OPEN ACCESS
Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 04 | Issue 06 | Nov.-Dec. | 2024
Journal homepage: https://gjrpublication.com/gjrals/

Research Article

# Potential impacts of altering heavy precipitation events on crop production in Dong Thap province over three past decades

*Hoang Thi Viet Ha

Dong Thap University, Vietnam

DOI: 10.5281/zenodo.14192635 Submission Date: 28 Sept. 2024 | Published Date: 20 Nov. 2024

***Corresponding author: Hoang Thi Viet Ha**
Dong Thap University, Vietnam
783, Pham Huu Lau Str., 6 Ward, Cao Lanh City, Dong Thap Province, Vietnam.

## Abstract

*This study assesses heavy precipitation trends for in Dong Thap province of Vietnam based on daily precipitation data applying the Mann-Kendall test and Sen's slope estimate, in order to detect the change trends in the period 1985-2021. The results of the analysis show that the number of heavy precipitation events (20 ≤ R < 50) at Cao Lanh and Hong Ngu stations is relatively high, with an average of 18.7 and 15.7 days per year while the number of precipitation events from 50 ≤ R ≤ 100 mm is relatively low, with an average of 3.5 and 2.9 days per year. However, the extreme precipitation intensity (Rmax) has recorded 82.1 and 73.1 mm and detected an increasing trend in Cao Lanh station and decreasing in Hong Ngu station. The result indicates a change in the characteristics of heavy precipitation in Dong Thap province over the past three decades. The findings will provide valuable insights into the impacts of heavy precipitation events on crop production in the region and will support policymakers and farmers to develop solutions to mitigate the effects of these events.*

**Keywords:** *Heavy precipitation, crop production, yield loss, non-parameters, trend.*

## 1. Introduction

Climate change is a pressing global issue that has far-reaching impacts on various aspects of our lives, including agriculture (Singh et al., 2013; Tian et al., 2021). The increasing frequency and intensity of heavy precipitation events are of particular concern (Mondal and Mujumdar, 2015), as they can have devastating effects on crop production and food security (Pingale et al., 2014; Rosenzweig et al., 2002). Heavy precipitation events can lead to soil erosion, landslides, and flooding, which can result in significant losses to agricultural production (Gitz et al., 2016; Guido et al., 2020).

The International Panel on Climate Change (IPCC) has identified climate change as a major driver of changes in heavy precipitation events worldwide (Iizumi, et al., 2010; Tramblay et al., 2012). The increasing frequency and intensity of heavy precipitation events have been reported in various regions, including continental America (Singh et al., 2013; Seleshi and Zanke, 2004), the Upper Oueme River Valley (Attogouinon et al., 2017), the Black Sea Western Coast (Croitoru et al., 2013), Northern Ethiopian Highlands (Adamseged et al., 2019) and in sub-Saharan Africa by Guido et al. (2019. These changes have been attributed to the intensification of the hydrological cycle, which has increased the risks of both droughts and heavy precipitation events to agriculture (Adamseged et al., 2019; Gitz et al., 2016; Li et al., 2019; Vogel et al., 2019).

Extreme precipitation events can have negative impacts on crop production, particularly in regions with poorly drained lowlands (Irmak, 2014; Patil et al., 2016). Studies have shown that heavy precipitation can reduce maize yields by up to 17% in regions with poorly drained soils (Li et al., 2019). The effects of heavy precipitation on crop production have been under-studied, which are well-documented climatic-impact drivers of crop production (Anderson et al., 2021).

Dong Thap province, located in the Mekong Delta of Vietnam, is one of the main agricultural production provinces in the region (Dinh and Dang, 2021). The province is a land plain with relatively low terrain, making it vulnerable to crop loss due to heavy precipitation events (Lee and Dang, 2019). The agricultural sector in Dong Thap province is a significant contributor to the local economy, with rice being the main crop grown in the region.

The aim of this study, therefore, is to analyze and assess heavy precipitation event trend using the Mann-Kendall test and Sen's slope estimate to provide early warnings and minimize the negative effects of heavy precipitation events on crop production in Dong Thap province over the past three decades (1985-2021).

## 2. Materials and methods

## 2.1 Study area

Dong Thap is a province located in the Mekong Delta region of southern Vietnam, in the western part of the South Central (Figure 1). It is one of the three provinces with the largest area of cultivated land in the Plain of Reeds (Dinh and Dang, 2022). The province is situated at a latitude of 10°07' to 10°58' north and a longitude of 105°12' to 105°56' east, bordering Prey Veng Province (Cambodia) to the north, Vinh Long and Can Tho cities to the south, An Giang Province to the west, and Long An and Tien Giang provinces to the east (Figure 1).

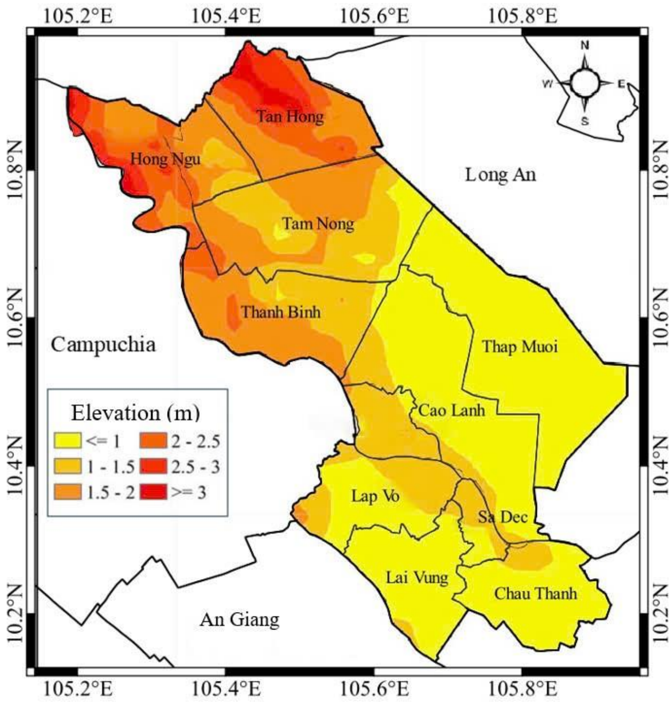


**Fig. 1:** The map of study area

The province is divided into 12 administrative units, with Cao Lanh as the provincial capital. Dong Thap Province is divided into two regions by the Tien River which includes the districts of Hong Ngu, Tan Hong, Tam Nong, Thanh Binh, Cao Lanh, Thap Mươi, and the city of Cao Lanh, with a relatively flat terrain while the south bank, which includes the districts of Lap Vo, Lai Vung, Chau Thanh, and Sa Dec town, with a terrain shaped like a basin, sloping from both sides of the river towards the center (Lee and Dang, 2020). The province has an average elevation of 0.7 to 1.5 meters above sea level, with the highest point at 3.6 meters in some areas of the districts of Hong Ngu, Tan Hong, and the lowest point at 0.7 meters in the districts of Thap Mươi, Chau Thanh, Lai Vung, and Lap Vo. The terrain is generally flat, especially in the Dong Thap Muoi area, with a height difference of about 2.0 meters (Dinh and Dang, 2022). The area is located in the tropical monsoon climate region, influenced by two main wind seasons namely the Northeast monsoon and the Southwest monsoon (Lee and Dang, 2020). The Northeast monsoon brings hot air, resulting in a dry season, while the Southwest monsoon brings moisture, contributing to abundant precipitation in the region during the wet season (Dinh and Dang, 2022). The province receives an average annual precipitation of approximately 1504.1 mm, with the wet season typically occurring from May to November, accounting for around 90% of the annual precipitation (Figure 2).

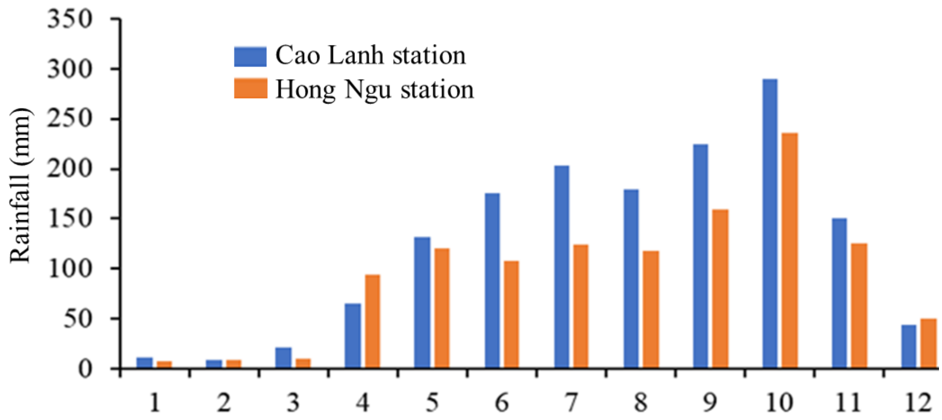


**Figure 2:** Mean monthly precipitation at stations in the study area for the period of 1985-2020

The highest precipitation is usually recorded in October, with an average precipitation of 289.3 mm in Cao Lanh and 235.4 mm in Hong Ngu (Figure 2). The dry season, which begins in December and ends in April of the following year, accounts for around 10-15% of the annual precipitation, with the lowest precipitation typically recorded in February (Figure 2).

## 2.2 Precipitation data collection for detecting change trends

To investigate the changes in precipitation patterns, the study used daily precipitation data from 1985 to 2021 from two observation stations, Cao Lanh and Hong Ngu. The World Meteorological Organization (WMO) suggests a range of heavy precipitation indices for analyzing changes in precipitation patterns at various scales, including national, regional, and global levels. These indices, outlined in Table 1, have been widely utilized in previous studies (Attogouinon et al., 2017; Lee and Dang, 2020). In this research, a subset of these indices was selected for analysis, including the number of very heavy precipitation events ($20 \leq R < 50$), the number of days with precipitation arrange from $50 \leq R \leq 100$ mm, and the occurrence of maximum precipitation intensity (Rmax).

**Table 1:** Heavy precipitation indices established by the World Meteorological Organization

| Index | Indicator name | Definitions | Units |
|---|---|---|---|
| R10 | Number of heavy precipitation days | Annual count of days when PRCP ≥ D 10mm | days |
| R20 | Number of very heavy precipitation days | Annual count of days when PRCP ≥ D 20mm | days |
| R25 | Number of days above mm | Annual count of days when PRCP ≥ D 25mm | days |
| CDD | Consecutive dry days | Maximum number of consecutive days with RR≤1mm | days |

PRCP is the daily precipitation amount; RR is the daily precipitation amount on day.

These indices were chosen based on a preliminary assessment of precipitation characteristics, such as the timing, intensity, and extent of precipitation, as well as the impact of heavy, very heavy, and extreme precipitation on social and economic activities and particularly agriculture. These sectors are highly susceptible to the effects of heavy precipitation events in the study area, and therefore, it is essential to monitor and analyze these indices to understand the changing precipitation patterns and their implications for the region.

To ensure the reliability of the statistical analysis, we selected precipitation data with less than 10% missing values, allowing us to maintain a robust dataset for trend detection. The Mann-Kendall test and Sen's slope estimate, two widely used statistical methods in hydrometeorology and environmental research (Attogouinon et al., 2017), were employed to identify the monotonic trends in the precipitation data.

The Mann-Kendall test is a non-parametric statistical method used to detect monotonic trends in time series data. The test is based on the correlation coefficient between the data points and their ranks, allowing for the detection of trends in the presence of autocorrelation (Lee and Dang, 2020). The test statistic is calculated as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{Sign}\,(X_j - X_i) \quad (1)$$

Where Sign $(X_j - X_i)$ is defined based on formula (2)

$$\text{Sign}\,(X_j - X_i) = \begin{cases} +1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{cases} \quad (2)$$

With $X_j$, $X_i$ are the annual data series and j, i with the condition is j > i.

and variance (Var) is defined by formula (3).

$$\text{Var}(S) = \frac{1}{18}\left[\, n(n-1)(2n+5) - \sum_{j=1}^{m} t_j(t_j - 1)(2t_j + 5)\right] \quad (3)$$

In the formula (3), m and $t_j$ are the number of the tied groups and the number of ties to extent j in the data series.
For the sample size n > 10, the values of S and Var(S) are defined by the statistics of standard test ($Z_s$) and, $Z_s$ is given follow as:

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases} \quad (4)$$

And S in the formula (4) is calculated by formula (5)

$$\tau = \frac{S}{D} \quad (5)$$

D in Formula (5) is defined by formula (6)

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{m} t_j(t_j - 1)\right]^{\frac{1}{2}} \left[\frac{1}{2}n(n-1)\right]^{\frac{1}{2}} \quad (6)$$

The statistic $Z_s$ test is applied to detect the monotonous tendencies. Where $Z_s$ in formula (4) will present an upward trend if $Z_S$ is positive, otherwise $Z_S$ will describe a downward trend (Attogouinon et al. 2017).

The Sen's slope is defined as follow:

$$\beta = \text{Median}\left(\frac{X_i - X_j}{i - j}\right) \quad \text{with } j < i \quad (7)$$

where $X_i$, $X_j$ are data series at time scales $t_i$ and $t_j$, respectively.

To identify the monotonic trends in heavy precipitation patterns, a statistical analysis was conducted using the Mann-Kendall test and Sen's slope estimator with a 95% confidence level. This approach allowed us to determine whether the null hypothesis of no trend could be rejected in favor of the alternative hypothesis of a significant trend. Specifically, if the absolute value of the Sen's slope estimator (|Zs|) exceeded the critical value of 1.96, the null hypothesis of no trend was rejected, indicating the presence of a statistically significant trend in the heavy precipitation data (Lee and Dang, 2020).

## 3. Results and discussion

### 3.1 Basic statistical characteristics of precipitation variables

The basic statistical characteristics of rainfall variables (minimum, maximum, and mean) for September, October, and November during the period 1985-2021 at Cao Lanh and Hong Ngu stations are presented in Table 2. The mean rainfall values for these months are 179.6 mm, 284.8 mm, and 146.5 mm, respectively. The minimum rainfall values for these months are 45.5 mm, 113.8 mm and 31.2 mm, respectively while the maximum rainfall values are 524 mm, 528 mm, and 423 mm. In terms of standard deviation (SD), the values for September, October, and November are 97.3 mm, 93.5 mm, and 91.6 mm, respectively. These values indicate that the rainfall data for these months exhibit relatively high variability. The coefficient of variation (CV) is a measure of the relative dispersion of the data. The CV values for September, October, and November are 0.40, 0.33, and 0.62, respectively. These values suggest that the rainfall data for October and November exhibit relatively low dispersion, while the data for September exhibit relatively high dispersion.

For Hong Ngu station, the minimum, maximum, and mean rainfall values for September, October, and November at Hong Ngu station are also presented in Table 2. The mean rainfall values for these months are 239.9 mm, 282.7 mm, and 146.8 mm, respectively. The minimum rainfall values for these months are 85.4 mm, 110.9 mm and 12.8 mm, respectively while the maximum rainfall values are 303.4 mm, 639.5 mm, and 390.6 mm. In terms of standard deviation (SD), the values for September, October, and November are 69.6 mm, 104.1 mm, and 88.6 mm, respectively. These values indicate that the rainfall data for these months exhibit relatively high variability.

**Table 2**: Basic statistical characteristics of rainfall parameters in Dong Thap province in the period 1985-2021.

| Factors | Min | Mean | Max | SD | CV | Period |
|---|---|---|---|---|---|---|
| Cao Lanh station | | | | | | |
| September | 45.5 mm | 179.6 mm | 524 mm | 97.3 | 0.40 | 1985-2021 |
| October | 113.8 mm | 284.8 mm | 528 mm | 93.5 | 0.33 | 1985-2021 |
| November | 31.2 mm | 146.5 mm | 423 mm | 91.6 | 0.62 | 1985-2021 |
| 20≤ R< 50 | 11 days | 18.7 day | 31 days | 4.96 | 0.25 | 1985-2021 |
| 50≤ R< 100 | 0 day | 3.52 day | 11 days | 2.29 | 0.63 | 1985-2021 |
| Max precipitation | 41.7 mm | 82.1 mm | 147.9 mm | 26.6 | 0.31 | 1985-2021 |
| Hong Ngu station | | | | | | |
| September | 85.4 mm | 239.9 mm | 303.4 mm | 69.6 | 0.39 | 1985-2021 |
| October | 110.9 mm | 282.7 mm | 639.5 mm | 104.1 | 0.37 | 1985-2021 |
| November | 12.8 mm | 146.8 mm | 390.6 mm | 88.6 | 0.60 | 1985-2021 |
| 20≤ R< 50 | 7 days | 15.7 day | 26 days | 4.89 | 0.30 | 1985-2021 |
| 50≤ R< 100 | 0 day | 2.93 day | 7 days | 1.77 | 0.59 | 1985-2021 |
| Max precipitation | 49.2 mm | 73.1 mm | 123.3 days | 21.2 | 0.28 | 1985-2021 |

The coefficient of variation (CV) values for September, October, and November are 0.39, 0.37, and 0.60, respectively. These values suggest that the rainfall data for October exhibits relatively low dispersion, while the data for September and November exhibit relatively high dispersion. Overall, the analysis of the basic statistical characteristics of rainfall parameters in Dong Thap province during the period 1985-2021 suggests that the rainfall data for both Cao Lanh and Hong Ngu stations exhibit relatively high variability, with the exception of October at Hong Ngu station.

For Cao Lanh station, the number of very heavy precipitation events ($20 \leq R < 50$) is relatively low, with an average of 18.7 days per year. This suggests that the station experiences relatively high very heavy precipitation events. The minimum and maximum values for this parameter are 11 day and 31 days, respectively, indicating a relatively narrow range of values (Table 2). The number of days with precipitation ranged from $50 \leq R \leq 100$ mm is also relatively low, with an average of 3.5 days per year. This indicates that the station experiences relatively few moderate to heavy precipitation events. The minimum and maximum values for this parameter are 0 day and 11 days, respectively, indicating a relatively narrow range of values. The occurrence of maximum precipitation intensity (Rmax) at Cao Lanh station is also noteworthy, with a maximum value of 15.7 days recorded in the available period. This suggests that the station is capable of experiencing relatively intense precipitation events.

At Hong Ngu station, the number of very heavy precipitation events ($20 \leq R < 50$) is relatively low, with an average of 15.7 days per year. This suggests that the station experiences relatively few very heavy precipitation events. The minimum and maximum values for this parameter are 7 days and 26 days respectively, indicating a relatively narrow range of values. The number of days with precipitation ranged from $50 \leq R \leq 100$ mm is also relatively low, with an average of 2.9 days per year. This indicates that the station experiences relatively few moderate to heavy precipitation events. The minimum and maximum values for this parameter are 0 day and 7 days, respectively, indicating a relatively narrow range of values. The occurrence of maximum precipitation intensity (Rmax) at Hong Ngu station is also noteworthy, with a maximum value of 12 days recorded in the available period. This suggests that the station is capable of experiencing relatively intense precipitation events.

Overall, the analysis of the statistical characteristics of rainfall parameters at Cao Lanh and Hong Ngu stations suggests that both stations experience relatively few very heavy precipitation events, but may experience more moderate to heavy precipitation events. Additionally, both stations are capable of experiencing intense precipitation events, with Cao Lanh station experiencing more extreme events.

**Table 3:** Trend results of rainfall variables in Dong Thap province in the period 1985-2021.

| Station | Zs | p-value | β |
|---|---|---|---|
| Cao Lanh station | | | |
| September | -0.47 | 0.485 | -0.087 |
| October | 1.63 | 0.218 | 1.000 |
| November | -1.38 | 0.321 | -0.500 |
| 20≤ R< 50 | -0.19 | 0.410 | 0.000 |
| 50≤ R< 100 | 0.84 | 0.145 | 0.029 |
| Max precipitation | 0.72 | 0.186 | 0.286 |
| Hong Ngu station | | | |
| September | -1.61 | 0.425 | -0.212 |
| October | -0.62 | 0.222 | -1.037 |
| November | 1.041 | 0.450 | 0.064 |
| 20≤ R< 50 | -0.36 | 0.323 | -0.031 |
| 50≤ R< 100 | 0.18 | 0.410 | 0.000 |
| Max precipitation | -0.32 | 0.342 | -0.170 |

For the month of October, the Sen's slope estimator (β) is 1.000, indicating an upward trend in rainfall. The p-value is 0.218, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is 1.63, indicating an upward trend. For the month of November, the Sen's slope estimator (β) is -0.500, indicating a moderate downward trend in rainfall. The p-value is 0.321, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -1.38, indicating a downward trend (Figure 3).

For the number of very heavy precipitation events (20 ≤ R< 50), the Sen's slope estimator (β) is 0.000, indicating no trend in the number of very heavy precipitation events. The p-value is 0.410, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -0.19, indicating no trend. For the number of days with precipitation arrange from 50 ≤ R ≤ 100 mm, the Sen's slope estimator (β) is 0.029, indicating a slight upward trend in the number of days with precipitation. The p-value is 0.145, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is 0.84, indicating an upward trend. For the Rmax, the Sen's slope estimator (β) is 0.286, indicating a slight upward trend in the occurrence of maximum precipitation intensity. The p-value is 0.186, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is 0.72, indicating an upward trend.

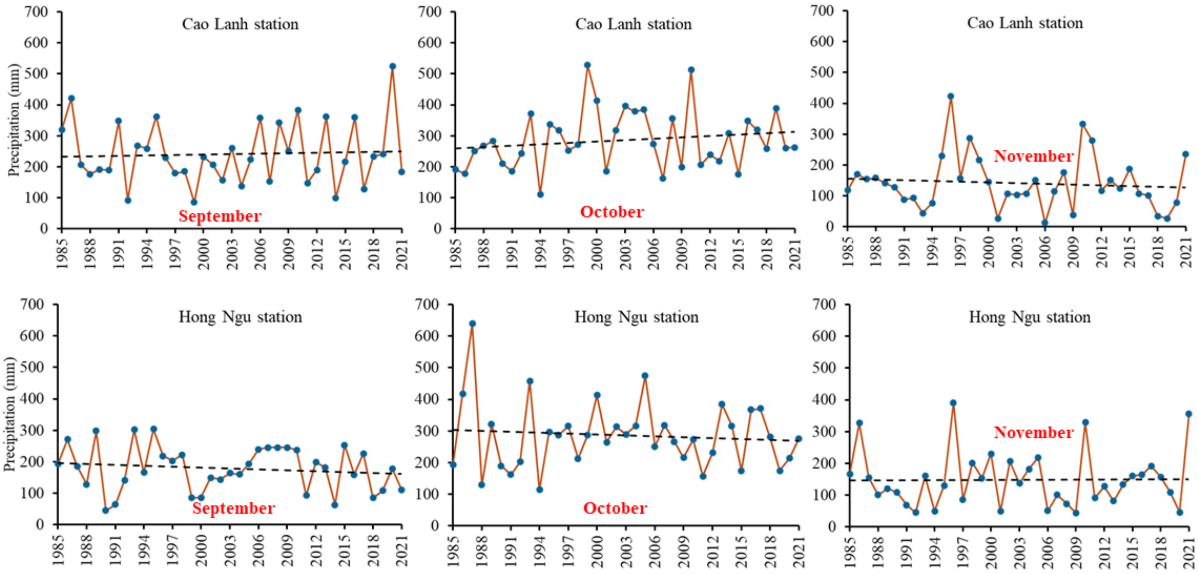


**Figure 3:** Changed trends in precipitation of September, October and November at Cao Lanh and Hong Ngu stations during the period 1985-2021

The changed trends of rainfall variables at Hong Ngu station during the period 1985-2021 are presented in Table 3. For the month of September, the Sen's slope estimator (β) is -0.212, indicating a slight downward trend in precipitation. The p-value is 0.425, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -1.61, indicating a downward trend. For the month of October, the Sen's slope estimator (β) is -1.037, indicating a strong downward trend in rainfall. The p-value is 0.222, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -0.62, indicating a downward trend. For the month of November, the Sen's slope estimator (β) is 0.064, indicating a slight upward trend in rainfall. The p-value is 0.450, indicating that the null hypothesis of no trend cannot be rejected. The Z-S value is 1.041, indicating an upward trend.

For the number of very heavy precipitation events (20≤ R< 50), the Sen's slope estimator (β) is -0.031, indicating no trend in the number of very heavy precipitation events. The p-value is 0.323, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -0.36, indicating no trend. For the parameter 50≤ R< 100, the Sen's slope estimator (β) is 0.000, indicating no trend in the number of days with precipitation. The p-value is 0.410, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is 0.18, indicating no trend. For the Rmax, the Sen's slope estimator (β) is -0.170, indicating a slight downward trend in the occurrence of maximum precipitation intensity. The p-value is 0.342, indicating that the null hypothesis of no trend cannot be rejected. The Zs value is -0.32, indicating a downward trend (Figure 4). Overall, the analysis of the trend results of rainfall variables at Cao Lanh and Hong Ngu stations suggests that both stations experience some degree of trend in rainfall, but the trends are not always significant.

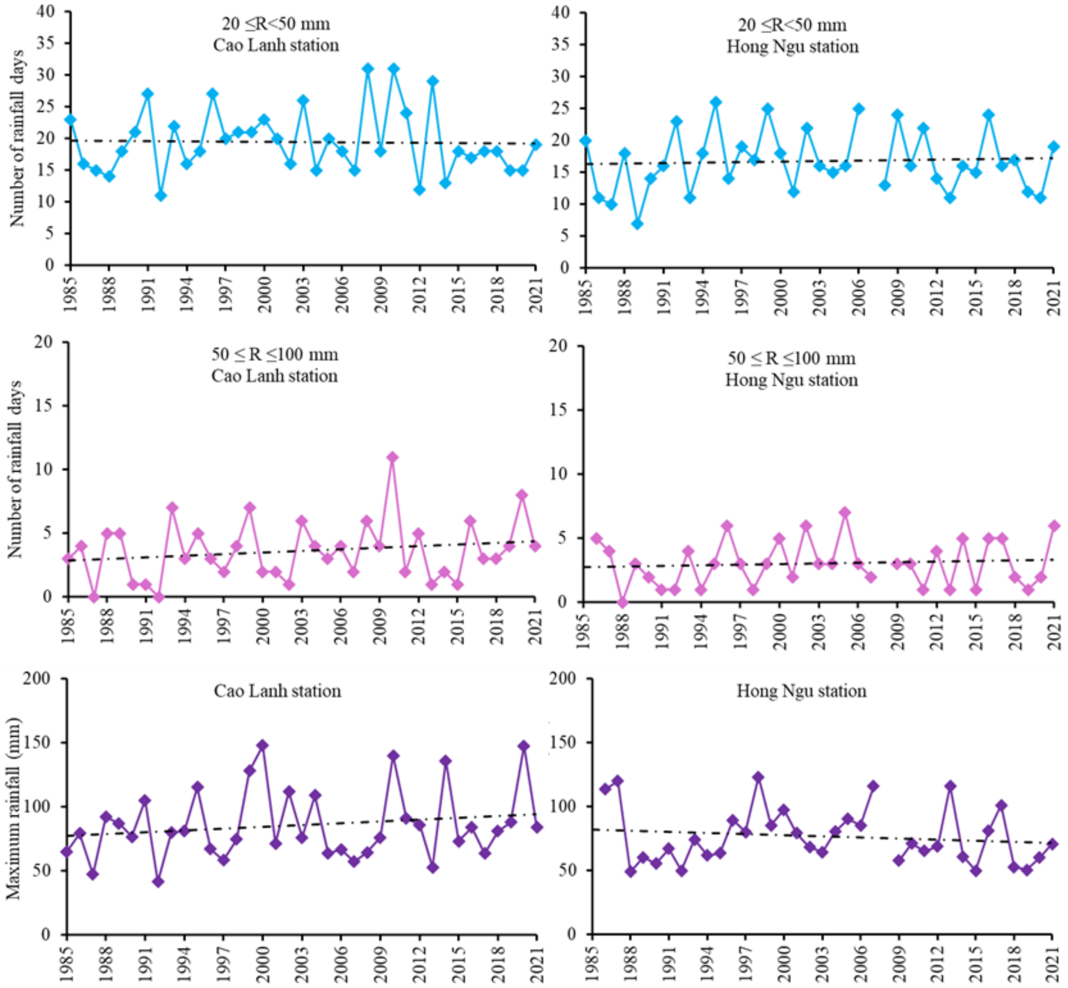


**Figure 4:** Changed trends of the number of very heavy precipitation events (20 ≤ R< 50), the number of days with precipitation arrange from 50 ≤ R ≤ 100 mm and the maximum precipitation intensity at Cao Lanh and Hong Ngu stations during the period 1985-2021

## 4. Conclusion

This study investigated the changed trends in heavy precipitation indices (September, October, November and 20≤R<50, 50 ≤ R ≤ 100 and Rmax) across Dong Thap province of Vietnam applying the Mann-Kendall test and Sen's slope estimator during the period 1985-2021. The results of the study show that the trend of heavy precipitation events in Dong

Thap province over the past three decades has undergone significant changes. The number of heavy precipitation events and precipitation events from $50 \leq R \leq 100$ mm are relatively high and the intensity of extreme precipitation has shown an increasing trend in Cao Lanh station. This result indicates a significant change in the characteristics and intensity of heavy precipitation events in Dong Thap province. This result is of great importance for predicting and managing heavy precipitation events, as well as their impact on agricultural production and the lives of people in Dong Thap province.

## References

1. Adamseged, M.E., Frija, A., Thiel, A., 2019. Dynamics of rural livelihoods and precipitation variability in Northern Ethiopian Highlands. Climate risk management, 25:100195. doi: 10.1016/j.crm.2019.100195
2. Attogouinon, A., Lawin, A.E., Po, Y.N.M., Houngue, R., 2017. Extreme precipitation indices trend assessment over the Upper Oueme River Valley (Benin). Hydrology, 4, p.36. doi:10.3390/hydrology4030036
3. Croitoru, A.E., Chiotoroiu, B.C., Todorova, V.I., Torica, V., 2013. Changes in precipitation extremes on the Black Sea Western Coast. Global and Planetary Change, 102, pp.10-19. doi: 10.1016/j.gloplacha.2013.01.004
4. Dinh, T. K. H.; Dang, T. A. Potential risks of climate variability on rice cultivation regions in the Mekong Delta, Vietnam. Brazilian Journal of Agricultural and Environmental Engineering. v.26, p.348-355, 2022. http://dx.doi.org/10.1590/1807-1929/agriambi.v26n5p348-355.
5. Donat, M., Lowry, A., Alexander, L., O'Gorman, P., Maher, N., 2016. More extreme precipitation in the world's dry and wet regions. Nature Climate Change, 6, pp.508-513. Doi: 10.1038/nclimate2941
6. Gitz, V., Meybeck, A., Lipper, L., Young, CD., Braatz, S., 2016. Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO) Report, 110, pp.2–4.
7. Guido, Z., Zimmer, A., Lopus, S., Hannah, C., Gower, D., Waldman, K., Krell, N., Sheffield, J., Caylor, K., Evans, T., 2020. Farmer forecasts: impacts of seasonal precipitation expectations on agricultural decision-making in sub-Saharan Africa. Climate Risk Management, 30: 100247. Doi: 10.1016/j.crm.2020.100247
8. Iizumi, T., Shiogama, H., Imada, Y., Hanasaki, N., Takikawa, H., Nishimori, M., 2018. Crop production losses associated with anthropogenic climate change for 1981-2010 compared with preindustrial levels. International Journal of Climatology, 38(14). Doi: 10.1002/joc.5818.
9. Lee, S. K.; Dang, T. A. Extreme rainfall trends over the Mekong Delta under the impacts of climate change. International Journal of Climate Change Strategies and Management. v.12, p.639-652, 2020. https://doi.org/10.1108/IJCCSM-04-2020-0032.
10. Li, Y., Guan, K., Schnitkey, G., DeLucia, E., Peng, Bin., 2019. Excessive precipitation leads to maize yield loss of a comparable magnitude to extreme drought in the United States. Global Change Biology, 25(2), pp.2325-2337. Doi: 10.1111/gcb.14628.
11. Mondal, A., Mujumdar, P.P., 2015. Modeling non-stationarity in intensity, duration and frequency of extreme precipitation over India. Journal of Hydrology, 521, pp.217–231. Doi: 10.1016/j.jhydrol.2014.11.071
12. Patil, M.D., Wani, S.P., Garg, K.K., 2016. Conservation agriculture for improving water productivity in vertisols of semi-arid tropics. Current Science, 110(9), pp.1730-1739. Doi: 10.18520/cs/v110/i9/1730-1739
13. Pingale, S.M., Khare, D., Jat, M.K., Adamowski, J., 2014. Spatial and temporal trends of mean and extreme precipitation and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India. Atmospheric Research, 138(1), pp.73-90. Doi: 10.1016/j.atmosres.2013.10.024
14. Rosenzweig, C., Tubiello, F., Goldberg, R., Mills, E., Bloomfield, J., 2004. Increased crop damage in the US from excess precipitation under climate change. Global Environmental Change, 12, pp.197-202. Doi: 10.1016/S0959-3780(02)00008-0.
15. Seleshi, Y., Zanke, U., 2004. Recent changes in precipitation and rainy days in Ethiopia. Journal of Climatology, 24(8), pp.973-983. Doi: 10.1002/joc.1052
16. Singh, D., Tsiang, M., Rajaratnam, B., Diffenbaugh, N.S., 2013. Precipitation extremes over the continental United States in a transient, high-resolution, ensemble climate model experiment. Journal of Geophysical Research (Atmospheres), 118, pp.7063-7086. Doi: 10.1002/jgrd.50543.
17. Tian, L.X., Zhang, Y.C., Chen, P.L., Zhang, F.F., Li, J., Yan, F., Dong, Y., Feng, B.L., 2021. How does the waterlogging regime affect crop yield? A global meta-analysis. Frontiers in Plant Science, 12. Doi: 10.3389/fpls.2021.634898
18. Torres, M., Howitt, R., Rodrigues, L., 2019. Analyzing precipitation effects on agricultural income: why timing matters. 20(1), pp.1-14. Doi: 10.1016/j.econ.2019.03.006
19. Tramblay, Y., Badi, W., Driouech, F., El Adlouni, S., Neppel, L., Servat, E., 2012. Climate change impacts on extreme precipitation in Morocco. Global and Planetary Change, 82(2), pp.104-114. Doi: 10.1016/j.gloplacha.2011.12.002.
20. Vogel, E., Donat, M.G., Alexander, L.V., Meinshausen, M., Ray, D.K., Karoly, D., Meinshausen, N., Frieler, K., 2019. The effects of climate extremes on global agricultural yields. Environmental Research Letters, 14, p.054010. doi: 10.1088/1748-9326/ab154b

21. Wu, F.T., Wang, S.Y., Fu, C.B., Qian, Y., Gao, Y., Lee, D.K., Cha, D.H., Tang, J.P., Hong, S., 2016. Evaluation and projection of summer extreme precipitation over East Asia in the Regional Model Inter-comparison Project. Climate Research, 69(1), pp.45-48. Doi: 10.3354/cr01384
22. Yigezu, G., 2021. The challenges and prospects of Ethiopian agriculture. Cogent Food & Agriculture, 7(1):1923619. Doi: 10.1080/23311932.2021.1923619.

**CITATION**

H. Thi Viet Ha. (2024). Potential impacts of altering heavy precipitation events on crop production in Dong Thap province over three past decades. In Global Journal of Research in Agriculture & Life Sciences (Vol. 4, Number 6, pp. 57–65). https://doi.org/10.5281/zenodo.14192635