Soil Carbon Contents of Teak Plantation in Agroforestry Farming of Ban Tham Suea, Kaeng Krachan District, Phetchaburi Province, Thailand

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Abstract
Increase of atmospheric carbon dioxide is a serious global environmental concern. Teak plantation can store substantial amount of carbon. Soil carbon contents and properties were studied in 3, 6 and 13-years-old teak plantations located in agroforestry farming areas of Ban Tham Suea, Kaeng Krachan District, Phetchaburi Province. Soil samples were collected at 0-30 cm depth by a non-disturbed method from 14 locations. Physical and chemical soil properties including texture, soil bulk density, total nitrogen, available phosphorus, available potassium and soil organic carbon were analyzed. Finding revealed that soil texture as sandy loam, silt and clay loam with bulk density was 1.2, 1.2 and 1.3 g/cm^3 and total nitrogen 0.06, 0.09 and 0.10 % in 3, 6 and 13-year-old teak plantation, respectively. Soil organic matter was the highest at 2.84 in 3-year-old teak plantation, followed by 2.09 and 1.96 % in 3, 6 and 13-year-old teak plantation, respectively. Highest available phosphorus was recorded at 3-year-old teak plantation at 153.08, followed by 6 and 13-year-old teak plantation at 87.88 and 40.90 mg/kg, respectively. Available potassium was highest at 118.01 in 3-year-old teak plantation, followed by 6 and 13-year-old teak plantation at 85.58 and 60.14 mg/kg, respectively while soil carbon stock was highest in 13-year-old teak plantations, followed by the 6 and 3-year-old teak plantations at 37.44, 29.52 and 19.08 tC/ha, respectively.

Keywords: Soil carbon, Teak plantation, Ban Tham Suea Agroforestry

Introduction

Climate change is a recent phenomenon that resulting from the release of large quantities of greenhouse gases (GHG) into the atmosphere. Increasing atmospheric concentrations of carbon dioxide (CO_2) is considered the predominant cause of global climatic change (Jose, S. & Bardhan, S., 2012). Agroforestry refers to the practice of purposeful growing of trees and crops and/or animals, with interacting combinations for a variety of benefits and services such as increasing crop yields, thereby enhancing food security and environmental services while promoting the resilience of agroecosystems (Ajayi et al., 2011). Both agriculture and forestry are combine as integrated agroforestry system to achieve maximum benefits through greater usage efficiency of resources such as nutrients, light, water capture and climate change adaptation and mitigation. The potential of agroforestry systems for carbon sequestration depends on the biologically mediated uptake and conversion CO_2 into inert, long-lived, C-containing materials which a process that called biosequestration (Lorenz, K.&Lal, R., 2014). Teak (*Tectona grandis* Linn f.) has been a principal tree species for timber since the middle of the nineteenth century and commands a high value for its durability, mellow color, and long straight cylindrical bole. Teak belongs to the family Lamiaceae and is grown in plantations in around 60 countries (Reddy et al., 2014). Although native to South and Southest Asia, mainly India, Myanmar, Laos and Thailand, teak is also cultivated in other parts of the world, including in Java, Indonesia. Teak performs well in plantations under favorable conditions and is most commonly found in moist and dry deciduous forests below 1,000 m elevation (Boonyanuphap, J. & Kongmeesup, I., 2016). Primary factors affecting the growth of teak are soil depth, soil texture, drainage, moisture status and fertility. Teak plantations can store substantial amounts of carbon. Most previous studies conducted on agroforestry teak plantations emphasized on estimation biomass, carbon stocks, and the change in carbon stocks in relation to plantation ages, while few correlated age and chemical properties. Soil organic carbon data in equatorial zones are limited, especially in Thailand. Therefore, soil carbon contents and some physical and chemical properties of 3, 6 and 13-years-old teak plantation were studied in agroforestry farming areas of Ban Tham Suea, Kaeng Krachan District, Phetchaburi Province. Incorporation of trees or shrubs on farms or pastures can increase the amount of sequestered carbon compared to monoculture fields of crop plants or pasture.

Materials and Methods

The study area was located in Ban Tham Suea Agroforestry situated about 15 km to the north eastern of Kaengkrachan District and covering 18,786 rai (3,005.76 ha). Phetchaburi province is located north of the Gulf of Thailand and its climate is influenced by southwest monsoon winds. Rainfall data form 2007 to 2017 averaged 86.84 mm/month with average temperature ranging from 21.4°C to 35.7°C. According to the Universal Transverse Mercator (UTM) grid value, the teak plantations were located between 576605 – 577933E and 1420895 – 1422492 N. Elevations of the study sites were about 300 MSL. This study area consisted of mixed tree planting such as rambutan, durian, mangosteen, lime, pineapple, banana, natural forest, vegetable and teak plantation. This agroforestry had the teak plantation area was about 26 rai (4.16 ha) with 434 standing teak trees of all age. Soils in 3, 6, and 13-years-old teak plantation were surveyed. At 14 sample locations, 1x1x1 m^3 pits were dug to determine the soil profile. Sample pits were selected by considering topography and soil distribution and comprised of four pits for 3-year-old plantations, 9 pits for 6-year-old plantations and 1 pit for 13-year-old plantations (Figure 1). Non-disturbed soil samples were collected at 0-30 cm depth to analyze bulk density (Black, 1965). Particle size distributions were determined by hydrometer method (Blake, G.R. & Hartge, K.H., 1996). Soil sample were air-dried and crushed to pass through a 2 mm mesh sieve to remove roots and other plants and debris before analysis of soil organic carbon by the wet oxidation method (Walkley, A. & Black, C.A., 1934). Total nitrogen was determined by the micro-Kjeldahl digestion technique (Black, 1965). Available phosphorus was determined using the Bray II method (Bray, R.H., & Kurtz, L.T., 1945), and available potassium was analyzed by 1N of ammonium acetate extraction procedure buffered at pH 7.0 using an atomic absorption spectrophotometer (AAS) (Pratt, P.E., 1965). Soil carbon content were determined by a CHN analyzer for carbon content (%), bulk density and soil depth, including calculated carbon stock.

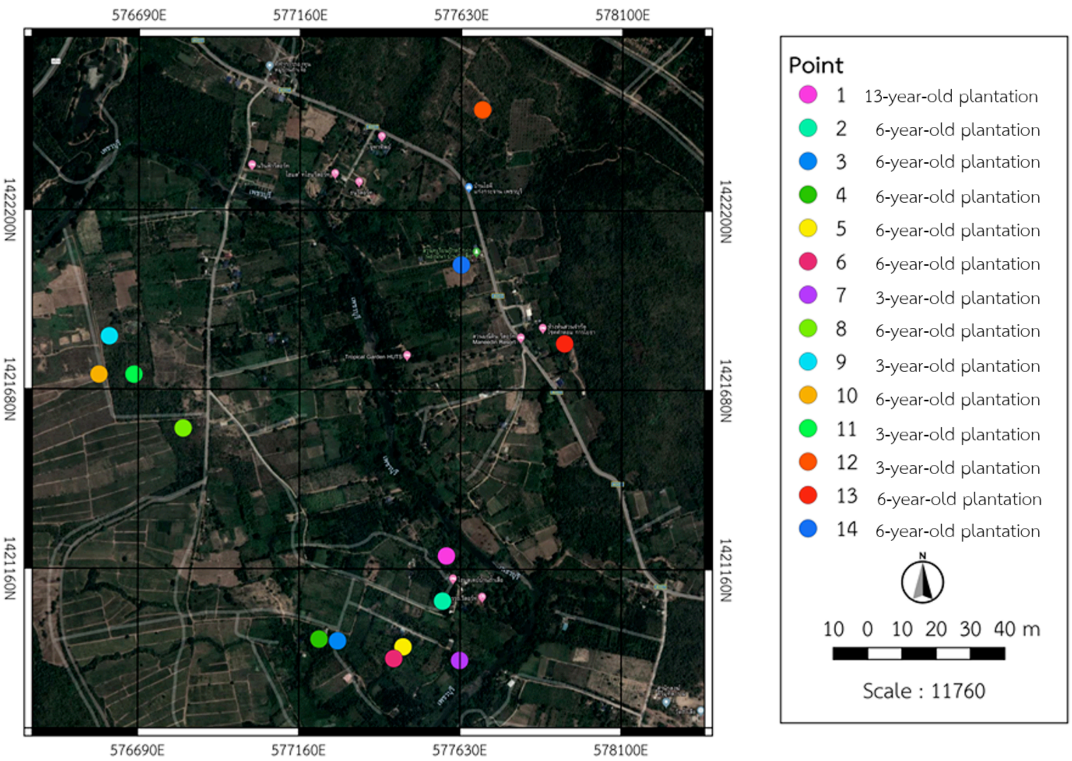

Figure 1: Location of teak plantation sites in Ban Tham Suea Agroforestry.

Result and Discussion

Soil, as a heterogeneous unit, shows great variability in physical, chemical, biological and mineralogical properties. Results for soil texture, bulk density, carbon content and carbon stock for 3, 6 and 13-year-old teak plantations are shown in Table 1. Sand ranged from 36.31-61.87%, silt ranged from 25.53-39.38% and the clay ranged from 12.60-25.79%. Soil texture varied as sandy loam, loam, clay loam and silt loam. Sand particle were highest in 13-year-old teak plantations compared to other soil fractions. This result was attributed to parent materials, climate and land use which influence to pedogenesis and properties of soils. Sandy soils reflect their parent material as coastal plain sand. Sandiness of soils suggest low carbon exchange capacity and high water infiltration. Silt particle content was low, indicating that most of silt had weathered into clay. Clay particle content of the soils was also low, indicating that vegetation cover may have reduced the rate of water movement and reduced clay translocation (Osujieke et.al, 2018). Bulk density ranged between 1.20 and 1.3 g/cm^3. This result concurred with Sharma, C. (2015) who found that teak plantation in Dimoria Tribal Belt of Assum, India had bulk density at 1.41 g/cm^3.

Soil carbon stock is an important aspect of total ecosystem carbon sequestration as detailed in the Kyoto protocol. Soil carbon stock correlated highly with the ages of teak plantation. Highest soil carbon stock of 37.44 tC/ha was found in 13-year-old teak plantations, while plantations age 3 years had the lowest soil carbon stock of 19.08 tC/ha. This result agreed with Boonyanuphap, J. & Kongmeesup, I (2016) who found that teak plantation in subtropical region of lower Northern Thailand with ages between 35 and 36 years had higher total carbon stock than those ages between 21 and 23 years. Table 2 shows the results of soil organic matter, total nitrogen, available phosphorus and available potassium in 3, 6 and 13- year-old teak plantation. Organic matter and total nitrogen were generally low compared to other studies. Organic matter ranged between 1.96 and 2.84 %. Total nitrogen was low with a range of 0.06-0.10 % compared with critical values (1.5-2.0%) for tropical soils. Nitrogen is a major constituent of all proteins and all protoplasm, causing an increase in leaf growth. Phosphorus is also a vital ingredient for many enzyme reactions that depend on phosphorylation and is necessary for the development of meristematic tissue (Omatayo et al., 2010). Available phosphorus and available potassium was highest in 3-year-old teak plantations, followed by 6 and 13-year-old, respectively. These results were similar to Al Mahmud et at. (2017) who reported that the exchangeable phosphorus and potassium content negatively correlated with teak monoculture plantation age in Bangladesh; younger teak plantations had higher contents compared to older plantations.

Pearson correlation among parameters shown in Table 3. Analysis determined a significant positive correlation between bulk density and total nitrogen, available potassium and soil carbon stock. Similarly, total nitrogen exhibited a significant correlation with available phosphorus, available potassium and soil carbon stock, while a significant correlation was shown between available potassium and soil carbon stock.

Table 1 Average soil texture, soil carbon content and carbon stock in 3, 6 and 13- year-old teak plantation

Plantation age (year)	Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cm^3)	Soil carbon content (%)	Soil carbon stock (tC/ha)
3	36.31	37.90	25.79	1.20	0.53	19.08
6	46.77	39.38	13.86	1.20	0.82	29.52
13	61.87	25.53	12.60	1.30	0.96	37.44

Table 2 Average organic matter, total nitrogen, available phosphorus and available potassium in 3, 6 and 13-year-old teak plantation

Plantation age (year)	Organic matter (%)	Total nitrogen (%)	Available phosphorus (mg/kg)	Available potassium (mg/kg)
3	2.84	0.06	153.08	118.01
6	2.09	0.09	87.88	85.58
13	1.96	0.10	40.09	60.14

Table 3 Relationships among soil parameters

Soil property	Bulk density	Organic matter	Total nitrogen	Available phosphorus	Available potassium	Soil carbon stock
Bulk density	1	-	-	-	-	-
Organic matter	-.496	1	-	-	-	-
Total nitrogen	.730*	-.520	1	-	-	-
Available phosphorus	-.514	.260	-.706*	1	-	-
Available potassium	-.857**	.527	-.774*	.634	1	-
Soil carbon stock	.800**	-.536	.688*	-.513	-.967**	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Results showed that soil carbon stock and some soil properties in 3, 6 and 13-year-old teak plantation had positive relationship. The soil contained high proportions of sand but with low proportions of clay. Highest carbon stocks were recorded in 13-year-old teak plantations, followed by 6 and 3-year-old teak plantations. Organic matter, available phosphorus and potassium contents were the highest in 3-year-old teak plantations, followed by 6 and 13- year-old teak plantations, respectively. Bulk density ranged between 1.2 and 1.3 g/cm^3. Total nitrogen was relatively low at 0.06-0.1%. Teak plantation in agroforestry have the potential for carbon sequestration and contribute to climate change mitigation.

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