SYSTEMATIC REVIEW ABOUT THE EFFECT OF WATERSHED SIZE ON THE NRCS-CN METHOD

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INTRODUCTION

The NRCS-CN method was developed in the 1950s by the USDA Natural Resources Conservation Service (NRCS) based on rainfall event observations across a series of rural watersheds in the United States. This method aims to estimate direct surface runoff from observed rainfall depth and is one of the most widely used methods globally for watershed water resources management (Hawkins *et al*., 2009). However, the literature diverges on the suitability of the method as the area of the watersheds increases.

This research aims to conduct a systematic review on the effect of the watershed spatial scale on the NRCS-CN method, seeking to identify gaps and trends in the global scenario. The research was developed based on the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, which guides the study with a focus on transparency, accuracy, and organization (Page *et al*., 2021).

METHODOLOGY

A list of keywords and their commonly used synonyms in the hydrological literature was developed to construct the search string. The study was based on the PRISMA 2020 (Page *et al*., 2021) to ensure transparency and standardization for the research.

Initially, baseline criteria were adopted regarding language, analysis period, and database. English was selected as the language. The Scopus database was chosen given its extensive collection of available journals. This review considered the records retrieved from Scopus using the defined search string, resulting in an analysis period from 1981 to 2025.

Using the 'Article title, Abstract, Keywords' function (topic search), the search was conducted via the following search equation: (("curve number" OR "SCS-CN" OR "NRCS-CN" OR "runoff curve number") AND ("basin area" OR "catchment area" OR "watershed area" OR "drainage area" OR "basin size" OR "watershed size" OR "catchment size") AND (calibrat* OR optimiz* OR estimat* OR "observed rainfall" OR "measured runoff")).

Based on the retrieved records, the exclusion and inclusion criteria were applied (Table 1) in 5 categories, where SC 01 e 02 are search criteria 01 and 02 respectively; VR is vague relationship; PR is partial relationship and SR is strong relationship.

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Table 1: Exclusion and inclusion criteria.

Exclusion/Inclusion	Criterion	Description	Identification
Direct Exclusion	Search	Not a scientific article	SC01
		Language is not English	SC02
Exclusion based on abstract	Vague Relationship	Articles that used the NRCS-CN only as a secondary tool for purposes unrelated to watershed-size effects	VR
Inclusion	Partial Relationship	Articles that estimated the CN using observed data and discussed the effects of the catchment area on the estimate, or at least touched upon it	PR
	Strong Relationship	Articles that directly discuss the effect of the watershed area size on the NRCS-CN method	SR

The initial sample of studies comprised 109 publications. In the first screening phase, applying the direct exclusion criteria, 18 publications were excluded based on criterion SC01 (document type) and 4 were excluded based on criterion SC02 (language). In the second screening phase, exclusion or inclusion decisions were made based on the abstract reading of the remaining articles. At this stage, 81 publications were excluded based on the VR criterion.

The remaining 6 articles were subjected to full-text reading. As a result, these articles were included in the consolidated sample: 3 strongly related articles (SR) and 3 partially related articles (PR). These screening processes are represented in Figure 1.

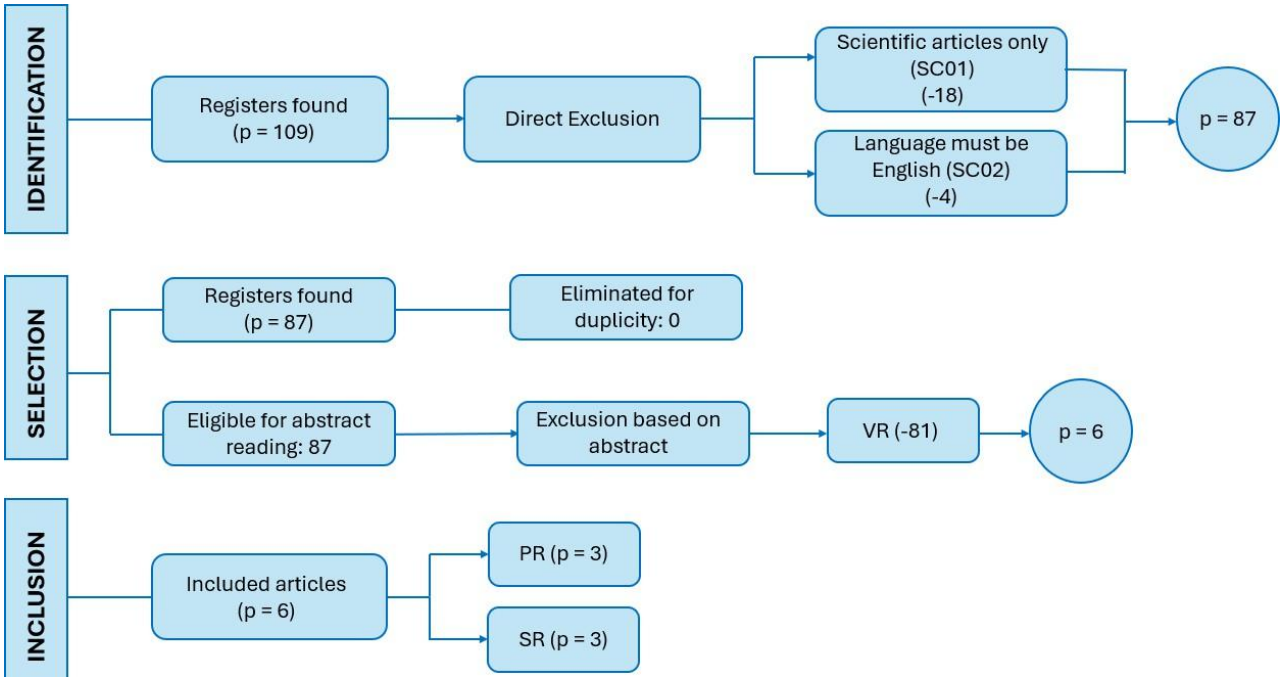


Figure 1: Screening sequence.

RESULTS AND DISCUSSIONS

The main conclusions observed in the six selected articles are summarized in Table 2.

Table 2: Summary of the selected researchs

References	Conclusion
Ponce & Hawkins 1996	There is no mathematical formulation or correction for spatial scale effects; the application of the NRCS-CN method must be approached with caution in watersheds larger than 250 km².
Johnson, 1998	Watershed area, by itself, is not an impediment to the application of the method; the limitations stem more from hydraulic storage within channels and insufficient rainfall monitoring
Brocca et al., 2009	With increasing area, the linear relationship between initial soil moisture and the degree of saturation weakens, while baseflow dynamics gain importance in estimating antecedent moisture.
Ares et al., 2012	The method is applicable to watersheds of this order of 110 km², but the local empirical determination of the parameters is indispensable to reduce flood estimation errors when transposing the method.
Fabrega et al., 2012	The transfer of functions between scales requires metric adjustments: inter-scale modeling should not use absolute baseflow values, but rather its relative magnitude, parameterized by the drainage area.
D'Asaro, Grillone & Hawkins, 2014	For watersheds larger than 160 km², a regionalized approach that correlates the calibrated CN with physical and morphoclimatic factors of the basin provides a strong relationship between parameters.

The empirically studied areas were 0.0065 km² (Fabrega et al., 2012), 13–137 km² (Brocca et al., 2009), 116 km² (Ares et al., 2012), 160 km² (D'Asaro, Grillone & Hawkins, 2014), and 250 km² (Johnson, 1998), which highlights the divergence in the literature regarding a threshold area that limits the use of the NRCS-CN method. However, despite these differences, the studies converged on the proposition that the magnitude of the watershed area alone was not the sole determining factor for the method. Instead, they attributed a role to morphoclimatic conditions, leading to the need for local calibration of the method or a more efficient monitoring of the watershed's hydrological events. This indicates that the watershed area should not be viewed in isolation, but as a factor that may be combined with the characteristics of the region where the basin is located, as well as its soil type, land use, and land cover.

Furthermore, there is a relationship between the watershed's hydrological signature and its area: research by Brocca *et al.* (2009) and Fabrega *et al.* (2012) points to the weakening of the linear relationship between initial soil moisture and the degree of saturation as the watershed area increases since initial soil moisture becomes influenced by more complex subsurface processes that do not progress linearly with saturation. Fabrega *et al.* (2012) indicate a greater role of baseflow, leading to the necessity of adopting relative magnitudes of such flow, parameterized by the drainage area of the watershed.

CONCLUSIONS

The systematic review structured by the PRISMA 2020 methodology indicates a gap in the global literature regarding the spatial scale effects on the NRCS-CN method, filtering an initial sample of 109 publications down to only 6 articles that directly or partially addressed this specific relationship.

The synthesis of these studies identified a clear divergence in the scientific community: while some authors recommend caution for watersheds exceeding 250 km², others argue that area size is not a physical barrier, attributing application failures to insufficient rainfall monitoring and channel hydraulic storage. Also, it is worth noting that this research was based on only six retrieved articles and did not involve a formal evaluation of the methodological quality of each included study.

Furthermore, the analysis demonstrates that spatial scale fundamentally alters the hydrological signature of catchments, affecting variables such as near-surface soil moisture linear relationships and increasing the significance of baseflow dynamics as the area expands. Consequently, inter-scale predictive modeling cannot rely on absolute parameter values, requiring regionalized modeling and local empirical determinations to mitigate flood estimation errors when transposing the method. Future research should focus on expanding meta-analyses to establish mathematical correction factors or metric adjustments capable of standardizing the NRCS-CN application across diverse territorial magnitudes.

REFERENCES

ARES, M. G; et al. (2012). "*Runoff Curve Number calibration of a 116 Km² agricultural basin, Buenos Aires, Argentina*". Agrociencia, v.46, p.535-541.

BROCCA, L.; et al. (2009). "Assimilation of Observed Soil Moisture Data in Storm Rainfall-Runoff Modeling". Journal of Hydrologic Engineering. v.14, p.153-165

D'ASARO, F.; GRILLONE, G.; HAWKINS, R. H. (2014). "*Curve Number: Empirical Evaluation and Comparison with Curve Number Handbook Tables in Sicily*". Journal of Hydrologic Engineering, v.19, p.1-13.

FABREGA, J. R. D; PINZÓN, R.; VALLESTER, E.; VEJA, D. (2012). "*Rainfall – CN (Curve Number) relationships in a tropical rainforest microbasin within the Panamá Canal watershed*". Revista Facultad de Ingeniería Universidad de Antioquia, v.62, p.170-176.

HAWKINS, R. H; WARD, T. J; WOODWARD, D. E; VAN MULLEM, J. A (2009). "*Curve Number Hydrology"* The ASCE/EWRI Curve Number Hydrology Comittee/VA, 106p.

JOHNSON, R.R (1998). "*An investigation of curve number applicability to watersheds in excess of 25000 hectares (250 Km²)*". Journal of environmental hydrology, v.6, paper 7.

PAGE, MATTHEW J. et al. (2021). "*The PRISMA 2020 statement: an updated guideline for reporting systematic reviews*".The BMJ journals, v.71, p.1-9.

PONCE, V. M; HAWKINS, R. (1996). "Runoff Curve Number; Has it reached maturity?". Journal of Hydrologic Engineering. v.1, p.11-19.