Original Research Article

Homogeneity evaluation of historical rainfall and temperature series in Mato Grosso

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ABSTRACT

The homogeneity investigation of a series can be done through several statistical tests nonparametric, that serve to detect artificial changes or non-homogeneities in variables climatic. The objective of this work was to evaluate two methodologies to verify the homogeneity of the historical climatological series of precipitation and temperature in Mato Grosso state. The series homogeneity evaluation was done using non-parametric Wald-Wolfowitz tests (for series with one or no interruption) and Kruskal-Wallis (for series with two or more interruptions), and Mann-Kendall test for time series trends analysis. The analysis results of precipitation series homogeneity of National Water Agency stations, analyzed by Kruskal-Wallis and Wald-Wolfowitz tests, presented 61.54% of homogeneous stations, being well distributed throughout Mato Grosso state. And those of trend analysis, allowed to identify that 87.57% of rainfall stations showed a positive trend concentrated, mainly in the rainy season. From National Institute of Meteorology of Mato Grosso conventional stations, seven were homogeneous for the precipitation variable; for maximum temperature were five; and for minimum temperature were four homogeneous stations. For trend analysis in the 11 stations, positive trends of a random nature were observed, indicating increasing alterations in the analyzed variables. Therefore, trend analysis performed by Mann-Kendall test in the precipitation climatic series and maximum and minimum temperature indicated that several data series showed increasing trends, indicating a possible increase in precipitation and temperature values over the years. And the results of Kruskal-Wallis and Wald-Wolfwitz tests for homogeneity showed more than 87% of homogeneous seasons.

Keywords: Mann-Kendell, Kruskal Wallis, Wald-Wofwitz.

1. INTRODUCTION

Information about climatic elements is of great importance in the various activities developed by man, such as in agriculture, through crop and zonation forecasts, water resources management, and climatic studies related to atmospheric phenomena. This is only possible because climatic data provide a lot of information about atmospheric environment, but to make use of historical climatological series it is essential to identify possible changes in meteorological records. So, in order to guarantee the reliability of climate studies, it is necessary to use reliable data, whose homogeneity has been verified, because, when using non-homogeneous data in analyzes, the chances of contradictory and misleading conclusions increase.

The main problems found in historical series are the difficulties in obtaining meteorological data with long and reliable time series and failures (discontinuities in the series). It is important to emphasize that the occurrence of these faults can compromise the analysis and data interpretation. However, according to [1], failures (interruptions) occurred in climatological series do not make them unfeasible, but it is not possible to estimate the missing data without changing the frequency distribution dispersion scale [2].

Thus, in order to make use of climatic data it is necessary to verify if they are statistically homogeneous, however, there is still a lack in studies whose objective is to analyze such homogeneity in all meteorological elements in Mato Grosso. [4, 5] argue that the non-homogeneity on climatic series may be of different origin, such as vegetation growth and / or urbanization in stations vicinity, changes in location or de-calibration in measuring instruments, and errors during instrument reading .

The verification of the series homogeneity can be done through several statistical tests nonparametric, that lend themselves to allow to detect artificial changes or non-homogeneities in variables climatic. The evaluation of the series consistency can be done using Wald-Wolfowitz and Kruskal-Wallis non-parametric tests, depending on the occurrence or not of interruptions in data series [1], and Mann-Kendall test for analysis of possible trends in all-time series.

The Wald-Wolfowitz and Kruskal-Wallis non-parametric tests are a more traditional way of analyzing homogeneity, but more recently, another method is proposed, which is the Mann-Kendall trend analysis, with the objected to detect possible temporal trends.

In this way, two methodologies that can present contrasting information about climatological series were used. Therefore, the objective was to evaluate two methodologies to verify the homogeneity of the historical climatological series of precipitation and temperature in Mato Grosso state.

2. MATERIAL AND METHODS

The daily temperature data (maximum and minimum) and precipitation were obtained from National Institute of Meteorology (INMET), and the other precipitation data analyzed were obtained from National Water Agency (ANA). Data series with a minimum of 10 years of observation were used, totaling 10 conventional INMET stations and 169 ANA rainfall stations.

Data were organized in tens to verify their homogeneity, considering that, with the grouping in tens, it is possible to detect more easily variations in the analyzed series. In this way, annual data, including those from leap years, were standardized over 36 periods. In addition, no bug-filling was performed, so there would be no interference to data sets.

Two data analysis methodologies (Wald-Wolfowitz and Kruskal-Wallis) were used to analyze the climatological series, one that verifies the data set homogeneity, and another that analyzes the trend occurrence in the series (Mann-Kendall). For both methodologies the significance level of 1% was used.

To verify the homogeneity, the non-parametric tests (Wald-Wolfowitz and Kruskal-Wallis) were used. When series showed no interruption, their homogeneity was verified by Wald-Wolfowitz test for a sample. This test consists of determining the series median, then comparing the values sequences number above or below the median in the observations chronological order, with the expected theoretical value with the same freedom degree.

If the data presented an interruption, the Wald-Wolfowitz unilateral test of iterations was applied to two samples, this test is applicable when it is desired to prove the null hypothesis, that two samples have been extracted from the same population, against the hypothesis that the two groups differ in any way [5].

For series that presented two interruptions or more, Kruskal-Wallis test was applied, in order to test if the samples sets came from the same distribution. That is, to test the null hypothesis that all-time series have equal distribution functions against the alternative hypothesis that at least two of the time series have different distribution functions [6].

The historical series trend analysis was verified using the Mann-Kendall test, which is a sequential and non-parametric method that was used to determine if the data series had a statistically significant change in temporal trend.

As described by [7] according to the MK test, each value Yi, i = 1, ..., n -1 is compared with all values that follow Yj, j = i + 1, i + 2, ..., n, generating a new series Zi which contains an indicator of the relative value of the difference between terms of the series Yi, according to:

$$Z_{i=}\ signal\left(Y_i - Y_j\right) = \begin{cases} 1\ se\ Y_i > Y_j \\ 0\ se\ Y_i = Y_j \\ -1\ se\ Y_i < Y_j \end{cases}$$

The S statistic is then calculated using the following equation:

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i=1} signal\ (Y_i - Y_j)$$

And the variance defined by:

$$VAR\ (S) = \frac{1}{18}\left[n\ (n-1)(2n+5)\right]$$

Where *n* is the time series size.

However, the significance of S for the null hypothesis can be tested using a bilateral test and can be rejected for large values of the statistic Z (t) defined according to:

$$Z(t) = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}}\ if\ S > 0 \\ 0 \qquad if\ S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}}\ if\ S < 0 \end{cases}$$

Since a positive Z value indicates growth tendency and negative Z indicates a downward trend and a large magnitude of the Z value indicates that the trend is strongly significant.

3. RESULTS AND DISCUSSION

When analyzing ANA pluviometric stations historical series using the Kruskal-Wallis and Wald-Wofowitz tests, it was observed that, of the 169 analyzed stations, 104 presented homogeneity in all their deciles, according to Table 1, being that of the 65 stations in the case of Mann-Kendall test, only 21 stations with no trend in their decays were verified, as can be seen in Table 2, with 496 deciles increasing trend.

Table 1: Relation of ANA rainfall stations with homogeneous series in Mato Grosso until 2016.

01154000	01452004	01554001	01058004
01455009	00956001	01554005	01455004
01456010	00957001	01251002	01351000
01455011	01653005	01558000	01055002
01455010	01060001	01455008	01055003
01454003	01059000	01557005	01360003
01459003	01058005	01655001	01359001
00957002	01755003	01555004	00958004
00956002	01756001	01655003	00958002
01354001	01457001	01150001	01058002
01454000	01552006	01152001	01556000
01654004	01552002	01052000	01555000
01055000	01251000	01358005	01254002
01656001	01257000	01155000	01255002
01757001	01258001	01255001	01553003
01656004	01158003	01156000	01552001
01657001	01657002	01457004	01654005
01652001	01658000	01055004	01653002
01052001	01557004	01154002	01755000
01157000	01757002	01254001	01157001
01157002	01353001	01659001	01057000
01156001	01358001	01560000	01058006
01558003	01357001	01559006	01159000
01558005	01555005	00951000	01259001
01557003	01158004	01452000	01058003
01054000	01050000	01150006	01256002

Table 2: List of ANA rainfall stations with series without trend in Mato Grosso until 2016.

01753000	01055001	01552002	01154000	01656003
01653004	01555000	01353001	01354000	01756001
00857000	01255002	01352002	01251001	01158001
01755003	01553003	01150001	01655001	01652002
01159000				

By observing the both tests results, it can be seen that Mann-Kendall test found that more than 87% of the stations have a statistically significant temporal change trend, either positive or negative, the Mann-Kendall test is a much more robust and rigorous method of analysis [8], since homogeneity verification method detected only 38% of non-homogeneous stations.

The Mann-Kendall test revealed an increase in rainfall in most of the analyzed stations, since most of the decades that presented a positive trend were concentrated in the rainy season, which could mean that there was a significant increase in precipitation over the years in those seasons. Similar behavior was obtained by [8], in which a positive trend was identified in the rainfall series analysis in Western Amazonia in the rainy season (January to April).

Authors such as [9, 10, 8] used the trend analysis to verify climatic variability in historical series, which is an advantage of this analysis, since it allows observing changes in the series behavior and determining which regions are suffering significant variations over time. Thus, it can be considered that Mann-Kendall trend analysis test is used to identify the climate change occurrence.

Therefore, it is important to emphasize that the study of rainfall behavior makes it possible to detect trends or changes in climate, at local or regional scales, and, with due understanding, becomes an analysis element in the organization of territorial and environmental planning due the high interference degree, impact and repercussion in time and space [11]. However, it is worth emphasizing that such changes are not necessarily the anthropization result. They may be just a natural process that has been occurring with land, such as intensification of solar activity and natural phenomena such as El Niño and La Niña [12].

It is observed in Figure 1 that the stations that presented homogeneity by Kruskal-Wallis and Wald-Wolfowitz tests are distributed throughout Mato Grosso state. In Mann-Kendall test result, stations that did not present a tendency, in addition to their reduced number, are not distributed throughout the state, according to Figure 2.

The occurrence of non-homogeneity and / or discontinuities in climatological time series may interfere in the climatic variability characterizationof a locality. This non-homogeneity may be due to several non-climatic factors, such as vegetation growth or urbanization in the vicinity of the stations, or by a change in location or de-calibration in measuring instruments and even by observation habits [3, 4].

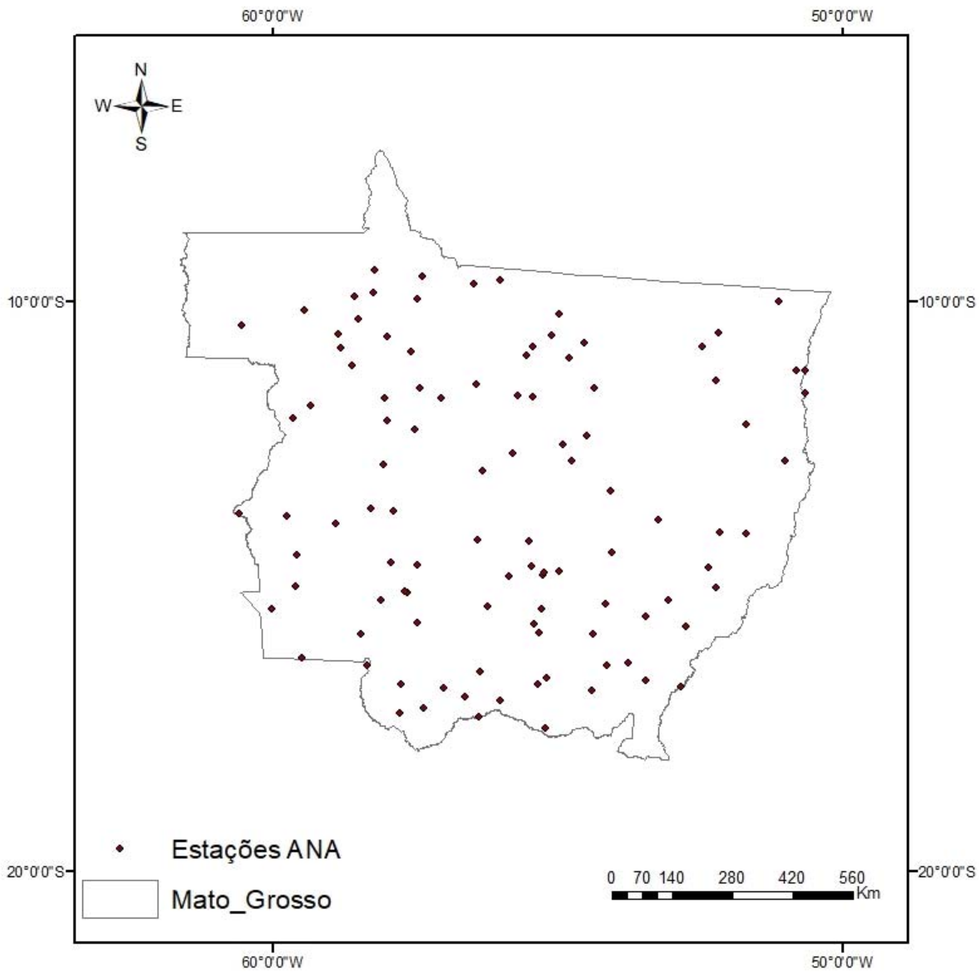

Figure 1: Relation of ANA rainfall stations with homogeneous series, analyzed by Kruskal-Wallis and Wald-Wolfowitz tests in Mato Grosso until 2016.

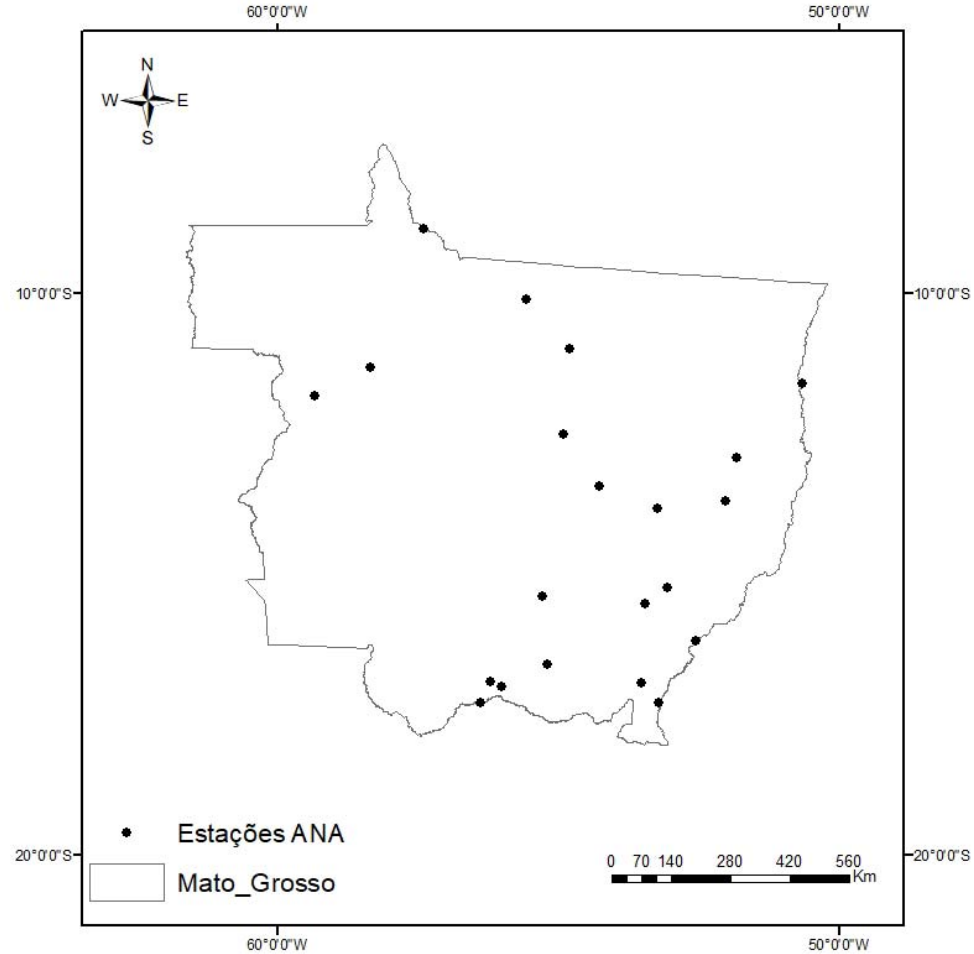

Figure 2: Relation of ANA rainfall stations with series without trend, analyzed by the Mann-Kendall test in Mato Grosso until 2016.

From conventional INMET stations of Mato Grosso, seven were homogeneous for precipitation variable; for maximum temperature were five; and for minimum temperature were four homogeneous stations (Table 3). For trend analysis in the 11 stations, positive trends were observed in at least one decade, indicating increasing changes in analyzed variables.

The trends observed at the INMET stations for the three analyzed variables were random, unlike what can be seen with ANA rainfall stations that concentrated the trends in the rainy season, but, in any case, these increasing trends indicate an increase in the values of maximum temperature, minimum temperature and rainfall over the years.

Table 3: Relation of conventional INMET stations with homogeneous series in Mato Grosso until 2016, for the variable's precipitation, maximum temperature and minimum temperature.

Precipitation	Maximum temperature	Minimum temperature
Cáceres	Canarana	Cáceres
Cuiabá	Matupá	Canarana
Gleba Celeste	Padre Ricardo Remetter	Padre Ricardo Remetter
Matupá	Rondonópolis	São José do Rio Claro
Padre Ricardo Remetter	São José do Rio Claro	
Rondonópolis		
São José do Rio Claro		

The homogeneity analysis results of the climatological series obtained in this work are useful for guidance on issues important to agriculture, such as the choice of appropriate crop for a given locality, best sowing season, and agricultural planning in general, given that the climatological series are useful for characterizing the weather and climate conditions of the region.

4. CONCLUSION

The Mann-Kendall trend analysis, in the climatic series of precipitation and maximum and minimum temperature, indicated that several data series showed increasing trends, indicating a possible increase in precipitation and temperature values over the years. And the results of Kruskal-Wallis and Wald-Wolfwitz tests for homogeneity showed more than 87% of homogeneous seasons.

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