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Research paper

Gap Filling and consistency analysis in monthly rainfall series: a case study in the southeast of Mato Grosso

Preenchimento de falhas e análise de consistência em séries pluviométricas mensais: estudo de caso no sudeste mato-grossense.

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ABSTRACT: Analyzing rainfall time series is crucial for understanding climate patterns and managing water resources. However, data gaps caused by missing information, technical issues, and data transmission failures compromise the accuracy of climate analyses and forecasts. This study aims to address these gaps and assess the consistency of monthly rainfall series in southeastern Mato Grosso using the regional weighting method and the double-mass analysis. We selected data from five rain gauge stations: Vale Rico (01654005), Alto Araguaia (01753000), Fazenda Taquari (01853000), Alto Garças (01653004), and Itiquira (01754000), covering the period from 1984 to 2019. Data were extracted from the Hidroweb platform of the National Water and Sanitation Agency (ANA). The regional weighting method was effective in filling gaps. Consistency checks using the double-mass method revealed a linear trend in data, indicating no inconsistencies in the filled data. Notably, the Fazenda Taquari (01853000) station, which had the most gaps filled, showed a pronounced linear trend, demonstrating the methodology's effectiveness. The findings suggest that the regional weighting method is a suitable approach for gap-filling in rainfall series, thereby enhancing the quality of data for hydrological studies in the region.

Keywords: Water resources management, precipitation, regional weighting, double-mass.

RESUMO: *A análise de séries temporais de precipitação é fundamental para entender os padrões climáticos e gerir recursos hídricos. Contudo, dados com falhas, causadas por ausência de informações, problemas técnicos na transmissão de dados e erros de transcrição comprometem a precisão das análises e previsões climáticas. Este estudo visa preencher falhas e, posteriormente, analisar a consistência de séries pluviométricas mensais no sudeste mato-grossense, utilizando, respectivamente, o método da ponderação regional e o método da dupla-massa. Foram selecionadas cinco estações pluviométricas: Vale Rico (01654005), Alto Araguaia (01753000), Fazenda Taquari (01853000), Alto Garças (01653004) e Itiquira (01754000), com dados de 1984 a 2019, extraídos da plataforma Hidroweb da Agência Nacional de Águas e Saneamento Básico (ANA). O método da ponderação regional mostrou-se eficaz no preenchimento das falhas. Na verificação de consistência pelo método da dupla-massa, a distribuição dos dados se ajustou a uma tendência linear, indicando a ausência de inconsistências nos dados preenchidos. A estação Fazenda Taquari (01853000), com a maior quantidade de falhas preenchidas, obteve tendência linear marcante, evidenciando a eficácia da metodologia. Conclui-se que o método da ponderação regional se mostrou adequado para preencher falhas em séries pluviométricas, contribuindo para a qualidade dos dados a serem utilizados em estudos hidrológicos na região.*

Palavras-chave*: Gestão de recursos hídricos, precipitação, ponderação regional, dupla massa.*

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INTRODUCTION

Analysis of rainfall time series is essential for understanding climate patterns and managing water resources. However, failures resulting from technical problems in data collection or transmission can compromise the data quality. These gaps can undermine the accuracy of climate analysis and predictions, making it necessary to develop effective methods to fill them.

According to Law No. 12,527 of November 18, 2011, which regulates access to information, the fundamental right to access public information, including environmental and climate data, is guaranteed. However, many locations still face challenges in obtaining long and reliable time series necessary for comprehensive studies and the formulation of effective public policies (Mello; Kohl; Oliveira, 2017).

The lack of continuous and consistent data can be attributed to several factors, such as interruptions in measurements due to equipment failures, changes in collection methods, or discontinuity of meteorological stations. This compromises the quality of climate analysis and forecasts, as well as difficulties the water resource management, especially in regions where agriculture and water supply depend heavily on rainfall variability (Amador; Silva, 2023).

Regional weighting, a method based on spatial interpolation, is widely used to fill gaps in data by employing information from neighboring stations to estimate missing values (Cunha Junior; Firmino, 2022). Studies show that the regional weighting method performs well in filling gaps in rainfall time series, highlighting that the researcher must know the climate pattern of the region studied so as not to use data that deviates too much from the regional pattern (Diaz; Pereira; Nóbrega, 2018).

However, some studies show that gap-filling methodologies may perform less well when precipitation data from neighboring stations are less correlated. This can result in estimates that deviate from the original series and increase errors in the results, especially in heterogeneous regions, making it necessary to assess the consistency of the completed series (Ruezzene *et al*., 2020).

After filling in the gaps, it is necessary to adopt assessment procedures regarding the quality of such fillings. Consistency analysis using the Double-Mass Method is widely recommended to verify the consistency of fillings in time series (Oliveira; Sanches; Ferreira, 2021).

In southeastern Mato Grosso, the reliability of rainfall time series is particularly important due to the climate variability and agricultural and hydrological dependence. The region is also home to important national river basins, such as the Paraguay River Basin and the Araguaia River Basin.

This study aims to fill gaps and analyze consistency in monthly rainfall time series, using, respectively, the regional weighting method and the double-mass method. The initial focus of the study is to fill gaps in the rainfall series of the Itiquira (01754000) station and, consequently, of all surrounding stations.

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MATERIAL AND METHODS

In this study, filling gaps in the data will be conducted using the regional weighting method. Then, the consistency of the time series will be analyzed using the double-mass method.

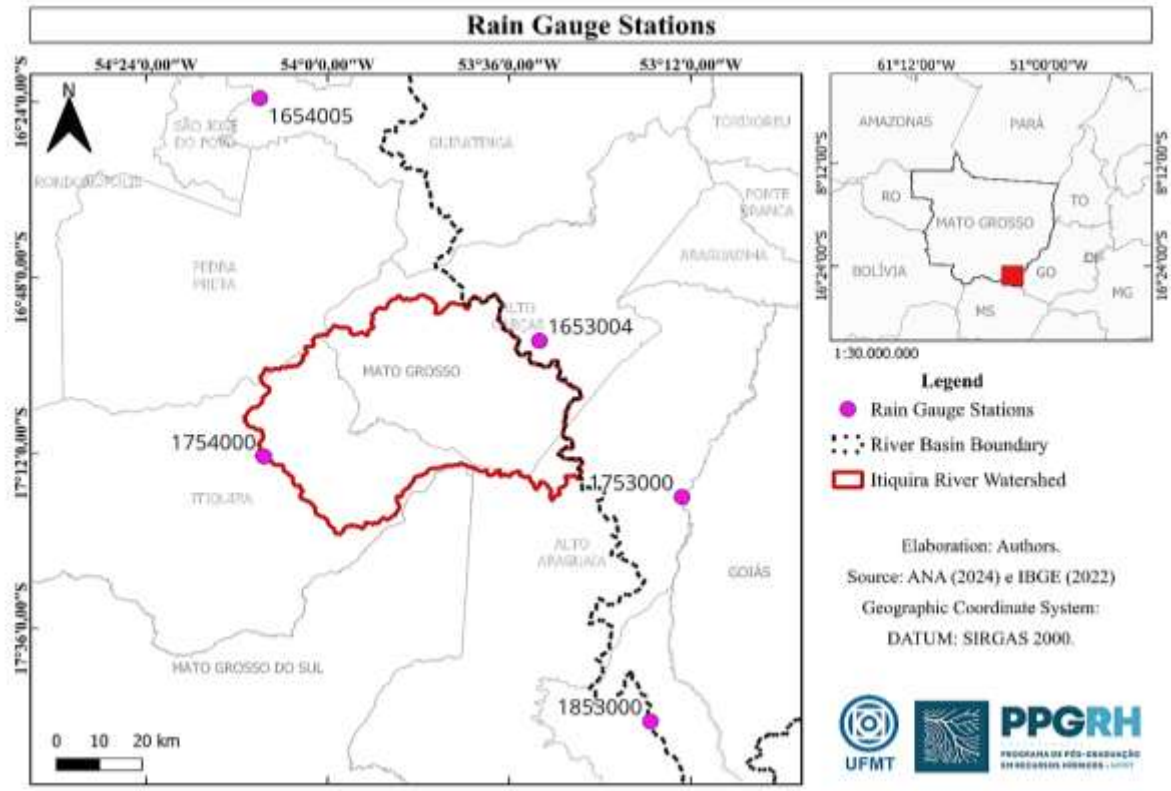
Study area

The study area is located in the municipalities of Alto Araguaia, Alto Garças, Alto Taquari, Guiratinga, and Itiquira in the southeastern region of Mato Grosso. The region covers the border of the Paraguay and Araguaia River basins.

To fill the data gaps in the rainfall time series at Itiquira (01754000), a survey of rainfall stations within a 60 km radius was conducted, resulting in the identification of four other stations with available data and with a failure rate in monthly data of less than 5% (**Figure 1**). Thus, five rain gauge stations were selected for the study: Vale Rico (01654005), Alto Araguaia (01753000), Fazenda Taquari (01853000), Alto Garças (01653004), and Itiquira (01754000). Monthly rainfall data were extracted from the Hidroweb platform of the Brazilian National Water and Basic Sanitation Agency (ANA), covering the period from January 1984 to December 2019.

The region is situated in a tropical climate. According to the Köppen-Geiger classification (Kotter *et al*., 2006), the local climate is of the Aw type. This type of climate is characterized by a rainy season in summer, from October to April, and a well-defined dry season in winter, from May to September, with July being the driest month. The relief is classified as Taquari-Itiquira Plateau (IBGE, 2009). Land use is predominantly composed of pastures and savanna formations (Projeto Mapbiomas, 2022).

Figure 1. Location map of the study area



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Regional Weighting

The regional weighting method is a simplified technique frequently used to complete monthly or annual rainfall time series. This method aims to homogenize data throughout the analyzed period and statistically analyze rainfall (Tucci, 2015).

It consists of estimating the missing values at a given station using the weighted average of data from neighboring stations, considering the proximity and similarity of historical data (Collischonn; Dornelles, 2013).

It is necessary to select at least three stations in the neighborhood that have at least 10 years of data (X1, X2, and Xn) to fill station Y. Equation 1 is adopted for this procedure (Tucci, 2015):

$$Y = \frac{1}{n} * \left(\frac{X_1}{Xm_1} + \frac{X_2}{Xm_2} + \cdots + \frac{X_n}{Xm_n}\right) * Ym \quad (1)$$

Where: Y represents the precipitation of station Y to be estimated. The variables X_1, X_2, ..., X_n correspond to the precipitation observed in neighboring stations for the month or year to be filled in, Ym denotes the average precipitation of station Y, and Xm_1, Xm_2, ..., Xm_n represent the average precipitation in neighboring stations.

Five neighboring stations with a minimum of 10 years of consistent data were selected to fill the gaps in the data from the focus station (Itiquira station).

Consistency analysis

After completing the series, it is necessary to analyze its consistency from a regional perspective, that is, to verify the degree of homogeneity of the data available at a station in relation to the observations recorded at neighboring stations. The Double Mass method, developed by the Geological Survey (USA), is a customary practice adopted in Brazil and is valid only for monthly or annual series (Tucci, 2015).

The Double-Mass Method is based on the principle that the graph of one accumulated quantity, plotted against another accumulated quantity during the same period, must be a straight line whenever the quantities are proportional. The slope of the line adjusted in this process represents the proportionality constant (Collischonn; Dornelles, 2013).

RESULTS AND DISCUSSIONS

Station failures ranged from 0.2% to 2.5%. The Alto Garças (01653004) and Vale Rico (01654005) stations had the lowest number of failures, while the Fazenda Taquari (01853000) station had the highest number of failures, as shown in **Table 1**.

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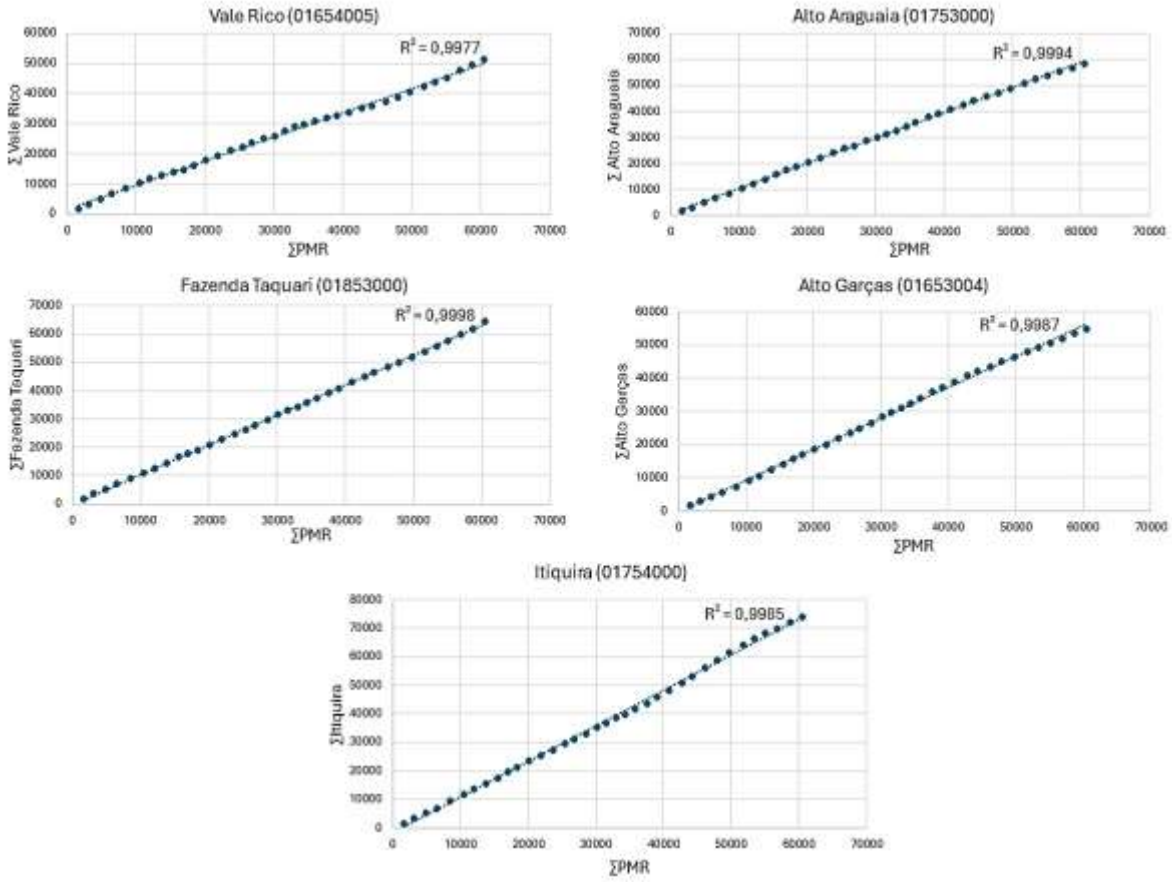
Table 1. Rain gauge data

Code	Station	Start	End	Amount of data		Failed months	% failure
				Year	month		
1653004	Alto Garças	1977	2023	46	552	1	0.2%
1654005	Vale Rico	1984	2023	39	468	1	0.2%
1753000	Alto Araguaia	1964	2023	59	708	10	1.4%
1754000	Itiquira	1966	2023	57	684	2	0.3%
1853000	Fazenda Taquari	1969	2023	54	648	16	2.5%

The results indicated that the gaps were adequately filled at the five rainfall gauge stations (**Figure 2**). The Vale Rico (01654005) station, with only one filled fault, and the Alto Garças (01653004) station, also with a single filled fault, showed a very clear linear trend in their analyses. The Alto Araguaia (01753000) and Fazenda Taquari (01853000) stations, with 10 and 16 filled faults, respectively, also showed strong linear trends. The Itiquira (01754000) station, with two filled faults, followed the same pattern. These results indicate that the filling method used was effective in maintaining data consistency in the time series analyzed.

Figure 2. Graphical representation of the double mass analysis of monthly data from rainfall stations



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Results analysis reveals that the regional weighting method performed well in filling data gaps, indicating consistency between the rainfall time series. Notably, the Fazenda Taquari (01853000) station, which had the highest number of gaps to be filled, exhibited a strong linear trend. This result can be attributed to the appropriate selection of neighboring stations and the homogeneity of the data used. This result suggests that the regional weighting method approach was successful, and that gap-filling was performed reliably.

CONCLUSION

Filling gaps in historical rainfall time series, conducted using the regional weighting method, proved to be an effective methodology for filling gaps in the five rain gauge stations studied.

Confirmation of the consistency of the data entered, as evidenced by the linear trends obtained using the Double-Mass Method, confirms the technique's suitability for analyzing rainfall in the Southeast region of Mato Grosso.

The applied methodology offers a solution to the flaws found in the time series and contributes to complementing the database for future studies related to hydrological modeling in the region.

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