Temporal Variation of Air Temperature of Dalugha (*Cyrtosperma merkusii* (Hassk.) Schott) Habitat in Variation of its Exterior and Interior Environments

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***Abstract*—This article describes our study on the temporal temperature variations of three dalugha (giant swamp taro) habitats with different exterior and interior environments. Dalugha grows in soil with high salinity variations. This study was part of a research on dalugha habitat, associated with the development of this plant as a food alternative. The study was conducted on three different transects exterior and interior environmental conditions. Temporal changes in air temperature and the surrounding environment dalugha habitat obtained through mathematical modeling measurement data at nine positions along the transects. The results showed that the temporal changes in air temperature at all positions have the same pattern, a sinusoidal shape. For the same position, the air temperature on three transects was different. Temperature differences during the day and night were more significant.**

***Index Term*— Dalugha, giant swamp taro, air temperature, transect**

I. INTRODUCTION

GLANT swamp taro (*Cyrtosperma merkusii* (Hassk.) Schott) is the only species in the genus that is edible [1]. Other names are *C. lasoides*, *C. edule*, and *C. chamissonis* [2]. In the district of Sangihe Islands, North Sulawesi, Indonesia, this plant is named '*dalugha*.' They can grow well in wetland soils flooded with brackish water temporarily, water saturated throughout the day, salinity from 0.59 to 1.91 ppt and daily sludge pH 6.9 -9.8 [3]. Dalugha is a very important food crop for people in Sangihe Islands and surrounding areas in relation to food security and climate change impacts.

Wetlands are known as beneficial ecosystems to provide water, raw materials and food, water purification and prevent flooding, and other intangible values such as religious and cultural values. Yet, threats to these ecosystems has been increasing with more than half of the world's wetlands has lost [4]. Therefore, dalugha plant habitat condition is an interesting issue to study in the scope of wetlands study, especially tidal freshwater swamp [5, 6]. Dalugha in Sangihe grows well in swamps near the coast, where the swamp is partly inundated by sea water at high tide and some are not. Most swamp obtains supplies of fresh water from the surface water runoff and some from the subsurface flow. Researches on habitat conditions are needed to acquire information about the variation of environmental conditions that support the growth and productivity of dalugha. This information can be used as a reference for the cultivation and conservation of local foods are degraded due to swamp conversion into rice fields, settlements, etc. Substrate formation and dalugha growth as of other marsh plants are influenced by many factors such as atmospheric, hydrological, geological, and biological factors. Range of values of these factors is typical for marsh plants including dalugha. For instance, dalugha can tolerate a maximum temperature of 38 ºC and minimum of 15.5 ºC [7].

Study of air temperature under the canopy of dalugha and in the external environment bordering dalugha habitat needs to be done to determine the daily air temperature range where dalugha can grow well. Temperature and humidity are atmospheric factors that control the process of organic matter decomposition in the formation of the substrate. Thermal diffusion between the external environments with dalugha habitat describes the effect of environmental changes on dalugha growth. Variations in the temperature are the indicator of the thermal diffusion between the external environments with the ecosystem that can be used to predict the effects of global warming [8] to the sustainability of dalugha crop. The air temperature is a microclimate variable sensitive to environmental and ecosystem changes [9-11]. This paper is aimed to provide information on the daily variation and fluctuations in air temperature at three locations within the dalugha habitats with variations in exterior and interior environments.

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II. METHODS

The study was conducted in two villages in the district of Sangihe Islands, North Sulawesi, Indonesia, by choosing three transects which allows acquisition of data of varying temperatures (Figs. 1 and 2). Each transect has different exterior and interior environmental characteristics. The exterior environments were distinguished based on the conditions of surrounding vegetation bordering dalugha habitat and conditions of temporary inundated-no inundated by brackish water. The interior environments were differentiated based on conditions of dalugha canopy coverage, other trees canopy coverage, and dalugha's height.

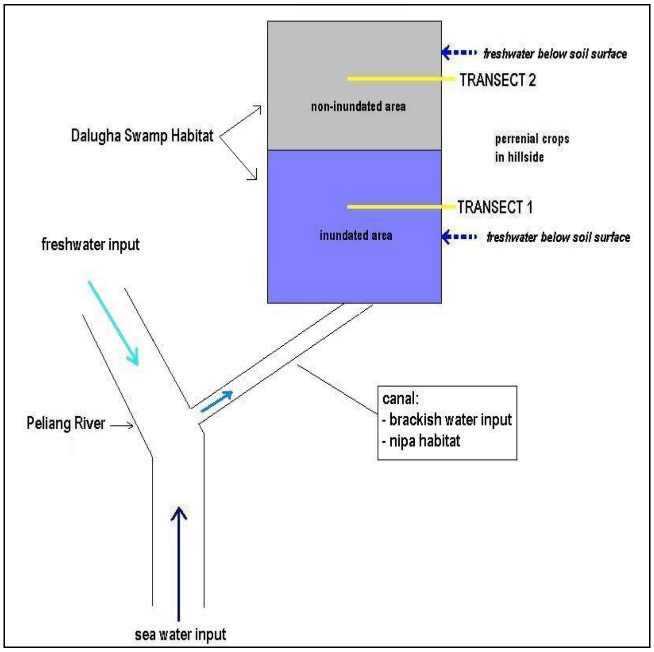


Fig. 1. Sketch map of the situation of Transects 1 and 2 in the Pokol village.

Transects 1 and 2 were located in Pokol village, and transect 3 was located in Nagha 1 village. Transect 1 was chosen crossing dalugha border towards the center. Dalugha plants in transects 1 were inundated during high tide. The dalugha area obtains supplies of fresh water from rivers and ground water flowing from the surrounding hill that is overgrown by perennial plants. The exterior environment consists of palm vegetation that grows naturally in the drain connecting the river and dalugha swamp and annual plants that grow in the hills around the dalugha swamp. Palm vegetation serves to control the sedimentation process while reducing substrate erosion by the tidal and river activities. Dalugha's height varied between 2.72 to 3.91 m and their canopy coverage was 60% - 75%, and other trees canopy coverage was 65% - 80%.

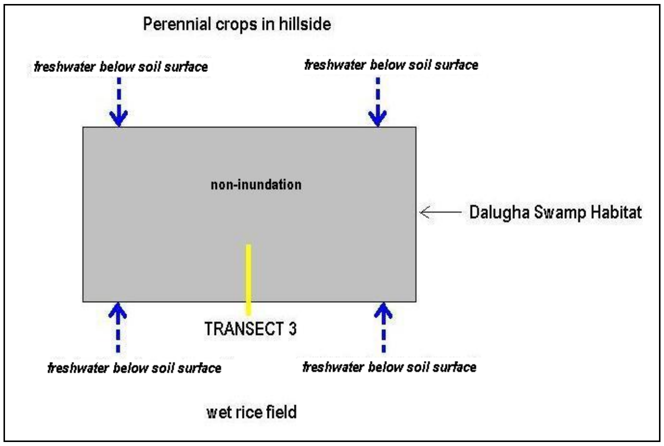


Fig. 2. Sketch map of the situation of Transect 3 in the Nagha 1 village

Transect 2 was not inundated by brackish water, but was assumed to have sea water intrusion during high tides. The dalugha area obtains supplies of fresh water from the ground water. The bordering land was vegetated by trees with canopy density of 55% - 78%. Dalugha's height varied between 3.03 to 5.22 m with the highest at the shaded areas. Dalugha canopy cover varied between 87% - 95%.

Transect 3 is bordered by rice fields and are not influenced by brackish water, but was assumed to have sea water intrusion during high tides. The dalugha area obtains supplies of fresh water from the ground water and seepage water from the rice paddies. The dalugha canopy coverage between banks to a distance of 12 m from the edge varied between 85% - 95%. At a distance of 12 to 20 m the canopy density reduced but the area was shaded by tree canopy between 50% - 68%. The height of dalugha located from the edge of the habitat to distance of 32 m varied between 2.7 to 5.31 m.

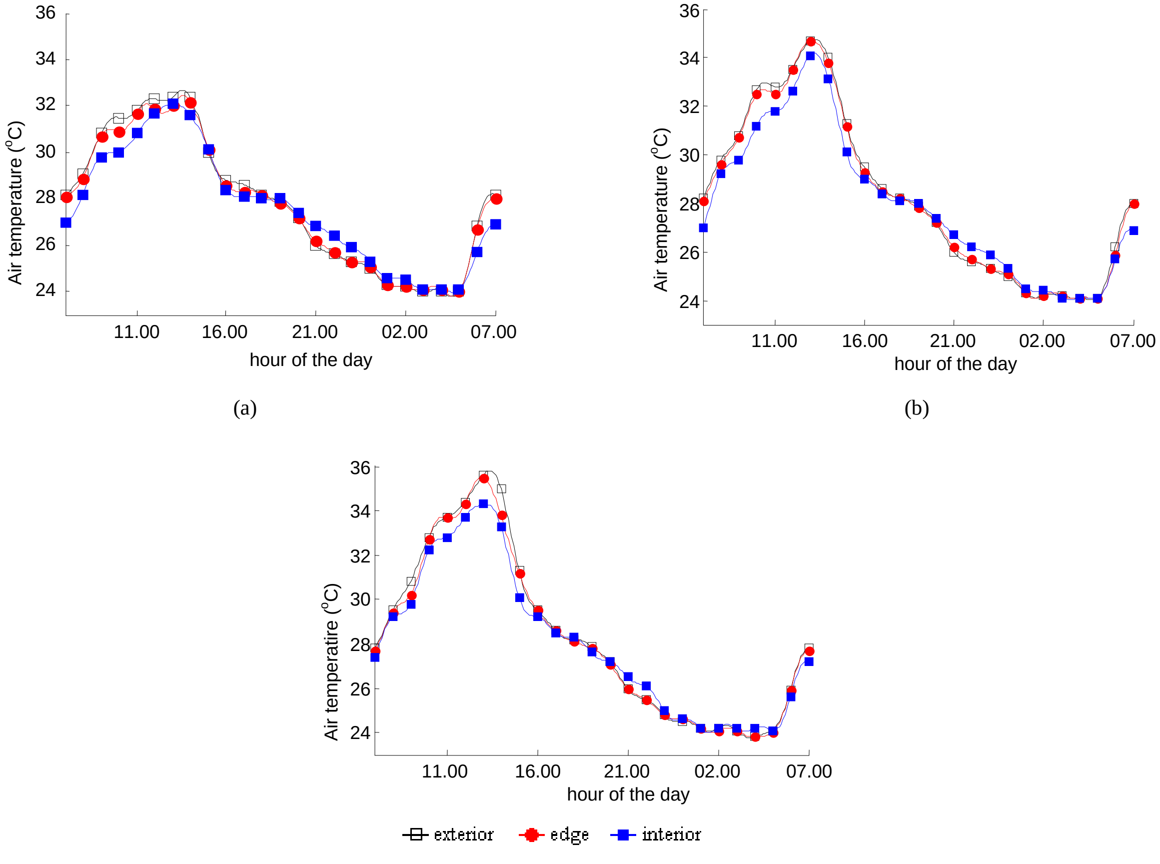
Measurement points in each transect was determined by the logarithmic distance from the edge according to changes in the spatial pattern of the microclimate between the environments and the forest ecosystem. Spatial variations of the microclimate variables around the ecosystems edges was exponential [10, 12, 13]. Measurement points along the transect were situated 4 m and 2 m outside the edge, on the edge (point-0 and was used as the reference), 1 m, 2 m, 4 m, 8 m, 16 m, and 32 m from the edge to the center of the dalugha field.

Measurements of air temperature were made using a "four in one" Luxtron LM-8000 that measures air temperature, humidity, solar intensity, and wind speed simultaneously. Measurements of the temperature were carried out at a level of 80 cm above the soil surface. This position was below the dalugha canopy. Measurements from one position to the next position along the transect were done in motion, so the air temperature data was time synchronized [13]. Data synchronization was a correction to the temperature changes that occurred due to the time difference between measurements (ranged 1 - 1.5 minutes). The microclimate variables measurement started at 07.00 on August 18, 2012 until 07.00 on August 19, 2012. Time interval between measurements at each measurement points was one hour.

Comparative analysis of temporal changes in air temperature between transects was conducted for three positions: 4 m beyond the edge, on the edge, at a distance of 16 m from the edge to the center of the clump. Analysis of temporal and spatial changes in temperature yielded values of the quantitative parameters as the characteristics of each dalugha ecosystem. The quantitative parameters included the highest and lowest temperatures, maximum temperature difference between the outside and interior of dalugha field in daytime and at night, times of the transition of thermal diffusion direction, depth of edge effects in the daytime and at night, the highest edge gradient and the corresponding direction in the daytime and at night. The highest and lowest values were determined using extreme conditions temporal function ($dT/dt = 0$) [13]. Edge gradients and depth of edge effects of air temperature were determined from the gradient function as the first derivative function of spatial function ($G(x) = dT(x)/dx$, $T(x)$ is a function of spatial air temperature). The gradient of edge temperature was the value of $G(x)$ for $x = 0$ (dalugha edge) while the depth of edge effects was the distance x at which the value of $G(x)$ is equal or close to zero [14, 15]. The values of quantitative parameters were also used to compare the changes in daily air temperature in all three transects (ecosystems).

III. RESULTS AND DISCUSSION

The temporal (daily) changes in temperature are presented in Figure 3. Figure 3a, 3b and 3c respectively represent the temporal changes in air temperature at location P1 (transect 1); location P2 (transect 2), and location P3 (transect 3). Temporal changes in daily air temperature has similar pattern for all three transects, and for all measurement positions outside and inside dalugha clumps, i.e. sinusoidal shape with a period of 24 hours.



(a)

(b)

(c)

Fig. 3. Daily changes in air temperature at the transect 1 (a), transect 2 (b), and transect 3 (c). Black curve represents the outside air temperature (4 m from the edge), the red curve is for the edge (point-0), and the blue curve is for inside the dalugha clump (32 m from the edge).

The graph of temperature changes throughout the day shows a greater fluctuation during the day (hour of observation 1 or 07.00 hour to hour of observation 12 or 18.00 hour). The temporal pattern is consistent with the results of previous studies elsewhere [10, 12, 14-16]. During the day, the air temperature in the dalugha clump was lower than the air temperature at the edge and outside the clump. Temperature under the dalugha canopy is lower because of the intensity of solar radiation that penetrates the canopy gap is lower in comparison with the radiation that reaches the surface of the land outside of the dalugha clump. During the night the air temperature in the dalugha clump was slightly higher than the air temperature at the edge and outside of the clump.

Comparing the air temperature charts between transects, we found that the daytime air temperatures differed significantly between them. At night, the air temperature was almost the same among the three transects. Differences in air temperature during the day were affected by differences in ecosystem conditions (structure and canopy density) and environmental conditions bordering the field [10]. The lowest air temperature for all positions occurred in transects 1, while the highest temperature occurred in transect 3. This difference was caused by the shade of palm trees at the front edge and shades of other trees bordering the dalugha clumps behind transect 1. The shade of trees reduces the penetration of solar radiation, hence reducing the air temperature at each position along the transects. Open land (paddy fields) on transect 3 causing daytime air temperature at position 4 m from the edge was higher than the air temperature at the same position for transects 1 and 2. During the day, the air temperature at the position 16 meters from the edge, was higher in transect 3 than in transects 2 and 1. The higher tightness of canopy cover in transect 3 than in transect 1 caused differences in air temperature under the dalugha canopy. This was caused by the thermal diffusion in horizontal direction. The high environmental temperatures in transect 3 resulted in the thermal energy flowing into the lower canopy (thermal diffusion process in the horizontal direction) higher than that in transect 1.

Air temperatures variations of each transect are presented in Table I. It shows that the highest temperature during the day varies significantly while the lowest temperature at night is almost the same across the three transects. The highest temperature reached in the three transects at 13:00. The difference between the external and internal temperatures (at location 16 meters from the edge) in daytime in transects 1 and 2 is the same (1.5 ºC). The difference in transect 3 is 1.8 ºC. These figures are lower than other studies [10, 16-19]. In average the differences varies between 0.7 to 0.8 ºC, that is lower than the results of Chen et al. [20] that noted the difference in temperature of 1 ºC.

The time of the first transition of thermal diffusion (change of direction of diffusion from outside-inside of the clump to inside-outside of the clump) occurred at different times between the three transects. Second diffusion transition time (inside-outside to outside-inside) was also taking place at different times between the three transects. Transition time difference depends on the difference in the dynamics of diffusion or thermal energy changes in the ecosystem and the environment [12]. Thermal diffusion is controlled by solar radiation and thermal energy emitted by the components of the ecosystem and the environment.

Depth of edge effects in daytime and at night in all three transects was different. During the day, the deepest edge effect (distance from the edge to the center) occurred in transect 1 which was as deep as 33.13 m. Transect 3 shows edge effects during the day at 26.24 m. Variations in the depth of edge effects of air temperature obtained in this study were within the range of variation in the depth of edge effects study by Moore *et al.* [21] which was between 15 to 60 m, but was lower than the study by De Siquerian *et al.* [22], who found 90-120 meters. Our lower finding was due to the canopy in our study was lower than that studied by De Siquerian *et al*. [22]. The greater the absorption of thermal energy by particles in the air under the dalugha canopy, the lower the depth of edge effects.

TABLE I
THE AIR TEMPERATURE VALUES IN TRANSECTS 1, 2, AND 3.

Air Temperature	Transect 1		Transect 2		Transect 3	
	value	time	value	time	value	time
Highest daily temperature (ºC) & time of measurement (hour, minute)	32.3	13.00	34.7	13.00	35.5	13.00
Lowest daily temperature (ºC) & time of measurement (hour, minute)	24.0	03.00	24.0	04.00	23.8	04.00
Difference of exterior – interior highest temperature in daytime (ºC)	1.5	10.00	1.5	10.00	1.8	14.00
Difference of exterior – interior highest temperature at night (ºC)	0.8	22.00	0.7	22.00	0.7	22.00
Depth of edge effect in daytime (m)	33.13	12.00	30.63	12.00	26.24	13.00
Depth of edge effect at night (m)	21.62	01.00	25.86	21.00	24.42	21.00
Highest edge gradient in daytime (ºC/m)	−0.951	09.48	−0.985	10.00	−1.051	10.48
Highest edge gradient at night (ºC/m)	0.547	21.24	0.611	22.18	0.674	22.12

TABLE II
THE HEIGHT OF DALUGHA IN THE OPEN-SHADED VARIATIONS, DALUGHA CANOPY COVERAGE, AND TREES CANOPY COVERAGE.

Parameter	Transect 1	Transect 2	Transect 3
Dalugha canopy coverage (%)	60 – 75	87 – 95	85 – 95
Trees canopy coverage (%)	65 – 80	55 – 78	50 – 68
Height of dalugha (m) in the open solar radiation	2.72 – 3.11	3.03 – 4.02	2.7 – 2.99
Height of dalugha (m) in the shaded condition	3.14 – 3.91	3.71 – 5.22	3.76 – 5.31

Depth of edge effects in daytime and at night in all three transects was different. During the day, the deepest edge effect (distance from the edge to the center) occurred in transect 1 which was as deep as 33.13 m. Transect 3 shows edge effects during the day at 26.24 m. Variations in the depth of edge effects of air temperature obtained in this study were within the range of variation in the depth of edge effects study by Moore *et al.* [21] which was between 15 to 60 m, but was lower than the study by De Siquerian *et al.* [22], who found 90-120 meters. Our lower finding was due to the canopy in our study was lower than that studied by De Siquerian *et al*. [22]. The greater the absorption of thermal energy by particles in the air under the dalugha canopy, the lower the depth of edge effects.

The edge gradient during the day shows a negative sign that means the environment temperature is higher than the temperature inside the dalugha clump. During the day the direction of thermal flux is from the environment into the grove. At night the edge gradient sign is positive that means the direction of the thermal flux is from the clump to the adjacent environment. The daily thermal diffusion pattern is in an agreement to the results of previous studies [12, 14, 23]. The highest edge gradient in the daytime occurred in transect 3 was due to higher outside air temperature. Dalugha canopy in transect 3 was quite tight, so that the temperature decrease was steeper.

Results of analysis of temporal variation of air temperature on the three transects showed that dalugha plants can grow well in temperature fluctuations between temperatures of transects 1 and 3. Dalugha grows higher in the shaded area than in the open area, but they are shorter in transect 1 that is affected by brackish water (Table II). Relationship of temperature and air temperature fluctuations with the productivity and size of tubers need to be further investigated.

IV. CONCLUSION

The conclusion that can be drawn from this study is that air temperature can be used as a variable to monitor conditions and changes in dalugha crop conditions and environmental influences on dalugha. The values of quantitative parameters in transects were different due to differences of ecosystem and environmental conditions. When compared to mangrove ecosystems and forest on land, the air temperature parameters in dalugha ecosystems tend to be lower. Values of air temperature parameters in dalugha can be used as a reference in further research and evaluation of the impact of environmental change on plant dalugha.

The study was conducted on normal weather conditions with average rainfall of 186.8 mm. The results did not indicate the temperature range under extreme conditions, for example in the event of drought. Further research needs to be done in such condition.

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