

Impact of Data Source on Evapotranspiration Calculation: On-Site Vs. METMalaysia Weather Stations

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Abstract

Crop water requirement is the estimation of water that needs to be replenished due to the crop evapotranspiration (ET_c) by the crop. This process is critical for ensuring adequate irrigation and maximizing crop yield. In Malaysia, climate data from Malaysia Meteorological Department (METMalaysia) stations are commonly used for ET_c estimation. Although these METMalaysia stations are not located directly within the plantation area, these data are easily accessible and widely utilized for ET_c calculation. However, misleading climate data will result in a wrong estimation of evapotranspiration (ET), which may lead to over or under-irrigation, resulting in plant damage thus decreasing the yield. Durian (*Durio zibethinus*), known as the "king of fruits", holds significant economic importance in Malaysia due to its high demand in both domestic and export markets across ASEAN countries. Understanding the ET of durian is essential for optimizing irrigation practices and enhancing crop revenue for farmers. The objective of this study is to compare ET_c from climate data consisting of daily minimum and maximum temperature, humidity, wind speed, and sun radiation, obtained from on-site weather station and METMalaysia weather station. This study is conducted in a durian plantation at Durian Valley, Kluang, Johor. Data analyses were conducted using a T-test. The result shows a significant difference between calculated ET_c using climate data obtained from the on-site weather station compared to data from the METMalaysia weather station which emphasizes the importance of accurate, location-specific climate data for effective irrigation management in durian cultivation.

1. Introduction

Water is a critical resource for agricultural production, playing a pivotal role in the growth and yield of crops. This is particularly true for durian cultivation, which is significant in Southeast Asian countries such as Thailand, Malaysia, Singapore, Brunei, Cambodia, and the Philippines. The high demand for durian in these regions underscores the importance of efficient water management to ensure optimal production and profitability for farmers.

Agricultural success hinges on maximizing production and profitability while minimizing costs. Effective water irrigation is crucial, significantly enhancing crop yields and revenue [1]. However, improper irrigation can

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lead to crop diseases, pests, and fungi, such as root and stem rot due to overwatering, resulting in plant death and virus infections [2]–[4].

Ensuring adequate crop water is crucial for achieving high crop yields and water efficiency. This study aims to determine the total water requirement for durian plantations and assess the capability of aquifers to meet these needs. This study also compares calculated crop evapotranspiration (ET_c) values derived from Malaysian Meteorological Department (METMalaysia) climate data with those obtained from on-site weather stations. The goal is to ensure accurate irrigation practices that prevent water excess or deficit, thereby protecting durian trees and maximizing yield. By understanding and optimizing the water requirements for durian cultivation, this research aims to support sustainable agricultural practices and enhance the profitability of durian farming in Southeast Asia.

2. Literature Review

2.1 Introduction to Crop Water Requirement and Evapotranspiration

Effectively managing water resources hinges on accurately assessing crop water needs, a process that involves calculating crop evapotranspiration (ET_c). This calculation is performed by multiplying reference evapotranspiration (ET_o) with a crop-specific coefficient, known as K_c [5]. ET_o is especially important because it influences multiple facets of water management.

Beyond its role in scheduling irrigation, ET_o is also critical in providing input data for hydrological water-balance models, which help in evaluating water availability across regions and basins. Additionally, precise ET_o estimation is necessary for determining actual evapotranspiration, a key factor in optimizing water use efficiency in agriculture [6]. Consequently, any inaccuracies in ET_o calculation can have significant implications for irrigation strategies and the broader management of water resources.

2.2 Impact of Data Sources on ET Calculation

The precision of estimating crop evapotranspiration (ET_c) is heavily influenced by the sources of data used to derive reference evapotranspiration (ET_o). ET_o can be gathered from on-site weather stations or METMalaysia stations, and differences in the quality and detail of this data can result in varying ET_c estimates. These discrepancies can influence irrigation practices and impact overall water use efficiency. The selection of data sources is crucial for accurate ET calculations in agricultural management.

Research has shown that different sources can lead to diverse outcomes in ET estimation. A study combined atmospheric data with Landsat imagery to assess surface evapotranspiration in the Heihe River Basin, with the goal of improving water resource management [7]. For instance, research has explored maize evapotranspiration under drought conditions using a dual crop coefficient method, underscoring the importance of soil water stress factors in obtaining accurate ET estimates [8].

Another study introduced an innovative technique that bypasses traditional crop coefficients, employing modern technologies to estimate water requirements and highlighting the value of daily crop coefficient data in ET calculations [9]. The importance of accurate data in ET_c calculations is evident when using detailed crop and growth stage data to derive ET_c from ET_o and K_c [10]. However, research also demonstrates that, in the absence of comprehensive weather data, practical estimations of ET_c can still be achieved based on ET_o , highlighting the adaptability of ET assessments using available resources [11].

2.3 Integrating Water Management and Agricultural Practices

Integrating water management with agricultural practices is vital for promoting sustainable farming and making the most of available resources. Merely managing water supplies may not sufficiently address water stress; it is essential to complement precise irrigation methods with comprehensive agricultural practices [12]. For example, drip irrigation combined with optimized fertilization (DIF) has been found to lower water usage and reduce nitrogen runoff, which enhances both water efficiency and crop yields [13]. Accurate crop evapotranspiration (ET_c) calculations are essential for these methods to be effective, highlighting the need for dependable weather data.

Real-world applications of drip irrigation reveal its significant benefits. Studies have shown that implementing drip irrigation in horticultural crops allows for precise water application, leading to the conservation of both water and fertilizers while increasing crop yields [14]. Similarly, other research highlights that drip irrigation enhances water efficiency, reduces water loss, manages soil salinity, and boosts overall crop production [15]. These observations illustrate the benefits of combining advanced irrigation methods with accurate ET_c measurements to improve water management and enhance agricultural productivity.

2.4 Sensor-Based Irrigation Scheduling and Its Importance

In modern agriculture, sensor-based irrigation scheduling has become increasingly important for optimizing water use by monitoring soil moisture levels and adjusting irrigation as needed [16]. For crops like durian, which can demand up to 360 liters of water per day for mature trees, precise estimation of crop evapotranspiration (ET_c) is vital. This accuracy prevents both under- and over-irrigation, ensuring optimal yields and preventing unnecessary water use [17].

Advanced irrigation systems now utilize technologies such as the Internet of Things (IoT) and Wireless Sensor Networks (WSN) to provide detailed moisture data and enhance irrigation schedule [18]. These systems are designed to minimize water consumption, improve irrigation efficiency, and either sustain or increase crop yields [19]. They offer a significant improvement over traditional irrigation methods, effectively addressing common issues and enhancing water management in various agricultural contexts [20].

The benefits of sensor-based irrigation are evident across different crops. For example, research has shown that integrating these systems with surge flow irrigation techniques can significantly reduce water use while maintaining crop yields and boosting economic returns [21]. The effectiveness of sensor-based irrigation extends to crops like winter wheat, okra, and potatoes, where it has been found to enhance water productivity and crop performance [22]–[24].

Moreover, integrating soil moisture sensors with computer models offers a robust method for predicting irrigation needs more accurately and reducing uncertainties in scheduling [25]. By incorporating sensor feedback and wireless moisture monitoring, precision irrigation can be achieved, leading to better water use and improved crop yields [26].

2.5 Sustainable Use of Water and Soil Resources

Effective and sustainable management of water and soil resources is essential for agriculture, as intensive irrigation practices directly influence various aspects of crop growth, including the accumulation of dry matter. In durian trees, for instance, dry matter accumulation is significantly affected by irrigation practices, which in turn are influenced by micro-environmental factors such as soil moisture and local climate conditions [27]. These factors are closely related to evapotranspiration (ET), as accurate ET estimations help optimize irrigation schedules, ensuring sufficient water availability without over-irrigation. This balance supports both dry matter accumulation and overall crop health, highlighting the need to manage micro-environmental factors effectively for sustainable agricultural outcomes.

Accurate determination of crop evapotranspiration (ET_c), derived from reference evapotranspiration (ET_o) and crop coefficients (K_c), is fundamental to optimizing irrigation practices. ET_c calculations help ensure that crops receive adequate water without the risk of over-irrigation, which can lead to nutrient leaching, soil degradation, and wasted water resources. This precision is particularly important in managing micro-environmental factors that directly affect crop health, yield, and resource efficiency.

However, errors in ET_c estimations often arise from inconsistencies or inaccuracies in weather data inputs, such as temperature, wind speed, relative humidity, and solar radiation. These discrepancies can lead to misaligned irrigation schedules, resulting in either water stress or excessive water application. For instance, overestimating ET_c may prompt unnecessary irrigation, exacerbating issues such as waterlogging, increased salinity, and soil erosion. Conversely, underestimating ET_c could lead to water shortages, reducing crop growth and productivity.

3. Methodology

3.1 Study Area, Planting Material, and Experimental Design

The study was conducted in the durian plantation at Sri Lalang, Kluang, Johor (2.014°N, 103.226°E). The total area of the plantation as shown in Fig. 1 is 40 acres consisting of 83% Musang King, 8% Black Horn, and 5% Golden Pheonic. All trees were at the vegetative growth stage aged between 5 and 8 months. The source of water is from the groundwater pump, and it will flow to the main line and next to the 16 sub-main lines. From the sub-main, water will flow into the laterals where the durian trees are in the study area. As many as five (5) drips were attached to a looped pipe for each tree. The flow rate of each drip was 8 L/h.

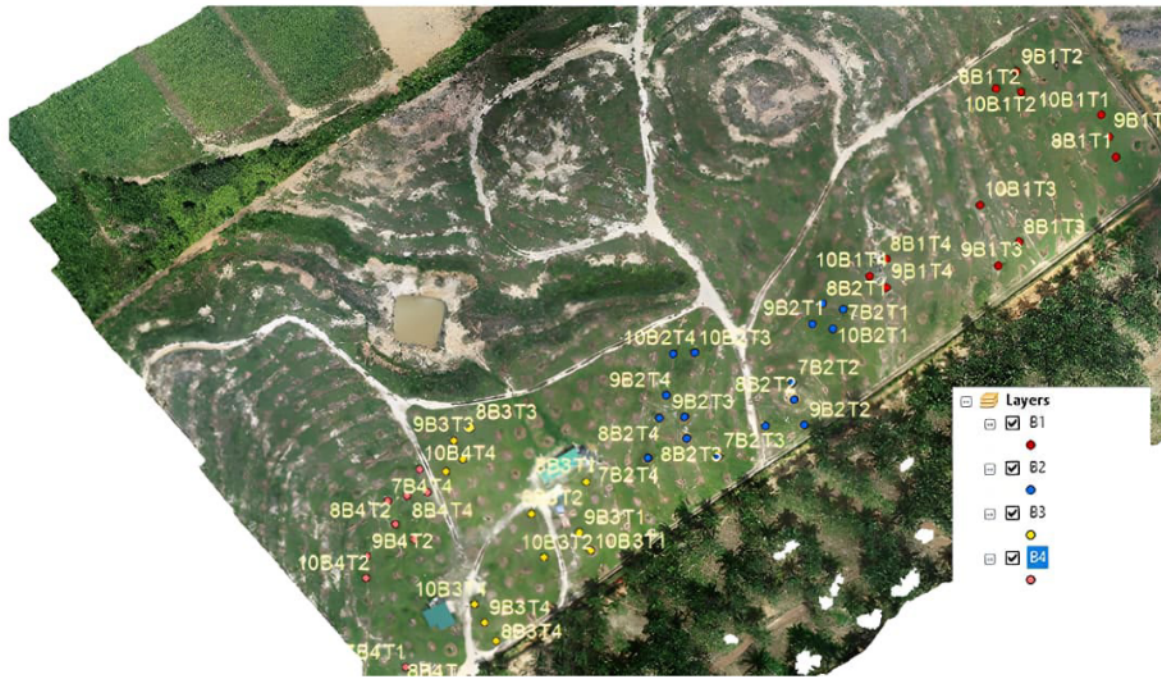


Fig. 1 Durian plantation at Sri Lalang, Kluang, Johor
 Note: B1, B2, B3, and B4 represent the treatment blocks

The study consists of two (2) treatments which are labeled as treatment 1 (T1) for climate data obtained from the on-site weather station (Spectrum Watchdog 2900ET, Spectrum Technologies, Inc. Aurora Illinois, United States) and treatment 2 (T2) for Climate data obtained from the MET weather station. Each treatment contained eleven (11) calculated ET_c values from February until December. On-site weather station and METMalaysia weather station have been used to obtain climate data to calculate ET_c . Data will be calculated using the CROPWAT 8.0 software. The ET_c in mm/day can be calculated from the equation below:

$$ET_c = K_c \times ET_o \quad (1)$$

Crop coefficient, K_c is the standard crop coefficient, where $K_c = 0.6$ for durian trees at the vegetative growth stage [28]. ET_o is the reference evapotranspiration rate over a water well-watered crop land completely covered by a short green, grass-like crop. ET_o will be calculated from the Penman-Monteith formula using CROPWAT 8.0 software, incorporating the average previous five (5) years of climate data for Kluang station obtained from METMalaysia. The climate data includes daily temperature, wind speed, sun radiation, and humidity. For this treatment, irrigation was also given twice daily.

3.2 Weather Station Components

The weather station (Spectrum Watchdog 2900ET, Spectrum Technologies, Inc. Aurora Illinois, United States) includes several essential sensors that monitor different environmental conditions. Thermometers measure temperature in Celsius ($^{\circ}\text{C}$), with a range of 30 meters to 100 feet, offering valuable temperature data for weather tracking. A hygrometer measures relative humidity (%RH) by detecting changes in capacitance, which occur as water molecules from the air are absorbed by a capacitor. Barometers monitor atmospheric pressure in pascals (Pa), with a pressure range of 300 to 1100 hPa and an accuracy of ± 4 to 2 hPa, providing insight into atmospheric shifts. An anemometer tracks both wind speed (km/h) and direction ($^{\circ}$), using a cup anemometer with three aluminum cups placed at a 45° angle for $\pm 5\%$ accurate speed readings. The wind vane detects wind direction within a 360° range. Rain gauges measure rainfall in millimeters (mm), using a 159.6mm ABS plastic bucket that accurately records precipitation from 0 to 4 mm/min, with a detection accuracy of $\pm 0.4\text{mm}$, and operates within a temperature range of 0 to 60°C . These sensors work together to provide comprehensive data that is crucial for agricultural planning and weather forecasting.

For agricultural purposes, the station should be situated in a location that accurately reflects field conditions. This is essential due to the high spatial variability of rainfall and the impact of built environments on temperature. To ensure accurate observations, stations should be positioned to minimize the influence of obstructions like buildings and trees, as shown in Fig. 2.



Fig. 2 An on-site weather station at the study area field

3.3 Data Collection

Fig. 3 shows the flow of data collection of in this research. Monthly ET_o is calculated using CROPWAT 8.0 by accessing climatic data from both the on-site weather station (T1) and the METMalaysia climatic database (T2). The climate data obtained from the weather station located on-site will be collected daily and thereafter uploaded in the form of an Excel file. Data collection started in the seventh (7th) week following the installation of the on-site meteorological station, and it took place from April to December 2020. For T2, a total of five (5) years of historical climate data for the Kluang station were acquired from METMalaysia. The METMalaysia weather station in Kluang, Johor, is situated at a distance of 10 km from the research area.

Once the data has been gathered from both sources, the estimation of ET_o will be performed using CROPWAT 8.0, which utilizes the Penman-Monteith equation [29]. The calculation of ET_c in millimeters per day can be achieved using Equation 1.

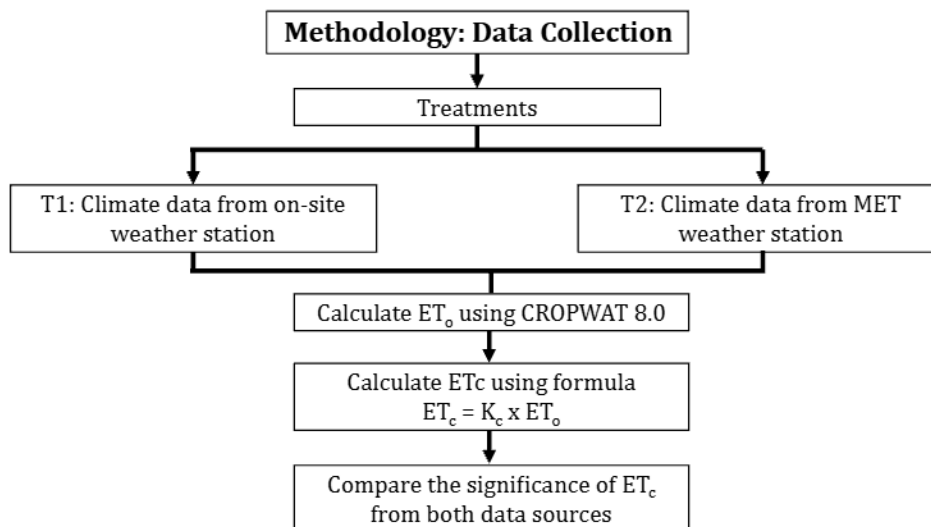


Fig. 3 Data collection framework

3.4 Data Analysis

The ET_c values obtained from the two sources were statistically analyzed by t-test (independent t-test) using Excel 2013 (Microsoft Corp, Redmond, WA, USA). A t-test was performed to determine the statistical significance of the

varying water requirements at the vegetative stage of durian, resulting from different sources of data. A significant difference is anticipated between the ET_c values calculated using climate data from the on-site weather station and the METMalaysia weather station.

4. Finding and Analysis

Tables 1 and 2 show the results of ET_o and ET_c for both weather stations from different climatic resources. The results show a significant difference in ET_o , ET_c between the METMalaysia weather station and the on-site weather station. The values for ET_o , and ET_c for the on-site weather station were higher than the METMalaysia weather station for all months.

Table 1 Value of ET_o , ET_c for on-site weather station (T1)

Month	$ET_o \times K_c$	ET_c
February	5.32 x 0.6	3.192
March	5.57 x 0.6	3.342
April	5.46 x 0.6	3.276
May	5.04 x 0.6	3.024
Jun	4.85 x 0.6	2.91
July	4.94 x 0.6	2.964
August	5.20 x 0.6	3.12
September	5.41 x 0.6	3.246
October	5.38 x 0.6	3.228
November	5.00 x 0.6	3
December	4.84 x 0.6	2.904

Table 2 Value of ET_o , ET_c for MET weather station (T2)

Month	$ET_o \times K_c$	ET_c
February	4.3 x 0.6	2.58
March	4.49 x 0.6	2.694
April	4.27 x 0.6	2.562
May	3.92 x 0.6	2.352
Jun	3.67 x 0.6	2.202
July	3.65 x 0.6	2.19
August	3.87 x 0.6	2.322
September	3.93 x 0.6	2.358
October	3.75 x 0.6	2.25
November	3.47 x 0.6	2.082
December	3.26 x 0.6	1.956

Based on the results, ET_c for the on-site weather station was higher than the METMalaysia weather station in Kluang, Johor. This discrepancy is due to the differing distances between the stations and the study area; the METMalaysia weather station in Kluang, Johor is 10 km away from the study area. Additionally, the on-site weather station is located near the plants and provides current climate data, while the METMalaysia data is historical data from the past five years. In Malaysia, annual daily mean temperature, daily mean maximum temperature, and daily mean minimum temperature increased significantly at all stations, with rural areas showing a significant increment for mean and warm extreme indices [30].

From Table 3, there is a significant difference between both ET_c calculated from on-site and METMalaysia weather stations for all months. As a whole, all ET_c values from the on-site weather station had higher ET_c values compared to ET_c from the METMalaysia weather station. This difference is likely because the on-site weather station is located at the experimental site, making it more accurate for capturing the specific microclimatic conditions that influence ET_c . Studies have shown that localized weather stations provide more reliable data for site-specific agricultural modeling compared to regional stations, as they account for field-level variations in temperature, humidity, and solar radiation [31]. This agrees with the finding that in a time series of climatological data, numerous inconsistencies can occur due to alterations in measurement systems, such as station relocations, updates to instruments, changes in exposure settings, or variations in observational methodologies, rather than actual climate variations [32].

The ET_c from the on-site weather station uses current climate data measured in the study area, surrounded by the durian trees. These climate data represent the actual environmental conditions of the area and can provide accurate information for ET_c estimation for the durian trees. Conversely, ET_c from the METMalaysia weather station uses an average of five years of historical climate data for ET_c estimation. Historical climate data pertain to past events and conditions specific to the area of the durian plantation. Such data include most manually or automatically generated data within a certain purpose. Analyzing historical data to discern trends, correlations, and other statistical relationships can provide insights into current conditions. However, five years of historical data from the METMalaysia station must be used cautiously when estimating ET_c , as the actual data from the on-site weather station have proven to be significantly different. Due to climate change, with variations in long dry seasons and less wet seasons, it is almost impossible to predict the same climate trends in subsequent years. Based on the water requirements for the durian trees in the study area, more irrigation is needed according to the on-site weather station compared to the METMalaysia weather station. Moreover, accurately determining crop water requirements can conserve water and reduce overall irrigation management costs [33].

Table 3 ET_c calculated from weather station data and on-site weather station data from February to December 2020, presented as monthly averages ($n = \pm 30$ days per month)

Months	Treatment		Significance
	T1: On-site Weather Station ET_c (mm/day)	T2: METMalaysia Weather Station ET_c (mm/day)	
Feb	3.189	2.588	$t(52) = -18.5^*$
Mar	3.342	2.694	$t(58) = -31.6^*$
Apr	3.272	2.535	$t(57) = -21.1^*$
May	3.004	2.353	$t(38) = -19.0^*$
Jun	2.908	2.224	$t(58) = -28.9^*$
Jul	2.961	2.188	$t(38) = -34.1^*$
Aug	3.12	2.321	$t(48) = -41.1^*$
Sep	3.244	2.389	$t(47) = -21.9^*$
Oct	3.229	2.247	$t(54) = -55.1^*$
Nov	3.002	2.09	$t(49) = -48.2^*$
Dec	2.904	1.957	$t(50) = -44.2^*$

Note: *significant at $p < 0.05$, respectively.

5. Conclusion

This study compared durian ET_c at the study area in Kluang, Johor, using data from the METMalaysia weather station in Kluang and an on-site weather station. The METMalaysia data comprised five years of historical records, while the on-site data were collected and transferred by plantation workers. The study revealed significant differences in ET_c values between the two sources, with higher ET_c values from the on-site station indicating a greater water requirement for durian trees. This demonstrates that different climate data sources result in varying ET_c values.

The findings highlight the significant impact of Malaysia's climate on crop water requirements, emphasizing the importance of accurate ET_c estimation to optimize water use and reduce costs for farmers. Installing on-site weather stations near plantations is crucial for accurately calculating ET_o and determining precise crop water needs, ultimately enhancing crop production and quality.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Wan Fazilah Fazlil Ilahi, Nur Syaffiqa Izleen Rosdi, Muhammad Hazim Shahemi; **data collection:** Wan Fazilah Fazlil Ilahi, Muhammad Hazim Shahemi; **analysis and interpretation of results:** Wan Fazilah Fazlil Ilahi, Nur Syaffiqa Izleen Rosdi, Muhammad Hazim Shahemi; **draft manuscript preparation:** Wan Fazilah Fazlil Ilahi, Nur Syaffiqa Izleen Rosdi. All authors reviewed the results and approved the final version of the manuscript.

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