Crop water requirement of Soursop (Annona muricata L) in Nawungan orchard, Selopamioro village, Imogiri sub-district, Bantul regency, Yogyakarta

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Abstract. The aim of this study was to measure actual evapotranspiration and to determine the water requirement and crop coefficient (Kc) of soursop (Annona muricata L). The soursop was farmed at Nawungan orchard in Selopamioro village, Imogiri sub-district. Village monographs, 1: 25,000 scale Indonesian earth map and climate data were used to get the purpose of study. An Automatic Weather Station (AWS) was installed in Nawungan orchard to record rainfall, air relative humidity, wind velocity, solar radiation, as well as soil moisture every fifteen minutes. A set of surface runoff equipment was set in soursop farming land. Infiltration test was conducted in nine selected locations of soursop farming land and later, it was used to find soil percolation value. The purposive sampling method was adopted to assign the nine locations of infiltration test. The reference evapotranspiration (ET₀) was calculated by the Penman-Monteith method. Later, water balance formula was applied to determine the actual plant water requirements (ETₐ) and plant coefficient value (Kc). This study proved the reference evapotranspiration (ET₀) of the study area was 5.74 mm / day, the actual crop water requirement (ETₐ) of soursop was 7.98 mm / day. And Kc of soursop was 0.576.

1. Introduction

Dry land in Indonesia is one of the potential land resources to be developed to support agricultural development both in terms of area as well as opening up opportunities of producing various agricultural commodities. Dry land areas in Indonesia reached more than 140 million hectares, of which 6.1 million hectares are in the island of Java [1]. In 2013, the government of Bantul pioneer orchards by utilizing the 35 hectares of dry land areas located in the hamlet Nawungan. One kind of commodity that was developed is soursop.

The dominant limiting factor for soursop cultivation is the availability of water for plants, especially when the dry season arrived, where the state of the soil and climate in the Nawungan orchard became very dry and hot. In order to meet the water needs of plants during the dry season, irrigation administration needs to be done in order to support the growth of soursop remains optimal. In the
application of the provision of irrigation water should pay attention to the crop water needs and water availability in the area, considering the difficulty of water sources in the Nawungan Orchard. The amount of crop water requirements can be approximated by using the value of crop coefficient (Kc). However, in the book FAO 56 there is no information available about the value of Kc soursop [2].

2. Methodology
The study was conducted in the area of Nawungan Orchard, Selopamioro Village, Imogiri, Bantul, which began from November 2018 to March 2019. This study consisted of three phases: preparation, field data collection, and data processing. The determination of the parameters in this study used the basic guidelines of the book Food and Agriculture Organization (FAO) 56 and the principles of water balance. The methods of data collection were observation and identification of agro-climatic water balance and laboratory testing and documentation. Rainfall data from the last 10 years available from the Institute for Water Resources Management (BPSDA) DIY, Barongan climate station, which is the closest climate station from the Selopamioro village. Microclimate data were collected by Automatic Weather Stations (AWS), soil moisture was measured by taking disturbed soil samples around the plant roots of soursop. Percolation was measured by using a double ring infiltrometer and Surface Runoff (SRO) was measured by isolating the land then placed the container in the form of a series of pipes and bucket. A descriptive analysis of qualitative and quantitative through classification analysis of climate by the method of Schmidt-Fergusson, evapotranspiration by the method of Penman-Monteith and water balance were applied. Unit Land (SUL) was obtained by overlaying topography, soil type and land use maps. Kc (crop coefficient) soursop was calculated dual due to intercropping system applied by farmers (peanut and soursop).

3. Results and Discussion

3.1. Study Area
Geographically, the Selopamioro Village is located at coordinates -7.951495 ° S / 110.392040 ° E and the administration are in Imogiri, Bantul, Yogyakarta Special Province (DIY) as seen in Figure 1. Selopamioro village has an area measuring 22.75 km². With the distance from the central government of the City/County as far as 13 km. The boundaries of the Village area Selopamioro namely in the north bordering with Srijarjo, Imogiri, in the south, Regency of Gunung Kidul, in the west adjacent to the Village Seloharjo, Pundong, and in the east by the Banyuwoso village and Mangunan village, District Dlingo [3].

![Figure 1. Administrative Map of Selopamioro](image-url)
3.2 Soil, Climate and Topography Research Area

The soil around the soursop fruit orchard loam texture (clay), solum moderate to shallow depth (90 – 200 cm), angular blocky structure, and has a neutral to slightly alkaline pH [4].

![Figure 2](image_url). Average monthly rainfall year 2008-2016

The rainfall pattern of Selopamioro village of the year 2008 - 2016 is presented in Figure 2. Based on the analysis of rainfall from year 2008 - 2016 with algebraic methods, was obtained an annual average rainfall Selopamioro Village area of 764 to 2,544 mm. Monthly rainfall in the village of Selopamioro relatively high in November to April, which rainfall > 100 mm (wet season), while relatively low rainfall in the months of May to October, which rainfall < 100 mm. Dry months occurred in June-September.

Based on the climate classification Schmidt-Ferguson, known in the year 2008 - 2016 Selopamioro village has 6 months of wet months and dry months amounted to 4 months. From the calculations, the Q value of 0.67 and is categorized into type D or temperate climate. At the time of observation, soursop fruit orchards have a mean minimum temperature of 23°C, mean maximum air temperature of 32°C, wind speed average of 0.246 m/s, RH mean at the time of sun irradiation amounting to between 54% and the average RH at sunset by 99%. Orchard Nawungan has varying heights. Soursop fruit orchard located at an altitude of 210 – 260 meters above sea level, with an area of 7 ha and hilly terrain with slopes 11.5°.

3.3 Water Balance

Figure 3 that the value of surface runoff is directly proportional to rainfall, the higher rainfall will cause the surface runoff is getting higher too, and vice versa, the lower rainfall also will cause the surface runoff getting smaller. In Nawungan Orchard, in the event of rain that thickness below 5 mm does not produce surface runoff, which is where all the water from the rain seep directly into the ground. The runoff occur when the rainfall was 8 mm.

In this study, the method used to calculate the moisture content is the gravimetric method. To calculate the estimated water storage in soil (ΔSM), the root zone of plants is assumed to be as deep as 40 cm. Water storage in soil (ΔSM) from time to time served on Figure 4. From the graph, it can be seen that the amount of water storage in the soil that occur are volatile. It can be influenced by climatic factors namely temperature, humidity, and net radiation affecting soil evaporation. Plant also very influential factor in the dynamics of moisture content as it affects plant transpiration done by soursop.
Figure 3. Relationship rainfall and surface runoff

Based on Figure 5 that the increase in moisture content occur in the presence of precipitation. Moisture content soil in the soursop block in the event of rain and no rain fluctuated quite high, this is caused by the type of soil on land that is ground Regosol which can absorb water quickly so that precipitation occurs much absorbed by the soil, but the soil Regosol is also difficult to keep water in the soil in the long term. Regosol soil has poor organic matter (0.95%) and therefore the ability to store water and nutrients is very low because the nutrient is leached while the existence of organic matter helps to balance some physical properties of soil.

Figure 4. Chart Changes ΔSM Against Time

Figure 5. Relationship rainfall and ΔSM
3.4. Crop Water Requirement

The calculation of reference evapotranspiration ($ET_0$) using the FAO Penman-Monteith (Equation 1)

$$
ET_0 = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_2)}
$$

where:
- $ET_0$ = Reference evapotranspiration (mm/day),
- $Rn$ = Net radiation at the plant surface (MJ/m$^2$/day),
- $G$ = Density of heat continuously on the ground (MJ/m$^2$/day),
- $T$ = Average daily temperature at a height of 2 m (oC)
- $u_2$ = Wind speed at a height of 2 m (m/s),
- $e_s$ = Saturated vapor pressure (kPa),
- $e_a$ = Actual vapor pressure (kPa),
- $\Delta$ = The curve slope of the vapor pressure (kPa/°C),
- $\gamma$ = Constant psychrometric (KPa/°C).

![Figure 6. Graph $ET_0$ Values Against Time](image)

Based on Figure 6, the value of the reference evapotranspiration ($ET_0$) fluctuate with time. This happens because reference evapotranspiration ($ET_0$) is affected by micro-climate environments such as net radiation, air temperature, humidity, and wind speed. During observations of the microclimate in the garden soursop always changing every day, with a mean maximum temperature of 31.9 °C, the mean minimum temperature of 23.9 °C, the average wind speed of 0.246 m/s, the mean RH when the sun shines for 56% and the average RH during the night at 99%. The highest $ET_0$ value occurred on February 12, 2019 with a value of 6.2 mm.day$^{-1}$, the lowest $ET_0$ values occurred on February 26, 2019 and value$ET_0$ average is equal to 5.8 mm.day$^{-1}$.

Actual evapotranspiration ($ET_a$) was calculated using the water balance equation (Equation 2). During the observation, rainfall in soursop fruit orchards occurred in large categorized, it was 676 mm. In the area of soursop orchards had no irrigation water, so that rainfall was the only water input into the system. Further components of the water balance is Surface Runoff (SRO) with a value of 0.9 mm, percolation whose value amounted to 105.3 mm and the soil moisture content value was changing every day.
\[ \text{ET}_a = \text{CH} + I - \Delta \text{SM} - \text{SRO} - P \]  \hfill (2)

Where:
- \( \text{ET}_a \) = Actual Evapotranspiration
- \( \text{CH} \) = Precipitation
- \( I \) = Irrigation
- \( \Delta \text{SM} \) = Saves Water
- \( \text{SRO} \) = Surface runoff
- \( P \) = Percolation

Figure 7. Actual evapotranspiration

Figure 7, the actual evapotranspiration value fluctuates over time because it is influenced by climatic factors, soil factors, and crop factors. Results of \( \text{ET}_a \) value was calculated by water balance equation with actual data from the observation. Actual data to calculate the actual evapotranspiration (\( \text{ET}_a \)) is the rainfall data, moisture content, percolation, and surface runoff. The highest \( \text{ET}_a \) occurred on February 11, 2019 with value of 9.7 mm.day\(^{-1}\), while the lowest \( \text{ET}_a \) value occurred on February 27, 2019 with value of 7.4 mm.day\(^{-1}\). \( \text{ET}_a \) average value in soursop orchards during the observation was 8.6 mm.day\(^{-1}\).

3.5 Crop Coefficient (Kc)

In the soursop block of Nawungan Orchard, plants grew in intercropping systems between soursop plants and peanut plants. Thus, in determining the crop coefficient in a dual soursop done by determining Kc land first, then dividing by the canopy area between soursop and peanuts.

Soursop is a tough plant which Kc value will tend to be stable when it passed its infancy. The future growth of soursop to produce a productive fruit that is 4 – 6 years according to the type of soil and climate where the cultivation and care [5]. Soursop plant in Nawungan Orchard was started since 2014, which means soursop plant in the Nawungan Orchard had been planted for 5 years now. However, lack of maintenance as well as the drying up Nawungan Fruit Garden area during the dry season, coupled with the lack of implementation of irrigation cause the soursop plant growth in some of the slope becomes less good.
Based on Figure 8, the value of Kc soursop in the Nawungan Orchard fluctuated over time but the range of the value is not high which it can be said that the value of Kc soursop in the Nawungan Orchard relatively stable over time. During the observation, the highest value of Kc soursop occurred on February 15, 2019 with value of 0.642 while the lowest value of Kc soursop occurred on March 10, 2019 with value of 0.554. The value of Kc means soursop plant in Nawungan Orchard during the observation that is equal to 0.576. Kc value which was obtained during the observation can be used as a reference for the planned provision of irrigation water in the garden, especially for soursop plants which have received less attention in the dry season.

4. Conclusion
Reference evapotranspiration (ET₀) the study area was 5.74 mm.day⁻¹, the actual crop water requirement (ETₐ) of the study area was 7.98 mm.day⁻¹ and Kc of soursop was 0.576.

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