Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2014.19.2.101

Evaluation of Primary Macro Nutrients on Arboretum Area in Lampung University Campus, Gedong Meneng

Nur Afni Afrianti and Tamaluddin Syam

Soil Science Laboratory, Faculty of Agriculture, University of Lampung
Jl. Prof. Soemantri Brojonegoro No.1, Bandar Lampung 35145, Indonesia
e-mail: nur_afnii@yahoo.com

Received 04 April 2014 / accepted 02 May 2014

ABSTRACT

Vegetation has a strong influence on soil characteristics. Vegetation can contribute organic matter sand nutrients to the soil. This study aimed to assess soil fertility through various approaches physical and chemical soil on various types of cover crop in the arboretum area at University of Lampung, and determined the type of cover crop that had the best effect on soil fertility. The research was be conducted by a survey method, which made observations on the soil characteristics of six species of cover crops following were rosewood (*Dalbergia latifolia*), teak (*Tectona grandis*), albizia (*Paraserianthes Albiziaria*), acacia (*Acasia mangium*), fern tree (*Filicium desipiens*), and mahogany (*Swietenia macrophylla* King). Soil characteristics observed data were the physical and chemical properties, obtained by field observations, through boring profiles and soil sampling. The results showed that soil fertility on rosewood, albizia, acacia and mahogany on campus area of Lampung University had contents of soil organic C, organic matter, and soil total N higher than teak and Fern tree. Litter from Rosewood, Albizia, and acacia had the best effect on soil fertility, so they could be the best covered vegetation to improve soil characteristics related to optimal and sustainable of land management.

Keyword : Acacia, albizia, arboretum, cover crop, fern tree, litter, macronutrient, mahogany, rosewood, teak and vegetation

INTRODUCTION

Soil is a natural body composed of minerals, gas, water, organic matter and micro-organisms. Soil properties are affected by five factors, there are parent material, climate (such as rainfall and temperature), soil biology (such as vegetation, soil fauna and human action), Topography (such as slope angle and slope position), and Time. In this research, the element that affected soil properties in relation to soil characteristics is soil biology, such as vegetation (Brady and Weil 2008). Vegetation do not only prevent soil erosion, but also play important roles in soil ecosystem development. Their litter fall is the main process of transferring organic matter and nutrients from aboveground tree biomass to soil. Thus, its quantification would aid in understanding biomass and nutrient dynamics of the ecosystem (Mnawar *et al.* 2011).

Vegetation has a strong influence on soil characteristics. Vegetation can contribute organic matter to the soil through plant litter and it will stimulate the activities of soil fauna and also affect the stability of the soil structure. Chemical elements content in various plants also very influent on the soil chemical properties. The example is the types of pine will provide the metal cations, such as Ca, Mg, and K, are lower than broadleaf plants. As a result, soils under the pine trees are usually more acidic than the soil under broad-leaved trees (Arsyad 2010; Hillel 2008; Harjowigeno 2007).

Decomposed organic matter is called humus. Humus is the main constituent parts of soil organic matter which was stable and difficult to be degraded. The importance of humus exceeds its effect on cation adsoption and even its role in plant nutrition. Humus tends to coagulate with clay and serves as cementing agent, binding, and stabilizing assemblages of soil particle (called agregates), thus improving soil structure, water holding capacity, biological activity organisms, and provide cation exchange capacity of soil. The cation exchange capacity of humus is much greater per unit mass than that of clay, and humus may store, and slowly release, nutrients that promote plant growth (Hillel 2008 ; Mouhamad *et al.* 2015). Its caused the organic matter often become a barometer of soil fertility level. In general, the higher the content of humus in the soil, the higher the level of soil fertility. Differences in the type and composition of litter added to the soil will surely give difference effect to the soil, such as organic matter composition and soil nutrients, the examples is litter from tree canopy have a positive effect on soil fertility. If the litter is from leguminous tree canopies, it will more improve soil properties more than non-legumes. *Rhizobium* infected root of legume plants and it makes legume plant can fixing nitrofen from atmosphere (Singer and Munns 2006; Debeux Jr *et al.* 2014).

Environmental changes or management activities that reduce litter inputs might result in the loss of soil C (Lajtha *et al.* 2014). Changes of land use and intensity of land use, in fact is part of the agricultural progress development history. The quality and sustainability of land use should be taken seriously by both scientists and practitioners of agriculture through measures that do not damage the soil (Gardiner and Miller, 2008). Based on the description above shows that vegetation has an important role in influencing the land characteristics. Therefore, research on the effects of various cover crop to land characteristic is very important to do, which in the end to get the best type of cover crop to improve soil characteristics in relation to optimal and sustainable of land management. This study aimed to assess soil fertility through various approaches physical and chemical soil on various types of cover crop in the aboretum area at Lampung University, and to determine the type of cover crop that had the best effect on soil fertility.

MATERIALS AND METHODS

Research Site Description

The research was based on survey and experimental plot of arboretum area at University of Lampung in Bandar Lampung City, Indonesia. It was situated at 5°20' - 5°30' S dan 105°28' - 105°37' E. Observation of the research was soil chemical properties under trees canopy and litter nutrients content. The six species of trees canopy of research area were rosewood (*Dalbergia latifolia*), teak (*Tectona grandis*), albizia (*Paraserianthes Albiziaria*), acacia (*Acasia mangium*), fern tree (*Filicium desipiens*), and mahogany (*Swietenia macrophylla* King).

Soil Analyses and Leave Litter Analyses

Field observations and laboratory analysis refers to the standard manual on methods of soil sampling and analysis (Carter and Gregorich, 2008). The techniques for soil sampling of the reseach were soil cores. The effect of litter under some trees canopy on some soil properties investigated through soil samples from under each trees canopy were randomly taken at 0-20 cm depts (efective root zone) using soil cores, and collecting into plastic bags to obtain composite samples. Five soil samples (as replication) from soil under each trees canopy were air-dried and brought to Soil Science Laboratory of the Faculty of Agriculture, Univesity of Lampung for soil analyses. The soil texture was determined using hydrometer method; soil pH H_2O and total organic C were, respectively, determined using electrically method and Walkey and Black method; whereas total N content, available P content, and cation K content were, respectively, determined using Kjeldahl method, Bray-1 method, and extracted using 1*N* NH_4OAc pH 7. Litter sampling was measure using a Graund Litter Sampling (GLS) technique. a square rope sampling template of 25 × 25 cm (625 cm^2) placed on the surface of the trees canopy as a cutting guide. Leaves litter were collect into plastic bag and oven-dried at 70°C until constant weight. Some oven-dried samples were used to analyses using the wet destruction method. Analyses parameter of leaves litter were content of total N, total P, total K, and C/N ratio to determine the level of litter decomposition.

Data Analyses

Part data were illustrated in the form of table. Analysis of variance (ANOVA) was employed. When the treatment effect were significant, the treatment mean effects were analyzed using least significant different (LSD).

RESULTS AND DISCUSSION

Vegetation, like cover crop, is an important role in influencing the land characteristics. Vegetation will contribute organic matter in the soil. In the forest vegetation, litter is one of the important sources of soil organic matter. Decomposed organic matter (called Humus) indicates the positive effects of soil properties, ie. soil physical, soil chemical, and soil biology (Murphy, 2014). Proses of organic matter (litter) decomposition will increase soil organic matter levels, supplies nutrients that will be immediately used by plants, carbon to heterotrophic soil microorganisms, soil structure, soil porous, aeration, drainage, carbon and nitrogen rate (Chivenu 2013; Bothwell *et al*. 2014 ; Esmaeilzadeh and Ahangar, 2014). It also will improve soil ability of soil to retain water and many plant nutrients (water and nutrient retention), nutrients leaching, sustaining a greater microbial biomass by increasing substrate availability, facilitate the SOM accumulation as microbial products in the long term (Crow and Dunn 2013; Wei *et al*. 2014), the development of a degrader's food web, and an important for nurient cycling in such ecosystems (Esperchütz *et al*. 2013; Liu *et al*. 2015).

Soil Texture under Trees Canopy

Soil texture is one of the factors that influence the process of organic matter decomposition in the soil. Soil texture will determine porosity, density, aeration, availability of water, nutrients, air, and microbial biomass for organic matter decomposition. The example is clay texture will give high ability to hold the water and nutrients, low ability in drainage and aeration, but sustaining a greater microbial biomass. Clay also facilitates the SOM accumulation as microbial products in the long term. Therefore, generally soil with high clay have organic matter is greater than low clay in soil (Chivenu 2013; Osman 2013).

Table 1 shows that soil texture under the canopy of albizia (*P. Albiziaria*) and acacia (*A. mangaium*) had clay or fine-textured. It means the soil has the high capacity to retain water and nutrient. It caused clay particle called the nutrient storehouse (Chivenu 2013). Soil organic matter tends to increase as the clay content increases. Bonds between the surface of clay particles and organic matter retard the decomposition process and soils with higher clay contents increase the potential for aggregate formation that protects organic matter molecules from further mineralization (Bot and Benites 2005).

Soil texture under the canopy of rosewood (*D. latifolia*), teak (*T. grandis*), and mahogany (*S. macrophylla* King) has clay loam texture or slight fine texture. It means the soil containing approximately equal amounts of sand, silt and clay. The soil conditions are the best conditions for plants and soil microorganisms because the soil has enough water and air for the needs of living things in the soil. Price (2006) stated that a texture in the mid-range of sand, silt and clay content and organic matter to allow air and water movement is the ideal soil for plant growth.

Soil texture under the canopy of fern tree (*F. desipiens*) has sandy clay loam texture. Sand particles in the soil under fern tree canopy are dominant by soil fraction sand (47.38%), than follow by clay (32.91%) and silt (19.71%). It shows that the soil has more macro pore and micro pore than meso pore. The meso pores known as storage pores because of the ability to store water useful to plants. The low of meso pores in soil can caused decreased water storage in soil that can be used by plant.

Soil Chemical Properties under Tree Canopy and Litter nutrient contents

Table 2 shows that the soil under the rosewood canopy has acidic soil pH (5.19); content of C-organic, organic matter, and soil total N are medium, while the ratio C/N, content of available P, and K-dd are low. While soil under albizia and acacia canopy have the same class, which have acidic soil pH; content of C-organic, organic matter, soil total N and K-dd are medium; and ratio C / N and soil available P are low (Table 2). Rosewood has a scientific name *Dalbergia latifolia*, albizia has a scientific name *P. Albiziaria*, and acacia has a scientific name *A. mangium*. These trees are frequently used as a agroferestry plant and they are from the family of Fabaceae (*Leguminosae*). Their roots can fixing nitrogen from the air by symbiosis with *Rhizobium* bacteria and provide available nitrogen in soil (Bhattacharya *et al*. 2013). It was showed in Table 2 and Table 3. In Table 2, content of soil total N and soil organic C of rosewood, acacia, and abizia are generally higher than the other trees, as well as content of their litter total nitrogen that are higher than three other trees (Table 3).

Symbiotic nitrogen fixation by legume plants have the ability to form a symbiotic relationship with

Table 1. Soil texture under the canopy of some forest trees in the Arboretum area University of Lampung.

Parameter	Rosewood	Teak	Albizia	Acacia	Fern	Mahogany
Texture Class	Clay loam	Clay loam	Clay	Clay	Sandy clay loam	Clay loam
Sand (%)	37.77	33.46	26.91	27.95	47.38	38.55
Silt (%)	30.55	20.17	26.77	31.69	19.71	24.98
Clay (%)	31.68	46.37	46.32	40.36	32.91	36.47

*) The evaluation criteria for soil analysis by the Soil Research Institute of Bogor (2009)

Table 2. Soil chemical properties under the canopy of some forest trees in the Arboretum area University of Lampung.

Parameter		pH H_2O	Organic C (%)	OM (%)	Total N (%)	C/N Ratio	Available P (ppm)	K-dd (me/100g)
Rosewood	Value*)	5.19 bc	2.01 b	3.47 a	0.31 b	6.48 a	6.77 c	0.22 ab
	Class**)	acid	medium	medium	medium	low	low	low
Teak	Value*)	5.01 b	1.64 a	2.83 a	0.19 a	8.63 d	3.59 ab	0.16 a
	Class**)	acid	low	low	very low	low	very low	low
Albizia	Value*)	5.42 c	2.11 b	3.64 a	0.26 ab	8.12 c	3.19 a	0.36 c
	Class**)	acid	medium	medium	medium	low	very low	medium
Acacia	Value*)	4.68 a	2.26 b	3.9 a	0.3 b	7.53 b	3.58 ab	0.51 d
	Class**)	acid	medium	medium	medium	low	very low	medium
Fern	Value*)	6.38 d	1.49 a	2.57 a	0.17 a	8.76 d	5.89 c	0.65 e
	Class**)	slight acid	low	low	low	low	low	high
Mahogany	Value*)	5.37 c	2.6 c	4.48 a	0.33 b	7.88 c	6.39 c	0.33 bc
	Class**)	acid	medium	medium	medium	low	low	low

*) Values in the same row followed by the same letter are not significantly different at 0.05 probability level.
**) The evaluation criteria for soil analysis by the Soil Research Institute of Bogor (2009).

Table 3. Litter nutrient contents of forest trees in the Arboretum area of Lampung University.

Parameter		Total N (%)	Total P (%)	Total K (%)	C (%)	C/N Ratio
Rosewood	Value*)	2.98 d	0.02 a	1.67 b	25.6 b	8.59 b
	Class**)	normal	deficient	normal		
Teak	Value*)	2.68 c	0.03 a	2.12 c	28.4 d	10.6 d
	Class**)	normal	deficient	normal		
Albizia	Value*)	3.92 e	0.02 a	1.74 b	24.9 a	6.35 a
	Class**)	normal	deficient	normal		
Acacia	Value*)	2.73 cd	0.01 a	1.69 b	26.3 c	9.65 c
	Class**)	normal	deficient	normal		
Fern	Value*)	1.49 a	0.02 a	1.65 a	26.2 c	17.6 f
	Class**)	deficient	deficient	normal		
Mahogany	Value*)	2.38 b	0.01 a	1.12 a	29 e	12.2 e
	Class**)	deficient	deficient	normal		

*) Values in the same row followed by the same letter are not significantly different at 0.05 probability level.
**) The evaluation criteria for soil analysis by Kalra (1998).

nitrogen-fixing bacteria (collectively called rhizobia), *Rhizobium* will infect root of legume palnts, forming nitrogen-fixing root nodules (special root organs). The symbiotic relationship will increase soil nitrogen availability (Singer and Munns 2006; Biswas and Gresshoff 2014) and it will increase the rate of decomposition process of litter plant. It was shown in C/N ratio of leaves litter of albizia, rosewood, and acacia. They had a C/N ratio which were significantly lower than teak, mahogany, and fern tree (Table 3). This suggests that plants litter of albizia, rosewood, and acacia will decompose faster than teak, mahogany, and fern tree. The rate of organic matter decomposition will provide positive influences on the environment, such as the addition of organic matter and nutrients available.

Acidic soil pH supposedly as a result of the release of organic acids from root exudates and decomposition of organic matter. Several substance of root exudates release by root such as amino acids, organic acid, enzymes, flavones, etc, and one of the type of organic matter decomposition product is organic acid (Mukerji *et al.* 2006; Paul 2007). Table 2 also showed that C-organic content of rosewood, albizia, and acacia are medium. Sources C-organic and organic matter in the soil is derived from their litter. High litters production of rosewood, albizia and acacia are potentially for source of carbon nutrients and soil organic matter (Saptono, 2008 ; Aprianis, 2011). Soil C/N ratio is low, it showed the organic matter in the soil has undergone decomposition and then it will release nutrients into the soil (nutrient mineralization), such as nitrogen, sulfur, phosphorus, potassium, calcium, magnecium, micro nutrients, etc (Sylvia *et al.* 2005; Leytem *et al.* 2011).

Soil under teak canopy had acidic soil pH; content of C-organic, organic materials, C/N ratio, and K-dd was low; and content of soil total N and available soil P was very low (Tabel 2). Teak has a scientific name *Tectona grandis* and a family from Lamiaceae (family of flowering plants). Teak tree will produce litters, such as the fallen of leaves and twigs, and will be a source of soil organic C. The litter decomposition rate of teak leaves is slower than rosewood, albizia and acacia. It shows by litter C/N ratio of teak was higher than them (Table 3) and it causes content of organic matter and available nutrient in soil under teak canopy were lower than rosewood, albizia and acacia (Table 2). Visual observation results also showed that the soil under teak canopy looks more dry than rosewood, albizia and acacia. Swarnalatha and Reddy's reseach (2011) showed that teak leaf litter had low N concentration (0.88%) and high initial C/N ratio (60.29), that caused decomposition of teak leaf litter was running slow.

Soil under fern tree canopy had slightly acidic soil pH; content of C-organic, organic matter, soil total N, C/N ratio, and soil available P were low; and content of soil K-dd was high (Table 2). Fern tree has a scientific name *Filicium decipiens*, is a tree that is often used as a roadside tree and have moderate relative growth rate (Rahmad *et al.* 2014). This tree has a strong wood, strong and deep of root system. Fern is a shade tree with wide canopies, so it is not easy to fall. This is causes fern only can produce litters in small amounts. Nitrogen content of leaves litter of fern tree was deficient (Table 3) and microbial will retrieved soil available N to litter decomposition process (immobilization). Immobilization is degradation of organic matter with low levels of nitrogen will consume or immobilize ammonium and nitrate nitrogen as degrading microorganisms scavenge available nitrogen from the soil system (Walworth 2013; White *et al.* 2014).

Soil under Mahogany canopy had acidic soil pH; content of C-organic, organic matter, and soil total N were medium; and content of C/N ratio, soil available P, and soil K-dd were low (Table 2). Content of C-organic and organic matter was derived from mahogany leaf litters that fall and then decomposed by microbes (C/N ratio is low), so it will release available nitrogen in the soil. Similar to fern tree, nitrogen content of leaves litter of mahogany was deficient (Table 3), it will caused immobilization process and soil available has decreased. Mahogany tree has the scientific name *Swietenia macrophylla*, is a forest tree that can produce hardwood and often used as an agroforestry. Mahogany can produces litter and can be a source of organic matter for the surrounding area, but its nature is resistant to drought caused the mahagony leaves is not easy to fall. Saptono research results (2008) showed that the Mahogany tree can produce litter about 1,8 mg ha^{-1} $year^{-1}$.

Utilization of forest trees as cover crop, such as rosewood, albizia, and acacia, needs to be developed. These trees have potential to be developed. rosewood, albizia, and acacia are from the family of Fabaceae (*Leguminosae*) and they can produce high leaves litters. Litters addition to the soil can increase soil organic matter and soil N availibility.

CONCLUSIONS

The results showed that soil fertility on rosewood, albizia, acacia and mahogany on campus area of Lampung University had soil C-organic content, organic matter, and soil total N which were higher than teak and fern tree. Total N content of leaves litter of rosewood, albizia, and acacia were higher than teak, mahogany, and fern tree, while C/N ratio of litter leaves of albizia, rosewood, and acacia had C/N ratio which were lower than teak, mahogany, and fern tree. Litter from rosewood, albizia, and acacia had the best effect on soil fertility, so they can be the best covered vegetation to improve soil characteristics related to optimal and sustainable of land management.

REFERENCES

Aprianis Y. 2011. Produksi dan Laju Dekomposisi Serasah *Acacia crassicarpa* A. Cunn. di PT. Arara Abadi. *J Tekno Hutan Tanaman* 4: 41-47.

Arsyad S. 2010. *Konservasi Tanah dan Air*. Edisi Kedua. IPB Press. Bogor. 472 p.

Bhattacharya C, B Deshpande and B Pandey. 2013. Isolation and characterization of *Rhizobium* sp. form root of legume plant (*Pisum sativum*) and its antibacterial activity against different bacterial strains. *Intern J Agric Food Sci* 3: 138-141.

Biswas B and PM Gresshoff. 2014. The role of symbiotic nitrogen fixation in sustainable production of biofuels. *Inter J Molecular Sci* 15: 7380-7397. Doi:10.3390/ijms15057380.

Bot A and J Benites. 2005. *The Importance of Soil Organic Matter*. Food anad Agriculture Organization of the United Nations. 78p.

Bothwell LD, PC Selmants, CP Giardina and CM Litton. 2014. Leaf litter decomposition rates increase with rising mean annual temperature in Hawaiian tropical montane wet forests. *PeerJ* 2: e685. doi : 10.7717/ peerj. 685.

Brady NC and RR Weil. 2008. *The Nature and Properties of Soils*. 14th Edition. Pearson Prentice Hall. 965 p.

Carter MR and EG Gregorich. 2008. *Soil Sampling and Methods of Analysis*. 2nd Edition. Canadian Society of Soil Science. 1224 p.

Chivenu, C Nnaemeka, Unanaonwi, O Esio, Amonum, and J Igba. 2013. Physical and chemical characteristics of forest soil in southern guinea savanna of Nigeria. *Agric, Fores Fish*. 2: 229-234. Doi: 10.11648/j.aff.20130206.15.

Crow WT and RA Dunn. 2013. Soil Organic Matter, Green Manures and Cover Crops For Nematode Management. IFAS Extension University of Florida. http://edis.ifas.ufl.edu/pdffiles/VH/ VH03700.pdf

Debeux Jr, J CB, MA Lira, MVF Santos, J Muir, MA Silva, VI Teixeira, and ACL Mello. 2014. Soil characteristics under legume and non-legume tree canopies in signalgrass (Brachiaria decumbens) pastures. *Afr J Range Forage Sci* 31: 1-6.

Esmaeilzadeh J and AG Ahangar. 2014. Influence of soil organic matter content on soil physical, chemical and biological properties. *Inter J Plant Animal, Environ Sci*. 4 : 244-252.

Esperchütz J, C Zimmermann, A Dümig, G Welzl, F Buegger, M Elmer, JC Munch and M Schloter. 2013. Dynamics of microbial communities during decomposition of litter from pioneering plants in initial soil ecosystems. *Biogeosciences* 10: 5115-5124. doi : 10.5194/bg-10-5115-2013.

Gardiner DT and RW Miller. 2008. *Soils In Our Environment*. 11th Edition. Pearson Prentice Hall. 600 p.

Hardjowigeno S. 2007. *Ilmu Tanah*. Edisi Baru. Akademi Pressindo. Jakarta. 288 p. (in Indonesian).

Hillel D. 2008. *Soil In the Environment*. Elsevier. 307 p.

Kalra YP. 1998. Hand book of reference method for plant analysis. CRC press. Bicara Raton Boston London New York Washington, D.C. 287 p.

Lajtha K, RD Bowden and K Nadelhoffer. 2014. Litter and root manipulations provide insights into soil organic matter dynamics and stability. *Soil Sci Soc Am J*. doi: 10.2136/sssaj2013.08.0370nafsc.

Leytem AB, RS Dungan and A Moore. 2011. Nutrient availability to corn from dairy manures and fertilizer in a calcareous soil. *Soil Sci* 176 : 1-9. doi: 10.1097/ S S.0b013e31822391a6.

Liu J, X Fang, Q Deng, T Han, W Hunag and Y Li. 2015. CO_2 enrichment and N addition increase nutrient loss from decomposing leaf litter in subtropical model forest ecosystems. *Sci Reports* 5: 7952. doi : 10.1038/srep07952.

Mouhamad R, A Atlyah, R Mohammad and M Iqbal. 2015. Decomposition of organic matter under different soil texture. *Curr Sci Persp* 1: 22-25.

Mukerji KG, C Manoharachary and J Singh 2006. *Microbial Activity in the Rhizosphere*. Springer-Verlag Berlin Heidelberg. 349p.

Murphy BW. 2014. *Soil Organic Matter and Soil Function – Review of the Literature and Underlying Data : Effects of soil organic matter on functional soil properties*. Grain Reseach & Development Corporation, Department of the Environtment Australia Goverment. 155p.

Munawar A, Indarmawan and H Suhartoyo. 2011. Litter production and decomposition rate in the reclaimed mined land under albizia and sesbania stands and their effects on some soil chemical properties. *J Trop Soil*. Vol 16(1) : 1-6. DOI : 10.5400/jts.2011.16.1.

Osman KY. 2013. *Forest Soils*. Springer International Publishing Switzerland. doi : 10.1007/978-3-319-02541-4_2.

Paul EA. 2007. *Soil Microbiology, Ecology and Biochemistry*. Academic Press, Elsevier. 532p.

Price G. 2006. *Australian Soil Fertility Manual*. 3rd Edition. Fertilizer Industry Federation of Australia, Inc. & CSIRO. 168p.

Rahmad ZB, PA Fordjour, M Asyraf, and NFN Rosely. 2014. Mistletoe abundance, distribution and associations with trees along roadsides in Penang, Malaysia. *Trop Ecol* 55: 255-262.

Saptono M. 2008. Agroteksos. Potensi Biomasa dan Produksi Seresah Pohon dan Ubikayu pada Sistem. *Agroforestri* 18: 37-45 (in Indonesian).

Singer MJ and DN Munns. 2006. *Soil an Introduction*. Pearson Education, Inc., Upper Saddle River, New Jersey. 446 p.

Soil Research Institute. 2008. Analisis Kimia Tanah, Tanman, Air, dan Pupuk. Bogor (in Indonesian).

Swarnalatha B and MV Reddy. 2011. Leaf litter breakdown and nutrient release in three tree plantations compared with a natural degraded forest on the coromandel coast (Puducherry, India). *Ecotropica* 17: 39-51.

Sylvia DM, JJ Fuhrmann, PG Hartel and DA Zuberer. 2005. *Principles and Application of Soil Microbiology*. Pearson Prentice Hall, Upper Saddler, New Jersey. 640 p.

Walworth J. 2013. Nitrogen in Soil and the Environment. College of Agriculture and Life Sciences, The University of Arizona. http:/ extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1591.pdf.

Wei H, B Guenet, S Vicca, N Nunan, H Asard, HA Elgawad, W Shen and IA Janssens. 2014. High clay content accelerates the de composition of fresh organic matter i n arti û cial soils. *Soil Bio Biochem* 77 : 100-108.

White CM, AR Kemanian and JP Kaye. 2014. Implications of carbon saturation model structures for simulated nitrogen mineralization dynamics. *Biogeosciences* 11: 6725-6738. doi:10.5194/bg-11-6725-2014.