International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 14, Issue 9, 2020

Microclimate Analysis of Forest Management on Small Island

Christophil S. Medellu, Physics Department, Manado State University, Indonesia, Email: chrismedellu@yahoo.co.id

This article describes the results of forest microclimate analysis, to evaluate forest conditions and forest functions for water availability in the dry season. The results of the microclimate analysis are also used to reflect the socio-cultural aspects of the community in the preservation of forest functions, especially for the availability of clean water. The study was conducted on Kahakitang Island, which often experiences water shortages in the dry season. Microclimate variables studied included air temperature, air humidity and soil temperature. Microclimate analysis includes vertical profiles of air temperature and horizontal thermal diffusion. The results show that the condition of the forest in Behongang village is at a critical limit. The results of study recommend the planting trees and land cover vegetation in a buffer location that is currently used by the community for planting spices and vegetables. Inputs from research results include: making biopores in forests and buffer zones; diverting the cultivation of spices and vegetables from buffer zones by utilising home yards; utilising waste for compost; and the community are responding well to them. The limitation of this study is that the feedback has a long positive impact and is not immediately felt by the community.

Key words: *Microclimate Analysis, Forest Management, Small Island, Clean Water*

Introduction

The main challenge in small island life is the limited land for plantations and settlements, and the availability of clean water (Medellu, 2018). This challenge raises the local wisdom of resource management. Resource management in small islands should be done comprehensively by taking into account the benefits versus resource degradation (Mercer et al., 2007; Medellu, 2018). The mapping of vulnerable and critical areas for ecosystem management must be based on comprehensive studies covering biophysical, socio-cultural and economic elements. Information on ecosystem conditions should be considered for utilisation and resource protection (Pregiwati et al., 2015; Medellu, 2018). Components of land resource utilisation in small islands that interact directly with each other are utilisation of residential areas, plantations and forests. Although the community has an agreement or local wisdom, it still takes scientific research to strengthen local wisdom as well as control, protect and restore resources. Community knowledge, awareness and responsibility for forest conservation, compliance with regulations, initiatives to carry out forest restoration etc. needs to be studied scientifically to strengthen the role of the community in maintaining the existence of forests and the function of forests.

A microclimate is defined as a state of climate in a zone or area that is ecologically different from the surrounding environment (Chen et al., 1999; Medellu, 2012; 2018). Microclimate variables characterise ecosystem conditions. Microclimate change is significantly influenced by changes in ecosystem conditions such as deforestation and environmental structure changes (Godefroid et al., 2006; Berger et al., 2008). Microclimate variables can provide local spatial information such as the influence of forest reshuffle and the occurrence of patches or gaps in the forest (Pinto et al., 2010; Zulkiflee & Blackburn, 2010). Microclimate change can increase the insecurity or degradation of forest structures and the life of biota in them (Magnago et al., 2015; Schmidt et al., 2017; Kimberley, 2019). Suggitt et al., (2011) and Kearney et al., (2014) argue that the local scale climate pattern is important in habitat and species analysis.

The microclimate is relevant for the evaluation and monitoring of ecosystem conditions and the utilisation of inland natural resources in small islands. Microclimate variables that were studied by experts are the intensity of solar radiation, air temperature and air humidity (Hennenberg et al., 2008; Medellu, 2012; de Lima et al., 2013; Medellu & Tulandi, 2018). Another variable examined by an expert is ground temperature (Imaizumi et al., 2019). These variables interact and characterise the daily changes and spatial variations of the ecosystem (Medellu, 2012). The microclimate variables in small islands change significantly and rapidly due to the thermal interaction between the ecosystems components (Medellu & Tulandi, 2018). The quantity of the microclimate variable is expressed in the form of quantitative parameters, namely: maximum daily quantity; maximum difference of edge-interior; the depth of edge effect; maximum edge gradient, time and duration of thermal equilibrium between ecosystem and environment; and the plane area of daily dynamics of microclimate gradients. Changes in the magnitude of microclimate parameters indicate changes in ecosystems and the environment (Medellu, 2012; 2013; Medellu & Tulandi, 2018). The analysis of microclimates in this study includes vertical profile of air temperature, and horizontal thermal diffusion between forest ecosystems and the environment. Temperature vertical profile analysis is needed to detect the presence of other thermal sources besides the sun which significantly affects the temperature in the forest, plantations and residential areas. The horizontal thermal diffusion between forest ecosystems and plantation areas, and between forest ecosystems and residential areas, is based on the quantity of parameters and the pattern of daily changes of air temperature, humidity and ground temperature. The results of horizontal thermal diffusion analysis, describe the pressure or influence of environmental thermal energy on the forest ecosystem. The results of an integrated analysis of microclimate parameters provide information on the thermal interaction between the forest ecosystem and the environment, and become a reference prediction of forest conditions related to groundwater availability in the dry season.

Literature review

Microclimate is sensitive to changes in forest interiors as well as the influence of thermal energy from the surrounding environment (Medellu et al., 2012). The daily change of microclimate becomes an indicator of the biophysics process in the ecosystem (Godefroid et al., 2006; Bunyan et al., 2012). The change of microclimate becomes an early indicator of changes in forest interiors such as patches or gaps (Pinto et al., 2010; Zulkiflee & Blackburn, 2010; Medellu et al., 2012). Changes occurring in the environment will cause microclimate change on the edge and interior of the forest (Godefroid et al., 2006; Berger et al., 2008). Conditions of the microclimate at the edge or at the boundary of the forest with the environment, affects the forest structure and tree mortality (Magnago, 2015). Laurence et al., (2011) concluded that a forest reshuffle could alter microclimate changes such as rising of air temperatures and then affecting the existence and composition of species. Similarly, the fragmentation process raises new edges that increase the penetration or diffusion of thermal energy into the forest, causing abiotic environmental changes, biodiversity and the loss of biomass (Harper et al., 2005; Pu ̈tz et al., 2011). Microclimate research is essential for evaluating, controlling and restoring forest ecosystems. Thermal equilibrium should be maintained to ensure the continuity of the forest ecosystem and the existence of various species in it (Kearney et al., 2014; Moning & Muller, 2009). The studies of the forest microclimate that has been conducted by previous experts, is based on quantitative parameters as follows:

Maximum difference of edge-interior

Researchers who use the parameters of the maximum difference between edge and interior of forests are: Pinto et al., (2010), Magnago et al., (2015), and Tuff et al., (2016). The results showed that the microclimate differences of edge and interiors varied depending on the forest structure, canopy density and the adjacent environmental condition. Large differences occur in forests with solid canopy cover, bordered by open spaces (Didham & Lawton, 1999; Pohlman et al., 2007; Medellu, 2013).

Depth of edge effect

The depth of the edge effect is the farthest distance to the forest interior affected by the microclimate conditions at the edge or forest borders. The magnitude of this parameter changes throughout the day due to illumination influences. Researchers who used this parameter are Latimer & Zuckerberg (2016), who concluded that the air temperature was reduced by increasing the distance from the central settlement. A similar conclusion was expressed by Li et al., (2011, 2013), that the soil temperature increased by the reduction of the distance from the settlement. The depth of edge effects can indicate the fragmentation or gaps in the forest or changes in the structure of the forest (Harper et al., 2005; Medellu et al., 2012; Magnago et al., 2015). The depth of edge effects also changes with the occurrence of changes in the bordered environment.

The maximum edge gradient

The quantity of edge gradient changes throughout the day depending on the illumination intensity at the edge of the forest. The edge gradient is associated with a thermal energy flow between the environment and the forest ecosystem (Heithecker & Halpern, 2007; Medellu, 2013; Chatterjea, 2014). The maximum edge gradient is the highest edge gradient value in a day. Researchers using the edge gradient parameters were: Wright et al., (2010) and von Arx G et al., (2017). Researchers have suggested that the edge gradient of the air temperature, ground temperature, radiation intensity and wind velocity has a negative value, indicating that the quantities of these variables are higher on the edge than in the interior. Davies-Colley et al., (2000) suggests that the ground temperature and illumination intensity have a more rugged gradient than the air temperature and humidity. Medellu (2012, 2013) found that during the day, the gradient of air temperature on the edge of the mangrove forest had a negative value, but between the hours of 20.00 to about 04.00, the temperature gradient had a positive value.

Plane area of the daily dynamics of microclimate gradients

The preceding three parameters: the maximum diference of the edge-interior, the depth of the edge effect, and the maximum edge gradient describe the forest condition at a certain time. The magnitude and timing of the magnitude is not always consistent even though the condition of the ecosystem, environment and weather has not changed (Medellu, 2012; 2013). The plane area of daily dynamics of the microclimate gradient is a quantisation of accumulated reception of solar radiation energy, absorption, thermal re-emissions by the environment and components of forest ecosystem for one day or one period of illumination. This parameter has a relatively consistent magnitude, if measurements are performed on the same weather conditions. The magnitude of this parameter can indicate the presence of patches or gaps, indicating the ecosystem differences due to the difference in canopy cover, distinguishing the interaction of ecosystems with different environments. This parameter can detect changes in the structure or canopy cover based on the data measured at two different times (Medellu, 2013; Medellu & Tulandi, 2018). These four parameters relate to each other. The broad parameter of the field of daily dynamics of microclimate gradients specifically characterises the interaction of forest ecosystems with the environment. This parameter can monitor changes occurring in both the forest ecosystem and the adjacent environment (Medellu, 2012; 2018; Medellu & Tulandi, 2018).

The benefit and excellence of microclimate research on land and forest management in small islands is the sensitivity of microclimate parameters to the changing of ecosystems. This indicates that the parameters of microclimate can be an early indicator of changes in ecosystem and environment. In general, the use of space by communities in small islands includes forest areas, plantations and settlements. Communities in small islands have an agreement to maintain the equilibrium of such space, especially to ensure the availability of clean water. The size or utilisation is based solely on experience, without scientific study. The analysis of thermal equilibrium between residential areas, plantations and adjacent forests using microclimate parameters can indicate equilibrium of groundwater. Kimberley et al., (2019) suggests that diminished forest function caused increased air temperature and decreased water vapour pressure (VPA) thus disrupting groundwater balance and biota presence. A buffer forest that has a thick canopy effectively reduces extreme temperatures and a vapour pressure deficit. Suggitt et al., (2011); Frey et al., (2016); von Arx et al., (2017) suggest that dense trees will function well in controlling the extreme climate. A buffer forest that has a thick canopy effectively reduces extreme temperatures as well as a vapour pressure deficit due to diffusion from the environment. In this regard, information and scientific research results are needed in evaluating the water balance and forest function of the buffer, to ensure the stability of microclimate all the time (Kimberley et al., 2019).

Method

Research location

The research was conducted on the island of Kahakitang (Figure 1), Tatoareng Sub-district, Sangihe Regency, North Sulawesi province. The village which is the object of study is Behongang Village as the sub-district capital (Figure 2) and the sub village of Kundaha (Figure 3). Behongang Village area includes residential areas, village forest and Kundaha sub-village, which is the location of the school and garden or community plantation area. The hilly forest above Kundaha sub-village supplies the clean water for the people in Kundaha sub-village and Behongang village. Behongang village community has a local wisdom embraced hereditary.

Figure1: Kahakitang island, with forest area (A), school building and garden (B), mangrove area (C) Behongang village (D)

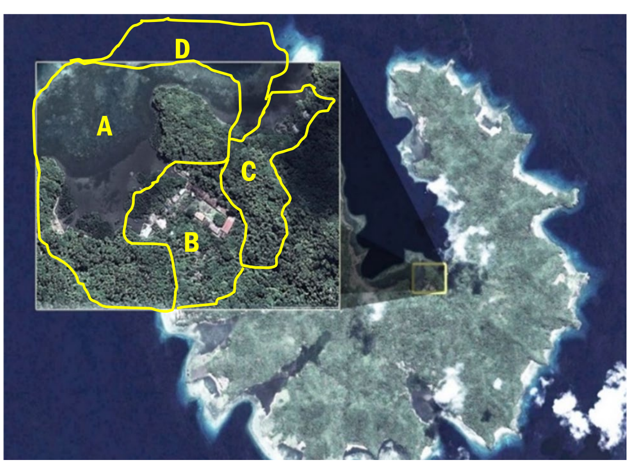


Figure 2: Behongang Village, Kahakitang Island

Figure 3: Kundaha sub-village of Behongang

Local wisdom among others is related to land use for settlements and plantations. The community has agreed not to overhaul the village forest to maintain the availability of clean water. The entire Behongang village forest area is 24,120 m^2. The area of the plantation and school building is 15,742 m^2, while the area of residential is 16,240 m^2. In Behongang village there is a sea port for inter-island transportation. In Behongan village there are no cars and only 5 motorcycles, so air pollution due to the use of motor vehicles is relatively low.

Measurement and vertical profile modelling of air temperature

Measurements were conducted in ten positions, namely on the surface, 0.20 m, 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m, 3 m, 3.5 m and 4 m above the land surface. Measurements are conducted at 06:00, 13:00 and 18:00 local time. Measurements were carried out using three "four in one" instruments. Measurements at three locations are performed simultaneously. The measurement position using logarithmic distances is based on the assumption that changes in air temperature are significantly closer to the surface compared to higher positions.

Measurement modelling and determination of thermal diffusion parameters between forest ecosystems and the environment

Thermal interactions between forest ecosystems and plantation areas, and between forest ecosystems and residential areas, are based on temporal changes and spatial variations of microclimate parameters throughout the day. Measurements were carried out on two transects. Each transect is taken perpendicular to the edge of the forest. The first transect starts from the edge of the forest border towards the forest centre. Coordinates of Transect 1 at the forest edge are $3^0$10’17” N, 125^0 31’12” E. Coordinates of forest centre are $3^0$10’05” N, $125^0$31’27”E. The second transect starts from the edge of the forest bordered by plantation area. Coordinates of Transect 2 at the boundary of plantation area are $3^0$10’18” N, $125^0$31’29”E. Measurements were carried out at the edges, 1 m, 2 m, 4 m, 8 m 16 m and 32 m from the edge to the forest centre. The use of logarithmic distances is based on the need for spatial modelling with the assumption that there is a greater thermal energy absorption near the edges which decreases with increased distance from the edges. The measurement time interval for each position is two hours. The measurement from one to the next position is done on the move (mobile system). Measurements of air temperature, air humidity and ground temperature for each position were performed simultaneously. Air temperature and humidity were measured using "four in one" instruments, while a soil thermometer was used to measure the ground temperature.

The steps of thermal diffusion analysis between the environment and the forest ecosystem are: (1) the modelling of temporal functions and the determination of the parameters: maximum magnitude and the maximum difference of edges and interior; (2) data synchronisation for the concurrent measurements between position; (3) the modelling of spatial function f (x) and the determination of the depth of edge effect and the maximum edge gradient parameters; (4) determination of the edge gradient value by differentiation of spatial function (f (x)) for position x = 0 (forest edge); (5) modelling the daily dynamics of the microclimate gradient function using the resulting data from stage 4; and (6) the determination of the area of microclimate gradient dynamics, resulting from a numerical integration process of gradient dynamics functions. The daily dynamics function of the microclimate gradient can also show the duration of thermal equilibrium or the duration of environmental impact on forest ecosystems. The four parameters of microclimate used to analyse conditions and thermal interactions between forests and plantations and between forests and settlements, is an integrated analysis.

Data acquisition of socio-cultural conditions

Data on forest management, plantation lands and settlement areas is done through direct observation. Data on government regulations, village community agreements, knowledge, awareness and initiatives to conserve forest resources was obtained through a questionnaire that was explored through interviews with community leaders, teachers and religious leaders. Socio-cultural data were analysed qualitatively. The results of the analysis of socio-cultural data are reflected from the analysis of microclimate conditions to produce feedback on strengthening or controlling activities that can improve the sustainability of forest functions, especially for the availability of clean water.

Results

Vertical profile of air temperature

The Pictures 4, 5 and 6 represent the vertical profile of air temperature at three locations, in centre of: settlements, gardens and forests, with time measurement at 06:00, 13:00 and 18:00.

Figure-4 Vertical profile of air temperature in residential area of Behongang village

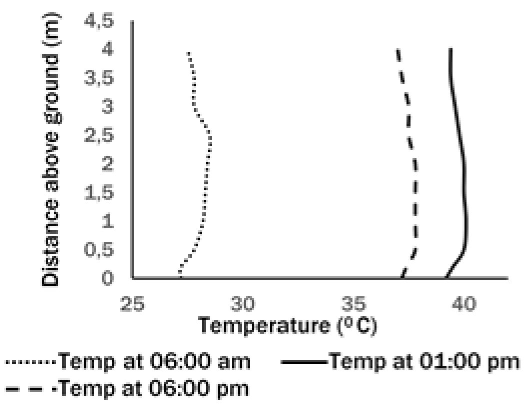
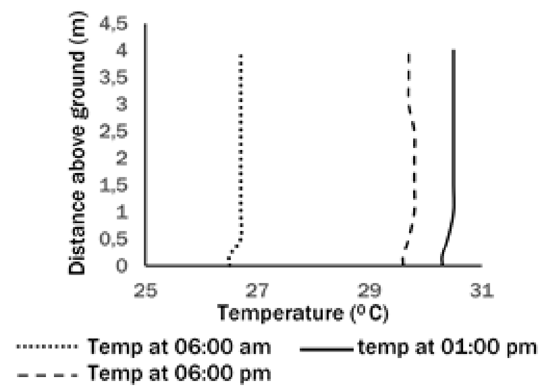
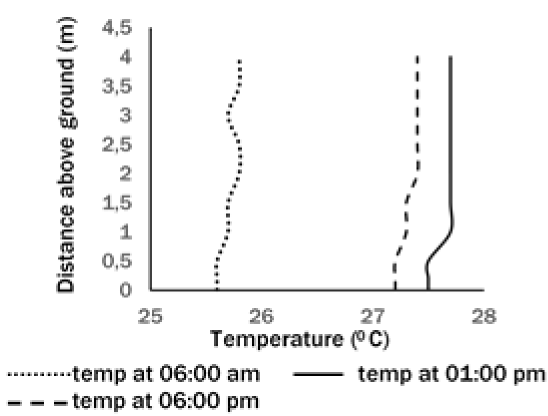


Figure-5. Vertical profile of air temperature in the garden area of Kundaha sub village



Figures 4, 5 and 6 show that the highest air temperature at all three locations occurred between 13:00 and 14:00. For each measurements time, the air temperature at residential locations is higher than in forest and plantation areas. In the centre of settlement, the higher temperature reached 40.1^{0}C. Figure 4 indicates that the highest air temperature at each measurement time occurred at a position of 50 cm to 250 cm above the land surface.

Figure-6. Vertical profile of air temperature in forest area of Behongang village



Besides the sun illumination, this air temperature is also influenced by the people activities in the home and environment, such as cooking and burning garbage. Some people cook using firewood that is high in thermal energy emission. The closest house causes the air to be drained between the walls; it does not flow freely and becomes hotter than the air layer above it. For the location of measurements in the garden (Figure 5) and forest (Figure 6), the air temperature on the surface to a position about 1 m above the land surface is lower than the upper layer. At the time of measurement, field conditions show that low air temperature in the near surface is caused by the moist land surface.

Thermal diffusion and equilibrium of forest-environment

The difference of thermal conditions between environments with forest ecosystems led to the occurrence of horizontal thermal diffusion through the forest boundary (Medellu, 2020). If the environment has a higher temperature, the diffusion direction is from the environment into the forest. Conversely if the forest has a higher temperature, the thermal diffusion direction is from the forest to the environment (Medellu, 2012; 2013). Microclimate variables such as air temperature change temporally (Figure 7) and vary spatially (Figure 8) (Medellu, 2012; 2013). Figure 7 shows the temporal changes in the air temperature at the edge of the forest, at a distance of 4 m and 16 m from the edge towards the forest centre. The time enumeration in the abscissa associated with the measurement clock starts at 06:00 a.m. The highest air temperature on the edge occurred around 13:00 (time enumeration 8) i.e. 37.9^{0}C. The maximum air temperature difference between edge and the central of forest is 3.4^{o}C, occurred around 13:00 p.m.

Figure 7: Temporal changes of air temperature

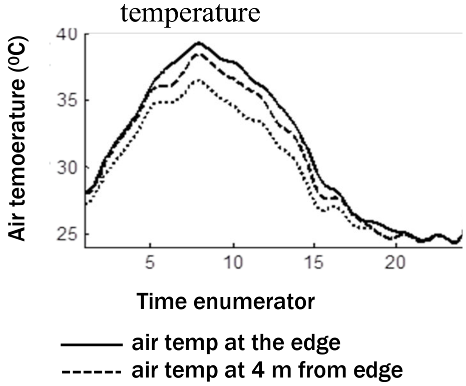


Figure 8: Spatial changes of air temperature along Transect 1

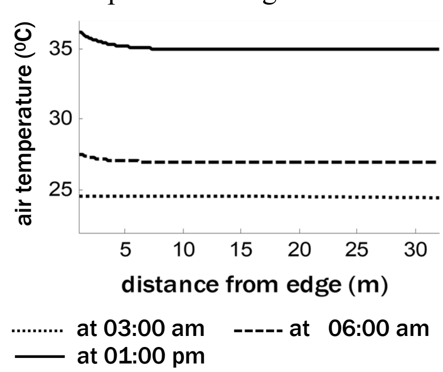


Figure 9: Daily dynamic of air temperature gradient of Transect 1

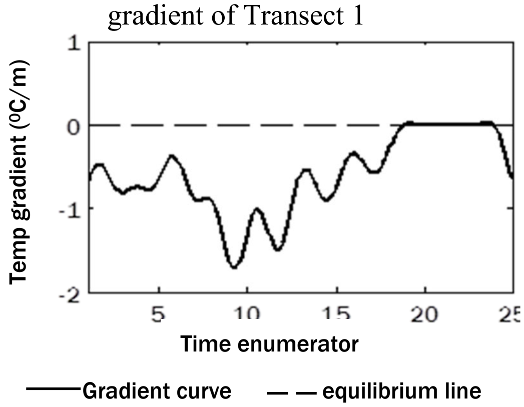


Figure 8 shows the spatial variation of the air temperature throughout Transect 1 at 06:00, 13:00 and 18:00. Figure 8 shows that at 06:00 and at 13:00 the air temperature gradient has a negative value, indicating the thermal diffusion from the residential area into the forest. The highest air temperature gradient occurred around 13:00. The farthest edge effect of air temperature is 28 m, occurring around 13:00. The changing pattern of temporal and spatial ground temperature is the same as the air temperature, while the humidity is the opposite.

The air temperature gradient dynamic

Figure 9 presents the dynamic graph of the air temperature gradient at the edge of the forest bordered by residential areas. The graph shows that between 05:00 and 22:00 the air temperature gradient is located below the thermal equilibrium line. It means that at this time interval, the air temperature in the forest is lower than in the residential area. The temperature in the forest becomes the same as in the residential area at around 0:00 to 05:00. In this time interval, the forest and environment area is in thermal equilibrium. During this interval of time ecological recovery of forest from the thermal diffusion by environment occurred. Summary of analysis and modelling results i.e. the magnitude of microclimate parameters for air temperature, humidity and ground temperatures are presented in Table 1.

Table1: Microclimate parameters data of Transect 1 and Transect 2

Transect	Microclimate parameter	Microclimate variables					
		Air temperature		Relative humidity		Soil temperature	
		quantity	unit	quantity	unit	quantity	unit
1	Daily maximum quantity at the edge	37.9	ºC	89.4	%	29.4	ºC
	Edge-interior maximum difference	3.4	ºC	7.2	%	4.4	ºC
	The depth of edge effect	26	m	25.4	m	10.5	m
	Maximum edge gradient	-1.8	ºC/m	-2.7	%/m	-0.4	ºC/m
	Duration of thermal equilibrium (ecological recovery)	5.8	hour	7.8	hour	8.2	hour
	The area of microclimate gradient (day)	14.46	ºC.hour/m	18.24	%.hour/m	7.42	ºC.hour/m
	The area of microclimate gradient (night)	0	ºC.hour/m	0	%.hour/m	0	ºC.hour/m
2	Daily maximum quantity at the edge	35.4	ºC	92.6	%	27.7	ºC
	Edge-interior maximum difference	2.2	ºC	4.8	%	2.4	ºC
	The depth of edge effect	14.4	m	15.2	m	8.8	m
	Maximum edge gradient	-0.8	ºC/m	-0.9	%/m	-0.3	ºC/m
	Duration of thermal equilibrium	8.4	hour	8.7	hour	9.5	hour
	The area of microclimate gradient (day)	6.8	ºC.hour/m	8.22	%.hour/m	4.86	ºC.hour/m
	The area of microclimate gradient (night)	0	ºC.hour/m	0	%.hour/m	0	ºC.hour/m

Results of analysis of social and cultural data

From the results of identification of forest conditions it can be concluded that the condition of the forest is classified as very good. The community is very strict in protecting and maintaining existing forest areas, to maintain the availability of water in the dry season. The community has traditionally understood the function of the forest in the availability of clean water, so they have an agreement to maintain the existence of the village forest. The forest buffer land located at the foot of the hill is used intensively by the community for the cultivation of spices. Plantation land is open to sunlight and farmers consider it good for plant growth. Home yards are not used by the community for the cultivation of spices and vegetables, even though this commodity is very expensive because it goes through the buying and selling process four to five times from producers. The community has a high awareness to build a common life such as monitoring forest destruction, rotating the utilisation of clean water during long droughts, maintaining environmental cleanliness etc. Waste management is done by burning, and there is no initiative to compost. The community does not yet have initiatives to improve forest functions such as making biopori holes or planting trees in the plantation area as a forest buffer. Communities do not understand the effect of the environment on forest function. Communities lack knowledge about how the high thermal effects in residential and plantation areas can cause an increase in air temperature and decrease air and soil moisture in the forest. Based on repeated experiences of water shortages in the dry season, the community knows that the condition of the forest is already critical. People are reluctant to reforest plantation areas, due to the shared need for spices and vegetables. The community agreed to be given examples of hydroponic cultivation of spices and vegetables that use home yards. The community received good input making biopori holes in the forest and buffer zones to increase the availability of clean water.

Discussion

The results of thermal diffusion analysis between the environment and the forest show the significant difference of microclimate parameters between the two transects. Transect 1 showed the higher quantity of parameter: different edges-interiors; depth of edge effects, maximum edge gradient; and the plane area of daily dynamic of microclimate gradient; than Transect 2 for the three measured variables: air temperature, humidity and ground temperature. These results showed that forests are experiencing more intensive thermal diffusion from residential than from plantation areas. The duration of thermal equilibrium between the forest and the plantation area, are longer than between the forest and the residential area. Longer thermal equilibrium between forests and plantation areas is caused by a faster decrease in thermal energy after sunset. It is influenced by the canopy cover in some areas of the plantation that reduce the radiation penetration, as well as the land surface covered by the shrub. The more intensive thermal diffusion from the residential environment is due to the more intensive illumination on the open land (sandy soils), resulting in more intensive thermal emissions. Thermal emissions due to combustion and cooking activities lasting up to around 21:00 contributed to a higher thermal diffusion and longer from the residential environment. Latimer & Zuckerberg (2016) found that a residential neighbourhood close to the edge of the forest would increase the edge effect. Increased edge effect leads to increased quantity of the parameter plane area of daily dynamic gradient and decreased duration of thermal equilibrium between forests and environments. Increased depth of edge effect and edge gradient indicate an increased intensity of environmental influences on forest ecosystems. Increased edge gradient, the depth of edge effect and the plane area of the daily dynamics of the edge gradient, due to increased thermal diffusion from the environment, will continue until it achieves the limit of the forest capacity to receive thermal influence from the environment. If this capacity is exceeded, for example due to long droughts, then the magnitude of these parameters will be reduced. If the forest canopy is already deciduous, light penetration will increase and the condition of forest microclimate is almost equal to the environment. In such cases, the size of these parameters decreases to zero (Medellu, 2012).

A comparative analysis of the two transects concluded that to reduce the thermal diffusion of the residential area it was necessary to plant trees both in the yard and around the edge of the forest. Li et al., (2011) suggested that the surface temperature of land in residential areas can be controlled by planting trees. The width of the land between the edge of the forest and the settlement boundary is around 15-20 m, with a slope of 40 to 55 degrees. The community has an agreement not to use this land for settlement. Planting trees in this open area serves as a buffer for the microclimate of the forest, as well as for controlling groundwater subsidence (Kimberley et al., 2019). The results of the study concluded that the trees function as a buffer ecosystem against extreme climatic influences (Suggitt et al., 2011; Frey et al., 2016; von Arx et al., 2017). Tree canopy functions to control direct radiation and soil surface temperature (Ueno et al., 2015), so that it will control the decrease in groundwater. Regarding the availability of ground water, the plantation area in the Kundaha sub-village shows a better capacity than the residential area. In the dry season which lasts for three months, well water in Kundaha still exists even though the discharge has decreased. The well water in Behongang village will be exhausted if the dry season reaches three months. The results of the analysis of the microclimate condition of the forest and adjacent environment, related to the availability of water, recommending the creation of infiltration wells in forests and buffer zones. Making infiltration wells or biopores, planting trees and vegetation cover on open land between the edge of the forest with the settlement and at the plantation location, is a priority to reduce thermal diffusion from the edge into the forest, while increasing water infiltration into the soil. The community responded well to feedback on the research results, namely: for making biopori holes in forests and buffer zones; planting trees in the area between forests and settlements; the use of yards for the cultivation of spices and vegetables; and composting to avoid burning waste. The limitation of this study is the feedback of research results to the community, where the positive impact is not directly felt by the community.

Conclusion

The magnitude of the microclimate parameter indicates that the condition of the forest in Behongang village is at a critical limit, so it is necessary to plant trees and vegetation cover on the buffer location to reduce thermal diffusion into the forest. Making infiltration wells or biopores in the forest and in buffer areas needs to be done to increase rainwater infiltration and the availability of groundwater in the dry season. The results of the study provide feedback to strengthen the role of communities in protecting forests. The community responded well to the research results which included making biopores in forests and buffer zones, diverting the cultivation of spices and vegetables from buffer zones by utilising home yards and making compost.

Acknowledgment

The author wishes to thank the Ministry of Research, Technology and Higher Education for funding research related to this article. Researcher expresses high gratitude for active participation and positive response of community of Behongang Village, to receive research findings. The author also thanks the colleagues of the Faculty of Mathematics and Natural Sciences, especially those who are in the expertise group of natural resource and environmental management, and their learning. High appreciation was given to students of the Physics Department who participated in carrying out data measurement and tabulation.

REFERENCES

Berger U, Rivera-Monroy V.H, Doyle Th.W, Dahdouh-Guebas F, Duke N.C, Fontalvo-Herazo M.L, Hildenbrandt H, Koedam N, Mehlig G, Piou C, Twilley R.R. 2008. Advances and limitations of individual-based models to analyze and predict dynamics of mangrove forests. Aquat. Bot., 89: 260–274. https://www.sciencedirect.com/journal/aquatic-botany

Bunyan M, Jose S, Fletcher R. 2012. Edge Effects in Small Forest Fragments: Why More Is Better?. Am. J. Plant Sci., 3: 869-878. http://www.SciRP.org/journal/ajps

Chatterjea K. 2014. Edge effects and exterior influences on Bukit Timah forest, Singapore**,** Eur. J. Geogr., 5(1): 8 – 31. http://www.eurogeographyjournal.eu/article

Chen J, Saunders S.C, Crow T.R, Naiman R.J, Brosofske K.D, Mroz G.D, Brookshire B.L, Franklin J.F. 1999. Microclimate in Forest Ecosystem and Landscape Ecology, BioScience, 49(4): 288-297. https://publons.com/journal/18361/bioscience-research

Davies-Colley R.J, Payne G.W, van Elswijk M. 2000. Forest microclimate gradients. NEW ZEAL J ECOL., 24(2): 111-121. http://www.nzes.org.nz/nzje/

De Lima B, Gilma N, Galvani E, 2013. Mangrove Microclimate: A Case Study from Southeastern Brazil. EARTH INTERACT., 17: 1–16.
https://www.ametsoc.org/index.cfm/ams/publications/journals/earth-interactions/

Didham R.K, Lawton J.H. 1999. Edge structure determines the magnitude of changes in microclimate and vegetation structure in tropical forest fragments. Biotropica., 31: 17–30. https://bioone.org/*journals*/*BIOTROPICA*

Frey S.J, Hadley A.S, Johnson S.L, Schulze M, Jones J.A, Betts M.G. 2016. Spatial models reveal the microclimatic buffering capacity of old-growth forests. – Sci. Adv. 2: e1501392.
https://onlinelibrary.wiley.com/journal/21983844.

Godefroid S, Rucquoij S, Koedam N. 2006. Spatial variability of summer microclimates and plant species response along transects within clearcuts in a beech forest. Plant Ecol., 185: 107–121.

http://link.springer.com/journal/11258

Harper K.A, Macdonald S.E, Burton P.J, Chen J, Brosofske K.D, Sauders S.C, Euskirchen E.S, Roberts D, Jaiteh, M.S, Esseen P.A. 2005. Edge Influence on Forest Structure and Composition in Fragmented Landscapes, Biol. Conserv., 19(3): 768–782.

http://www.journals.elsevier.com/biological-conservation/

Heithecker T.D, Halpern Ch.B. 2007. Edge-related gradients in microclimate in forest aggregates following structural retention harvests in western Washington. FOREST ECOL MANAG., 248(3): 163-173. http://link.springer.com/journal/11258

Hennenberg K.J, Goetze D, Szarzynski J, Orthmann B, Reineking B, Steinke I, Porembski S. 2008. Detection of seasonal variability in microclimatic borders and ecotones between forest and savanna. BASIC PPL ECOL., 9(3): 275 – 285. http://www.journals.elsevier.com/basic-and-applied-ecology/

Imaizumi, F.; RyokoNishii, R.; Ueno, K.; Kurobe, K., (2019). Forest harvesting impacts on microclimate conditions and sediment transport activities in a humid periglacial environment. Hydrol. Earth Syst. Sci. Discuss., 23(1): 155–170 (16 pages). https://www.hydrol-earth-syst-sci.net/23/155/2019/

Kearney M.R, Isaac A.P, Porter W.P. 2014. Microclimate modelling at macro scales: a test of a general microclimate model integrated with gridded continental-scale soil and weather data. Methods Ecol Evol, 5(3): 273-286. http://www.methodsinecologyandevolution.org.

Kimberley T. D, Dobrowski S.Z, Holden Z.A, Higuera Ph.E, Abatzoglou J.T. 2019. Microclimatic buffering in forests of the future: the role of local water balance, Ecography., 42: 1-11.
http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1600-0587/

Latimer C.E, Zuckerberg B. 2016. Forest fragmentation alters winter microclimates and microrefugia in human-modified landscapes. Ecography., 39: 1-13.

http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1600-0587/

Laurance W.F, Camargo J.L.C, Luizão R.C.C, Laurance S.G, Pimm S.L, Bruna E.M, Stouffer P.C, Williamson G, Benítez-Malvido J, Vasconcelos H.L, et al. 2011. The fate of Amazonian forest fragments: a 32-year investigation. Biol. Conserv., 144: 56–67.

http://www.journals.elsevier.com/biological-conservation/.

Li J, Song C, Cao L, Zhu F, Meng X, Wu J. 2011. Impacts of landscape structure on surface urban heat islands: a case study of Shanghai, China. Remote Sens Environ., 115: 3249–3263.
https://www.elsevier.com/journals/remote-sensing-of-environment/0034-4257.

Li J, Li C, Zhu F, Song C, Wu J. 2013. Spatiotemporal pattern of urbanization in Shanghai, China between 1989 and 2005. Landsc Ecol., 28: 1545–1565.
https://www.springer.com/journal/10980.

Magnago L.F.S, Rocha M.F, Meyer L, Martins S.V, Meira-Neto J.A.A. 2015. Microclimatic conditions at forest edges have significant impacts on vegetation structure in large Atlantic forest fragments. Biodivers. Conserv., 24: 2305–2318. https://www.springer.com/journal/10531.

Medellu Ch. S, Soemarno, Marsoedi, Berhimpon S. 2012. The Influence of Opening on the Gradient and Air Temperature Edge Effects in Mangrove Forests. IJBAS., 12 (2): 53-57. http://www.sciencepubco.com/index.php/

Medellu Ch. S. 2012. Mathematical Modelling of Daily Climate Gradients in Mangrove Forests. Dissertation - Brawijaya University, Malang-Indonesia. http://digilib.ub.ac.id; http://www.lib.ub.ac.id.

Medellu Ch.S., 2013. The area and index of diurnal dynamic of microclimate gradient as a mangrove – environment interaction parameter. J. Nat. Sci., 3(14): 68-77.

https://www.iiste.org/Journals/index.php/JNSR/article/view/9701

Medellu Ch.S, Tulandi Dj. 2018. Parameter: The Area of Microclimate Gradient Diurnal Dynamic for Characterization and Monitoring of Forest Ecosystem and Environment. IJEAB., 3(3): 934-943. http://www.ijeab.com

Medellu Ch. S. 2018. Variability of microclimate daily dynamics in small island. IJEAB., 3(6): 2168-2176. http://www.ijeab.com

Medellu Ch. S. 2020. Compatibility between microclimate parameters in the characterization and monitoring of forest ecosystem conditions and environmental interactions. International Journal of Innovation, Creativity and Change. 13(7): 2020 273-289. https://www.ijicc.net/

Mercer J, Dominey-Howes D, Kelman I, Lloyd K. 2007. The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. Environmental Hazards, 7: 245–256.

https://www.hilarispublisher.com/journal-environmental-hazards.html.

Moning C, Muller J. 2009. Critical forest age thresholds for the diversity of lichens, molluscs and birds in beech (Fagus sylvatica L.) dominated forests. Ecol Indic., 9(5): 922-932.

https://www.journals.elsevier.com/ecological-indicators.

Pinto S.R.R, Mendes G, Santos A.M.M, Dantas M, Tabarelli M, Melo F.P.L. 2010. Landscape attributes drive complex spatial microclimate configuration of Brazilian Atlantic forest fragments. TROP CONSERV SCI., 3(4): 389-402. https://us.sagepub.com/en-us/nam/tropical-conservation-science/journal202589.

Pohlman C.L, Turton S.M, Goosem M. 2007. Edge effects of linear canopy openings on tropical rain forest understory microclimate. Biotropica., 39: 62–71. https://onlinelibrary.wiley.com/journal/17447429.

Pregiwati L.A, Wiryawan B, Baskoro M.S, Wisudo S.H, Satria A. 2015. Linking indicators for ecosystem approach to fisheries management and management of marine protected area effectiveness in Anambas Island, Indonesia. Aquac Aquar Conserv Legis., 8(6): 1048 – 1063. http://www.interscience.wiley.com/jpages/1052-7613/ ...

Pu¨tz S, Groeneveld J, Alves L.F, Metzger J.P, Huth A. 2011. Fragmentation drives tropical forest fragments to early successional states: a modelling study for Brazilian Atlantic forests. Ecol Model., 222(24): 1986–1997. https://www.researchgate.net/journal/0304-3800_Ecological_Modelling.

Schmidt M, Jochheim H, Kersebaum K, Lischeid G, Nendel C. 2017. Gradients of microclimate, carbon and nitrogen in transition zones of fragmented landscapes – a review. AGR FOREST METEOROL., 232 (15): 659–671. https://www.mdpi.com/journal/forest.

Suggitt A.J, Gillingham P.K, Hill J.K, Huntley B. 2011. Habitat microclimates drive fine-scale variation in extreme temperatures. – Oikos., 120: 1–8. http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1600-0706.

Tuff K.T, Tuff T, Davies K.F. 2016. A framework for integrating thermal biology into fragmentation research. Ecol Lett., 19: 361–374. https://onlinelibrary.wiley.com/journal/14610248.

Ueno K, Kurobe K, Imaizumi F, Nishii R. 2015. Effects of deforestation and weather on diurnal frost heave processes on the steep mountain slopes in south central Japan, Earth Surf. Process. Landf., 40: 2013–2025. https://onlinelibrary.wiley.com/journal/10969837.

von Arx G, Arroyo-Rodrı´guez V, Saldan˜a-Va´zquez R.A, Fahrig L, Santos B.A. 2017. Does forest fragmentation cause an increase in forest temperature?. Ecol Res., 32: 81–88. https://besjournals.onlinelibrary.wiley.com/journal/13652745.

Wright T.E, Kasel S, Tausz M, Bennett L.T. 2010. Edge microclimate of temperate woodlands as affected by adjoining land use. Agric For Meteorol., 150: 1138–1146. http://www.sciencedirect.com/science/journal/01681923.

Zulkiflee A.L, Blackburn G.A. 2010. The effects of gap size on some microclimate variables during late summer and autumn in a temperate broadleaved deciduous forest. Int. J. Biometeorol., 54: 119-129. http://www.springerlink.com/openurl.asp?genre=journal&issn=0020-7128.