EFFECTS OF OIL PALM CULTIVATION ON THE PROPERTIES OF SOIL IN SOME SELECTED AREAS OF NAGODA DIVISIONAL SECRETARIAT IN THE GALLE DISTRICT, SRI LANKA

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ABSTRACT

A research was carried out to determine the effects of oil palm cultivation on the properties of soil in some selected areas of Nagoda Divisional Secretariat in the Galle district, Sri Lanka. The results clearly indicated that oil palm cultivation had significantly affected on the moisture content of soil in comparison with rubber monoculture and, bulk density of soil was not seriously affected due to oil palm compared to tea, where very high bulk density values were reported. It is evident from the results that ability to hold water in oil palm cultivation was in between rubber and tea. However, the results revealed that oil palm soil is significantly acidic like other monocultures leading to possible soil degradation in the near future. Cation Exchange Capacity (CEC) of oil palm cultivated soil was fairly good. The results for earthworm population were high in oil palm planted soil compared to tea and rubber monocultures. A drastic decrease/drop of termite population has been recorded for Oil palm cultivated soil. Comparatively dense weed cover over the ground of a 22-year- old oil palm cultivation had conserved moisture compared to a 2 year old site and a significantly low bulk density has resulted in 22-year- old cultivation. A significantly high moisture holding capacity, low aggregate stability, a reasonable increase of pH, a significantly high CEC and an unexpected increase of earthworm population were observed for the 22-year- old plantation. Overall results indicated that soils under oil palm are not affected significantly due to this monoculture. However, the results highlighted a significant acidification by oil palm compared to other monocultures and low aggregate stability in cultivated soils. Since oil palm cultivation has been rapidly expanding in many areas in Sri Lanka, further research is required to decide on the adoption of suitable management plan to reduce the loss of soil quality with long term cultivation.

Key words – moisture content, bulk density, water holding capacity, soil degradation

Introduction

Oil Palm (*Elaeis guineensis Jacq.*) has become one of the most rapidly expanding equatorial food and bio fuel crops in the world (USDA, 2011). The areas where the annual rainfall is more than 1800mm, temperature is 20^0C- 40^0C and sun setting is more than 05 hours per day are suitable for the oil palm cultivation. Accordingly, in Sri Lanka, there is a feasibility to grow oil palm in the districts of Matara, Galle, Kalutara, Colombo and Kegalla, and Gampaha, Kurunegala, Kandy, Matale and Ratnapura districts as well. The oil palm cultivation initiated in an area of about 20 hectares of Nakiyadeniya estate in year 1969 had been expanded to 1200 hectares by the year 1974, and it was further expanded to 03 State Plantation Companies in Kalutara and Matara districts in the year 2000. In addition, oil palm refinery factory was commenced in Kalutara district in the year 2007. At present, the oil palm cultivation has expanded to approximately 7000 hectares and the cultivation in the estates has been entirely undertaken by the Regional Plantation Companies. Since the introduction of oil palm to Sri Lanka in 1969, a large amount of land under rubber plantation in Galle and Kalutara districts were replaced by oil palm. In recent years, some plantation companies started replacing tea also with oil palm.

The environmental impact of oil palm plantation establishment may be categorized based on three principle effects: change in the greenhouse gas balance (Hamer,1981), reduction of biodiversity by fragmentation, disturbance and destruction of natural habitats (Laidlaw, 2000) and reduction of fresh water and soil quality (Fitzherbert *et al.*, 2008).

Soil quality is an important factor for a country like Sri Lanka, where agriculture is still the main livelihood of most of the people. Therefore, soil degradation can directly affect the country's economy due to low productivity from degraded lands. Although the oil palm cultivation is being expanded within the country, any environmental impact assessment has not been done to identify the potential threats of the cultivation to the environment. Therefore, it is imperative that baseline studies should be

carried out to understand the effects on soil by this newly introduced monocultures so that measures could be taken without delay.

The main objective of the present study is to understand the status of soil under oil palm cultivation based on soil physical, chemical and biological properties in comparison with two other monocultures and a regenerated forest as the control. Therefore, the study was primarily designed to assess the soil quality changes with different crop types and with different age of the oil palm cultivation.

Materials and methods

Soil samples for determining the soil quality parameters were collected from five different sites: two year old oil palm cultivation, twenty-two-year-old oil palm cultivation, a tea plantation, a rubber plantation and a regenerated forest. Sample collection was done using Randomised Complete Block Design (RCBD).

All physical(moisture content, bulk density, porosity, maximum water holding capacity and aggregate stability), chemical(pH and CEC) and biological (earth warm and termite populations) properties of the soil samples were determined using standard methods(Robinson,1994). Changes of the soil quality parameters with the crop type and age of the oil palm cultivation were separately analyzed using simple t-test.

Results and discussion

The results of the present study show that % moisture content and Water Holding Capacity(WHC) of oil palm are similar to the forest indicating no significant change due to monoculture. However, these values are comparatively higher than tea monoculture and lower than rubber cultivation(Fig 1 & 2). This could be due to the having an underground cover with a densely grown cover crop (*Pueraria phaseoloides*) in oil palm cultivated land and thereby releasing decaying organic matter as reported by Ahukaemere *et.al.*,(2012). Therefore, no significant difference (t = 1.2665) was recorded between oil palm cultivation and the regenerated forest.

Figure 1- Variation of the soil moisture content

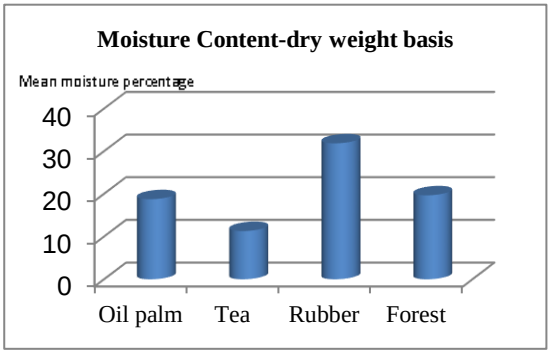
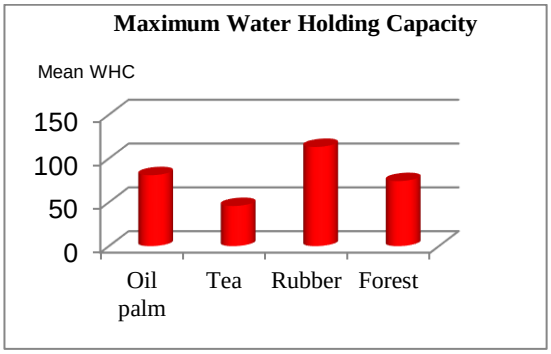


Figure 2- Variation of the maximum water holding capacity



According to USDA Report, one of the reasons for high bulk densities is lack of organic matter in the soil. Lalfakzuala *et.al.*,(2008) suggested that heavily cultivated agricultural areas disrupt soil productivity due to depletion of soil organic matter. Since oil palm cultivations are heavily fertilized, depletion of organic matter could be expected. However, present results on bulk density clearly indicated that oil palm soil was not significantly affected compared to forest(t = 0.7095). Further, Tea monoculture soil is severely degraded based on bulk density values(t = 4.72). Having a soil cover under oil palm monoculture would have protected the soil by supplying adequate organic matter through decomposition thus improving porosity. The results for % porosity in the present study highlighted that porosity of Oil palm cultivation has exceeded all the other tested monocultures and the forest. Therefore, it is evident that oil palm cultivation as a monoculture does little environmental damage as reported by Henson(1994).

Discussing about the soil quality indicators, USDA Report(2011) suggested that organic matter increases a soil's ability to hold water, both directly and indirectly. Having similar values for both WHC and aggregate stability for oil palm cultivated soil and forest soil further established the fact that organic matter improves soil structure and aggregate stability, resulting in increased pore size and volume. Aggregate stability is an important soil parameter in deciding on the soil quality and also an indicator on the presence of Organic Matter(OM)(Eneje and Kalu, 2012). Therefore, low aggregate stability reported in this study for Oil palm compared to the forest could be a sign of structural change in soil due to oil palm even though OM is there in abundance.

Soil acidification is a particular concern in oil palm; for example on permeable soils in a high rainfall zone of Papua New Guinea, soil pH in the upper 20 cm of soil declined between 0.52 and 0.96 pH units over four years, likely due to leaching of nitrate from ammonium-based fertiliser (Nelson *et al*., 2011). In the present study too, the pH has significantly increased (t =

9.15) in comparison with the forest. This could be due to high leaching under oil palm thus leaving more stable cations like Fe and Al as reported by Ahukaemere(2012) or could be due to application of fertilisers as reported by Nelson *et.al*.,(2011). However, this could be a sign of soil degradation and should be further investigated.

Figure 3- Changes of the CEC of soil

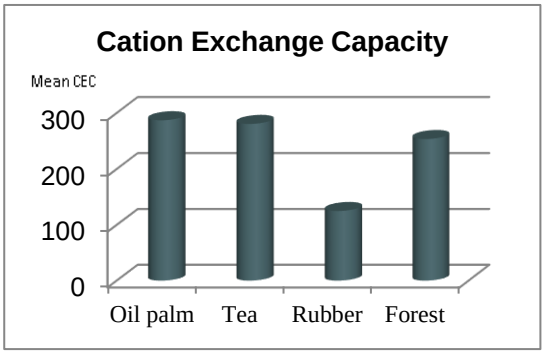
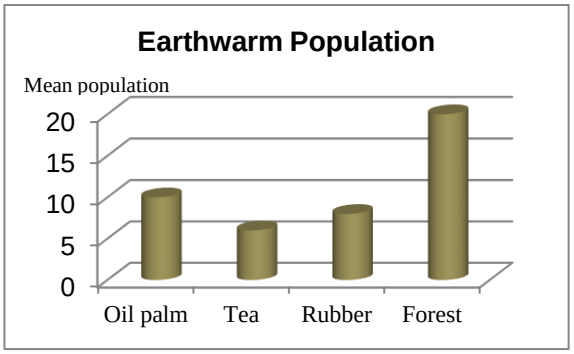


Figure 4 - Changes of the earthworm Population



Among nine major first generation biofuels, oil palm was the most sustainable with respect to soil quality, based on the quantity of organic matter in the soil one year after application of crop residues (de Vries *et al.*, 2010). Further, Cation Exchange Capacity(CEC) of a soil is directly proportional to the amount of organic matter of that soil. Therefore, data obtained for CEC in the present study clearly shows that oil palm cultivated soil has high CEC thus confirming the presence of uninterrupted supply of organic matter as highlighted to bulk density data in this study. This high organic matter could be due to the fibrous root system of oil palm that helps to reduce leaching and also high accumulation of organic matter under oil palm canopies by the recommended management practices.

Lalfakzuala *et al*., (2008) suggested that it is important to study biological properties as well because they act as sensitive indicators that can be used to quantify soil fertility and quality. Earthworms are considered as one of the most important soil fauna that provide channels to increase the porosity in soil to have high infiltration(Lee, 1985). Further, earthworms contribute to soil turnover, structure formation and serve as a fertility enhancer in various ways. Earthworms and their casts are useful in land improvement, reclamation and in organic waste management (Villenave *et al*.,1999). In the present study, earth warm population is significantly high in the forest compared to oil palm soil($t = 4.32$). This decline of earthworm under oil palm could be due to the management practices, high soil temperature under monocultures, preference of plant species, site of sampling etc., as reported by Sabrina *et.al*., 2009.

Termites are one of the popular studied insect to the research community nowadays and this is mainly due to the economic damage caused by their voracious appetite for wood as well as their potential in biomass conversion to fuel (Bong *et.al*.,2012). However, the data in the present study reveals that termite population is very low under oil palm cultivation even though their presence is important in soil. This could be due to the unsuitability of biotic and abiotic elements present under oil palm soil.

Soil in cultivated land may change its productivity after forest conversion and it is possibly related with the change of chemical properties and fertility of the soil. Soil chemical properties and soil fertility rate are both crucial components of soil that greatly subjected to the impact of the forest conversion into oil palm plantation (Dewi, 2007). Measuring of these changes with the age of the plant is one way of getting an understanding on the soil quality changes with plantations.
The moisture content of the present study is significantly higher in the 22-year- old oil palm plantation than 2-year-old plantation($t = 16.51$). This may be due to densely grown weed cover and availability of decaying organic matter with the age of the cultivation.

When bulk density values of the present study is considered, it is clear that a value similar to forest has been recorded for older plantation and this could be due to the availability of organic matter with the age. Since the porosity and the amount of decaying plant debris were higher in 22 year old oil palm cultivation, the water holding capacity too showed significantly higher value than 2-year plantation($t = 9.417$). When the cultivation is established over a period of time with good management practices and with recommended doses of fertilizer, most of the physical parameters remain unaffected as reported by Seca *et.al.*, 2014.

Table 1- Comparing the means of soil quality parameters with the age of the oil palm cultivation

Soil quality parameter	**Comparing crops**	**Calculated t value**	**Significantly different or not**
Soil moisture content	22 yr old oil palm and 2 yr old oil palm	16.353	Significantly different
Bulk density	22 yr old oil palm and 2 yr old oil palm	2.489	Significantly different
Porosity	22 yr old oil palm and 2 yr old oil palm	1.4602	No significant difference

Maximum water holding capacity	22 yr old oil palm and 2 yr old oil palm	9.417	Significantly different
Aggregate stability	22 yr old oil palm and 2 yr old oil palm	3.4045	Significantly different
pH	22 yr old oil palm and 2 yr old oil palm	5.3874	Significantly different
CEC	22 yr old oil palm and 2 yr old oil palm	4.904	Significantly different
Earth warm population	22 yr old oil palm and 2 yr old oil palm	3.7735	Significantly different
Termite population	22 yr old oil palm and 2 yr old oil palm	1.6186	No significant difference

Significantly higher aggregate stability values of 2 yr old oil palm cultivation (t = 3.404) may be due to the removal of A horizon of soil by heavy soil erosion under monoculture plantations and during site preparation as reported by Gardiner and Miller(2004). Sub soil is always stable as it is not affected by the routine eluviation processes in soil.

Nelson *et.al.*,(2011) reported that soil pH was acidified with time in the Oil palm agro-ecosystem in Indonesia. The results of the present study too revealed that pH of 2-year cultivation has decreased compared to the forest but significantly increased when the site is 22-yrs-old (t = 5.38). However, initial acidifying the soil could have adverse impacts on yields and management practices should be aligned to have suitable measures to control. Basuki(2014) reported that the highest CEC value in a 22-year-old oil palm cultivation may be due to availability of organic matter and continuous application of chemical fertilizer for 22 years. Therefore, it is evident from this study that both pH and CEC are getting adjusted with time with no harm to the soil.

Soil organic matter content seems to be the factor affecting the abundance of different earthworm populations in different sites. Therefore, presence of plant debris in 22 year old oil palm cultivation might have provided a better soil environment for the survival of earthworms(t = 3.77).

General conclusion

The results of this study indicate that oil palm cultivation do little harm to the soil compared to other monocultures such as tea and rubber. However, pH and aggregate stability which are two very significant properties of soil have been affected by oil palm and should be extensively investigated to reach a final conclusion. When the effects with age of oil palm on soil are considered, it is obvious from the results that two-year-old oil palm cultivation has affected the soil more than 22-yr-old cultivation. Effect of twenty two year old oil palm cultivation for most of the properties of soil is negligible. However, the economic life of the oil palm tree is 20 – 25 years. So when it reaches 22 years, it is almost abandoned. Such plantations are usually uprooted and the oil palm cultivation is re-established by the farmers. As a result, soil degradation may take place continuously. The study found no significant deterioration in the measured soil properties over the years, suggesting that appropriate management practices for oil palm can improve several aspects of soil quality as far as long term cultivations are concerned.

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