Leaf Shedding Phenology of Ficus Glaucə, Terminalia Catappa, and Cassia Fistula

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Abstract. Phenology is a study that explores periodic tree lifecycle events and how those events are influenced by seasonal climatic variation. This study aimed to observe the leaf-shedding period of three commonly found deciduous tree species in the tropics: Ficus glaucə, Terminalia catappa, and Cassia fistula; and to analyze the climatic driving factors to trees’ phenological phases. A field survey was conducted to observe the samples, each species consisted of five trees. The survey was conducted weekly from September 2016 to February 2017 in Bogor City and Regency. It was found that F. glaucə shed its leaves more than once a year. The canopy coverage reached its lowest in February (65.7% coverage). Leaf shedding process in T. catappa reached its peak in January (83.7% coverage), meanwhile, C. fistula’s shedding period is suspected to happen before September because its canopy coverage kept increasing during the survey (60.7%–95.1% coverage). The climatic factor that significantly affected F. glaucə was the previous month’s rainfall. When the rainfall in the previous month decreases, the leaf shedding increases. T. catappa and C. fistula were significantly affected by day length. For T. catappa, when day length decreases, the leaf shedding decreases. Meanwhile, for C. fistula, when day length increases, it is shedding its leaves. Leaf phenology of deciduous trees in a tropical climate was affected by different climatic factors depending on their species.

Keywords: climate influence, deciduous, leaf shedding, photo grid analysis, tropical tree

1. Introduction

Plant phenology is an interdisciplinary field of research that focuses on the timing of phases in the plant’s life cycle (phenophases), such as leaf-flushing, flowering, fruiting, and leaf-shedding [1]. Phenology is widely utilized in biology and ecology. Plant phenological events are influenced by various environmental factors, such as temperature, rainfall, day length, etc. [2].

In the landscape architecture field, phenology is very useful in improving the quality of the landscape because the visual changes in plants can provide special effects for those who see it. Seasonal changes that occur in plants can affect a person’s visual perception of the landscape [3]. Plants are an important element in the composition of green open space areas that create the aesthetic value of the landscape. This makes the identification of plants’ visual changes process through phenology observation is important in landscape architecture field.

Research on plant phenology keeps increasing due to the increase in global climate change issues. Various studies show that climate change causes shifts in the phenological phase timing [4][5]. The shifting of phenological phase timings in plants may cause disruption of migration and breeding timings in animals, as well as various asynchronous events between species [6]. Those events may cause an ecosystem imbalance. By studying phenology, researchers can become more sensitive to environmental changes and can reduce the risk of the damage.

In Indonesia, research on tree phenology continues to grow, but existing research tends to focus only on the flowering period without observing the leaf phenology. Leaves are a large...
part of the tree that shows the physiological condition of the tree [7]. Therefore, leaf phenology is needed to be studied further.

In this study, we observed the leaf shedding phenology of three tree species, which were *Ficus glauca* (Liebm.) Miq., *Terminalia catappa* (Linn.), and *Cassia fistula* (Linn.). These three species are deciduous tree species that are commonly found in tropical climate landscapes. *F. glauca* (local name: Bunut) is a tree of the fig family that has a wide canopy and hanging aerial roots. *T. catappa* (local name: Ketapang) is a tree with a spreading canopy and open branches that are often planted as shade or ornamental trees. *C. fistula* (local name: Trengguli) is a deciduous tree with yellow flowers that is often planted as an ornamental tree.

Limited knowledge of the leaf shedding phenology of these trees makes the timing unknown. Therefore, this study aimed to observe the leaf-shedding and leaf-flushing period in three deciduous tree species: *Ficus glauca*, *Terminalia catappa*, and *Cassia fistula*, and to analyze the role of climatic factors in the leaf phenological phases of the said species.

2. Material and Methods

2.1. Study area

This study was conducted through a field survey to the samples consisting of three deciduous tree species, namely *F. glauca*, *T. catappa*, and *C. fistula*. Each species consisted of five tree samples. Tree samples were chosen deliberately by considering the condition of the tree. The trees should look relatively uniform, mature, and appear healthy. The proximity of each sample was also considered. Figure 1 shows the locations of the samples.

![Figure 1. The samples' locations in Bogor Regency (left) and Bogor City (right)](image)

The study area is the living locations of the sample trees. One research location in Bogor Regency was the parking lot of the Faculty of Animal Science, Institut Pertanian Bogor Dramaga (*T. catappa*'s place of growth). The other three locations in Bogor City were Kebun Percobaan Balai Penelitian Tanaman Rempah dan Obat Cimanggu (*C. fistula*'s place of growth), and two road greenbelts at Jalan Dr. Semeru and Jalan Ir. H. Juanda (*F. glauca*'s place of growth). The leaf shedding phenological phase was observed for 6 months from September 2016 until February 2017.

2.2. Data collection and analysis method

The timing of leaf shedding phenology was estimated by observing the canopy coverage on the tree. When the canopy coverage decreases, it is assumed as the time of leaf shedding phase, meanwhile, when the canopy coverage increases, it is assumed as the time of leaf flushing phase. Trees’ canopy sample photos were taken once a week from a consistent distance using a digital camera Nikon Coolpix S4400. The canopy coverage is estimated digitally following the photo grid analysis method [8]. The photo size is 3000 x 4000 px and processed with
Adobe Photoshop. The area covered by leaves is marked with a 50 x 50 px squares. The number of
squares is used to estimate the canopy coverage following Equation (1).

\[
\text{% canopy coverage} = \frac{\sum \text{squares covered by leaves}}{\sum \text{maximum number of squares of tree i during observation}} \times 100\% \quad (1)
\]

To examine climatic factors that affect the leaf shedding phenology, we collected the
following data: rainfall, rainy days, temperature humidity (RH), day length (DL), solar
radiation (SR), and wind velocity (WV). The data were obtained from the Meteorological,
Climatological, and Geophysical Agency (BMKG). The influence of climatic factors on
the percentage of tree canopy coverage is analyzed by linear regression in SPSS 24. The canopy
coverage data are analyzed with three periods of climatic data: weekly, monthly, and previous
monthly. This is to detect whether there is a possibility that some climatic factors might not
directly affect the leaf phenology. Certain climate factors may take time to affect the leaf
phenology. Therefore, in the analysis part, the previous month’s climatic data were considered.

3. Results and Discussions

3.1. General climatic condition

The climatic condition during the observation period is shown in Table 1. The data were
collected from the same station except for the rainfall data which had been collected from three
different stations. The stations were Dramaga (Dr), Kebun Raya Bogor (KRB), and Cimanggu
(Ci) station. Every station’s data was used for different species due to different places of growth,
Dramaga station for T. catappa, KRB for F. glauca, and Cimanggu for C. fistula. Each station
showed a similar trend, the rainfall increased from August to September, then slowly decreased
until November, and significantly decreased in December and January, then lastly significantly
increased in February.

The average temperature (T) in the study area was relatively stable but it seemed to
noticeably decrease in February. Relative humidity (RH) also seemed stable with an average
of 84.4%, so is wind velocity with an average of 4.3 km/hr. Day length (DL) data is the
percentage of the length of the day in 12 hours. If the sun shines for 12 hours in a day, then the
day length would be 100%. Based on Table 1, day length tended to decrease towards the end of
the observation period, but solar radiation (SR) tended to fluctuate throughout the period.

Table 1. The climatic condition during the observation period

| Mo. | Total rainfall (mm) | Daily rainfall (mm) | Rainy day (days) | T (°C) | RH (%) | DL 12h (%) | SR (cal cm/ mnt) | WV (km/hr) |
|-----|---------------------|---------------------|------------------|--------|--------|-----------|----------------|-----------|
|     | Dr                  | KRB                 | Ci               | Dr     | KRB    | Ci        | Dr             | KRB       |
| Aug | 299.2               | 211.0               | 191.5            | 9.7    | 6.8    | 6.2       | 16             | 16        | 26.1 | 82.2 | 71.1 | 320.1 | 4.1 |
| Sep | 439.2               | 507.1               | 381.8            | 15.7   | 17.5   | 12.7      | 25             | 21        | 22   | 26.2 | 83.5 | 63.4 | 327.3 | 4.4 |
| Oct | 398.2               | 515.4               | 390.5            | 13.7   | 16.6   | 12.6      | 28             | 20        | 27   | 26.0 | 86.0 | 39.5 | 285.5 | 3.7 |
| Nov | 343.1               | 349.4               | 312.5            | 11.4   | 12.5   | 10.4      | 23             | 22        | 21   | 26.0 | 86.5 | 44.5 | 278.2 | 3.7 |
| Dec | 116.6               | 141.4               | 126.5            | 4.3    | 4.9    | 4.1       | 22             | 20        | 15   | 26.0 | 82.0 | 39.4 | 318.6 | 4.8 |
| Jan | 130.4               | 192.5               | 132.0            | 4.7    | 7.7    | 4.3       | 23             | 22        | 17   | 25.9 | 82.9 | 29.8 | 320.9 | 4.7 |
| Feb | 526.2               | 742.7               | 623.0            | 18.8   | 26.5   | 22.3      | 27             | 27        | 26   | 25.0 | 87.8 | 19.6 | 287.4 | 4.7 |
| Mean | 321.8               | 379.0               | 305.3            | 11.2   | 13.2   | 10.4      | 23             | 21        | 21   | 25.9 | 84.4 | 43.9 | 305.4 | 4.3 |

Source: Processed data from BMKG (2017)

3.2. Ficus glauca

During the observation period, the lowest canopy coverage of 65.7% occurred in February,
meanwhile, the highest of 89.5% occurred in October (Figure 2). In this study, we estimated
trees’ leaf-shedding percentage through trees’ canopy coverage. We assumed that when the
canopy coverage is low, the leaf-shedding percentage is high. This assumption would make the lowest canopy coverage as the peak of the leaf-shedding phase.

If observed weekly, the lowest canopy coverage occurred in the 20\textsuperscript{th} week (3\textsuperscript{rd} week of January) with a coverage of 63.2\% (Figure 3). Meanwhile, the highest canopy coverage occurred in the 11\textsuperscript{th} week (3\textsuperscript{rd} week of November) with a coverage of 93.0\%. The lowest average canopy coverage in both weekly and monthly graphs is still quite far from 0\%. But if the samples were observed individually, the lowest canopy coverage almost reached 0\% as seen on the 3\textsuperscript{rd}, 4\textsuperscript{th}, 10\textsuperscript{th}, and 18\textsuperscript{th} week. These conditions are represented with minimum values (diamond symbols) in Figure 3. These findings show that the leaf shedding was asynchronous between \textit{F. glauca} samples despite growing in a close and similar environment.

![Figure 2. Monthly average of canopy coverage in \textit{F. glauca}](image)

| n\textsuperscript{th} week | % Canopy coverage | % Leaf shedding / loss |
|-----------------------------|------------------|-----------------------|
| Sep                         | 85.4             | 72.6                  |
| Oct                         | 78.1             | 68.5                  |
| Nov                         | 72.1             | 62.1                  |
| Dec                         | 90.3             | 89.5                  |
| Jan                         | 92.3             | 89.7                  |
| Feb                         | 76.0             | 65.7                  |

![Figure 3. Weekly average canopy coverage in \textit{F. glauca}](image)

The leaf shedding period in \textit{F. glauca} individuals did not occur at the same time. This is suspected to happen because of the nature of some \textit{Ficus} species. \textit{Ficus} tend to show intra-population inter-tree asynchronous phenological phase, yet show strong intra-tree synchronous phenological phases [9]. There was an interesting finding in \textit{F. glauca}’s leaf shedding phase, the leaf flushing process occurred within one week after it shed its leaves. The photos of one leaf-shedding \textit{F. glauca} sample in a span of a week are shown in Figure 4.

\textit{F. glauca} shed their leaves more than once a year. During the observation period, there were individuals that shed their leaves twice. Each individual is suspected to shed their leaves 2-5 times a year without a fixed interval, similar to \textit{Ficus fistulosa} [10].

The summary of the significant climatic factors that affect \textit{F. glauca}’s leaf shedding is shown in Table 2. The most significant factor is the rainfall in the previous month, including the total rainfall and average daily rainfall. When the rainfall in the previous month decreases, the canopy coverage in the next month decreases as well (leaf shedding increases). Low rainfall
in the previous month causes soil humidity to decrease and drought stress to increase. It shows that *F. glauca* is not directly affected by rainfall, but soil humidity instead [11].

![Figure 4. *F. glauca* sample in leaf shedding (left) and leaf flushing (right) period](image)

Another significant climatic factor is wind velocity. If the wind velocity increases, the canopy coverage decreases (the leaf shedding occurs). When the tree is exposed to drought, the petiole weakens [12] and the wind may cause the petiole to flutter [13]. Therefore, the leaf is more vulnerable to fall.

The interaction between temperature and relative humidity (RH) also significantly affected leaf shedding in *F. glauca*. The analysis result shows that when temperature and RH increases, the canopy coverage increases (leaf shedding decreases). This might be related to the opening and closing of stomata. Stomatal opening is not directly affected by relative humidity's changes, but it is related with humidity gradient [14]. When the temperature increases, the humidity gradient will increase or becomes steeper. Steeper humidity gradient means more stomatal closing during the day. The closing of stomata is plants’ effort to increase the water efficiency and decrease the transpiration rate. This phenomenon of stomatal closing might be the cause of less leaf shedding when the temperature and relative humidity is high.

| Climatic factor          | Period        | Equation              | $R^2$ | Sig F   |
|--------------------------|---------------|-----------------------|-------|---------|
| Wind velocity            | Weekly        | $y = -6,309x + 105,390$ | 0.176 | 0.033*  |
|                          | Monthly       | $y = -15,728x + 146,336$ | 0.678 | 0.044*  |
| Total rainfall (TR)      | Previous month| $y = 0.057x + 59,797$  | 0.903 | 0.004** |
| Daily rainfall (DR)      | Previous month| $y = 1,698x + 59,322$  | 0.849 | 0.009** |
| $T (x_1)$ & RH ($x_2$)   | Weekly        | $y = 13,030x_1 + 2,056x_2 - 433,415$ | 0.244 | 0.040*  |
| TR ($x_1$) & Rainy days ($x_2$) | Previous month | $y = 0.060x_1 - 1,054x_2 + 79,974$ | 0.957 | 0.009** |
| DR ($x_1$) & Rainy days ($x_2$) | Previous month | $y = 1,909x_1 - 1,524x_2 + 87,735$ | 0.955 | 0.009** |

**Annotation:** Significant at 95% (*) and 99% (**) confidence level

### 3.3. *Terminalia catappa*

*T. catappa* samples shed their leaves during the observation period, but there was no individual that reaches leafless condition. The lowest canopy coverage occurred in January with a percentage of 83.7%, meanwhile, the highest canopy coverage occurred in September with 97.0% (Figure 4). In the weekly graph (Figure 6), the lowest canopy coverage occurred in the 19th week (2nd week of January) with a percentage of 76.8% and the highest occurred in the 1st week (1st week of September) with a percentage of 98.2%. There was no significant difference between the weekly samples’ minimum and maximum value. The highest difference is seen in the 19th week because there was an individual which canopy coverage is relatively low.
The frequency of leaf shedding in *T. catappa* in one year cannot be confirmed through this observation. According to Orwa *et al.* [15], leaf shedding usually occurs twice a year. In a subtropical location such as Florida, especially when there is a sudden rain in winter, *T. catappa* sheds its leaves synchronously so the tree becomes leafless and the leaf flushing period is following soon after that. *T. catappa* might not become leafless in the study area because it is different from its natural habitat in ocean beaches, coastal plains, or near river mouths [15].

Based on the analysis result, climatic factors that significantly affected *T. catappa*'s leaf shedding phenology are day length and the interaction between day length and solar radiation (Table 3). The canopy coverage percentage of *T. catappa* and day length has a positive correlation so when day length increases, the canopy coverage also increases. When day length decreases, the canopy coverage decreases, or it is assumed as leaf shedding increases.

Some species’ leaf shedding phase may be affected by the combination of aging leaves and the decrease of day length [16]. Another study found that in places with low fluctuation of day length, such as tropical countries, an increase in day length of 30 minutes or less may induce leaf flushing [17].

**Figure 5.** Monthly average of canopy coverage in *T. catappa*

**Figure 6.** Weekly average canopy coverage in *T. catappa*

**Table 3.** Summary of regression analysis result between significant climatic factors and leaf coverage percentage in *T. catappa*

| Climatic factor | Period       | Equation                  | R²   | Sig F  |
|-----------------|--------------|---------------------------|------|--------|
| Day length (DL) | Weekly       | $y = 0.137x + 85.245$     | 0.277| 0.006**|
|                 | Previous month| $y = 0.263x + 78.354$     | 0.706| 0.036* |
| DL ($x_1$) & Solar rad. ($x_2$) | Weekly | $y = 0.208x_1^3 - 0.026x_2^2 + 90.172$ | 0.419| 0.002**|

Annotation: Significant at 95% (*) and 99% (**) confidence level.
3.4. Cassia fistula

During the observation period, the canopy coverage kept increasing from the beginning of observation in September until January and then slowly decreasing in February (Figure 7). Due to this trend, the leaf shedding timing is still unknown, but it is suspected to occur before September. The weekly canopy coverage of C. fistula is shown in Figure 8. Judging from the minimum and maximum value, the inter-individual variation between C. fistula samples seemed to be quite low. In India, leaf flushing phase of C. fistula usually occurs from March to July and the flowering phase starts from April to July, or sometimes in October [15].

The climatic factors that significantly affecting leaf phenology of C. fistula are summarized in Table 4. Based on the analysis result, day length and the interaction between day length and solar radiation are significant factors. When day length increases, the canopy coverage decreases, and vice versa. In other words, when day length increases, C. fistula is shedding its leaves. When day length increases, air temperature tends to increase. High temperature may cause soil humidity to decrease until it becomes dry and drives the leaf shedding process. This is what might happen with C. fistula, so it sheds its leaves when day length increases.

![Figure 7. Monthly average of canopy coverage in C. fistula](image)

![Figure 8. Weekly average canopy coverage in C. fistula](image)

| Climatic factor | Period      | Equation                  | $R^2$     | Sig F    |
|-----------------|-------------|---------------------------|-----------|----------|
| Day length (DL) | Weekly      | $y = -0.325x + 101,223$   | 0.408     | 4.43x10^{-4}**|
|                 | Monthly     | $y = -0.605x + 111,684$   | 0.692     | 0.040*   |
|                 | Previous month | $y = -0.621x + 117,655$  | 0.847     | 0.009** |
| $T (x_1)$ & RH ($x_2$) | Weekly | $y = -12.876x_1 - 1.570x_2 + 554.381$ | 0.249     | 0.037*   |
| DL ($x_1$) & Solar rad. ($x_2$) | Weekly | $y = -0.459x_1 + 0.048x_2 + 91,888$ | 0.541     | 1.30x10^{-4}** |

Annotation: Significant at 95% (*) and 99% (**) confidence level
3.5. Leaf shedding phenology utilization in the landscape

Utilizing the trees leaf shedding phenology may be quite challenging since the timing of each tree might differ from each other. To create a uniform visual of the trees, we can try to modify the microclimate of the growth place. For *F. glauca*, since soil humidity is a significant factor, we should manage the water availability in the soil for each tree. Drought and flooding activity is a method to manage the water balance in the soil [18]. Drought method is to limit the amount of available water for the tree, meanwhile flooding method is to supply more water for the tree.

For *T. catappa* and *C. fistula*, which leaf phenology is most affected by day length, the duration of sun exposure and the amount of solar radiation need to be managed. One way to manage it is to alter the structure of the tree canopy by reducing the biomass of the tree with pruning, thinning, girdling, or defoliation [18]. If the canopy size is relatively uniform, the leaf phenology timing should occur in the near time.

Utilizing tropical deciduous trees in landscape designs should be done with care. Visually, the trees would look good if they are mass-planted in a row so the leaf shedding process would be able to catch people’s attentions. The trees will enhance the landscape quality by adding a temporary attraction to the site. The landscape manager should maintain the microclimate by considering the species’ significant climatic factors to adjust the leaf phenology timing.

4. Conclusion

The leaf shedding period in tropical deciduous trees are determined by different climatic factors depending on the species. *F. glauca* shed their leaves around February, then the leaf flushing phase occurred about one week after that. The climatic factor that mainly drove the leaf shedding was low rainfall in the previous month and high wind velocity at the time. For *T. catappa*, the peak leaf shedding period occurred in January when the daylength tended to decrease. On the contrary, *C. fistula* shed their leaves when the daylength tended to increase, which suspected to have occurred outside the observation period before September.

To optimally utilize the leaf shedding phenology of the trees, microclimate modification may be needed. Drought and flooding methods could help in maintaining water soil availability for *F. glauca*. As for *T. catappa* and *C. fistula*, modifying the structure of the tree canopy is necessary to manage the sun exposure received by the tree. By creating the same living environment for every tree, the leaf phenological phase timing hopefully could be easily predicted. In the landscape, these trees are better planted in a row so the leaf phenology could catch people’s attentions. Landscape managers should carefully manage the visual and the microclimate of the trees’ environment.

References

[1] Walkovich E M Cook B I and Davies T J 2014 Progress towards an interdisciplinary science of plant phenology: Building predictions across space, time and species diversity New Phytol. 201 4 p 1156–1162
[2] Haggerty B P and Mazer S J 2008 The Phenology Handbook (Santa Barbara: UCSB)
[3] Ergölu E Mösürizzoğlu H and Kesim G A 2012 The effect of seasonal change of plants compositions on visual perception J. Environ. Eng. Landsc. Manag. 20 3 p 196–205
[4] Environmental Protection Agency 2013 Climate Change Impacts on Phenology : Implications for Terrestrial Ecosystems (Wexford: EPA)
[5] Fitchett J M Grab S W and Thompson D I 2015 Plant phenology and climate change Prog. Phys. Geogr. Earth Environ. 39 4 p 460–482
[6] Cohen J M Lajeunesse M J and Rohr J R 2018 A global synthesis of animal phenological responses to climate change Nat. Clim. Chang. 8 3 p 224–228
[7] Johnstone D Moore G Tausz M and Nicolas M 2013 The measurement of plant vitality in landscape trees Arboric. J. 35 1 p 18–27
[8] Hall F C 2002 Photo Point Monitoring Handbook (Portland: U.S. Department of Agriculture)
[9] Janzen D H 1979 How to be a fig Annu. Rev. Ecol. Syst. 10 p 13–51
[10] Corlett R T 1987 The Phenology of Ficus fistulosa in Singapore Biotropica 19 2 p 122–124
[11] Yadav R K and Yadav A S 2008 Phenology of selected woody species in a tropical dry deciduous forest in Rajasthan, India Trop. Ecol. 49 1 p 25–34
[12] Tyree M T Cochard H Cruiziat T Sinclair B and Ameglio T 1993 Drought-induced leaf shedding in walnut:
evidence for vulnerability segmentation Plant, Cell Environ. 16 p 879–882
[13] Tadrist L, Julio K, Saudreau M and de Langre E 2015 Leaf flutter by torsional galloping: Experiments and model J. Fluids Struct. 56 p 1–10
[14] Hall A E and Kaufmann M R 1975 Stomatal Response to Environment with Sesamum indicum. L. Plant Physiol. 55 455–9
[15] Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S 2009 Agroforestry Database: a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)
[16] Rivera G and Borchert R 2001 Photoperiodic control of seasonal development and dormancy in tropical stem-succulent trees. Tree Physiol. 21 4 p 213–21
[17] Rivera G, Elliott S, Caldas L S, Nicolossi G, Coradin V T R and Borchert R 2002 Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain Trees 16 p 445–456
[18] Charrier G, Ngao J, Saudreau M and Améglio T 2015 Effects of environmental factors and management practices on microclimate, winter physiology, and frost resistance in trees Front. Plant Sci. 6 p 1–18