Changes in soil chemical properties in agroforestry system at USU Arboretum Kwala Bekala

M Rizwan1*, A Rauf2, Rahmawaty3, and E N Akub2
1 Doctoral Program of Agricultural Sciences Faculty of Agriculture, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia
2 Program Study of Agrotechnology, Faculty of Agriculture, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia
3 Faculty of Forestry, Universitas Sumatera Utara, Padang Bulan, Medan 20155, Indonesia

*Corresponding author’s e-mail address: muhammadrizwanagr@gmail.com

Abstract. One of the opportunities for utilization and optimization of the Arboretum land is by intensive cultivation of crops commodities to fulfill the needs of food, vegetables and other commodities. This study aims to analyze changes in soil nutrient status in four types of forest trees combined with agroforestry using soybean. Soil survey was carried out in area of USU Arboretum Kwala Bekala by soil sampling and then analyzed in the laboratory. Composite soil samples were taken from Jabon tree stands, (Anthocephalus cadamba Miq.), Gmelina (Gmelina arborea Roxb.), Rubber (Hevea brasiliensis), and Mindi (Melia azedarach L.) at a depth of 0-30 cm. This sampling was carried out twice, namely before planting and after harvesting of soybeans. The results of soil analysis were assessed based on the criteria of Soil Research Center. Parameters observed for soil sample were N total (Kjeldahl method), phosphate (Bray method), C organic (Walkey and Black), Potassium and Sodium (Flame photometer), Calcium and Magnesium (AAS). The data obtained were analysed using a paired t test at the level of α 0.05. Almost all of the values of soil chemical properties gradually increased, and significant differences in those chemical properties were found between two condition, before and after the growing of soybean in four type stand of woods. Generally, Agroforestry system in four main stands (Rubber, Gmelina, Mindi and Jabon) with soybean for period 1-year can improve soil chemical fertility through increasing pH, C organic, N total, P available, Potassium, Na and Ca.

1. Introduction
USU Arboretum was built on area of USU Campus Kwala Bekala. USU Arboretum will be used to maintain tree species and plants as collections. The University of North Sumatra Arboretum was built by University of North Sumatra (USU) in collaboration with Wampu Sei Ular Watershed Center (BP-DAS). The construction design was performed by the Indonesian Forestry Minister and USU Chancellor on June 19th, 2006 and since then has collecting 57 species of trees consisting of 32 types of forest commodities, 9 types of tree/industrial commodities, 12 types of fruit trees, and 4 types of vegetable commodities. Of the 57 tree species, 11 of them are existing trees (existed before the arboretum was built), and the remaining 46 species are introduced plants/trees [1]. The most commonly found forestry tree species are Pulai (Alstonia scholaris), Mindi (Melia azedarach), Gmelina (Gmelina arborea), Teak (Tectona grandis) and Mahogany (Swietenia mahagoni).
One of the opportunities for utilization and optimization of the Arboretum land is by intensive cultivation of crops commodities to fulfil the needs of food, vegetables and other commodities. Alternative land use between tree crops (agroforestry) can be done by planting tolerant shade species, providing the right fertilizer and optimal population density. Therefore, a combined planting pattern-based agroforestry system could provide an important method to promote the sustainable development of agriculture and the environment in woods plantations [2, 3]. This study aims to analyse changes in soil nutrient status in four types of forest trees combined with agroforestry using soybean.

2. Materials and Methods

2.1. Places and Time of Research

Soil chemical analysis research was conducted at the Arboretum of Universitas Suamtera Utara located in Kwala Bekala, Deli Serdang, Sumatera Utara.

2.2. Research Method

Soil survey was carried out in area of USU Arboretum Kwala Bekala by soil sampling and then analyzed in the laboratory. Composite soil samples were taken from Jabon tree stands, (Anthocephalus cadamba Miq.), Gmelina (Gmelina arborea Roxb.), Rubber (Hevea brasiliensis), and Mindi (Melia azedarach L.) at a depth of 0-30 cm. This sampling was carried out twice, namely before planting and after harvesting of soybeans. The results of soil analysis were assessed based on the criteria of Soil Research Center. Parameters observed for soil sample were N total (Kjeldahl method), phosphate (Bray method), C organic (Walkey and Black), Potassium and Sodium (Flame photometer), Calcium and Magnesium (AAS). In addition, intensity of solar radiation was also measured under each selected tree stand. The data obtained were analysed using a paired t test at the level of α 0.05 [4].

3. Results and Discussion

Location of soil sampling was carried out at 4 tree stand with agroforestry system, namely 4 year old rubber stands with a spacing of 5.5 x 5.5 m, 4 years old mindi stand with 5 x 5 m spacing, 4 years old Jabon with a spacing of 4 x 4.5 m, and 4 years old Gmelina with a spacing of 5 x 5 m. Topography of USU Arboretum is flat to gentle sloping with a slope of 0-8% and at an altitude of 120 meters above sea level. The soil type is dominated by Ultisol order (Red Yellow Podosolic). Climate type is type B with an average rainfall of 2000-2500 mm per year. Based on data from climatology stations, average of light intensity in the four types of shade during the study is ranged from 1,476 - 2,040 cal/cm²/day. Minimum average shade temperature during the study was 28.33 °C and the maximum is 38.1 °C. Average humidity in the shade of rubber, Gmelina, mindi and Jabon is 59.27%, 68.9%, 80.67% and 54.2%, respectively.

Table 1. Value of some soil chemical properties in the research site before and after soybeans planting under tree stands

| Parameter        | Rubber  | Gmelina | Mindi | Jabon |
|------------------|---------|---------|-------|-------|
|                  | Before  | After   | Before| After | Before | After | Before| After |
| pH               | 4.83    | 6       | 6.22  | 6.29  | 5.25   | 6.42  | 4.5   | 5.23  |
| C organic (%)    | 0.91    | 1.04    | 1.75  | 1.98  | 0.75   | 1.43  | 1.27  | 1.64  |
| N-total (%)      | 0.1     | 0.11    | 0.17  | 0.19  | 0.1    | 0.16  | 0.18  | 0.19  |
| P-available (ppm)| 9.46    | 14.31   | 17.2  | 18.41 | 19.34  | 15.54 | 8.2   | 14.8  |
| K (me/100g)      | 0.549   | 0.621   | 0.629 | 0.758 | 0.64   | 0.728 | 0.619 | 0.482 |
| Na (me/100g)     | 0.252   | 0.351   | 0.437 | 0.461 | 0.106  | 0.516 | 0.127 | 0.273 |
| Ca (me/100g)     | 0.591   | 2.628   | 2.352 | 2.539 | 0.57   | 2.419 | 0.742 | 2.207 |
| Mg (me/100g)     | 0.613   | 0.512   | 0.428 | 0.394 | 1.339  | 0.424 | 0.685 | 0.468 |
| CEC (me/100g)    | 19.59   | 10.26   | 10.37 | 10.83 | 20.69  | 10.2  | 17.97 | 9.76  |

Source: Soil Analysis
The effects of agroforestry system on the chemical properties of soil are presented in Table 1. Almost all of the values of soil chemical properties gradually increased, and significant differences in those chemical properties were found between two condition, before and after the growing of soybean in four type stand of woods.

In general, soil fertility in the selected locations for agroforestry systems is quite suitable and support for plant growth. The level of soil fertility at the end of treatment in rubber stands increased compared to initial level. From 9 parameters which has been analysed, 8 parameters show increase in value, while 1 parameter (CEC) decreased. Value of soil chemical properties under Mindi and Jabon stands is more varied where pH, C organic, N total, K, Na and Ca increase in concentration, while P, Mg and CEC decrease. The results showed that the application of agroforestry systems at the study site could improve the quality of soil fertility as indicated by an increase in pH, soil organic matter, N total, P available, and alkaline elements such as K, Na, Ca and Mg. Similar results were acquired in this study, which found that the nutrients of total C, N, Ca, and K in the soils of a natural tropical rain forest maintain a high level [5].

Table 2. Results of t-test and correlation of soil chemical parameters in agroforestry stands

| Parameter       | t   | Correlation | Sig. |
|-----------------|-----|-------------|------|
| pH              | 3.020* | 0.717       | 0.283|
| C organic (%)   | 2.944* | 0.843       | 0.157|
| N-total (%)     | 2.100* | 0.837       | 0.163|
| P-available (ppm) | 0.964ns | 0.638       | 0.362|
| K (me/100g)     | 0.638ns | 0.302       | 0.698|
| Na (me/100g)    | 2.022ns | 0.206       | 0.794|
| Ca (me/100g)    | 3.324* | 0.263       | 0.737|
| Mg (me/100g)    | 1.561ns | 0.113       | 0.887|
| CEC (me/100g)   | 2.763* | 0.731       | 0.269|

Note: *= significant at level α 0.05, ns= not significant at level α 0.05

Table 2 shows that soil pH, C organic, N total and Ca was significantly increased, while P available, K and Na show not significantly increase in soil samples of all types of stands. Conversely, Mg levels have decreased not significantly and CEC has decreased significantly. Increasing soil pH in rubber stand have changes the value of soil pH from acidic (4.83) to slightly acidic (6), while increasing soil pH in other stands does not change its value, namely slightly acidic. Increasing the pH value by agroforestry is also indicates an improvement of soil chemical properties. The increase in soil pH is very influential to support growing environment. It is well known that increase in pH is closely related to increasing levels of alkaline elements such as P, K, Na, Ca and Mg.

The highest increase in soil C organic levels found in Mindi stands, from very low level (0.75) to low (1.43). The C content significantly increased by 14.3%, 13.1%, 90.7% and 29.1% for rubber, Gmelina, Mindi and Jabon, respectively (P < 0.05). Increased levels of C organic can be a source of soil carbon which affects the microbial activity of the soil, converted into nutrients such as N, thereby increasing soil fertility. This is proven by the increase in the total N of soil.

The N content was similar to the C content across the four agroforestry types. The total P content showed not significant differences under the four agroforestry types among each sampling, increasing in the order of Jabon > Rubber > Gmelina, in contras decreasing in Mindi. The total K content also showed not significant variation under the four agroforestry types, with higher values in Gmelina plantation systems, followed by Mindi and Rubber. In contras, decreasing values in Jabon. The total Ca contents were significantly higher in Rubber agroforestry, followed by Mindi and Gmelina. Vice versa, in Jabon sites showed decreasing value of Ca.

Increase in soil N nutrient concentration in agroforestry is presumed from decomposition of organic matter (litter) that falls to the ground from soybean with shading trees which supply high N
elements. In addition, high N in the agroforestry area is also because the cultivated crops is legumes that have easily fall leaves, contain root nodules and with the help of rhizobium bacteria are able to fix (bind) N in the air. In other hand, high concentration of P in this area is comes from organic matter as a result of decomposition of plant litter and the presence of minerals or soil rocks derived from decaying parent material.

In relation to the chemical properties, nutrients balance requires an evaluation and comparison of the inputs and outputs of the nutrients in the soils. In plantations systems, nutrient inputs are mostly from (1) mineral fertilizers, which originate from applying fertilizer; (2) manure and other organic fertilizers, which are mostly derived from leaves and roots of the tree in monoculture system, or from leaves and roots of the tree and the intercropping trees in agroforestry systems; and (3) other sources, including wet and dry deposition, nitrogen fixation and sedimentation [6, 7]. Nutrient outputs contain (1) harvested products, which refer to rubber latex and wood products in monoculture, or involve additional intercropping products in agroforestry systems; (2) soil erosion; and (3) other forms, i.e., crop residues, leaching and gaseous losses.

4. Conclusion
Agroforestry system in four main stands (Rubber, Gmelina, Mindi and Jabon) with soybean for period 1-year can improve soil chemical fertility through increasing pH, C organic, N total, P available, Potassium, Na and Ca.

References
[1] Rauf A 2009 Profil Arboretum USU 2006-2008 (Medan: USU Press)
[2] Viswanathan P K, Shivakoti G P 2008 J. For. Res. 13 1–14
[3] Van Noordwijk M, Tata H L, Xu J, Dewi S, Minang P A 2012 Segregate or integrate for multifunctionality and sustained change through rubber-based agroforestry in Indonesia and China. In: Agroforestry–The Future of Global Land Use, pp. 69–104
[4] Gomez K A, A A Gomez 1984 Statistical Procedures for Agricultural Research, 2nd Edition (UK: Wiley-Interscience Publication)
[5] Chen C, Liu W, Wu J, Jiang X, Zhu X 2019 Geoderma 335 149–160
[6] Stoorvogel J J, Smaling E M A 1990 Assessment of Soil Nutrient Depletion in Sub-Sahara Africa: 1983–2000, 4 Volumes. Report 28. The Winand Staring Centre for Integrated Land, Soil and Water Research, Wageningen, The Netherlands
[7] Bindraban P S, Stoorvogel J J, Jansen D M, Vlaming J, Groot J J R 2000 Agric. Ecosyst. Environ. 81 103–112