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Analysis of Potential Cropping Seasons of Cayenne Pepper (*Capsicum frustescens* L.) Based on Water Balance in Alfisol Dryland, Tuban Regency, East Java, Indonesia.

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Abstract

Dryland agriculture is crucial for understanding how to effectively manage land water for the crops. Water balance analysis plays a pivotal role in comprehending the hydrological cycle and water availability for crop production. The Tuban Regency is one of the fifth largest cayenne pepper-producing areas in East Java, Indonesia, particularly in Grabagan and Bancar Districts. However, for sustainable growth, it is imperative to extend cultivation to other sub-districts within Tuban Regency. In the cultivation of cayenne pepper, attention to soil water availability is important due to its susceptibility to drought, directly impacting vegetative growth and overall plant production. This research aims to establish a planting pattern for cayenne pepper based on water balance analysis in Alfisol drylands within Montong, Kerek, and Singgahan Districts of Tuban Regency. The study, conducted from July to September 2023, employed Thornthwaite and Mather water balance analysis, drought index assessment, and day without rain analysis. The research findings reveal variations in water balance conditions within the study areas, with Montong and Kerek Districts experiencing a land water surplus for three months and a nine-month deficit. Singgahan District, on the other hand, encountered a surplus for four months and a deficit for eight months. The drought index indicates a high level, peaking in September for Montong (87%), Kerek (91%), and Singgahan (87%) Districts. Cayenne pepper plants exhibit the potential for annual cultivation in Alfisol drylands of Montong, Kerek, and Singgahan Districts, with a growing duration of six months. The optimal planting window spans from December to May, followed by potentially a second planting in June and July for crops with a minimum available water value exceeding 19% or those with a shorter harvest life. From August to November, the land lies fallow due to a soil water availability that is close to 0% and a 27% risk of days without rain in the extreme drought category, rendering the soil unsuitable for growing crops.

Keywords: dryland, water balance, cropping season, soil water availability

Introduction

Water availability is a crucial factor influencing the success of plant cultivation in dryland areas, as highlighted by Garello et al. (2023). Managing land water needs in dryland agriculture systems is essential, and a key component of this is understanding the water balance. According to Cunha et al. (2019), water balance analysis is critical for comprehending the hydrological cycle and ensuring adequate water availability for crop production. This analysis is particularly significant in predicting water requirements for various crops in dryland cultivation (Koch and Missimer, 2016). Timely water availability data is crucial for preparing effective cropping patterns, maximizing land potential, and avoiding crop failure (Rusastra et al., 2019).

Tuban Regency is as the fifth largest producer of cayenne pepper in East Java, with production currently concentrated in Grabagan and Bancar Districts (BPS, 2022). To enhance overall cayenne pepper production in the region, it is important to expand cultivation to other districts. According to Ricardez-Miranda et al. (2021), cayenne pepper plants are highly susceptible to drought, directly impacting vegetative growth and crop production. Therefore, attention to soil water availability is essential in cultivating cayenne pepper. Sabaruddin et al. (2021) emphasize the significance of choosing the optimal planting time in dryland areas to avoid water requirements' critical phases and maximize planting duration. Fan et al. (2022) further support the idea that adopting appropriate planting patterns can increase crop yields and optimize land-water use.

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According to Taufiq et al. (2007), over 50% of Tuban Regency's land is predominantly Alfisols, originating from calcite rock and marl parent materials. Most plant cultivation activities in Tuban Regency occur on dry land, with 39% of these activities taking place on Alfisols (BPS, 2022). Pathak et al. (2013) highlight that Alfisols are well-suited for crop production due to their good soil fertility. However, these soils tend to have low water retention capacity, primarily due to lower organic matter levels. Hence, comprehensive land use planning relying on complete data information are essential to ensure accurate decision-making (Martha, 2016). The significance of water balance in Tuban Regency lies in its role as a foundational element for understanding the potential of climate, soil, and plants. This understanding proves invaluable in planning agricultural development. The water balance provides crucial insights into the net amount of water available, the surplus water that cannot be accommodated, and the timing of the water balance occurrence (Akas et al., 2019). These data serve as a basis for the planning and management of cayenne pepper cultivation, especially in the context of dryland Alfisols in Tuban Regency. Given the importance of land water balance, particularly in dryland, it is important to study the water balance analysis for potential cayenne pepper planting in the dryland Alfisols of Tuban Regency. Such research is crucial for informed decision-making in the planning and management of agricultural activities in the region.

Material and Methods

The research was conducted from July 2023 to September 2023 in Tuban Regency, East Java Province, Indonesia. Climate data obtained from Bureau of Meteorology, Climatology and Geophysics (BMKG) Tuban Regency for 2018 – 2022 includes rainfall, air temperature, air humidity, duration of sunlight, and wind speed in the observation area of Montong District, Kerek District and Singgahan District.

Water balance analysis was calculated using the formula (Thornthwaite and Mather, 1957) :

$$P-(PET+R)=\Delta S$$

where
P = Precipitation (mm)
PET = potential evapotranspiration (mm), PET obtained from the formula ETo Kc (Crop Coefficient) Cayenne pepper
R = run off (mm)
ΔS = changes in soil water content or accumulation of soil water content (mm)

ETo (Evapotranspiration Rate) was calculated using the formula (Penman-Monteith,1977)

$$\text{ETo} = \frac{0{,}408 \cdot \Delta\,(\text{Rn} - \text{G}) + \gamma \cdot \frac{900}{\text{T}+273} \cdot u2 \cdot (es - ea)}{\Delta + \gamma \cdot (1 + 0{,}34 \cdot u2)}$$

where :
ETo = evapotraspirasi Rate (mm)
Rn = net radiation (MJ/m^2)
G = soil heat flux (MJ/m^2)
Δ = slope of the vapor pressure curve (kPa/°C)
= psychrometric constant (kPa/°C)
T = average temperature (°C)
u2 = wind speed (m/s)
es = saturation vapor pressure (kPa)
ea = actual vapor pressure (kPa)

Determining the drought index at the research location is based on the water deficit value with the potential evapotranspiration value in the Thornthwaite and Mather water balance using the formula:

$$\text{Ia} = (\text{D}/\text{PET}) \times 100\ \%$$

where :
Ia = drought index (%)
D = Deficit (mm)
PET = potential evapotranspiration (mm)

The drought index according to Thronthwaite and Mather is determined by several levels based on the drought index class to determine the peak of land drought and the beginning of the planting season. The drought index values can be seen in Table 1.

Table 1. Drought index levels

Drought index (%)	Levels
0.00-16.7	Low
16.7-33.3	Medium
> 33.3	High

Calculation of the three-month probability of a day without rain (DWR) was based on daily rainfall data from 2018 to 2022. Daily rainfall data is then analyzed based on the DWR criteria, as seen in Table 2.

Day without rain (day)	Criteria
1 – 5	Very short
6 – 10	Short
11 -20	Middle
20 -30	Long
31 – 60	Very long
> 60	Extreme dryness

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Result and Discussion

Water Balance

The analysis of water balance in the observation area reveals variations in surplus and deficit conditions.

Figure 1 illustrates variations in land water surplus and deficit conditions across the three observation areas. In Montong District, a surplus is observed in January, March, April, and December, while deficits occur in February, May, June, July, August, September, October, and November. Keret District experiences a surplus in February, March, April, and December, with deficits in January, May, June, July, August, September, October, and November. Singgahan District sees a surplus for four months (January, February, March, April, and December) and deficits from May to November.

December to May (Ia 0 – 14%), mirroring the pattern in Kerek District, where the wet months extend from December to May (Ia 0 – 7%). Meanwhile, Singgahan District experiences wet months from November to May (Ia 0 – 5). The peak of drought is observed in Montong District in September (87%), Kerek District in September (91%), and Singgahan District also in September (87%).

Number of Days Without Rain

The analysis of the probability of days without rain is depicted in Figure 3, showcasing the monthly variations in DWR probability in Tuban Regency.

During the period from December to February, there is a 97% chance that the days without rain falls into the very short category, indicating acceptable soil water availability. However, from March to May, there

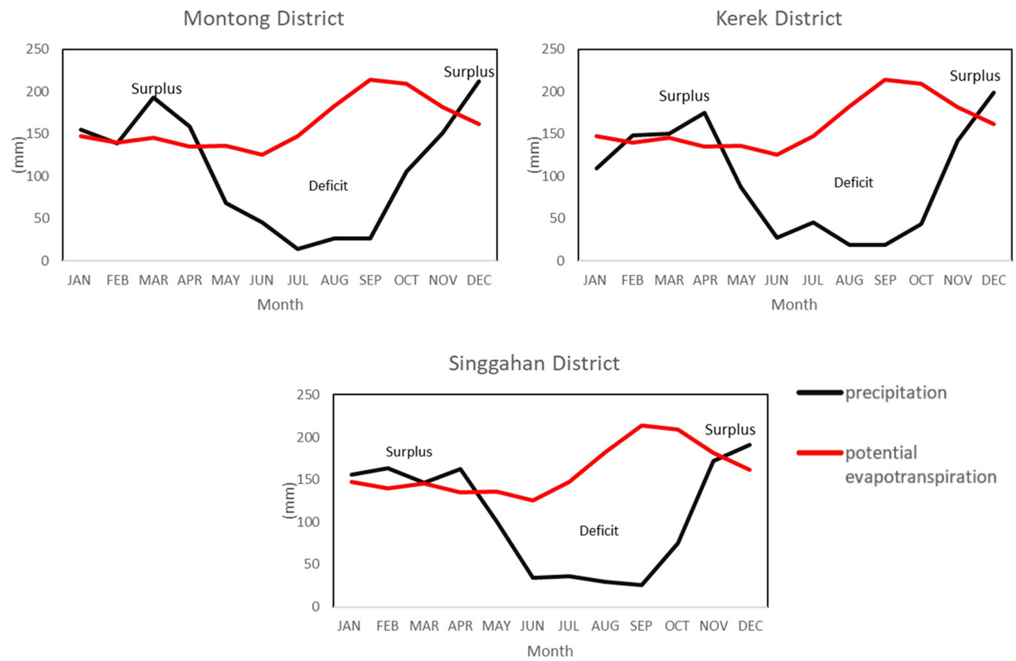

Figure 1. Water surplus and deficit in Montong District, Kerek District, and Singgahan District, Tuban, East Java, Indonesia.

Drought Index

The drought index (Ia) is determined by the ratio between the water deficit value and potential evapotranspiration. Figure 2 displays the analysis of the drought index in Alfisol for Montong District, Kerek District, and Singgahan District.

The analysis results reveal that the drought index in Montong, Kerek, and Singgahan sub-districts falls within the high category (>33.33%). The magnitude of the drought index provides insights into wet and dry months. In Montong District, the wet months span from

is a 57% probability of DWR being in the very low category, 21% in the short category, and 16% in the long category. The 16% chance of DWR entering the long category indicates a need for caution due to the risk of soil water capacity. From June to August, there is a 43% chance of DWR falling into the medium category and only a 27% chance of being in the very short category. In the months of September to November, there is a 29% chance of DWR being in the very short category. However, there is also a 27% chance of experiencing extreme drought and a 20% chance of being in the very long category. Therefore, during these months, it is advisable to fallow to

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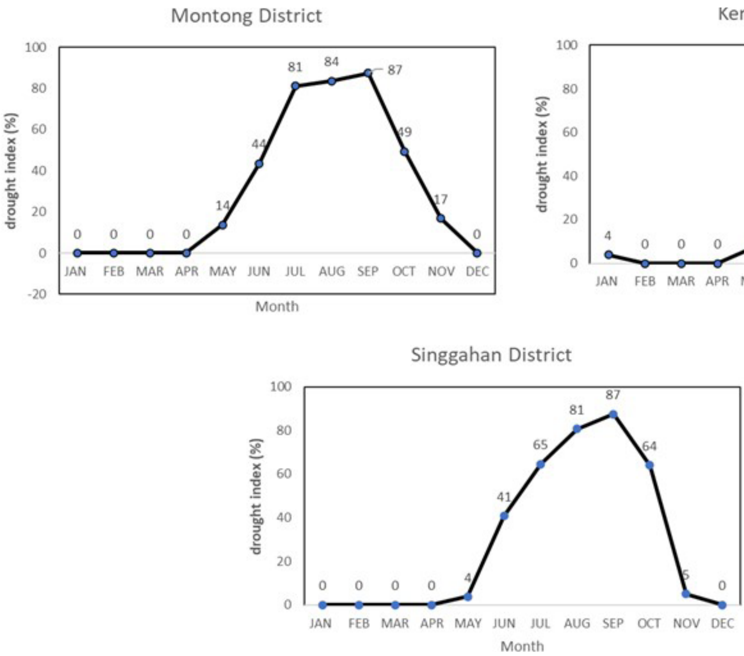

Figure 2. Drought index in Montong District, Kerek District, and Singgahan District

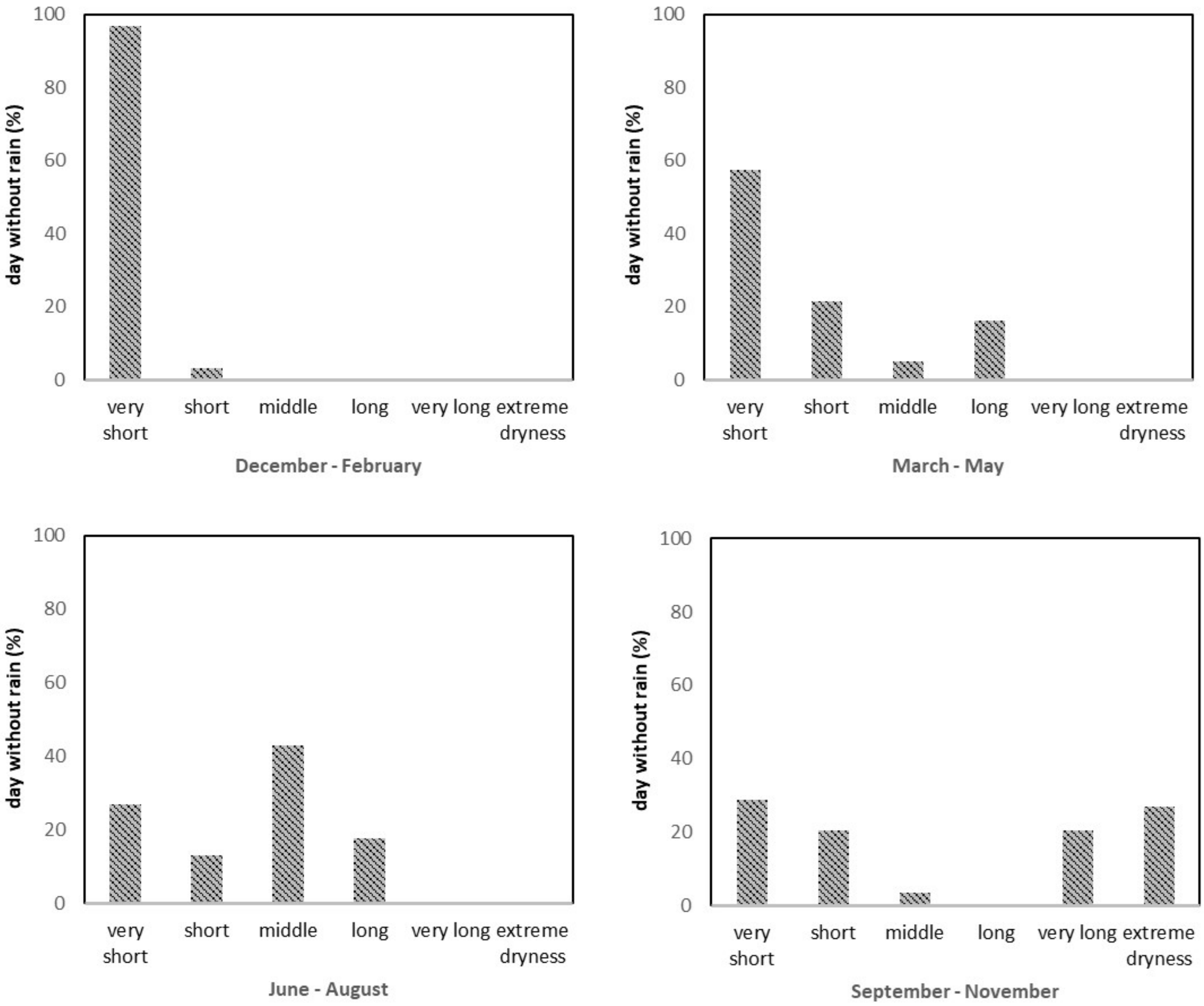

Figure 3. Probability of days without rain in Tuban Regency, East Java, Indonesia.

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manage the potential risks associated with soil water availability.

Cropping Season

Drawing upon the water balance analysis, a drought index and a rain-free day analysis can be formulated. This serves as an illustrative example of a cropping pattern calendar for cayenne pepper plants over the course of one year. The analysis is specific to Alfisol, encompassing Montong District, Kerek District, and Singgahan District.

at least every 3 to 4 days, is recommended.

During June, the soil water availability in Montong District, Kerek District, and Singgahan District dropped below 25%, rendering it unsuitable for cayenne pepper cultivation. According to FAO (1977), cayenne pepper plants require a minimum SWA of 60% to ensure optimal production. In June and July, it becomes imperative to select plants with a minimum SWA value exceeding 19% or opt for plants with a short harvest period, thereby maximizing production potential. The SWA values close to 0 (Table 3) highlight

Table 3. Recommendation of cayenne pepper cropping season in Montong District, Kerek District and Singgahan District,Tuban, East Java, Indonesia.

Dec		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Montong District	SWA (%)	100	100	100	100	100	46	19	4	1	0	0	0
	CS	Cayenne pepper						Second crop		Fallowed			
Kerek District	SWA (%)	100	65	100	100	100	58	19	6	1	0	0	0
	CS	Cayenne pepper						Second crop		Fallowed			
Singgahan District	SWA (%)	100	100	100	100	100	67	24	7	1	0	0	0
	CS	Cayenne pepper						Second crop		Fallowed			

Note: green highlights indicate the recommended months to grow cayenne pepper. SWA = soil water availabilty; CP = cropping season.

Table 3 indicates that cayenne pepper can potentially be planted once a year at the three observation locations, each with a maximum duration of 6 months. The drought index analysis suggests that the optimal time for initial planting is in December for Montong District, Kerek District, and Singgahan District, as indicated by a drought index value of 0 (Figure 2) and a soil water availability of 100% (Table 3). Aligning with findings by Ricardez-Miranda et al. (2021), it is essential to ensure sufficient available water during the early growth stages of cayenne pepper. Land preparation can commence in November for Montong District, Kerek District, and Singgahan District, coinciding with increased rainfall or the onset of the rainy season (Figure 1) in these research areas. The planting window for cayenne pepper extends from December to May, spanning six months in these districts. It is crucial to note a 20% probability of long drought water requirement during March to May (Figure 3). During this period, vigilance is required to address potential risks associated with soil water capacity. Zuhdi et al. (2022) reported that Alfisol has the capacity to supply water for up to five days post-rainfall. Beyond this timeframe, the soil may reach the permanent wilting point phase and regular watering,

the need for careful consideration. From August to November in Montong District, Kerek District, and Singgahan District, there exists an increased risk of drought water requirement falling into the extreme drought category, reaching 27%. Consequently, the land is no longer conducive for cultivating plants as the soil water content has reached a permanent wilting point. In such cases, it is advisable to leave the land fallow during this period.

Conclusion

The water balance in the observed areas exhibits variations in land water conditions, with Montong District and Kerek District facing a surplus for three months and a deficit for nine months. In contrast, Singgahan District experiences a surplus for four months and a deficit for eight months. The drought index is notably high, reaching its peak in September at 87% for Montong District, 91% for Kerek District, and 87% for Singgahan District. In Alfisol, encompassing Montong District, Kerek District, and Singgahan District, cayenne pepper plants have the potential for annual cultivation with a maximum

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life cycle of 6 months. The optimal planting window spans from December to May. However, during June and July, it is advisable to consider alternative crops with a minimum available water value exceeding 19% or plants with a shorter harvest life. From August to November, the soil water availability approaches 0, posing a significant risk of drought water requirement reaching an extreme drought category of 27%. Consequently, during this period, the land is no longer optimal for cultivating crops as the soil water content has reached the permanent wilting point.

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