Trend Analysis of Various Hydrometeorological Parameters of Magat River Basin and Reservoir in Isabela, Philippines

Melanie A. Baguio
College of Engineering, Isabela State University

Roger A. Luyun, Jr
College of Engineering and Agro-Industrial Technology, University of the Philippines

https://doi.org/10.5109/7395557

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.466-471, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Trend Analysis of Various Hydrometeorological Parameters of Magat River Basin and Reservoir in Isabela, Philippines

Melanie A. Baguio[1,2] and Roger A. Luyun, Jr.[2]
[1]College of Engineering, Isabela State University – Echague Campus, Echague, Isabela 3309 Philippines, [2]College of Engineering and Agro-Industrial Technology, University of the Philippines – Los Baños, Laguna 4030 Philippines
Corresponding Author Email: melanie.aquino@isu.edu.ph

Abstract: *The objective of this study is to determine the trend of rainfall observed from the three stations within the Magat River Basin and the trends of inflow, outflow, and water level for the Magat Reservoir situated in Ramon, Isabela, Philippines. The MK-test and Sen's Slope estimator were employed to determine a trend in a data series obtained from 1991 to 2023. The results reveal that annual or seasonal trends in inflow, outflow, or water level are not statistically significant which suggest a dominance of interannual variability. However, significant monthly trends were detected such as an increasing inflow in March and increasing outflows in February and June. Among the three rainfall stations, only Dumayup exhibited a statistically significant increasing trend. These findings underscore the variability of rainfall and reservoir behavior which could be driven by climate variability and operational adjustments. This study also accentuates the importance of trend analysis to develop sustainable and adaptive water resource management strategies for the Magat Reservoir.*

Keywords: Hydrometeorological Variables; Magat River Basin and Reservoir; Mann-Kendall Test; Sen's Slope Estimator; Trend Analysis

1. INTRODUCTION

The global hydrological cycles are affected by climate resulting in higher occurrence of extreme weather events and changes to rainfall patterns [1,2,3]. These changes affect the management of water resource such as in areas that depend on reservoirs for water and flood control [4]. The key to understand the possible impacts of climate change on water supply, flooding, and reservoir management, is to examine the historic trends of the hydrometeorological parameters [1]. Such analyses are essential to be able to develop adaptive management strategies for long-term sustainability of water resources [5] for the provision of water for irrigation, domestic and commercial use [6]. An example is the study conducted in the Pampanga River Basin in the Philippines [7] which explored the rapid hydrological response to intense tropical cyclones over time and the implications of extreme intensity rainfall in terms of reservoir management.

Trend analysis techniques have been used to study the behavior of hydrometeorological variables in various regions [1,8,9]. The most commonly used statistical methods in detecting and measuring trends in time series data are the Mann-Kendall test and Sen's slope estimator [8,10,11]. These methods can be used to analyze rainfall trends [12,13], river discharge patterns, and reservoir water levels, which are useful to water resources planning and management [14,15,16]. In addition, the relationship between rainfall and reservoir behavior is vital to predict the water that can be conveyed in the future and to optimize reservoir operations [17,18,19].

The Magat watershed and reservoir covers portions of Ifugao, Nueva Vizcaya, and Isabela provinces [20]. The dam is located in Isabela province and serves as an essential element of the water resource infrastructure in the region. The reservoir, on the other hand, serves several functions, including irrigation, flood management, and hydropower production. Recognizing the long-term patterns of hydrometeorological factors related to the reservoir enhances the water resources management, flood mitigation strategies, and the sustainability of reservoir operations.

This study examines the trends of essential hydrometeorological parameters in the Magat River Basin and Reservoir over a 30-year span from 1992 to 2022. The main focus is to analyze the patterns of precipitation in the river basin, along with the inflow, outflow, and water levels of the reservoir. The outcomes will offer essential perceptions into the long-term dynamics of the Magat Reservoir system and aid in formulating sustainable water management strategies. This will also aid mitigating climate change-induced challenges by enhancing the long-term sustainability of this vital water resource.

2. MATERIALS AND METHODS

2.1 Description of the Study Area and Data

The Magat Watershed and Reservoir (Fig. 1), spanning the provinces of Nueva Vizcaya, Ifugao and Isabela in the Philippines, is a critical resource for the region. The watershed spans approximately 4,150 square kilometers and is a vital tributary of the Cagayan River Basin [1,21,22]. The Magat Dam is a rock-fill dam that impounds the Magat River. The dam is constructed between 1975 and 1982 and serves multiple purposes which includes irrigation, flood control, and hydroelectric power generation [20]. The reservoir created by the dam has a surface area of about 11.7 square kilometers and a maximum water depth of 193 meters. This reservoir supplies water for agricultural activities, particularly for irrigating approximately 85,000 hectares of farmland in the region [15,22,23]. The Magat watershed is characterized by diverse topography and land use, including forested areas, agricultural lands, and settlements. This diversity makes it an ideal study area for analyzing various hydrometeorological parameters, such as rainfall, inflow, outflow and reservoir water levels [1,15,21].

This research utilized a 33-year dataset covering the period from 1991 to 2023 obtained from the National Irrigation Administration. This dataset includes rainfall (Fig. 2) data collected from various rain gauge stations situated within the Magat River Basin, specifically Halong, Dumayup and Magat rain gauges. This extensive dataset will enable a detailed analysis of hydrometeorological trends and patterns, including the inflow, outflow and water level in the Magat reservoir (Fig. 3).

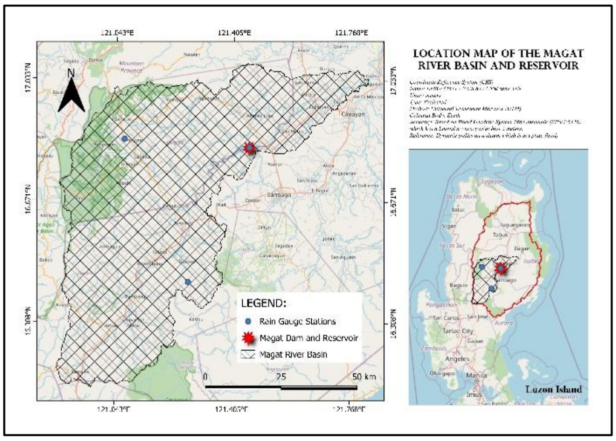

Fig. 1. Map showing the location of the study area.

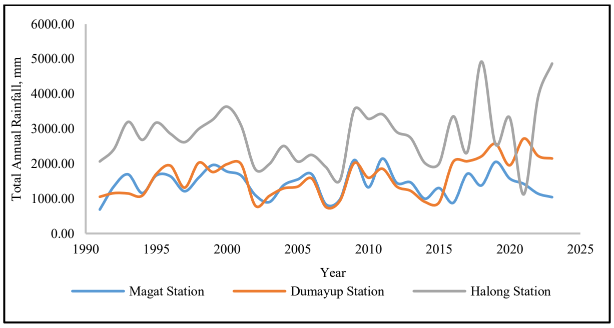

Fig. 2. Total annual rainfall data obtained from Halong, Dumayup and Magat rain gauge stations.

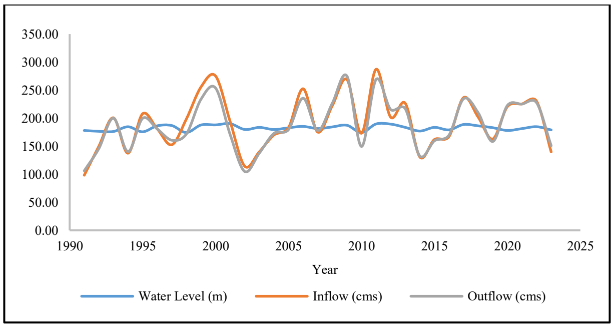

Fig. 3. Annual data on water level, inflow and outflow at the Magat Reservoir.

2.2 Statistical Analyses

The two statistical tests, as presented in the next sections, were utilized in analyzing the trend of the hydrometeorological variables at Magat River Basin and Reservoir.

2.2.1 Mann-Kendall Test

This test is a non-parametric statistical method, employed to identify monotonic trends in the hydrometeorological parameters of the Magat River Basin and Reservoir. This test is particularly suitable for non-normally distributed data and is robust against the influence of outliers [27]. It detects the presence and magnitude of a monotonic trend within a time series, without imposing assumptions regarding the linearity of said trend [28]. The test statistic, S, is calculated as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_i - x_j)$$

Where x_i and x_j represent the data values at times i and j, respectively, and n is the length of the time series [29]. The function sgn (x) is defined as

$$sgn(x) = \begin{cases} +1, if\ x_i - x_j > 0 \\ 0, if\ x_i - x_j = 0 \\ -1, if\ x_i - x_j < 0 \end{cases}$$

The variance of S, Var(S) is calculated as,

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m} t_k(t_k - 1)(2t_k + 5)}{18}$$

Where n represents the data points number in the sample, m denotes the quantity of tied groups (sets of observations sharing identical value) and t_k specifies the count of data points in the k^{th} tied group. When the sample size (n) is exceeds 10, the standard normal test statistic Z_s is calculated accordingly to assess the significance of trends in the dataset.

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & for\ S > 0 \\ 0 & for\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & for\ S < 0 \end{cases}$$

When the value of Z_s is positive, then the trend is increasing, while negative Z_s value indicates a decreasing trend. A presence of monotonic trend in a series of data indicates acceptance of the alternative hypothesis and rejects the null hypothesis. To determine if the calculated Z_s are significant, they will be compared to a Z-value obtained from the standard normal distribution with significance levels of $\alpha = 0.01$ and $\alpha = 0.5$. If the absolute value of the calculated Z-score exceeds the critical Z-value of 1.96 and 2.576 at 5% and 1% level of significance, then rejects null hypothesis. This indicates a presence of a significant trend.

2.2.2 Sen's Slope Estimator

Sen's Slope estimator is used to estimate the slope of a trend in time series data. The method outlined in the study of Gocic and Trajkovic [30] was employed, which is defined as [31],

$$Q_t = \frac{x_i - x_j}{i - j}\ for\ t = 1, \dots, N$$

where x_i and x_j are the values of data at i[th] and k[th] (i>j) times, respectively. The value for N can be obtained using this equation, $N = \frac{n(n-1)}{2}$, for 1 datum in each time period and $N < \frac{n(n-1)}{2}$, for multiple observations in one or more time periods, where n indicates the number of time periods and total number of observations, respectively. The N values of Q_i were ranked from smallest to largest, then the Sen's slope is computed as follows,

$$Q_{med} = \begin{cases} Q_{[\frac{N+1}{2}]}, if\ N\ is\ odd \\ \dfrac{Q_{[\frac{n}{2}]} + Q_{[\frac{N+2}{2}]}}{2}, if\ N\ is\ even \end{cases}$$

A confidence interval for the slope was also determined to assess the significance of the trend. The equation below is used to determine the confidence interval,

$$C_\alpha = Z_{1-\alpha/2}\sqrt{Var(S)}$$

where Var(S) is the standard error for the Mann-Kendall test and $Z_{1-\alpha/2}$ is taken from the standard normal distribution table. The level of significance at 5% was employed in this test. After computing the confidence interval, the result is used to determine the lower and upper limits of the confidence interval as follows,

$$M_1 = \frac{N-C_\alpha}{2} \text{ and } M_2 = \frac{N+C_\alpha}{2}$$

where M_1[th] largest and (M_2+1)[th] largest of the N ordered slope estimates are the lower and upper limits, respectively [32]. When the two limits have the same sign, then the Sen's Slope is statistically different than zero. This approach is widely used in environmental and climate studies, as well as in economics and hydrology, where detecting subtle trends in data is crucial for informed decision-making.

3. RESULTS AND DISCUSSION

3.1 Trends in Hydrometeorological Variables

3.1.1 Hydrological Variables

Tables 1, and 2-4 show the result of the MK-test and Sen's Slope estimator for the hydrological variables (reservoir water level, inflow and outflow) for annual, seasonal and monthly basis, respectively. It can be noted that both annual and seasonal analysis revealed a non-significant result using MK-test, which can be infer that the series has no significant trend or variability on the hydrological variables. This may suggest that short-term variability dominates over long-term directional change which is consistent with the findings of Kahya & Kalayci [34] that such parameters are influenced by interannual climate variability in tropical basins. The positive or negative signs of the values denote an increasing or decreasing trend of the series, respectively. For the annual basis and dry season, the water level, inflow and outflow have increasing trend. While for wet season, water level and outflow are both increasing, and the inflow has decreasing trend. This can be attributed to the decreasing amount of rainfall that affects the amount of inflow to the reservoir.

For the monthly basis as depicted in Fig. 4, no significant trend is recorded for the reservoir's water level as well as for inflow and outflow data, except for the month of March for inflow with 5% level of significance, and months of February and June for outflow data with 1% and 5% level of significance, respectively. It can also be noted that most of the decreasing trends are observed in the later months of the year, while most of the increasing trends were obtained during the early months. This is notable for the trend of the water level, where the increasing trends are persistent from February to August, and the decreasing trends are notable from September to January. On the other hand, the trend for the outflow from the reservoir are mostly increasing, specifically from the months of April to September, having significant trends where the Sen's Slope estimator, further revealed that the significant values have increasing trends. The magnitude of increase in the outflow for the month of February is 1.19cms and 2.44cms for the month of June, while for the inflow is 1.89cms for the month of March. Furthermore, the confidence interval at 95% level validates a significant rise in reservoir releases for the month of June, and a significant increasing inflow during March. These significant increases in monthly inflow and outflows during March, and February and June, respectively, can be linked to a changing or varying operational management or rainfall events during these months. Also, the significant increase in the outflows during February and June could be attributed to the increased in irrigation releases during the vegetative stage of rice production in the service area of Magat Reservoir.

Table 1. Trend analysis of the different hydrological variables (water level, inflow and outflow).

	Water Level	Inflow	Outflow
Annual Basis	0.42^{ns}	1.26^{ns}	1.38^{ns}
Seasonal Basis			
Dry Season	0.74^{ns}	0.96^{ns}	1.36^{ns}
Wet Season	0.46^{ns}	-0.46^{ns}	0.65^{ns}
Monthly Basis			
January	-0.31^{ns}	1.95^{ns}	1.86^{ns}
February	0.12^{ns}	1.46^{ns}	2.63^{**}
March	0.93^{ns}	2.53^{*}	-0.48^{ns}
April	1.67^{ns}	1.30^{ns}	1.84^{ns}
May	1.39^{ns}	0.62^{ns}	0.79^{ns}
June	1.33^{ns}	1.29^{ns}	2.18^{*}
July	0.22^{ns}	-0.40^{ns}	0.59^{ns}
August	0.56^{ns}	-0.34^{ns}	0.99^{ns}
September	-0.43^{ns}	-0.68^{ns}	0.22^{ns}
October	-1.83^{ns}	-0.25^{ns}	-0.09^{ns}
November	-1.89^{ns}	0.40^{ns}	0.22^{ns}
December	-1.58^{ns}	-0.09^{ns}	-0.23^{ns}

Zvalue: 5% = 1.96; 1% = 2.58

ns = not significant, * = significant at 5%, ** = significant at 1%

Table 2. Sen's slope and the lower and upper limit of the reservoir water level.

	Sen's Slope	95% Confidence Interval	
	Water Level	Lower	Upper
Annual Basis	0.05	-0.16	0.26
Seasonal Basis			
Dry Season	0.06	-0.13	0.30
Wet Season	0.05	-0.16	0.31
Monthly Basis			
January	-0.01	-0.12	0.11
February	0.02	-0.30	0.30
March	0.20	-0.27	0.51

April	0.35	-0.04	0.83
May	0.30	-0.11	0.80
June	0.20	-0.11	0.55
July	0.03	-0.25	0.42
August	0.08	-0.23	0.35
September	-0.02	-0.21	0.09
October	-0.09	-0.17	0.01
November	-0.05	-0.12	0.002
December	-0.08	-0.21	0.01

Table 3. Sen's slope and the lower and upper limit of the reservoir inflow.

	Sen's Slope Inflow	95% Confidence Interval	
		Lower	Upper
Annual Basis	1.30	-0.87	3.11
Seasonal Basis			
Dry Season	1.02	-1.06	2.90
Wet Season	-0.72	-2.51	2.12
Monthly Basis			
January	2.11	0.00	4.95
February	1.18	-0.38	2.73
March	1.89	0.40	4.22
April	1.11	-0.92	2.73
May	0.76	-2.14	3.32
June	1.05	-0.90	3.05
July	-0.78	-5.24	3.06
August	-0.44	-3.32	3.67
September	-1.89	-6.45	3.02
October	-1.00	-8.47	6.45
November	-1.09	-7.22	4.98
December	-0.34	-6.45	5.17

Table 4. Sen's slope and the lower an upper limit of the reservoir outflow.

	Sen's Slope Inflow	95% Confidence Interval	
		Lower	Upper
Annual Basis	1.39	-0.39	2.95
Seasonal Basis			
Dry Season	0.78	-0.64	2.51
Wet Season	0.86	-1.07	3.32
Monthly Basis			
January	1.86	-0.03	2.75
February	1.19	0.33	2.16
March	-0.23	-1.34	1.01
April	1.66	-0.05	3.34
May	0.94	-1.55	4.24
June	2.44	0.22	4.84
July	1.26	-0.92	3.15
August	2.09	-0.41	6.05
September	0.94	-2.85	5.07
October	1.45	-5.08	6.77
November	2.18	-3.04	6.79
December	0.44	-3.2	4.41

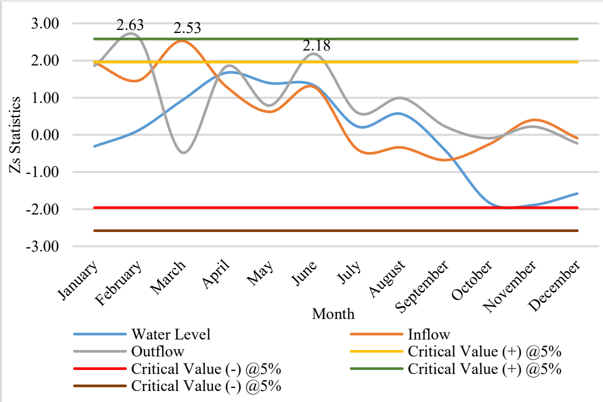

Fig. 4. MK trend analysis of the monthly water level, inflow and outflow.

3.1.2 Rainfall

There are three (3) stations within the Magat River Basin that were considered in this study, namely Dumayup, Halong and Magat, as presented in Table 3. The result reveals that among these stations, only Dumayup station exhibits a statistically significant increasing trend with a Z-value of 2.77 as compared to the 1% critical value of 2.58, indicating a strong upward trend in rainfall over the analysis period. The Sen's slope further revealed an increasing magnitude of 27.57mm/year with lower and upper value of 7.09 and 43.00, respectively, at 95% confidence interval. While Halong and Magat stations show a non-significant increasing (Z-value: 0.82) and decreasing (-0.29) trends, respectively, as denoted by the positive and negative signs. This suggests that any observed rise or fall in rainfall is not statistically robust. In addition, the Sen's slope for Halong and Magat Stations of 12.32mm/year and -3.17mm/year, respectively, with a confidence interval that includes zero, indicates that the uncertainty at these stations is high, and further confirms that the trend is not statistically significant. The variation in the magnitude of the trend across these stations suggests that the uneven rainfall distribution within the basin is affected by climate variability [35].

Table 3. Rainfall data trend analysis from the 3 rain gauges within the Magat River Basin.

Stations	MK Test	Sen's Slope	95% Confidence Interval	
			Lower	Upper
Dumayup	2.77**	27.57	7.09	43.00
Halong	0.82ns	12.32	-20.09	50.38
Magat	-0.29ns	-3.17	-17.50	14.39

(+) means increasing; (-) means decreasing; Zvalue: 5% = 1.96; 1% = 2.58

ns = not significant, * = significant at 5%, ** = significant at 1%

4. CONCLUSION AND RECOMMENDATIONS

This study carried out a comprehensive analysis of critical hydrometeorological variables—specifically rainfall, reservoir inflow and outflow, and water levels—throughout a 33-year period in the Magat River Basin located in Ramon, Isabela, Philippines. The Mann-Kendall test and Sen's slope estimator were used to examine patterns over annual, seasonal, and monthly basis. The analysis indicated statistically insignificant trends in inflow, outflow, and water levels on both annual and seasonal timeframes, which imply that long-term hydrological patterns are predominantly influenced by short-term variability and interannual climate changes.

There were notable upward monthly trends observed, for example, inflow in March climbed by 1.89cms, whereas outflows rose by 1.19cms and 2.44cms in February and June, respectively. The significance of these parameters indicates the necessity for operational modifications or concentrated precipitation during these months, possibly associated with irrigation schedules or the commencement of seasonal rains. The prevalence of significant trends at the monthly level highlights the susceptibility of reservoir management to variability over these timescales—insight essential for enhancing operating protocols and forecasting water supply for agricultural and energy purposes.

The rainfall trends analysis demonstrated geographic variation within the basin. Among the three stations considered, only the Dumayup station had a statistically significant upward trend in precipitation, increasing by 27.57mm per annum. The Halong and Magat stations exhibited negligible trends, underscoring the effect of localized meteorological and landscape factors on rainfall patterns. Substantial increases in rainfall at Dumayup may affect upstream runoff contributions and inflow predictions, requiring more localized hydrological assessments in reservoir models.

Although long-term trends in the Magat Reservoir system appear stable, the developing monthly patterns indicate changing dynamics which can be attributed to climate variability and utilization demands. These findings can be used to explore on how monthly trend variability can be integrated into hydrological models and reservoir operational guidelines to improve water allocation precision, enhance flood risk management strategies, and support adaptive, climate-resilient reservoir governance in the face of future hydrological uncertainties.

5. ACKNOWLEDGMENT
The authors would like to recognize the extended financial support by the Department of Science and Technology – Engineering Research and Development for Technology (DOST-ERDT), as well as the National Irrigation Administration – Dam and Reservoir Division (NIA-DRD) by providing the data and information needed to complete this study.

6. DECLARATION OF AI USE
While preparing this work, the authors employed the following AI to improve its readability and language (grammar and style) as well as its similarity to other works: Grammarly, Turnitin, ChatGPT, and Quillbot. Following their use, the authors thoroughly reviewed and edited the content as necessary and assumes full responsibility of its final content.

7. REFERENCES
[1] Almazroui, M., Şen, Z. Trend Analyses Methodologies in Hydro-meteorological Records. Earth Syst Environ 4, 713–738 (2020). https://doi.org/10.1007/s41748-020-00190-6.

[2] Valipour, M., M. Bateni, S., R. Dalezios, N., Almazroui, M., Heggy, E., Şen, Z., & N. Angelakis, A. (2021). Hydrometeorology: Review of Past, Present and Future Observation Methods. IntechOpen. doi: 10.5772/intechopen.94939.

[3] Adnan, M.S., Sharif, M., Sabar, M.N., Ali, R.A., Nda, M., Biantoro, A.W. and Anuar, M.A. (2024). Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.1058-1064, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences. https://doi.org/10.5109/7323389.

[4] Raju, B. C. K., & Nandagiri, L. (2017). Analysis of historical trends in hydrometeorological variables in the upper Cauvery Basin, Karnataka, India. Current Science, 112(3), 577–587. http://www.jstor.org/stable/24912443

[5] Tilocca, Y. (2024). Adaptive Management Strategies for Reservoirs in a Changing Climate. Ukrainian Journal of Ecology, 14(1).

[6] Lopena, J.B.B, Libot, P.J.A. and Bocobo, A.E. (2024). Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.938-942, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences. https://doi.org/10.5109/7323372.

[7] Macalalad, R. V., R. A. Badilla, O. C. Cabrera, and G. Bagtasa, 2021: Hydrological Response of the Pampanga River Basin in the Philippines to Intense Tropical Cyclone Rainfall. J. Hydrometeor., 22, 781–794, https://doi.org/10.1175/JHM-D-20-0184.1.

[8] Musa Esit; Investigation of innovative trend approaches (ITA with significance test and IPTA) comparing to the classical trend method of monthly and annual hydrometeorological variables: a case study of Ankara region, Turkey. Journal of Water and Climate Change 1 January 2023; 14 (1): 305–329. doi: https://doi.org/10.2166/wcc.2022.356

[9] Karakus, C. B. (2017). Trend Analysis Methods for Hydro-Meteorological Parameters. International Journal of Scientific and Technological Research, 3(2), 1-10.

[10] Kerketta, J., & Singh, A. (2020). Temporal Trend Analysis of Temperature Data Using Mann-Kendall Test and Sen's Slope Estimator. Journal of Water Engineering and Management, 1(1), 31-43.

[11] Han, J., Gelata, F. T., & Gemeda, S. C. (2023). Application of MK Trend and Test of Sen's Slope Estimator to Measure Impact of Climate Change on the Adoption of Conservation Agriculture in Ethiopia. Journal of Water and Climate Change, 14(3), 977-988.

[12] Babar, S., & Ramesh, H. (2014). Analysis of extreme rainfall events over Nethravathi basin. ISH Journal of Hydraulic Engineering, 20(2), 212–221. https://doi.org/10.1080/09715010.2013.872353

[13] Nema M.K., Khare D., Adamowski J., Chandniha S.K. 2018. Spatio-temporal analysis of rainfall trends in Chhattisgarh State, Central India over the last 115 years. Journal of Water and Land Development. No. 36 p. 117–128. DOI: 10.2478/jwld-2018-0012.

[14] Akhundzadah, N. A. (2024). Analyzing Temperature, Precipitation, and River Discharge Trends in Afghanistan's Main River Basins Using Innovative Trend Analysis, Mann–Kendall, and Sen's Slope Methods. Climate, 12(12), 196. https://doi.org/10.3390/cli12120196

[15] Grover, R., Sharma, S., Jindal, P., Kumar, N., & Verma, A. (2024). Trend Analysis of Rainfall for Multi-Purpose Water Resources Projects Using Machine Learning Predictive Model-ARIMASN Computer Science, 5, 1110.
[16] Widodo, R. H., & van Noordwijk, M. (2022). Rainfall & Discharge Relationship: A Simple Technique to Diagnose the Health of a Watershed. Center for International Forestry Research.
[17] Ehsani, N., Vörösmarty, C.J., Fekete, B.M., & Stakhiv, E.Z. (2017). Reservoir operations under climate change: Storage capacity options to mitigate risk. Journal of Hydrology, 555, 435-446. https://doi.org/10.1016/j.jhydrol.2017.09.008.
[18] Qin, P., Xu, H., Liu, M., Du, L., Xiao, C., Liu, L., & Tarroja, B. (2020). Climate change impacts on Three Gorges Reservoir impoundment and hydropower generation. Journal of Hydrology, 580, 123922, ISSN 0022-1694,
https://doi.org/10.1016/j.jhydrol.2019.123922.
[19] Gorguner, M. & Kavvas, M.L. (2020). Modeling impacts of future climate change on reservoir storages and irrigation water demands in a Mediterranean basin. Science of the Total Environment, 748, 141246. https://doi.org/10.1016/j.scitotenv.2020.141246
[20] Singson, C. L., Alejo, L. A., Balderama, O. F., Bareng, J. L. R., & Kantoush, S. A. (2023). Modeling climate change impact on the inflow of the Magat reservoir using the Soil and Water Assessment Tool (SWAT) model for dam management. Journal of Water and Climate Change, 14(3), 633–650.
[21] Dulce D. Elazegui and Edwin A. Combalicer. (2004). Realities of the Watershed Management Approach: The Magat Watershed Experience. Philippine Institute for Development Studies.
[22] National Irrigation Administration. (n.d.). Overview of Magat Dam. Retrieved from NIA. https://opfais.nia.gov.ph/Viewer/Magat
[23] Exploring Magat Dam, Isabela: A Stunning Getaway. (2024). Retrieved from Pinaywise.
[24] Mockus, V. (1972). Estimation of the length of a time series. Journal of Hydrology, 16(3), 251-257.
[25] Bhattacharya, A. K., et al. (2013). An educational interface for hydrological processes analysis. CIGR Journal, 15(2), 28-36.
[26] Kottegoda, N. T. (1980). Adequacy of length records. Journal of Hydrology, 48(1-2), 149-155.
[27] Wang, F., Shao, W., Yu, H., Kan, G., He, X., Zhang, D., Ren, M., & Wang, G. (2020). Re-evaluation of the Power of the Mann-Kendall Test for Detecting Monotonic Trends in Hydrometeorological Time Series. Frontiers in Earth Science, 8, 14.
[28] Hamed, K. H. (2008). Trend detection in hydrologic data: The Mann-Kendall trend test under the scaling hypothesis. Journal of Hydrology, 349(3-4), 350-363.
[29] Hirsch, R. M., Slack, J. R., & Smith, R. A. (1982). Techniques of trend analysis for monthly water quality data. Water Resources Research, 18(1), 107-121.
[30] Gocic, M. and Trajkovic, S. (2012). Analysis of changes in meteorological variables using Mann-Kendall and Sen's Slope estimator statistical tests in Serbia. Global and Planetary Change. 100 (2013) 172-182. https://www.academia.edu/6955354/Trend_Analysis_MK_Sen_Slope.
[31] Sen, P.K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association 63, 1379-1389.
[32] Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. John Wiley & Sons, New York.
[33] Subramanya, K. 1994. Engineering Hydrology. Second Edition. Tata McGraw-Hill Publishing Company Limited. New Delhi.
[34] Kahya, E., & Kalaycı, S. (2004). Trend analysis of streamflow in Turkey. Journal of Hydrology, 289(1–4), 128–144. https://doi.org/10.1016/j.jhydrol.2003.11.006
[35] Kumar, V., Jain, S. K., & Singh, Y. (2010). Analysis of long-term rainfall trends in India. Hydrological Sciences Journal, 55(4), 484–496. https://doi.org/10.1080/02626667.2010.481373