Agromet 37 (1): 44-53, 2023

Agromet

journal.ipb.ac.id/index.php/agromet

ISSN : 0126 - 3633

PERHIMPI

Micrometeorological Method in Determining Plant Capacity to Absorb Pollutant: Oil Palm Case Study

Za'immatul Mu'allimah[1], Tania June[1], Resti Salmayenti[1], Yon Sugiarto[1], Handoko[1], Christian Stiegler[2], Alexander Knohl[2]

[1]Division of Agrometeorology, Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Dramaga Campus, Bogor, Indonesia 16680

[2]Bioclimatology, University of Gottingen, Busgenweg 2, Gottingen, Germany 37077

ARTICLE INFO

Received
07 December 2022

Revised
30 May 2023

Accepted for Publication
06 June 2023

Published
22 June 2023

doi: 10.29244/j.agromet.37.1.44-53

Correspondence:
Tania June
Department of Geophysics and Meteorology, IPB University, Indonesia
Email: taniajune@apps.ipb.ac.id

ABSTRACT

The vegetation canopy's height and characteristics directly affect the turbulence that controls the exchange of mass and energy between the vegetation and the surrounding atmosphere. Turbulence also controls the momentum transfer towards the mass-carrying plant canopy and the accompanying atmospheric properties so that vegetation can contribute to pollutant deposition. This study aims to estimate the canopy capacity of oil palms to absorb pollutants based on their momentum transfer, the influence of atmospheric stability dynamics, and rainy and dry periods upon absorbed pollutants from PTPN VI in Jambi province for the period of January to December 2015 used micrometeorological observation data. The results showed that the dry deposition capacity value at the stable, neutral, and unstable atmospheric conditions were 2.06 x 10^{-3} kg/m^2, 3.50 x 10^{-3} kg/m^2, and 4.35 x 10^{-3} kg/m^2, respectively. The stable or unstable conditions affected the momentum transfer through decreasing or increasing turbulence. In stable conditions, the cooling of the atmosphere impacts the turbulence to be restrained. The result also showed that the dry deposition capacity during the dry and rainy periods were 4.5 x 10^{-3} kg/m^2 and 2.9 x 10^{-3} kg/m^2, respectively. Further, atmospheric conditions tended to be unstable during the dry period, while the rainy period tended to be stable. This research showed that the momentum transfer method can estimate gas type pollutants by vegetation.

KEYWORDS
atmospheric stability, dry deposition capacity, momentum transfer, pollutants, turbulence

INTRODUCTION

Clean air is essential in life, but the development of air quality in Indonesia has decreased in relation to city development, due to the increasing number of transportation, industries, as well as due to environmental issues such as forest and land fires. Forest fires are one of the severe problems in the case of air pollution in Indonesia (Hein et al., 2022). One of Indonesia's regions with the potential for forest fires is Sumatera Island which has a relatively large forest area (Saptwan et al., 2019). According to the Jambi Provincial Forestry Service, forest and land fires in Jambi Province in 2015 reached 19,528 hectares (Supriyanto et al., 2018). Forest and land fires can cause significant changes in ambient air quality due to the large number of pollutants produced. The number of pollutants in the air can be reduced by biological mechanisms through vegetation absorption (Diener and Mudu, 2021; Mandal et al., 2023).

Vegetation can reduce concentration of pollu-tants in the air through the absorption mechanism of

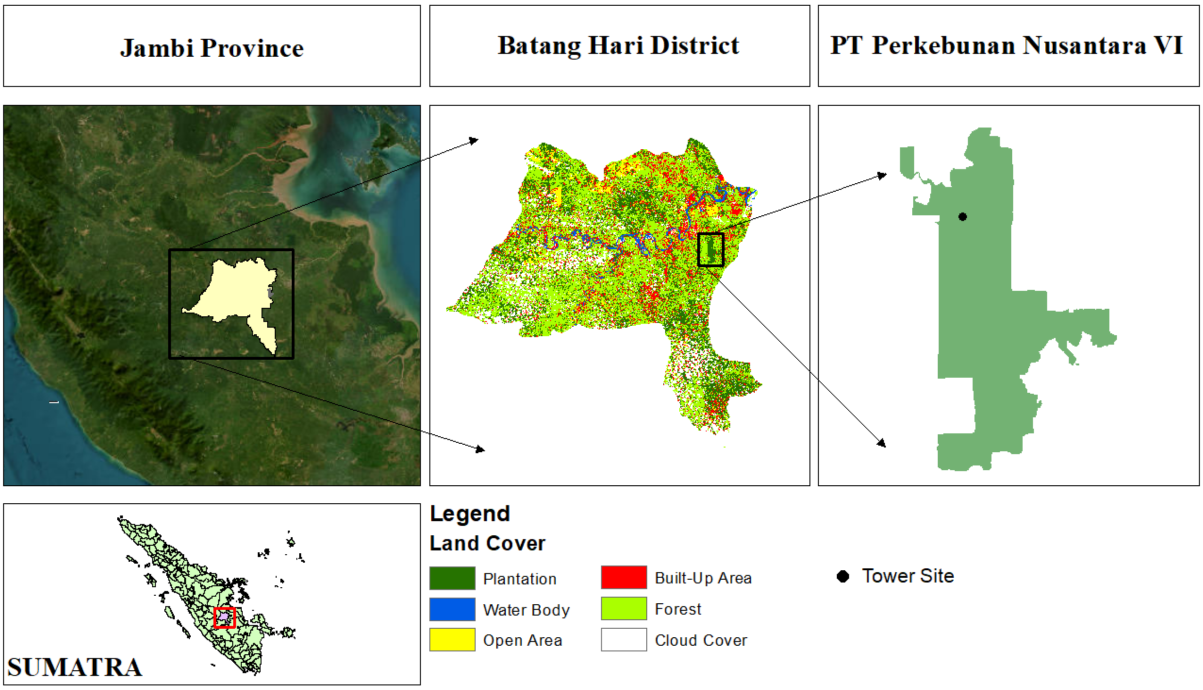

Figure 1. Research sites in PT Perkebunan Nusantara VI Batang Hari, Jambi.

gas pollutants and the absorption of particles (Diener and Mudu, 2021). The process of gas absorption by plants occurs mainly on the surface of the canopy (Desyana et al., 2017; Gardner et al., 1991). We use oil palm as our study case in The type of plant. Jambi Province is among the top ten Indonesian palm oil producing provinces in terms of area and production (Saragih et al., 2020). Oil palm plants have a canopy consisting of spiral-shaped fronds, and their numbers follow the Fibonacci sequence with the shape of compound leaves (Husin et al., 2020). The height and canopy characteristics of oil palm plants directly influence the plant canopy's turbulence level and its capacity to absorb air mass (Hardwick et al. 2015).

The air mass and energy exchange between oil palm plants and the atmosphere are influenced by the turbulence above and within the plant canopy (June et al. 2018; Hong et al., 2002). The transfer of mass from the atmosphere to vegetation that occurs due to turbulence is called momentum transfer (Barahimi and Sui, 2023; Yi, 2008). The magnitude of the momentum (air mass) displaced by each unit of area is a function of the drag coefficient and wind speed. The higher the drag coefficient and wind speed, the higher the momentum value transferred from the airflow to the vegetation canopy (June et al., 2018). Momentum transfer analysis is the central concept used in this study to estimate the ability of the oil palm canopy to absorb pollutants and to determine the effect of the dynamics of atmospheric stability and the impact of the dry and rainy periods on the ability of oil palm plants to absorb pollutants.

RESEARCH METHODS

Study Area

The study area of this research was PT Perkebunan Nusantara VI Batang Hari, Jambi Province, Indonesia (Figure 1). Geographically, PTPN VI Batang Hari Jambi Province is located in sub-plot 23 (01°41'35.0" S and 103°23'29.0"E) with a land area of 2,025 hectares (June et al., 2018).

Data Source

This study used observational data of weather variances from the micrometeorology tower at PTPN VI Batang Hari, Jambi, for the period of January to December 2015 in the form of air temperature data and air humidity at altitudes of 12.3 m, 16.3 m, and 22 m, wind speed data at heights of 13 m, 15.4 m, and 18.5 m, rainfall and air pressure data.

Atmospheric Stability Analysis

Atmospheric stability conditions were determined using Richardson number (Ri) calculations in Equation (1) (Newman and Klein, 2014) and average virtual potential temperature (K) in Equation (2).

$$\mathrm{Ri} = \frac{g\left(\frac{\partial \theta v}{\partial z}\right)}{\theta va\left(\frac{\partial u}{\partial z}\right)^2} \quad (1)$$

$$\theta va = \frac{\theta v(z_{T1}) + \theta v(z_{T2}) + \cdots + \theta v(z_{Tn})}{n} \quad (2)$$

There g was the acceleration of gravity (9.8 m s^{-2}), z was the measurement height value in meters, $\partial\theta v/\partial z$ and $\partial u/\partial z$ were the potential virtual temperature gradient (km^{-1}), and the wind speed gradient (s^{-1}), θ and θv potential temperature (K) and the virtual potential

Table 1. Classification of atmospheric stability, stability parameter (ζ), universal function for momentum, and stability function for wind profile based on Ri value.

Classification	Stable	Neutral	Unstable
Stability parameter (ζ)	$\zeta = \frac{Ri}{1-(5Ri)}$, for $0.01 \leq \mathrm{Ri} \leq 0.1$; $\zeta = 0.2$, for $\mathrm{Ri} > 0.1$	$\zeta = 0$	$\zeta = \mathrm{Ri}$
Dimensionless wind shear ϕm (ζ)	$\varphi m(\zeta) = (1 + (5\zeta))$	$\varphi m(\zeta) = 1$	$\varphi m(\zeta) = (1-(15\zeta))^{-0.25}$
Stability function for wind profiles	$\Psi m(\zeta) = -6.0\,\zeta$	$\Psi m(\zeta) = 0$	$\Psi m(\zeta) = \ln\left[\left(\frac{1+x^2}{2}\right)\left(\frac{1+x}{2}\right)^2\right] - 2tan^{-1}x + \frac{\pi}{2}$; $x = (1-19.3\,\zeta)^{0.25}$

temperature (K) (Equation 3 and 4). The value of the potential virtual temperature was determined by first calculating the value of potential temperature (θ) (Stull, 1988), specific humidity (q) (Equation 5), actual water vapor pressure (e) (Equation 6), and saturated water vapor pressure (e_s) (Equation 7) (Riegel, 1992). Value of e_{s0} = 0.611 mbar was the vapor pressure of saturated water at 0°C, p was air pressure (mbar), RH(z) was relative humidity (%) and Γd = -0.00976 km^{-1} was dry adiabatic lapse rate (June et al., 2018).

$$\theta = T(z) - \Gamma d\, z \quad (3)$$

$$\theta v = \theta\,(1 + (0.61\,q)) \quad (4)$$

$$q = \frac{0.622\,e}{p - 0.378e} \quad (5)$$

$$e = \frac{RH\,e_s}{100} \quad (6)$$

$$e_s = e_{s0}\,\exp\left(\frac{17.27\,T(z)}{T(z)+237.3}\right) \quad (7)$$

Atmospheric Stability Analysis

Correction of atmospheric stability needed to be done for wind profile analysis and surface flux in non-neutral atmospheric conditions (stable and unstable conditions) (Monin and Yaglom, 1971). Stability correction was carried out using the Monin-Obukhov Stability Parameter correction factor (ζ or z-d/L). Monin-Obukhov values were determined based on the gradient value of Richardson number (Ri) (Hartogensis and bruin, 2005). Ri < −0.01 refers to unstable condition, -0.01 ≤ Ri ≤ 0.01 neutral condition, and Ri > 0.01 stable condition (Table 1). In applying the aerodynamic method, the atmospheric stability conditions were strongly influenced by wind shear (Hostlag et al., 2012).

Roughness Characteristics

Parameters of zero-plane displacement (d), roughness length (z_0), and friction velocity (u*) were determined based on the logarithmic equation of wind profiles at various altitudes (Kimura et al., 1999; Yuhao et al., 2007). Zero-plane displacement (d) and roughness length (z_0) were functions of surface roughness (June, 2022). Surface roughness parameters were determined under neutral atmospheric conditions. This neutral condition can represent the value of roughness in all atmospheric stability conditions (Tsai et al., 2005).

Generally, the average wind speed u(z) increased linearly with concerning ln (z-d). The value of d (zero-plane displacement) (Equation 9) was analyzed aerodynamically using the value of d_0 (initial zero-plane displacement) and the value of a (wind speed) (Equation 10) (Riou, 1984). d_0 (zero-plane initial displacement) was calculated using Equation 8 (Oke, 1987), h was the average height of oil palm plantations, Δu was the difference in wind speed at the heights of z_2 and z_1, and Δu' was the difference in wind speed at altitude z_3 and z_2.

$$d_0 = \frac{2}{3}h \quad (8)$$

$$d = \frac{\left[a^2\left(\frac{\Delta u}{\Delta u\prime}\right)^2 z_1\right] z_3}{a^2\left(\frac{\Delta u}{\Delta u\prime}\right)^2 - 1} \quad (9)$$

$$a = \frac{\dfrac{\ln\left(\frac{z_3-d_0}{z_2-d_0}\right)}{[(z_3-d_0)(z_2-d_0)]^{-0,5}}}{\dfrac{\ln\left(\frac{z_2-d_0}{z_1-d_0}\right)}{[(z_2-d_0)(z_1-d_0)]^{-0,5}}} \quad (10)$$

A simple regression model determined roughness length (z_0) parameters and friction velocity in the plant canopy (u*). The value of such parameters was determined using the linear relationship between u(z) and ln (z-d) at a point (Equation 11), where u(z) was the x-axis and ln (z - d) was the y-axis (Yanlian et al., 2006). Then produce the equation Slope = k/u*. Parameter values z_0 and u* were calculated using

Equations (13) and (14). Where k = 0.4 was the Von Karman constant, ϕm (ζ) was the universal function for wind shear (Table 1), and Ψm (ζ) was the wind profile stability function.

$$\ln (z - 3d) = \text{slope } u(z) + \text{Intercept} \quad (11)$$

$$u_0{}^* = \frac{k}{\text{Slope } \varphi_m(\zeta)} \quad (12)$$

$$z_0 = \exp(\text{Intercept} + \Psi m(\zeta)) \quad (13)$$

$$u^*(z) = \frac{k\,(z-d)\,\partial u}{\varphi_m(\zeta)\,\partial z} \quad (14)$$

Transfer Momentum

The calculation of momentum transfer in this study used the aerodynamic method. Aerodynamic methods directly measure fluctuations in vertical wind speed at several heights. The momentum transfer in various atmospheric stability conditions can be calculated using Equation (15) and (16) (Arya, 1999). where ρ = 1.2 kgm^{-3} was the air density, and ∂u/∂z was the wind speed gradient.

$$K_m = \frac{k\,(z-d)\,u^*(z)}{\varphi m\,(\zeta)} \quad (15)$$

$$\tau = \rho K_m \frac{\partial \bar{u}}{\partial z} \quad (16)$$

Dry Deposition Capacity

The capacity of plants to absorb pollutants was quantified using aerodynamic methods based on momentum transfer analysis. The transfer of pollutants from the air to the plant canopy was called dry deposition. The deposition of pollutants in the dry deposition process was influenced by the force of gravity (Xinga and Brimblecombe, 2019). This study also estimated the dry deposition capacity of pollutants at various heights of oil palm plantations (Equation 17).

$$\text{Dry deposition capacity} = \frac{\tau}{g} \quad (17)$$

Determination of Dry and Rainy Period

The dry and rainy periods were determined based on monthly rainfall data using the Schmidt-Ferguson classification. The Schmidt-Ferguson classification was carried out by calculating the average number of dry months and the average rainy months. Based on the Schmidt-Ferguson classification, months with a rain amount of less than 60 mm were dry months. In comparison, the month with a rain amount greater than 100 mm was rainy.

RESULTS AND DISCUSSION

Atmospheric Stability

Atmospheric stability in research sites showed stable conditions at night, unstable during the day, and neutral conditions in the morning (Figure 2). Unstable atmospheric conditions during the day were due to a significant degree of turbulence caused by the positive vertical heat fluxes of the soil surface. Meanwhile, stable atmospheric conditions that occured at night were caused by zero or minimal heat fluxes, reducing the influence of turbulence (Bardal et al., 2018). The Richardson number was a parameter that represents the relative value of the wind shear and buoyancy in generating turbulence (Rodrigo et al., 2015).

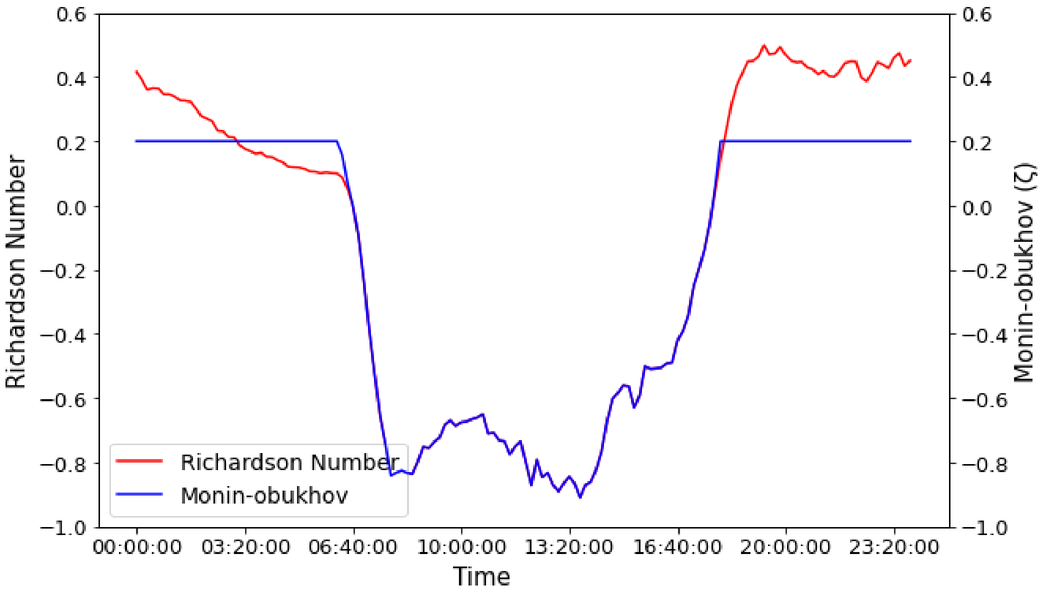

Figure 2. The diurnal plot of Richardson Number (red solid line) and Monin-obukhov (blue solid line) on oil palm land in 2015.

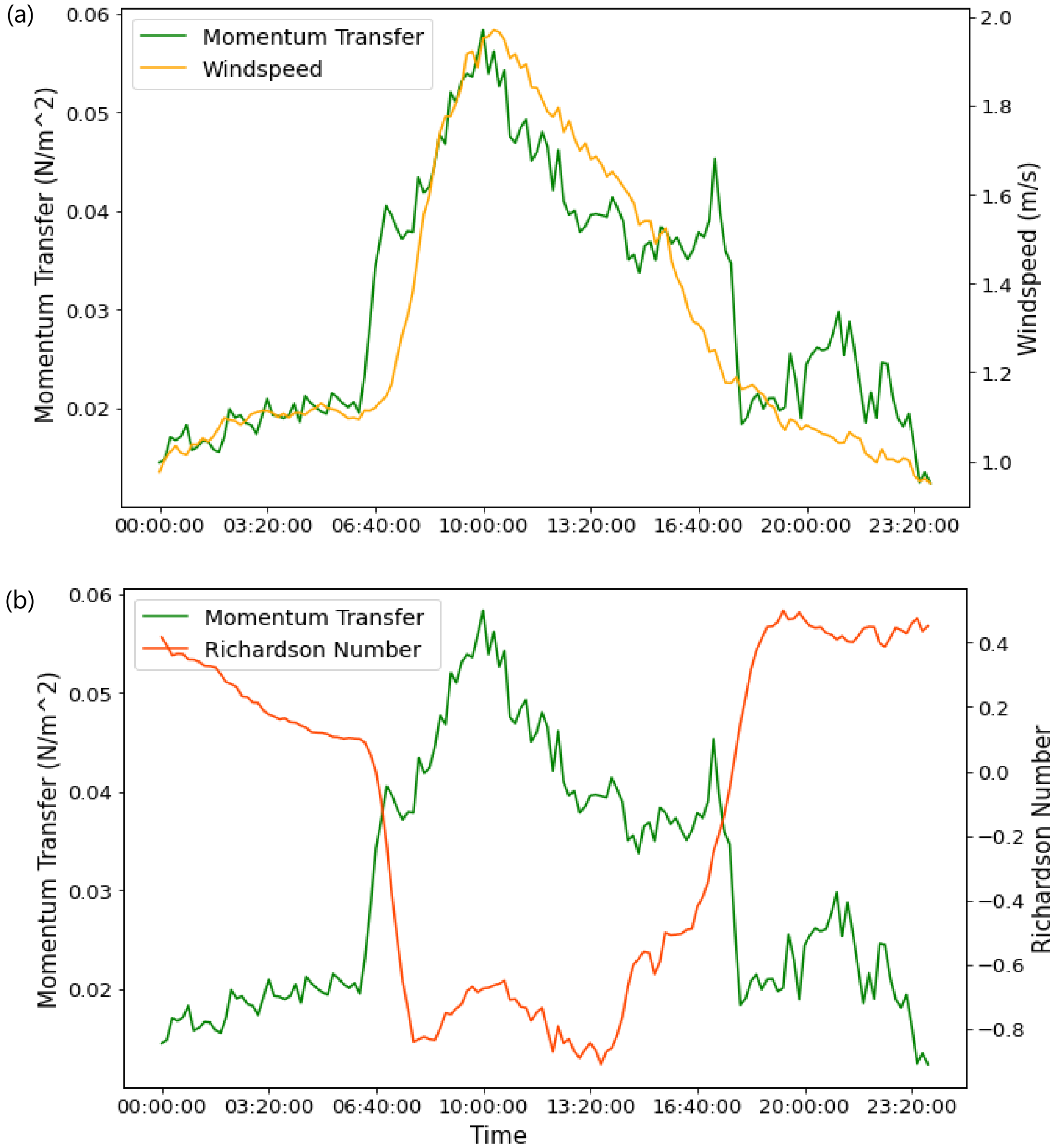

Figure 3. Diurnal plot of (a) momentum transfer (green solid line) and wind speed (yellow solid line), and (b) momentum transfer and Richardson numbers (red solid line) on oil palm land in 2015.

Atmospheric stability values on oil palm lands were range from 0.07 to 0.4 in stable conditions and -0.09 to -0.9 in unstable atmospheric conditions (Figure 2). The average value of the Richardson Number at a stable state was more than 0.25, indicating a transition from turbulent to laminar flow (Galperin et al., 2007). Correction of atmospheric stability used the theory of the Monin-Obukhov equation needed to be carried out to analyze wind profiles and surface fluxes at non-neutral atmospheric conditions (Monin and Yaglom, 1971). Monin-Obukhov's theory, in general, can be used if the surface was uniform and horizontal. The contour of research sites, was relatively flat. The type of plant that was planted uniformly was an oil palm with the same height and spacing so that it met the requirements for using the Monin-Obukhov theory. The Richardson Number and Monin-Obukhov results showed the same pattern in unstable atmospheric conditions. In stable conditions, Richardso Number value tended to be higher than Monin-Obukhov value (Figure 2).

Table 2. Atmospheric stability during the dry period and rain on oil palm land in 2015.

Period	Ri Average	Atmospheric Stability
Dry period	-0.1407	Unstable
Rainy period	1.2939	Stable

The average value of the Richardson Number in the dry period was -0.1407, while in the rainy period, it was 1.2939. Atmospheric stability conditions in the dry period tended to be unstable, while in the rainy period, atmospheric stability conditions tended to be stable (Table 2). The dry and rainy periods were determined based on the monthly distribution of precipitation in 2015. The dry period was from June to September and

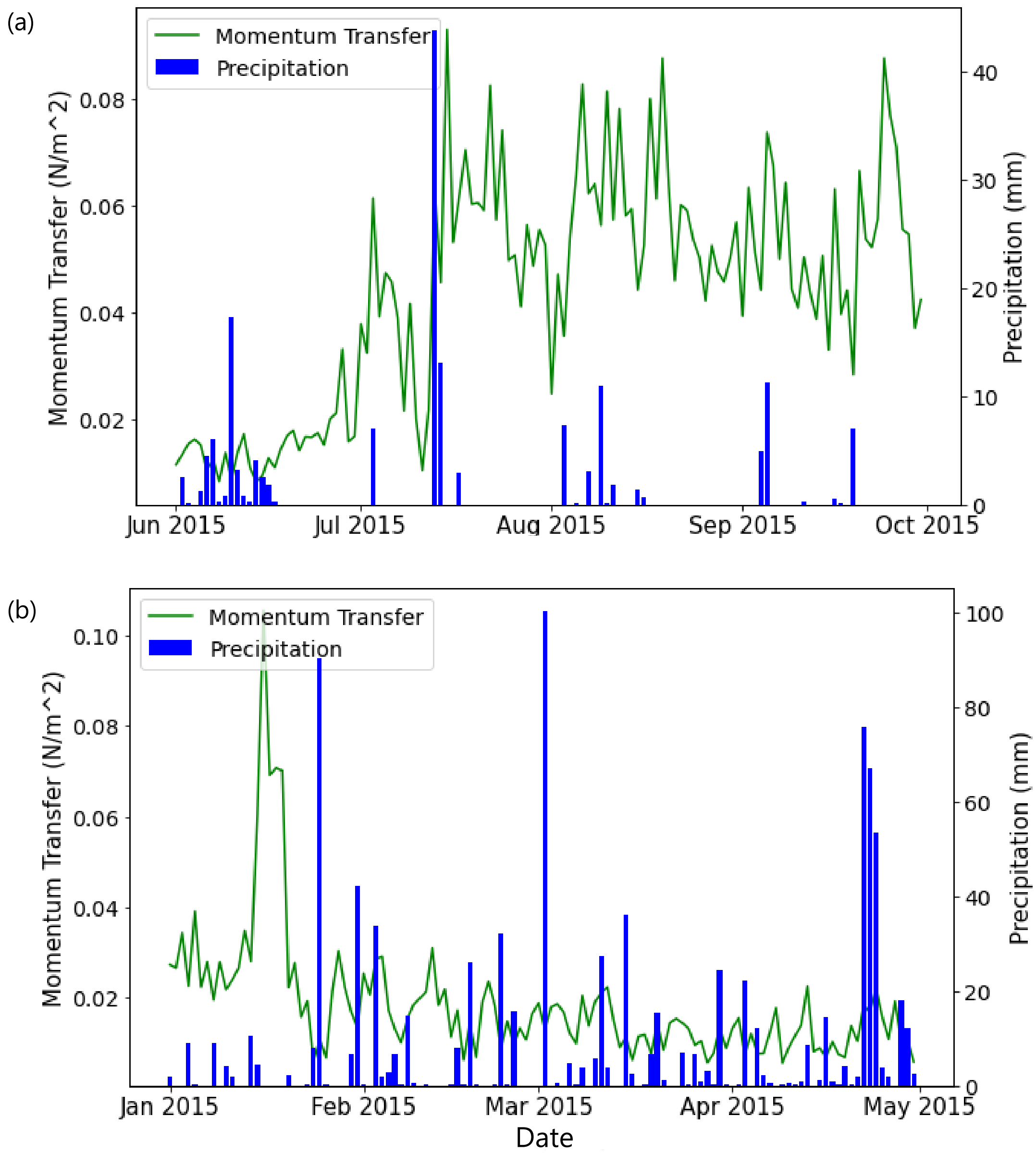

Figure 4. The daily plot of rainfall (blue bar) and momentum transfer (green solid line) in (a) dry periods, and (b) rainy periods on oil palm land in 2015.

and the rainy period was from January to April. The magnitude of heat flux influences atmospheric stability patterns due to solar insolation and terrestrial radiation (Edokpa and Nwagbara, 2017). The value of the heat flux in the dry period was higher, causing the turbulence to increased. Increased turbulence causes the atmosphere to be in an unstable state. In the rainy period, atmospheric conditions tended to be stable because the heat flux value tended to be lower, causing turbulence to be suppressed. The atmosphere in stable conditions generally occured when there was rain with low intensity or after the occurrence of rain (HR and Thakur, 2020; Zhen-li, 2016).

Momentum Transfer

The momentum transfer value on oil palm land in 2015 increased in the morning to noon with a maximum value of 0.056 N/m^2 and decreased at night with a minimum value of 0.012 N/m^2 (Figure 3a). The relationship between momentum transfer and wind speed was showed in Figure 3a. Wind affected the mass, momentum, and material transfer process between the atmosphere and the vegetation canopy. Momentum transfer and wind speed had a positive relationship where the value of momentum transfer increases with the increasing wind speed. This condition occured because the amount of momentum (air masses) moved by each area unit was a function of the drag coefficient and wind speed. The higher the drag coefficient and wind speed, the higher the momentum value transferred from the airflow to the vegetation canopy. Wind speed and momentum transfer reached a maximum during the day when the wind speed was on average 1.95 m/s and a minimum

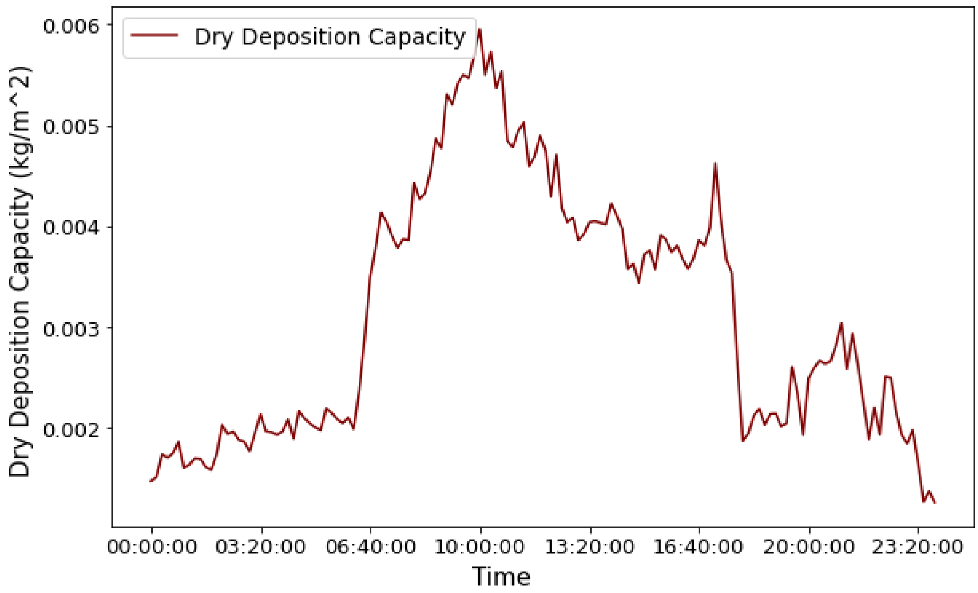

Figure 5. The diurnal plot of dry deposition capacity of oil palm plantations in 2015.

at night when the wind speed was 0.95 m/s. The wind speed during the day was higher due to the decrease in air density due to the warming of the air near the surface so that the air was easier to move (Riegel, 1992).

The atmospheric stability condition affected the value of the momentum transferred from the airflow toward the vegetation canopy. The momentum transfer value increased in unstable atmospheric conditions, i.e., in the morning to noon, and decreased in stable atmospheric conditions i.e., at night (Figure 3b). At night (stable atmospheric conditions), the atmosphere cools down so that turbulence tended to be restrained, caused the vertical displacement of momentum to be very low (Paulson, 1970). Conversely, during the daytime, when the convective boundary layer (unstable atmospheric conditions), the turbulence becomed strong so that the momentum transfer will increased.

The daily pattern of momentum transfers on oil palm land in 2015 had diverse fluctuations, ranging from low to high. The momentum transfer value in the dry period (Figure 4a) was higher than in the rainy period (Figure 4b). The amount of precipitation had no direct effect on the transfer of momentum. However, the conditions of atmospheric stability on rainy days and non-rainy affected the magnitude of the momentum transfer. The greater the sun's intensity in the dry period it will increase the convective mixing so that the turbulence on the surface becomes strong (Edokpa and Nwagbara, 2017). The high turbulence led to a high momentum transfer. Conversely, on rainy days the atmosphere tended to be stable (Table 2), so restrained turbulence can causes lower momentum transfer.

Dry Deposition Capacity

The value of dry deposition capacity indicated the magnitude of the air masses conducted towards the plant canopy. Such air masses contain particles and gaseous pollutants. The dry deposition capacity value indicated the capacity to absorb pollutants, not the actual value of pollutants that plants can absorb. The dry deposition capacity increases from morning to noon with a maximum value of 5.3 x 10^{-3} kg/m^2 and decreases at night with a minimum value of 1.26 10^{-3}. Conversely, in stable atmospheric conditions at kg/m^2 (Figure 5). The average values of dry deposition capacity under stable, neutral, and unstable atmospheric conditions were 2.06 x 10^{-3} kg/m^2, 3.50 x 10^{-3} kg/m^2, and 4.35 x 10^{-3} kg/m^2. In unstable atmospheric conditions during the day, the dry deposition capacity will increased because the turbulence increases. night, the turbulence weakens so that the absorption capacity by plants or dry deposition capacity was lower. The momentum transfer coefficient in the dry period (June-September) was higher than in the rainy period (January-April) in

Table 3. Average dry deposition capacity for dry and rainy periods in oil palm plantations in 2015.

Period	u (m/s)	u* (m/s)	KM (m^2/s)	τ (N/m^2)	Dry Deposition Capacity (kg/m^2)
Dry period	1.3661	0.2315	0.6894	0.0437	4.5 x 10^{-3}
Rainy period	1.2768	0.1956	0.4622	0.0288	2.9 x 10^{-3}

Table 4. Estimated dry deposition capacity at various heights of oil palm plantations.

h (m)	d (m)	z_0 (m)	KM (m^2/s)	τ (N/m^2)	Dry Deposition Capacity (kg/m^2)
2	1.4	0.182	0.048	0.00288	0.2939×10^{-3}
4	2.8	0.364	0.096	0.00613	0.6264×10^{-3}
6	4.2	0.546	0.144	0.00946	0.9663×10^{-3}
8	5.6	0.728	0.192	0.01293	1.3194×10^{-3}
10	7	0.91	0.24	0.01748	1.7844×10^{-3}
12	8.4	1.092	0.288	0.02211	2.2570×10^{-3}

Table 3. The average wind speed in the dry period was more significant than in the rainy period. In dry periods, the friction velocity was higher, indicating that the shear stress was more meaningful and triggered more excellent turbulence production, so the momentum transfer in the dry period was more significant than in the rainy period. The high turbulence caused the air masses passing through the plant canopy to be trapped inside the canopy. The particles and pollutant gases in these air masses were also trapped in the canopy during deposition. Conversly in rainy period, the intensity of turbulance decreases, caused particles and pollutant gases trapped in the plant canopy also to be low so that the dry deposition capacity was lower in the rainy period.

Estimated of dry deposition capacity by oil palm crops at various plant heights were shown in Table 3. Zero-plane displacement (d) and roughness length (z_0) can be estimated by taking into account the height of the plant canopy (h) (Kimura et al. 1999). Zero-plane displacement (d) was 0.667 of the plant height (Oke, 1987). The value of d was then used to guess the value of the roughness length (z_0). The value of the wind speed gradient (du/dz) was estimated from the value of du/dz in all three atmospheric conditions, namely stable, neutral and unstable. The minimum du/dz value was the du/dz value in stable conditions, while the maximum du/dz value was the du/dz value in unstable conditions. The value of z used to determine the momentum transfer coefficient was 1.3 of the height of the plant canopy. The value was the lower limit of the inertial sublayer, where the measurement value indicates the overall average.

Zero-plane displacement (d) increases as plant height increases (Table 4). In addition to the height and density of the plant, the mechanical sturdiness of the vegetation stem also defines the displacement height where the wind speed was close to zero (June et al., 2018). Plant height of 2 meters can be at the age of 1.5-2 years, for a plant height of 12 meters obtained at the age of 7-8 years in medium oil palm plant types (Yudistina et al., 2013). The canopy of oil palm plants with a height of 2 meters had a lower roughness length (z_0) value than plants with a height of 12 meters (Table 4). The roughness length (z_0) value indicated a position where momentum was well absorbed by the absorption element (June et al., 2018). Plants with a height of 12 meters had a higher momentum transfer because the higher the plant, the canopy distance between plants will be smaller, and the momentum absorption area will be more significant. Therefore, the absorption capacity of dry deposition by oil palm plants also increases as the plant grows in height (age). The large canopy surface area of leaves, stems, and branches and the air turbulence created by the plant structure, the more effective in absorbing pollutants rather than shorter vegetation (Lovett, 1994; Powe and Willis, 2004).

CONCLUSIONS

The momentum transfer analysis could be used to estimate the capacity of vegetation to absorb pollutants. The dry deposition capacity value indicated the ability to absorb pollutants (in the deposition process), not the actual value of pollutants that plants can absorb. Dry deposition capacity increased in unstable atmospheric conditions (afternoon) due to increased turbulence. Meanwhile, the plant absorption capacity got lower when turbulence reduced in a stable atmosphere at night. The value of dry deposition capacity in the dry period was 4.5 x 10-3 kg/m^2 and in the rainy period was 2.9 10-3 kg/m^2. During the dry period, atmospheric conditions were more unstable, and atmospheric conditions were more stable during the rainy period. Because there was no vertical oscillation in the atmosphere when it was stable, the absorption capacity of plants was reduced. The absorption capacity value by plants with a height of 2 meters was 0.29 x 10-3 kg/m^2, and a height of 12 meters was 2.2 x 10-3 kg/m^2. The increase in plant height, the higher the value of dry deposition capacity by oil palm plants because the higher the plant, the smaller the canopy distance between plants, so the momen-tum absorption area will be more significant. This research showed that mature oil palm plantation, managed sustainably with higher leaf area and total biomass will act as a pollutant absorber from the surrounding area and hence contribute to cleaner air.

ACKNOWLEDGEMENT

The authors would like to thank CRC990 for providing micrometeorological data of research site PTPN VI Batanghari Jambi and Agrometeorology Division-FMIPA IPB University for providing opportunity and support for first author to attend international seminar ISS2022 and publish this manuscript in AGROMET journal.

REFERENCES

Barahimi, M., Sui, J., 2023. Effects of Submerged Vegetation Arrangement Patterns and Density on Flow Structure. Water 15, 1-23. https://doi.org/10.3390/w15010176.

Bardal, L.M., Onstad, A.E., Saetran, L.R., Lund, J.A., 2018. Evaluation of methods for estimating atmospheric stability at two coastal sites. Wind Engineering 42, 561–575. https://doi.org/10.1-177/0309524X18780378.

Desyana, R., D., Sulistyantara, B., Nasrullah, N., Fatimah, I., S., 2017. Study of the effectiveness of several tree canopy types on roadside green belt in influencing the distribution of NO2 gas emitted from transportation. IOP Conf. Series: Earth and Environmental Science 58, 1-9.

Diener, A., Mudu, P., 2021. How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective - with implications for urban planning. Science of The Total Environment 796, 148605. https://d-oi.org/10.1016/j.scitotenv.2021.148605.

Edokpa, D.O., Nwagbara, M.O., 2017. Atmospheric Stability Pattern over Port Harcourt, Nigeria. Journal of Atmospheric Pollution 5, 9-17.

Galperin, B., Sukoriansky, S., Anderson, P.S., 2007. On the critical Richardson number in stably stratified turbulence. Atmospheric Science Letters 8, 65-69.

Hardwick, S.R., Toumi, R., Pfeifer, M., Turner, E.C., Nilus, R., Ewers, R.M., 2015. The relationship between leaf area index and microclimate in tropical forest and oil palm plantation: Forest disturbance drives changes in microclimate. Agricultural and Forest Meteorology 201, 187–195. https://doi.org/10.1016/j.agrformet.2014.11.010.

Hartogensis, O.K., bruin, H.A.R.De., 2005. Monin–Obukhov Similarity Functions of the Structure Parameter of Temperature and Turbulent Kinetic Energy Dissipation Rate in the Stable Boundary Layer. Boundary-Layer Meteorology 116, 253–276. https://doi.org/10.1007/s10546-004-2817-1.

Hein, L., Spadaro, J.V., Ostro, B., Hammer, M., Sumarga, E., Salmayenti, R., Boer, R., Tata, H., Atmoko, D., Castañeda, J.-P., 2022. The health impacts of Indonesian peatland fires. Environmental Health 21, 62. https://doi.org/10.1186/s12940-022-00872-w

Hong, J., Kim, J., Miyata, A., Harazono, Y., 2002. Basic characteristics of canopy turbulence in a homogeneous rice paddy. Journal of Geophysical Research 107, 1-20.

Husin, A., N., Khairunniza-Bejo, S., Abdullah, A., Kassim, M., Ahmad, D., Azmi, A., 2020. Application of Ground-Based LiDAR for Analysing Oil Palm Canopy Properties on the Occurrence of Basal Stem Rot (BSR) Disease. Scientific Reports 10, 6464. https://doi.org/10.1038%2Fs41598-020-62275-6.

June, T., Dewi, N.W.S.P., Meijide, A., 2018. Comparison of Aerodynamic, Bowen-Ratio, and Penman-Monteith Methods in Estimating Evapo-transpiration of Oil Palm Plantation. Agromet 32, 11-20. https://doi.org/10.29244/j.agromet.-32.1.11-20

June, T., Meijide, A., Stiegler, C., Kusuma, A.P., Knohl, A., 2018. The influence of surface roughness and turbulence on heat fluxes from an oil palm plantation in Jambi, Indonesia. IOP Conf. Series: Earth and Environmental Science 149, 1- 11.

June, T., 2022. Evaluasi Status Air Wilayah Pertanian Berdasarkan Partisi Penggunaan Energi Matahari. Bogor: IPB Press.

Kimura, R., Otsuki, K., Kamichika, M., 1999. Relationship between the zero-plane displacement and the roughness length over sorghum and alfalfa canopies. Journal of Agricultural Meteorology 55, 15-24.

Lovett, G.M., 1994. Atmospheric deposition of nutrients and pollutants in North America: An ecological perspective. Ecological Applications 4, 629-650.

Monin, A.S., Yaglom, A.M., 1971. Statistical Fluid Mechanics. Cambridge (US): M.I.T. Press.

Newman, J.F., Klein, P.M., 2014. The impacts of atmospheric stability on the accuracy of wind speed extrapolation methods. Resources 3, 81-105. https://doi.org/10.3390/resources30100 81.

Oke, T.R., 1987. Boundary Layer Climates. London: Methuen & Co Ltd.

Paulson, C.A., 1970. The mathematical representation of wind speed and temperature profiles in the unstable atmospheric surface layer. Journal Applied Meteorology 9, 857-861.

Powe, N.A., Willis, K.G., 2004. Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. Journal of Environment Management 70, 119-128.

Praneeth, H., Thakur, A., 2020. The Detrimental Effect of Rainfall on Performance and Stability Characteristics of Aircrafts-A Comprehensive Review. International Journal of Aviation, Aeronautics, and Aerospace 7. https://doi.-org/10.15394/ijaaa.2020.1533.

Riegel, C.A., 1992. Fundamental of Atmospheric Dynamics and Thermodynamics. New Jersey (US): World Scientific Pub Co Inc.

Riou, C.h., 1984. Simplified calculation of the zero-plane displacement from wind speed profiles. Journal Hydrology. 69, 351-357.

Rodrigo, J., Cantero, E., Garcia, B., Borbon, F., Irigoyen, U., Lozano, S., Fernandes, P., Chavez, R., 2015. Atmospheric stability assessment for the characterization of offshore wind conditions. Journal of Physics: Conference Series 625, 1-11. https://doi:10.1088/1742-6596/625/1/012044.

Saptawan, A., Ammar, M., Erina, L., Ermanovida, Alamsyah., 2019. The determinant of forest fires in Sumatera Island, Indonesia. International Journal Of Scientific & Technology Research 8, 660-667.

Saragih, I.K., Rachmina, D., Krisnamurthi, B., 2020. Analisis status keberlanjutan perkebunan kelapa sawit rakyat Provinsi Jambi. Journal of Indonesian Agribusiness 8, 17-32.

Stull, R.B., 1988. An Introduction to Boundary Layer Meteorology. Dordrecth (NL): Kluwer Academic Publishers.

Supriyanto, Syarifuddin, Ardi, 2018. Analisis kebijakan pencegahan dan pengendalian kebakaran hutan dan lahan di Provinsi Jambi. Jurnal Pembangunan Berkelanjutan 1, 94-104.

Tsai, J.L., Suang, B.L., Lu P.S., 2005. Measurements of aerodynamic roughness. bowen ratio. and atmospheric surface layer height by eddy covariance and tethersonde systems simultaneously over a heterogeneous rice paddy. Journal of Hydrometeorology 11, 452-466.

Xinga, Y., Brimblecombe, P., 2019. Role of vegetation in deposition and dispersion of air pollution in Urban Parks. Atmospheric Environment 201, 73-83.

Yanlian, Z., Xiaomin, S., Zhilin, Z., Renhua, Z., Jing, T., Yunfen, L., Dexin, G., Guofu, Y., 2006. Surface roughness length dynamic over several different surfaces and its effects on modeling fluxes. Science in China Series D: Earth Sciences 49, 262-272.

Yi, C., 2008. Momentum transfer within canopies. Journal of Applied Meteorology and Climatology 47, 262-275.

Yudistina, V., Santoso, M., Aini, N., 2013. Hubungan antara diameter batang dengan umur tanaman terhadap pertumbuhan dan hasil tanaman kelapa sawit. Buana Sains 17, 43-48.

Yuhao, M., Shuhua, L., Chenyi, Z., Lichao, L., Jing, L., 2007. Study of Aerodynamic Parameters on Different Underling Surfaces. Acta Meteorologica Sinica 1, 87-97.

Zhen-li, Lv., 2016. Water Content Calculation and Stability Analysis of Slope under Persistent Low- intensity Rainfall Infiltration. Electron J Geotech 21, 1381–1399.