in estimating runoff. They proposed a slope-adjusted CN model based on detailed rainfall-runoff data coming from 1779 storm events that took place in 39 watersheds with a varying average slope on the Korean Peninsula. The proposed variants were compared with the original model achieving good agreement between the observed and estimated runoff by one of the proposed variants of the CN model. The proposed variant incorporated slope adjusted CN values and an altered initial abstraction ratio, $\lambda = 0.01$. The obtained results also indicated that the effects of rainfall and other runoff-producing factors must be incorporated in CN value estimation to accurately reflect the watershed conditions.

Shi and Wang [4] also attempted to consider the watershed slope as well as the initial moisture conditions and storm duration to improve the performance of the SCS-CN method. The proposed method combines the tabulated CN value with a slope gradient, a soil moisture, and a storm duration factor. It was successfully tested using a detailed dataset coming from three runoff plots in a watershed of the Loess Plateau of China. Additionally, a sensitivity analysis indicated that the most sensitive factor is soil moisture followed by storm duration and slope, while initial abstraction ratio was found to be less sensitive.

Krajewski et al. [11] investigated the variability of the initial abstraction ratio in urban and agroforest land uses using as an example two small Polish watersheds with corresponding land use types (urban and agroforest). To this end, detailed data for the storm events recorded between 2009 and 2017 in the case study watersheds were analyzed to investigate the variability of the initial abstraction ratio across events, seasons, and land use types. The obtained results indicated that λ varied between storm events and seasons and was often lower than the original value of 0.20. The study concluded that optimally λ should be locally verified.

Caletka et al. [12] investigated the applicability of the original SCS-CN method in five representative experimental watersheds in the Czech Republic and attempted to determine appropriate initial abstraction ratio values for the physiographic conditions of Central Europe to improve direct-runoff estimates. The possible influence of individual storm event characteristics was also assessed using principal component and cluster analysis. The obtained results indicated that the original CN method in its traditional arrangement does not perform sufficiently well in the studied watersheds and that watershed depended

modifications of λ and CN parameters are required. The need for a systematic yet site-specific revision of the traditional CN method, which may help to improve the SCS-CN method performance was also highlighted.

Młyński et al. [6] systematically analyzed and compared the performance of various CN-based rainfall-runoff models to determine the design hydrograph and the related peak flow in a mountainous watershed. To this end, the observed series of hydrometeorological data for the Grajcarek watershed in Poland for the years 1981 to 2014 were utilized. The obtained results indicated that the EBA4SUB model may be a good alternative in determining the design hydrograph in ungauged mountainous catchments as compared to Snyder and NRCS-UH models. However, it was also emphasized that a decisive factor influencing the performance of rainfall-runoff models is the quality of meteorological data constituting the input signal.

Ling et al. [10] presented a method for the improved watershed-specific calibration of SCS-CN model using non-parametric inferential statistics with rainfall-runoff data pairs. The proposed method generated confidence intervals to determine the optimum parameter values by analyzing the corresponding data. The proposed method was tested in the Wangjiaqiao watershed in China and overperformed the runoff prediction accuracy obtained by the asymptotic curve number fitting method, the linear regression model, and the conventional direct SCS-CN model.

Kang and Yoo [14] tested the applicability of the SCS-CN method in a study area with distinctive characteristics, namely the volcanic Jeju Island, South Korea. Three key issues regarding the application of the SCS-CN method were investigated; i.e., the relationship between the initial abstraction and the maximum potential retention, the determination of the maximum potential retention, and the effect of the antecedent soil moisture condition (AMC) on the initial abstraction and CN, by analyzing several storm events observed in the Hancheon watershed. The obtained results indicated that the optimum accumulated number of days for AMC determination is four or five. The antecedent five-day rainfall amount for the AMC-III condition was found to be higher than 400 mm, and for AMC-I less than 100 mm. These values are overpoweringly higher than the values included in the method documentation signifying the importance of local assessment in that distinctive environment. The optimum λ value was also found to be around 0.3.

Lastly, Psomiadis et al. [7] employed SCS-CN method along with earth observation to make a comparative assessment of the hydrological effect of gradual and abrupt land cover changes using as an example a Mediterranean peri-urban watershed in Attica, Greece. The study area underwent a significant population increase and a rapid increase of urban land uses, from the 1980s to the early 2000s and was also affected by several wildfires. A key observation of this study is that the impact of forest fires is much more prominent in rural watersheds than in urbanized watersheds and that runoff increments due to urbanization seem to be higher than runoff increments due to forest fires affecting the associated hydrological risks. The results of this study indicated that SCS-CN method in conjunction with earth observation is a valuable tool for similar assessments in a simple but efficient way.

In conclusion, this special issue provided the ground for the presentation of the latest developments on SCS-CN method including important steps towards addressing the key challenges and limitations. At the same time, some areas for possible further improvement were also identified and highlighted.

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References

1. NRCS National Engineering Handbook Part 630 Hydrology. Available online: <https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1043063> (accessed on 5 January 2021).
2. Ponce, V.M.; Hawkins, R.H. Runoff Curve Number: Has It Reached Maturity? *J. Hydrol. Eng.* **1996**, *1*, 11–19. [[CrossRef](#)]
3. Hawkins, R.H.; Moglen, G.E.; Ward, T.J.; Woodward, D.E. Updating the Curve Number: Task Group Report. In *Proceedings of the Watershed Management 2020: A Clear Vision of Watershed Management—Selected Papers from the Watershed Management Conference 2020*; American Society of Civil Engineers (ASCE): Reston, VA, USA, 2020; pp. 131–140.
4. Shi, W.; Wang, N. An improved SCS-CN method incorporating slope, soil moisture, and storm duration factors for runoff prediction. *Water* **2020**, *12*, 1335. [[CrossRef](#)]
5. Ajmal, M.; Waseem, M.; Kim, D.; Kim, T.W. A pragmatic slope-adjusted curve number model to reduce uncertainty in predicting flood runoff from steep watersheds. *Water* **2020**, *12*, 1469. [[CrossRef](#)]
6. Młyński, D.; Wałęga, A.; Ksiazek, L.; Florek, J.; Petroselli, A. Possibility of using selected rainfall-runoff models for determining the design hydrograph in mountainous catchments: A case study in Poland. *Water* **2020**, *12*, 1450. [[CrossRef](#)]
7. Psomiadis, E.; Soulis, K.X.; Efthimiou, N. Using SCS-CN and earth observation for the comparative assessment of the hydrological effect of gradual and abrupt spatiotemporal land cover changes. *Water* **2020**, *12*, 1386. [[CrossRef](#)]
8. Soulis, K.X.; Valiantzas, J.D. SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds—The two-CN system approach. *Hydrol. Earth Syst. Sci.* **2012**, *16*, 1001–1015. [[CrossRef](#)]
9. Soulis, K.X.; Valiantzas, J.D. Identification of the SCS-CN Parameter Spatial Distribution Using Rainfall-Runoff Data in Heterogeneous Watersheds. *Water Resour. Manag.* **2013**, *27*, 1737–1749. [[CrossRef](#)]
10. Ling, L.; Yusop, Z.; Yap, W.S.; Tan, W.L.; Chow, M.F.; Ling, J.L. A calibrated, watershed-specific SCS-CN method: Application to Wangjiaqiao watershed in the three Gorges Area, China. *Water* **2020**, *12*, 60. [[CrossRef](#)]
11. Krajewski, A.; Sikorska-Senoner, A.E.; Hejduk, A.; Hejduk, L. Variability of the initial abstraction ratio in an urban and an agroforested catchment. *Water* **2020**, *12*, 415. [[CrossRef](#)]
12. Caletka, M.; Michalková, M.Š.; Karásek, P.; Fučík, P. Improvement of SCS-CN initial abstraction coefficient in the Czech Republic: A study of five catchments. *Water* **2020**, *12*, 1964. [[CrossRef](#)]
13. Soulis, K.X.; Psomiadis, E.; Londra, P.; Skuras, D. A New Model-Based Approach for the Evaluation of the Net Contribution of the European Union Rural Development Program to the Reduction of Water Abstractions in Agriculture. *Sustainability* **2020**, *12*, 7137. [[CrossRef](#)]
14. Kang, M.; Yoo, C. Application of the SCS-CN Method to the Hancheon Basin on the Volcanic Jeju Island, Korea. *Water* **2020**, *12*, 3350. [[CrossRef](#)]
15. Soulis, K.X. Estimation of SCS Curve Number variation following forest fires. *Hydrol. Sci. J.* **2018**, *63*, 1332–1346. [[CrossRef](#)]
16. Soulis, K.X.; Ntoulas, N.; Nektarios, P.A.; Kargas, G. Runoff reduction from extensive green roofs having different substrate depth and plant cover. *Ecol. Eng.* **2017**, *102*, 80–89. [[CrossRef](#)]