Journal of Experimental Agriculture International

Volume 45, Issue 10, Page 355-366, 2023; Article no.JEAI.107653
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Rainfall Versus Water Balance Components Using R Software: A Case Study on a Micro-watershed in the Mid-lands of Kerala

A. P. Bowlekar [a++*], K. K. Sathian [a#] and Vaisakh Venu [b†]

[a] Department of Soil and Water Conservation Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala Agricultural University, Kerala, India.
[b] Department of Basic Engineering and Applied Sciences, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala Agricultural University, Kerala, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2023/v45i102228

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc. are available here: https://www.sdiarticle5.com/review-history/107653

Original Research Article

Received: 06/08/2023
Accepted: 13/10/2023
Published: 19/10/2023

ABSTRACT

Quantitative information on an area's water balance components is essential to plan water management activities. In most cases, these water balance components, viz. rainfall, runoff, soil moisture, groundwater storage, and evapotranspiration, will be missing, especially in the developing world. At the same time, most countries have rainfall data in a reasonably acceptable spatial resolution. Hence, if a relationship between rainfall and other water balance components can be developed, then using these relations, the values of those water balance components can

[++] *Ph.D. Research Scholar;*
[#] *Professor and Head;*
[†] *Assistant Professor;*
**Corresponding author: E-mail: adwaitbowlekar1808@gmail.com;*

be determined. Hence, a study has been taken up in which important water balance components, viz. rainfall, runoff, soil moisture, the height of groundwater table from MSL, and evapotranspiration, are measured from a watershed, and the relationship between rainfall and other components have been determined through regression analysis. R software was used to determine relationships between rainfall and other water balance components. The Pearson’s correlation coefficient (r) between rainfall vs. runoff was 0.83, rainfall vs. soil moisture was 0.80, rainfall vs. the height of GW table from MSL was 0.72, and rainfall vs. evapotranspiration was -0.64, which indicates a good correlation in the majority of the cases. The relationship between rainfall vs. runoff, rainfall vs. soil moisture, rainfall vs. the height of the GW table, and rainfall vs. evapotranspiration was a polynomial equation with degrees 4, 3, 5, and 3, respectively. The study concludes that it is possible to estimate most other water balance components using the regression estimates by measuring the rainfall. These relationships can be used effectively in water management programs.

Keywords: R software; rainfall; relationship; ungauged watershed; water balance.

1. INTRODUCTION

Quantitative information on water balance components of a river basin or a sub-basin is essential for formulating effective water management plans to resolve water-related issues. From the water management perspective, the most crucial water balance components are rainfall, runoff, soil moisture, groundwater storage, and evapotranspiration (ET). Unfortunately, this information will be missing in most of the developing worlds as most of the river basins or their sub-basins will be ungauged, and none of these hydrologic data will be available. At the same time, as a blessing, rainfall data will be available in some cases, as most of the countries have a network of raingauge stations. Further, gridded rainfall data is available, which has been developed through interpolation of the measured data. Even if rainfall data is unavailable, it is easy to establish a raingauge station to start recording it [1,2,3]. On the other hand, information on all other hydrologic water balance components will be altogether missing. To resolve this issue, if simple statistical relationships can be developed between rainfall and other water balance components, it can go a long way in solving water-related problems faced in many parts of the world [4,5,6].

Hence, this study has been conducted to build statistical regression equations between the easily measurable hydrologic parameter rainfall and other parameters, viz., runoff, soil moisture, groundwater and ET, which are otherwise difficult to measure. Once these relationships are developed, they can be used to predict unknown water balance parameters, and the same can go as an input in many water management decisions. A short description of water balance components considered in this study are described below.

Runoff is the portion of precipitation that flows over the land surface and eventually reaches rivers, streams, and other water bodies. The relationship between rainfall and runoff is positively correlated. When rainfall intensity exceeds the soil’s infiltration capacity or the land's ability to retain water, excess water becomes runoff. Runoff is essential in assessing flooding risks and water availability [7,8,9]. Evapotranspiration is the combined process of water vapour being released into the atmosphere through evaporation from soil and water surfaces, as well as transpiration from plants. The interactive relation between rainfall and evapotranspiration is crucial for determining water availability and the water deficit in a region. If rainfall exceeds evapotranspiration, the surplus water can contribute to runoff and groundwater recharge. Conversely, if evapotranspiration exceeds rainfall, it can lead to a water deficit. Rainfall affects soil moisture content, influencing various water balance components. Adequate soil moisture is necessary for plant growth and maintaining the water balance within the ecosystem. Excessive rainfall can saturate the soil, increasing runoff and reducing infiltration [10,11,12].

Groundwater recharge occurs when water from precipitation percolates through the soil and reaches the groundwater table. The relation between rainfall and groundwater recharge is evident in regions with permeable soils and suitable hydrogeological conditions. Higher rainfall usually leads to increased groundwater recharge, which is essential for sustaining groundwater levels. The change in storage of water bodies, such as lakes, reservoirs, and wetlands, is influenced by the difference between inflows (primarily from rainfall and runoff) and outflows (evaporation, groundwater discharge, and human withdrawals). Rainfall contributes directly to the inflow component of storage change [13,14,15].

Understanding the relationships between rainfall and water balance components is crucial for water resources management, flood prediction, agricultural planning, and ecosystem sustainability. Changes in rainfall patterns due to climate change can significantly impact these relationships and a region's overall water balance [16,17,18,19]. Hence, a study to establish a relationship between easily measurable water balance components and others would be worthy. Considering the above points, the present study was conducted on an ungauged micro-watershed from the midlands of Kerala to determine the relationships between rainfall and other water balance components using R software.

2. MATERIALS AND METHODS

2.1 Study Area

The Perassannur micro-watershed is located in the Malappuram district of Kerala, between 10°50' and 10°58' N latitude and 76°2' and 76°7'

E longitude (Fig. 1). The area and perimeter of the basin are 79.66 km^2 and 56.60 km, respectively. The average annual rainfall in this area is 2582.16 mm, and the average temperature is 27.38°C, with an annual mean relative humidity of 77%, with a site having a mean wind velocity of 2.16 $km.hr^{-1}$. The region's climate is humid tropical, and it experiences high humidity during the monsoon months from June to October. The main streams play an essential role in the socio-economic development of society by providing water for domestic agriculture and other activities.

2.2 Data Acquisition

The Perassannur watershed was ungauged, and hence, the water balance components were determined by installing various instruments for measuring rainfall, runoff, soil moisture storage, and groundwater storage for 17 months from August 2021 to December 2022. There were four rain gauges for recording rainfall, a gauging station for recording runoff, soil moisture sensors for recording soil moisture, and a water table sensor for recording groundwater table.

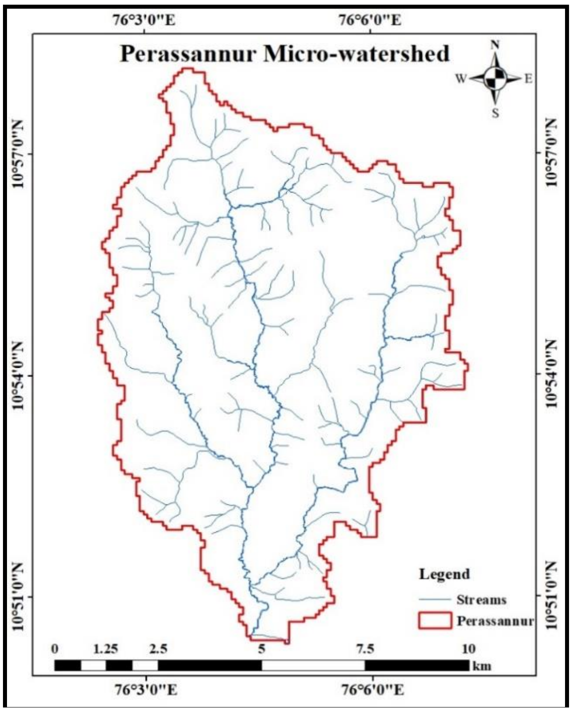

Fig. 1. Perassannur micro-watershed with drainage network

2.3 R Software

R software is an Integrated Development Environment (IDE) for the R programming language, which is widely used for statistical computing, data analysis, and data visualization. It provides a user-friendly interface that helps researchers, data scientists, and analysts work efficiently with R. It is an efficient statistical tool for conducting regression analysis in the R programming language. It provides an interactive and flexible environment for each step of the regression analysis process, from data import to model evaluation. Regression analysis can be efficiently performed by combining R's statistical capabilities with R software's user-friendly interface [19,20,21,22].

2.4 Steps Involved in Regression Analysis in R Software

The steps involved in performing regression analysis include inputting, exploring and pre-processing data, choosing the regression model, fitting a regression model, assessing the fitted model, interpreting results, checking assumptions, making predictions, visualization of results, and reporting and documentation. The procedure involved is shown in a flow diagram in Fig. 2.

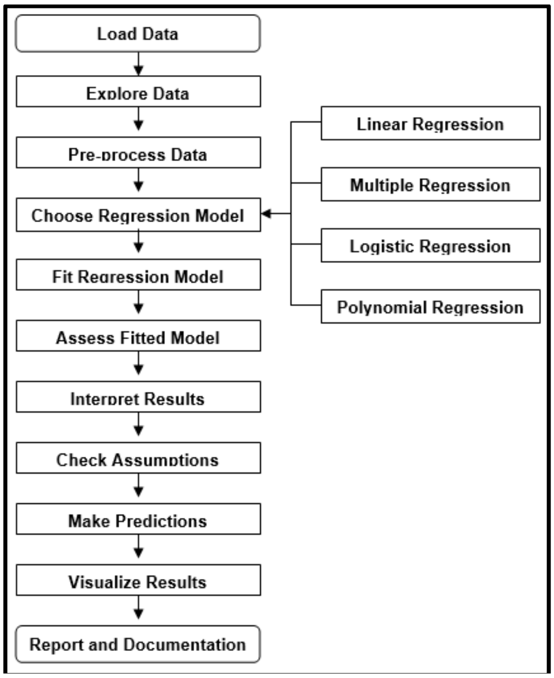

Fig. 2. Steps followed for regression analysis in R Software

First, the data is imported into R Software from various file formats such as CSV, Excel, or databases. The data is then explored using multiple tools to understand the distribution and relationships among variables. Then, the data is pre-processed, which involves handling missing values, transforming variables, or dealing with outliers. The regression model is then chosen to decide the type of regression model to be fitted. The results are then interpreted using the P value to understand the relationships between the independent and dependent variables.

It is to be ensured that the regression assumptions are met, including assumptions about linearity, independence of errors, constant variance, and normality of residuals. After that, the predictions are made to predict unknown data. The results are then visualized using various packages for creating plots to visualize the relationships between variables, the model fit, and the residuals. Finally, the reporting and documentation are done using R markdown, which involves creating a document that includes the code, explanations, visualizations, and results in a single file.

2.5 Relation between Rainfall and Water Balance Components

The following are the statistical parameters for determining the relations between various water balance components.

2.5.1 Pearson's correlation coefficient

Pearson's correlation measures the strength of the linear relationship between two variables. It has a value between -1 and +1, with a value of -1 meaning a total negative linear correlation, 0 being no correlation, and +1 indicating an absolute positive correlation. The Pearson's correlation coefficient is given by Eq. 1.

$$r = \frac{\sum_{i=1}^{n}\left[(O_i - \bar{O}) * (P_i - \bar{P})\right]}{\sqrt{\left[\sum_{i=1}^{n}(O_i - \bar{O})^2 * \sum_{i=1}^{n}(P_i - \bar{P})^2\right]}} \quad \text{..................(1)}$$

Where,
i is the counter for individual observed and predicted values
n is the number of observations
Oi is the observed values
$\bar{O}$ is the mean of observed values
Pi is the predicted values
$\bar{P}$ is the mean of predicted values

R software determined the Pearson's correlation coefficient between all the measured water balance components for monthly and weekly time scales. This statistical test was used to find the strength of the linear relationship between the water balance components, i.e. rainfall, runoff, soil moisture, the height of groundwater, and evapotranspiration.

2.5.2 Regression model

Regression analysis is a powerful technique for uncovering the associations between variables observed in data, but it cannot easily indicate causation. In statistical modelling, regression analysis is a set of statistical processes for estimating the relationships between a dependent variable and one or more independent variables.

This study developed a regression model after testing the relationship for linear, polynomial, exponential, logarithmic, and power functions in the R software. The model was selected based on the coefficient of determination (R^2), shown in Eq. 2, and the p-value obtained from R software.

$$R^2 = \left\{ \frac{\sum_{i=1}^{n}\left[(O_i - \bar{O}) * (P_i - \bar{P})\right]}{\sqrt{\left[\sum_{i=1}^{n}\left(O_i - \bar{O}\right)^2 * \sum_{i=1}^{n}(P_i - \bar{P})^2\right]}} \right\}^2 \quad \text{……….(2)}$$

The regression plot was made with a 95 % confidence interval, and the mathematical equation was determined.

2.5.3 Residual vs. fitted plot

Residual vs. fitted plots were used to assess whether the chosen model was appropriate for the data. This plot also helps to identify outliers, which are data points that significantly deviate from the expected behaviour of the model. A residual plot has the residual values on the vertical axis and the independent variable on the horizontal axis. A "residuals versus fitted plot" is frequently created when conducting a residual analysis. It is a scatter plot of residuals on the y-axis and fitted values (estimated responses) on the x-axis. The plot is used to detect non-linearity, unequal error variances, and outliers. The residuals are calculated from Eq. 3.

$$e_i = y_i - \bar{y}_i \quad \text{…………………………………….(3)}$$

Where,

i is the counter for individual observed and predicted values
e_i is the residual
y_i is the predicted value
$\bar{Y}_i$ is the observed value

2.5.4 Normal Q-Q (Quantile-Quantile) plot

The study utilized a standard Q-Q plot to check whether the dataset followed a normal distribution and whether the chosen model was appropriate and reliable. The normal Q-Q plot is handy in graphically analyzing and comparing two probability distributions by plotting their quantiles against each other. If the two distributions are exactly equal, then the points on the Q-Q plot will perfectly lie in a straight line.

The Normal Q-Q plot allows the selection of the points that do not fall close to the reference line. The points on the Normal Q-Q plot indicate the univariate normality of the dataset. If the data is normally distributed, the points will fall on the 45-degree reference line. On the other hand, the points will deviate from the reference line if the data is non-normally distributed.

3. RESULTS AND DISCUSSION

3.1 Water Balance Components

The results of monthly water balance components from August 2021 to December 2022 for the Perassannur watershed are shown in Table 1. The table contains measured rainfall, runoff, soil moisture, water table height, and estimated ET values. It was observed that the highest rainfall was recorded during October 2021, followed by July 2022. The similar trends were also reflected in the monthly runoff. The height of the GW table above MSL was also the maximum during these months. The result indicates enough excess water in the watershed, as the significant runoff reveals. However, during the January and February months of 2022, there was no rainfall at all. However, some flow in the stream flow could be attributed to the base flow and delayed lateral flow contribution. The runoff drastically reduces in March and April of 2022, reaching a trickling state. Baseflow indicates that detention storage occurs as soil moisture and groundwater storage. The evapotranspiration was highest during March, followed by April, possibly due to the high temperatures during these months. The lowest ET was in August 2022, followed by November 2021, for which the air temperature was low with high humidity.

3.2 Relationships between Rainfall and Water Balance Components

3.2.1 Pearson's correlation coefficient (r)

Fig. 3 shows the Pearson's correlation coefficient (r) between the monthly rainfall and other water balance components for the Perassannur watershed. It was observed that the 'r' between rainfall vs. runoff was 0.83, rainfall vs. soil moisture was 0.80, rainfall vs. the height of the GW table was 0.72, and rainfall vs. evapotranspiration was -0.64. The values close to +1 indicate an excellent positive linear correlation, and those close to -1 show strong negative linear correlation. The values close to ±0.6 indicate satisfactory correlation results.

Pearson's correlation coefficient was also observed as 0.76 between runoff and soil moisture, 0.89 between runoff and height of GW table, and -0.76 between runoff and ET. The 'r' value between soil moisture and height of the GW table was 0.76, and between soil moisture and ET was -0.85. Also, the 'r' value between the height of the GW table and ET was -0.86. This indicates that ET negatively correlates with other water balance components. The result is expected as ET takes place at the expense of other water balance components. The values of 'r' between monthly rainfall vs. runoff and rainfall vs. soil moisture show an excellent correlation; rainfall vs. depth to the GW table also indicates a good correlation. The results are also reasonable, as water received from rainfall contributes to runoff, soil moisture and groundwater storage.

Table 1. Water balance components of the Perassannur Watershed

Month	Rainfall (mm)	Runoff (mm)	Soil Moisture (%)	Height of Groundwater Table from MSL (m)	Evapotranspiration (mm)
Aug-21	356.63	220.47	29.98	44.99	65.36
Sep-21	309.62	233.27	29.78	44.98	71.90
Oct-21	529.08	412.22	31.21	45.63	69.95
Nov-21	279.18	230.00	30.52	45.18	58.51
Dec-21	12.05	129.18	25.74	44.58	85.32
Jan-22	0.00	70.28	19.95	44.39	102.55
Feb-22	0.00	25.27	17.63	44.26	101.99
Mar-22	35.96	4.70	19.36	43.88	127.17
Apr-22	68.67	1.57	22.84	43.48	113.74
May-22	342.89	77.29	26.90	44.18	97.23
Jun-22	392.19	141.76	28.55	44.81	76.11
Jul-22	502.62	391.95	29.85	45.95	60.38
Aug-22	351.32	352.78	28.31	45.11	54.68
Sep-22	180.54	182.20	27.25	44.93	83.57
Oct-22	114.69	108.94	26.12	44.91	82.19
Nov-22	59.58	60.83	26.81	44.74	69.73
Dec-22	135.40	77.04	26.93	44.72	72.40

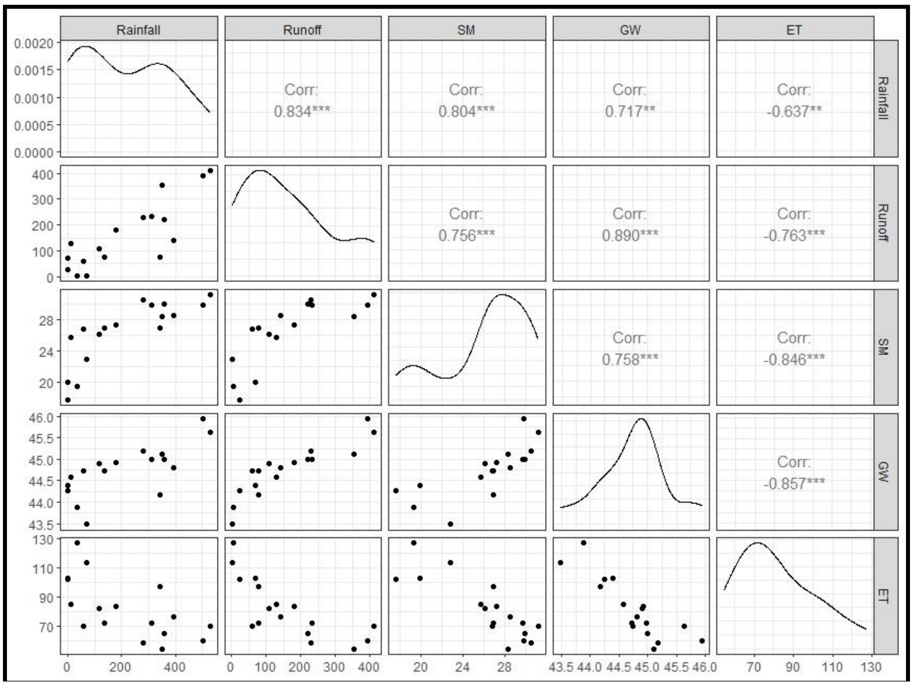

Fig. 3. Pearson's Correlation Coefficient for Perassannur Watershed

3.2.2 Regression model

A polynomial non-linear regression model was developed between monthly rainfall vs. runoff (Fig. 4). The curved line shows the fitted model, which is a non-linear polynomial equation of degree 4, as shown by Eq. 4. The band represents the 95% confidence interval for this regression model. The monthly rainfall and runoff relationship for the Perassannur watershed had R^2 of 0.78 and a P value of 0.001, having an F-statistic of 10.64 on 4 and 12 degrees of freedom. It is seen that most of the points are falling within this 95% confidence band.

$$121.55\,x^4 + 34.01\,x^3 + 85.13\,x^2 + 434.60\,x + 159.99 = 0 \quad \text{.................................. ....(4)}$$

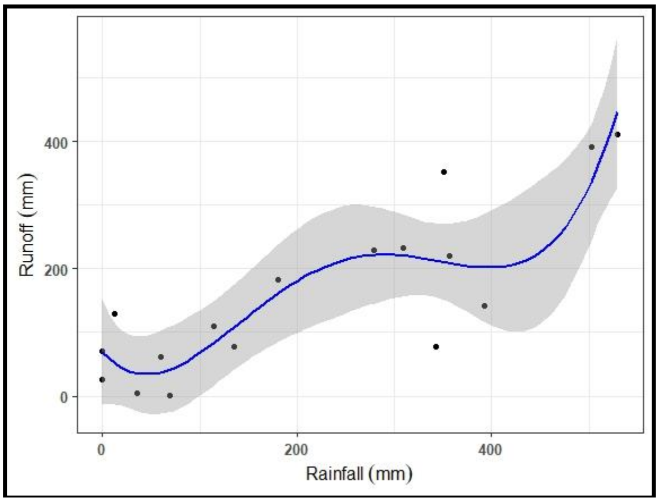

Fig. 4. Relation between monthly rainfall and runoff

The monthly relationship between rainfall and soil moisture for the Perassannur watershed is given by Eq. 5, which is a polynomial equation of degree 3, with R^2 of 0.77 and a P value of 0.001, having an F-statistic of 14.99 on 3 and 13 degrees of freedom. Fig. 5 represents the fitted non-linear regression model between rainfall and soil moisture. Here, the curve represents the fitted model, and the band represents the 95% confidence interval. Most points fall within a 95% confidence interval, meaning the model fits well.

$$3.49\,x^3 - 4.72\,x^2 + 13.14\,x + 26.34 = 0 \quad \text{............ ..(5)}$$

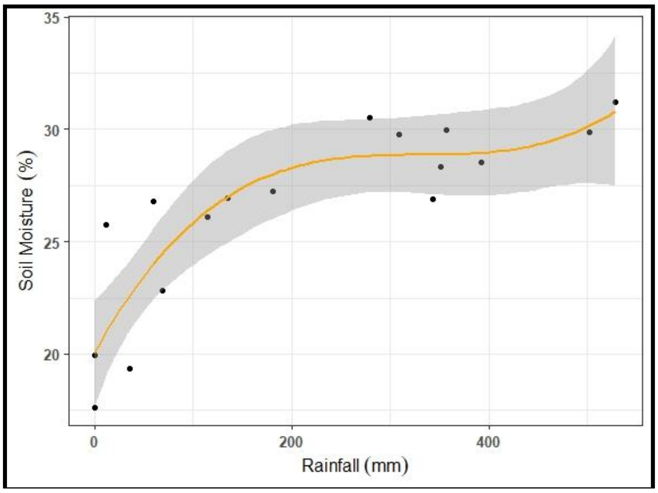

Fig. 5. Relation between monthly rainfall and soil moisture

The monthly relationship between rainfall and height of GW table from MSL for the Perassannur watershed is given by Eq. 6, with R^2 of 0.69 and P value of 0.01, having an F-statistic of 4.84 on 5 and 11 degrees of freedom. The equation is a non-linear polynomial equation of degree 5, fitted with a smooth line. The 95% confidence interval is shown with the grey band in Fig. 6. The line shows drastic curves since the rainfall needs some time to percolate and become groundwater.

$$-0.69\,x^5 + 0.52\,x^4 + 0.40\,x^3 + 0.32\,x^2 + 1.73\,x + 44.75 = 0 \quad \ldots. \quad (6)$$

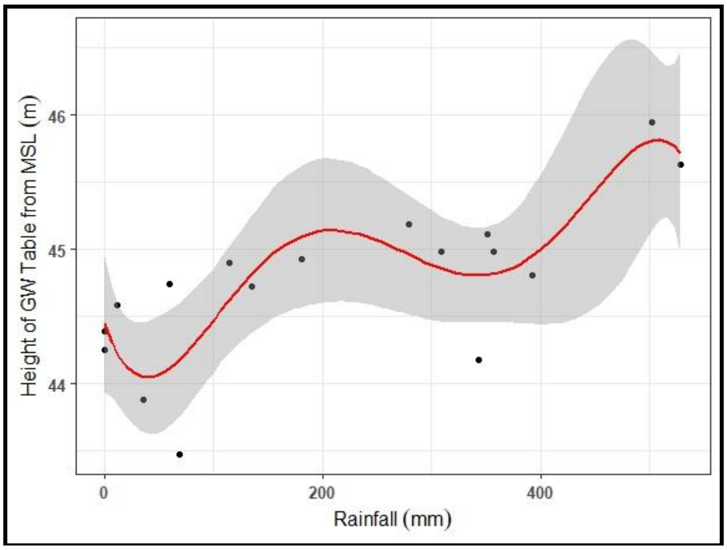

Fig. 6. Relation between monthly rainfall and height of GW table from MSL

The polynomial non-linear regression model developed between monthly rainfall and evapotranspiration is shown in Fig. 7. The relation between them is given by Eq. 7, with R^2 of 0.45 and a P value of 0.04, having an F-statistic of 3.62 on 3, and 13 degrees of freedom. It is seen that evapotranspiration increases with rainfall, which is related to the region's temperature.

$$-4.93\,x^3 + 17.57\,x^2 - 52.06 + 81.93 = 0 \quad \ldots\ldots.(7)$$

Thus, the polynomial regression analysis appeared better and represented a non-linear relationship between rainfall and other water balance components, meaning a curved best-fit line.

3.2.3 Residual vs. fitted plot

Fig. 8 to Fig. 11 show the residual vs. fitted plot between rainfall vs. runoff, rainfall vs. soil moisture, rainfall vs. the height of the GW table, and rainfall vs. evapotranspiration for the

Perassannur watershed. The x-axis indicates the monthly water balance components, and the y-axis indicates the residuals. All these figures show that the fitted line is not a straight line passing through zero residual, indicating non-linearity between the plotted variables.

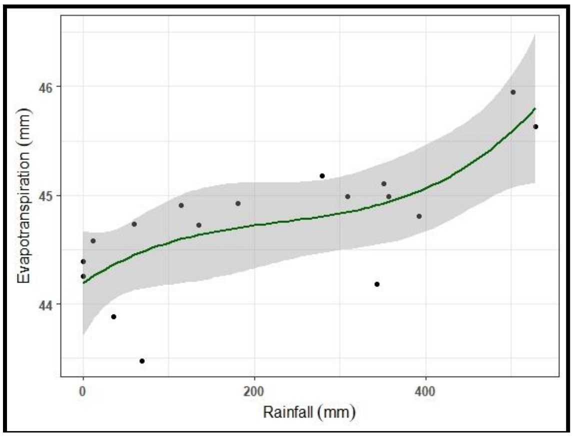

Fig. 7. Relation between monthly rainfall and evapotranspiration

In Fig. 8, the fitted points are scattered around zero along the x-axis, which means there is no discernible pattern or trend in the residuals, which implies a good model. Thus, the selected model is appropriate for determining the relationship between rainfall and runoff. But, if we see Fig. 9, the plot slightly deviates from the centre. However, the deviation between them is less than ±2% for soil moisture, which states that the selected regression model is good. Similarly, in Fig. 10, there is a slight deviation in the plot from the centre, which is less than 0.2 m for the height of the GW table; hence, the selected model is acceptable. Also, in Fig. 11, the deviation of the plot from the centre is less than 5 mm for rainfall vs. evapotranspiration, which signifies that the selected model was appropriate.

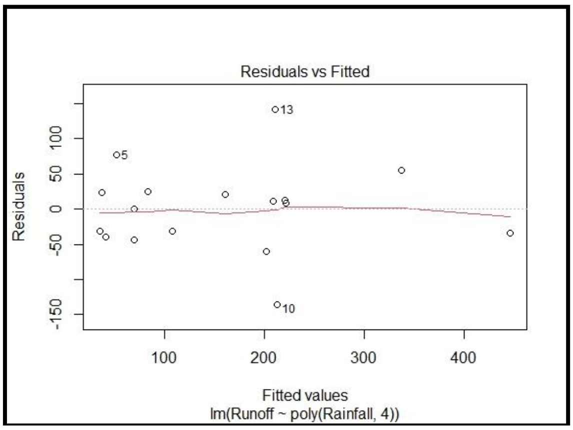

Fig. 8. The residual vs. fitted plot between rainfall and runoff

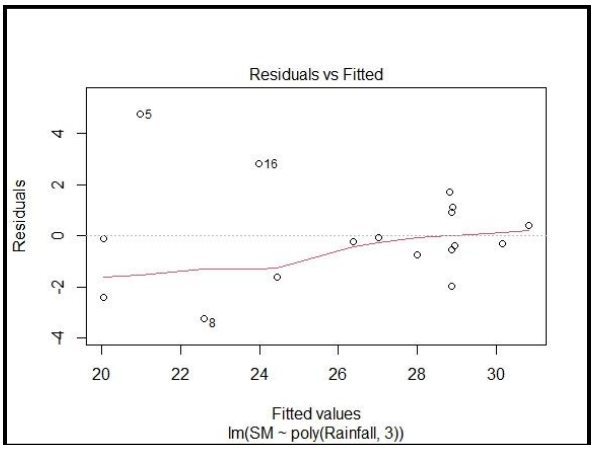

Fig. 9. The residual vs. fitted plot between rainfall and soil moisture

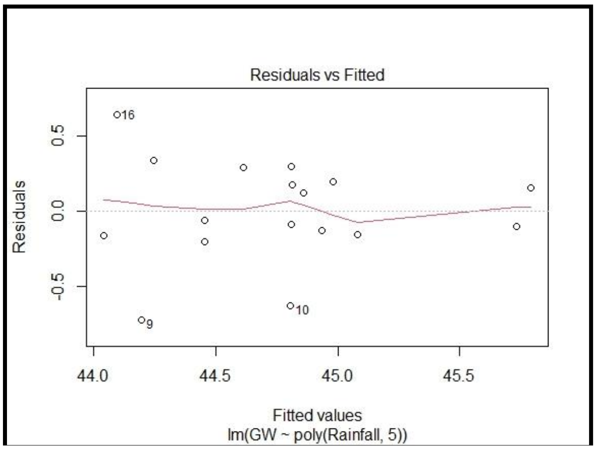

Fig. 10. The residual vs. fitted plot between rainfall and depth to GW table

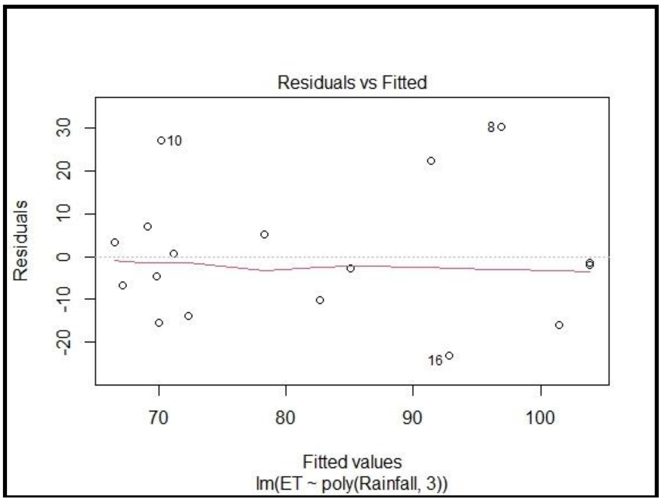

Fig. 11. The residual vs. fitted plot between rainfall and evapotranspiration

3.2.4 Normal Q-Q plot

Fig. 12 to 15 show the Normal Q-Q plot between rainfall vs. runoff, rainfall vs. soil moisture, rainfall vs. the height of the GW table, and rainfall vs. evapotranspiration for the Perassannur watershed. The x-axis indicates the theoretical quantities of the water balance component, and the y-axis shows the standardised residuals.

Fig. 12 shows that the data points align with a straight line, which indicates a good agreement with the quantiles of a theoretical normal distribution. The tail (without considering the outliers) shows minimal deviation from the straight line, indicating that the dataset's tails are reasonably consistent with a normal distribution.

The central portion of the plot shows data points closely following a normal distribution pattern. The outlier suggests that extreme values in the dataset deviate significantly from a normal distribution. Fig. 13 indicates that the curve moves upward away from the straight line at the ends, suggesting that the data has heavier tails than a normal distribution.

Fig. 14 shows that the points are positioned away from the straight line, suggesting slight skewness in the data. However, these points are close to the straight line. From Fig. 15, it is seen that the points curve shifts downward away from the straight line at the ends, and it suggests that the data has lighter tails than a normal distribution.

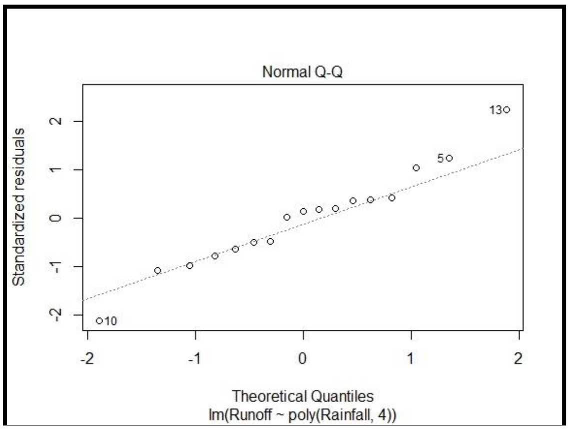

Fig. 12. The normal Q-Q plot between rainfall and runoff

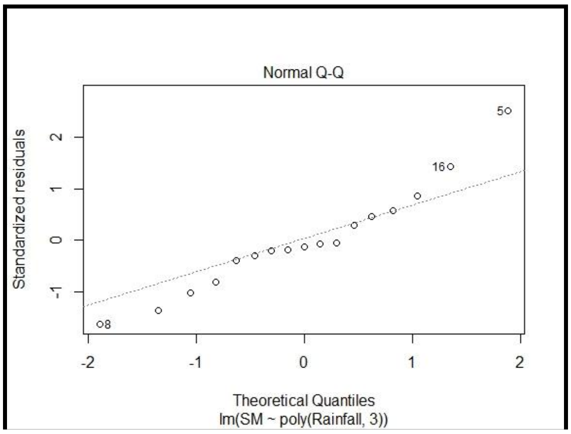

Fig. 13. The normal Q-Q plot between rainfall and soil moisture

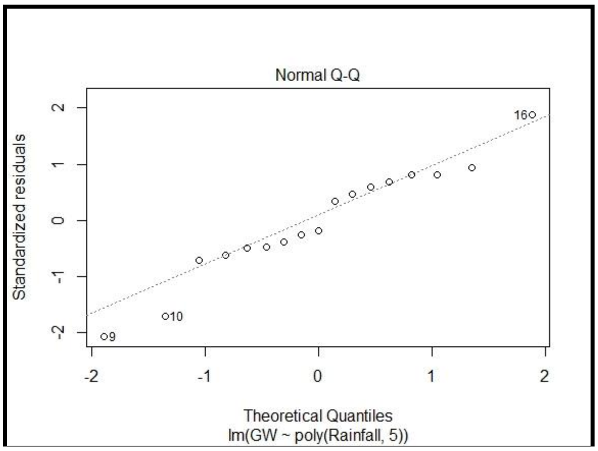

Fig. 14. The normal Q-Q Plot between rainfall and depth to GW table

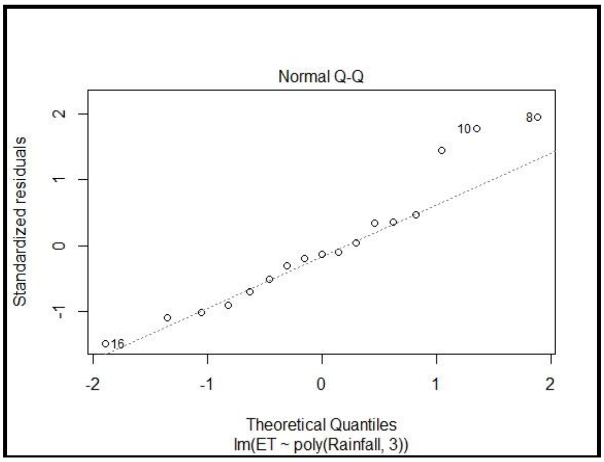

Fig. 15. The normal Q-Q plot between rainfall and evapotranspiration

4. CONCLUSION

The study was to determine the water balance components of a micro watershed and develop a relationship between easily measurable rainfall and other water balance components. All the hydrological processes in the watershed were measured by installing an appropriate instrumental set-up, as the watershed was an ungauged basin. Relationships between rainfall and other water balance components were developed with the help of R software. It was found that good correlations existed between rainfall and other water balance components, with the ‘r’ value ranging between 0.70 and 0.83. The maximum correlation was seen between rainfall and runoff, followed by rainfall and soil moisture. The importance of the study lies in the fact that by measuring the rainfall, it is possible to estimate most of the other water balance components using regression estimates, which otherwise are very difficult to measure or predict through simulation studies. The professionals and planners can utilize these relationships to plan water management scientifically.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Biddoccu M, Ferraris S, Cavallo E, Opsi F, Previati M, Canone D. Hillslope Vineyard Rainfall-Runoff Measurements in Relation to Soil Infiltration and Water Content. Proc Environ Sci. 2013;19:351-360.
2. Krishnan G, Kumar KS, Rejani R. Application of SWAT model for estimating runoff of Nethravathi River basin using sequential uncertainty fitting technique. Int J Sci Res. 2018;9(3):893-902.
3. Zheng H, Nie X, Liu Z, Mo M, Song Y. Identifying optimal ridge practices under different rainfall types on runoff and soil

loss from sloping farmland in a humid subtropical region of Southern China. Agric Water Manag. 2021;255:1-11.

4. Song JH, Her Y, Suh K, Kang MS, Kim H. Regionalization of a rainfall-runoff model: Limitations and potentials. Water. 2019; 11(11):2257.
5. Gonzalez-Alvarez A, Molina-Perez J, Meza-Zuniga B, Viloria-Marimon OM, Tesfagiorgis K, Mouthon-Bello JA. Assessing the performance of different time of concentration equations in urban ungauged watersheds: Case study of Cartagena de Indias, Colombia. Hydrol. 2020;7(3):47.
6. Karki N, Shakya NM, Pandey VP, Devkota LP, Pradhan AM, Lamichhane S. Comparative performance of regionalization methods for model parameterization in ungauged Himalayan watersheds. J Hydrol: Regional Stud. 2023;47:101359.
7. Eini MR, Javadi S, Delavar M, Gassman PW, Jarihani B. Development of alternative SWAT-based models for simulating water budget components and streamflow for a karstic-influenced watershed. Catena. 2020;195.
8. Liu Z, Yao Z, Wang R, Yu G. Estimation of the Qinghai-Tibetan Plateau runoff and its contribution to large Asian rivers. Sci Total Environ. 2020;749.
9. Kumar A, Kanga S, Taloor AJ, Singh SK, Durin B. Surface Runoff Estimation of Sind River Basin using Integrated SCS-CN and GIS Techniques. Hydro Res. 2021;4:61–74.
10. Li Q, Luo Z, Zhong B, Zhou H. An improved approach for evapotranspiration estimation using water balance equation: case study of Yangtze River Basin. Water. 2018;10(6):812.
11. Tan M, Zheng L. Increase in economic efficiency of water use caused by crop structure adjustment in arid areas. J Environ Manag. 2019;230:386-391.
12. Wang Z, Wu Y, Cao Q, Shen Y, Zhang B. Modeling the coupling processes of evapotranspiration and soil water balance in agroforestry systems. Agric Water Manag. 2021;250.
13. Touhami I, Chirino E, Andreu JM, Sánchez JR, Moutahir H, Bellot J. Assessment of climate change impacts on soil water balance and aquifer recharge in a semiarid region in south east Spain. J Hydrol. 2015; 527:619-29.
14. Zhang Y, He B, Guo L, Liu J, Xie X. The relative contributions of precipitation, evapotranspiration, and runoff to terrestrial water storage changes across 168 river basins. J Hydrol. 2019;579..
15. Nasiri S, Ansari H, Ziaei AN. Simulation of water balance equation components using SWAT model in Samalqan Watershed (Iran). Arabian J Geosci. 2020; 13: 1-51.
16. Verma S, Mishra SK, Verma RK. Improved Runoff Curve Numbers for a Large Number of Watersheds of the USA. Hydrol Sci. 2020a;65(16):2658-2668.
17. Verma S, Singh PK, Mishra SK, Singh VP, Singh V, Singh A. Activation Soil Moisture Accounting (ASMA) for Runoff Estimation using Soil Conservation Service Curve Number (SCS-CN) Method. J Hydrol. 2020b;589:1-26.
18. Lian H, Yen H, Huang C, Feng Q, Qin L, Bashir MA, et al. CN-China: Revised runoff curve number by using rainfall runoff events data in China. Water Res. 2020; 177:1-10.
19. Chambers JM. Software for data analysis: Programming with R. New York: Springer; 2008.
20. Matloff N. The art of R programming: A tour of statistical software design. No Starch Press; 2011.
21. Noguchi K, Gel YR, Brunner E, Konietschke F. nparLD: an R software package for the nonparametric analysis of longitudinal data in factorial experiments; 2012.
22. Abdulla F, Al-Shurafat AW. Rainfall-runoff modeling for semi-arid and trans-boundary Yarmouk River Basin. Proc Manuf. 2020; 44:180-188.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/107653