Some climatological factors of pine in the lake toba catchment area

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Abstract. The article deals with climatological factors of Pine at the Lake Toba Catchment Area also called drained basin, *Pinus merkusii* is a plant endemic in Sumatra. A central population of Pine in North Sumatra is located in the Tapanuli region to south of Lake Toba. Junghuhn discovered the species in the mountains range of Sipirok. He provisionally named the species as *Pinus sumatrana*. The article presents a detail analysis of approaches to climate factors, considers rainfall, air temperature, humidity, stemflow, throughfall and interception following calculation of regression to determine relationship between precipitation with stemflow and interception. Stemflow, it is highly significant with significance of difference between correlation coefficients and *z* normal distribution. Temperature and relative humidity are the important components in the climate. These components influence the evaporation process and rainfall in the catchment. *Pinus merkusii* has the big crown interception. Stemflow and interception has an opposite relation. Increasing of interception capacity will decrease stemflow. This type of Pine also has rough bark however significant channels so that, it flows water even during the wet season and caused the stemflow in *Pinus merkusii* relatively bigger.

1. Introduction

The genus *Pinus* is one of the most widely distributed genera of trees in the extra-tropical Northern Hemisphere [1] In the evolutionary term the genus has evolved into 105 species with two main centers of speciation which are globally recognized. These are in southeastern Eurasia and southern North America. Perhaps from these sites *Pinus* populations have migrated into the tropics. The range of extension of pines in tropical South Asia has been described by [2] and [3] Schweinfurth [4] has compiled additional information and references on the distribution of pines in South East Asia which are provided by vegetation maps of the Himalayas, China, Cambodia, Vietnam, Sumatra, and Thailand.

A central population of Pine in North Sumatra is located in the Tapanuli region to south of Lake Toba. Junghuhn discovered the species in the mountains range of Sipirok. He provisionally named the species as *Pinus sumatrana*. The herbarium material was sent to Governor Merkus who in turn passed it on to Professor de Vriese who published the first botanical description in 1845, renaming the species *Pinus merkusii* Junghuhn et de Vriese in honour of the Governor who had died in the interim [3]

An indigenous species is the one that grows naturally in a country at certain site only. With these native species, there are not political or quarantine problems to obstruct its use in a plantation program, and in fact, there are some important biological advantages [5]: Growth of natural stands provides some indication of possible performance in plantation. The species is adapted to the environment and already filling an ecological niche. This may render it less susceptible to serious
damage from diseases and pests since controlling agents (predators, viruses, and climatic factors) are already present. Indigenous species, even in monoculture, are generally considered more ecologically valuable than exotics for conservation of native flora and fauna. The timber is likely to be known to local wood-using industries.

For these reasons if an indigenous species is grown well in a plantation on the sites for afforestation, there is no compelling reason to widen the choice especially in using other introduced species [5] Buys et al. (1928) in [3] mentioned that several localities in the region from which *Pinus merkusii* has been reported, mostly in small stands, groups or even as scattered trees. The most extensive occurrence, estimated at about 1200 ha in the 1920s, is associated with two mountains, Dolok (mount) Tusam and Dolok Pardumahon. This stated region is the Dolok Saut Nature Reserve, which contains some 40 ha of *Pinus merkusii* associated with hardwood forest. Most of the reported occurrences are observed at an altitude of 1000 to 1500 m a.s.l.

Mirov [6] stated that the area around Lake Toba (1000 m a.s.l.) was once covered to a large extent by natural stands of pine as is evidenced by scattered remnants and the place name. For example Tusam for pine forest in Parapat which is in the vicinity of Girsang sampling station. In the Tapanuli region, 17,000 ha of pine are recorded but this which also includes large plantations in the vicinity of Lake Toba. No exact recent figures are available for the natural pine areas but these are probably in the order of less than 3,500 ha.

2. Research Methods
In this article the author study the typical climatological factors of Pine as an endemic plant in the catchment are of Lake Toba.

2.1. Rainfall
The data of rain days, rain months and rain year were obtained from direct measurements with rain gauges (observatory type) at some stations: Bahal Batu station (02° 08’ 893” NL; 098° 59’ 712” EL); Girsang Simpangan Bolon station (02° 39’ 044” NL; 098° 57’ 853” EL); The diameter of gauge was 20 cm. The measured rainfall is calculated based on arithmetic means follows:

\[
\frac{\sum_{i=1}^{n} R_{m,i}}{n} \text{ The monthly rainfall average at } m \text{ month from all gauges} \quad (2.1)
\]

\[
\sum_{m=1}^{12} R_{m} \text{ The yearly rainfall average as a result of sum of monthly rainfall} \quad (2.2)
\]

2.2. Air temperature
All averages for a month, season, year or even a long period of years are built upon the mean daily temperatures as the basic unit [7]. The daily mean is thus the individual brick out of which the general temperature structure is composed. In some countries this basic unit of daily temperature is derived by computing the average of temperatures observed at certain definite hours during the day, as for instance, (0700 hours + 1400 hours + 1700 hours +1700 hours)/4. The United States Weather Bureau at present uses the formula (Maximum + Minimum)/2, or, in other words, the average of the highest and the lowest temperature recorded during the 24-hr period. According to Tjasyono [8], in Indonesia the average temperatures are derived by computing the average temperatures observed at:

\[
T_{\text{avg}} = \frac{2T_{7} + T_{13} + T_{18}}{4} \quad (2.3)
\]

\[
T_{7}, T_{13}, T_{18} \text{ are observed temperature at 0700 hrs; 1300 hrs and 1800 hrs.}
\]

2.3 Humidity
The relative humidity RH is the relative of actual to saturation vapor pressure at the same temperature. In percentage terms

\[
\text{RH} = 100 \text{ ea/es} \quad (2.4)
\]
Saturation vapor pressure increases exponentially with increasing temperature [9]

\[ es = 0.61078 \exp \left(17.269 \frac{T}{T_0} + 237.30 \right) \]  
(2.5)

Where \( es \), is the saturation vapor pressure in kPa and \( T \) is temperature in °C

\[ ea = es - AP(T - Tw) \]  
(2.6)

Where \( T \) and \( Tw \) are dry and - wet bulb temperature (°C)

\( P \) is the actual vapor pressure and \( es \) is the saturation vapor pressure at \( Tw \).

\( A \) is a constant of proportionally and is slightly dependent on \( T \). \( A \), according to [10] has a value of:

\[ A = 6.6 \times 10^{-4}(1 + 1.15 \times 10^{-3} \cdot Tw) \]  
(2.7)

When the respiration rate is sufficiently rapid, say 3 – 4 ms\(^{-1}\) or more.

2.4. Factors Affecting Runoff (stemflow, throughfall and interception)

Part of the precipitation reaching a stream is evaporated or transpired. The remainder become runoff but takes many different routes over a long time span to reach a stream. The route and timing depend on character of the drainage basin and precipitation intensity. Each path affects the rate and amount of runoff in a different way.

- **Stemflow**

Some precipitation falls on the trunks of trees or stems of plants and runs to the ground. The water reaching the ground, called stemflow, which is largely dependent on the roughness of the trunks and stems. Stemflow from smooth surfaces is greater than composite the rough surfaces.

Measurement of stemflow can be done by string around stem of plastic tubing to collect water flow from the tree branch and stem, than flows to the catcher (bottle). The volume of is calculated with the equation:

\[ Sf = (Vs/L) \times 10 \]  
(2.8)

Where, \( Sf \) : Stem flow (mm)

\( Vs \) : Volume of flow (cm\(^3\))

\( L \) : Wide of crown (cm\(^2\))

10 : Conversion cm to mm

- **Throughfall**

If rain continues after the leaves can hold no more water, additional precipitation accumulates in droplets and falls to the next lower leaves. Eventually, the storage capacity of all leaves is reached and drops fall to the earth. The amount reaching the earth is called throughfall.

Measurement of throughfall can be done with gauges (in this study, place 10 observatory type gauges) under tree canopies. Volume of throughfall which is caught would be calculated with the equation

\[ Th = (Vt/A) \times 10 \]  
(2.9)

Where, \( Th \) : throughfall (mm)

\( Vt \) : volume of water catch (cm\(^3\))

\( A \) : Wide of longitudinal section (cm\(^2\))

10 : Conversion cm to mm

- **Interception**

If the ground is covered with vegetation, the first drops of precipitation striking the plant leaves are retained, spreading over the leaf surface in a thin layer. This process and the water stored are called interception [11].

Measurement of interception at canopy scale would be carrying out with the volume balance approach i.e., with measure gross rainfall, stemflow and throughfall. The procedure of this method can be done with gauges, place stemflow and throughfall equipment at sampling site of study area with specific vegetation. The interception of the site would be calculated with the equation:

\[ Ic = Pg - (Th + Sf) \]  
(2.10)

Where, \( Ic \) : canopy interception (mm)

\( Pg \) : gross precipitation (mm)
This equation should be developed to find out the total interception:

\[ \text{It} = \text{Ic} + \text{If} \]  

(2.11)

Where, If : litter interception

\[ \text{If} = \text{Pn} - \text{Pe} \]  

(2.12)

Where, Pn : net precipitation

\[ \text{Pn} = \text{Th} + \text{Sf} \]  

(2.13)

\[ \text{Pe} = \text{Th} + (\text{Sf} - \text{If}) \]  

(2.14)

- **Evaporation**

The evaporation of the study site was calculated based on the evaporation from bare land and forest area. For bare land and under canopy, the evaporation was measured by using microlysimeters (tubing with 20 cm long and 8 cm diameter). In this study 10 lysimeters were placed in each station. The lysimeter is planted to the land with a hammer up to 0.5 cm left above soil surface and filled with soil. After that the tubing was lifted up by digging the surrounding soils and cleaned for the first balanced. After balancing the tubing was closed with the plastic below and replaced to the previous hole for the second balanced. The first balancing was done at 0600 hours and the second at 1800 hours over a one-year period. Evaporation was calculated with the equation:

\[ E = (\text{Ws} - \text{Wf})/A \]  

(2.15)

Where, E : evaporation

\[ \text{Wf} : \text{first weigh (gr)} \]

\[ \text{Ws} : \text{second weigh (gr)} \]

\[ A : \text{surface wide (cm}^2\text{)} \]

2.5. **Regression model**

The independent variables are noted by \( X_1, X_2, \ldots, X_m \) on the horizontal axis and the dependent variable by Y on the vertical axis. A hat on the \( \hat{Y} \) is used when it value is estimated instead of actually measured. Regression analysis is appropriate for determining the coefficient (b’s) of any prediction equation (or model) that takes the form [12]

\[ \hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_mX_m \]  

(2.16)

3. **Results and discussion**

3.1. **Rainfall**

Rainfall is one of important components of climate in the Lake Toba catchment area. The primary data that are measured since 1999-2002 in three stations are representing in Figure 1.

![Figure 1 Monthly rainfall and rain day in Bahal Batu station (02° 08’ 893” NL; 098° 59’ 712” EL). Girsang station (02° 39’ 044” NL; 098° 57’ 853” EL). Rainfall in mm, and Rainday in day](image-url)
According to the graph of rainfall and rain day, the pattern is the same with the rain season in October to November and dry season in May to July. March to April is the transition season. The variability of rainfall is almost the same throughout the year.

3.2. Temperature and Relative humidity
Temperature and relative humidity are the important components in the climate. These components influence the evaporation process and rainfall in the catchment. The fluctuation of daily temperature and daily relative humidity are showed in Figures 3.2

Based on those figures, the fluctuation of average daily temperature was relatively stable, whereas the temperature fluctuations between day and night are distinct as shown in Bahal Batu station. This situation most probably due to the area has more open bare ground compared with others. At Rianiate area (representative for Samosir Island), the fluctuation of temperature and relative humidity are small. This is probably due to the sites are very close to the lake.

![Figure 2. Monthly temperature in Bahal Batu station (02° 08’ 893” NL; 098° 059’ 712” EL). Girsang station (02° 39’ 044” NL; 0980 57” 853” EL)](image1)

![Figure 3. Relative humidity in Bahal Batu station (02° 08’ 893” NL; 098° 059’ 712” EL). Girsang station (02° 39’ 044” NL; 098° 057” 853” EL)](image2)

3.3. Stemflow, Throughfall and Interception
Stemflow, throughfall and interception are the important component in hydrologic cycle. Although small value, however these parameters are very important in the scale of a catchment area, particularly to find out the value of water balance. In a short time interception was not important but it can influence the water yield and net precipitation in a long time. Intensive works have done at the three stations however one addition station was added during the sampling period.

- **Girsang station**

Table 1 shows that from 149 days precipitation the value of T/P varies between 78.88 to 88.31 % with an average 83.95 %, S/P 0.101 to 0.378 % and an average 0.206 to 0.259 %. I/P are varied between 11.437 to 20.810 % with an average 15.786 %. The net precipitation in this area is 84%

- **Bahal Batu station**
Table 2 shows that from 129 days precipitation, the value of T/P vary between 73.62 to 88.52 % with an average 83.81 %. S/P 0.07 to 0.519 % and average 0.237 to 0.374 %. I/P are varied between 11.908 to 36.472 % with an average 19.45 %. The net precipitation in this area is 83%. Tables 1 and 2 also show the comparison between throughfall, and interception to rainfall. From these tables the readings can be obtained indicating that the parameters of throughfall, stemflow and interception are various.

**Table 1.** The comparison between Troughfall, Stemflow and Interception to Rainfall at Girsang Station

| Months     | Rain days | Through Fall (T) (mm) | Stemflow (s) (mm) | Interception(I) (mm) | T/P (%) | S/P (%) | I/P (%) |
|------------|-----------|-----------------------|-------------------|----------------------|---------|---------|---------|
| January    | 13        | 129.28                | 110.29            | 0.405                | 0.382   | 18.588  | 18.611  | 85.31   | 0.314   | 0.296   | 14.378  | 14.396  |
| February   | 11        | 219.86                | 190.65            | 0.484                | 0.411   | 28.729  | 28.802  | 86.71   | 0.22    | 0.817   | 13.067  | 13.100  |
| March      | 12        | 291.22                | 243.06            | 0.539                | 0.561   | 47.616  | 47.594  | 83.46   | 0.185   | 0.193   | 16.351  | 16.343  |
| April      | 15        | 143.73                | 117.64            | 0.367                | 0.447   | 25.718  | 25.639  | 81.85   | 0.255   | 0.311   | 17.893  | 17.838  |
| May        | 8         | 121.96                | 97.13             | 0.147                | 0.214   | 24.681  | 24.614  | 79.64   | 0.121   | 0.176   | 20.236  | 20.182  |
| June       | 4         | 59.20                 | 47.79             | 0.067                | 0.080   | 11.339  | 11.326  | 80.73   | 0.113   | 0.135   | 19.155  | 19.132  |
| July       | 6         | 137.36                | 120.80            | 0.259                | 0.311   | 16.310  | 16.258  | 87.94   | 0.189   | 0.227   | 11.873  | 11.835  |
| August     | 8         | 95.80                 | 75.57             | 0.294                | 0.294   | 19.936  | 19.936  | 78.88   | 0.307   | 0.307   | 20.81   | 20.81   |
| September  | 14        | 337.24                | 297.83            | 0.69                 | 0.715   | 38.717  | 38.692  | 88.31   | 0.205   | 0.212   | 11.481  | 11.473  |
| October    | 27        | 278.17                | 238.48            | 0.282                | 0.697   | 39.4    | 38.98   | 85.73   | 0.101   | 0.251   | 14.164  | 14.015  |
| November   | 14        | 126.32                | 108.66            | 0.299                | 0.556   | 17.358  | 17.101  | 86.02   | 0.237   | 0.440   | 13.740  | 13.538  |
| December   | 17        | 207.70                | 172.08            | 0.467                | 0.784   | 35.151  | 34.834  | 82.85   | 0.225   | 0.378   | 16.924  | 16.770  |
| **Total**  | 149       | 2147.8               | 1819.98           | 4.301                | 5.452   | 323.543 | 322.39  | 83.95   | 0.206   | 0.259   | 15.839  | 15.786  |

The relationship between interception and stemflow to precipitation is varied; even with the same species of plant in the same location the value may be different, due to a lot of influencing factors like rainfall characteristic, variety, age and density of plant, also growth period.

Morphological characteristic of plant like stem, canopy, leaf types and plant age gave big variation to stemflow and interception. The variation of plants with different type of canopy, leaf and stem is shown in Table 3. At Bahal Batu station, stemflow it is highly significant with significance of difference between correlation coefficients and z normal distribution (two-tailed test of the normal distribution) was found z = 3.07 (z table 1.96 at level 0.05). Morphologically there is the bark different among *Pinus merkusii*

At Girsang station, for stemflow is highly significant with significant difference between correlation coefficients and z normal distribution (two-tailed test of the normal distribution) is found z = 2.570 (z table 1.96 at level 0.05).
Table 3. Relationship between precipitation with stemflow and interception.

| Station      | Relationship               | Diameter (cm) | Regression equation               | R   |
|--------------|----------------------------|---------------|-----------------------------------|-----|
| Bahal Batu   | Precipitation and          | 43            | Y = 0.003x + 0.0011               | 0.918 |
|              | Stemflow                   | 23            | Y = 0.0022x + 0.0005              | 0.937 |
|              |                            | 39            | Y = 0.0025x − 0.002              | 0.869 |
|              | Precipitation and          | 43            | Y = 0.1056x + 0.2214             | 0.794 |
|              | interception               | 23            | Y = 0.1064x + 0.223              | 0.752 |
| Girsang      | Precipitation and          | 40            | Y = 0.0031x + 0.0015             | 0.787 |
|              | Stemflow                   |               |                                   |      |
|              | Precipitation and          | 40            | Y = 0.0418x + 0.7101             | 0.422 |
|              | interception               |               |                                   |      |

The range from 0.40 – 11 canopy interception capacity. Based on this analysis, the conclusions are as follow: *Pinus merkusii* has the big crown interception. Stemflow and Interception has an opposite relation. Increasing of interception capacity will decrease stemflow. *Pinus merkusii* has rough bark however significant channels so that, it flows water even during the wet season and caused the stemflow in *Pinus merkusii* relatively bigger.

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