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Potential Risk Analysis due to Alteration in Rainfall during the Growth Phases of Rainy Season Rice (*Oryza sativa L.*)

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Abstract

Agricultural activities in the parts of world are facing by heavy precipitation events (HPEs) and off-seasonal rainfall with an expectation of increasing frequency under the impacts of climate variability (ICV). The increase tendencies of HPEs have seriously affected the grain filling and harvesting processes of rainy season rice (RSR) in the Tan Chau downtown due to the collapse and inundation, resulting in large losses in the rice yield. This is one of the key causes that result in the decline of the quality and grain yield. Understanding their effects on growth processes of rainy season rice can actively support in mitigating the negative effects, improving grain quality and crop yield. This research examined the effect of rainfall variability on the growth phases of rainy season rice in the Tan Chau downtown applying the non-parametric statistical methods for the period 1978-2015. The results carry out that the current cultivation condition of rainy season rice is not quite suitable for pollinating and grain filling stages as well as their harvest activities. It is necessary to get recommendations from specialized agencies about the future weather situation before each crop is sown, contributing for reducing the potential risks of the weather features as well as increasing rice yield in the study area.

Keywords: ***Off-seasonal rainfall; Decline; Rainy season rice; Potential risks; Climate variability***

1. Introduction

In recent years, agricultural activities around the world are being seriously threaten by HPEs as well as off-seasonal rainfall under the ICV [1,2]. Vietnam is known as the second world's large rice producer with the country's rice exports reached 6.37 million ton in 2019 [3,4]. The HPEs have already caused substantial damage to harvest rice crops the Mekong Delta and the Tan Chau downtown is no exception under the ICV in recent years [2,5,6] and are expected to continue increasing in its frequency and severity [7-9]. Rainfall is considered a key factor in dominating the growth processes of plants [10-12] and serve as direct inputs to the development process of crops, the changing in rainfall features can lead to a significant impact on the

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crop yield [13,14]. According to Kunimistu and Kudo [15], the annual fluctuations of rice production resulting from rainfall. The potential risks and damages on agriculture sector due to HPEs caused in recent years under the ICV are drawing attention from researchers [2,16,17]. For example, a study on the ICV on agricultural activities in the period 2000-2010 by Gornall *et al*. [17] reported that it is likely to witness one of the highest agricultural productivity losses in the world under the ICV. APN [8] stated that the rice crops are sensitive to rainfall which consequently comes under the key factor influenced by climate change. Lesk *et al*. [13] conducted a study on the extreme weather disasters on global crop production. They showed that irrigated rice yields may decrease up to 7.0% in 2050. Asseng *et al.* [10] confirmed that climatic parameters are closely interrelated in their influence on crop yield and changing in the rainfall features can caused great fluctuations in crop production.

Recognizing the important of HPEs to reducing of grain quality as well as rice yield, many studies on the impacts of HPEs on crop yield have been conducted around the world [2,18]. In Turkey, Wailes and Watkins [19], investigated the impacts of HRE in August 2016 in Arkansas and reported that these rainfall events damaged vegetable and melon farms with loss about 500 acres of cantaloupes and a market value approximately of $1.5 million. In Denmark, Kristensen et al. [20] investigated the relation between rainfall features and plant yields and carried out that winter rainfall did not affect significantly on crop yield. Rosenzweig *et al*. [21] simulated the impacts of HPEs on crop growth of corn in the US. They reported that the HPEs in the US has caused great damage to crop production. In Vietnam, Trang [22] reported that the effects of rainfall are closely related with rice market in Vietnam. APN [8] stated that the climate patterns are changing around the world and Mekong Delta is also no exception. In Mekong Delta, agriculture sector is the largest occupation of livelihood to approximately about 20 million people in the Mekong Delta [4,22]. The lack of detailed and qualitative studies on the impacts of HPEs leaves a critical knowledge gap [11,12,23], which may hinder our ability to understand the ICV on rice planting crops.

The cultivation activities in the Tan Chau downtown base on the marked seasonality of rainfall to which it has adapted. However annual variability in rainfall continues to threaten the rice cultivation activities in the area, especially rainy season rice. Rice farmers commonly bewail great losses following during the cultivation periods of excess rainfall. This research is, therefore, conducted to investigate the impacts of rainfall on the growth phases of rainy season rice in the Tan Chau downtown contributing to mitigate the damage caused by high-intensity rainfall events.

2. Materials and Methods

2.1 Study area

The field experiment of this research was conducted in the Tan Chau downtown represented on the maps below (FIG. 1). Tan Chau downtown is known as one of rice-growing regions in An Giang Province, covering a fertile plain approximately 29,241,25 ha rice lands. Agricultural is known as the main sector with annual rice production approximately of 207.924 tons [2,3]. The terrain of the area is lowered from North to South in ranging from 1.0 to 2.5 m a.m.s.l and surrounded by Hau and Tien Rivers and other irrigation canals provided year-round irrigation for rice fields [8,9].

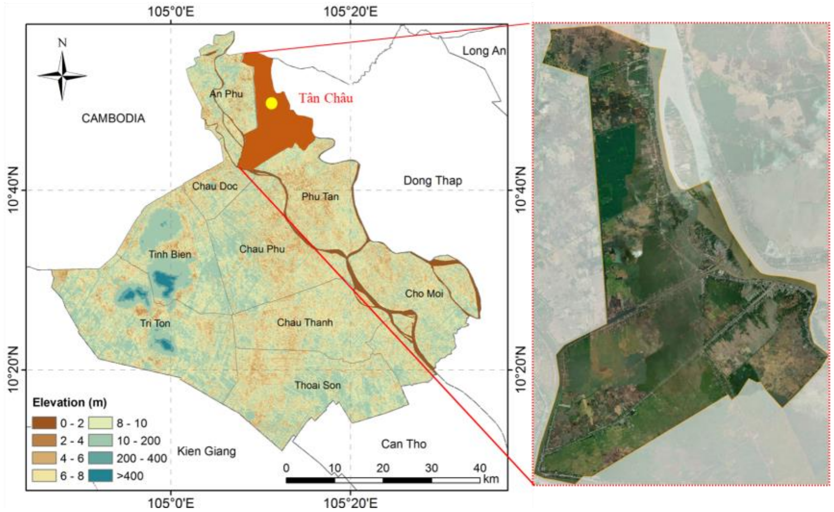

FIG. 1. **Map of the study area with rainfall observation station marked yellow circle. (Source: drawn by the author and download from google earth).**

The climate of the area is predominantly a tropical monsoon circulation with two northeast and southwest seasons. In the months from December to April, the northeast monsoon brings less air moisture and creates only 15 percent of the total annual rainfall in the whole study area (FIG. 2). The wet season (from May to November) brings an abundant moisture and creates high rainfall (e.g., 85 percent of the total annual rainfall) (FIG. 2), leading to the potential risks of the collapse and inundation of rainy season rice in the study area [3, 8].

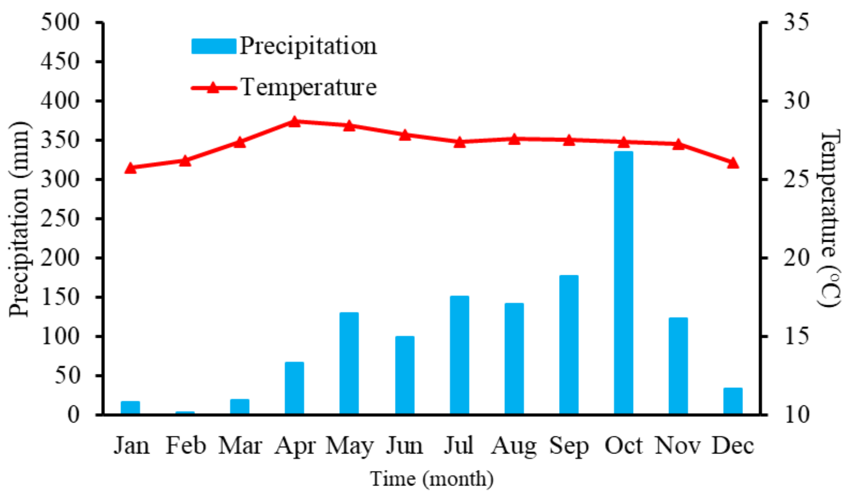

FIG. 2. **Distribution of mean annual rainfall and air temperature at Tan Chau station in the period of 1985-2015.**

2.2 Rice production data

In the study area, farmers commonly plant their rice crops from two to three times per year [4,5] include winter-spring crop (December to March), summer-autumn (May to August) and sometime autumn-winter crop (September to November). The farming calendar of each planting crop depend on the local weather conditions [2,3]. The rice variety OM 6976 is considered as a high yield potential, can reach up to 9 tons/ha with resistant to brown planthopper, blast, less insect pests and salt tolerance

3-4 ‰, alum resistance is quite good and is planted widely in the area. Summer-autumn crop season is classified as the rainy season rice, rice is planted mostly a short-duration variety around 85 to 95 days with the growth phases is presented in FIG. 3. For rice production data, details about crop transplanted date, growth phases of rainy season rice at rice paddies were collected from the Department of Agriculture and Rural Development of provinces as An Giang.

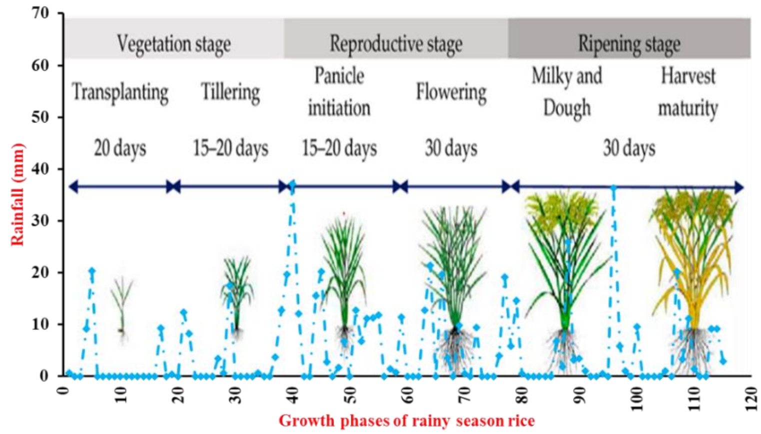

FIG. 3. **Distribution of rainfall during the growth phases of rainy season rice [24].**

According to International Rice Research Institute (2017) [24], there are three growth stages of transplanted rice include vegetation, reproductive and ripening stages (FIG. 3). When the rice is sown directly, the first two phases namely the transplanting and tillering are combined. The duration of this phase varies from 35-40 days after transplanting (DAT) with approximately of 18% of potential evaporation and 20% water use requirement are needed to apply for the normal growth of rainy season rice (TABLE 1). The reproductive stage includes the panicle initiation and flowering phases varying from 45-50 DAT.

TABLE 1. **Irrigation use requirements and potential evaporation for growth stages of rice plants.**

No.	Stage	Irrigation water requirements	Potential evaporation
1	Vegetation	20%	18%
2	Reproductive	40%	42%
3	Ripening	35%	40%
	Total (%)	**95%**	**100%**

The duration of this phase, with a requirement of 42% and 40% potential evaporation and water use requirement. For ripening stage, the final two phases include the dough and maturity are combined and need an irrigation water requirement approximately of 40% of potential evaporation and 35% of water use requirement is needed to utilize (TABLE 1).

2.3 Rainfall data

Daily rainfall data at Tan Chau station was collected from the Southern Regional Hydro-meteorological Centre (SRHC) for the period 1978-2015. The homogeneity analysis of the recorded data series at Tan Chau station was conducted using Pettitt's test during the period 1978-2015. The effects of rainfall on rainy season rice were assessed applying the statistical methods. Non-parametric statistical method was applied to assess the relationship daily rainfall with the growth stages includes the pre-flowering, flowering, post-flowering and harvesting stages of rainy season rice.

2.4 Non-parametric statistical methods

Trend analysis is a change detection way over time of any data series which can be based on non or parametric tests to define the magnitude and its change tendency [25]. In this work, a trend analysis of rainfall data series in the period 1978-2015 was conducted applying the Man-Kendall test while its magnitude was defined applying Sen's estimator. The Man- Kendall is a statistical method which is commonly applied to judge the null hypothesis of no trend versus the alternative hypothesis of the existence of the monotonic trends of observed hydro-climatic data series [25,26]. The Mann-Kendall test is suitable for those observed data series in which the change trends may be supposed to be monotonic [27,28]. An advantage of the Mann-Kendall test is that it is very simple, not being controlled by sample values as well as less sensitivity to disruption created by heterogeneity of input data [25,28]. The statistic S is defined as shown in Eq.(1)

$$S = \sum_{I=1}^{n-1} \sum_{j=I+1}^{n} Sgn(X_j - X_i) \quad (1)$$

Where X_j, X_i are annual values in years j and i, j > i respectively, n is the number of data points and Sgn (X_j-X_i) is calculated by Eq.(2)

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

Where data series values with n greater than or equal to 10, a standard distribution quantity (Z_S) is defined by Eq.(3)

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{\mathrm{Var(S)}}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S-1}{\sqrt{\mathrm{Var(S)}}} & \text{if } S < 0 \end{cases} \quad (3)$$

Where Var(S) in the Eq.(3) is defined as shown in the Eq.(4)

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{m} t_j(t_j - 1)\right]^{\frac{1}{2}} \left[\frac{1}{2}n(n-1)\right]^{\frac{1}{2}} \quad (4)$$

Accordingly, if the calculated values of Zs are positive or negative these average that analyzed data series occurred an increase or decrease trends [29].

In most studies on hydro-meteorological and environmental problems, if Mann-Kendall test is often applied to detect the monotonic trends the Sen's slope estimator is commonly applied to define its magnitude [29]. Sen's slope (β) is defined by Eq. (5).

$$\beta = \text{Median}\left(\frac{X_i - X_j}{i - j}\right) \quad \text{with } j < i \qquad (5)$$

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

At an established confidence level of α, if $|Z_S| \geq Z_{1-\alpha/2}$, it averages that a significant an increase or decrease trend in the observed data series recorded. In this word, a confidence level of 95% corresponding to $\alpha = 0.05$, and the null hypothesis of no trend is rejected if $|Z_S| > 1.96$.

3. Results and Discussions

3.1 Relationship between rainfall and pre-flowering phase

The trend analysis of daily rainfall data series in the pre-flowering phase of rainy season rice across the study area during the period 1979-2015 was proceeded applying the Man- Kendall test and Sen's slope estimator with significance level of 95%. The total daily rainfall of pre-flowering phase was 56.5 mm, with average daily rainfall was approximately 3.7 mm (FIG. 4a). According to Abbas and Mayo [1] rainfall has the effects on rice production in the grain filling stage. For rainfall trend, the results showed that an increased trend (FIG. 4) recorded with Z_s value is 0.018, p-value 0.875 and Sen's slope is 0.004 (TABLE 2).

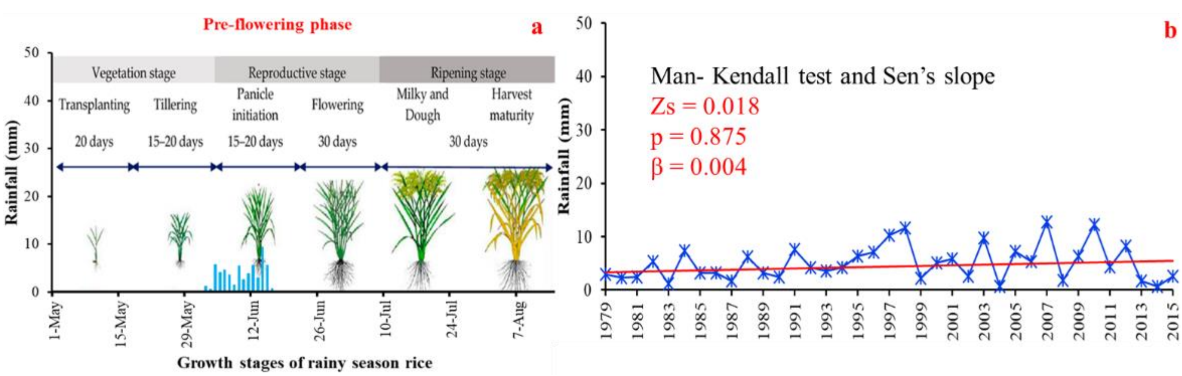

FIG. 4. **Analyzed results of a) average daily rainfall and b) their trend lines in the pre-flowering stage of rainy season rice.**

Table 2: Analyzed results of rainfall trends in the growth stages of rainy season rice.

Phase	Zs	p-value	β
Pre-flowing	0.018	0.875	0.004
Flowering	-0.074	0.521	-0.018
Post-flowing	0.137	0.234	0.063
Harvesting	0.137	0.234	0.063

3.2 Relationship between rainfall and flowering phase

The analyzed results of average daily rainfall in the flowering stage across the study area in the period of 1979-2015 with their trend lines are illustrated in FIG. 5. The results carried out that average daily rainfall in the flowering stage at all gauge stations approximately 11.1 mm (FIG. 5a). The lowest daily rainfall records 8.0 mm whereas the highest value is 14.4 mm (FIG. 5a). According to Subash et al. [30], the flowering stage of rice plants is very sensitive to rainfall. Therefore, during flowering days, daily rainfall intensity above 10 mm will significantly affect the grain filling process. Accordingly, the results show that recorded daily rainfall in the flowering stage is approximately of 11.1 mm.

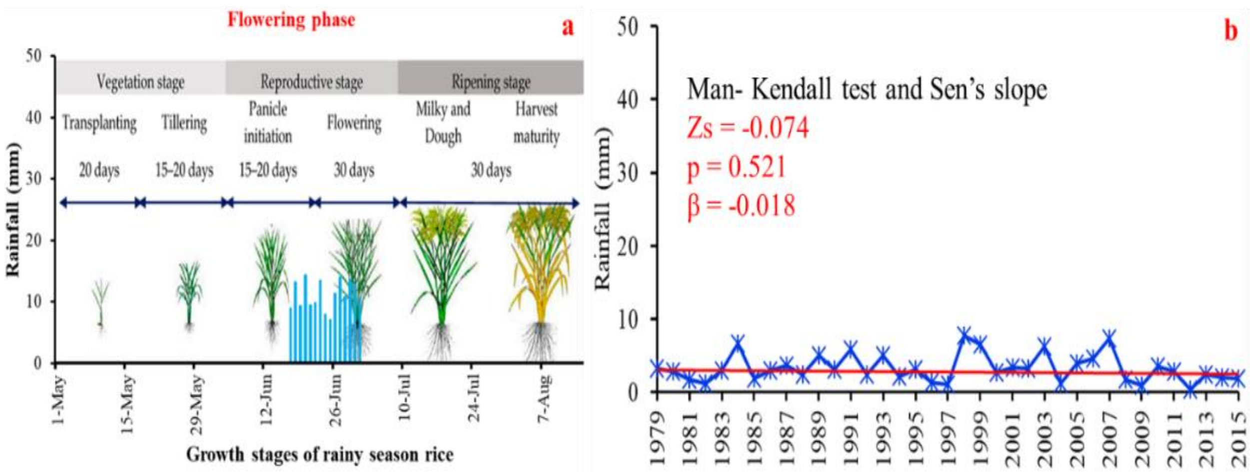

FIG. 5. **Analyzed results of a) average daily rainfall and b) their trend lines in the flowering stage of rainy season rice.**

This implies that the rainfall distribution over time during the flowering stage of rice plants is in excess of the irrigation use requirement of the rainy season rice and therefore the rainfall values are not appropriate for the grain filling process of rice.

For daily rainfall trends, the analyzed showed that a slight downward trend was found with Z_s = -0.074, p = 0.521, and β= -0.018 (TABLE 2). In general, the decreasing trend of daily rainfall during the flowering stage of rainy season rice is favorable for the grain filling process of rice. According to Nhan et al. [29], the flowering stage of rice plants is very vulnerable to weather anomalies.

3.3 Relationship between rainfall and post-flowering stage

For post-flowering stage, the total daily rainfall at Tan Chau station approximately 103.9 mm and average daily rainfall reaches 6.8 mm (FIG. 6a). Nhan et al. [29] stated that rice plant is very sensitive to change in rainfall in the post-flowing stage of rainy season rice and farmers, therefore, have coped with rainfall anomalies applying appropriate farming methods. The analyzed results of daily rainfall trends in the post-flowering stage show that a slight upward trend with the values of recorded with Z_s = 0.137, p = 0.234 and β = 0.063, respectively (FIG. 6b).

In general, a slight increase trend of daily rainfall in the post-flowering stage did not adversely affect the ripening stage of rainy season rice (FIG. 6a).

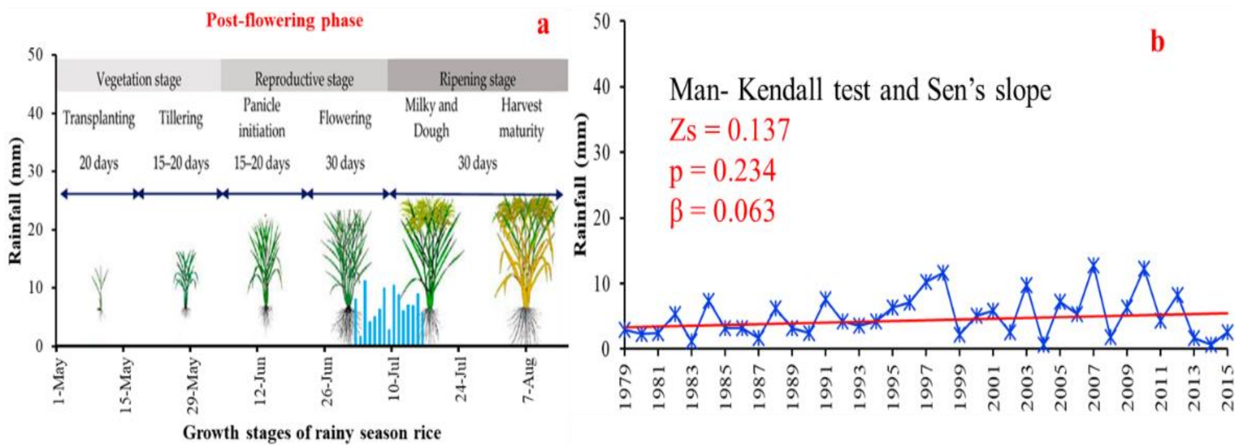

FIG. 6. **Analyzed results of a) average daily rainfall and b) their trend lines during the post-flowering stage of rainy season rice.**

3.4 Relationship between rainfall and harvesting stage

The analyzed results of daily rainfall series and rainfall trend lines in the harvesting stage of rainy season rice during the period 1978-2016 illustrated in FIG. 7. The total daily rainfall in the harvesting stage is 120 mm and the lowest daily rainfall records 2.4 mm while the highest value up to 16.1 mm (FIG. 7a) and mean daily rainfall approximately of 8.06 mm.

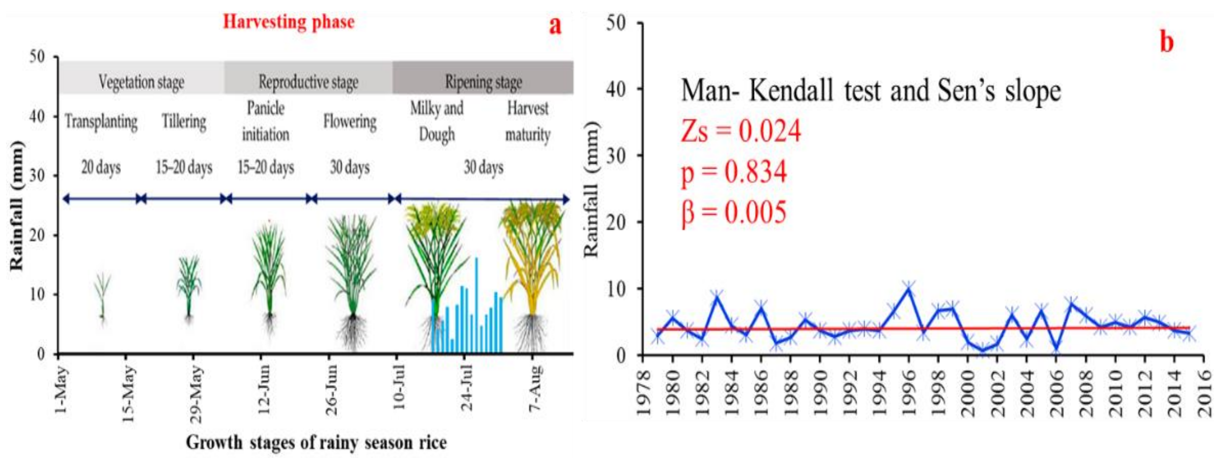

FIG. 7. **Analyzed results of a) average daily rainfall and b) their trend lines during the harvesting stage of rainy season rice.**

It implied that the harvesting stage of slight faces the potential risks of yield loss due to the impacts of the HPEs. According to Fukai et al. [31], daily rainfall just needs an enough volume for the physiological requirements in the harvesting stage of rice will ensure productivity. Conversely, if high rainfall intensity compared to water use demand of rice, leading to water inundation will cause certain difficulties when using the harvester, resulting in loss of grain yield during the harvesting activities.

For analysis trends, results show that a slight upward trend in the harvesting stage records with the values of $Z_s = 0.024$, p =

0.834, and β = 0.005, respectively (TABLE 2). Indeed, the increasing tendency of daily rainfall during the harvesting stage have contributed to an increase in the potential risks of lost productivity and reduce grain quality due to HPEs.

4. Conclusions

The studied results of the rainfall data series across the study area in the period of 31 years (1985-2015) were conducted based on non-parametric statistical methods showed that the pre-flowering stage of rainy season rice is very close to the most suitable level of irrigation water demand for rice pollination and development whereas the flowering and post-flowing stages are not quite suitable for pollination and harvest of rainy season rice. However, the results also showed that if the flowering stage of rice on 18 June will be suitable for the normal growths of rice.

Thus, the results of this study propose that it needs to consider the suitable growing time of rainy season rice, contribute to mitigate the negative effects as well as improve rice yield in the study area. The study revealed that rainfall has affected directly on the growth stages of rainy season rice. The response of rice yield to high intensity rainfall during the flowering and harvesting stages might an adverse effect on grain yield of rainy season rice in the study area.

The study carried out insight into the effective solutions to minimize negative effects of the HREs on the important growth stages of rainy season rice in the study area as well as other area.

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