The Influence of Opening on the Gradient and Air Temperature Edge Effects in Mangrove Forests

Christophil S. Medellu, Soemarno, Marsoedi, and Sigfried Berhimpon

***Abstract*—This research aimed to analyze the influence of the opening or open space to daily changes and spatial variation of air temperature in mangrove forests. The research was conducted on two transect; one of them is in an area where there was an open space that is inundated when sea tide is low. The ambient temperatures at both locations were compared based on quantitative parameters: maximum value, the difference of the maximum air temperature of the periphery with the interior of the forest, the edge gradient and the depth of the edge effects. The results showed that the widely open gap caused the decrease in the difference of the forest interior-edge temperature, the reduction of the depth of the edge effects, and decreasing of gradient edge.**

***Index Terms*— mangroves, temperature, edge gradient, edge effects.**

I. INTRODUCTION

A number of policies in the form of laws and regulations for the management of mangrove forests has been established in many countries. In Indonesia, the standard criteria of mangrove forests destruction is published in the Act 32 year 2009, article 21 verse 3d, paragraph 4. The Act mentions that the standard criteria of environmental damage are the direct and/or indirect changes on the physical and chemical properties of the environment. Ideally, the standard criteria should be quantitative, so it can be used as a precedent for the assessment and monitoring of changes in mangrove forests conditions and the surrounding environment.

Micro-climate is an ecosystem characteristic which reflects the interior condition of the forest and its response against lighting and thermal energy change in the bordering environmental. An overhaul of the mangrove forests causes a change in physical conditions that are detected early through microsite climate change [1, 2]. Micro-climate changes potentially cause interference on the growth of mangrove forest and its ecological function as a habitat of biota [2-4]. Micro-climate is an early indicator of changes in the structure of forest and bordering environment.

Researches on micro-climate mangrove forest are very rare [5], whereas micro-climate research is needed in generating data for assessment reference or monitoring the conditions of mangrove forests [6]. Krauss *et al*. [7] suggested that in the future, researches to identify the threshold temperature and its effects on the structure and ecological function of mangrove ecosystems are vitally important associated with global warming. Physically, daily micro-climate change in the forest is the same to that of mangrove forests. Therefore, the mangrove forest micro-climate research can be developed referring to micro-climate research in the forest.

Air temperature is one of the micro-climate variables widely studied [8-10]. The gradient and depth of edge effects on the air temperature are quantitative parameters that are widely used by researchers to characterize the forest micro-climate [11, 12]. Many micro climate forest researches described the temperature gradient as the spatial variation of air temperature throughout the transect from the periphery into the forest interior with steep-medium-slope category [13]. Descriptive information cannot be used as a reference to monitoring changes in the ecosystems conditions of the forest (and mangroves forests). Many experts use the periphery-interior gradient as a comparison between the differences of micro-climate periphery -interior forest with the distance from the edge to the measurement position in the forest [8, 10, 14, 15]. The periphery-interior gradient data illustrates the relationship between the changes of micro-climate on the edge with the depth of the influence of the environment into the interior of the forest. The depth of the air temperature edge effect (and other micro-climates) is a parameter that explains the distance from the edge into interior of the forest, which is still affected by adjoining environment micro climate. A number of micro climate researches in the forest set the depth of the edge effect based on the measurements inside the forest, where the air temperature becomes constant or equal between the two adjoining positions. The determination of the depth of edge

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effects in this way requires a lot of measurement points inside the forest. If the distance of the measurement points is far apart then data accuracy of edge effect depth will degrade. While mobile measurement from point to point will lead to a large bias. The ambient temperature (and other micro-climate variables) changes fast throughout the day, so the data from two different points can be the same or different, due to the changes that occur during the interval time of movement.

This study aimed to evaluate the influence of opening to temporal and spatial changes of the temperature in mangrove forest.

This research was carried out in two transects in one area of a mangrove forest, ecotype fringe. The condition of the ecosystem such as canopy blocking and height of the woods is identical in both transects, except for the gap that presented in one of the transects. The air temperature parameter used to characterize and distinguish the two mangrove ecosystems was the maximum and minimum temperatures, maximum temperature difference at the edge with that in the forest interior, edge gradient, and the depth of edge effects. The determination of these parameters was carried out on the basis of mathematical procedures, starting from temporal and spatial modeling of air temperature. We developed a method of determining the edge temperature gradient of mangrove forests. The edge temperature gradient is a gradient of temperature at the edge of the mangrove, which indicates the difference in the thermal quantity and the direction of thermal diffusion throughout the day between the environment and the mangrove ecosystem. The determination the edge effect depth was based on the gradient function value approaching zero. The depth of edge effect is the distance from the border to the position where the gradient value is approaching zero (the spatial temperature became constant).

II. Methods

To study the influence of the opening, two sites in the region of the mangrove forest in the Village of Talengen, Sangihe Regency, North Sulawesi Province were selected. The first location was a 68 m wide mangrove area with a 30 m wide open space inside the forest. During the measurement time (24 hours), this open area was inundated by sea water. The second location was approximately 124 m westwards from the first location. The width of the mangrove forest at this second location was 140 m.

The transects (Transect-1 and Transect-2) were made crossing the mangrove forest from the sea side to the interior of the forest 36 meters in length. For each transect there were 9 points of measurement. The measurement points were located at 4 and 2 meters outside the boundary; and 0, 1, 2, 4, 8, 16, 32 m from the boundary into the mangrove. To model the spatial functions from the field data, it needed more data around the boundary, so the measurement point distance was set logarithmically. The determination of logarithmic distance referred to the nature of thermal diffusion and the thermal energy spatial changes in the form of an exponential. The measurements were carried out by moving from one point to the next points along the transects. The measurement time in each point was one hour. The air temperature was measured using a four-in-one digital instrument that measures four variables simultaneously: air temperature, humidity, solar lighting, and wind speed. The measurements were done during the smallest tidal fluctuations (during the quarter moon) and bright atmosphere conditions, without rain and low wind speed.

Stages of analysis and modeling were started from modeling the temporal function ($T(t)$) for each measurement point. Later on data synchronization was done to eliminate the air temperature change biases during time interval in measurement relocation. The spatial modeling ($T(x)$) was done for every one hour time interval. Temporal function modeling employed Fourier series, according to the air temperature sinusoidal changes. Modeling of spatial variation of air temperature along the transect (horizontal direction) employed an exponential function model according to the nature of thermal diffusion and spatial thermal energy changes from the border to the forest interior). The spatial function was constructed from three measurement data at positions 0, 1, and 2 m, then was controlled (computer iterations) using measurement data from positions 4, 8, and 16 m. Data from position 32 m from the edge as used to test the validity prediction of spatial function in determining the value of air temperature at positions far into the forest.

The data for maximum and minimum temperatures were determined from extreme temporal functionality values ($dT/dt = 0$), while the difference in maximum temperatures were determined from the biggest difference in the value of the temporal function of the edge positions and the interior positions for the same time ($|T_{edge}(t_1) - T_{\mathrm{interior}}(t_1)|_{\max}$). The edge gradient and the depth of edge effects air temperature were determined from the air temperature gradient function as the first derivative of the spatial function ($G(x) = dT(x)/dx$). The edge gradient is the value of $G(x)$ for $x = 0$ (the edge/boundary of mangroves), while the depth of the edge effect is the value of x (the distance from the edge), where $G(x)$ is equal or close to zero. Function modeling processes to the determination of air temperature parameter were done by using a computer program created specifically for modeling and analysis of micro-climate forests and mangrove forests.

III. Results and Discussion

Figs. 1 and 2 show the graphs of the air temperature temporal function from the modeling measured from 07:00 on 30 May 2011 (hour 1) up to 07:00 on May 31, 2011 (hour 25). The graphs show that the air temperature in the forest was more stable than at the edge of the forest. The highest daily temperature on Transect -1 (there was an open space) of 36.4 °C was reached at 13:00 and Transect -2 (36.7 °C) was also reached at 13:00. The maximum air temperature difference between the edge and forest interior in Transect -1 at noon was 2.3 °C (the temperature at the edge was higher) and by night was 0.5 °C (the temperature in the forest was higher than at the edge). In Transect -2, during the day the temperature at the edge was 3.8 °C higher than inside the forest, whereas at night the temperature inside the forest was 0.8 °C higher than at the edge. The maximum temperature difference in Transect-2 was higher than in Transect -1, day and night.

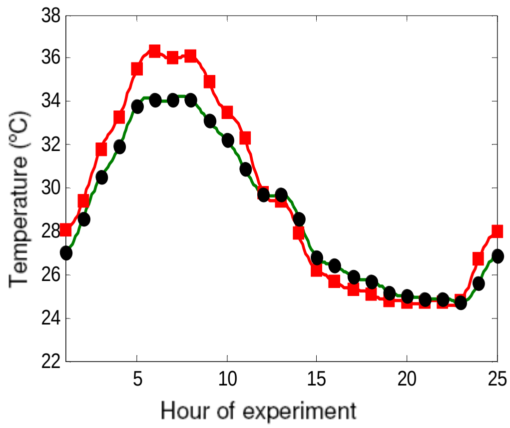

Fig. 1 Air temperature temporal variation in Tra nsect-1 showing peaks at data nos. 5 – 7 associated to day time of 12:00 – 14:00. ■ (red squares) is at the edges and ● (black dots) are locations 32 m from the edge.

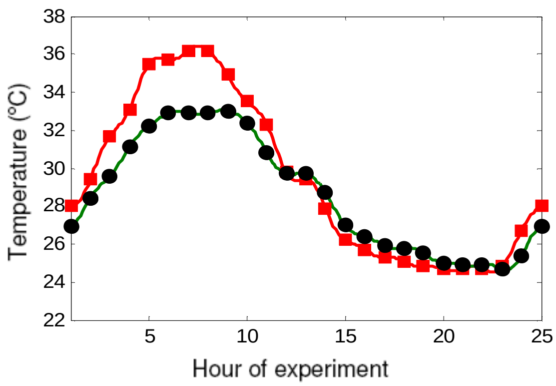

Fig. 2. Air temperature temporal variation in Transect-2 showing peaks at data nos. 5 – 8 associated to day time of 12:00 – 15:00. ■ (red squares) is at the edges and ● (black dots) are locations 32 m from the edge.

Spatial variation of air temperature was presented in Figs. 3 and 4. The air temperature spatial functions changed throughout the day because of thermal diffusion and thermal quantity changes along the measurement transects. The accuracy of spatial function in the results of modeling was proven by averaged deviation of modeling data towards the measured data at the position 32 m from the edge. The averaged deviation of modeling data towards the data measurements in Transect-1 was 0.004 and in Transect-2 was 0.092. This averaged deviation data is small compared to the variations in air temperature between 24.5 °C – 36.7 °C. The spatial changes indicated that during the day, temperature in the edge was higher and decreased exponentially with the increasing of distance from the edge to the interior of the mangrove. The graph shows that the difference of air temperature at the edge with the forest interior at 12:00 was higher than at 07:00. The graph of the spatial variation of air temperature at 22:00 reveals that the temperature in the forests was higher than at the edge.

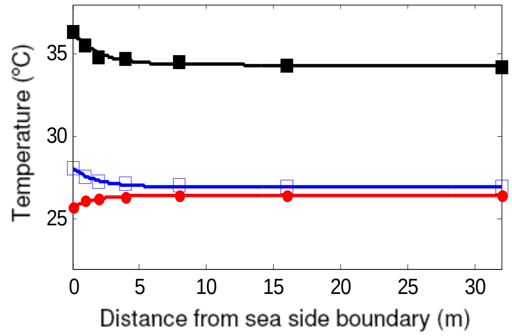

Fig.3. Air temperature spatial variation in Transect-1 measured at 07:.00 ( ), 12:00 (■), and 20:00 (●). The *x*-axis represents the distance of the measurement points measured form the seaside boundary of the mangrove forest.

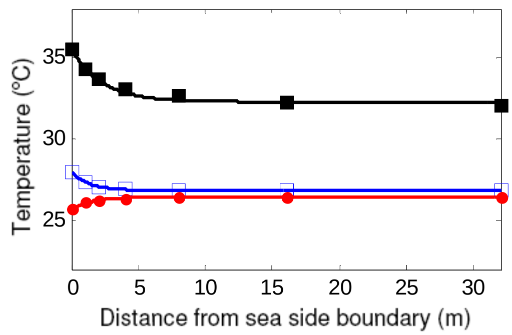

Fig.4. Air temperature spatial variation in Transect-2 measured at 07:.00 ( ), 12:00 (■), and 20:00 (●).The *x*-axis represents the distance of the measurement points measured form the seaside boundary of the mangrove forest.

The depth of the edge effect in both transects changed throughout the day. The air temperature maximum depth of the edge effect in Transect-1 at noon was 38,13 m, achieved at 11:00, while at nigh it was 22.7 m, achieved at 24:00. The air temperature maximum depth of the edge effect in Transect-2, in the afternoon was 44.6 m, achieved at 13:00, and in the morning it was 24.36 m, achieved at 02:00. The penetration effect of air temperature in Transect-2 was further into the forest than it was on Transect-1, day and night.

Similar to the edge effects, the air temperature edge gradient also changed throughout the day. The maximum edge gradient in Transect-1 was 1,051 °C/m, occurred at 12:18 afternoon, and at night it was 0,491 °C/m, at 20:42. The maximum edge gradient in the Transect-2 was 1,400 °C/m, occurred at 11:12 afternoon, and at night it was 0.570 °C /m, occurred at 24:36. The maximum edge gradient of the air temperature in Transect-2 was higher than that in Transect-1, day and night.

The results showed that the difference in air temperature of edge-interior forest in Transect-1 was significantly different from that in Transect-2. Although the maximum temperature at the edge was almost the same for both transects (36.4 °C and 34.7 °C), but the difference in the temperature of the edge-interior differed significantly (2.3 °C and 3.8 °C). This means that decrease of air temperature from the edge into the forest was larger in Transect-2. Associating with the condition of the ecosystem, it can be concluded that the small temperature difference in the edge-interior was caused by the influence of open space. The mangrove border with the gap became a new border, and the thermal diffusion in the afternoon occurred from two edges, e.g. the mangrove edge that faces the sea, and the mangrove forest boundaries with the gap or open space is in the inside part. Two way thermal diffusion in Transect-1 created a double edge effect and influenced the difference of thermal energy between the edge and forest interior [16-18]. In Transect-2, the horizontal thermal diffusion only came from the the sea, because the edge of the mangrove bordered with the beach vegetated and the distance was far from the transect border. The influence of the gap on the decreasing of edge-interior temperature difference also happened during the night. When the thermal energy of the air was above the surface of the sea/open surface dropped and became lower than the thermal energy of the air under the mangrove canopy, then the thermal diffused from the forest to the environment. In Transect-1, the thermal flux flowed through the two edges so the temperature difference of edge-interior in Transect-1 was lower than that in Transect-2.

The influence of open space on the thermal diffusion was also indicated from the higher temperature gradient in Transect-2 rather than in Transect-1. The canopy cover and the wood height were identical in both transects. But since there were wide open spaces, the increase of thermal energy of the air above the open surface causes thermal flux into the forest and contributes to the increasing temperature under the mangrove canopy in Ttransect-1. The increasing of temperature under the mangrove canopy was larger in Transect-1 and caused the gradient edge temperature becoming lower than in Transect-2. The influence of open space which increased the temperature under the canopy was also identified through the depth of the edge effect. The depth of the edge effect in Transect-1 was less compared to that in Transect-2. The effect of double edges (two-way thermal diffusion) in Transect-1 caused the temperature becoming more prevalent in distance closer to the edge. The influence of the space on the thermal diffusion from inside the mangrove to the environment was also shown by the edge gradient at night, which was lower in Transect-1 than in Transect-2.

IV. Conclusion

The results of this research shows that the wide gap in the mangrove forests significantly affected the mangrove micro-climate, which was detected through the parameters: the maximum edge-interior temperature difference, the depth of the edge effect, and the edge gradient. These quantities of microclimates parameters are the characteristics of mangrove ecosystem, that can be used for monitoring the ecosystem change as well as thermal condition changes that occur in the bordering environment.

The next work to be carried out is to monitor the microclimate change in the mangrove forest that will be converted into fish ponds.

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