Correlation of microclimates dynamic to plants survivorship and space amenity of Cibodas Botanical Garden

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Abstract. The microclimate extreme amplitudes decrease plant survival chance in the field. In order to find out the impact of microclimates to plants survivorship, an action research was conducted in Cibodas Botanical Garden by inventoried microclimate data series of temperature, humidity, rainfall, wind velocity, air pressure, and solar radiation, from 2012 to 2016, and the correlation to plants loss of the garden. The study has also conducted the analysis of the dynamics of space amenity. Space amenity was assumed comparable with temperature-humidity index (THI) value. The quality of space amenity was measured by the correlation between THI to the number of tourists. The results indicated that an increase in plants loss caused by an extreme microclimate, especially heavy rainfall that occurred in early and end of the year, along with the decrease of the visits. Total plants loss were 790 specimens and the lost which occurred at early-end of the years contributed 64.2% of total lost, bigger than the middle of the year. Despite THI never exceeded comfort value (< 26), still occurred decreased of the visits. Therefore, to minimize the impact of uncertain future microclimate conditions, operators should give better plants management to anticipate the greater losses.

Keywords: microclimate impact, plants management, Temperature Humidity Index (THI).

1. Introduction

The microclimate, which can be defined as a small scale pattern of climate that is influenced by site topography as well as local built forms and materials, can be heavily affected by vegetation [1]. Favorable microclimates in otherwise inhospitable landscapes allowed the survival of climate relict tree populations and associated biodiversity in the past, and are predicted to buffer populations against ongoing environmental change [2, 3]. When discussing individual sites, we thus use the term 'microclimate' to refer to vegetation and environmental variability on a sub-landscape scale, at which topographic factors can create suitable conditions for localized tree populations and woodland communities to survive potentially unfavorable regional climatic regimes [4].

Microclimates have a direct effect to plant growth and survivorship in the field. An extreme amplitude can cause a decrease in plant survival and development. The rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum [5]. These values were summarized by Hatfield et al. [5] for a number of different species typical of grain and fruit production. Heat waves or extreme temperature events are projected to become more intense, more frequent, and
last longer than what is being currently been observed in recent years [6]. The extreme temperature events may have short-term durations of a few days with temperature increases of over 5°C above the normal temperatures. Extreme events occurring during the summer period would have the most dramatic impact on plant productivity; however, there has been little research conducted to document these effects as found by Kumudini et al. [7].

Space amenity is not straightforward because this amenity is especially difficult to characterize [8]. Space amenity is not only perceived the experience of a high value of aesthetical view of the site but also provide a cohesive environment and a more identifiable character. A cohesive environment comprises man-made infrastructures, natural qualities, such as climate, topography, water resources and cultivated landscapes. In this paper, microclimates elements i.e. temperature and humidity, are also forming space amenity, in the context of the results of the complex interaction between built and green spaces. A comfort temperature-humidity will invite visitors when associated with a global climate change and the impacts to discomforts of surrounding environment. Recently, urban residents prefer to visit tourist area which offers a ‘natural sense’ as their attraction. Related to both, mountain area which provides a comfort temperature-humidity frequently become a tourist destination. These are interconnected with comfort felt, balmy temperature. Space microclimates comfort which formed by temperature and humidity can be represented by temperature-humidity index (THI). THI describes the degree measure of comfort that is experienced by the human from the combination of air temperature and humidity [9]. Generally, the value THI can describe initial microclimates amenity surrounding the area. This is important to support for tourism, especially for the visits of tourist.

Cibodas Botanical Garden (CBG) as a conservation area for ex-situ plant, research and education and also ecotourism destination, is closely related to microclimates condition. Fluctuation and dynamic condition of microclimates are influencing of plants growth and space amenity for visitors. Therefore, this study purposes were to analysis the impact of microclimates factors (i.e. temperature, humidity, rainfall, wind velocity, air pressure, and solar radiation) to plants survivorship, which represented by the number of lost plants and their correlation, and to assess space amenity, which represented by the correlation between THI and the number of visits along last five years. The results were expected to be the main consideration for site planning and management action, in order to minimize the impact of uncertain future microclimate conditions, which operators should give better attention to plants and management to anticipate greater losses.

2. Methods
The study was conducted at CBG which administratively located in Cipanas District, Cianjur Regency, West Java Province. CBG is located at mountainside of Mount Gede and Mount Pangrango at altitude of approximately 1,300-1,425 meter above sea level, with area of 84.99 hectares. In accordance with its functions, CBG had an obligation to perform of ex situ conservation efforts, especially for the types of plants from tropical wet highlands zone, for research and education, and also for ecotourism. CBG is a comfortable place to rest while enjoying the beauty of the various types of plants that originated from Indonesia, especially from tropical wet highland, and other foreign countries. CBG is located± 100 km from Jakarta and ± 80 km from Bandung.

2.1. Data acquisition
Collected data were consisted three main data, microclimates series data (i.e. temperature, humidity, rainfall, average wind velocity and solar radiation), lost plants data of each month and the number of tourists who visits CBG. All the data were recorded and collected from 2012 to 2016. Microclimates data were collected from the weather station which established at CBG. Weather equipment was obtained from Precision Weather Station Davis Instruments Vantage Pro2 Plus™. The equipment was automatic constantly sent current data to the server regarding microclimates condition of CBG. The observation equipment was located in front of management office of CBG. The collected data were accurate to describe weather condition surrounding equipment minimum in a radius of the one-kilometer square.
The second data was the plants loss, which defines as the reduced of garden plants collection. Plants loss were assumption closely related with survivorship, increasingly of the plants loss was indicated that the survivorship decreased, and vice versa. The dynamic of plants richness of CBG were routinely recorded by ‘Registration Unit’ of CBG [10].

The third data was the number of CBG visitors. CBG is a government institution which also conducting ecotourism. Tourists who visit CBG will be charged in form of tickets for entrance based on accordance with applicable regulations.

2.2. Data analysis
The differences between three databases, both in value and unit, were transferred in natural logarithm, ln(x_i). A standard deviation (σ) was used, in order to quantify the amount of variation of microclimates series data. A low σ indicates that the data points tend to be close to the mean or less variety, while a high σ indicates that the data are spread out over a wider range of values or much variety.

In addition, in order to analyze space amenity, the study was used temperature-humidity index (THI). THI is representing an index to specify the comfort by quantitatively which combined with temperature and relative humidity, with formula [9]:

\[ THI = 0.8 \times T_a + \frac{(RH \times T_a)}{500} \]  

(1)

The equation 1 resulted in THI value is representing an index to specify the comfort of the space which combined with temperature (T_a) and relative humidity (RH). Based on tropical condition, the THI value which defined as a ‘comfort condition’ is the value between 20 to 26. If the value less than 20 the condition concludes as ‘too cold’ condition and if exceed than 26 concludes as ‘too hot’ condition [9].

In order to analyze the correlation between two factors, microclimates unit (x_1) and plants loss (y_1), and between THI (x_2) and the number of tourist visits (y_2) were tested with Pearson correlation (equation 2). The microclimates unit are including temperature, humidity, rainfall, average wind velocity and solar radiation. The Pearson correlation coefficient was tested using the formula:

\[ r = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\left[ n \sum x_i^2 (\sum x_i)^2 \right]^{1/2} \left[ n \sum y_i^2 (\sum y_i)^2 \right]^{1/2}} \]  

(2)

In order to statistically test, then arranged the hypothetic that \( H_0: r = 0 \); \( H_1: r \neq 0, \alpha = 0.01 \). The value of \( r = 0 \) means that there is no any correlation between two factors, in reverse, the value of \( r \neq 0 \) means that there is a correlation. The \( r \) value will not exceed from \( |1| \) when approaching to the value of -1 means that there is a negative linear relationship, and when approaching to the value of 1 means that there is a positive linear relationship. In order to assess the degree of significance, a \( t \)-test in ANOVA with \( \alpha = 0.01 \) was also conducted. If \( r \neq 0 \), p-value < \( \alpha \) means that the correlation between two factors is significant, and if p-value > \( \alpha \) means that the correlation between two factors is not significant.

3. Results and Discussions
Based on data series from 2012 to 2016, the microclimates data, the number of plants loss and the number of tourist of CBG were described in the below. There was a dynamic value trend both in month and year.

3.1. Data inventory
Microclimates series data of CBG from 2012 to 2016 were details presented in Table 1. Nevertheless, several times occurred errors either in the weather equipment or the server, it cause these data can not be recorded.
n.d.: no data, there weren’t recorded data to be collected, because of error or malfunction of the equipment. Courtesy of Agus Darmawan.

Based on microclimates series data, the unit which has the widest amplitude was rainfall (Table 2), and the others have a minor variety. This was supposed because of the location of CBG in the elevation of the mountain with wet tropic zone characteristics [11]. it means temperature, humidity, wind velocity, air pressure and solar radiation less diverse. Heavy rainfall (>100 mm per-month) which occurred in early and end of the year (wet season) given a significant variant of microclimates condition surrounding CBG. The number of wet months more than dry months, between seven to eight months per year, and accumulatively above 1,000 mm annual rainfall [12] [13]. Based on Schmidt-Ferguson classification, CBG was the type of C to B, or less wet to wet, and based on Koppen, it can be included to tropical rainy climates or wet tropic ‘Am’.

**Table 1. Microclimates dynamic series data CBG.**

| Year | Temperature (°C) | Humidity (%) | Rainfall (mm) | Avg. wind velocity (kph) | Air pressure (mbar) | Solar rad. (W m²) |
|------|------------------|--------------|---------------|--------------------------|---------------------|-------------------|
| 2012 | 19.73            | 85.60        | 162.00        | 5.21                     | 999.00              | 87.10             |
|      | 19.74            | 85.20        | 366.00        | 17.26                     | 998.96              | 110.00            |
|      | 19.70            | 84.30        | 113.80        | 6.00                      | 998.73              | 92.20             |
|      | 19.60            | 91.50        | 371.60        | 3.00                      | 998.17              | 109.20            |
|      | 19.50            | 89.10        | 179.80        | 3.60                      | 998.56              | 115.00            |
|      | 19.20            | 86.00        | 36.60         | 3.60                      | 999.42              | 119.00            |
|      | 19.80            | 83.80        | 24.60         | 4.20                      | 1000.40             | 130.00            |
|      | 18.80            | 80.90        | 54.20         | 4.20                      | 1000.20             | 151.00            |
|      | 19.40            | 82.00        | 74.00         | 4.20                      | 108.00              | 140.00            |
|      | 19.90            | 86.40        | 235.60        | 4.20                      | 107.00              | 137.00            |
|      | 19.80            | 91.20        | 323.90        | 4.20                      | 100.00              | 150.00            |
|      | 19.50            | 91.20        | 250.00        | 4.20                      | 99.81               | 143.00            |

**Table 2. Standard deviation(σ) value of the normalized microclimates unit.**

| Microclimates unit | σvalue of the normalized microclimates unit, ln (x) |
|--------------------|--------------------------------------------------|
| Temperature        | 0.033                                            |
| Humidity           | 0.045                                            |
| Rainfall           | 1.316                                            |
| Average wind velocity | 0.556                                           |
| Air pressure       | 0.070                                            |
| Solar rad.         | 0.212                                            |
The next data inventory was the plants loss. The loss can be caused by several reasons, e.g. fell or hit by other fallen bigger plant(s) or tree(s), pests and diseases causes, dried, and withered. The effect of microclimates was dominant in these cases. The others are old ages, disappear from its location (eaten by wild animals, erosion, flood, and revoked by humans) or intended to be cutting off for human safety importance or infrastructures development (very rare). The details number of plants loss of CBG were presented in Table 3 [10].

Table 3. The number of plants loss (n-specimens) of CBG.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012 | 92  | 6   | 7   | 23  | 7   | 7   | 6   | 8   | 33  | 4   | 32  | 0   |
| 2013 | 14  | 17  | 10  | 7   | 7   | 5   | 7   | 3   | 5   | 20  | 12  | 7   |
| 2014 | 4   | 4   | 11  | 6   | 6   | 2   | 4   | 6   | 12  | 11  | 42  | 49  |
| 2015 | 19  | 38  | 16  | 13  | 3   | 21  | 15  | 15  | 9   | 14  | 25  | 0   |
| 2016 | 7   | 11  | 15  | 6   | 6   | 2   | 0   | 33  | 6   | 1   | 8   | 11  |

The plants loss in CBG tended to occur in early-end of the year (Figure 1). At this time, accumulatively the number of plants loss was 507 (totally 790) specimens or 64.2%, then in the middle of the year. The cause of loss was dominated by fell or hit by other fallen tree(s), float off and increasing diseases attack [10]. The biggest loss occurred in January 2012, 92 specimens and secondly, in December 2014, 49 specimens were lost, both have occurred in early-end of the year.

![Figure 1. The number of plants loss (n-specimens) of CBG.](image)

Furthermore, as an eco-tourism destination, CBG has also organized tourist visits, both in regular tourism and for research and education interest. The number of tourists based on sold entrance tickets were presented in Table 4.
Table 4. The number of tourists of CBG.

| Year | Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012 |        | 58,402 | 35,524 | 29,303 | 39,021 | 63,254 | 78,206 | 56,512 | 91,190 | 62,237 | 49,551 | 19,030 | 21,049 |
| 2013 |        | 29,802 | 19,555 | 33,759 | 39,021 | 68,911 | 59,359 | 13,757 | 88,745 | 41,936 | 32,708 | 24,195 | 24,875 |
| 2014 |        | 37,128 | 21,770 | 42,674 | 32,879 | 47,299 | 50,756 | 32,126 | 88,021 | 41,497 | 38,952 | 26,176 | 28,914 |
| 2015 |        | 35,290 | 23,801 | 38,285 | 35,502 | 74,582 | 57,612 | 77,727 | 72,210 | 45,844 | 40,446 | 26,503 | 30,625 |
| 2016 |        | 47,367 | 27,960 | 35,095 | 33,737 | 83,551 | 114,759 | 52,945 | 35,664 | 36,105 | 37,197 | 46,164 |        |

The peak visiting occurred in June to August each year (Figure 2), which coincide with ‘school long holidays’. Nevertheless, even at the end of December to early January also has long holidays, the visits to CBG still lower than the middle of the year. In 2012 to 2016, accumulatively the number of tourist in the middle of the year, April to September, was 1,692,580 persons or contributed 62.8%, then in early-end of the year, those were 19.3% and 17.9%.

3.2. THI value

There were occurred microclimates dynamic in CBG between early-end of the year condition than in the middle. These data can be generated THI value of local CBG along 2012 to 2016 (Table 5).

Table 5. The THI value of CBG.

| Year | Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 2012 |        | 19.2 | 19.2 | 19.1 | 19.3 | 18.7 | 18.3 | 18.1 | 18.7 | 19.4 | 19.5 | 19.2 |
| 2013 |        | 19.3 | 19.3 | 19.5 | 19.9 | 19.7 | 19.6 | 18.8 | 18.5 | 19.3 | 19.3 | 19.5 | n.a.a |
| 2014 |        | 19.4 | 19.8 | n.a.a | n.a.a | n.a.a | n.a.a | n.a.a | n.a.a | n.a.a | n.a.a | 18.8 |
| 2015 |        | 18.0 | 18.2 | 18.6 | 18.6 | 17.9 | 17.7 | 17.3 | 17.5 | 17.8 | 18.3 | 19.1 | 18.8 |
| 2016 |        | 19.2 | 19.3 | 19.5 | 19.5 | 19.4 | 18.9 | 18.5 | 17.9 | 18.7 | n.a.a | n.a.a | n.a.a |

a) n.a.: not available (because there weren’t any data can be further analyzed).
THI value of CBG was range about 17.3 to 19.9 (Table 5) and never exceeded to value 26, a boundary value of discomfort [9]. These conditions included ‘too cold’ condition [9], which THI below 20 to 21, although it was understandable because of the altitude of CBG located on the mountainous side. Temperatures were tended to drop in July to September or in dry months, but humidity tended to constantly in high values (> 80%) or very humid condition.

3.3. Correlation between microclimates and plants survivorship
Rainfall in CBG as microclimates unit has most diverse and biggest deviation amplitude. Heavy rainfall has occurred in early-end of the year, and along with solar radiation decreased. This can be understood when heavy rainfall occurred, cloud very thick that prevent solar radiation penetrations. Furthermore, rainfall occurred closely related to air pressure differences, bigger differences will give a bigger chance for rain occurrence.

Data showed that the biggest plants lost was also occurred in the early-end year. The lost in time range was contributed more than 64% of the total. The biggest loss, such as in January 2012 and December 2014, the level of rainfall was also very high (> 150 mm per month). Along with the high-level volume of rainfall at previous months, and this influenced to reduce soil aggregates and surface runoff which can cause surface erosion and flood [14], and reduce the capability of plants to adsorb the soil. The secaused the plants will befell because they may not be able any longer to hold the standing. These conditions were caused decreasing of plants survivorship [15][16] in the garden and vulnerable have occurred of plants loss. Fallen plant(s), especially tree(s), is not only harm human safety in the garden, but also hurt other plants collection because of stroked of this coverage. A tall tree(s) with widespread canopy and stem diameter can cause massif damages to other plants collection up to tens.

The disadvantages of a massif rainfall condition with plants loss [15] can be analyzed based on the correlation between them in Table 6. Each microclimates unit has a correlation to plants loss ($r \neq 0$), then reject $H_0$. Based on Pearson test, the correlation between rainfall and plants loss has the highest value than others. The correlation value was positive, which mean that the higher value of rainfall can cause a higher risk of plants loss. Although the index value was not close with value ‘1’ (0.496), or correlation was moderate or less strong, but based on $t$-test value found that a highly significant correlation between them ($p < \alpha = 0.01$). So this can be described that rainfall was linear significantly influence to plants loss at a moderate level.

| Microclimates unit          | Plants loss |
|-----------------------------|-------------|
|                             | r  | α    |   p-value         |
| Temperature                 | 0.433 | 0.01 | 1.44 x 10^{-4}   |
| Humidity                    | 0.156 | 0.01 | 1.08 x 10^{-9}   |
| Rainfall                    | 0.496 | 0.01 | 1.18 x 10^{-7}   |
| Avg. wind velocity          | 0.031 | 0.01 | 3.09 x 10^{-7}   |
| Air pressure                | 0.236 | 0.01 | 4.06 x 10^{-13}  |
| Solar rad.                  | -0.139 | 0.01 | 1.15 x 10^{-9}   |

*Table 6. Average correlation index (r) between microclimates unit and plants loss*.

$^a$ because the lack of data for several months (n.d.: no data) in microclimates, then the data were averaged for available data in the same month.

The occurrences of heavy rainfall in the early-end of the year were not only directly reduced the ability of plants standing but also increased of diseases stroked [17]. Rotten roots, stem and/or other parts of plants and fungus stroked were also increased in this time range. Strokes of fallen plants and diseases have dominated the causes of plants loss, more than three-quarter, than other causes [10].
Several actions have been conducted by CBG operator in order to anticipate of this disadvantages, such as regular pruning, pests and diseases controlling, strengthening of hills side of the garden by concrete. And for the results, in 2016 the number of plants loss was the lowest than previously, nevertheless lost which caused by extreme microclimates, especially severe rainfall still dominated [10]. This was difficult to anticipate especially the fallen risk of tall and big tree(s).

3.4. Correlation between THI and number of visits
The diverse of THI values along five years were also relatively constant with low amplitude. This condition should be encouraged tourist to keep visiting CBG or at least constantly. But in fact, there was a big difference of visits between early-end compared to the middle of the year. Data was showed that ‘school long holiday’ (June to August) which occurred in the middle of the year, not always contributed to the leap of the number of visits than in the early-end year. These can be analyzed on data, such as in July 2013 was the lowest visits along time range observation, or in July 2014 was lower than March, June, or September in the same year. So that in June 2016 was the lowest visits of the year.

Based on Pearson test, it was obtained the value of $ r = -0.71 $ with $ p $-value $ < \alpha = 0.01 $, so reject $ H_0 $ or there is a correlation between THI and the number of visits. The negative value was meant that bigger THI value (being more discomfort) then the number of visits became lower. Although the result was shown a significant correlation between THI and the number of visits, this still has not explained the dynamics of the number of visits which occurred. This because in fact, THI value for five years was relatively constant, but in the other part, the number of visits was dynamically raised up and downed, especially between the early-end which compared to the middle of the year (Figure 3).

![Figure 3](image)

Figure 3. Proportionally comparison of the normalized THI value to the normalized number of tourists.

The contribution of the visits along ‘school long holiday’ (June to August) also has not sufficient to explain the dynamic. The test showed that correlation between THI and the number of visits at the peak time resulted in $ r = -1 $ (negative correlation and reject $ H_0 $), but with $ p $-value $ = 0.02 > \alpha = 0.01 $ or has no significance.

The next assumption that there was any other microclimates unit, besides temperature and humidity (as the composer of THI) which influence to the visits, and that was rainfall [18]. The high volume of rainfall in the early-end year was assumed directly influencing the tourist interest to visit than any other. As eco-tourism destination, most tourist like to enjoy the beautiful scenery and space amenity of CBG. When heavy rainfall occurred, it was difficult to sense this comfort. This can be proven with the
correlation between rainfalls to the number of visits. Based on test, the $r = -0.59$ (reject $H_0$), with $p$-value $<\alpha = 0.01$. This corresponded with the previous assumption, which increasing rainfall will be decreased of visits (negative correlation or opposite) [18]. This analysis was consistent with the fact that the high volume of rainfall which occurred in the early-end year along with the decreasing of the visits at the same periods.

This condition has to be anticipated by CBG operator in order to manage the number of tourist visits. Heavy rainfall occurred in the early-end year may not be able to manage because it is major forces, but the operator can manage space order of CBG. For example, by developing shelters both natural or man-made structure, so tourist may still to enjoy the scenery of the garden without disturbed by rainfall, or rain can be organized as a natural attraction, such as ‘rain theme park’ adjusted with conservation principles value. So that rainfall was not an obstacle but organized as a new attraction to pull tourists interest.

4. Conclusions
There were significantly proven the correlations between microclimates to plants survivorship, and to build space amenity of the local condition of CBG. The most microclimates unit which influencing both was rainfall. The extreme rainfall occurred in the early-end of the year influenced to reduce plants survivorship, which plants loss in this period tended to increase. The correlation was positive, that bigger rainfall directionally with bigger plants loss. Furthermore, the THI value has the negative influenced correlation to tourist visits. Nevertheless, the better microclimates unit which able to describe the dynamic of the visits over time was rainfall. Rainfall was assumed as an obstacle factor for tourist interest to visit. The correlation was negative that increasing rainfall will influence tourist visits more decreasingly. This needed the operator concern to anticipate these disadvantages by a routine maintenance and developing a better space organization.

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