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Developing IT infrastructure of evaporative irrigation by adopting IOT technology

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Abstract. The primary key to the modernization of irrigation is the effectiveness of agricultural water use that should be supported by good infrastructure, including information technology (IT). The objective was to evaluate the performance of IT infrastructure in collecting weather data for evaporative irrigation. The system was set up under a natural environment since 10 July 2020 in the Kinjiro Farm, Bogor. The system consisted of three parts, i.e., integrated sensors suite (ISS), console (data logger), and the server, including the dashboard system. The ISS involved several sensors, namely: *Pyr* solar radiation, rain gauge, air temperature, and humidity sensors, together with wind speed and direction. All data were collected through the console and data logger and then transferred into a local computer server to the dashboard system using an internet connection. The users can access all data from the dashboard system as numerical and graphical data. The system showed a reliable performance, as all data were well properly sent to the server every 30 minutes. The weather parameters, including rain events, were correctly monitored every 30 minutes. All observed data were found to directly affect the reference evapotranspiration, a parameter that will be used for further consideration in determining irrigation scheduling.

1. Introduction

Information Technology (IT) has been widely utilized in all sectors, including agriculture. Agriculture, a primary sector in providing food for human beings, is facing many issues such as regional climate change, water scarcity, or pest attacks reducing crop yield. Applying IT enables agriculture to be more precise, versatile, and efficient; it makes it possible to utilize irrigation for better rice farming and its sustainability [1]. Using specific sensors and their networks to measure environmental parameters such as wireless sensor networks can improve monitoring and decision-making and affect management [2, 3]. IT also plays an essential role in disseminating information and knowledge sharing between farmers and corporates in order to improve productivity, economic benefits, social responsibility, and environmental sustainability [4, 5].

Due to advancements in IT infrastructure in Indonesia, even in remote areas, IT field monitoring can be used in the agriculture sector to make water use more effective and thus increase productivity. When adopting the Internet of Things (IoT), various benefits and advantages can be achieved, such as more efficiency in the use of inputs, better cost efficiency, more profitable activities, and better protection of the environment, and sustainability [6]. In addition, the Ministry of Public Works and Housing initiated a program for the modernization of irrigation in 2011, with five pillars, including irrigation management [7]. The primary focus of this pillar is the effectiveness of agricultural water use.

Many irrigation technologies have been introduced in Indonesia; one of them is evaporative irrigation [8]. The evaporative irrigation is a concept in controlling irrigation water, which is based on the plant response represented by evaporation and evapotranspiration rate [8]. Implementing this technology is essential to monitor weather parameters affected by evaporation and evapotranspiration on the crop. Therefore, the present study proposes to implement weather data collection by adopting IoT. The main objective of this study was to evaluate the functionality of IT infrastructure in collecting weather data for evaporative irrigation. Then, from the monitored data, reference evapotranspiration of FAO's standard model was determined.

2. Methodology

2.1. IT infrastructure set up

The IT infrastructure was set up by utilizing various instruments such as sensor, logger, and connection system, including the interface. The system was set up under the natural environment since 10 July 2020 in the Kinjiro Farm, Bogor, West Java. The coordinate of location is 6° 35' 35.36" S and 106° 46' 17.95" E. Here, we cultivated rice-fish farming by adopting evaporative irrigation with three water regimes scenarios and two replications. The water regimes consisted of continuous flooding, wet and dry regimes. In the paddy cultivation system, we adopted the *System of Rice Intensification* (SRI) farming with some elements, i.e., single transplanting with 14 days seedling (young seed), and 30 x 30 cm spacing between plant hills. These elements were similar to the previous study focusing on minimizing greenhouse gas emissions [9].

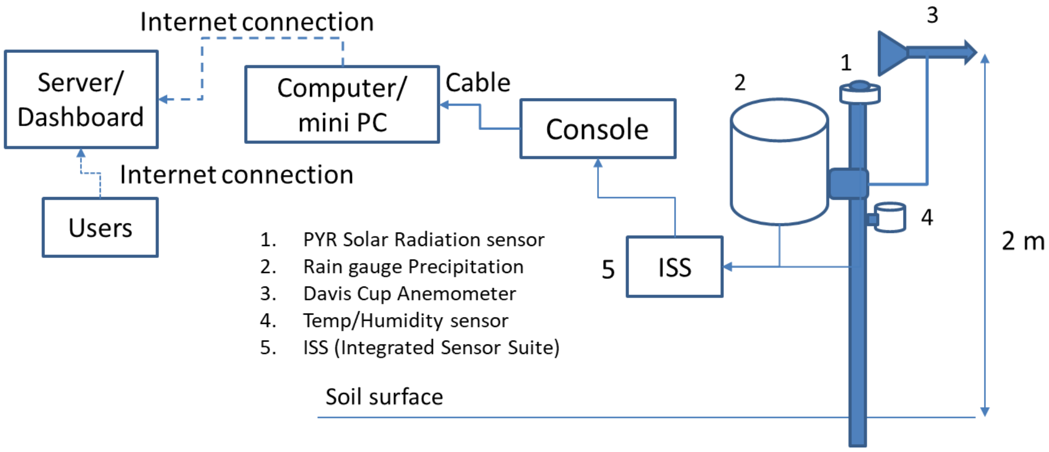


Figure 1. IT infrastructure network of evaporative irrigation.

The network of IT infrastructure was shown in Figure 1. The system consisted of three parts, i.e., integrated sensor suite (ISS), console (as a data logger), and the server, including the dashboard system. The ISS is connected to weather sensors, i.e., Pyr solar radiation, rain gauge, anemometer, temp/humidity. The sensors were set up to measure all weather parameters every 15 minutes in the console, and they were connected to the local computer/mini PC. All data were then sent by a local computer/mini PC every 30 minutes automatically to the server equipped with a dashboard system. The users can access all data from the dashboard system under the form of numerical and graphical data.

2.2. Data analysis

All of the data stored on the server were then analyzed on a daily basis. Solar radiation, air temperature, humidity, and wind speed data were used to determine reference evapotranspiration by the Penman-Monteith model according to the FAO's standard model [10] by the following equation:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T_{mean} + 273}u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u)} \quad (1)$$

$$\Delta = \frac{4098[0.6108\exp(\frac{17.27T_{mean}}{T_{mean} + 237.3})]}{(T_{mean} + 237.3)^2} \quad (2)$$

where ETo is reference evapotranspiration (mm/d), Rn is nett radiation at the crop surface ($MJ/m^2/d$), G is soil heat flux density ($MJ/m^2/d$), T_{mean} is daily average air temperature (°C), u is wind speed at 2 m height (m/s), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), Δ is slope vapour pressure curve (kPa/°C), and γ is pychromatric constant (kPa/°C).

2.3. The constraints of the study
The current study only demonstrated IT infrastructure's functionality in collecting field data real-time and precision, particularly weather parameters, and then use the data to determine ETo during vegetative plant growth (approximately two months). Hence, water use efficiency and its correlation to land productivity of the current experiment (three water regimes) were planned for the second phase of the study.

3. Results and Discussion

3.1. Dashboard system
All data can be accessed through https://dataonline.co.id/. Only registered users can access the data protected by username and password. After login, the users can access three main menus, i.e., *Dashboard, Table, and Chart*. The dashboard menu presents the latest uploaded weather data, as illustrated in Figure 2. The interface was set in the local language (Indonesia) in terms of air temperature, humidity, rain, solar radiation, wind speed, and direction. By this interface, the users can monitor actual field conditions in every 30 minutes.

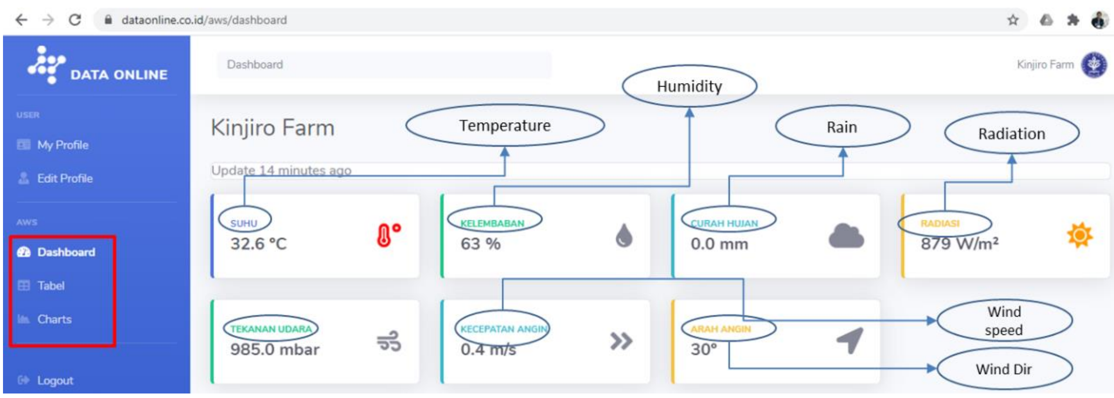


Figure 2. Dashboard system of field monitoring.

The second menu is shown in Figure 3. Here, the user can select the number of data that will be accessed and downloaded in MS Excel format (numerical data). There are some sub-menu such as *Today*, *Yesterday*, *Last 7 Days*, *Last Month*, etc. (Figure 3). These numerical data showed weather conditions measured by the sensors and uploaded to the server every 30 minutes. The data will then be used for further analysis to determine reference evapotranspiration according to equations 1 and 2. Also, daily mean, minimum, and maximum weather data will be determined to identify its dynamic impact on evaporation and evapotranspiration rates.

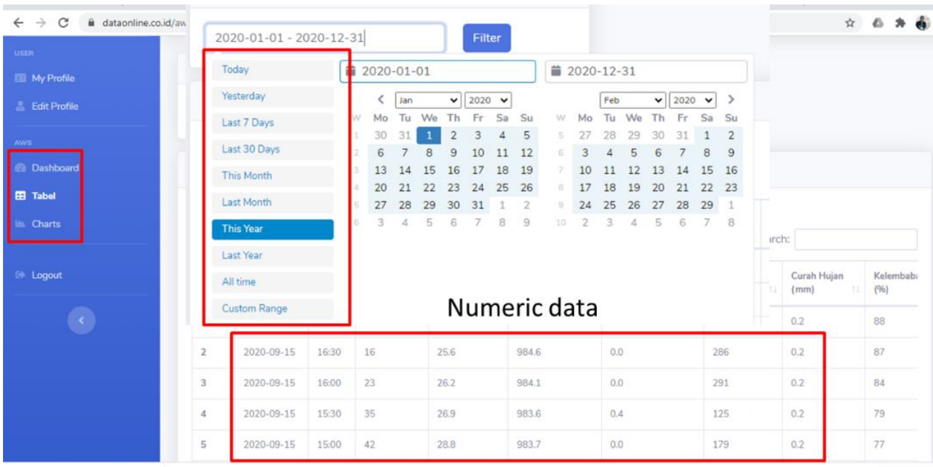


Figure 3. The interface of numeric data in the table format

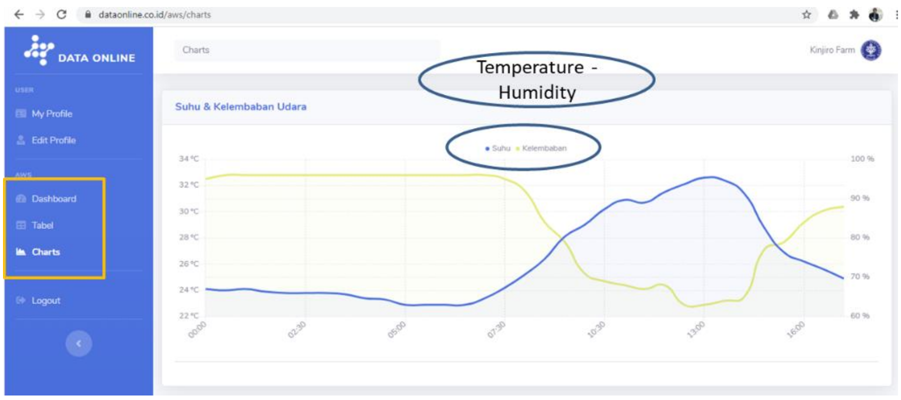
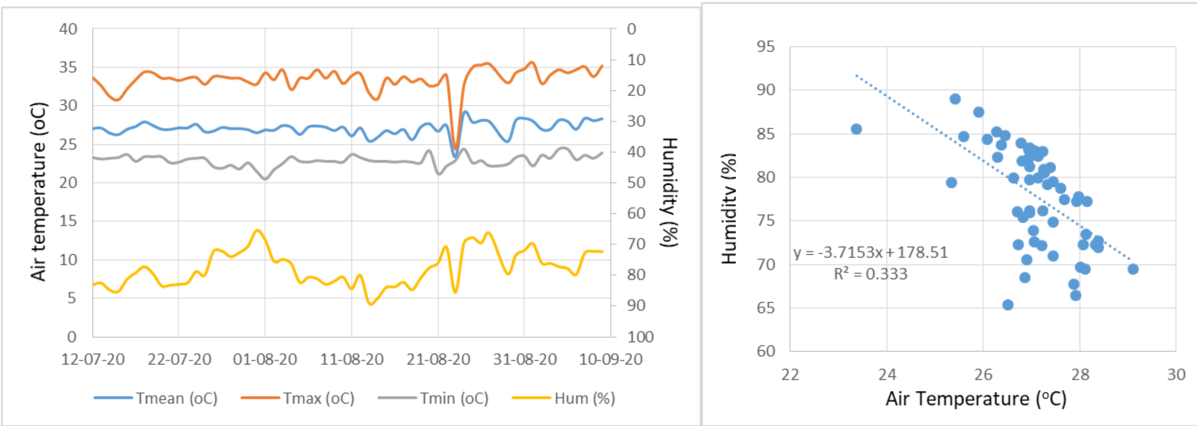


Figure 4. Graphical data of temperature and humidity in the interface of field monitoring.

The last menu is *Chart*, which presents graphical data in terms of all-weather data (Figure 4). By this graphical data, the daily trend of each weather parameter can be accessed. For example, the maximum air temperature occurred at 01.00 pm on 15 September 2020. On the other hand, the humidity reached the minimum value at this time (Figure 4). The currently developed dashboard is user-friendly, and it enables viewing and interacting with the actual field condition and *table*, *chart*, and *maps* of location in a single display. An interactive dashboard system is key to support decision-making and enable performance monitoring [11].

3.2. Weather Data

Based on the monitored data during two months of monitoring, air temperature and relative humidity were found to fluctuate following opposite trends (Figure 5). Although R^2 was less than 0.4, a clear correlation between air temperature and humidity were shown in Figure 5b as represented by the negative slope number. The lowest and highest air temperatures were respectively, 20.5°C and 35.6°C. It occurred on 1 August and 1 September 2020, respectively. Meanwhile, the trend of relative humidity decreased from the end of July to early August 2020. Then, it increased until the end of August 2020. The lowest and highest relative humidity occurred on 31 July 2020 and 13 August 2020 when their values reached 65.4% and 89.0%.



(a) (b)

Figure 5. The dynamic change of air temperature and humidity (a) and its linear correlation (b).

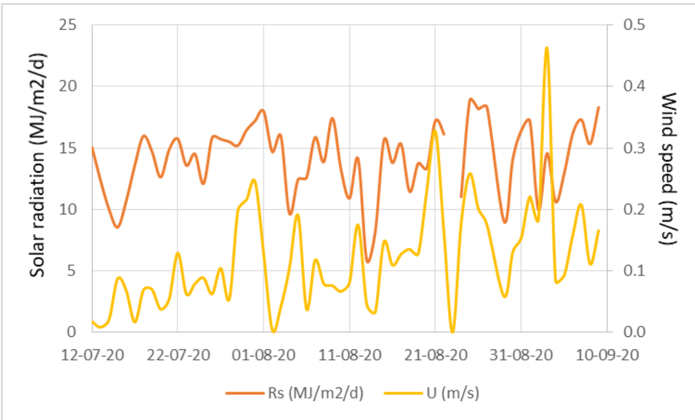


Figure 6. The dynamic change of solar radiation and wind speed.

The dynamic change of daily solar radiation and wind speed, as shown in Figure 6. These trends have fluctuated under maximum values of 18.9 MJ/m^2/d and 0.5 m/s, respectively. The trend of wind speed showed a slight increase from July to September 2020. Meanwhile, the solar radiation was found relatively constant between 10 to 20 MJ/m^2/d. Through the tested technology, it was shown that all weather data were well monitored following 30 minutes intervals and a daily basis as well.

3.3. *Reference Evapotranspiration (ETo)*

According to equations 1 and 2, ETo is affected by four weather parameters which correlation varied, as shown in Table 1. ETo showed a very strong correlation to solar radiation with a R^2 reaching 0.94 followings by humidity, air temperature, and wind speed. It was indicated that ETo rate was clearly affected by solar radiation. Therefore, solar radiation became the main weather parameter in estimating ETo. When the data were not available, an estimation method was proposed in order to estimate solar radiation while using neural networks and empirical models [12].

Table 1. Correlation between ETo to weather data

Correlation	R^2
Solar radiation - ETo	0.94
Air Temperature - ETo	0.32
Humidity - ETo	0.59
Wind speed - ETo	0.25

As it was directly affected by solar radiation, daily reference evapotranspiration also fluctuated (Figure 7) along with solar radiation (Figure 6). The maximum reference evapotranspiration was 4.2 mm when solar radiation reached its maximum value on 25 August 2020. On the other hand, its minimum amount was 1.1 mm when solar radiation was minimum on 13 August 2020.

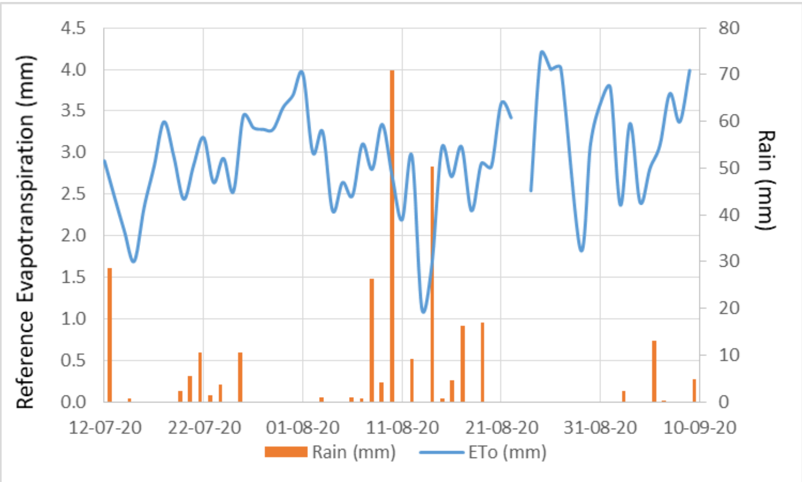


Figure 7. The daily reference evapotranspiration and rain precipitation.

The reference evapotranspiration rate and trend were also affected by rainfall (Figure 7). Between the end of July and 25-30 August 2020, no rain occurred, and the reference evapotranspiration reached its peak with an average of 3.3 mm. Conversely, when many rain events occurred during the 7-18 August period, the average value of reference evapotranspiration was lower (2.6 mm). It is known that reference evapotranspiration is the main factor in determining crop water requirement in evaporative irrigation, and that is affected by the combination of weather parameters, including rain events. Therefore, the monitored data are needed for further analysis in determining irrigation scheduling by evaporative irrigation.

4. Conclusion

The current study was undertaken in order to evaluate IT infrastructure's functionality and performance in collecting weather data for the management of evaporative irrigation. During two months of monitoring, weather parameters, including rain events, were correctly monitored every 30 minutes. The IT infrastructure was made of an interactive and user-friendly dashboard that enabled viewing and interacting not only on the actual field condition but also by having *table*, *chart*, and maps of location in a single display. According to the monitored data, reference evapotranspiration, which is the main factor in determining crop water requirement in evaporative irrigation, was well determined and analysed.

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