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Techniques to Compute Antecedent Moisture and Correlation of Effectiveness of Various Methods: A Review

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***Abstract*: The Hydrological cycle includes the continuous circulation of water in the earth's atmosphere. Water is an irreplaceable resource, and there is no substitute. Although it is generally considered typical, water is the most well-known substance. Because of its obvious importance, water is the best-studied material on earth. In this paper, a review precisely has been done about calculating the initial humidity condition, which occurs due to the essential step of the water cycle, i.e., runoff. Antecedent moisture conditions change continuously and can significantly affect the flow responses during wet weather. This paper provides details of the two best-known methods, SCS_CN and MS model, to derive the antecedent moisture equation using different parameters. The various performance criteria methods (RMSE, nRMSE, Standard error, Nash and Sutcliffe's efficiency) have been described in this manuscript, along with their applications and comparison in terms of calculating the antecedent moisture efficiency.**

***Keywords*: Hydrological cycle, Antecedent moisture, SCS-CN, MS model, RMSE, nRMSE, Standard error, Nash and Sutcliffe's efficiency**

1. Introduction

Water is an irreplaceable resource, and there is no substitute. Although it is generally considered typical, water is the most well-known substance. We wash, fish-swim, drink, and cook. We are made of two-thirds of water, and we need water to survive. Without water, lifeforms cannot develop & sustain. Because of its obvious importance, water is the best-studied material on earth. Water is misunderstood by people as well as by scientists working with it every day [1]. In developing countries, quite one billion individuals lack clean water. That could be a matter, after all, in industrialized countries Each day, between 14,000 and 30,000 people die from water-borne diseases, the majority of whom are young children and the elderly [2]. In expressing his current understanding of natural resources, Ismail Serageldin, the deputy governor of the World Bank, said: "Many wars in this century are related to oil, but the next century will be related to water." By Population growth and urban growth, global water consumption will increase. As long as the water cycle ensures a steady supply of freshwater, global population growth will drive water demand. The J-curve is expanding at a faster rate than it has ever done before. Well, almost 90 million people are born each year. Many people have trouble grasping the concept of today's global population of 5.8 billion. that the population was only 1.6 billion people at the dawn of the new millennium It was only about 100 years ago, when the world's population was about 250 million people, that the world's population began to recover. Today's population is 1.6 billion, less than a century ago. Later on, the earth will be home to another 4 billion people. It is expected that this exponential growth rate will not decline at any time. Developing countries accounted for 95% of population growth. How the water cycle keeps pace with the needs of the growing population [3].

A. Hydrological Cycle Flow

It also created many geographical features found on the earth, such as alpine ice caps, icebergs, rivers and valleys, lakes, etc. Therefore, it is essential to understand and study the water cycle or address it as a hydrological cycle. A never-ending cycle, but let's begin with the ocean, which contains approximately 96 percent of all water on the planet. The hydrological cycle is the process by which water circulates continuously throughout the earth's atmosphere. Several of the numerous processes involved in the water cycle are described below. The loop remains essentially the same, and its distribution in the various processes is constantly changing, as shown in Fig. 1.

1) Evaporation: This is the process by which water on the surface evaporates. Evaporation occurs when water absorbs the heat of the sun and converts to steam. Oceans, lakes, and rivers are the primary sources of evaporation. Moisture enters the atmosphere through the hydrosphere, and as it evaporates, it cools the surrounding bodies.

2) Condensation: When water evaporates, it enters the atmosphere as water vapour. At high altitudes, due to the low temperature, water vapour condenses into extremely small ice particles. This is referred to as condensation. These nanoparticles congregate in the sky to form larger particles and fog.

3) Sublimation: Sublimation, like evaporation, contributes to the creation of water vapours in the air. Sublimation is the process through which ice immediately changes to water

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vapour without passing through liquid water. Whenever the temperature or pressure are too low or too high, this performance is displayed in real time. The ice sheets at the Northern and Southern Hemispheres, as well as the ice caps atop mountain ranges, are the principal source of sublimated water. It requires slightly more time than evaporation.

4) Precipitation: Precipitation is the consequence of liquid water condensing within the atmosphere that falls thanks to the gravity of a cloud. Precipitation embrace in the form of drizzle, rain, sleet, snow, ice balls, gravel, and hail. Precipitation occurs when part of the atmosphere is saturated. So that the water condenses and "falls down" or falls off.

5) Transpiration: As crystals are formed, some of the water is absorbed by plant as well as soil. This water has been used in the process of transpiration. Transpiration converts water from its liquid state to vapor. The tree roots soak up the fluid water and prompt it toward the leaf; excess water is extracted from the leaves via pores as evaporation wherever it is used for photosynthesis. As a result, water to enter the area and exits as evaporated water.

6) Infiltration: Some falling water does not flow into the river but is absorbed or evaporated by plants. Water went deep underground, which is known as penetration. Water is flowing in and replenishes the groundwater table with drinkable water. Infiltration is evaluated in inches of water per hour soaked into the soil.

7) Runoff: When water flows out (in any form), it causes drainage. Runoff is the manner in which water runs across the earth's surface. Snow is melting through into water, resulting in runoff. The topsoil is washed away and minerals are carried along with the water flow. These runoffs are connected to canals and rivers and flow into lakes, oceans, and oceans. This is where water enters the hydrosphere [4].

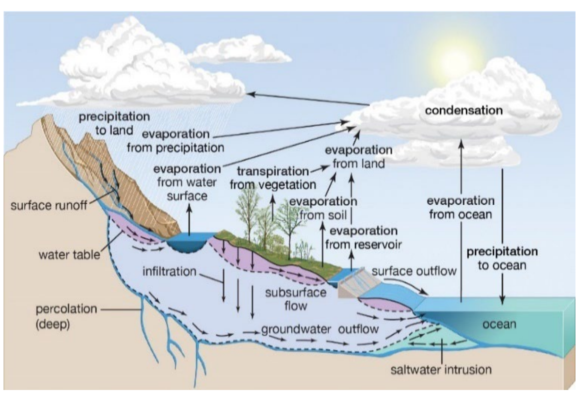

Fig. 1. Example of a hydrological cycle

Antecedent moisture: The term antecedent essentially implies that "preceding circumstances," By combining the terms "antecedent" and "moisture," "preceding humidity situations" are meant. Antecedent wet is the constant shift in the comparative wetness or xerotes of a sewer system, which can have a significant impact on the output responses in these systems during wet weather. If antecedent moisture levels are severe, it indicates that significant precipitation has occurred recently, as well as that the soil is saturated. When there was little rainfall, and the soil became dry, the previous humidity conditions were low. Antecedent moisture conditions are important for modeling and analysis challenges in the field of hydrology.

2. Existing Models

A. SCS-CN Method

The SCS-CN methodology was designed in 1954 and is highlighted in the NEH-4's section four. SCS-CN is among perhaps one of the most most often utilised techniques in NEH-4 for computing direct surface runoff for a specific rainfall [5], [6]. The SCS-CN approach is composed of the water equation given and two fundamental hypotheses, denoted as:

$$\frac{Q}{P - I_a} = \frac{F}{S} \tag{1}$$

$$P = I_a + F + Q \tag{2}$$

$$I_a = \lambda S \tag{3}$$

The total precipitation is represented by P, the initial abstraction is indicated by Ia, the accumulated infiltration is defined by F, the direct surface runoff is given by Q, the maximum potential retention is stated by S, and the initial abstraction coefficient is written by Ia. Incorporating Equations.1 and 2 yields SCS-CN approach's prevalent form [7]:

$$Q = \frac{(P - I_a)^2}{P - I_a + S}, \qquad for\ P > I_a \tag{4}$$

Watersheds that are gauged and those that are not gauged, $\lambda = 0.2$, and S is represented as:

$$S = \frac{25400}{CN} - 254 \tag{5}$$

where S signifies millimetres and CN represents the curve variety determined by ashore use, hydrologic soil type, hydrologic condition, and preceding wetness condition.[8]

B. MS model

By applying the C Equaled Sr idea, in which C represents the runoff constant and Sr specifies the saturation degree [7] As follows, Eq. (1) is changed for M :

$$\frac{Q}{P - I_a} = \frac{F + M}{S + M} \tag{6}$$

By Putting Eq. (6) in Eq. (2) leads to:

$$Q = \frac{(P - I_a)(P - I_a + M)}{P - I_a + M + S} \tag{7}$$

$$M = \frac{S_1(P_5 - \lambda S_1)}{P_5 + (1-\lambda)S_1} \quad (8)$$

Here, M is denoted for antecedent moisture in (mm), I_a corresponds to equation (3), P_5 represents the precipitation in the previous 5 days, and S_1 represents the maximum possible retention under drought conditions. Therefore, Equations 3, 7, and 8 comprise the MS model. The infiltration water volume (F) during the last 5 rainy days (P_5) before the soil is completely dry is assumed to be the beginning of rainfall. Approximately equal to the maximum absolute limit potential (S_0):

$$S_1 = S_0 = S + M \quad (9)$$

It is worth mentioning that for optimal retention potential, S_0 is not a completely dry state but is entirely reliant on the pond's properties. Equation 5, 8 can be used to derive the corresponding CN_0 by using $S = S_0$ $or\ M = 0$. Give a quadratic formula with roots that are effective:

$$M = 0.5\left[-(1+\lambda)S + \sqrt{(1-\lambda)^2S^2 + 4P_5S}\right] \quad (10)$$

Eq. 10 calculates the quantity of water that P_5 rainfall adds to the dry soil profile. As a result, the MS model's modified effective method of equations 3, 7, and 10 [7].

3. Performance Criterion

A. The Levenberg-Marquardt Algorithm

The LM of restricted least – square is used to optimise the characteristics pertaining to all approaches. Levenberg pioneered non-linear optimization, and the Marquardt algorithm presented a more elegant and refined execution of that concept. With this method, you can smoothly transition between the steepest descent and the Inverse-Hessian method's two ends. In reality, where the latter is employed when the trial solution exceeds the bare minimum, and when the bare minimum is approached, it tends to revert to the former. This method is sometimes referred to as the Marquardt method, and it has been demonstrated to be practical, serving as the de facto industry standard for non-linear least squares procedures [9]. Nonlinear least squares problems are solved using the LM method. The gradient descent and gauss-newton methods are combined in this curve-fitting approach. Iterative algorithms, such as gradient descent and gauss-newton, use a sequence of calculations to arrive at a solution. It varies from the gradient descent in that the solution is updated by selecting values that reduce the function value in each iteration. For comparative evaluation of model performance, there are several methods used here RMSE, nRMSE, Standard error, Nash and Sutcliffe's efficiency (E), respectively. RMSE Calculating the root-mean-square error is one technique to determine how often a regression model works a dataset. This is a metric that indicates the typical gap between the model's expected values and the dataset's actual values. The RMSE is proportional to the model's efficiency, and vice versa. A root mean square error of zero suggests an outstanding result. The ubiquitous use of RMSE work samples in various publications is [10], [11] etc. It is an irrational amount. It is a low value of zero, with a greater degree of accord on the verge of 0. However, it will be expressed as a percentage by multiplication it by 100. Clearly, nRMSE provides the root mean square error for the mean rain runoff depth/unit [12], [13] and numerous others have made use of this criterion. to compare method. The SE worth is proportional to the model's performance, or vice versa. A SE worth of zero indicates an optimal match. The advantage of the SE is that it uses the identical units to the variable and caters for the degree of freedom adequately in linear models [14]. Many others incorporated the SE criterion into their research. The efficiency of Nash and Sutcliffe, where E is less than or equal to 1.A value of 1.0 shows complete agreement between the observed value & calculated value, while a reduced value indicates poor agreement [15]. E may be negative, indicating that the model's forecast is less accurate than the average measurement [16].

1) $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Q_{obs} - Q_{comp}\right)_i^2}$

2) $nRMSE = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(Q_{obs} - Q_{comp}\right)_i^2}}{\overline{Q_{obs}}}$

3) $SE = \sqrt{\frac{1}{N-m+1}\sum_{i=1}^{N}\left(Q_{obs} - Q_{comp}\right)_i^2}$

4) $E = \left[1 - \frac{\sum_{i=1}^{N}(Q_{obs} - Q_{comp})_i^2}{\sum_{i=1}^{N}(Q_{obs} - \overline{Q_{obs}})_i^2}\right]$

where Q_{obs} is the measured storm runoff in millimetres, Q_{comp} is the computed outflow in millimetres, and), $\overline{Q_{obs}}$ is mean observed storm runoff millimetres, N is shown by total number of rainfall-runoff occurrences, and 1 is an integer between 1 and N.

t-Test: For analysing the two group mean in the form of statistical analysis that is called a t-test. Models based on average RMSE values were compared for comparison. When the average difference was positive, the former model was superior to it, and vice versa.

Correlation coefficient: The Pearson 's product - moment coefficient of correlation, alternately referred to as Pearson's correlation coefficient or simply the coefficient of correlation, is the most frequently used measure of the relationship between two quantities. Correlation coefficients indicate how closely two variables change statistically in reference to one another. The numbers range from 0 to 1. Measurement errors are denoted by numbers with decimal places less than or equal to one. -1.0 means there's no association, whereas 1.00 means there is one, which means there is no difference between the two! There is no correlation between the two variables if the correlation is set to 0.0. It is common to see the correlation coefficient employed in a wide range of fields of study. Karl

Table 1
Comparison and summary report

S. No.	Authors	Performance criterion	Advantage	Disadvantage	Application
1	[10]	RMSE	Because it is differentiable, the solution is simple to estimate or compute. It is symmetric and quadratic, making it appropriate for Gaussian noise & Considered as a measure of the agreement between calculated and observed runoff levels. Minimizing RMSE, in general, finds an estimate for the conditional expected value of the next observation (to be forecast) given the explanatory factors (the past in time series).	———	The larger the root mean square error, the less accurate the model is, and vice versa. In meteorology, see how successfully the behaviour of the atmosphere is predicted by a mathematical model.
2	[12]	nRMSE	It's a quantity without dimensions. The value is a minimum of 0.0, with a better accord at 0. nRMSE offers the RMSE per unit average depth for storm runoff.	———	When the nRMSE is larger, the less efficient the model is and vice versa
3	[14]	Standard error (SE)	A SE value equal to null is perfectly suitable. SE unit is millimetres. The advantages of SE are that they have the same units as the variable and correctly reflect the sense of flexibility of the model. It's applicable to both linear and nonlinear modelling.	E=0 indicates that proposed model does not forecast anything superior to arithmetic mean of observational data. E can be negative, showing that the forecast of the model is poorer than the average observation.	When SE is higher, model performance is less effective and vice versa.
4	[18],[19]	Nash and Sutcliffe's efficiency (E)	The NSE compares the difference between errors and observations. The NSE spans from − to 1.0, with the optimum value being NSE = 1.	The NSE is also unable to detect partiality and sensitive to high levels. The NSE is more adaptable to changes in the simulated means and observed differences than the determination coefficient, making it a versatile improvement, which is frequently employed in the assessment of the fitness of the hydrological and hydroclimatic models.	If the observed average is equal to the model's, the value is zero; if, the observed average is better than the model's.
5	[11]	t-Test	The arithmetic mean is independent and generally normally distributed. compare groups that have a comparable amount of the variance.	Data is normally distributed.t-test might not have reliability.	the first model was worse than the second, and vice versa if RMSE had a positive mean discrepancy.
6	[17]	Correlation coefficient	Simply because two variables are linked doesn't mean they are jointly responsible. Calculating and analysing the correlation coefficient is straightforward.	As a result, it can only track changes in one direction: from one variable to the next. A nonlinear relationship will yield an inaccurate result.	A metric for evaluating the strength and direction of a linear relationship.

Pearson derived the correlation coefficient from Francis Galton's 1880s notion, which Auguste Bravais derived and published in 1844 as a mathematical formula. While R stands for Pearson's correlation coefficient, R2 is the square root of R.

The below equation shows the correlation coefficient formula.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

- r = The Correlation coefficient
- n = number in the given dataset
- x = first variable in the context
- y = second variable

While correlation and regression are distinct approaches, they are not exclusive. A regression model uses only the data from the study to make predictions, but a correlation model looks for the strength of a link. There are cases where the x variable is a random covariate of the y variable rather than a fixed or readily selected by the experimenter [17].

Deviation of runoff Volume: Variance in the volume of runoff. As far as goodness-of-fit criteria go, Dv may be the most straightforward. In 1986, the World Meteorological Organization (WMO) reported on runoff volume deviations. Runoff volume deviation is zero in a perfect model. The better the model performs, the smaller the runoff volume variance is. Increasing the amount of accuracy criterion for Dv does not need using distinct formulas for different years or seasons rather than an average of several years or seasons.

Index of agreement: To standardise the degree of model prediction inaccuracy, Willmott (1981) developed an agreement index (d) ranging from 0 to 1. The index of agreement measures the degree of agreement between two groups. Whereas a number of 1 signifies absolute agreement, zero implies complete disagreement. The index of agreement may detect discrepancies in observed and simulated means and variances that are additive and proportional, but d is extremely sensitive to extreme values because of the squared differences between the observed and simulated values.

4. Conclusion

In this paper, a thorough review of many literature papers combined and formed a report in which many vital topics were addressed as per hydrology concerns. It is focused on the origin of water correlated with the hydrological cycle and its important processes described for an overall understanding of a bigger picture of the importance of water in upcoming decades and how it is underestimated. Runoff is one of the critical processes of the hydrological cycle. Several factors affect runoff directly or indirectly among all the elements, and antecedent moisture is an essential factor. The preceding moisture in a watershed determines how wet or dry it is. It's important to remember that during rainy weather, antecedent moisture conditions can drastically alter flow pattern. Most hydrological systems, such as rainwater and intake and infiltrate sanitation, are influenced. Many problems of modeling and analysis can be overcome with antecedent moisture. The amount of soil humidity is a factor that affects the time until the soil is saturated. This outflow is referred to as overland saturation flow. After precipitation, the soil retains a degree of humidity. Constraint-based least squares has been used to solve the optimization problem of each technique. Non-linear optimization was first introduced by Levenberg, and the Marquardt algorithm gave a refined and enhanced variation of that approach. With this method, you can smoothly transition between the steepest descent and the Inverse-Hessian method's two ends. It is possible to use the LM algorithm to solve models that have numerous free parameters.

This moisture content influences the soil's ability for Infiltration. For the computation of the performance criteria of antecedent moisture, several approaches and methods have been used. Comparing these efficient techniques provided in Table 1 demonstrates the comparison of aspects of names, advantages, disadvantages, and application to forecast any given model efficiency concerning their respective values. In this study, we found that RMSE, nRMSE, & SE are directly proportional, or we can say it shows the same behaviour with larger the value lesser is the efficiency performance vice versa. When Nash and Sutcliffe's efficiency is zero, the observed average matches the model's performance exactly, whereas negative values demonstrate that the observed average outperforms the model's performance. However, if the RMSE difference was positive, the T-test showed that the first model performed worse than it did, and vice versa. Ongoing research focuses on creating a combination of objective functions that is more precise and balanced, with good balance and closure over multi objective spaces, and then we can say a simple and fast or far more accurate technique of calculating the prior moisture efficiency.

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