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Comparative Analysis of Some Existing Models for Estimating the Time of Concentration for Watersheds in Anambra State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author JCA designed the study while Author NCM wrote the introduction, managed the literature searches and performed the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

This study considered the estimation of the time of concentration (T_C) using 30 different watersheds in Anambra State, Nigeria. The study assessed the performance of some existing models for the estimation of time of concentration in the study area. Data for this research were collected from watersheds located at Awka-South Local Government in Anambra State. A measured time of concentration values was also obtained by using a tracer at the watershed divide and the time it took the tracer to get the outlet of the watershed was recorded. This was carried out on all the 30 watersheds at the same time. The length, slope and area of the 30 watersheds were also measured. Thereafter, the time of concentration was estimated using the 30 existing models. The extent of linear association between the observed and estimated time of concentration for the different models was determined. The outcome of the study revealed that the Ventura model (Tc12) developed in Italy recorded the highest correlation coefficient with a measure of 0.681, followed by DNOS model (Tc14) with a coefficient measure of 0.661 while the least performing model was

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Picking model (Tc13) with -0.423 correlation measure. There was also an obvious difference in the values of the time of concentration calculated using the different models. Therefore there is always a need to verify any model to be used for estimating the time of concentration in other to have a more robust design.

Keywords: Concentration; correlation; models; watershed; time.

1. INTRODUCTION

There are many definitions to time of concentration as well as for related estimation processes. It can be defined as the necessary time, used by the overland flow, to reach a balance. McCuen et al. [1] state that it is the necessary time taken by a water drop to superficially move from the most distant spot (within a hydraulic path) in the basin up to the outlet point. According to [2], the time of concentration is the time spent by a single raindrop to move from the most distant spot in the basin until its outlet point. The time of concentration can as well be viewed as the time spent by the overland flow to reach a balance [3]. In their contribution, [1] stated that it is the necessary time spent by a single water drop to superficially move from the most distant spot in the basin (in the hydraulic path) up to the outlet point.

Many researchers have developed empirical equations using experimental and analytic methods to estimate the time of concentration. Each equation resulted from studies performed in different fields. They were adjusted according to local physical and hydrologic features. However, such equations are useful tools to estimate time of concentration within watersheds. They are usually used in experiments that involve parameter settings; Fang et al. [4] suggested a method to identify the most effective equation to set time of concentration. The study by Fang et al. [4] found many differences among time of concentration that were estimated using different formulas using parameters of watersheds. The importance of a suitable model for estimating the concentration-time useful for accurately predicting flow rates from hypothetical storms becomes necessary in the study area [5,6]. This is because Anambra State has recently been hit by floods and the government is looking for ways to effectively manage and avoid subsequent devastation. A suitable model for predicting the concentration-time is expected to help engineers and hydrologists to accurately predict the reaction of a watershed to a particular rain event. This is usually important for infrastructure development, management and flood risk assessment.

2. LITERATURE REVIEW

Table 1 presents a review of twenty nine existing models for the estimation of time of concentration across the globe.

There are limitations associated with using some of the models for the estimation of the time of concentration. The study by Kirpich [9] recommended applying his adjustment curves only to rural basins that present area between 0.0040 and 0.8094 km^2. For small drainage basins that are dominated by channel flow, the Kirpich [9] equation can be used. Some authors use an adjustment factor for the Kirpich approach to correct for paved channels. Kirpich method yields very conservative or short times of concentration that result in high peak runoff rates, especially from the rational method. This method should only be used if the available data are limited to watershed length and slope (or) the method is specified by Kirpich.

A study conducted by [40] attempted to verify the application of the popular Kirpich Equation for determining the time of concentration using field data. Based on regression analysis, a modified Equation ($Tc = 331.43L^{1.7502} S^{-0.7692}$) was formulated. Results indicated no correlation between the measured and computed values of Tc. There were also marked variations between values obtained using the existing Equation and values obtained using the modified formula.

Also in another study conducted by Adaba et al. [24] to determine the adequacy of drainage channels in a small urban watershed in Nigeria a new time of concentration model was proposed for channel flow $Tc = 0.076L^{0.354} S^{-0.71}$. SCS Lag suits small rural basins of rural basins with A< 8km^2 in which the superficial flow is prevalent. The parameters reflect the behaviour of medium-sized basins as well as the prevailing flows in the canals. SCS Lag method did not take into consideration the total area of land contributing to the total runoff but rather the nature of the surface watersheds. Giandotti's equation is commonly used in Europe, mainly in Italy for A between170 km2 -70.000 km2 for a small agricultural watershed. Thus, diverse authors have been getting coherent results by applying the methodology to Italian basins. Radice et al. [19] highlight that the use of Giandotti's equation is mainly appropriate to mountainous basins considering the weather conditions.

Table 1. Some existing Models for estimating the Time of Concentration (Tc)

S/N	Name of Model	Models	Applications	References
1	Kerby-Hathaway	$Tc=0.606\ IN^{0.47}\ L^{0.47}\ 5^{-0.234}$	Analysis of overland Flow in experimental surface(L<0.37km) $A<0.0404685642\ km^2$ (10acres),slope <1% N< 0.8	(Kerby[7]; McCuen et al.[1])
2	Watt and Chow	$Tc = 0.0014(Lc/\sqrt{Sc})^{0.79}$		Watt and Chow [8]
3	Kirpich	$Tc =0.078L^{0.77}\ S^{-0.385}$ Ref: Kirpich (1940)	Data of rural basin(0.004 - 0.453 km^2)and (0.03<S<0.1) chow 3% to 10%	Kirpich [9]
4	FAA	$Tc=0.3788(1.1-c)\ L^{0.5}S^{-0.332}$	Valid for small water sheet where sheet flow and overland Data of aero ports flow dominates drainage	Chow et al. [10]; Silveira [11].
5	SCS Lag	$Tc=0.057(1000/CN^{-9})^{0.7}$ $L^{0.2}S^{-0.5}$	Data of rural basins ($A<8km^2$)	Folmar et al. [12]
6	Simas- Hawkins	$Tc=0.322A^{0.594}\ L^{-0.594}S^{-0.150}$ $S_{scs}{}^{0.313}$ $S_{SCS}=25400/CN -254$	Analysis for overland flow for ($A=0.001-14km^2$)	Simas – Hawkins [13]; Fang et al.[4]
7	Vente-Chow	$Tc= 0.1602\ L^{0.64}\ S^{-0.32}$	Area = (0.01-18.5 km^2) & (0.0051< S < 0.09)	Chow [14]; Silveria [11]
8	Dooge	$Tc=0.365A^{0.42}\ S^{-0.17}$	Area (145-948)km^2	Dooge [15]; Silveria [11]
9	Johnstone - Cross	$Tc=0.4623L^{0.5}S^{-0.25}$	Rural basin $A\leq12.000km^2$	Johnstone and Cross [16]; Silveria [11]
10	Giandotti	$Tc=\frac{\sqrt[4]{A+3/2L}}{0.8\sqrt{Hm}}$	A: (170-70.000)km^2 For small agricultural watershed	Giandotti [17]; Preti et al. [18]; Radice et al. [19]
11	Pasini	$Tc=0.108A^{0.332}L^{0.332}S^{-0.5}$	Applied for rural basins in Italy	Pasini [20]; Greppi [21]
12	Ventura	$Tc=4A^{0.5}L^{0.5}H^{-0.5}$	Rural basins	Mata-Lima et al. [21]
13	Picking	$Tc=0.0883L^{0.667}S^{-0.332}$	Data of rural basins	Mata-Lima et al. [22] Silveria [9]
14	DNOS	$Tc=0.419K^{-1}\ A^{0.2}L^{0.2}S^{-0.4}$	Rural basin ($A<0.45km^2$)&(0.03<S<0.1)	Silveria [9]
15	George Ribeiro	$Tc=0.267(1.05-0.2p)^{-2}L\ S^{-0.04}$	Applied to data of 7 rural basins in the USA and a rural basin in India ($A < 19000km^2$) and (0,03<S<0,1)	Ribeiro [23]
16	Dept. of Public works	$Tc = 60\left(\frac{11.9L^3}{H}\right)^{0.385}$	Applied to a rural basin	Adaba and Agunwamba [24]
17	Carter	$Tc=0.0977L^{0.6}S^{-0.2}$	$A<20.72km^2$ and(S<0.005) Developed from urban	Carter [25]; Sharrifi and Hosseini [26]

S/N	Name of Model	Models	Applications	References
			water sheds, $A<20.7199km^2(8km^2)$ $L<11.265km(7m)$	
18	Temez	$Tc=0.3(L/S^{0.25})^{0.74}$	Natural basins	Temez [27]; Mata-lima et al. [22]
19	Pickering	$Tc=(0.871L^3/H)$	Equivalent to Kirpick's	Mata-lima et al. [22]
20	California curvet practice (CHPW)	$Tc=0.95(L^3/H)^{0.385}$	For small mountain basins	Chow et al. [28]; Sharifi & Hosseini [26]
21	Bransby Willians	$Tc=0.605\ L/(100S)^{0.2}A^{0.2}$	Specially recommended for rural basins	MOTH [29]; ASDOT [30]
22	Epsey	$Tc=0.95(L/\sqrt{S})^{0.36}$	Applied for a rural basins	Hotchkiss and McCallum [31]; Mata-lima et al. [22]
23	Mata-Lima et al. [22]	$Tc = 4xA^{0.5}x\ Lw^{0.5}x\ Hm^{-0.5}$ Hm =height of the main hiller		Mata-lima et al. [22]
24	Williams	$Tc = (0.272\ x\ LA^{0.4})\ /\ DS^{0.2}$	Data of basins in India (A <129,5km2)	Williams [32]; Fang et al. [4]
25	Yen and Chow's	$Tc=1.2(nl/S^{0.5})^{0.6}$	Based on the theory of kinematic wave	Yen and Chow's [33];Wong [34]
26	Harktanir and Sezen (1990)	$Tc=0.7473L^{0.341}$	$A=11\text{-}9867km^2$	Harktanir and Sezen [35]; Fang et al. [4]
27	Fed. Aviation Admin (FAA)	$Tc = 18\ (1.1\ \ c)\ x\ L^{0.5}/S^{0.333}$		Joo-Hyon et al. [36]
28	Corps engineers	$Tc=0.191L^{0.76}\ S^{-0.19}$	$A\leq 12.000km^2$	Linsley [37]; Silveria [11]
29	Arizona DOT	$Tc=0.00956A^{0.1}(1000[L])^{0.25}$ $L^{0.25}ca\ S^{-0.2}$	Agricultural basins modified from FAA	Arizona DOT [38]

SOURCE: De Almeida et al. *[39]*

Definition of parameters presented in Table 1

Tc (hr) = time of concentration;
A (Km²) = area of the watershed;
C = overland flow coefficient of the rational method;
CN = Curve-number parameter of the SCS method;
D (Km) = equivalent diameter of the watershed;
H (m) = height difference between the ends of the main water line;
Hm (m) = mean altitude in the basin (it is the mean elevation starting from the mouth);
I (mm/h) = rainfall intensity;
K = coefficient of the type of surface;
L (Km) = length of the main water line;
Lca (m) = mean length starting from the concentration spot along the L up to the spot where L is perpendicular to the centroid of the basin (Arizona DOT);
N = retardance coefficient;
n ($m^{-1/3}$.s) = Manning's roughness = relation coefficient; between the vegetation cover and p the total area of the basin;

Greppi [21] have suggested that Pasini's equation must be applied to basins presenting smooth steepness where the basin data were collected. According to Mata-lima et al. [22], Temez's methodology suits natural basins presenting area as large as 3000 Km².

The Bransby William's method was mainly recommended to natural basins Arizona DOT is a modified form of FAA. It was developed from data from agricultural watersheds. In regards to ASCE, even though it is recommended only to length less than 0.09 km basins, Kang et al. (2008) proved its good performance in studies on big basins based on the topographical area. Yen and Chow's (1983) had proposed simplifying the ASCE. Williams (1922) developed the equation after performing a study on flood flow in India only. Haktanir and Sezen [35] developed their methodology using a regression analysis using data from basins located in Turkey. Kerby [7] Method can be used for small drainage basins that are dominated by channel flow. Some authors use an adjustment factor for the Kerby approach to correct for paved channels. The Kerby method is limited to the watershed with a drainage area of about 200 acres. The study by [41] evaluated the daily electricity flow forecasts using two simple conceptual models and one complex model for four large water catchment areas of the Tana Lake Basin (15,114 km2) in Ethiopia, which is a source of the Blue Nile Basin. The study compared the capabilities of the model to reproduce the observed current flow in the time and quantile domains. The model comparison based on several criteria shows that the simple conceptual models performed best in smaller catchment areas for reproducing the observed current flow in the time domain while the complex model performed best for the largest catchment area. The result showed that to reproduce the observed current flow in the quantile range, the simple conceptual models are best suited for the simulation of high, humid, medium and dry rivers in the Gilgelabay watershed; of dry and low rivers in the Gummera and Megech catchment areas and high rivers in the Ribb watershed. The results of the analysis show that the distributed models are particularly suitable for the complex watershed due to their physical heterogeneity. In general, the integration of these three models can be useful for assessing water resources.

3. MATERIALS AND METHODS

Estimations and derivation of time of concentration was done using data from catchment areas in Awka-South Local Government Area. Awka is a large city and the capital of Anambra State in Nigeria. Its population is about 300,000 people. The latitude of Awka, Nigeria is 6.210528**,** and the longitude is 7.072277. Awka, is located at *Nigeria* country in the Cities place category with the Global Positioning System (GPS) coordinates of 6° 12' 37.9008'' N and 7° 4' 20.1972'' E. Awka, Nigeria elevation is 105 meters height, that is equal to 344 feet.

A topographic map of the area was used to locate the watersheds, drainage network, locate and mark the downstream outlets of the watershed. Using the map, the possible watersheds were delineated and the areas of the perimeter of the watershed were be mapped out. After the delineation of the watersheds, the following parameters will be measured; the area of the watersheds, the flow length of the tributaries, the slope of the watershed. And also the time of concentration was measured.

3.1 The Watershed Area A,

Watershed areas are the land and water areas that contributes to the runoff or an area that drains all the streams and rainfall to a common outlet.

3.2 Flow Length L

the overflow length of the watershed which is the distance measured along the main channel from the watershed outlet to the basin divide was gotten by using a measuring tape to get the total length along that channel.

3.3 Watershed Slope S

Watershed slop reflects the rate of change of elevation with respect to distance along the principal flow path.

Fig 1. Map of the Study Area
Source: www.google.com/map

The slop was measured using the following steps;

A. located the catchment area of interest using the topographic map
B. get the highest and the lowest elevation on the map
C. subtracted the elevation of the lowest contour from the highest contour
D. measured the distance from that topmost height to the lowest height of the catchment area
E. divided this height by the difference in elevation to get the slope of the catchment area.

4. RESULTS AND DISCUSSION

The data presented in Table 2 shows the values of the watershed parameters which were gotten from the 30 selected watersheds in Awka-South.

Where,

W_1,…, W_{30} : watershed 1 to watershed 30
Tc : Time of concentration

The data presented in Table 2 was employed to estimate the time of concentration of the selected watersheds using the 30 time of concentration models.

The result presented in Table 3 represents the time of concentration values which were estimated using the existing Tc models with the Awka-south watershed parameters. There were significant variations amongst the Tc values. These significant differences may be due to different contributing factors. Firstly, the input variables used for the development of these models are different; secondly, the empirical coefficients (constants or exponential coefficients) of the Tc models are different because each of them was calibrated for a specific region with their range of input parameters different from the values of other catchments. Therefore, due to these limitations, it is relatively not possible to get the same Tc values when calculating the time of concentration of a particular watershed area using a Tc model developed from a different watershed data.

Table 2. Summary of 30 selected watershed parameters in the study area

S/N	Length(M)	Average width (M)	Area(M^2)	%Slope	Measured Tcs(S)
W_1	573.10	5.0	91.62	3.41	188.11
W_2	1047.63	1.5	107950.04	5.16	343.86
W_3	564.80	2.8	58326.99	1.11	185.38
W_4	660.59	3.0	58298.32	6.90	216.67
W_5	547.48	0.5	68843.15	1.11	179.57
W_6	407.96	0.5	26584.99	5.16	133.81
W_7	109.30	2.2	97095.53	3.41	358.5
W_8	549.58	1.5	75250.33	3.41	180.26
W_9	1,011.37	2.0	171888.52	1.11	331.72
W_{10}	831.02	1.5	115171.99	0.00	272.57
W_{11}	671.02	1.2	100,880.49	6.91	220.08
W_{12}	1,067.06	4.0	125486.99	5.16	349.98
W_{13}	600.24	5.0	62770.29	5.16	196.87
W_{14}	295.87	3.0	28965.99	3.41	103.54
W_{15}	207.91	2.0	16930.45	8.38	727.58
W_{16}	319.03	1.0	28150.26	0.00	478.54
W_{17}	398.07	3.0	59102.94	6.90	139.32
W_{18}	542.67	2.5	103200.81	5.16	189.93
W_{19}	709.81	3.0	59,722.90	3.41	248.43
W_{20}	517.74	1.0	88145.33	3.41	181.20
W_{21}	329.72	2.8	53966.18	6.90	115.40
W_{22}	169.21	2.5	25,458.72	5.16	567.7
W_{23}	343.50	2.9	66103.96	3.41	120.22
W_{24}	1249.54	0.7	189060.40	6.90	437.33
W_{25}	933.00	2.0	144345.05	5.16	326.55
W_{26}	647.81	2.5	100,811.69	3.41	226.73
W_{27}	768.84	1.0	108,372.19	5.16	269.09
W_{28}	649.98	1.5	107,994.17	5.16	227.49
W_{29}	768.19	0.8	9,7,686.69	3.41	268.88
W_{30}	516.49	1.0	107,333.88	3.41	180.771

Table 3. Summary result of time of Concentration for the selected Watersheds

S/N	T_C 1	T_C 2	T_C 3	T_C 4	T_C 5	T_C 6	T_C 7	T_C 8	T_C 9	T_C 10	T_C 11
W1	3.75	0.1302	54.0	4.600	11.382	957.78	6.301	0.582	15.038	652.32	2.15
W_2	4.44	0.178	74.59	5.265	18.883	98371.21	8.119	0.327	22.551	3278.54	48.577
W_3	4.765	0.2005	83.757	6.449	6.413	37676.79	8.940	0.552	11.276	2025.04	35.63
W_4	3.3364	0.110	46.7	3.805	17.392	54307.20	5.507	6.416	19.256	1673.58	13.56
W_5	4.684	0.145	81.77	6.344	6.314	40812.23	8.764	0.267	11.102	15406.57	12.507
W_6	2.846	0.084	36.084	3.285	11.783	24438.11	4.440	0.206	14.073	1060.15	12.56
W_7	1.689	0.035	15.336	2.009	4.971	22428.23	2.182	0.412	6.567	1519.66	19.75
W_8	3.609	0.126	53.189	4.505	11.146	50314.38	6.131	0.350	14.717	2745.2	55.77
W_9	6.251	0.3178	131.908	8.630	8.582	101197.73	12.978	0.478	15.090	3554.71	48.20
W_{10}	5.840	∞	117.385	0	0	0	11.836	0.432	13.326	0	16.34
W_{11}	3.360	0.111	47.291	3.828	17.509	75920.32	5.560	0.283	19.415	1749.77	53.89
W_{12}	4.474	0.182	75.563	5.313	19.057	108746.08	8.215	0.494	22.759	3417.71	15.57
W_{13}	3.414	0.115	48.519	3.985	14.292	51206.05	5.680	0.542	17.748	1564.89	8.219
W_{14}	2.286	0.050	25.18	2.542	11.626	22198.45	3.288	0.416	12.982	996.59	7.08
W_{15}	2.074	0.050	21.442	2.345	8.412	12524.74	2.884	0.369	10.046	910.31	9.668
W_{16}	2.536	0.070	29.823	2.905	10.419	16065.86	3.793	0.275	12.444	1642.39	15.94
W_{17}	3.161	0.097	41.492	3.834	9.486	35988.81	4.990	0.469	12.533	1635.91	13.93
W_{18}	2.907	0.087	37.295	3.233	17.302	69860.97	4.563	0.373	18.323	2448.86	36.78
W_{19}	5.423	0	103.966	0	0	0	10.700	0.578	12.316	2308.43	14.35
W_{20}	2.973	0.0984	38.763	3.953	15.379	60068.79	4.712	0.262	17.048	2158.33	12.13
W_{21}	2.576	0.071	30.451	2.953	10.593	32793.24	3.874	0.452	12.651	1635.76	9.18
W_{22}	2.033	0.048	20.785	2.447	6.055	12803.18	2.809	0.434	2.241	734.63	16.75
W_{23}	2.893	0.087	37.039	3.561	8.812	35238.88	4.538	0.462	11.642	1496.84	24.7
W_{24}	4.502	0.1825	76.392	5.233	23.893	159512.52	8.282	0.226	26.467	4082.13	51.45
W_{25}	4.200	0.162	67.833	4.968	17.819	109124.41	7.532	0.369	21.282	5018.46	22.97
W_{26}	3.899	0.143	60.425	4.891	12.101	66001.73	6.815	0.435	15.989	3699.33	43.85
W_{27}	3.835	0.1394	58.708	4.510	16.176	82095.87	6.6161	0.275	19.319	4199.94	43.446
W_{28}	3.544	0.122	51.587	4.147	13.137	74102.88	5.977	0.327	17.761	3264.43	41.44
W_{29}	4.223	0.164	68.834	5.326	13.178	71678.17	7.597	0.269	17.411	4130.19	24.053
W_{30}	4.196	0.1199	50.705	4.367	10.805	59880.22	5.892	0.296	14.276	3247.32	21.753

S/N	**Tc 12**	**Tc 13**	**Tc 14**	**Tc 15**	**Tc 16**	**Tc 17**	**Tc 18**	**Tc 19**	**Tc 20**	**Tc 21**	**Tc 22**
W1	5476.44	4.063	4.494	0	156423.23	3.454	19.179	5761.12	985.11	2.637	5433
W_2	2004.78	5.295	17.778	315.69	461998.7	4.566	12.825	9632.97	2909.55	0.004	62.708
W_3	113380.71	5.840	25.648	607.33	234787.62	4.285	4.731	4891.29	609.34	0.005	66.263
W_4	104892.20	3.535	12.679	0	184317.5	3.266	9.32	12614.64	1098.68	0.004	50.374
W_5	77654.70	5.720	26.344	0	101709.7	4.206	4.623	3347.57	640.54	0.004	65.524
W_6	36.535.48	2.823	11.126	202.61	1011829.1	2.593	6.382	2154.28	641.29	0.005	44.655
W_7	46067.67	1.345	12.994	249.96	42880.01	1.277	5.628	567.31	270.04	0.005	29.919
W_8	59013.19	3.951	17.056	0	247903.6	3.368	18.594	1082.22	1561.23	0.003	53.512
W_9	304489.70	8.614	35.771	1252.47	460159.0	6.0782	14.125	10811.51	1194.24	0.003	81.726
W_{10}	147904.90	0	0	0	366765.16	0	0	6218.64	2309.80	0	0
W_{11}	116350.28	3.570	14.196	226.60	135439.7	3.296	2.694	4614.12	852.96	0.002	50.659
W_{12}	178815.05	5.360	18.391	2413.47	489547.6	4.616	13.001	8441.63	3083.02	0.002	63.124
W_{13}	101945.88	3.652	14.273	534.86	147709.7	63.268	8.493	4591.48	930.24	0.004	51.314
W_{14}	49842.28	2.068	9.379	0	72889.794	2.017	1.469	2070.09	499.04	0.004	37.725
W_{15}	21656.854	1.800	5.081	0	74025.76	1.730	3.876	1019.93	466.19	0.005	35.034
W_{16}	32036.269	2.396	10.714	141.37	132273.42	2.236	5.320	1576.06	833.02	0.004	40.872
W_{17}	111049.00	3.186	23.978	400.04	134089.52	2.775	14.646	2512.43	844.46	0.003	47.646
W_{18}	47179.93	2.907	12.775	173.16	244307.07	2.792	1.996	2511.67	1538.59	0.001	45.364
W_{19}	64704.42	0	0	0	0	0	0	5687.69	1925.27	0	0
W_{20}	26944.43	3.00	13.115	228.97	221132.46	2.822	2.226	1986.53	1501.73	0.002	46.144
W_{21}	60419.50	2.499	12.283	0	144654.48	2.563	5.452	2161.97	911.00	0.002	41.360
W_{22}	283571.86	1.751	19.762	90.065	41765.92	1.619	7.534	851.76	263.03	0.003	34.488
W_{23}	173755.69	2.888	15.128	0	101236.16	2.539	13.132	1961.48	637.56	0.002	45.183
W_{24}	283571.86	1.162	17.605	1201.38	611786.51	4.788	4.273	11611.69	3852.89	0.002	63.367
W_{25}	173755.69	4.901	18.412	1572.10	666435.99	4.259	11.771	7069.45	4197.06	0.003	60.146
W_{26}	111519.76	4.409	18.683	223.79	197004.77	3.717	2.000	4347.92	3219.21	0.003	56.775
W_{27}	10126.707	4.307	16.725	229.73	622989.64	3.791	10.200	4478.98	3923.45	0.003	56.098
W_{28}	101041.76	3.851	16.161	195.69	392955.37	3.427	9.008	3934.33	2474.74	0.002	52.807
W_{29}	84019.03	4.139	19.217	282.53	532412.66	4.117	23.823	4035.41	3353.01	0.003	60.367
W_{30}	149171.02	3.791	18.085	157.34	336613.60	2.986	17.759	4453.49	2119.91	0.002	52.329

S/N	**T_C 23**	**T_C 24**	**T_C 25**	**T_C 26**	**T_C 27**	**T_C 28**	**T_C 29**	**T_C 30**
W1	531.53	243.42	24.728	148.41	6.517	22.97	18.831	170.05
W_2	40414.85	27202.68	31.41	13991.31	8.005	27.09	27.523	506.39
W_3	22962.77	4558.99	34.434	4269.84	6.485	33.21	23.105	256.56
W_4	14396.21	720.33	21.804	3290.89	6.841	19.47	18.324	399.78
W_5	8591.89	26442.31	33.797	25651.43	6.416	32.67	22.565	256.79
W_6	7242.35	18142.79	17.837	9331.37	5.804	16.89	13.441	274.67
W_7	16810134.48	1712.05	9.150	1049.33	3.704	10.02	5.346	149.05
W_8	28548.43	11401.80	24.115	7021.82	6.425	22.49	18.241	325.78
W_9	521735.85	17610.18	48.842	17.081.88	7.909	44.45	35.974	382.48
W_{10}	39136.15	0.00	0	0	7.397	0	0	0
W_{11}	11,991.94	22780.29	22.010	10175.19	6.877	19.63	18.544	425.65
W_{12}	46292.08	11035.17	31.759	5659.17	8.056	27.29	27.911	518.78
W_{13}	12271.44	542.73	22.488	1964.01	6.621	20.84	18.026	363.01
W_{14}	6779.29	2435.52	13.466	1112.68	5.202	13.03	9.952	249.41
W_{15}	7489.70	1929.82	11.903	992.56	4.612	12.05	8.053	187.43
W_{16}	13424.55	7312.10	15.390	3733.05	5.337	14.95	10.732	244.28
W_{17}	15908.14	3765.27	19.872	513.71	5.756	19.15	14.277	270.65
W_{18}	58658.19	9215.25	18.312	3933.71	6.397	16.59	15.323	399.42
W_{19}	26041.13	0	0	0	7.010	0	0	0
W_{20}	28367.84	19863.09	18.839	8926.26	6.245	17.24	15.227	268.91
W_{21}	20081.25	3501.49	15.698	1796.80	5.397	15.19	11.433	265.05
W_{22}	5610.51	1552.75	11.596	104.87	4.238	12.21	7.216	158.82
W_{23}	76911.98	3515.06	18.189	2932.38	5.473	17.76	12.793	25424
W_{24}	64556.24	72875.05	31.962	43850.66	8.501	26.78	29.744	618.53
W_{25}	84962.23	20559.58	29.301	10496.36	7.695	25.56	25.203	491.99
W_{26}	72402.44	9104.02	26.615	5524.26	6.795	24.42	20.670	364.19
W_{27}	81,790.81	30206.51	26.088	15412.26	7.204	23.20	21.757	433.99
W_{28}	52939.63	17000.67	23.588	8681.45	6.803	21.33	19.149	398.86
W_{29}	63073.09	33314.79	29.480	15923.01	7.202	26.60	23.524	398.38
W_{30}	54212.72	18616.603	23.233	8028.73	6.289	22.23	17.404	327.22

Table 4. Summary of Rank Analysis of the performance of the models based on the degree of linear relationship with the Actual/observed time of Concentration of the study area

Models	Correlation coefficient (r)	Rank
TC12	0.681	1
TC14	0.661	2
TC21	0.433	3
TC15	0.394	4
TC26	0.34	5
TC24	0.337	6
TC19	0.267	7
TC6	0.227	8
TC5	0.195	9
TC11	0.165	10
TC16	0.147	11
TC20	0.099	12
TC29	0.092	13
TC2	0.048	14
TC3	0.044	15
TC27	0.027	16
TC17	0.025	17
TC7	0.018	18
TC25	0.009	19
TC10	-0.009	20
TC22	-0.041	21
TC28	-0.049	22
TC4	-0.051	23
TC1	-0.079	24
TC9	-0.097	25
TC18	-0.205	26
TC8	-0.228	27
TC23	-0.303	28
TC30	-0.384	29
TC13	-0.423	30

The result obtained in Table 4 represents Correlation Coefficient values for the Tc models. The performance of the models with regards to linear association showed that the model with the highest correlation coefficient was Ventura model (Tc_{12}) with correlation coefficient value of 0.681 , followed by the DNOS model (Tc_{14}) with correlation coefficient value of 0.661 while the least performing model was the Picking model (Tc_{13}) with -0.423 measure. The Ventura model was developed by Mata-Lima et al. [22] using data collected from the rural basin in California. However, the Tc_{27} due to having the lowest overall ranking may not result in a reasonable estimation. This may be because; the model depends on only one parameter which is the length.

5. CONCLUSION

This study compared the performance of some selected watershed model for estimating the time of concentration for a watershed situation in Anambra State. The findings of the study revealed the estimated time of concentration for the Ventura model has a better linear association than the other model considered in the present study. The findings are in line with the outcome of the study by [39] where the authors stated that among the analyzed methodologies in their study, the Pasini and Ventura are the models with a higher similarity with the Observed. The outcome of this study also generated serious questions on the application of any empirical formula in the environment different from the locations where these equations were derived. Based on the findings of the present study, the need for the verification and validation of any time of concentration model with the data from another environment before application in the estimation of time of concentration is strongly recommended until further studies prove otherwise. Also, the need for this to avoid underestimation or overestimation of the time of concentration for a better design of hydraulic structures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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