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A CALIBRATED, WATERSHED-SPECIFIC SCS-CN METHOD AS APPLIED TO KAINJI DAM WATERSHED IN NIGER STATE, NIGERIA

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ABSTRACT

This paper explores the application of a calibrated, watershed-specific soil conservation service curve number (SCS-CN) method to the Kainji dam watershed in Niger State, Nigeria, addressing the challenges and opportunities associated with its implementation. The SCS-CN method is versatile and popular for quick runoff estimation is relatively easy to use with minimum data and it gives adequate results. This study presents a new $CN_{0.056}$ of 59 against the conventional $CN_{0.2}$ of 65. The E index increased by 5.2%, the BIAS of the predictive model was reduced by 58.3% and the model's RSS was lowered by 12.1%. In the event of rapid urbanization and climate change, SCS practitioners can conduct regional-specific calibration for the SCS model as proposed to derive region and time-period-specific CN values for the Nigerian watershed.

Keywords: SCS-CN method, Direct runoff, Initial abstraction ratio, Rainfall-runoff events

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INTRODUCTION

Managing water resources in the face of changing climate patterns and increasing human activities requires accurate and localised methodologies for assessing hydrological processes (UNEP, 2023). The Soil Conservation Service Curve Number (SCS-CN) method has long been a staple in hydrological modeling, providing a valuable tool for estimating runoff in various watershed scenarios (Ling *et al*., 2019). However, the need for calibration to specific geographical and environmental conditions has become increasingly evident (Smith *et al.*, 2023). This has led to the development of a calibrated, watershed-specific SCS-CN method, a tailored approach that takes into account the unique characteristics of individual watersheds (Wang *et al*., 2024).

In this context, the application of the calibrated SCS-CN method gains particular significance in hydrological studies related to the Kainji Dam. The Kainji Dam, a critical water resource infrastructure in Nigeria, plays a pivotal role in flood control, hydropower generation, and water supply. The accurate assessment of runoff and water availability in the Kainji Dam watershed is essential for effective dam management and sustainable water resource planning (KDMA, 2022).

Recent advancements in hydrological modeling techniques and the incorporation of high-resolution spatial data have facilitated the development of watershed-specific SCS-CN methods (Smith *et al.*, 2023). These methods not only consider the inherent variability in land use, soil types, and topography within a specific watershed but also incorporate calibration procedures to enhance the accuracy of runoff predictions Wang *et al*., 2024).

This paper explores the application of a calibrated, watershed-specific SCS-CN method to the Kainji Dam watershed, addressing the challenges and opportunities associated with its implementation. By integrating recent research findings and utilizing up-to-date references, we aim to provide insights into the relevance and effectiveness of this method in improving the precision of hydrological assessments in the context of the Kainji Dam and similar water resource systems.

MATERIALS AND METHODS

Study Site

Kainji Dam is a dam across the Niger River in Niger State of Central Nigeria. The Dam lies between longitude 04.61333^{0}E and latitude 09.86250^{0}N in the Borgu Local Government area of Niger State. The lake created behind the dam spans between latitude 9° 8' to 10°7' and between longitude 4°5' to 4°7'E with reference points 9.54N and 4.38E northwest of the Federal Capital Territory (FCT, Abuja) (Dukiya, 2013). The average rainfall at the headwaters of Niandan and Milo rivers at the source of the Niger at the Fouta Djallon Mountains in Guinea and its exit to the sea in Nigeria is 2200mm. The river flow regime is characterized by two distinct flood periods occurring annually namely the White and Black floods. The black flood derives its flow from the tributaries of the Niger outside Nigeria (flow lag October to May) and arrives at Kainji reservoir (Nigeria) in November and lasts until March at Jebba after attaining a peak rate of about 2,000m3 /sec in February. The White Flood is a consequence of flows from local tributaries especially the Sokoto Rima and Malendo river systems. The White flood is heavily laden with silts and other suspended particles (flow lag June to September) and arrives in Kainji in August in the pre-Kainji Dam River Niger having attained a peak rate of 4,000 to 6,000m3 /sec in September October in Jebba (Mohammed *et al*., 2018).

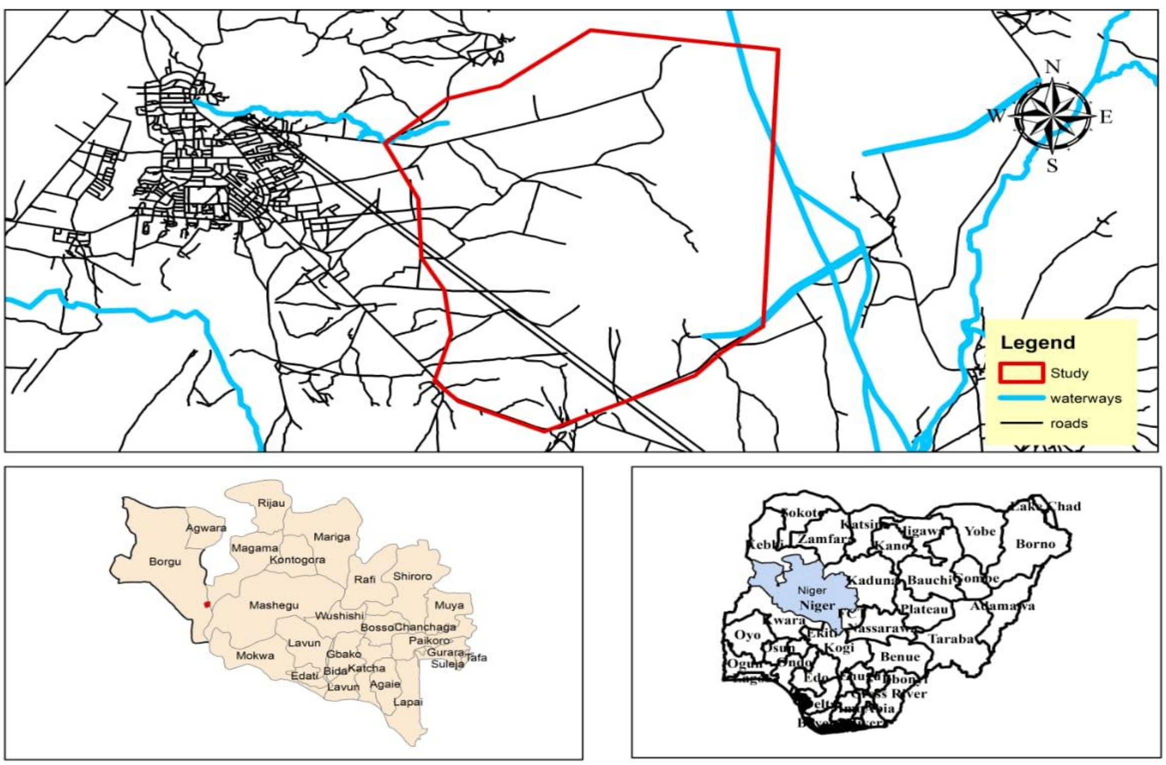

Figure 1: Maps of Nigeria and the Study Area

Method of Data Collection

Hydrological data collection

The hydrological data such as rainfall and runoff will be collected at the Mainstream Energy Solution of Nigeria, Kainji Hydro Power Plant Station New Bussa for 2 years.

Methodology for the Development of a CN for the watershed.

The CN for the study area was estimated using the following methods.

The Conventional Soil Conservation Service Curve Number (SSC- CN) method

The soil conservation service curve number (SCS-CN method) also known as the hydrologic soil group method was used, this method is versatile and popular for quick runoff estimation and is relatively easy to use with minimum data and it gives adequate results. The hydrologic methods which were originally developed to address specific situations were adopted immediately without professional review and criticism (Hawkins *et al*., 2009; Hawkins 2014; Lings *et al*., 2019). The work became the basic CN rainfall-runoff model:

$$Q = (P - Ia)^2/(P - Ia + S) \ldots\ldots.. (1)$$

Q = Amount of runoff depth (mm), P = Depth of rainfall (mm), S = Watershed maximum water retention potential (mm), Ia = Rainfall initial abstraction amount (mm).

SCS also hypothesized that Ia = λS = 0.2S where λ is the initial abstraction ratio coefficient and fixed at λ = 0.2 as a constant. This equation was tenuously justified with daily rainfall and runoff data. Its substitution simplifies Equation (2.1) into the existing SCS CN model as:

$$Q = (P - 0.2S)^2/(P - 0.8S) \ldots. (2)$$

if P < 0.2S, Q = 0

And $$CN = \frac{25{,}400}{S+254} \ldots\ldots (3)$$

The SCS CN methodology has been widely accepted since its inception in 1954. It has been incorporated in various types of software, adopted by many government agencies in design and even appears in every hydrology textbook. However, studies around the world from recent decades reported that Equation (2.3) inconsistently under and over-predicted runoff results. Curve Number (CN) selection from the SCS handbook for a watershed runoff prediction modeling was reported as subjective and often could not represent another watershed with similar land cover (Hawkins *et al*., 2009, Hawkins 2014, Ling *et al*., 2019).

Despite that, many recent studies started to develop and propose extended applications with Equation (2.2). Some researchers even proposed a global gridded CN concept for runoff modeling (Ross *et al*., 2018 and Jaafar *et al*., 2019) while others incorporated land-use information in their studies and the GIS modeling technique (Chen *et al*., 2020, Feng *et al*.,2020 and Yalcin, 2020). US researchers were the first to conduct large-scale studies on the SCS CN model by analyzing more than half a million rainfall events across 24 states in the USA and reported an optimum λ = 0.05 to achieve better runoff modeling results than Equation (2.2) in the USA (Jiang, 2001 and Hawkins *et al*.,2009). To date, SCS practitioners do not have a systematic approach to assess the SCS CN model framework and analyze the impact on runoff prediction when the model is not calibrated (Ling *et al*., 2021).

New Calibrated Model (C_λ) Method

This method proposed to use non-parametric inferential statistics as the guide to make a statistically significant selection of the two key parameters (S and λ values) to calibrate the fundamental SCS CN runoff framework (Equation 2.1), Equation (2.1) was re-arranged into a general form of $S_\lambda = f(P, Q, \lambda)$ in a previous study (Ling *et al*., 2019). When λ = 0.2, the corresponding $S_{0.2}$ value leads to the derivation of conventional CN values in use by SCS practitioners. Any other λ values will result in S_λ leading to the derivation of CN_λ values which are different from the SCS tabulated CN values. The general S_λ formula for derivation steps used by this study is presented in equation (2.4). Where S_λ = Total abstraction amount of any λ value (mm).

$$S_\lambda = \frac{\left[P - \frac{(\lambda-1)Q}{2\lambda}\right] - \sqrt{PQ - P^2 + \left[P - \frac{(\lambda-1)Q}{2\lambda}\right]^2}}{\lambda} \ldots.. (4)$$

The value of S will be substituted in equation (3.1) and it becomes

$$\mathbf{CN}_\lambda = \frac{25400}{S_\lambda + 254} \ldots. (5)$$

Methodology for the calculation of runoff using various CN values

Estimation of Runoff using the Conventional Soil Conservation Service (SCS – CN) ($CN_{0.2}$) Method.

The first concept is that the ratio of the actual amount of runoff to maximum potential runoff is equal to the ratio of actual infiltration to the potential maximum retention as presented in Equation (2.2) (Subramanya, 2013). In this case, the runoff for the conventional soil conservation service ($CN_{0.2}$) is presented in equation (2.6) below:

$$Q_{(0.2)} = \frac{\left[P-50.8\left(\frac{100}{CN_{0.2}}-1\right)\right]^2}{\left[P+203.2\left(\frac{100}{CN_{0.2}}-1\right)\right]} \ldots\ldots. (6)$$

Estimation of Runoff Using the New Calibrated Model (C_λ) Method.

The calibrated runoff is estimated using the S_λ from equation (2.4) and the S_λ value will be substituted in equation (3.5) to estimate the runoff of the watershed in this case equation is written as;

$$Q_\lambda = \frac{(P-\lambda S_\lambda)^2}{(P-\lambda S_\lambda+S_\lambda)} \ldots\ldots (7)$$

Models Comparison

Runoff models are compared and benchmarked for their model predictive accuracy in this paper. The model's residual sum of squares (RSS), predictive model BIAS prediction, and model efficiency index (E), also known as Nash–Sutcliffe index, were calculated with the following formulae to draw further comparison between them.

$$RSS = \sum_{i-1}^{n}(Qpredicted - Qobserved)^2 \quad \ldots. (8)$$

$$E = 1 - \frac{RSS}{\sum_{i-1}^{n}(Qpredicted-Qmean)^2} \ldots.. (9)$$

$$BIAS = \frac{\sum_{i-n}^{n}(Qpredicted-Qobserved)}{n} \ldots\ldots (10)$$

n = Total number of data pairs.

Lower RSS implies a better model. Index E lies on a spectrum of minus 1.0 to 1.0 whereby index value = 1.0 shows an ideal conjectured model. In the instance where $E < 0$, it is inferior to utilizing an average to predict the dataset. BIAS is the overall model prediction error indicator. A zero BIAS value indicates an error-free model prediction while a negative value indicates the overall predictive model's under-prediction tendency and vice versa.

RESULTS

Inferential Statistics Assessment to obtain Optimum λ, S and the New Curve Nuber

The soil conservation service curve number (SCS-CN method) which is versatile and popular for quick runoff estimation is relatively easy to use with minimum data gives adequate results is used to establish the $CN_{0.2}$ of the study area. The model is presented in equations (2.6) and (2.7) are used to calculate $CN_{0.2}$ and retention (S), the rainfall, and runoff dataset that were used are presented in Table 1. The $CN_{0.2}$ ranges from 39 to 83 with an average of 65, the average value of 65 will be adopted as the $CN_{0.2}$. Hence, the 65 will used for computation for the prediction of surface runoff for the $CN_{0.2}$.

This method proposed to use non-parametric inferential statistics as the guide to make a statistically significant selection of the two key parameters (S and λ values) to calibrate the fundamental SCS CN runoff framework (Equation 2.1), Equation (2.1) was re-arranged into a general form of $S_\lambda = f(P, Q, \lambda)$ in a previous study (Ling *et al*., 2019). When λ = 0.2, the corresponding $S_{0.2}$ value leads to the derivation of conventional CN values in use by SCS practitioners. Any other λ values will result in S_λ leading to the derivation of CN_λ values which are different from the SCS tabulated CN values. The general S_λ formula for derivation steps used by this study is presented in equation (2.4). Where S_λ = Total abstraction amount of any λ value (mm).

Table 1: Rainfall-runoff data of the Kainji Dam watershed

SN	Date	Rainfall P (mm)	Direct Runoff Q (mm)	I_a=λ*S	Retention S (mm)	λ= I_a/S
1	19/5/2022	10.05	0.66	3.41	52.02	0.066
2	9/5/2022	10.60	0.53	2.60	52.02	0.050
3	30/8/2022	11.10	0.63	3.16	55.76	0.057
4	3/9/2022	12.50	0.75	3.81	63.5	0.060
5	16/7/2023	13.50	0.75	3.76	67.83	0.056
6	19/7/2023	13.52	0.76	3.79	67.52	0.056
7	25/6/2023	14.00	0.88	4.50	71.64	0.063
8	2/7/2022	14.50	0.76	3.75	71.64	0.052
9	22/7/2022	15.00	0.88	4.45	75.87	0.059
10	21/6/2022	15.50	0.77	3.76	75.87	0.050
11	30/7/2022	15.60	0.99	5.09	80.21	0.063
12	11/9/2022	15.70	0.97	4.95	80.21	0.062
13	12/8/2022	16.20	0.85	4.20	80.21	0.052
14	4/7/2022	16.50	1.05	5.38	84.67	0.064
15	11/6/2023	17.00	0.93	4.63	84.67	0.055
16	24/7/2023	17.00	0.92	4.58	84.67	0.054
17	26/9/2022	17.30	0.42	1.84	75.87	0.024
18	8/6/2022	17.60	1.05	5.32	89.24	0.060
18	20/6/2023	17.90	0.98	4.88	89.24	0.055
20	12/5/2023	19.00	1.01	4.99	93.95	0.053
21	18/5/2023	19.08	1.05	5.17	94.06	0.055
22	1/7/2023	19.50	1.16	5.87	98.78	0.059
23	20/9/2022	20.08	1.02	5.01	98.78	0.051
24	2/9/2023	21.10	1.13	5.82	108.86	0.054
25	2/9/2023	21.30	1.32	6.74	108.85	0.062
26	29/5/2022	22.30	1.34	6.58	109.65	0.060
27	27/6/2022	23.00	1.23	6.10	114.12	0.053
28	27/8/2022	23.30	1.47	7.54	119.53	0.063
29	21/5/2022	24.70	1.50	7.59	125.10	0.061
30	24/8/2023	24.90	1.41	7.08	125.10	0.057
31	9/7/2023	25.30	1.33	6.57	125.10	0.053
32	12/7/2023	27.20	1.56	7.84	136.77	0.057
33	6/6/2023	28.00	1.73	8.82	142.88	0.062
34	9/8/2023	28.30	1.65	8.33	142.88	0.058
35	3/6/2022	30.07	1.60	7.93	149.17	0.053
36	9/9/2022	31.30	1.69	8.40	155.68	0.054
37	23/8/2023	32.40	1.82	9.12	162.39	0.056
38	10/6/2022	33.90	1.87	9.34	169.33	0.055
39	1/6/2023	34.50	1.74	8.54	169.33	0.050
40	26/82022	36.20	2.18	11.07	183.93	0.060
41	8/8/2023	38.30	2.13	10.65	191.61	0.056
42	15/9/2022	38.40	2.11	10.52	191.61	0.055
43	2/6/2023	38.40	2.11	10.52	191.61	0.055
44	16/6/2022	39.40	2.34	11.85	199.57	0.059
45	8/7/2023	39.80	2.24	11.23	199.57	0.056
46	24/5/2023	40.05	2.19	10.91	199.57	0.055
47	22/6/2022	40.35	2.12	10.48	199.57	0.053
48	28/7/2023	42.20	2.16	10.63	207.82	0.051
49	15/8/2022	44.20	2.71	13.81	225.25	0.061
50	29/6/2023	44.40	2.66	13.49	225.25	0.060
51	22/6/2023	51.50	2.66	13.11	254.00	0.052
52	12/9/2022	53.00	2.91	14.51	264.37	0.055
53	19/8/2023	53.40	2.82	13.96	264.37	0.053
54	30/8/2023	54.70	3.14	15.79	275.17	0.057
55	4/7/2023	57.40	3.16	15.76	286.43	0.055
56	1/8/2023	59.70	3.30	16.48	298.17	0.055
57	1/7/2022	63.00	3.23	15.91	310.44	0.051
58	5/9/2022	63.10	3.28	16.22	312.04	0.052
59	2/7/2023	67.00	3.82	19.19	336.70	0.057
60	12/8/2023	81.00	4.06	19.91	397.28	0.050

The Sixty rainfall events were analyzed with generalized reduced gradient (GRG) in Excel according to rainfall-runoff processes, and it was found that Ia/S ratios varied greatly between storms within the watershed. The calculated Ia/S values varied from 0.024 to 0.066, with a median of 0.046. The average initial abstraction ratio of the watershed was equal to 0.056 (Table 4.3). Figure 4.1 shows that the (Ia/S) ratio is predominantly around 0.055 and is not related to rainfall depth P.

Estimation of Runoff using the Conventional Soil Conservation Service (SCS – CN) ($Q_{0.2}$) Method, New Calibrated Model (Q_{λ}) and Differences in Runoff (Q_v).

The first concept is that the ratio of the actual amount of runoff to maximum potential runoff is equal to the ratio of actual infiltration to the potential maximum retention as presented in Equation (2.2). In this case, the runoff for the conventional soil conservation service ($CN_{0.2}$) is presented in equation (2.6). The calibrated runoff is estimated using the S_{λ} from equation (2.4) and the S_{λ} value will be substituted in equation (2.7) to estimate the runoff of the watershed in this case. The differences in the runoff Q_v are obtained from the differences between $Q_{0.2}$ and Q_{λ}. The Q_v shows under prediction of $Q_{0.2}$ from the ranges of P 15.6 mm to 44.20 mm, while over-prediction was noticed with $Q_{0.2}$ from the ranges of P 10.05 mm to 15.5 mm and P 44.21 mm to 81 mm, the implication of runoff prediction with $Q_{0.2}$ model is the uncertainties of under-prediction and over-prediction as clearly shown in Table 2.

Differences between SCS and New Model across different CN in Rainfall P (mm)

This study introduced runoff difference curves which were created with numerical analysis technique to visually present Equation (2.6) and (2.7) and to identify P with their corresponding Q. Runoff difference curves graph combines two runoff curves (of conjugate curve numbers) into a single runoff difference curve. The graph is plotted for specific $CN_{0.2}$ and CN_{λ} classes across multiple rainfall depth scenarios to show P and its corresponding Q values (Figure 1).

The SCS practitioners can adopt Equations (2.7) to estimate the worst-case runoff prediction errors of Equation (2.2) when compared to the newly found λ (0.056) model in Kainji dam. On the other hand, regional or watershed-specific equations can also be established by SCS practitioners for their study as proposed to avoid uncertainties during prediction.

Table 2: Presents the Obverse Runoff, SCS runoff, Calibrated runoff and Runoff differences.

SN	Rainfall P (mm)	Observed Runoff Q (mm)	$Q_{0.2}$ (mm)	Q_{λ} (mm)	Q_{v} (mm)
1	10.05	0.66	2.508	0.9600	1.5478
2	10.60	0.53	2.351	0.8300	1.5209
3	11.10	0.63	2.213	0.9300	1.2827
4	12.50	0.75	1.848	1.0500	0.7980
5	13.50	0.75	1.608	1.0500	0.5576
6	13.52	0.76	1.603	1.0600	0.5429
7	14.00	0.88	1.494	1.1800	0.3136
8	14.50	0.76	1.384	1.0600	0.3239
9	15.00	0.88	1.278	1.1800	0.0983
10	15.50	0.77	1.177	1.0700	0.1070
11	15.60	0.99	1.157	1.2900	-0.1328
12	15.70	0.97	1.138	1.2700	-0.1324
13	16.20	0.85	1.042	1.1500	-0.1079
14	16.50	1.05	0.987	1.3500	-0.3632
15	17.00	0.93	0.898	1.2300	-0.3320
16	17.00	0.92	0.898	1.2200	-0.3220
17	17.30	0.42	0.847	0.7200	0.1267
18	17.60	1.05	0.797	1.3500	-0.5530
19	17.90	0.98	0.749	1.2800	-0.5313
20	19.00	1.01	0.585	1.3100	-0.7254
21	19.08	1.05	0.573	1.3500	-0.7765
22	19.50	1.16	0.517	1.4600	-0.9432
23	20.08	1.02	0.443	1.3200	-0.8767
24	21.10	1.13	0.328	1.4300	-1.1023
25	21.30	1.32	0.307	1.6200	-1.3129
26	22.30	1.34	0.214	1.6400	-1.4260
27	23.00	1.23	0.159	1.5300	-1.3711
28	23.30	1.47	0.138	1.7700	-1.6323
29	24.70	1.50	0.059	1.8000	-1.7409
30	24.90	1.41	0.051	1.7100	-1.6595
31	25.30	1.33	0.035	1.6300	-1.5946
32	27.20	1.56	0.000	1.8600	-1.8598
33	28.00	1.73	0.003	2.0300	-2.0265
34	28.30	1.65	0.007	1.9500	-1.9425
35	30.07	1.60	0.062	1.9000	-1.8383
36	31.30	1.69	0.130	1.9900	-1.8597
37	32.40	1.82	0.213	2.1200	-1.9069
38	33.90	1.87	0.359	2.1700	-1.8114
39	34.50	1.74	0.427	2.0400	-1.6126
40	36.20	2.18	0.655	2.4800	-1.8250
41	38.30	2.13	1.003	2.4300	-1.4271
42	38.40	2.11	1.021	2.4100	-1.3886
43	38.40	2.11	1.021	2.4100	-1.3886
44	39.40	2.34	1.215	2.6400	-1.4253
45	39.80	2.24	1.297	2.5400	-1.2433
46	40.05	2.19	1.349	2.4900	-1.1407
47	40.35	2.12	1.414	2.4200	-1.0061
48	42.20	2.16	1.845	2.4600	-0.6149
49	44.20	2.71	2.376	3.0100	-0.6342
50	44.40	2.66	2.433	2.9600	-0.5275
51	51.50	2.66	4.881	2.9600	1.9213
52	53.00	2.91	5.507	3.2100	2.2966
53	53.40	2.82	5.680	3.1200	2.5598
54	54.70	3.14	6.261	3.4400	2.8209
55	57.40	3.16	7.558	3.4600	4.0984
56	59.70	3.30	8.760	3.6000	5.1599
57	63.00	3.23	10.639	3.5300	7.1086
58	63.10	3.28	10.698	3.5800	7.1184
59	67.00	3.82	13.160	4.1200	9.0403
60	81.00	4.06	24.096	4.3600	19.7365

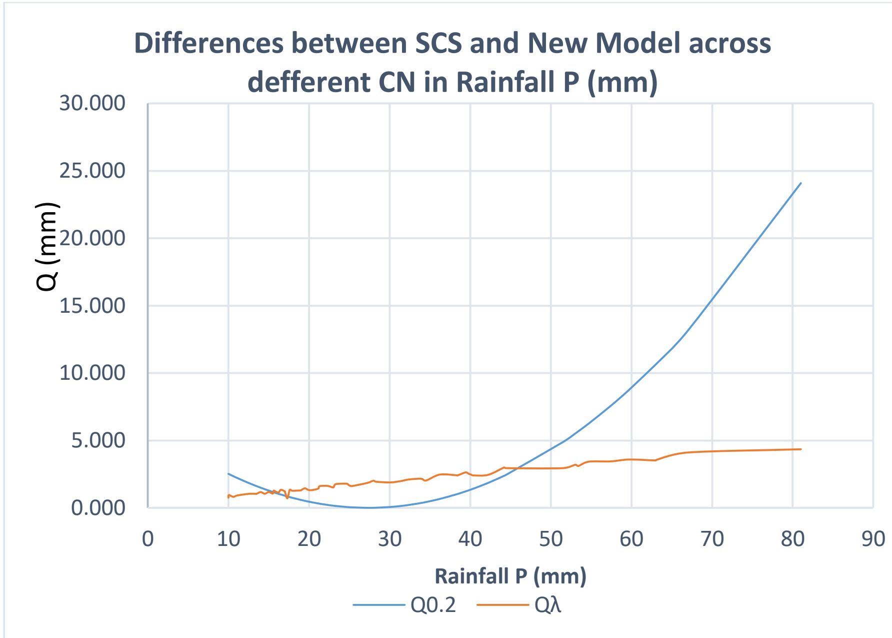

Figure 1: Runoff difference curve graph of Kainji dam.

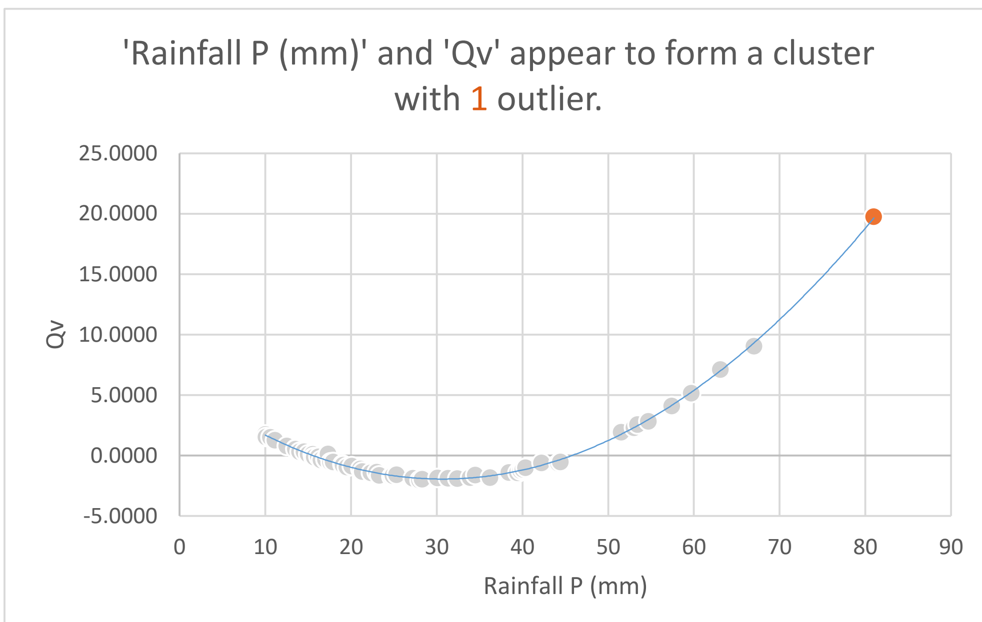

Figure 2: Runoff difference between the proposed calibrated model and the conventional SCS-CN model

The newly calibrated λ model has higher RSS with a lower E index compared to the runoff model formulated with the SCS $CN_{0.2}$ value. The Bias also shows that the λ model has very low bias meaning that the level disparity in runoff is low. The models' residual skewness is near zero, thus the mean residual value can act as an indicator of the predictive model's accuracy. The new λ model has a lower mean residual with a 99% confidence interval range which spans across zero, indicating its capability to achieve zero (residual) runoff prediction error. On the other hand, the SCS $CN_{0.2}$ model tends to under-predict runoff volumes since their mean residual confidence interval range is within a higher value range. The descriptive statistics indicate that the

SCS $CN_{0.2}$ model has a higher residual range. However, the standard deviation and variance in the model's residual are higher in the new λ model with smaller confidence interval ranges. Hence, the new λ model has higher stability and reliability for the dataset of this study. According to the runoff constraint defined by SCS any rainfall depths less than the I_a value would not initiate any runoff; hence, any model that failed to comply with the SCS constraint for these P-Q data pairs. On the other hand, the New λ model does not have these issues.

Table 3: SCS $CN_{0.2}$ methods and new λ runoff model's residual analysis.

Model Parameters and Statistics	$CN_{0.2}$ Model	λ Model
λ value	0.2	0.056
E	0.73	0.77
RSS	47.89	54.51
BIAS	0.72	0.13
Residual Standard Deviation	0.2092	0.0497
Residual Mean	0.1295	0.1097
Residual Skewness	3.1903	0.5925
Residual: Range	1.2078	0.2174
Residual Variance	0.0438	0.0025

DISCUSSION

The CN_λ values calculated vary from 30 to 82 with a median of 56 and an average of 59, in this case, the CN_λ adopted for the Kainji dam is the average of 59 as reported by Ling *et al*., (2021) conducted at Peninsula Malaysia where he got CN_λ value to be 67 against $CN_{0.2}$ 0f 72 and Tan *et al*., (2018) in his study conducted at Melana Watershed in Johor, Malaysia got the value CN_λ as 90.45 against $CN_{0.2}$ to be 94.47 respectively. The $Q_{0.2}$ curve shows under-prediction at the points where it crosses below the Q_λ, similarly, at the point where the $Q_{0.2}$ curve crosses above the Q_λ it shows over-prediction this is in agreement with studies of Hawkins *et al*., 2009; Ling *et al*., 2019 and Ling *et al*., 2021.

A more appropriate value of Ia/S would be about 0.055 in the Kainji dam area. More than 90% of Ia/S ratios were less than 0.2. This is to the study of Ling *et al*., (2021) conducted at Peninsula Malaysia where he got values of λ ranging from 0.034 to 0.051 with an average of 0.05, Zhi-Hau *et al*., (2009) in his study conducted in the Gorges area of Chine got λ values ranging from 0.010 to 0.0154 and an average of 0.048 and Tan *et al*., (2018) in his study conducted at Melana Watershed in Johor, Malaysia got the value of λ as 0.005. With the evidence above it is advisable for the values of λ for each watershed/catchment to be calibrated instead of adopting the UDSA λ-0.2 value.

The corrected SCS-CN model also managed to correct runoff prediction errors of the conventional SCS-CN model and achieved proximate runoff prediction results as the newly calibrated watershed-specific SCS-CN model, which proves that the presented residual modeling technique was effective at transforming Equation (2) into a better rainfall-runoff model. Without model calibration, the conventional SCS-CN model over-predicted runoff volume significantly from rainfall depths of 44.21 mm onward at the 1,243 km^2 Kainji Dam watershed in Nigeria. Through Equation (7), it is possible to quantify and model the runoff over prediction volume according to its corresponding rainfall depths. SPSS mapped that Q_v (m^3) was able to quantify the runoff over prediction volume from the conventional SCS-CN model with an Adj R^2 near to 1.0 and low standard error at ($p < 0.001$).

CONCLUSION

This study agreed with the previous research conclusion that the SCS runoff prediction model can be calibrated with regional-specific P-Q characteristics. Statistical assessment rejected H_{01} with a 99% confidence level. As such, Equation (2.2) became invalid to model runoff conditions in this study while the adoption of Equation (2.2) will commit a type II error.This study presented a new CN derivation approach with a supervised numerical optimization technique through the guide of inferential statistics The E index increased by 5.2%, the BIAS of the predictive model was reduced by 58.3% and the model's RSS was lowered by 12.1%. These improvements were achieved with a λ of 0.056 instead of 0.2, and lower *RSS* and *BIAS* to produce the smallest runoff prediction error at alpha = 0.01 level. CN value of 59 was derived to represent the P-Q conditions at the Kainji Dam watershed with the inherent statistical significance at alpha = 0.01 level.The Q_v shows under prediction of $Q_{0.2}$ from the ranges of P 15.60 to 44.20 mm, while over-prediction was noticed with $Q_{0.2}$ from the ranges of P 10.05 to 15.5 mm and P 44.21 to 81 mm, the implication of runoff prediction with $Q_{0.2}$ model is the uncertainties of under-prediction and over-prediction, Positive Q_v indicates that Equation (2.6) predicted a larger runoff amount compared to Equation (2.7) while the negative Q_v indicates the Equation (2.6) under predicted runoff amount compared to Equation (2.7) in study area. Direct CN derivation with rainfall-runoff conditions is a swift and economical solution to calibrate SCS runoff model to reflect the latest P-Q condition of any watershed. In the event of rapid urbanization and climate change, SCS practitioners can conduct regional-specific calibration for the SCS model as proposed to derive region and time-period-specific CN values for the Nigerian watershed.

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