American Journal of Applied Sciences

Original Research Paper

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

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Article history
Received: 12-01-2015
Revised: 05-05-2015
Accepted: 14-10-2015

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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 caribea*, *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* *macrophylla* have been planted to rehabilitate degraded lands in Universiti Putra Malaysia for over 20 years. However, fundamental information on soil fertility status under rehabilitated of degraded land in the university is still limited or even lacking.

Soil is a vital element for plant growth. Soil effects on plant growth operate through aeration, soil compaction, relation and soil temperature (Karam *et al.*, 2011; 2012; Arifin *et al.*, 2012). Soils are composed of solid particles that have spaces between them. Soil texture has major effect on the physical, chemical and biological properties of soil (Bird *et al.*, 2000; Alfaro, 2008; Chodak and Niklińska, 2010). Clay soils absorb and retain much more water than sandy soils, but are typically poorly drained and not well aerated. In the forest, soil is the source of nutrients essential to the successful growth of plant species (Guerrero *et al.*, 2001; Zimmerman *et al.*, 2002). Furthermore, soil helps in maintaining forest productivity because it is the site of biological and biochemical processes for nutrient cycling (Aiko *et al.*, 2000; Compton *et al.*, 2004; Zheng *et al.*, 2005). It is a complex biodiversity environment because in order for soil to function well, integration between physical, chemical and biological properties is essential in maintaining soil quality and sustaining forest productivity (Villar *et al.*, 2004; Susyan *et al.*, 2011).

Incorporation of pastoral or farm animals namely cow, sheep and goat in planted grassland known as silvipastoral is an important approach in agro forestry systems. Ainsworth *et al.* (2012) described that silvipastoral systems should have pastures with a number of trees, fodder banks, crops and live fences. In agriculture area or land, pasture is established mainly for dairy and meat production. Usually, well managed pasture land includes planting of quality grass in sufficient amount for cattle consumption. Usage of pasture for animal grazing must meet production needs and profits, without neglecting the importance of soil nutrients conservation. In the tropics, many pasture land are regarded as low quality and tensed environmental condition (van Houtert and Sykes, 1999). McIvor and Monypenny (1995) who carried out assessment of pasture management in Australia stated that performance of the animal is highly dependent on the quality and quantity of the pasture. Size of the tropical forest area opened for pasture increases each progressive year to ensure food security for increasing human population. Aide *et al.* (1995) stated that abandoned land eventually turns into permanent forest if no appropriate agriculture or forest treatments are given. The amount of woody trees species is extremely low in pasture land and it takes approximately 15 years to establish decent biomass (Aide *et al.*, 1995). Proper management of pasture land will ensure continuous growth and production of dairy and meet supplies for human needs and also in maintaining and sustaining the environmental quality of the pasture, especially for soil nutrient conservation.

Rehabilitation is a process of restoring or replacing some forms of vegetation cover usually tree cover to an area of land to improve its natural productivity, natural environment and aesthetic values (Arifin *et al.*, 2007; 2008). 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.

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*, while the third area remained under pasture. The annual mean temperature and rainfall at the sites is 27°C and 2,201 mm, respectively.

P. caribaea (Family: Pinaceae) is a tree species that is able to grow up to 45 m tall and achieves 1 meter diameter in size. The key features of the tree are its conical crown and needle type leaves. The barks of *P. caribaea* are dark in colour and possess fissure texture. The leaves of *P. caribaea* which are in needle shape form aids in avoiding direct or faster respiration and to maintain its humidity. *P. caribaea* can be found in Central American and the Carribean. 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 (H_2O) 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 (NH_4OAc) 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 cationex change 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:

$$\begin{aligned}\text{SFI} &= \text{pH} + \text{Organic matter}\left(\%\ \text{dry soil basis}\right)\\ &+\text{Available P (mg kg}^{-1}\text{dry soil)} + \text{Exchg. K (cmol}_c\text{kg}^{-1})\\ &+\text{Exchg.Ca (cmol}_c\text{kg}^{-1}) + \text{Exchg.Mg (cmol}_c\text{kg}^{-1})\\ &-\text{Exchg. Al (cmol}_c\text{kg}^{-1})\end{aligned} \tag{1}$$

$$\begin{aligned}\text{SEF} = &\ \{\text{Exch. Ca (cmol}_c\text{kg}^{-1},\ \text{dry soil)}\\ &+\text{Exch. Mg (cmol}_c\text{kg}^{-1},\ \text{dry soil)}\\ &+\text{Exch. K (cmol}_c\text{kg}^{-1},\ \text{dry soil)}\\ &-\log\left[1 + \text{Exch. Al (cmol}_c\text{kg}^{-1},\ \text{dry soil)}\right]\}\\ &\text{x organic matter}\left(\%,\ \text{dry soil basis}\right) + 5\end{aligned} \tag{2}$$

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:

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

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.

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

Parameters	Topsoil (0-20 cm) *P. caribaea*	*S. macrophylla*	Pasture
Clay (%)	44.50±1.15^{ns}	31.80±1.15^{ns}	33.50±1.73^{ns}
Silt (%)	26.50±1.15^{ns}	34.70±1.15^{ns}	22.90±1.15^{ns}
Sand (%)	29.00±1.15^{ns}	33.50±1.15^{ns}	43.60 ±1.15^{ns}
Bulk density (g cm^{-3})	2.27±0.01^{a}	1.49±0.01^{b}	2.14±0.01^{a}
Moisture content (%)	21.70±0.58^{c}	25.90±0.41^{b}	32.80±0.58^{a}
pH (H_2O)	4.120±5.09^{c}	5.09±0.01^{a}	4.72±0.01^{b}
Organic matter (%)	6.50±0.50^{a}	4.60±0.45^{b}	6.80±0.52^{c}
Total carbon (g kg^{-1} in soil)	2.70±0.12^{a}	0.95±0.01^{c}	1.55±0.12^{b}
Total nitrogen (g kg^{-1} in soil)	2.09±0.06^{a}	1.52 ±0.06^{b}	1.71±0.12^{b}
C/N ratio	1.29±2.00^{ns}	0.63±0.17^{ns}	0.91±1.00^{ns}
Exch. Ca (cmol$_c$ kg^{-1} in soil)	2.24±0.13^{a}	0.15±0.04^{b}	0.38±0.07^{b}
Exch. Mg (cmol$_c$ kg^{-1} in soil)	0.23±0.01^{a}	0.02±0.00^{b}	0.04±0.05^{b}
Exch. K (cmol$_c$ kg^{-1} in soil)	0.21±0.01^{a}	0.10±0.01^{b}	0.14±0.00^{ab}
Exch. Na (cmol$_c$ kg^{-1} in soil)	0.04±0.00^{ns}	0.05±0.00^{ns}	0.04±0.00^{ns}
Exch. Al (cmol$_c$ kg^{-1} in soil)	3.00±0.05^{ns}	3.87±0.11^{ns}	3.95±0.03^{ns}
CEC (cmol$_c$ kg^{-1} in soil)	12.51±0.09^{a}	8.83±0.12^{ab}	6.02±0.06^{b}
ECEC (cmol$_c$ kg^{-1} in soil)	5.72±0.20^{a}	4.19±0.16^{b}	4.55±0.15^{ab}
Available P (mg P kg^{-1})	1.79±0.15^{b}	1.45±0.26^{ab}	1.05±0.21^{a}
Aluminium saturation (%)	52.30±0.12^{a}	91.90±0.24^{b}	87.30±0.15^{b}
Subsoil (20-40 cm)			
Clay (%)	40.4±1.12^{ns}	37.7±1.15^{ns}	34.3±1.14^{ns}
Silt (%)	33.6±1.10^{ns}	25.5±1.12^{ns}	20.7±1.14^{ns}
Sand (%)	26.0±1.11^{ns}	36.8±1.16^{ns}	45.0±1.12^{ns}
Bulk density (g cm^{-3})	2.61±0.02^{a}	1.73±0.03^{b}	1.93±0.01^{b}
Moisture content (%)	20.4±0.58	23.7±0.58	31.1±0.58
pH (H_2O)	4.27±0.02^{c}	4.92±0.12^{a}	4.63±0.13^{b}
Organic matter (%)	4.35±0.66^{a}	3.70±0.58^{b}	4.50±0.68^{c}
Total carbon (g kg^{-1} in soil)	1.73±0.01^{a}	0.83±0.02^{b}	0.78±0.12^{b}
Total nitrogen (g kg^{-1} in soil)	1.23±0.01^{a}	0.86±0.01^{b}	0.84±0.03^{b}
C/N ratio	1.39±1.00^{ns}	0.96±2.00^{ns}	0.93±4.00^{ns}
Exch. Ca (cmol$_c$ kg^{-1} in soil)	0.46±0.03^{ns}	0.12±0.01^{ns}	0.26±0.00^{ns}
Exch. Mg (cmol$_c$ kg^{-1} in soil)	0.05±0.00^{ns}	0.03±0.00^{ns}	0.03±0.01^{ns}
Exch. K (cmol$_c$ kg^{-1} in soil)	0.11±0.00^{a}	0.10±0.00^{a}	0.70±0.12^{b}
Exch. Na (cmol$_c$ kg^{-1} in soil)	0.04±0.00^{ns}	0.04±0.00^{ns}	0.03±0.00^{ns}
Exch. Al (cmol$_c$kg^{-1} in soil)	3.05±0.07^{ns}	2.64±0.03^{ns}	2.85±0.06^{ns}
CEC (cmol$_c$ kg^{-1} in soil)	9.27±0.12^{a}	6.73±0.09^{ab}	5.43±0.013^{b}
ECEC (cmol$_c$ kg^{-1} in soil)	3.72±0.10^{a}	2.95±0.04^{b}	3.84±0.19^{ab}
Available P (mg P kg^{-1})	1.18±0.13^{b}	0.99±0.11^{ab}	0.91±0.08^{a}
Aluminium saturation (%)	81.9±1.25^{ns}	89.5±0.98^{ns}	74.1±0.14^{ns}

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

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. caribaea* 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. caribaea* 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. caribaea* compared to the other plots. Exchangeable K 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).

Evaluation of Soil Fertility Status

Table 4 shows the value of Soil Fertility Index (SFI) between study plot at topsoil and subsoil. *P. caribaea* plantation plot possessed the highest value of SFI followed by pasture plot and *S. macrophylla* plot for topsoil and subsoil layers. The Soil Evaluation Factor (SEF) values were also found to be higher in *P. caribaea* plots compared to *S. macrophylla* and pasture plots at topsoil. In contrast, pasture plot showed higher SEF followed by *S. macrophylla* and *P. caribaea* for subsoil. Higher fertility index possessed by *P. caribaea* plantation compared to the other plantation could be due to higher amount of cation exchange capacity. Higher cation capacity is very important in terms of retaining nutrients for *P. caribaea* uptake. Ratio of TC/TN also showed higher rate for *P. caribaea* followed by S. *macrophylla* and pasture which showed that the rate of nutrient mineralization is higher. This allows nutrient in organic matter to be synthesize in the form that wold be made available for *P. caribaea* uptake. As for pasture, the soil evaluation factor value seem to be higher in the 20-40 cm depths compared to the above layer where this phenomenon could be enhanced by leaching of nutrients to lower part of the soil. Less ground covered triggers faster rates of surface run-off and leaching down the soil profile. This phenomenon requires land manager to ensure proper management of forest plantation and pasture being carried out in ensuring the soil quality are not loss continuously. Conservation of soil will allow the area to be fertile for a long-term period and give a promising production and profit regardless of forest plantation or even pasture.

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

Species	Height (m)	DBH (cm)	Volume (m^3)
Pinus caribaea	23.06a±0.89	30.93a±1.32	1.17a±0.05
Swietenia macrophylla	23.42a±0.95	30.10a±1.56	1.18a±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 (m^3)
Pinus caribaea	1.15a±0.08	1.55a±0.03	0.06a±0.01
Swietenia macrophylla	1.17a±0.05	1.51a±0.07	0.05a±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.

Acknowledgement

This work was financially supported by The Fundamental Research Grant Scheme from the Ministry of Higher Education (MOHE), Malaysia through Universiti Putra Malaysia. We thank Mdm. Zarina Abdul Rahman and Mr. Ariffin Abu Hassan for their contributions and support in this research project.

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.

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Aiza Shaliha Jamaluddin: Involved in laboratory analysis and 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.

References

Abdu, A., N. Aderis, H. Abdul-Hamid, S. Jusop and D.S. Karam *et al*., 2011. Using *Orthosiphon stamineus* B. for phytoremediation of heavy metals in soils amended with sewage sludge. Am. J. Applied Sci., 8: 323-331. DOI: 10.3844/ajassp.2011.323.331

Ahmadpour, P., A.M. Nawi, A. Abdu, H. Abdul-Hamid and D.K. Singh *et al*., 2010. Uptake of heavy metals by *Jatropha curcas* L. planted in soils containing sewage sludge. Am. J. Applied Sci., 7: 1291-1299. DOI: 10.3844/ajassp.2010.1291.1299

Aide, T.M., J.K. Zimmerman, L. Herrera, M. Rosario and M. Serrano, 1995. Forest recovery in abandoned tropical pastures in Puerto Rico. Forest Ecol. Manage., 77: 77-86. DOI: 10.1016/0378-1127(95)03576-V

Aiko, S., H. Väre and R. Strömmer, 2000. Soil microbical activity and biomass in the primary succession of a dry health forest. Soil Biol. Biochem., 32: 1091-1100. DOI: 10.1016/S0038-0717(00)00019-5

Ainsworth, J.A.W., S.R. Moe and C. Skarpe, 2012. Pasture shade and farm management effects on cow productivity in the tropics. Agric. Ecosyst. Environ., 155: 105-110. DOI: 10.1016/j.agee.2012.04.005

Akbar, M.H., A.S. Jamaluddin, N.M.N.A. Majid, H. Abdul-Hamid and S. Jusop *et al*., 2010. Differences in soil physical and chemical properties of rehabilitated and secondary forests. Am. J. Applied Sci., 7: 1200-1209. DOI: 10.3844/ajassp.2010.1200.1209

Alfaro, S.C., 2008. Influence of soil texture on the binding energies of fine mineral dust particles potentially released by wind erosion. Geomorphology, 93: 157-167. DOI: 10.1016/j.geomorph.2007.02.012

Arifin, A., D.S. Karam, J. Shamshuddin, N.M. Majid and O. Radziah *et al*., 2012. Proposing a suitable soil quality index for natural, secondary and rehabilitated tropical forests in Malaysia. Afr. J. Biotechnol., 11: 3297-3309. DOI: 10.5897/AJB11.2903

Arifin, A., S. Tanaka, S. Jusop, N.M. Majid and Z. Ibrahim *et al*., 2008. Rehabilitation of degraded tropical rainforest in peninsular Malaysia with a multi-storied plantation technique of indigenous dipterocarp species. J. Forest Environ., 50: 141-152.

Arifin, A., S. Tanaka, S. Jusop, Z. Ibrahim and D. Hattori *et al*., 2007. Soil characteristics under rehabilitation of degraded forestland in perak, peninsular Malaysia. J. Appl. Sci., 51: 76-88. DOI: 10.3923/jas.2008.3795.3805

Bird, M.I., E.M. Veenendaal, C. Moyo, J. Lloyd and P. Frost, 2000. Effect of fire and soil texture on soil carbon in a sub-humid savanna ((Matopos, Zimbabwe). Geoderma, 94: 71-90. DOI: 10.1016/S0016-7061(99)00084-1

Blaser, J., A. Sarre, D. Poore and G. Johnson, 2011. Status of Tropical Forest Management 2011. 1st Edn., ITTO, Yokohama, ISBN-10: 4902045788, pp: 418.

Brunet, J., V. Falkengren-Grerup and G. Tyler, 1996. Herb layer vegetation of south Swedish beech and oak forests-effects of management and soil acidity during one decade. Forest Ecol. Manage., 88: 259-727. DOI: 10.1016/S0378-1127(96)03845-5

Chodak, M. and M. Niklińska, 2010. Effect of texture and tree species on microbial properties of mine soils. Appl. Soil Ecol., 46: 268-275. DOI: 10.1016/j.apsoil.2010.08.002

Compton, J.E., L.S. Watrud, L.A. Porteous and S. DeGrood, 2004. Response of soil microbial biomass and community composition to chronic nitrogen additions at Harvard forest. Forest Ecol. Manage., 196: 143-158. DOI: 10.1016/j.foreco.2004.03.017

Guerrero, C., I. Gómez, R. Moral, J. Mataix-Solera and J. Mataix-Beneyto *et al*., 2001. Reclamation of a burned forest soil with municipal waste compost: Macronutrient dynamic and improved vegetation cover recovery. Bioresou. Technol., 76: 221-227. DOI: 10.1016/s0960-8524(00)00125-5

Gupta, P.K., 2007. Soil, Plant, Water and Fertilizer Analysis. 2nd Edn., Agrobios (India), Jodhpur, ISBN-10: 8177543067, pp: 366.

Heryati, Y., D. Belawan, A. Abdu, M.N. Mahat and H. Abdul-Hamid *et al*., 2011a. Growth performance and biomass accumulation of a Khaya ivorensis plantation in three soil series of Ultisols. Am. J. Agric. Biol. Sci., 6: 33-44. DOI: 10.3844/ajabssp.2011.33.44

Heryati, Y., A. Abdu, M.N. Mahat, H. Abdul-Hamid and S. Jusop *et al*., 2011b. Assessing forest plantation productivity of exotic and indigenous species on degraded secondary forests. Am. J. Agric. Biol. Sci., 6: 209-213. DOI: 10.3844/ajabssp.2011.201.208

Kamal, I., K. Masseat, K.M. Poh, T.Y. Eng and S. Basir *et al*., 2010. Physical and mechanical assessments of fire retardant-treated *Shorea macrophylla* and *Acacia mangium* particleboards. Modern Applied Sci., 4: 3-8. DOI: 10.5539/mas.v4n7p3

Karam, D.S., A. Abdu, O. Radziah, J. Shamshuddin and N.M. Majid *et al*., 2011. Am. J. Applied Sci., 8: 854-859. DOI: 10.3844/ajassp.2011.854.859

Karam, D.S., A. Arifin, O. Radziah, J. Shamshuddin and N.M. Majid *et al*., 2012. Impact of long-term forest enrichment planting on the biological status of soil in a deforested dipterocarp forest in perak, Malaysia. Sci. World J., 2012: 1-8. DOI: 10.1100/2012/641346

Lee, S.B., C.H. Lee, K.Y. Jung, K.D. Park and D. Lee *et al*., 2009. Changes of soil organic carbon and its fractions in relation to soil physical properties in a long-term fertilized paddy. Soil Tillage Res., 104: 227-232. DOI: 10.1016/j.still.2009.02.007

Lo, Y.N., 1985. Root initiation of *Shorea macrophylla* cuttings: Effects of node position, growth regulators and misting regime. Forest Ecol. Manage., 12: 43-52. DOI: 10.1016/0378-1127(85)90135-5

Lu, D., E. Moran and P. Mausel, 2002. Linking amazonian secondary succession forest growth to soil properties. Land Degradat. Soil Develop., 13, 331-343. DOI: 10.1002/ldr.516

McIvor, J.G. and R. Monypenny, 1995. Evaluation of pasture management systems for beef production in the semi-arid tropics: Model development. Agric. Syst., 49: 45-67. DOI: 10.1016/0308-521X(94)00031-L

Saga, B.T., O.H. Ahmed, A.S. Jamaluddin, H. Abdul-Hamid and S. Jusop *et al*., 2010. Selected soil morphological, mineralogical and sesquioxide properties of rehabilitated and secondary forests. Am. J. Environ. Sci., 6: 389-394. DOI: 10.3844/ajessp.2010.389.394

Shamshuddin, J. and C.I. Fauziah, 2010. Weathered Tropical Soils: The Ultisols and Oxisols. 1st Edn., Universiti Putra Malaysia Press, Malaysia, ISBN-10: 9789673441464, pp: 147.

Susyan, E.A., S. Wirth, N.D. Ananyera and E.V. Stolnika, 2011. Forest succession on abandoned arable soils in European Russia-impacts on microbial biomass, fungal-bacterial ratio and basal CO_2 respiration activity. Eur. J. Soil Biol., 47: 169-174. DOI: 10.1016/j.ejsobi.2011.04.002

van Houtert, M.F.J. and A.R. Sykes, 1999. Enhancing the profitability of pasture-based dairy production in the humid tropics through improved nutrition. Preventive Vet. Med., 38: 147-157. PMID: 10081794

Villar, M.C., V. Petrikova, M. Díaz-Raviña and T. Carballas, 2004. Changes in soil microbial biomass and aggregate stability following burning and soil rehabilitation. Geoderma, 122: 73-82. DOI: 10.1016/j.geoderma.2003.12.005

Waterloo, M.J., J. Schellekens, L.A. Bruijnzeel and T.T. Rawaqa, 2007. Changes in catchment runoff after harvesting and burning of a *Pinus caribaea* plantation in Viti Levu, Fiji. Forest Ecol. Manage., 251: 31-44. DOI: 10.1016/j.foreco.2007.06.050

Wonisch, H., F. Gérard, M. Dietzel, J. Jaffrain and O. Nestroy *et al*., 2008. Occurrence of polymerized silicic acid and aluminum species in two forest soil solutions with different acidity. Geoderma, 144: 435-455. DOI: 10.1016/j.geoderma.2007.11.022

Zheng, H., Z.Y. Ouyang, X.K. Wang, Z.G. Fang and T.Q. Zhao *et al*., 2005. Effects of regenerating forest cover on soil microbial communities: A case study in hilly red soil region, Southern China. Forest Ecol. Manage., 217: 244-254. DOI: 10.1016/j.foreco.2005.06.005

Zimmerman, S., S. Braun, M. Conedera and P. Blaser, 2002. Macronutrients inputs by litter fall as opposed to atmospheric deposition into two contrasting chestnut forest stands in Southern Switzerland. Forest Ecol. Manage., 161: 289-302. DOI: 10.1016/S0378-1127(01)00477-7