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Original Article

Irregularity and time-series trend analysis of rainfall in Baybay City, Leyte, Philippines

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ABSTRACT

This study examined rainfall trends and variability in Baybay City, Leyte, Philippines, from 1991 to 2020. Utilizing the Mann–Kendall test, Sen's slope method, and Coefficient of Variation (CV), the analysis reveals a 26.41% increase in mean annual rainfall compared to earlier decades. However, annual and seasonal trends lack statistical significance, suggesting random fluctuations. Seasonal variability is highest during MAM (March, April, May), with CV of 59.76% followed by DJF (December, January, February), with a CV of 40.72%. These fluctuations are influenced by transitional monsoons and the intertropical convergence zone (ITCZ). Despite Baybay City's Type IV climate with year-round rainfall distribution, fluctuations reflect natural variability and extreme weather events. The findings emphasize the need for adaptive measures in water resource management, agriculture, and infrastructure to address climate variability and ensure community resilience.

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INTRODUCTION

The Philippines experiences distinct weather and climate conditions influenced by its geographic location and prevailing wind systems that vary across seasons (Villafuerte et al., 2014). Baybay City, located in the province of Leyte, falls under the Type IV climate category, characterized by relatively even rainfall distribution throughout the year without a pronounced dry or wet season (Coronas, 1920). This geographical and climatic context makes Baybay City susceptible to seasonal variations, with rainfall critical in supporting agriculture and local livelihoods.

Rainfall analysis, which involves studying patterns and trends in precipitation over time, is essential for understanding changes in the amount and frequency of rainfall and extreme weather events (Ioannidis et al., 2015). Such analysis is particularly relevant for Baybay City, where rainfall significantly impacts agricultural productivity and economic stability. Senapati (2020) argues that agricultural production is characterized by irregularity owing to its significant dependency on prevailing weather conditions. While irrigation offers a reliable and predictable water supply to meet the needs of plants on a regular basis, rain-fed agricultural systems are subject to the whims of unpredictable atmospheric processes. According to Dahal et al (2018), this makes rain-fed agricultural systems susceptible to variations in rainfall and exposes them to potential risks and challenges.

Despite its importance, no published studies have analyzed long-term rainfall trends specific to Baybay City. This study seeks to fill this gap by examining rainfall trends from 1991 to 2020. Seasonal and annual trends were analyzed using the Mann–Kendall test and Sen's slope method, while the Coefficient of Variation (CV) was used to assess rainfall variability. Understanding how rainfall has changed over the years is crucial for effective water resource management, agricultural planning, and mitigating the impacts of climate variability.

MATERIALS AND METHODS

Site Description

Baybay City, Leyte, is located on the western shoreline of Leyte and faces the Camotes Islands (Figure 1). The City of Baybay is recognized for its large land area of 459.3 square kilometers as per data from the Land Management Bureau of the Department of Environment and Natural Resources, making it one of the largest areas in the Eastern Visayas region. It comprises 92 barangays, with 24 classified as urban and 68 as rural (City of Baybay, Leyte, 2016).

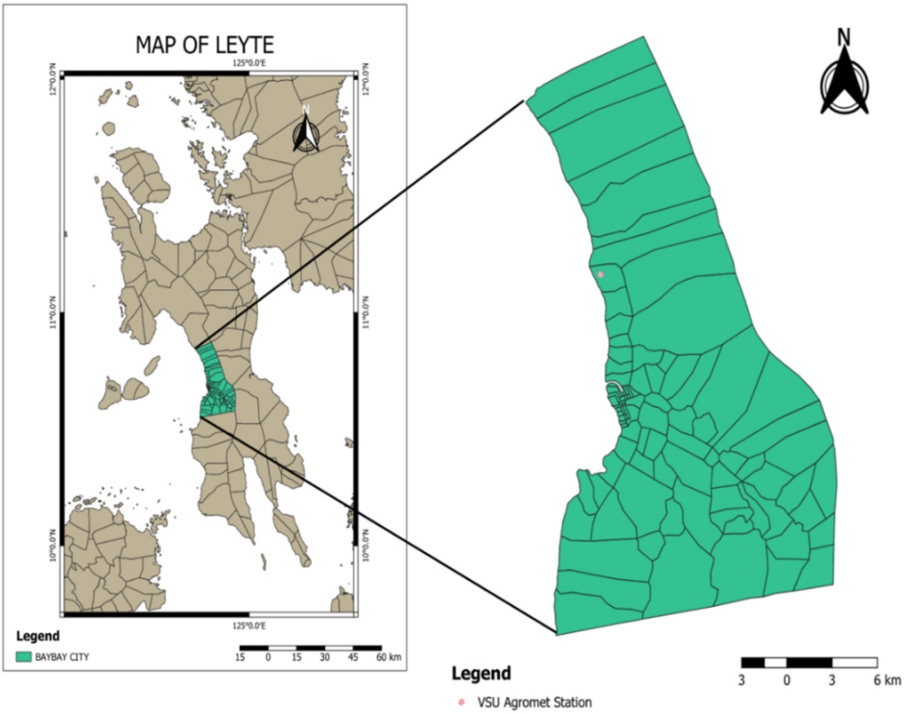

Figure 1. Map of the City of Baybay indicating the study area

Data Gathering

Thirty years of historical monthly rainfall of Baybay City, Leyte, from 1991-2020 were collected from the VSU Agromet Station. The gathered data were structured and organized in a tabular format using Microsoft Excel software. The dataset was complete, with no missing values, eliminating the need for data interpolation or imputation. The historical data were accumulated annually and seasonally for variability and trend analysis. To analyze the rainfall trends across different seasons, the year was divided into four quarters: JJA (June, July, August), SON (September, October, November), DJF (December, January, February), and MAM (March, April, May).

Rainfall Analysis

Variability of rainfall

The coefficient of variation (CV) was used to assess rainfall variability annually and seasonally for 30 years. The mean and the standard deviation were calculated first to obtain the CV. A higher CV indicates greater variability in rainfall for a particular year or season, while a lower CV suggests less variability and more consistent rainfall patterns. The CV for each series was calculated by the following formula (Achite et al., 2021):

$$CV = \frac{\sigma}{\mu} x100 \qquad [1]$$

Where, σ was the standard deviation for seasonal and annual rainfall and μ was was the mean for seasonal and annual rainfall. The degree of variability in rainfall was classified as less (CV<20%) moderate (CV≥20%≤30%) and highly variable (CV>30%) according to the estimated CV values.

Intensity of the Trend

Theil-Sen (TS) estimator was used to assess the trend's intensity. In computing the TS estimator, the initial step involved determining the values of the gradient Qi based on N pairs of data (Rahman & Abdullah, 2022):

$$Q_i = \frac{x_j - x_i}{j - i} \text{ for i = 1,2,3,......N} \qquad [2]$$

xj and xi were data values at time j and i (j > i), respectively. If there were n values of xj in the time series, there were N = n(n-1)/2 slope estimates. The N value of Qi were sorted from smallest to largest. Then Sen's Slope used median Qi (Q_{med}), which was calculated as follows (Vivekanandan, 2007):

$$Q_{med} = Q_{(\frac{N+1}{2})} \qquad \text{if N = odd} \qquad [3]$$

$$Q_{med} = \frac{Q_{(\frac{N}{2})} + Q_{(\frac{N+1}{2})}}{2} \qquad \text{if N = even} \qquad [4]$$

Positive value of Qi indicates an upward or increasing trend and a negative value indicates downward or decreasing trend in the time series.

Significance of the Trend

Ma nn-Kendall (MK) test was used to obtain the significance of the trend. The test was based on two hypotheses: one was null (H_0), and the other was alternate (H_1). The H_0 represented a non-significant trend, while H_1 indicated a significant increasing or decreasing trend in rainfall data. The significance of the trend was calculated by (Vivekanandan, 2007):

$$S = \sum_{k=1}^{n=1} \sum_{j=k+1}^{n} \operatorname{sign}(x_j - x_k) \qquad [5]$$

The value of $\operatorname{sign}(x_j - x_k)$ was computed as follows:

$$\operatorname{sign}(x_j - x_k) = \begin{cases} +1 (x_j - x_k) > 0 \\ 0 (x_j - x_k) \quad = 0 \\ -1 (x_j - x_k) < 0 \end{cases} \qquad [6]$$

RESULTS AND DISCUSSION

Variability of Rainfall

Table 1 presents the mean annual and seasonal rainfall variability of Baybay City, Leyte. The seasonal rainfall variability is formulated quarterly each year into DJF (December, January, February), MAM (March, April, May), JJA (June, July, August), and SON (September, August, November).

Table 1. Descriptive statistics of the annual and seasonal rainfall during 1991-2020

Rainfall Pattern	Mean (mm)	CV (%)	Minimum (mm)	Maximum (mm)
Annual	3160.26	26.00**	1690	4879
Seasonal				
DJF	1016.78	40.72***	310.80	1880.30
MAM	453.28	59.76***	78.30	1250.30
JJA	774.22	26.60**	244.90	1218.10
SON	915.97	27.79**	427.20	1678.80

CV is Coefficient Variation, *indicates less variability when CV<20%, **is moderate variability when CV ≥ 20% ≤ 30%, ***is high variability when CV>30%

According to PAGASA (2018), rainfall patterns in the Philippines have exhibited spatial variations. Notable increasing trends have been observed in the central regions of Luzon, the eastern part of Visayas, and the northeastern and southwestern sections of Mindanao, with rates ranging from 10mm per decade to over 40mm per decade. These trends in annual total rainfall are linked to extreme rainfall events.

From 1991 to 2020, Baybay City recorded an average annual rainfall of 3,160.26mm (Figure 2), ranging from 4,879mm to a minimum of 1,690mm. Data from 1965 to 2000, collected by various weather substations across the archipelago and analyzed by NAMRIA for BAR-SAIL, estimated an average annual rainfall of about 2,500mm for Baybay City (Lgubaybay, 2013). This comparison reveals a clear increase in the city's mean annual rainfall, rising from 2,500mm during 1965-2000 to 3,160.26mm from 1991-2020, showing an increase of 26.41%. According to Villarin et al., 2016, historical data from 1951 to 2008 reveals a rising trend in both the intensity and frequency of extreme rainfall events across various regions of the Philippines. Projections of future climate changes, based on the 1971–2000 baseline period, suggest that by the 2020s (2006–2020), temperatures may increase by 1.0°C to 1.1°C, with a further rise to 1.8°C to 2.2°C by the 2050s. Additionally, the dry season (March to May) is expected to become drier in most areas, while the wet or southwest monsoon season (June to November) is likely to experience increased rainfall, ranging from 0.9% to 63%. Moreover, by both the 2020s and 2050s, the frequency of dry days across the country is anticipated to rise, along with a greater occurrence of heavy rainfall days, particularly in Luzon and the Visayas (Villarin et al., 2016).

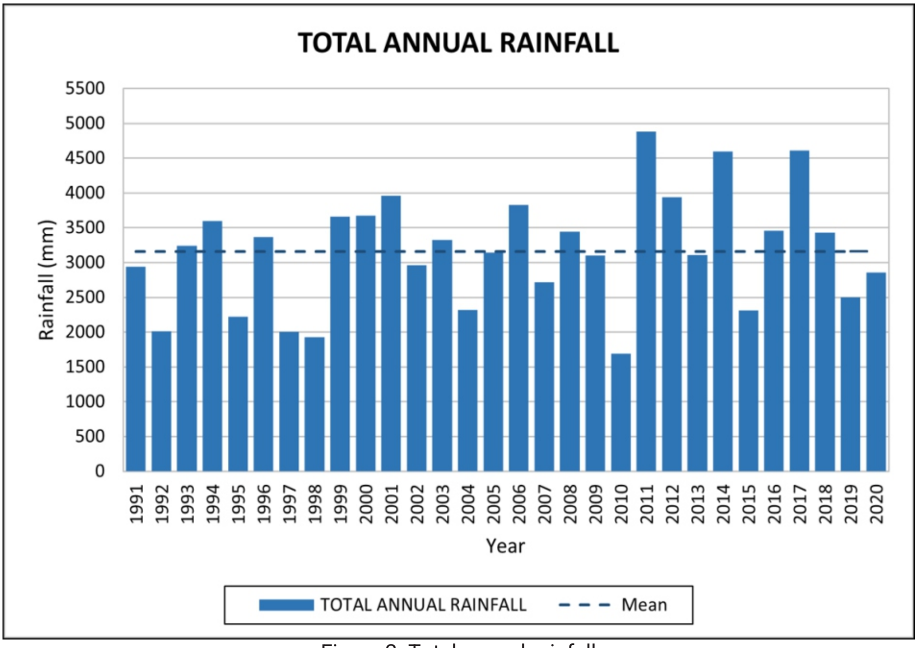

Figure 2. Total annual rainfall

At the seasonal level, the period of DJF exhibits the highest mean seasonal rainfall with 1016.78mm (Figure 3a), followed by SON with a rainfall mean of 915.97mm (Figure 3d), and by JJA, which records a mean rainfall of 774.22mm (Figure 3b), MAM, has the lowest mean seasonal rainfall at 453.28mm (Figure 3c). These figures align with the months during which the city experiences the most significant rainfall. Specifically, January to February and July to December witness elevated rainfall levels, while the summer months from March to May exhibit comparatively lower rainfall levels (Lgubaybay, 2013).

The coefficient of variation (CV) provides valuable insights into the variability of rainfall across different seasons. During DJF, the CV is notably high at 40.72%, indicating considerable fluctuations in rainfall levels. This trend continues into MAM, where the CV remains elevated at 59.76%, signifying continued unpredictability in rainfall patterns. Conversely, JJA experiences a decrease in CV to 26.60%. Similarly, SON maintains a moderate CV of 27.79%.

The March-April-May (MAM) season is typically the warmest in the Philippines, with May often recording the highest temperatures. This season is characterized by a gradual transition from the dry season to the onset of the rainy season, influenced by the weakening of the northeast monsoon and the gradual establishment of the southwest monsoon (PAGASA). The increased variability in the CV observed during MAM may be attributed to the transitional phase. This period is often characterized by unpredictable weather patterns as the climate shifts from one extreme to another (Chou et al., 2013). Furthermore, the higher CV of DJF is attributed to the significant shifts in weather patterns due to the southward migration of the intertropical convergence zone (ITCZ) and the influence of monsoons (Qian et al., 2013). Additionally, the annual CV of Baybay City falls under the moderate variability with 26%.

In the seasonal level for Baybay City, the highest maximum rainfall occurs during DJF, reaching 1880.30mm, followed by SON with 1678.80mm, MAM with 1250.13mm, and JJA with 1218.10mm. Regarding the minimum seasonal rainfall, Baybay City records the highest minimum during SON at 427.20mm, followed by DJF with 310.80mm, JJA with 244.90mm, and MAM with 78.30mm. The observed maximum and minimum seasonal rainfall values show the potential for extreme weather events, such as heavy rainfall, especially during the DJF season.

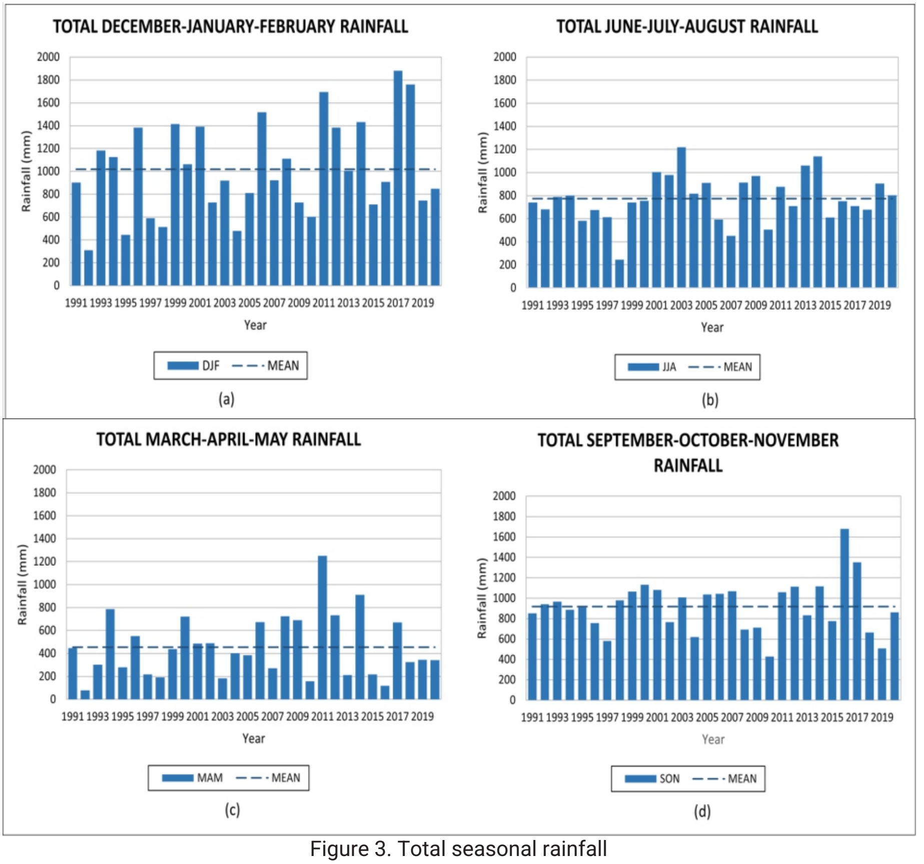

Figure 3. Total seasonal rainfall

Trend Analysis

Table 2 presents trends in annual totals and seasonal rainfall totals across four distinct seasons: DJF (December, January, February), MAM (March, April, May), JJA (June, July, August), and SON (September, October, November).

Table 2. Trends of annual and seasonal rainfall totals

Rainfall Pattern	Q_{med} (mm/year)	Z
Annual	19.12	1.11
Seasonal		
DJF	14.42	1.44
MAM	1.68	0.25
JJA	4.31	0.96
SON	3.75	0.46

Qmed is sen's slope (change per year), Z is mann-kendall's trend test, *indicates statistically significant trend when Z>1.96, is non-significant when Z<1.96

Table 2 reveals that the annual rainfall exhibits a positive Qmed value of 19.12mm/year, indicating an annual increase of 19.12mm. However, with a Z value of 1.11, which is below the threshold of 1.96, this trend is not statistically significant. Therefore, the observed increase in rainfall may be attributable to random fluctuations rather than a consistent pattern.

These random fluctuations can be attributed to natural climate variability, influenced by significant climate factors. As shown in Figure 4, the city recorded the lowest annual rainfall in 2010, coinciding with an El Niño event that occurred from 2009 to 2010 in the Philippines. This event was characterized by below-normal rainfall conditions and drought, which persisted until the summer of 2010 (Climate Gov, 2011). The El Niño-Southern Oscillation (ENSO) significantly influenced climate patterns during that period, leading to various impacts on agriculture and water resources (Yumul et al., 2010).

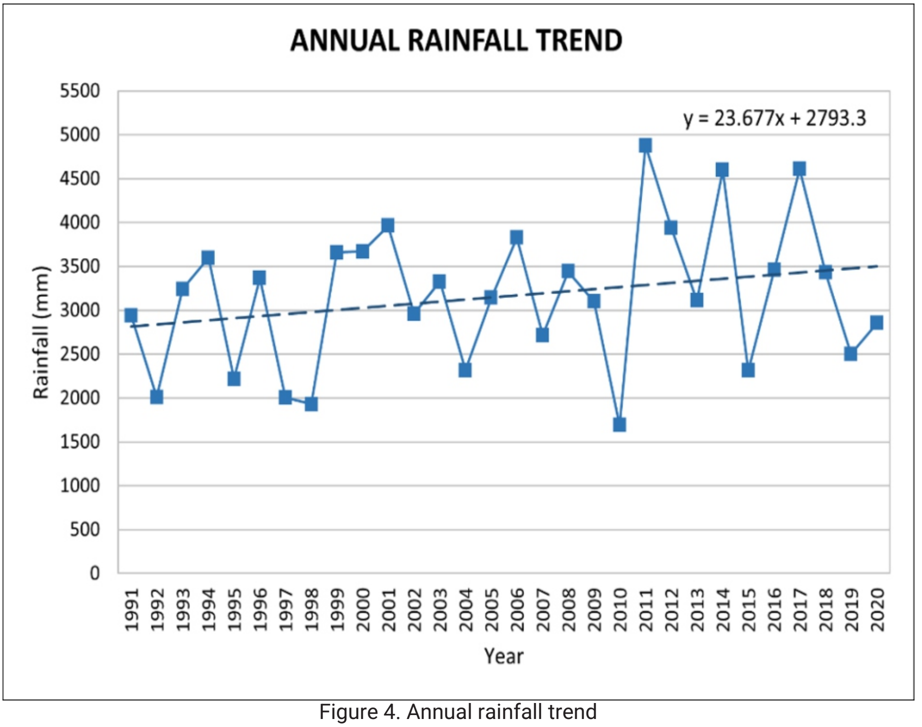

Figure 4. Annual rainfall trend

However, after the dry conditions of 2010, rainfall levels sharply increased in 2011, which recorded the highest annual rainfall. This was due to widespread flooding in the eastern part of the Philippines from late December 2010 to early January 2011. The flooding was attributed to the tail end of a cold front, which brought significantly heavier rainfall than usual. While the eastern part of the country typically experiences rain during this time of the year, the recorded rainfall was nearly twice the normal amount (Aben et al., 2011).

Similarly, the seasonal trends as shown in Figure 5 follow the same pattern seen in annual rainfall, with all four seasons showing positive Qmed values, signifying an increase in rainfall per year. Notably, the most significant increase was observed during the DJF season, with a rate of 14.42mm/year. This trend corresponds to the period when the city typically experiences its heaviest rainfall. As shown in Figure 5, an extreme rainfall event occurred during the year 2017 due to Typhoon Urduja, which brought intense rainfall and triggered landslides, particularly impacting Eastern Visayas, including Leyte (PAGASA).

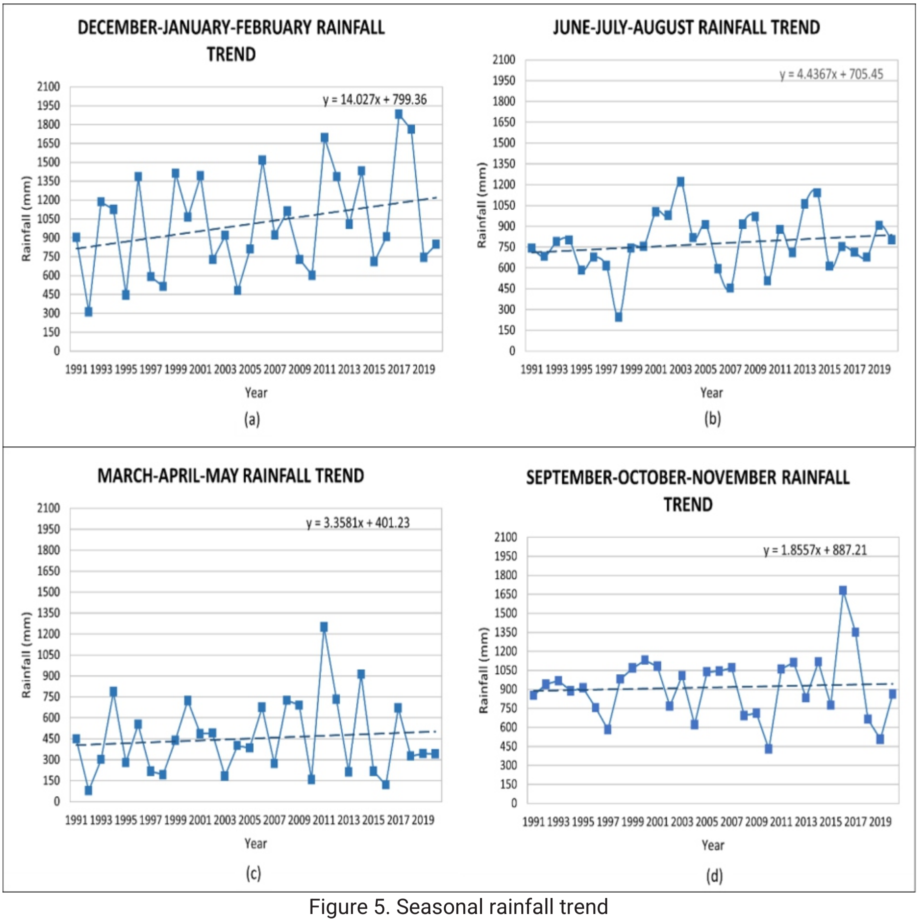

Figure 5. Seasonal rainfall trend

This is followed by JJA at 4.31mm/year, SON at 3.75mm/year, and MAM at 1.68mm/year. Nonetheless, the Z values for DJF, MAM, JJA, and SON are 1.44, 0.25, 0.96, and 0.46, respectively—all below 1.96. This indicates that these trends are not statistically significant, suggesting that the observed variations in rainfall may be due to random fluctuations rather than a discernible and consistent pattern. This is consistent with the values obtained in CV, where the annual and seasonal ranges between moderate and high CV indicate a lower likelihood of a consistent pattern in rainfall.

Baybay City falls under the Type IV climate category, characterized by an even distribution of rainfall throughout the year without a distinct dry or wet season. This classification suggests that variability is still expected while there is no significant seasonality in rainfall. The observed data showing variations in rainfall trends without consistent patterns aligns with this classification. It indicates that while rainfall is generally distributed throughout the year, the amounts can fluctuate due to various factors. Thus, while Type IV implies a lack of distinct wet and dry seasons, it does not guarantee uniformity in rainfall, reflecting the natural variability inherent in this climate type.

CONCLUSION

Over the past decades, there has been a marked increase in mean annual rainfall, rising from 2,500mm in the period 1965–2000 to 3,160.26mm in the period 1991–2020, reflecting a 26.41% increase. This trend corresponds with PAGASA's 2018 observation of increasing rainfall in certain regions of the Philippines, particularly in Eastern Visayas, attributed to extreme rainfall events. However, the annual increase of 19.12 mm and the seasonal increases, such as 14.42mm for DJF, lack statistical significance, suggesting these variations may be due to random fluctuations rather than consistent trends.

Seasonally, DJF records the highest mean and maximum rainfall, with significant variability indicated by a CV of 40.72%. This elevated variability during DJF can be attributed to the influence of the intertropical convergence zone (ITCZ) and monsoons. MAM exhibits the highest variability (CV of 59.76%) due to its transitional nature, marking the shift from the dry northeast monsoon to the wet southwest monsoon. In contrast, JJA and SON show relatively moderate variability, reflecting more stable rainfall patterns during these seasons.

Baybay City's Type IV climate classification, characterized by an even distribution of rainfall throughout the year without distinct wet or dry seasons, provides context to the observed variability. While rainfall is generally distributed year-round, seasonal and annual total fluctuations indicate the influence of natural variability and weather patterns, such as monsoons and extreme events. The potential for extreme weather, particularly during DJF, underscores the need for adaptive measures in agricultural planning such as providing flood-resistant crops and infrastructure development, including proper irrigation systems, drainage improvements, and water reservoirs, to mitigate impacts on local communities.

Although the increasing rainfall trends in Baybay City are consistent with the overall rainfall trends happening in various parts of the Philippines, the lack of statistical significance and high variability suggest that long-term climatic shifts and natural variability drive these changes. These findings highlight the importance of continuous monitoring, climate-resilient planning, and adaptation strategies to address the challenges posed by unpredictable rainfall and extreme weather events. Incorporating PAGASA's climate projections into planning can enhance adaptation strategies, while collaboration among stakeholders will support science-based policies for sustainable agriculture.

While the analysis provides valuable insights into rainfall variability and trends in Baybay City, it is important to note that the findings are based on data from a single station. This may introduce potential biases influenced by localized factors such as elevation, nearby land use changes, or microclimatic conditions. These site-specific influences could affect the generalizability of the results to broader areas. Additionally, although the dataset showed no missing values, the possibility of instrumentation changes or maintenance-related inconsistencies over the 30-year period may also affect data uniformity.

RECOMMENDATIONS

For further study, it is recommended to gather historical rainfall data from multiple stations rather than relying solely on data from a single station.

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AUTHOR CONTRIBUTIONS

MCA conceptualization, methodology, formal analysis, visualization, Writing: original draft. MGS writing: review and editing, investigation, validation, supervision.

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AVAILABILITY OF DATA AND MATERIALS

The data were acquired from the VSU Agromet Station, no primary data was produced.

ETHICAL CONSIDERATIONS

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare no conflict of interest.

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