Research project of counterparts funded at IPB

Name	Counterpart	Title
Tania June, Aulia Rahmadi Harfah, Ummu Marufah	A03	Micrometeorological-based modelling of oil palm canopy temperature and stomatal conductances

Canopy temperature is a good indicator for the ability of plants to conduct its physiological processes like photosynthesis and transpiration. It is a critical requirement that the leaf and canopy temperature remains as close as possible to the optimal for healthy growth. Plants have a range of mechanisms that help them optimize their temperature. Oil palm plants grow successfully under air temperatures 24-28 °C., with minimum temperature for growth is 19 °C. Within this optimum range they will produce the highest weight fresh fruit bunches. But oil palm physiological processes start to deteriorate at 36°C. Leaf and canopy temperature data are not always available and rarely measured. It is possible to model canopy temperature using data obtained from micrometeorology measurements. We therefore modelled oil palm canopy temperature using micrometeorology elements including solar radiation, air temperature, wind speed, RH, and vapour pressure deficit (VPD). Micrometeorological profile data were measured above the plant canopy. These data included solar radiation, air temperature, wind speed, humidity, and air pressure. They were obtained using the micrometeorological tower station in PTPN VI Jambi for the period 2015. Our results show that canopy temperature varied within the optimum temperature range for oil palm with heat fluxes acting as canopy temperature control mechanisms. The very high absorbed radiation during day time triggers the oil palm canopy to conduct distribution mechanisms to reduce heat load and stabilize the canopy temperature within the optimum range for oil palm. Thereby oil palms avoid temperature stress that hinders the physiological processes of photosynthesis and transpiration.

Objective

The objective of this study was to model canopy temperature based on micrometeorology elements including solar and terrestrial radiation, air temperature, windspeed, VPD and conductances.

Methods

The research site was the PTPN VI Oil Palm plantation in Jambi, Indonesia where the climate tower is installed (with measurement of air temperature, global radiation, wind speed, and VPD). The oil palm plantation was 14 years old with canopy height of 13.8 m and LAI 2.2. We used the following equation to model canopy temperature,

$$T_{canopy} = T_a + \frac{\gamma*}{s+\gamma*}\left[\frac{Rabs - \varepsilon_s \sigma Ta^4 - G}{Cp g_{HR}} - \frac{D}{\gamma * pa}\right]$$

where Rabs is radiation absorbed by the canopy, Ta is air temperature, D is VPD, g_{HR} is radiative convective conductance ($g_{HR} = g_{Ha} + g_r$), g_r is radiative conductance, and γ* is the psychrometric constant. The model output was then used to analyse the implication of canopy temperature for stomatal conductances and for the heat flux from the oil palm canopy.

Results

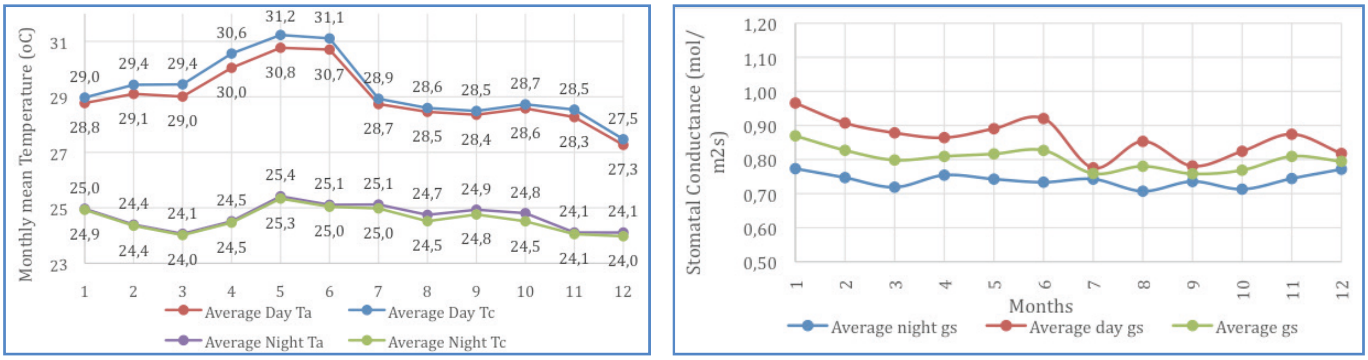

Figure 1. Mean monthly T_a and T_c (day and night) (above) and mean monthly stomatal conductance g_s (day and night) (below) January – December 2015. It shows that maximum mean day temperature occurred in May-June (coinciding with the months of the dry season in Jambi), reaching 31.2 °C, and minimum night temperature in December and March, coinciding with the rainy months in Jambi. Air temperature increased consistently from March to May-June due to the approach of the dry season. Canopy temperature T_c was always higher than air temperature T_a during the day and lower during the night. Within the period March-May June, the temperature differences between canopy and air increases from 0.1–0.3°C to 0.4–0.6°C. The reduced stomatal conductance gs, due to the dry months in March–June, influenced the increased differences between canopy-air temperature. Differences in $T_c - T_a$ are an indicator of water stress in oil palm. As these temperature differences were small, less than 1 °C, we conclude that other sources of water fulfilled the water demand of oil palm in PTPN VI Batanghari Jambi in 2015, despite it being a very dry year.

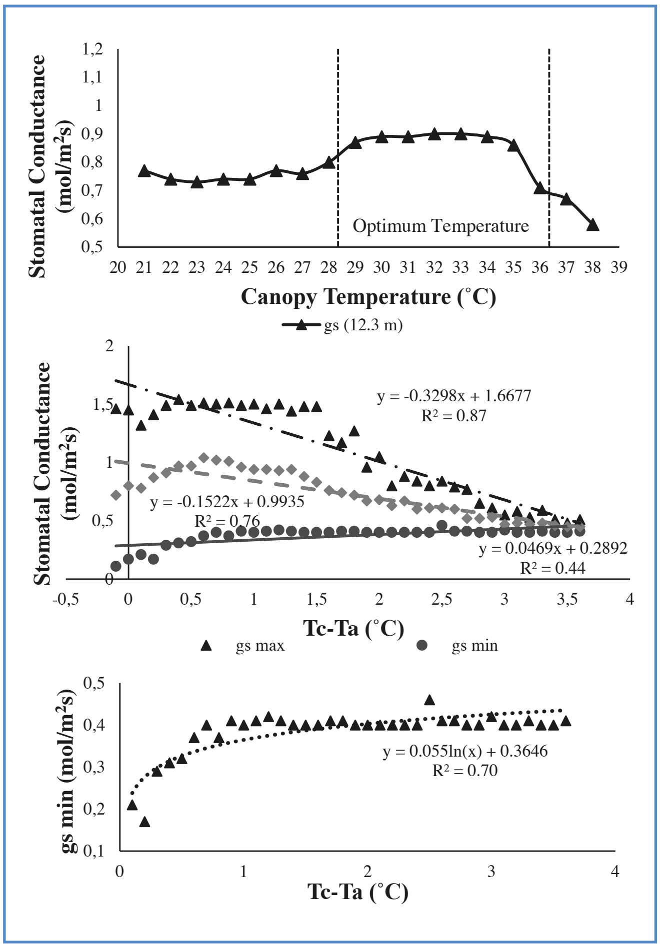

Figure 2. Relationship between canopy temperature T_c with stomatal conductances g_s (above), between T_c - T_a and gs (middle), between T_c -T_a and g_s minimum (below). Data were analysed for 2015. Stomatal conductances increased with increasing temperature to stabilize its state. Stomatal conductances were stable at 21–34 °C, with very little change from 0.8 to 0.9 mol/m²s and a drop after 35 °C. The optimum temperature range was at 26–34 °C.

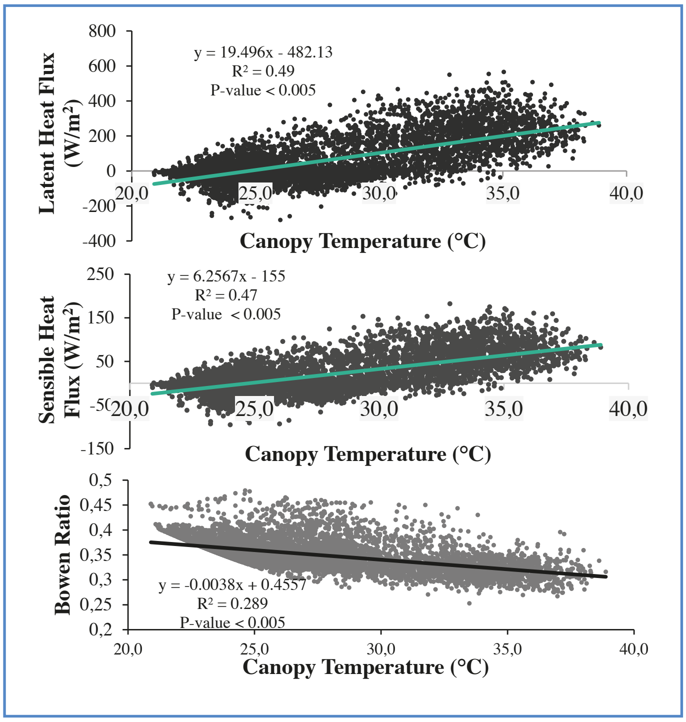

Figure 3. Relationship between canopy temperature and energy allocation for sensible and latent heat fluxes and with the bowen ratio. Heat fluxes are considered to be canopy temperature control mechanisms. The relationships between canopy temperature T_c and latent heat fluxes (LE) (above), T_c with sensible heat fluxes H (middle), and T_c with Bowen ratio (below) are significant with coefficient of correlation between Tc and LE r = 0.70 and correlation coefficient between Tc and H r = 0.69. Stomatal opening increased transpiration cooling and reduced heat as water (transpired through stomatal cavity). Oil palm used its energy dominantly for latent heat fluxes, hence effectively stabilize canopy temperature indicating small changes in stomatal conductances with changing dryness an temperature (see figure 2).

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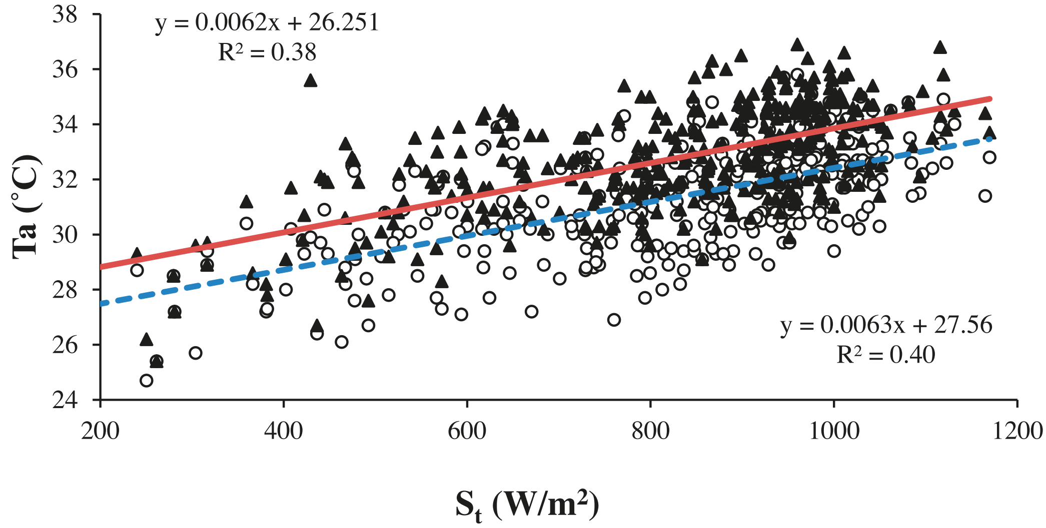

Figure 4. Correlation between air temperature Ta at maximum global radiation with S_t (o) (blue dashed trend line) and daily maximum T_a (▲) with St (red solid trend line). Canopy temperature T_c was modelled using air temperature T_a measured close to the oil palm canopy and therefore Tc will be closely linked to T_a. The correlation between Ta when S_t was maximum, as well as daily T_a maximum with increasing S_t suggested that the oil palm canopy is able to control its temperature within its optimum range even though energy input, solar radiation is at maximum level.