Research Journal of Recent Sciences ISSN 2277-2502
Vol. **6(6),** 5-12, June **(2017)** *Res. J. Recent Sci.*

Changes in soil nutrient levels under four Teak plantations and their corresponding natural vegetations in Ghana

Kofi Agyarko[1*], Akwasi A. Abunyewa[2], Zinekena S.T. Tii Bora[1], John Asare[1], Albert K. Boakye[1] and Randy Y. Abankwa[1]
[1]University of Education, Winneba, College of Agriculture Education, Department of Crop and Soil Sciences Education, Ashanti, Ghana
[2]Kwame Nkrumah University of Science and Technology, College of Agriculture & Natural Resources, Faculty of Renewable Natural Resources, Department of Agroforestry, Kumasi, Ghana
agyarkokofi@yahoo.com

Available online at: www.isca.in, www.isca.me
Received 17th April 2017, revised 30th May 2017, accepted 1st June 2017

Abstract

Though teak (Tectona grandis) plantations have been found in some cases to bring better soil conditions, other studies have found soil deterioration in teak plantations. The current study was therefore conducted to assess the impact of teak (Tectona grandis) plantation on some soil nutrients in four plantations of age, 7, 9, 12 and 17years in Ghana at Bedomase, Asamang, Ejura and Nsuta, respectively. Soil samples were randomly picked (0 -15cm) from the teak plantations and their adjacent natural vegetations; organic matter, total nitrogen, total phosphorus, available phosphorus, total potassium, exchangeable potassium, pH and electrical conductivity were determined using standard laboratory methods. Soil organic matter, total nitrogen, total and available phosphorus, total and exchangeable potassium, and electrical conductivity were higher in the 7 year old teak plantation than in the adjacent natural vegetation. With the exception of total phosphorus, total potassium and available phosphorus, all in the 12 year old plantation where the values were marginally higher in the teak plantation soil than its adjacent natural vegetation, all the other soil chemical properties were significantly higher in value in the natural vegetation than its adjacent 9, 12 and 17 year old teak plantations. The observed trend was assigned to the lower canopy closure, higher undercover vegetation and litter contribution in the 7 year old teak plantation which might have led to higher values in the assessed parameters than its adjacent natural vegetation in contrast to the older teak plantations (9, 12 and 17 year old teak plantations). Soil pH values between the teak plantations and their adjacent natural vegetations were not significant. The observed significant differences in soil nutrient values among teak plantations and among the natural vegetations could be attributed to differences in factors such as microclimate, soil biological community, litter quality, topography and nutrient status across the study areas. Generally the older teak plantations recorded lower values of soil nutrients than their adjacent natural vegetations as compared to the younger teak plantation. The current study has added to the observation that soil nutrients become deteriorated with age under teak plantations.

Keywords: Teak, Plantation, age, Natural vegetation, Soil nutrients, Deterioration.

Introduction

It is estimated that the global rainforest cover has decreased from 1,500 million hectares to less than 800 million hectares in the last 200 years, and just in the past 50 years, one third of tropical rainforests have been destroyed[1]. In this past 50 years much of the rainforests in Africa of which Ghana is part is being destroyed at double the rate of all previous estimates[2]. In Ghana the high rate of forest destruction has been attributed to factors such as wildfires, landownership systems, settlement development, shifting cultivation, illegal logging, mining and livestock grazing[3].

The importance of forest cannot be over emphasised, it is a pillar for man's survival in all aspects of life, socially, economically and environmentally. Forest destruction has therefore serious consequences on the environment, such as, decline in biological diversity leading to probable extinction of some plants and animals, alteration in climatic patterns, problems in water supply, soil erosion and deterioration in soil structure which may result in soil nutrients loss.

Governments, institutions and other bodies globally have seen the necessity to protect and conserve existing forests and restore degraded and deforested lands for the survival of man on earth.

Ghana's Forest and Wildlife Policy of 1994 encouraged economic tree planting[4], and this has led many to show interests in tree plantation development, especially teak (*Tectona grandis* Linn F) both as an investment potential and natural resource conservation. However, teak plantation establishment in Ghana started in the 1960s and has led to the establishment of large plantation areas both in-and off-forest reserves by government and private sectors[5]. Now farmers cultivate teak as part of their farming system.

Tree plantations have the potency to protect and restore degraded soils and their hydrological functions in the water cycle[6,7]. Trees have nutrient enrichment effect on soils[8]. Studies have indicated that tree plantations can reverse land degradation processes by stabilizing soils through development of extensive root systems, increasing soil organic matter through enhancement of aboveground litter production, moderation of soil pH and improvement of soil nutrient status[9].

Though teak plantations have been found in some cases to bring better soil conditions[10-12], other studies have found soil deterioration in teak plantations[13-15].

Considering the variations of results from soil characteristics studies under teak plantations and the possibility of farmers reusing lands in teak plantations for faming after harvest, further studies of soil characteristics under teak plantations are imperative. The current study was therefore aimed at assessing the impact of teak plantation on soil chemical properties of four teak plantations in Ghana.

Materials and methods

Study areas: The study was conducted between July, 2015 and October, 2015. The study areas comprised of four teak plantations located in Nsuta (Sekyere Central District - Longitudes 0°05'W and 1°30'W and Latitudes 6°55'N and 7° 30'N), Ejura (Ejura/Sekyedumase Municipality - Longitudes 1°5″W and 1°39″W and Latitudes 7°9″N and 7°36″N), Asamang and Bedomase (Sekyere South District - Longitude 1° 40'W and 1°25'W and Latitude 6°50'N and 7°10'N).

The plantations were 7, 9, 12 and 17years old for Bedomase, Asamang, Ejura and Nsuta areas respectively. Teak trees were regularly planted with an average planting distance of 3 x 3m. The plantations ranged between one to two hectares in size.

Soil sampling and analysis: Soil samples were randomly picked (0 -15cm) from the teak plantations and their adjacent natural vegetations with soil augur. Within each site ten samples were sampled. Out of the soil samples that were collected from each site, two sets of samples were mixed together to create five composite samples which served as replications. Soil samples were air dried and passed through a 2 mm sieve prior to soil analysis.

Standard laboratory methods were used to determine soil chemical properties. Organic matter were determined by the Walkley and Black[16] wet oxidation method, total nitrogen and total phosphorus were assessed through the methods described by Anderson and Ingram[17], total K and exchangeable K were determined by the method described by IITA[18] and available phosphorus determined through the Bray method[19]. Soil pH was measured in 1:2.5 soil-water suspensions with glass electrode pH meter. Electrical conductivity (EC) was measured by an electrical conductivity meter.

The data were subjected to analysis of variance (ANOVA) and the Least Significant Difference Test ($P<0.05$) for the separation of means using the GenStat (11th Edition) statistical software package.

Results and discussion

Soil organic matter (SOM) changes between teak plantation and adjacent natural vegetation in the four locations are shown in Figure-1. With the exception of the Bedomase study area with younger teak age (7 year old teak) the SOM was found to be higher in the adjacent natural vegetation (N) than its corresponding value under the teak plantation (T) for the Nsuta, Ejura and Asamang study areas. The differences in SOM value were significant at the Nsuta and the Bedomase areas. Among the teak plantations the highest SOM was recorded at the Nsuta area with older teak age (17 year old teak). Comparing the SOM values under the natural vegetations among the study areas, SOM value was found to increase with increasing age of the teak plantation.

The percentage total soil nitrogen was found to be higher though not significant in the natural vegetation cover than its corresponding teak plantation at Nsuta, Ejura and Asamang study areas (Figure-2). The value at the Bedomase area was rather significantly higher in the teak plantation soil than the natural vegetation. The changing pattern of the percentage total soil nitrogen seemed to be a reflection of the percentage SOM (Figure-1).

The total soil phosphorus was higher in the teak plantation than its adjacent natural vegetation at Ejura and Bedomase study areas but was at the other way round at Nsuta and Asamang study areas (Figure 3). Variations in total soil phosphorus values were noted between study areas. Among the teak plantations the Bedomase study area recorded the highest total phosphorus value which was significantly the same as the value from the Nsuta teak plantation; the 9 year old teak plantation at Asamang recorded the lowest value. The highest total phosphorus recorded among the natural vegetations was from the Nsuta study area and the lowest value was recorded at the Ejura study area.

Figure-4 indicates the soil available phosphorus measured in the study areas. At the Ejura and Bedomase study areas the soil available phosphorus was higher in the teak plantation than the corresponding natural vegetation, but was higher in the natural vegetation than the teak plantation at the Nsuta and Asamang study areas. The 7 year old teak plantation at Bedomase recorded the highest soil available phosphorus value among the teak plantations but the value was not significantly different from the others. Among the natural vegetations the Nsuta study area recorded significantly the highest soil available phosphorus value with the Bedomase study area registering the lowest value.

Similar to the pattern of soil total phosphorus changes (Figure-3), the total soil potassium was higher in the teak plantation than its adjacent natural vegetation at Ejura and Bedomase study areas but at Nsuta and Asamang study areas the potassium was higher in the natural vegetation than the teak plantation (Figure-5). Comparing the soil total potassium values among the teak plantations, the 12 year old plantation at Ejura recorded significantly the highest value while the Asamang teak plantation registered significantly the lowest value. Among the natural vegetations the soil total potassium values increased with increasing corresponding age of teak plantation.

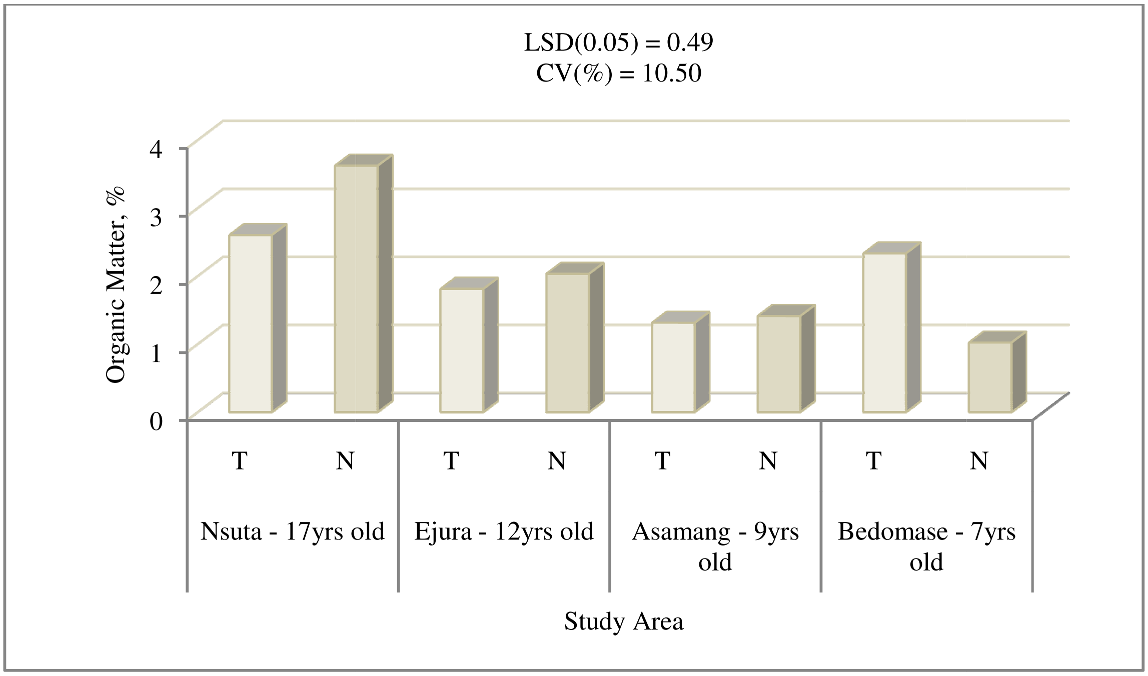

Figure-1: Soil organic matter under teak plantation (T) and natural vegetation(N) in four locations

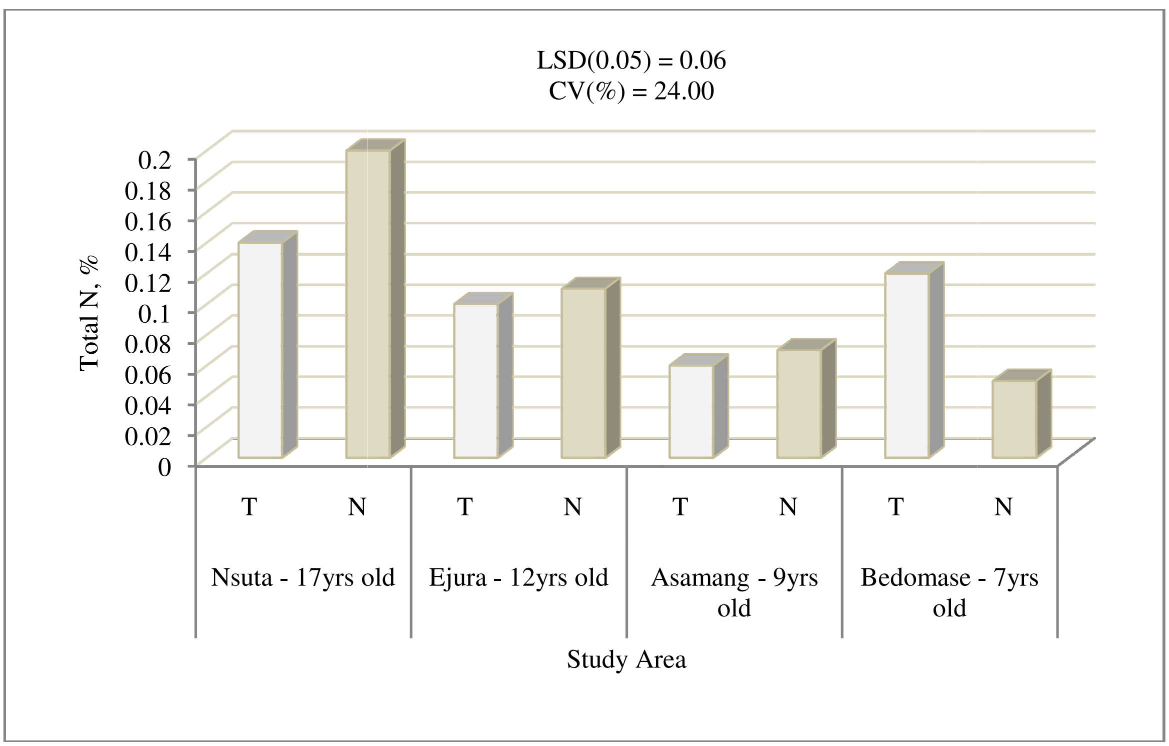

Figure-2: Soil total nitrogen under teak plantation (T) and natural vegetation (N) in four locations.

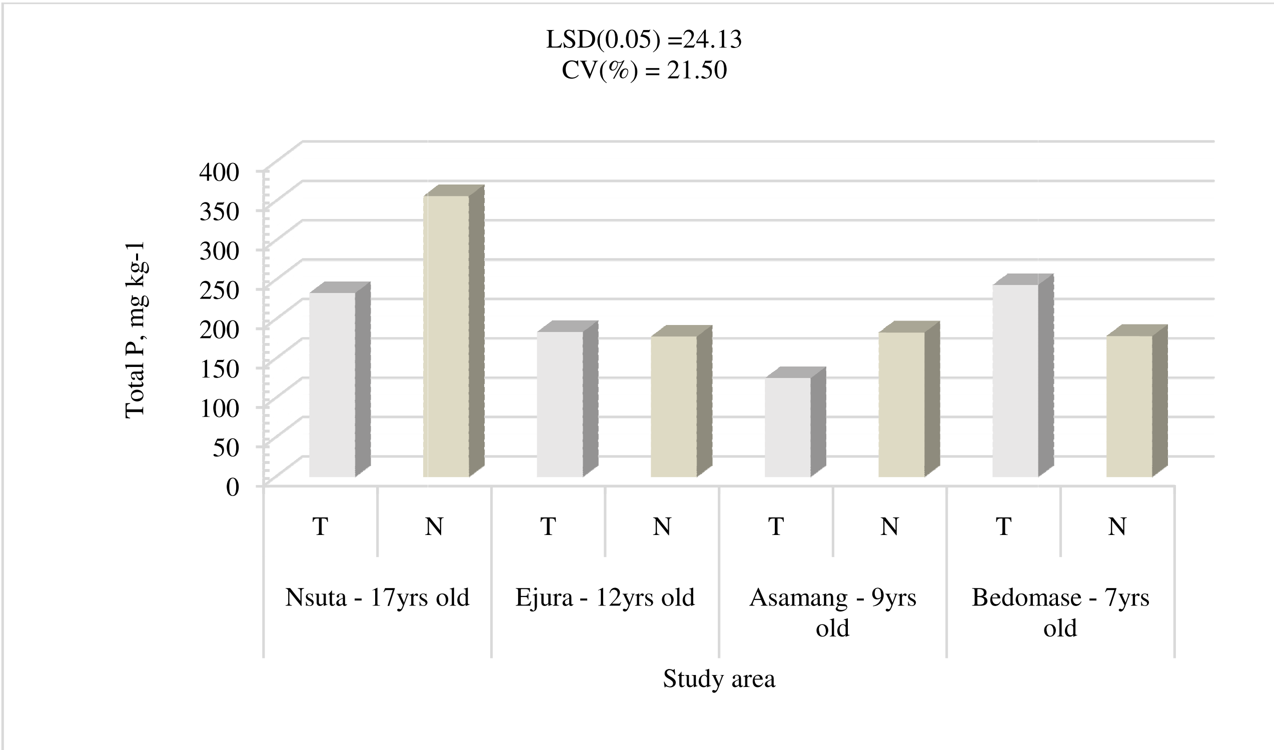

Figure-3: Soil total P under teak plantation (T) and natural vegetation (N) in four locations.

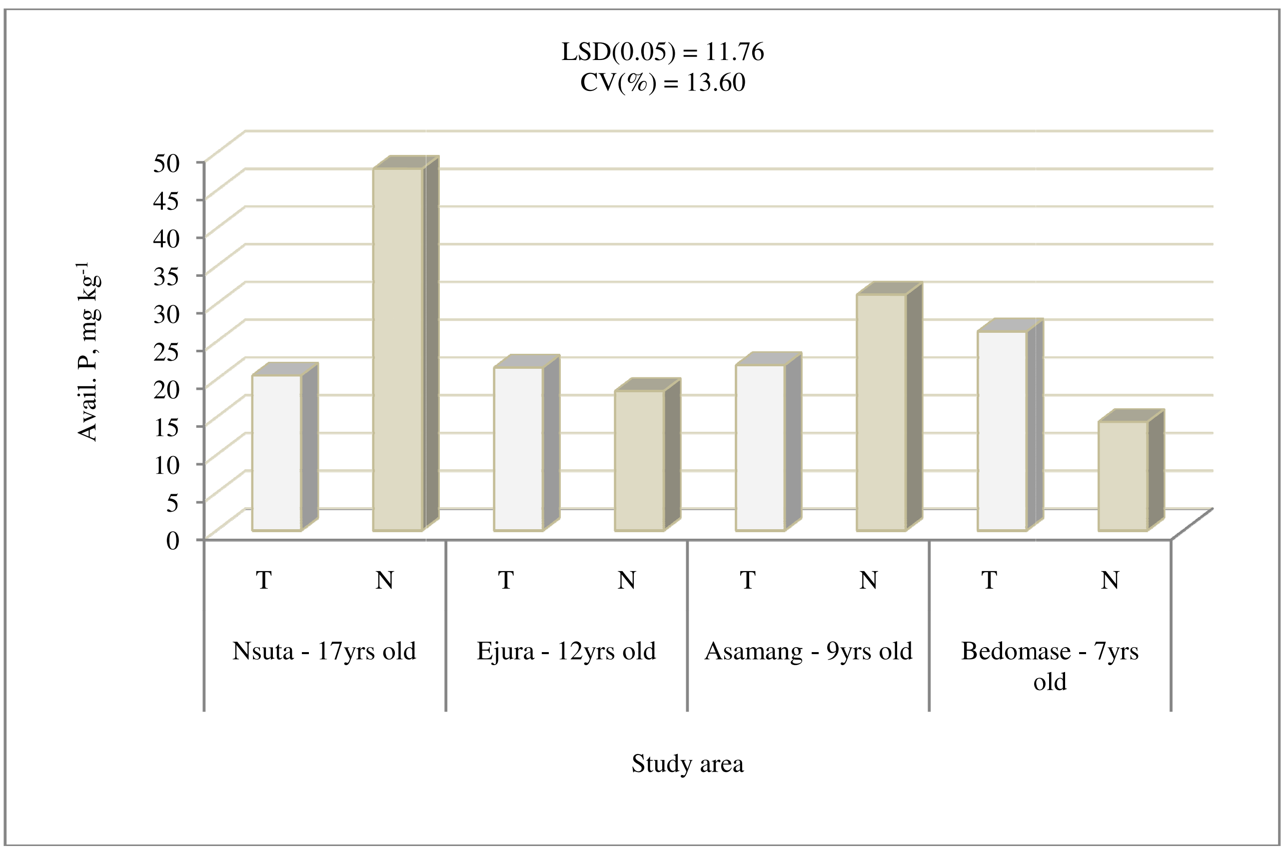

Figure-4: Soil available P under teak plantation (T) and natural vegetation (N) in four locations.

The soil exchangeable potassium assessed in the study areas is presented in Figure-6. With the exception of the Bedomase study area with younger teak age (7 year old teak) the soil exchangeable potassium was found to be higher in the adjacent natural vegetation (N) than its corresponding value under the teak plantation (T) for the Nsuta, Ejura and Asamang study areas. The 17 year old teak plantation at Nsuta recorded significantly the highest value for soil exchangeable potassium among the plantations with the 9 year old plantation from Asamang recording the lowest. Among the natural vegetations the Nsuta study area recorded significantly the highest soil exchangeable potassium value with the Bedomase study area recording the lowest value.

With the exception of the Bedomase study area, soils in the natural vegetations recorded higher electrical conductivity (Ec) than their adjacent teak plantations (Figure-7). The Bedomase teak plantation recorded significantly the highest value for the Ec among the teak plantations with the lowest value coming from the Ejura area, which was found to be similar to the value obtained from the Asamang area. Among the natural vegetations the Nsuta study area recoded significantly the highest Ec value with the Ejura study area registering the lowest value.

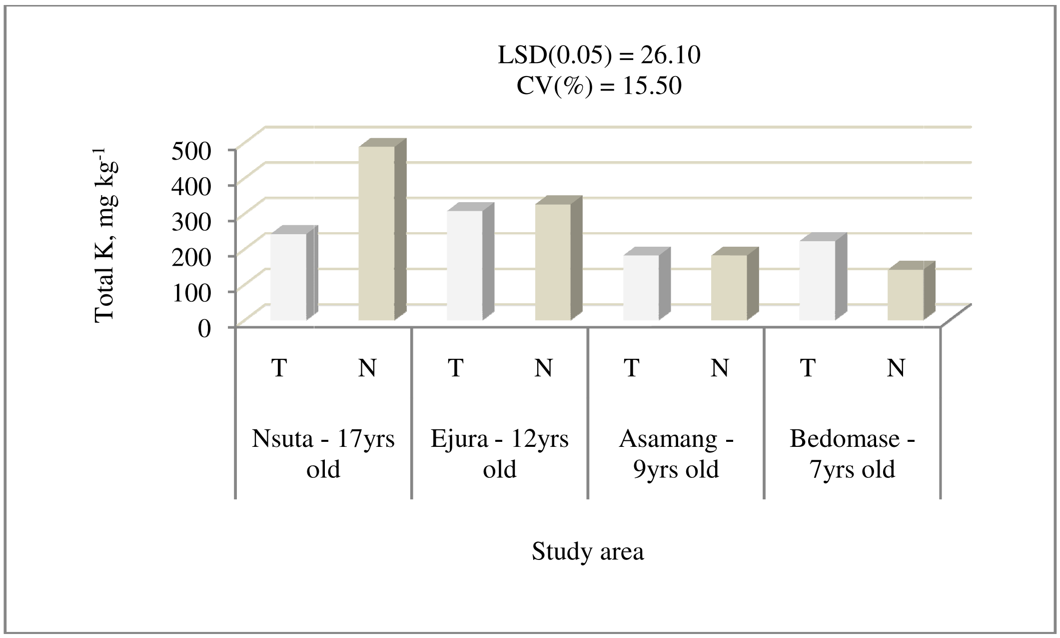

Figure-5: Soil total potassium under teak plantation (T) and natural vegetation (N) in four locations.

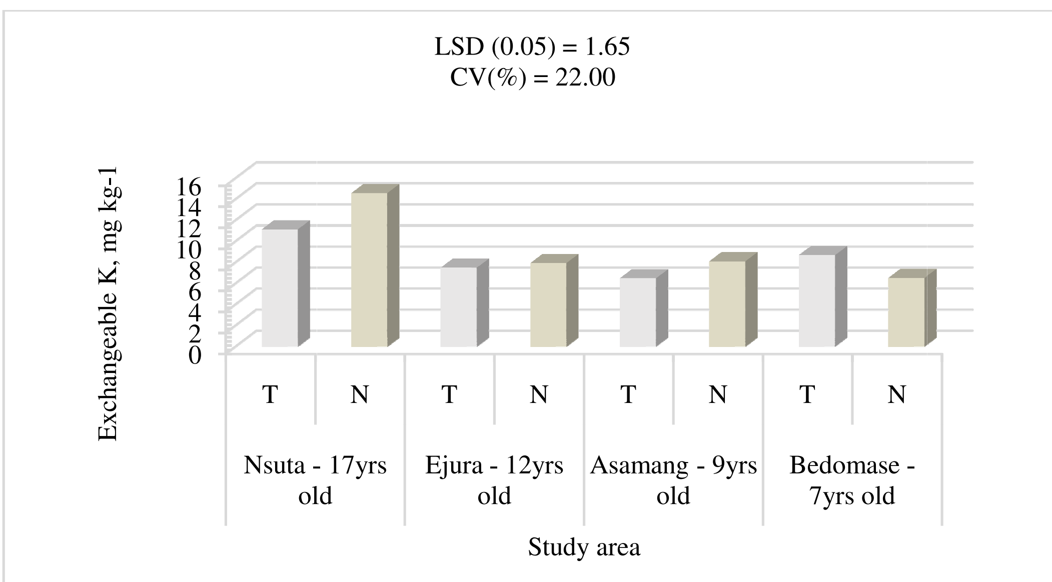

Figure-6: Soil exchangeable K from soils under teak plantation (T) and natural vegetation (N) in four locations.

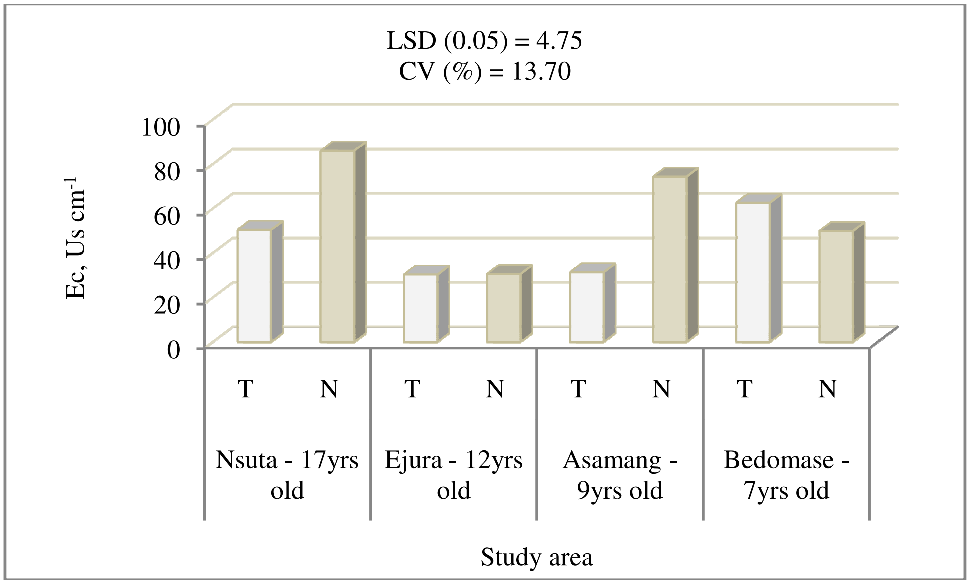

Figure-7: Soil electrical conductivity (Ec) under teak plantation (T) and natural vegetation (N) in four locations.

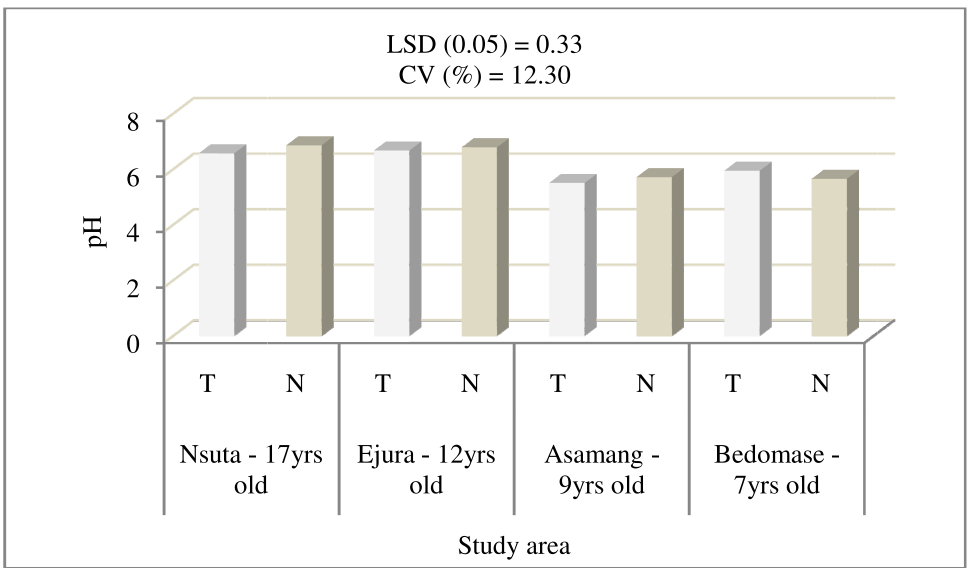

Figure-8: Soil pH under teak plantation (T) and natural vegetation (N) in four locations.

No significant differences were found in the soil pH values between the teak plantations and their adjacent natural vegetations (Figure-8).

Discussion: Soil organic matter, total nitrogen, total phosphorus, available phosphorus, total potassium, exchangeable potassium and electrical conductivity were higher in the 7 year old teak plantation than in the adjacent natural vegetation. However, with the exception of total phosphorus, total potassium and available phosphorus, all at Ejura where the values were higher in the teak plantation soil than its adjacent natural vegetation (the values were statistically not different), all the other soil chemical properties were higher in value in the natural vegetation than in the teak plantation (9, 12 and 17 year old teak plantations). Such decline in soil nutrients under the teak plantations has been observed in recent studies. Samndi and Jibrin[20] found available P and Total Exchangeable Bases (TEB) to decrease linearly with aging teak plantations. In comparative studies of soil nutrients in plantations and with the nutrients in the natural forest in Nigeria, Adekunle *et al.*[21] found an adverse impact of the plantations on soil nutrient status. Organic carbon, total carbon, total nitrogen and soil organic matter have been found to be lower in a teak plantation than in an undisturbed primary forest[22]. Decline in soil chemical properties under teak plantations have also been observed by Healey and Gara[14] and Boley *et al.*[15] in previous studies.

In other tree plantation studies, Goma-Tchimbakala *et al.*[23] in a comparative study of soil chemical properties in four *Terminalia superba* plantations (7, 12, 32 and 48 year old plantations) and a natural tropical forest found the properties to initially increase in the 7 year old plantation followed by a general decrease with plantation age. Karam *et al.*[24] evaluating the differences between soils under natural and planted forests on their physico-chemical and clay mineralogical composition found the total carbon, organic matter, acidity, exchangeable bases and ECEC to be lower in the planted forests. Ekukinam *et al*.[25] also observed the levels of exchangeable Ca, Mg and K in rubber plantation soils to decline with the age of rubber tree. The higher levels of the soil chemical parameters in the natural vegetation covers than their adjacent teak plantations (9, 12 and 17 year old teak plantations) may be attributed to higher litter contribution from the undercover vegetation and less leaching losses[13,26]. The 7 year old teak plantation with less canopy closure might have higher undercover vegetation and litter contribution than the natural vegetation cover and hence the observed trend.

Generally, single species tree plantations have been found to immobilize soil nutrients faster and return less nutrients to the soil than their native vegetation, and thus leading to soil nutrients depletion[27].

On the other hand, however, some studies have found soil chemical properties to increase under teak plantations. Choubey *et al*.[10] found Organic C, and N, P and K to be higher under teak plantations than under the adjoining forest, because of better management of the plantations. Imoro *et al.*[12] revealed that the mean levels of N, O-C and P under the *T. grandis* plantation were higher than its control plot. Chamshama *et al*.[28] observed a mixture of results, they found a general decrease in soil total N in young teak plantations and an increase in the semi-mature plantations, but available P decreased in both young and semi-mature stands.

As observed by Chamshama *et al*.[28] the soil pH from the teak plantations were not significantly different from their adjacent natural vegetations, probably the nutrient changes observed were not significant enough to cause significant changes in the pH.

Differences in soil chemical properties among teak plantations and among the natural vegetation covers may be due to some factors such as, the differences in microclimate, soil biological community, litter quality, topography and nutrient status across the study areas[29].

Conclusion

In general the older teak plantations (9, 12 and 17 year old teak plantations) recorded lower values of soil chemical properties than their adjacent natural vegetations while the younger teak plantation (7 year old plantation) had the opposite result. This trend may be due to the low canopy closure, high undercover vegetation and litter contribution in the 7 year old teak plantation which might led to higher values of the soil's chemical properties than its adjacent natural vegetation cover in contrast to the older teak plantations. The soil pH, however, did not change significantly between the plantations and their adjacent natural vegetations. Differences in microclimate, soil biological community, litter quality, topography and nutrient status may explain the differences in results of soil nutrient values among plantations and among the natural vegetations across the study areas.

Acknowledgement

We thank the Soil Research Institute (SRI), Kwadaso, Kumasi - Ghana for making their laboratory available for the analyses of the soil samples.

References

1. Young People's Trust For the Environment - YPTE (2016). Rainforests - Why are They Important?. https://ypte.org.uk. Retrieved in September 2016.
2. Rainforest Concern (2008). Why are they being destroyed?. http://www.rainforestconcern.org. Retrieved in August 2016.
3. Okali D.U.U. and Fasehun F. E. (1997). Sustainable forest Management in West Africa. *Ecology, Conservation and Research, Ghana Forestry Journal*, 4, 1-9.
4. Forestry Commission (2006). The 1994 Forest and Wildlife Policy. http://www.fcghana.com/publications/laws/foresty_wildlife_policy/index.html. Retrieved in October 2016.
5. Ochire-Boadu K., Adjei L.E. and Opoku R. (2014). Assessing the growth performance of teak (Tectona grandis Linn. f.) coppice two years after clearcut harvesting. *International Journal of Agronomy and Agricultural Research (IJAAR*), 5(6), 36-41.
6. Brauman K.A., Daily G.C. and Duarte T.K. (2007). The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annual Review of Environment and Resources*, 32, 67-98.
7. van Dijk A.I.J.M. and Keenan R.J. (2007). Planted forests and water in perspective. *Forest Ecology and Management*, 251, 1-9.
8. Davis M.R. and Lang M.H. (1991). Increased nutrient availability in topsoils under conifers in the South Island high country. *NZ J. For. Sci*., 21, 165-179.
9. Chakraborty R.N. and Chakraborty D. (1989). Changes in soil properties under *Acacia auriculiformis* plantations in Tripura. *Indian For*., 115(4), 272-273.
10. Choubey O.P., Prasad R. and Mishra G.P. (1987). Studies of the soils under teak plantations and natural forests of Madhya Pradesh. *Journal of Tropical Forestry*, 3(3), 235-238.

11. Mapa R.B. (1995). Effect of reforestation using *Tectona grandis* on infiltration and soil water retention. *Forest Ecology and Management*, 77(1-3), 119-125.

12. Imoro Z.A., Tom-Dery D. and Kingsley A.K. (2012). Assessment of soil quality improvement under Teak and Albizia. *Journal of Soil Science and Environmental Management*, 3, 91-96.

13. Amponsah I. and Meyer W. (2000). Soil characteristics in teak plantations and natural forests in Ashanti region, Ghana. *Communication Soil Science Plant Analysis*, 31(3-4), 355-373.

14. Healey S.P. and Gara R.I. (2003). The effect of a teak (*Tectona grandis*) plantation on the establishment of native species in an abandoned pasture in Costa Rica. *Forest Ecology and Management*, 176, 497-507.

15. Boley J.D., Drew A.P. and Andrus R.E. (2009). Effects of active pasture, teak (*Tectona grandis*) and mixed native plantations on soil chemistry in Costa Rica. *Forest Ecology and Management*, 257(11), 2254-2261.

16. Walkley A. and Black I.A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37, 29-38.

17. Anderson J.M. and Ingram J.S.I. (1993). Tropical soil biology and fertility: A handbook of methods. Wallingford, UK: CA International.

18. International Institute of Tropical Agriculture (IITA) (1985). Laboratory manual of selected methods for soil and plant analysis. IITA, Ibadan, Nigeria.

19. Bray R.H. and Kurtz L.T. (1945). Determination of total organic P and available forms of phosphorus in soils. *Soil Science*, 59, 39-45.

20. Samndi A.M. and Jibrin J.M. (2012). Pedogenesis and Classification of Soils Under Teak (Tectona grandis Linn. f) Plantation of Various Ages in the Southern Guinea Savanna of Nigeria. *Asian Journal of Agricultural Sciences*, 4, 16-25.

21. Adekunle V.A.J., Alo A.A. and Adekayode F.O. (2011). Yields and nutrient pools in soils cultivated with*Tectona grandis* and *Gmelina arborea* in Nigerian rainforest ecosystem. *Journal of the Saudi Society of Agricultural Sciences*, 10(2), 127-135.

22. N'Dri J.K., Andre H.M., Lagerlöf J., Tondoh J.E. and Hance T. (2013). Response of soil mite abundance and diversity to a monospecific timber *Tectona grandis* plantation in Ivory Coast. *Current Zoology*, 59(5), 633-643.

23. Goma-Tchimbakala J., Moutsambote J. M. and Makosso S. (2008). Comparison of some soil chemical properties in four *Terminalia superba* plantations and a natural tropical forest in Mayombe, Congo. *Journal of Applied Sciences*, 8, 4152-4158.

24. Karam D.S., Abdu A., Radziah O., Shamshuddin J., Husni M.H.A., Abdul-Hamid H. and Seema T. (2013). Changes in the physico-chemical properties of soils under rehabilitated lowland dipterocarps forest at Chikus Forest Reserve, Perak, Malaysia. *Journal of MacroTrends in Applied Science*, 1, 42-57.

25. Ekukinam E.U., Iwara A.I. and Gani B.S. (2014). Evaluation of phosphorus and exchangeable bases status of soil under rubber plantation of different ages in south-eastern Nigeria. *Open Science Journal of Bioscience and Bioengineering*, 1, 19-22.

26. Hossain I., Osman K.T., Kashem A. and Sarker A. (2014). Correlations of available phosphorus and potassium with pH and organic matter content in the different forested soils of Chittagong Hill Tracts, Bangladesh. *Int. J. Forest, Soil and Erosion*, 4, 7-10.

27. Aweto A.O. (2001). Impact of single species tree plantations on nutrient cycling in West Africa. *International Journal of Sustainable Development and World Ecology*, 8(4), 356-368.

28. Chamshama S.A.O., Mugasha A.G. and Sanga J.M. (2000). Comparison of some chemical properties of soil under teak and natural forests at Mtibwa, Morogoro, Tanzania. *Journal of Tropical Forest Science*, 12, 92-103.

29. Hossain M.I., Kashem M.A. and Osman K.T. (2014). Fertility Status of some Forested Soils of Chittagong Hill Tracts, Bangladesh. *International Journal of Latest Research in Science and Technology*, 3(1), 82-87.