The Fertility Status of Soils at Rehabilitated Degraded Land in Universiti Putra Malaysia Planted with *Pinus caribaea* and *Swietenia macrophylla*

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Abstract: Soil fertility (both physical and chemical) is one of the important factors limiting plant growth. So, the fertility of the soils should be determined before growing crops and after the establishment of forest rehabilitation. A study was conducted to determine the fertility status of soils at rehabilitated degraded land in Universiti Putra Malaysia. The main objective was to compare the fertility of soils planted forest and pasture. Three sites studied were pines plantation (*Pinus caribaea*), mahogany plantation (*Swietenia macrophylla*) and pasture area. At each site, three squares of 20×20 m were selected and two depths of soil sample were collected, topsoil (0-20 cm) and subsoil (20-40 cm), from six points within the squares. The physical properties of the soils analyzed were bulk density, soil texture and moisture content, while the chemical properties were pH, total C and N, cation exchangeable capacity and exchangeable cations (Al, Ca, Mg, K and Na). The mean annual increment of height, diameter and volume of planted forest were also taken. The increment of height, diameter at breast height and volume of *P. caribaea* and *S. macrophylla* did not show any comparative difference for the cause of the similarity in the increment of patterns catalysed at the same location and climatic condition. *P. caribaea* showed higher SFI value compared to the other study plots, especially for the topsoil. In contrast, pasture plot had higher SEF, followed by *P. caribaea* and *S. macrophylla* plantation plots. *P. caribaea* showed the highest SFI value, while pasture plot had highest SEF, followed by *P. caribaea* and *S. macrophylla* plantation plots. Further study on bigger forest plantation having different types of plant species and land topography needs to be conducted to allow individuals and bodies in the field of forest plantation to gain the opportunity and implement the right approaches to establish forest plantation with good planting establishment practices.

Keywords: Soil Fertility, Degraded Land, Pastures, *Pinus caribaea*, *Swietenia macrophylla*

Introduction

Tropical rain forests are considered as the most productive of all terrestrial ecosystem and they have the climate amelioration and soil conservation properties (Blaser et al., 2011). Wood or non-wood products harvesting have created large tracts of degraded secondary forest. Nowadays, degraded forest lands are becoming predominant and important forest type in the tropical countries due to scarcity of natural forest (Heryati et al., 2011a; 2011b). Forest plantation program in Malaysia mostly involves dipterocarp species and other fast growing exotic species. Fast growing exotic species such as *Pinus caribaea* and *Swietenia*...
**Materials and Methods**

**Study Sites Description**

The study area was located in Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan (N 3° 0'2.54"and E 101° 43'19.91")). It was conducted at two plantation areas and one pasture area. Formerly, two areas were under pasture but 20 years ago they were turned into forest by planting *P. caribaea* and *S. macrophylla*. The third area remained under pasture, especially for soil nutrient conservation. Rehabilitation activities may involve re-establishment of intact canopy as found in undisturbed forest. It not only improves the forest structure itself, but may also improve the functional aspect of the forest, including the soil fertility, nutrient cycle and production of organic matter so as to ensure forest ecosystem stability. Normally, the vegetation in a disturbed area will be able to recover naturally through succession process and the area naturally can replace itself with either the same species or other species. Commonly, the fast growing trees will take over the area. In Universiti Putra Malaysia (UPM), Malaysia, there are vast areas cultivated with agricultural crops and also with forest trees. *Pinus caribaea* and *Swietenia macrophylla* are the two selected forest tree species planted in UPM, as ornamental and also for educational purposes. Same goes to pasture land in UPM. The pasture was established for cattle production and research purposes. However, there is a lack of published information on the current fertility status of the soils at the mentioned areas. To fill the research gap with regard to soil fertility and growth status, this research was carried out to determine soil fertility status of rehabilitated degraded land under *P. caribaea* and *S. Macrophylla* using Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF). Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF) were developed by Lu et al. (2002). This study was also carried out to compare the fertility of soils and growth performance between *P. caribaea* and *S. macrophylla* planted in the rehabilitated degraded land.
form aids in avoiding direct or faster respiration and to maintain its humidity. *P. caribaea* can be found in Central American and the Caribbean. It is also widely planted for rehabilitation and industrial purposes for pulp and paper production in the North America, Asian countries and African tropical regions. Waterloo *et al.* (2007) summarized that the rapid and faster growth of *P. caribaea* is one of the predisposing factors that makes it to be chosen for planting on degraded land.

*S. macrophylla* (Family: Dipterocarpaceae), locally known as mahogany in Malaysia, is a tropical tree that can be found scattered in tropical forests around the world, especially in South America and Southeast Asia (Lo, 1985). The bark of *S. macrophylla* is usually reddish brown in colour and the complexion will get darker and darker over time and it is able to achieve faster growth and produce a wide spread crown (Kamal *et al.*, 2010). These trees grow well on well-drained soils regardless of high or low elevated areas (Kamal *et al.*, 2010). These tree species are logged for the production of furniture, boat construction and musical instruments. As a leading agriculture-based research institution in Malaysia, UPM possesses large farms of livestock and domestic animals for production, education and research purposes. Pasture area in UPM is an open space where the ground is fully covered with grass. Over grazing by livestock (like sheep, cow and goat) is a major threat that would lead to soil degradation.

**Soil Sampling**

At each sites, three squares of 20×20 were established. Soil samples were collected from the topsoil layer (0-20 cm) and subsoil layer (20-40 cm) from six points randomly at each plot. After the roots and dead plant were removed, the six samples were mixed together to make one composite sample. The soil were air-dried and crushed to pass through a sieve with 2 mm mesh. All the samples were analyzed according to the standard methods.

**Soil Analyses**

Soil texture (sand, silt and clay) was determined by the universal pipette method as described by Gupta (2007). Bulk density of the soil was determined using undisturbed core ring technique (Gupta, 2007). Gravimetric method was used to quantify the amount of available moisture in each soil sample (Gupta, 2007; Karam *et al.*, 2011). Soil pH was determined in water pH (H2O) using a glass electrode in a soil to solution of 1:5 (Abdu *et al.*, 2011; Saga *et al.*, 2010; Karam *et al.*, 2012). Total carbon and nitrogen were determined by dry combustion technique CN analyser. Exchangeable bases (Ca, Mg, Na and K) were extracted using 1M ammonium acetate (NH4OAc) adjusted to pH 7 (Ahmadpour *et al.*, 2010). Exchangeable bases in the extracts were determined by Atomic Absorption Spectrophotometer (AAS). The same sample that was used for extracting exchangeable bases was leached again using ethanol (Akbar *et al.*, 2010; Arifin *et al.*, 2012). The cation exchange capacity was then determined by titration method.

Soil Fertility Index (SFI) (Equation 1) and Soil Evaluation Factor (SEF) (Equation 2) formula by Lu *et al.* (2002) used to evaluate the fertility status of the soils in the study plots were as follows:

\[ \text{SFI} = \text{pH} + \text{Organic matter (\% dry soil basis)} + \text{Available P (mg kg}^{-1}\text{dry soil)} + \text{Exchg. K (cmol kg}^{-1}) + \text{Exchg.Ca (cmol kg}^{-1}) + \text{Exchg.Mg (cmol kg}^{-1}) \]

\[ \text{SEF} = (\text{Exch. Ca (cmol kg}^{-1}\text{, dry soil)} + \text{Exch. Mg (cmol kg}^{-1}\text{, dry soil)} + \text{Exch. K (cmol kg}^{-1}\text{, dry soil)}) - \log(1 + \text{Exch. Al (cmol kg}^{-1}\text{, dry soil)}) \times \text{organic matter (\%, dry soil basis)} + 5 \]

**Growth Parameter Analyses**

The height and Diameter at Breast Height (DBH) of trees at all study plots were measured using Haaga Altimeter and diameter tape. The volume of each tree in the study plots was calculated using the following formula:

\[ \text{Volume, } V = \frac{\pi \times (\text{dbh})^2 \times (h)(0.65)}{(4)(10,000)} \]

**Statistical Analyses**

Mean values between study plots (P1, P2 and P3) were compared using One Way Analysis of Variance (ANOVA) and post-hoc test was performed using Duncan Multiple Range Test. The data were analysed using SPSS ver. 16.0 software package.

**Results and Discussion**

**Soil Physical and Chemical Properties**

Table 1 show the physical and chemical properties of soils in the *P. caribaea*, *S. macrophylla* and pasture plots. The texture of the top- and subsoil under planted forest showed no significant differences in terms of clay, silt and sand content. Likewise, the bulk density of the soils in the *P. caribaea* and pasture plots showed no significant differences (p>0.05). In contrast, the topsoil of *S. macrophylla* plots possessed lower bulk density (p<0.05) compared to the other plots. The pasture plot had higher (p<0.05) moisture content compared to that of *S. macrophylla* and *P. caribaea* plots for both soil depths.
The soils at the three experimental sites were slightly acidic with pH ranging from 4.12 to 5.09 in the topsoil and 4.27 to 4.92 in the subsoil. The acid nature of the soils was due to the loss of bases through plant uptake and leaching (Brunet et al., 1996; Wonisch et al., 2008; Lee et al., 2009). Organic matter was found to be significantly higher (p<0.05) in pasture compared to that in S. macrophylla and P. Caribaea plots. This is maybe due to cow dung in pasture area which contribute to high organic matter as it is high in organic materials and nutrients. P. caribaeas plots showed significantly higher (p<0.05) level of total carbon at both soil depths compared to the other study plots. Total nitrogen was also comparatively higher (p<0.05) in P. caribaeas plot compared to that of pasture and S. macrophylla plots for both soil depths. The C/N ratio of < 20 was indicative of high mineralization rate (Arifin et al., 2012). Exchangeable Ca and Mg were significantly higher (p<0.05) in the topsoil of P. caribaeas compared to the other plots. Exchangeable K

### Table 1. Physico-chemical properties of the soils under P. Caribaea and S. macrophylla plantations and adjacent pasture in Universiti Putra Malaysia

| Parameters          | P. caribaea | S. macrophylla | Pasture |
|---------------------|-------------|----------------|---------|
| Moisture content (%)| 20.4±0.58   | 25.90±0.41     | 32.80±0.58 |
| Sand (%)            | 29.00±1.15  | 33.50±1.15     | 46.30±1.15 |
| Organic matter (%)  | 6.50±0.50   | 4.60±0.45      | 6.80±0.52 |
| Bulk density (g cm⁻³) | 2.27±0.01  | 1.49±0.01      | 2.14±0.01 |
| C/N ratio           | 1.29±2.00   | 0.63±1.77      | 0.91±1.00 |
| Exch. Ca (cmol.kg⁻¹ in soil) | 2.24±0.13 | 0.15±0.04      | 0.38±0.07 |
| Exch. Mg (cmol.kg⁻¹ in soil)  | 0.23±0.01  | 0.02±0.00      | 0.04±0.05 |
| Exch. K (cmol.kg⁻¹ in soil) | 0.21±0.01  | 0.10±0.01      | 0.14±0.00 |
| Exch. Al (cmol.kg⁻¹ in soil) | 3.00±0.05 | 3.87±0.11      | 3.95±0.03 |
| Available P (mg P kg⁻¹) | 1.79±0.15  | 1.45±0.26      | 1.05±0.21 |

### Subsoil (20-40 cm)

| Parameters          | P. caribaea | S. macrophylla | Pasture |
|---------------------|-------------|----------------|---------|
| Moisture content (%)| 25.5±1.12  | 23.7±0.58      | 31.1±0.58 |
| Sand (%)            | 26.0±1.11  | 36.5±0.16      | 45.0±1.12 |
| Bulk density (g cm⁻³) | 2.61±0.02  | 1.73±0.03      | 1.93±0.01 |
| C/N ratio           | 1.39±1.00  | 0.96±2.04      | 0.93±4.00 |
| Exch. Ca (cmol.kg⁻¹ in soil) | 0.46±0.03 | 0.12±0.01      | 0.26±0.00 |
| Exch. Mg (cmol.kg⁻¹ in soil)  | 0.05±0.00 | 0.03±0.00      | 0.03±0.01 |
| Exch. K (cmol.kg⁻¹ in soil) | 0.11±0.00 | 0.10±0.00      | 0.70±0.12 |
| Exch. Al (cmol.kg⁻¹ in soil) | 3.05±0.07 | 2.64±0.03      | 2.85±0.06 |
| Available P (mg P kg⁻¹) | 1.63±0.12  | 1.20±0.04      | 1.05±0.04 |

**Note:** Mean with different letter indicate significant difference at p<0.05 between plots at the same soil depth as determined using Duncan Multiple Range Test (DMRT). Total Carbon (TC); Total Nitrogen (TN); Cation Exchange Capacity (CEC); ECEC, Exch. K + Ca + Mg + Na + Al; Al saturation, (Exch. Al/ECEC)×100
was also higher in *P. caribaea* plots. For the subsoil, exchangeable Ca, Mg, Na and Al showed no significant differences \((p<0.05)\) between each plots. Only exchangeable K was found to be comparatively higher \((p<0.05)\) in pasture plots compared to *P. caribaea*. Aluminium saturation was found to be higher in the *S. macrophylla* and pasture compared to *P. caribaea* plots. Cation exchange capacity and effective cation exchange capacity of the soils were low. This is consistent with the findings of Shamshuddin and Fauziah (2010) that states most of soils in Malaysia have low CEC. Low CEC indicates that soils have low capacity to hold basic cations such as Ca, Mg and K.

**Growth Performance of Pinus Caribaea and Swietenia Macrophylla**

The growth performance of *P. caribaea* and *S. macrophylla* are summarized in Table 2. Results showed that there were no comparative differences detected between the height, diameter at breast height and volume of the trees in *P. caribaea* and *S. Macrophylla* plots. The two plantations were established near each other using the same silviculture technique. No fertilizer was applied on the soils of both plantations. This is believed to be the contributing factor for the no significant difference between the two plots. Mean Annual Increment for Height (MAIH), diameter at breast height (MAID) and volume (MAIV) showed no significant differences. Climatic condition which is hot and humid also contributes to the similarity in growth performance (Table 3).

Table 2. Height, DBH and volume of *Pinus caribaea* and *Swietenia macrophylla* in Universiti Putra Malaysia

| Species                  | Height (m)  | DBH (cm) | Volume (m³) |
|--------------------------|-------------|----------|-------------|
| *Pinus caribaea*         | 23.06±0.89  | 30.93±1.32 | 1.17±0.05   |
| *Swietenia macrophylla*  | 23.42±0.95  | 30.10±1.56 | 1.18±0.08   |

Note: Different letters within same column indicate significance different at \(p<0.05\) following Duncan Multiple Range Test (DMRT)

Table 3. Mean annual increment in height, diameter and in volume of the *P. caribaea* and *S. macrophylla* in Universiti Putra Malaysia

| Species                  | MAIH (m)   | MAID (cm) | MAIV (m³) |
|--------------------------|------------|-----------|-----------|
| *Pinus caribaea*         | 1.15±0.08  | 1.55±0.03 | 0.06±0.01 |
| *Swietenia macrophylla*  | 1.17±0.05  | 1.51±0.07 | 0.05±0.01 |

Note: Different letters within same column indicate significance different at \(p<0.05\) following Duncan Multiple Range Test (DMRT), Mean Annual Increment in Height (MAIH); Mean Annual Increment in Diameter (MAID); Mean Annual Increment in Volume (MAIV)

Table 4. The soil fertility index and soil evaluation factor of soils at *P. caribaea* and *S. macrophylla* plantations and pasture plots in Universiti Putra Malaysia

| Index                     | Depth (cm) | *P. caribaea* | *S. macrophylla* | Pasture |
|---------------------------|------------|---------------|------------------|--------|
| Soil Fertility Index (SFI) | 0-20       | 12.09         | 7.54             | 8.68   |
|                           | 20-40      | 7.37          | 7.22             | 8.18   |
| Soil Evaluation Factor (SEF) | 0-20   | 4.72          | 4.63             | 5.49   |
|                           | 20-40      | 4.54          | 4.80             | 5.54   |

Note: Different letters within same column indicate significance different at \(p<0.05\) following Duncan Multiple Range Test (DMRT), Mean Annual Increment in Height (MAIH); Mean Annual Increment in Diameter (MAID); Mean Annual Increment in Volume (MAIV)
Conclusion

The current studies implemented the use of soil quality index or indicator to evaluate the current soil fertility in the plantation of tropical regions. The increment of height, diameter at breast height and volume of *P. caribaea* and *S. macrophylla* did not show comparative differences for the cause of the similarity in increment patterns catalysed at the same location and climatic condition. *P. caribaea* showed the highest SFI value compared to the other study plots especially on the topsoil. In contrast, pasture plot had higher SEF followed by *P. caribaea* and *S. macrophylla* plantation plots.

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Author’s Contributions

Mohammad Nazrin Abdul Malik: Involved in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

Arifin Abdu: Involved in all experiments and editing of the manuscript.

Daljit Singh Karam: Involved in data analysis and technical help.

Shamshuddin Jusop: Involved in proofreading of the manuscript.

Hazandy Abdul Hamid: Involved in translation assistance and labatory manuscript.

Aiza Shalilha Jamaluddin: Involved in laboratory analysis and field work.

MohdHadi Akbar Basri: Involved in sample collection in the field work.

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Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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