Paradigm reference-global.com Ovidius University Annals Series: Civil Engineering, Year 27, 2025
DOI: 10.2478/ouacsce-2025-0016

On the monthly precipitation and monthly average temperature series in the Tărlung River basin

Maria-Ruxandra Galeș [1*], Alina Bărbulescu [2], Cristian-Ștefan Dumitriu [3]

1* Technical University of Civil Engineering of Bucharest (e-mail: galesruxandra91@gmail.com)
2 Transilvania University of Brașov (corresponding author, e-mail: alina.barbulescu@unitbv.ro)
3 Technical University of Civil Engineering of Bucharest (e-mail: cristian.dumitriu@utcb.ro)

Abstract – **In this article, we analyse the variations in temperature and precipitation in the Tărlung River basin (central Romania), based on 20-year weather data records, at monthly scales. The results have shown a high variability in monthly precipitation. Normality tests revealed deviations from the normal distribution, especially in the monthly scale datasets. Homoscedasticity tests confirmed variance homogeneity in most cases. Trend analyses indicated stable temperature patterns. Changepoint tests identified breakpoints particularly after 2010–2012. These results contribute to understanding local climate variability and its potential implications for hydrological processes, providing a solid foundation for predicting future impacts in the area.**

Keywords – change points, climate variability, statistical analysis, trend.

1. INTRODUCTION

Climate variability represents a fundamental aspect of regional and local environmental dynamics having direct implications for hydrological processes, ecosystem stability, and infrastructure planning. While the consequences of climate change have been predominantly associated with gradual variations in long-term average temperatures [1], precipitation serves as a fundamental indicator of climatic shifts, with variations in its frequency, intensity, and spatial distribution reflecting potential changes in climate regimes [2]. Climatic variables exhibit variability across both spatial dimensions (latitude, longitude, altitude) and temporal scales (hours, days, months, etc.), necessitating the collection of datasets within a defined area over a specified period, as determined by the spatio-temporal resolution [3].

The Curvature Carpathians region, in Romania, which includes the studied watershed, is characterized by a limited number of monitoring stations with available data, yet it experiences frequent torrential events and is highly susceptible to flash floods, posing significant risks to the local population [4]. In this context, this article presents the results of the statistical analysis of temperature and precipitation, aiming to assess the extent of the climate variability in a part of this region.

2. DATA SERIES AND METHODOLOGY

The study employed monthly precipitation and average temperature records from the Babarunca gauging station located on the Tărlung River (Brașov County) (Fig. 1), covering the period 2005–2024. The upstream catchment area of the Tarlung River (45 km^2) represents a relevant case study not only because of its geographical position in a mountainous setting, where topography strongly influences temperature and precipitation patterns, but also due to the availability of continuous climate records over the past two decades.

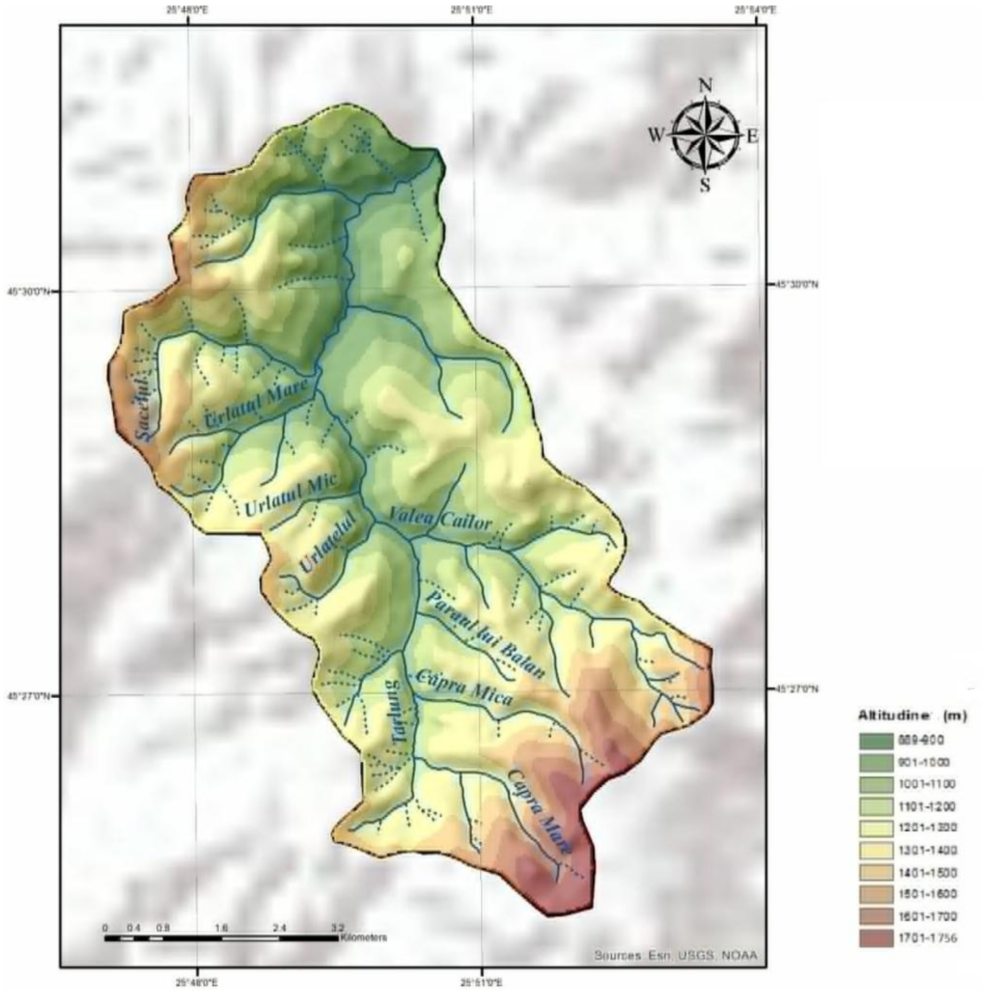

Fig. 1 Study area

The following methods were used:

- Computing the descriptive statistics (mean, median, variance, coefficient of variation, skewness, kurtosis), determine the outliers' existence;
- Investigate the autocorrelation in the data series using the autocorrelation function (ACF) and draw the histogram.

- Test the normality hypothesis against the non-normality by the Kolmogorov–Smirnov (KS), Anderson–Darling (AD), Ryan–Joiner (RJ) tests [5-8].
- Test the homoscedasticity hypothesis against heteroskedasticity by the Levene and Bonett tests [9,10] because they are not sensitive to departure from normality.
- Test the randomness of the data series against the existence of a monotonic trend by the Mann–Kendall (MK) trend test, followed by Sen's slope if the trend was found significant [11,12].
- Test the existence of no changepoint (CP) – null hypothesis (H_0) against the existence of at least of a CP using the Pettitt, Buishand, Lee & Heghinian tests and Hubert segmentation procedure [13-16]. The first and last tests do not impose restrictions on the series distribution. By contrast, the second and third ones can be used only when the series are Gaussian. If the normality hypothesis is rejected, a transformation could be used to attempt to reach normality, then the CP test is applied on the new series. This procedure does not affect the CP location.

All the calculations and statistical analyses were performed using three main statistical software packages: Minitab 16 (for descriptive statistics, normality, and homoscedasticity tests), R 4.5.1 (for trend analysis), and Khronostat (for change-point detection). Each software offers complementary functionalities, providing a comprehensive overview of climatic dynamics in the basin.

3. RESULTS AND DISCUSSION

The monthly average temperatures for the period 2005–2024 show high variability, with values ranging from –10.15 °C to 20.29 °C, an average of approximately 6.8 °C, a standard deviation of 7.765, and a coefficient of variation (CV) of 114.29 %. The series distribution is nearly symmetric (skewness coefficient = -0.07) and platykurtic (kurtosis = -1.29). The boxplot (Fig.2(left)) indicates that there are no outliers, while the autocorrelation function (ACF) (Fig.2 (right)) highlights a well-defined seasonal pattern, indicating clear temporal dependencies between successive values and emphasizing the need to account for seasonality when interpreting climate variability.

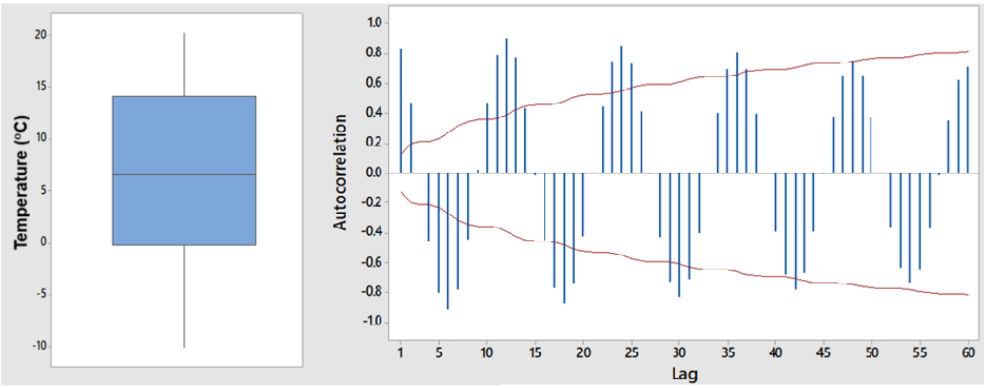

Fig. 2 (left) Boxplot of average temperature series (right) correlogram (vertical bars) and the 95% confidence interval (continuous curve)

All normality tests (Kolmogorov–Smirnov, Anderson–Darling, and Ryan–Joiner) indicate p-values < 0.01, confirming the rejection of the null hypothesis and showing that the distribution of monthly temperatures is not normal. The test plots (Fig.3) highlight clear deviations from the theoretical Gaussian distribution, especially at the extremes, reflecting the strong seasonality and climatic variability of the Babarunca basin. The histogram (Fig. 4) indicates a symmetrical spread of the data, characteristic of a continental climate with strong seasonality.

To perform the Bonett, and Levene tests, the data series was split into two sub-series, denoted in Fig.5 by C1 and C2, and their variances were compared. The p-values in the tests were greater than the significance level (0.05), indicating that the temperature variances are homogeneous, so the series is homoscedastic.

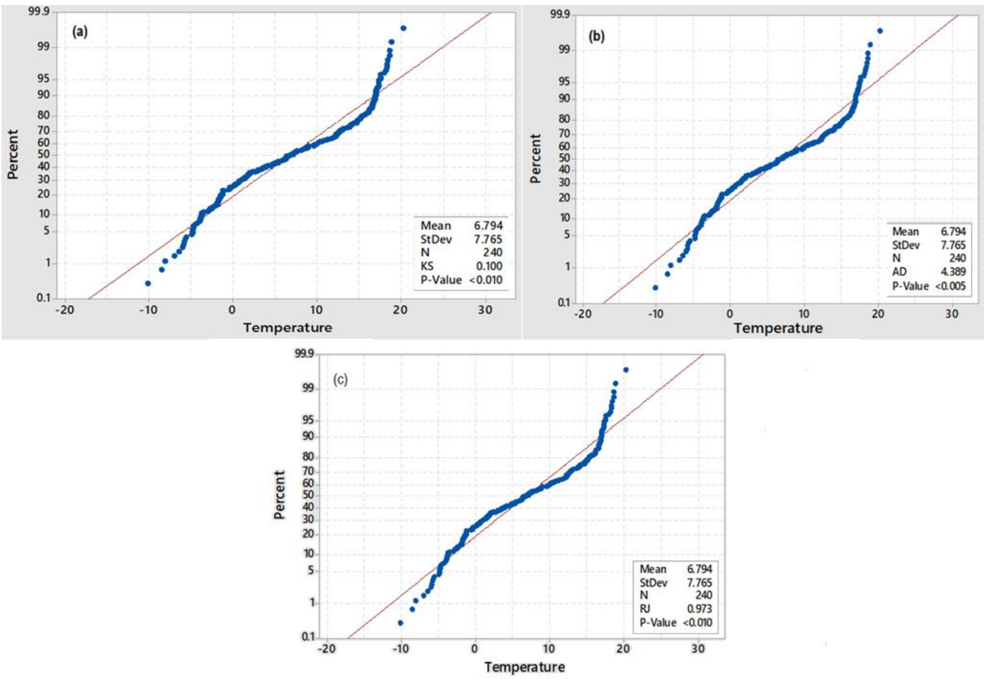

Fig. 3 Plots of the normality tests (a) KS, (b) AD and (b) RJ. The line represents the theoretical normal distribution

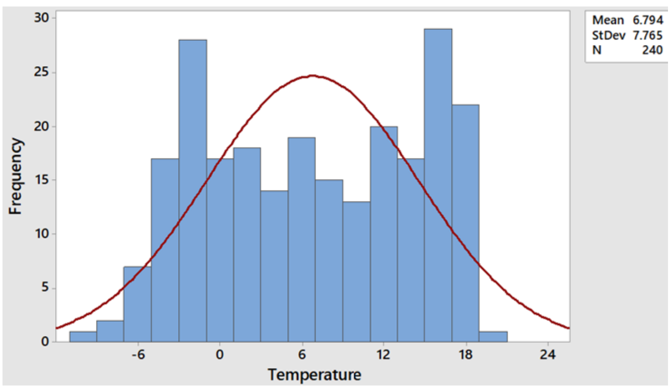

Fig. 4 Histogram of the monthly temperature series for the period 2005–2024

The Mann–Kendall test does not identify a statistically significant trend in the evolution of monthly temperatures (p = 0.7721), suggesting the absence of a consistent long-term monotonic increase or decrease during the 2005–2024 period.

Since the series is not Gaussian, a Box-Cox transformation was applied to reach normality, then the changepoint tests were applied. All indicated no significant change points for the period 2005–2024. The Pettitt and Buishand tests confirm the stability of the mean monthly temperature series, as the null hypothesis is not rejected at any significance level (90% and 95%), indicating the absence of structural discontinuities.

The Lee & Heghinian and Hubert methods found no changepoints as well, reflecting a stable evolution of temperatures dominated by seasonality rather than abrupt climatic shifts.

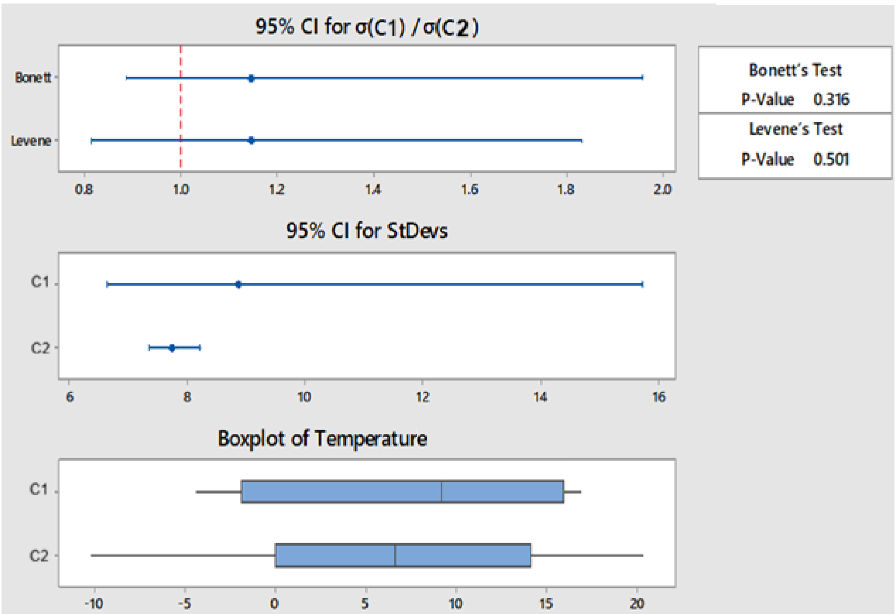

Fig. 5 Results of Bonett's and Levene's tests for comparing the variances of monthly temperatures in the two subseries C1 and C2. StDevs are te tandard deviation, and CI is the confidence interval

Monthly precipitation shows high variability (mean = 90.86 mm, coefficient of variation = 61.35%), with a positively skewed distribution (skewness=1.16) and occasional extreme precipitation events, characteristic of mountainous seasonal regimes. The histogram (Fig.6(left) and boxplot (Fig.6(right)) confirm the predominance of months with moderate precipitation values, alongside a few outliers exceeding 200 mm/month, indicating the sporadic occurrence of intense rainfall events.

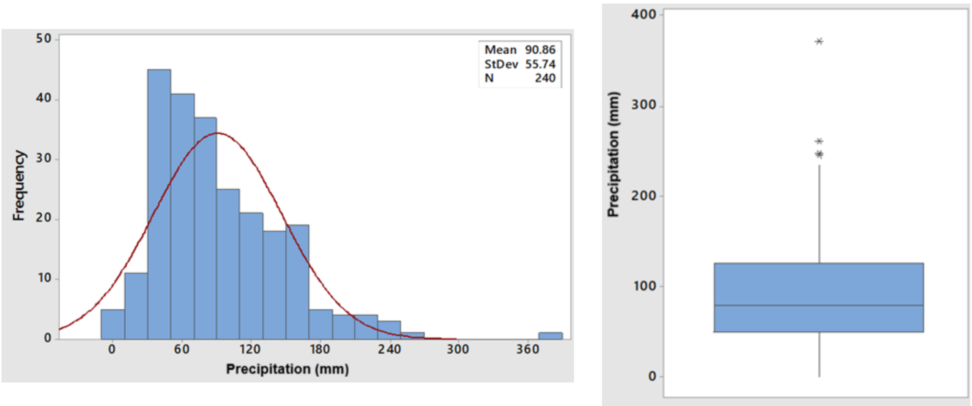

Fig. 6 (left). Histogram and (right) boxplot of the monthly precipitation series for the period 2005–2024

The results of the normality tests for the monthly precipitation series are presented in Table 1. All reject the null hypothesis, confirming the visual examination of the histogram.

This deviation from normality is mainly due to extreme values associated with intense rainfall episodes.

Table 1. Results of the normality tests for the monthly precipitation series.

Test	Value of the test statistics	p-value
Kolmogorov-Smirnov	0.097	< 0.010
Anderson-Darling	3.949	<0.005
Ryan-Joiner	0.964	< 0.010

The correlogram (Fig.7) reveals a predominantly random behavior of precipitation. The Bonett and Levene tests (Fig.8) provide p-values of 0.030 and 0.026, respectively, indicating the series heteroskedasticity, influenced by the existence of outliers (associated with high rainfall events).

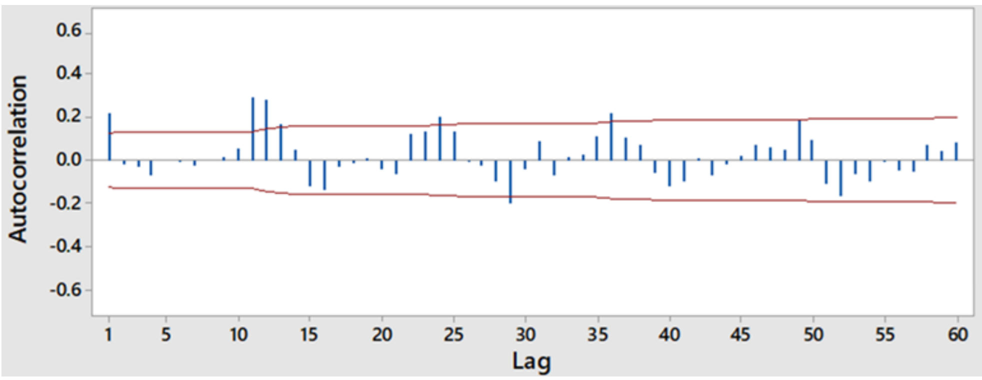

Fig. 7 Correlogram of the monthly precipitation series

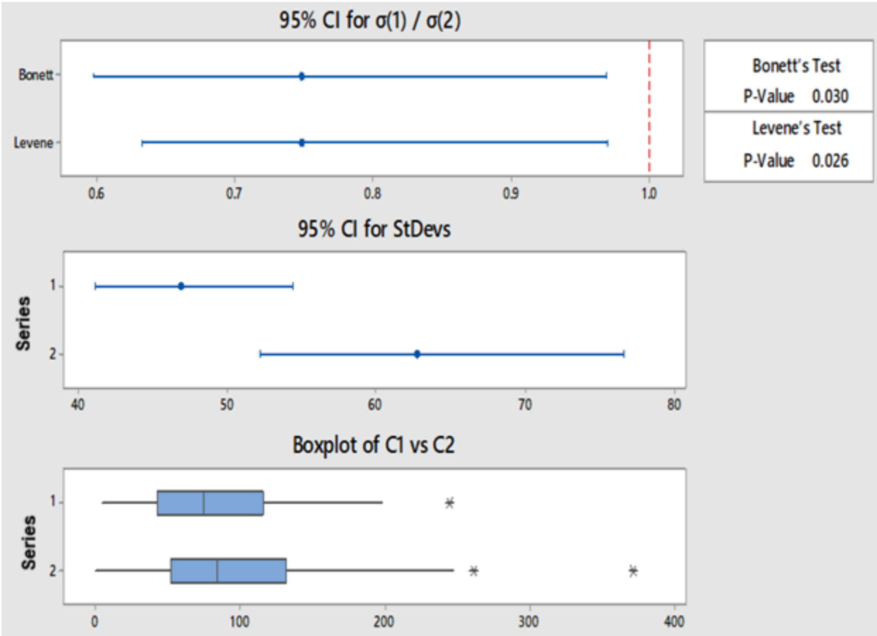

Fig. 8 Resuts of the Bonnett and Levene tests for the monthly precipitation series

The Mann–Kendall trend test reveals a statistically significant increasing trend in monthly precipitation ($p = 0.0383$), indicating a progressive intensification of the precipitation regime during the 2005–2024 period. The Sen's slope estimation confirms this trend, with a positive slope of 0.0925 mm/month and a confidence interval that does not include zero, demonstrating a statistically significant increase in precipitation.

The Pettitt test suggests the existence of a change point around 2012–2013, where the precipitation distribution shows a detectable modification at the 90–95% significance levels. The Buishand test rejects the homogeneity hypothesis at all significance level, confirming a structural discontinuity in the precipitation regime and a significant shift in the mean. The Hubert segmentation identifies three distinct intervals, with a clear increase in the mean after 2018, reinforcing the presence of a rupture point indicated by the other tests.

4. CONCLUSIONS

The study performed for the monthly average temperature series for the period 2005–2024 highlights the stability of the thermal regime, with all series showing deviations from normality due to seasonality but no structural breaks. The Mann–Kendall and Sen's slope tests indicate the absence of significant trends, suggesting a stationary thermal regime with no detectable warming or cooling signals in the Babarunca Basin.

In contrast, the precipitation regime is characterized by high variability, a non-normal distribution, and extreme rainfall episodes, typical of mountainous areas. Break-point tests reveal structural changes after 2018, suggesting a reorganization of the precipitation regime.

To deeply understand the variations in the hydrometeorological variables in the study basin, an extended analysis at the daily and seasonal scales will be further performed, followed by mathematical modeling. These stages are essential for providing the necessary background for water resource management and flood-risk assessment in the context of regional climate change.

5. REFERENCES

[1] Arrieta-Pastrana A., Saba M., Alcázar A.P. (2022*), Analysis of Climate Variability in a Time Series of Precipitation and Temperature Data: A Case Study in Cartagena de Indias, Colombi*a. Water, 14(9), 1378

[2] Nazeri Tahroudi M (2025), *Comprehensive global assessment of precipitation trend and pattern variability considering their distribution dynamics*, Sci. Rep. 15, 22458

[3] Moumen Z., Elhassnaoui I., Daid, F. (2021), *Statistical descriptive analysis of three climate variables: Precipitation, temperature, and relative humidity. Study cases* (*Innaouene watershed; Morocco*), E3S Web of Conferences, 314, 03004

[4] Strapazan C., Irimuș I.-A., Șerban G., Man T. C., Sassebes L. (2023), *Determination of Runoff Curve Numbers for the Growing Season Based on the Rainfall–Runoff Relationship from Small Watersheds in the Middle Mountainous Area of Romania*. Water, 15(8), 1452

[5] Kolmogorov A (1933), *Sulla determinazione empirica di una legge di distribuzione*, G. Ist. Ital. Attuari. 4, pag 83–91

[6] Smirnov N (1948), *Table for estimating the goodness of fit of empirical distributions*, Ann. Math. Stat., 19 (2), 279–281

[7] Anderson T. W., Darling D. A. (1952), *Asymptotic theory of certain "goodness-of-fit" criteria based on stochastic processes*, Ann. Math. Stat., 23(2), pp. 193–212

[8] Ryan T. A., Joiner B. L. (1976), *Normal* Probability Plots and Tests for Normality, Technical Report, Statistics Department, The Pennsylvania State University

[9] Levene, H. (1960) *Robust tests for equality of variances*, in Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling, I. Olkin et al. eds., Stanford University Press, 1960, pag. 278-292

[10] Bonett D. G. (2006), *Robust Confidence Interval for a Ratio of Standard Deviations*, Appl. Psychol. Measure., 30, pag 432–439

[11] Kendall M.G. (1975), *Rank Correlation Methods*, 4th edition, Charles Griffin, London.

[12] Sen P. K. (1968) *Estimates of the regression coefficient based on Kendall's tau,* J. Am. Stat. Assoc., 63 (324), pag. 1379–1389

[13] Pettitt A. N. (1979), A non - parametric approach to the change-point problem, Appl. Stat. vol. 28, 2, pag. 126 – 135

[14] Buishand T. A. (1984), Tests for Detecting a Shift in the Mean of Hydrological Time Series, J. Hydrol., 73, pag. 51-69

[15] Lee A.F.S., Heghinian S.M. (1977), *A Shift of the Mean Level in a Sequence of Independent Normal Random Variables—A Bayesian Approach*, Technometrics, 19, pag. 503-506

[16] Hubert P., Carbonnel, J.P., Chaouche, A. (1989) *Segmentation des séries hydrométéorologiques. Application à des séries de précipitations et de débits de l'Afrique de l'Ouest*, J. Hydrol., 110, pag. 349 – 367