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A Study on the Impacts of Corn cultivation (*Zea mays* (L.) Family – Poaceae) on the properties of Soil

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Abstract- Maize or Corn (Zea mays L.) is the most important cereal in the world after wheat and rice. It possesses high nutritive value and is important as a coarse grain. In Sri Lanka, this crop has cultivated, around 30,000ha and local consumption is around 200,000mt annually. Further, Maize is an easily grown crop and the cultivation has been popular among farmers as a cost effective crop with limited fertilizers. This Crop earns a reasonable foreign exchange as it is used as infant foods. Maize has a higher leafy mass and higher vegetative growth within shorter period of time than the other monoculture crops. Therefore, like for many other cereal crops, it is worthwhile in studying the environmental impacts due to this plant. Many researchers have shown that soil is the most affected environment due to monoculture plants. But no proper studies on soil quality changes due to this maize crop have been conducted in Sri Lanka. Therefore, it is high time for us to initiate this kind of preliminary study directing relevant authorities to implement suitable extensive research in this area. The objectives of the present study were to find out how soil properties have changed due to corn cultivation, to assess whether soil is under stress or degraded (reduced soil quality) and to suggest suitable measures to restore the soil or improve the soil quality. This study attempted to examine the level of soil deterioration occurred over the time and some impacts on soil quality during different growth stages of maize such as beginning stage, growing stage, blooming stage and after harvesting stage. Some selected soil characteristics (physical, chemical and biological) of maize sites were tested and soil samples of adjacent forest in Anuradhapura district were used as a control. Soil moisture, soil conductivity, soil organic carbon (SOC), soil nitrate and soil microbial biomass were higher in the natural forest than maize plantation. Bulk density, air content, soil permeability, course sand and fine sand content were higher in the maize plantation than the natural forest. It is obvious that maize planted soil is under stress or leading to some soil quality degradation. Therefore, necessary measures should be applied to avoid further damage and restore the soil quality for future generations.

Index Terms- Microbial biomass, bulk density, soil quality, degradation, monoculture crops

I. INTRODUCTION

The present world production of maize is about 335million tons and maize belongs to the genus *Zea* and tribe mayease [1]. Large quantities of maize are imported for fodder, as a staple food of man, a livestock feed, a raw material for many industrial products such as infant foods and as an export product to earn foreign currency [2]. Further this crop has been introduced to many areas in the country by many local and foreign companies. This plant shows very high vegetative growth within short period of time [3]. So the scientists feel that some sort of soil quality deterioration should be there and that could lead to severe soil degradation. Further, no proper studies have been conducted to investigate whether there is any impact on the soil quality due to this monoculture maize plantation, especially in Sri Lanka. Several studies have been carried out in other countries and they have indicated intensive soil quality changes due to corn cultivation. Maize has a large number of cultivars with different maturity periods and with different tolerance levels to environmental condition. Maize can be grown on a wide variety of soils, but well drained, deep, silt loams with adequate organic matter is the most suitable.

Soil is a valuable resource and the importance of soil has made the scientist to attempt in identifying its functions (sustains biological activity, diversity and productivity, regulates and partition water and solute flow, filters, buffers, degrades, immobilizes and detoxifies organic and inorganic materials including industrial and municipal wastes and atmospheric deposition stores and cycles nutrients and other elements within the biosphere) [4].The integration of growth-enhancing factors that makes a soil productive has often been referred to as "soil quality". The Soil Science Society of America (1984) defines soil quality as an inherent attribute of a soil which is inferred from soil characteristics or indirect observations (e.g., compactability, erodibility, and fertility). Soil quality is the capacity of a soil to function within an ecosystem and sustain biological productivity, maintain environment quality and promote plant and animal health [5]. The chemical and biological soil quality indicators for agro ecosystems which are useful in evaluating the soil quality status owing to their early reaction to soil condition change [6]. Among these indicators, microbial and biochemical properties have been widely reported for measuring the soil quality [7].

Soil quality can decline for many reasons. Not just wind and water erosion but also such degradative processes as nutrient losses from runoff and leaching, depletion of soil organic matter, crusting, compaction, and desertification. It can also decline through the accumulation of toxic substances such as residual pesticides. The maintenance or restoration of soil quality is highly dependent on organic matter and an array of beneficial macro organisms and microorganisms that it supports. The proper and regular addition of organic amendments such as animal manures and crop residues can effectively offset many of these degradation processes. It also is the best way to develop a biologically-active soil that requires less energy for producing crops; increases the resistance of plants to pests and diseases; and enhances the decomposition of toxic substances such as residual

pesticides [8]. Soil microorganisms and invertebrates play a vital role in the decomposition of organic matter and nutrient cycling, and could be important indicators of soil quality. Improved soil quality is generally indicated by increased infiltration, macro pores, aggregate size and stability, soil organic matter, and aeration, and by decreased soil resistance to tillage and root penetration, and decreased runoff and erosion [9].

Soil physical conditions have an influence on crop yield and it can be determined by **Soil Condition Index (SCI).** Extractable P and K, pH, Soil organic matter (SOM), active C, water-stable aggregates, bulk density, penetrometer resistance and microbial bio mass/ diversity were measured for the determination of **Soil Quality Index (SQI).** It is a good indicator to assess the soil quality and impacts of agricultural practices on the physical, chemical and biological fertility of soil. Microbial community also responds to these changes.

Soil deterioration/degradation is soil quality becoming reduced and not suitable for plant growth. The mechanisms that initiate soil deterioration/degradation are grouped as physical, chemical and biological. Chemical mechanisms are mainly related with the Fertility depletion. It is the qualitative and quantitative reduction of nutrients present in the soil. It occurs when the components which contribute to fertility are removed and not replaced and leading to poor crop yields. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management. Soil fertility decline is a major biophysical problem of any crop production. Biological degradation is mainly related with the depletions of the vegetation cover, organic matter and the total biomass including the microorganisms [10]. When certain human disturbances as a result of cultivation are happening in any soil environment, it is obvious that soil fertility decline could be increased. Crop rotation and organic management practices are thought to have positive impacts on the microbial biomass which is responsible for the release of nutrient from soil through the processes of mineralization and decomposition by the saprophytic bacteria, fungi and some protozoan [11].

Some researches done on soil quality studies due to monoculture maize based system in the world have indicated that bulk density and moisture content were changed. Soil physical, chemical, biological properties and overall index were evaluated when considering the effect of *Zea mays* on soil [12]. Soil Organic Matter (SOM) was depleted and poor structure was also noted due to harvesting of corn (*Zea mays* L.) [13]. Soil compaction enhanced by inappropriate soil management due to corn cultivation [14].

Not only the Corn, but also other monoculture plantations affected on the quality of soil negatively or positively. The efficiency of legume cover crops to improve some soil quality parameters in the short run was studied as compared to maize-based systems. It was observed that Microbial Biomass Carbon (MBC) was increased significantly by 50.7% and 86% under legume based condition an also due to supply of great quantities of readily decomposable organic matter to the soil, from legume based treatments [15].

Very few studies have been carried out to study the effects of monoculture plantations on soil quality in Sri Lanka. Periyapperuma and Abeynayake (1989) reported some valuable information regarding some soil properties of a natural forest and an adjacent monoculture (pine plantation) in the wet zone (southern province of Sri Lanka [16].) A notable decline in the percentage organic matter and moisture holding capacity in the surface soil (0-3cm) of the pine plantation compared to a natural forest was observed. In another study by Ratnayake & Jayasekara (2000), it was reported that Nitrogen, Phosphorous, Potassium, Calcium contents and Cation Exchange Capacity (CEC) were very low in the monoculture showing that mixed species are more effective in soil rehabilitation [17]. Weerasinghe (2012) found out that soil microbial biomass is declining with land degradation, chena cultivation and also with monocultures of Teak and Eucalyptus [18].

II. Materials and Methods

Two already harvested maize sites (New site- maize cultivated for the first time, Old site- maize cultivated in continuously for 10 years) were selected in Thirappane in order to understand the impact of corn plants on soil over the time. Another Corn grown site was selected in Eppawala in Anuradhapura to study the soil quality deterioration with different growth stages. Soil samples (30X30X30 cm^3) were collected randomly in polythene bags and tied with sufficient air [19]. Ten soil samples of each study site were tested for all physical (% moisture content, sand content and permeability), chemical (pH, conductivity, Cation Exchange Capacity, Organic Carbon[20], Nitrate[21] and phosphate content[22]) and biological (soil microbial biomass[23] and total bacterial count) parameters using standard methods given in Anderson and Ingram (1998) [21]. In addition, Air content was measured in the field and fresh soil core samples were collected for bulk density measurements using the same plots. Six soil samples were obtained from dry mixed evergreen forest in Anuradhapura (adjoining to the three study sites) randomly as a control. Finally, the results were analyzed using a one way **ANOVA** with Minitab statistical software Package [24].

III. Results and Discussion

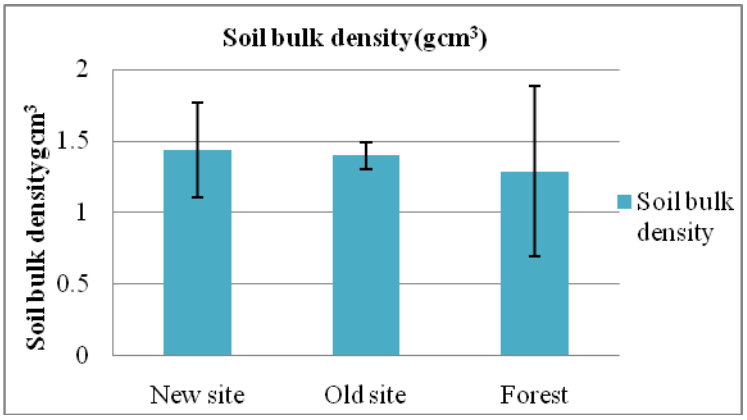

Fig 3.1- Bulk density changes with time

The data clearly shows that Bulk density has increased due to the Corn plantation within one year compared to the control(forest) indicating some sort of structural changes(1.28 –

1.45gcm$^{3)}$while observing slight decrease of bulk density over the ten years(1.45 – 1.38gcm^3). Even though results are not significant (P=0.835), these changes could be an indication of either compaction during site preparation or reduction of organic matter with the monocultures as reported by Blanco *et.al.(*2009)[25].

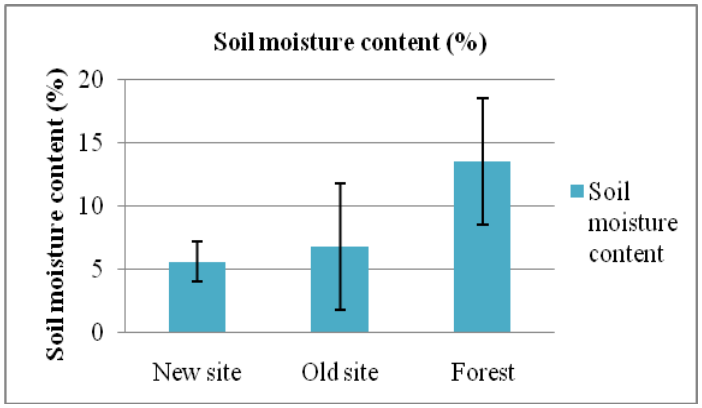

Fig 3.2 – Changes of soil moisture content with time

Moisture content has significantly decreased (13.5 to 5.61 % P = 0.017) within a year of Corn plantation. This is a serious threat by Corn cultivation and careful attention should be given to this drastic drop. This may be due to the exposure of land for heavy sunlight leading to high evaporation or due high vegetative upper biomass of Corn plants. This type of change within one year could affect on the survival of biological organisms thus creating poor biologically deteriorated soil [26].

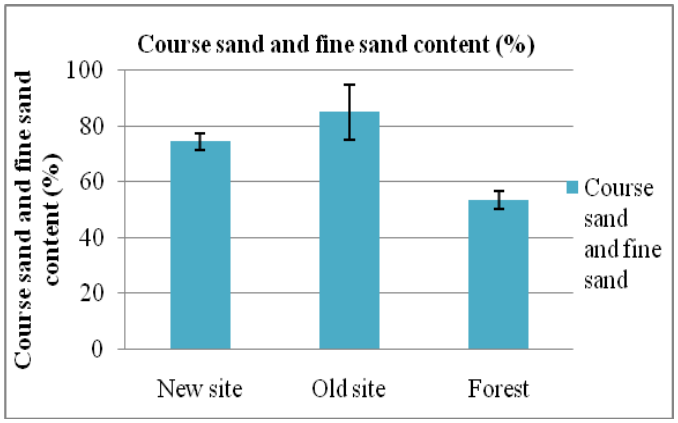

Fig 3.3 - Course sand and fine sand content of different sites

Coarse an fine sand content of soil within one year have significantly increased (P=0) from 53.8(natural) to 74.5%. It was further increased over the ten years indicating changes in soil structure with monoculture plantation as reported by. However, physical fractionation of the soils into size and size/density fractions clearly showed the effect of land use and management on the quantity and quality of Soil organic Matter(SOM). Elliot *et.al* (2000) showed that organic matter associated with the sand and silt fractions appeared to be more sensitive to changes in land use and management compared with that in clay [27]. This could be due to increased damage of soil structure and pore size due to erosion and lack of undergrowth in the maize plantation.

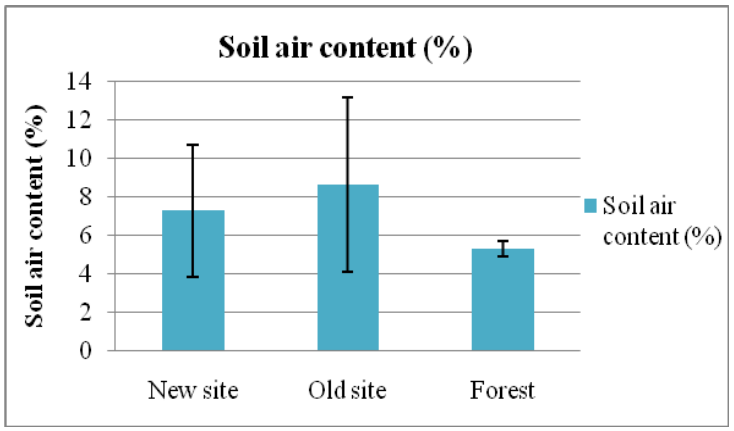

Fig 3.4 - Changes of percentage air content with time

The data clearly indicated that % air content has significantly increased (P=0.477) over the time both after one year and ten years.These results further endorse the increased coarse sand and fine sand content over the time reported in this study. It is obvious the presence of more air and less moisture with more sand content. As reported by Jagadamma(2009), the organic matter content of soil under Corn could be reduced over the time due to erosion and the absence of underground growth [28]. This also could be a result of reduced soil organic carbon due to fast growth and ersion as reported by Armand(2008) [6].

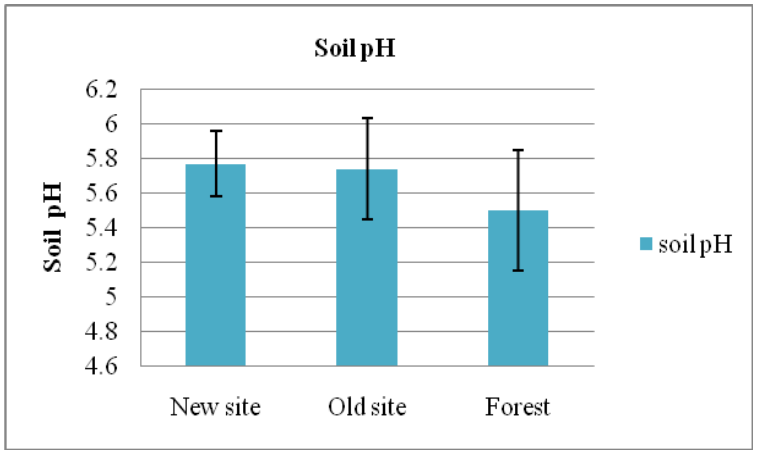

Fig 3.5 – Changes of soil pH with time

Soil pH has increased from 5.43(natural forest) to 5.77 by the end of one year indicating less microbial activity due to low soil organic matter (P=0.291). As explained by Armand(2008), single plantations always lead to create less acidic soil due to reduced moisture, low decomposition rates resulting low microbial activity[6]. No reasonable change of pH has been observed after ten years of continuous cultivation. pH changes may cause problems with nutrient absorption and retention as explained by Joan(2000)[29]. Since the pH of tropical forests is always towards acidic side, this development of less acidic condition is not favourable for biological organisms[29].

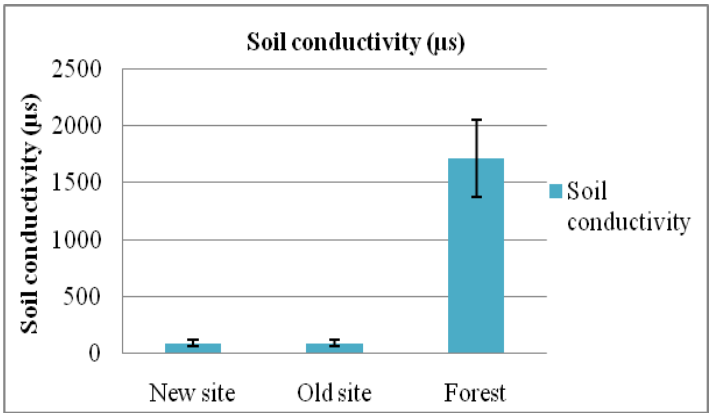

Fig3.6 – Changes of soil conductivity with time

Soil conductivity has been significantly decreased (P=0) by the end of first year from 1705 µs to 93.4 µs with no change over the ten years thereafter. This drastic drop clearly indicates the less availability of charged ions in the soil system. These results very well endorse the data obtained for ph giving further assurance on the non availability of nutrients due to less decomposition rates.

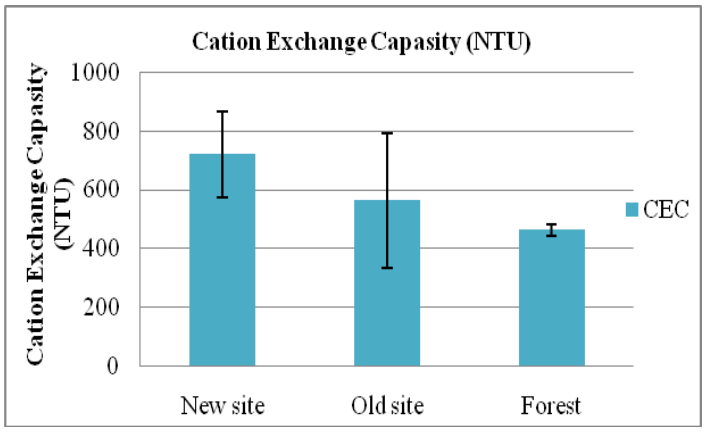

Fig 3.7 – Changes in Cation Exchange Capacity (CEC) with time

CEC in soil has significantly increased (P=0.067) from natural site(470NTU) to one year maize site (719.1) at 10% level (P<0.1). CEC of ten year old site is still higher than the forest indicating some sort of problem with anthropogenic activities on forest. This could be related to high application of fertilizers in to the maize plantation especially in the first year and slowly stabilizing with the subsequent years to have a lesser CEC. As reported by Eludoyin and Wokocha(2011) [30] cultivated soils are well supplemented with fertilizers and do not give a clear picture of real status of soil as mobilizations of ions are presumably superficial. This kind of fast ion exchange is obvious with high growth ate shown by Maize plants.

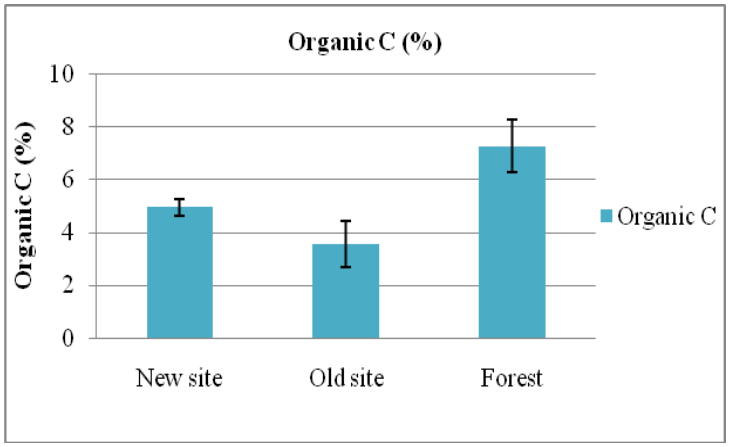

Fig 3.8 - % Organic Carbon of different sites

The data clearly shows that Organic Carbon content has significantly decreased (P=0) from forest(7.15%) to one year old (4.94%) indicating drop in soil quality with respect to Organic Matter which is the base for nutrients in soil. This further reduced over the time up to 3.55%. The reasons could be increased surface runoff, large amount of organic matter absorbed from soil by the maize due to its high upper biomass [29] and disrupted organic matter decomposition. According to Eludoyin & Wokocha(2011) [30] & Abiala *et.al.(*2013) [31] when a virgin soil is brought under cultivation or cropping, Organic Carbon content generally declines because the amount of organic matter returned to the soil decreases sharply. Nye and Greenland(1960) [32] Areola(1984) [33] and Agboola(1973) [34] have further endorsed this decline and confirmed that the decline could be due to erosion and leaching to degrade the soil[29].

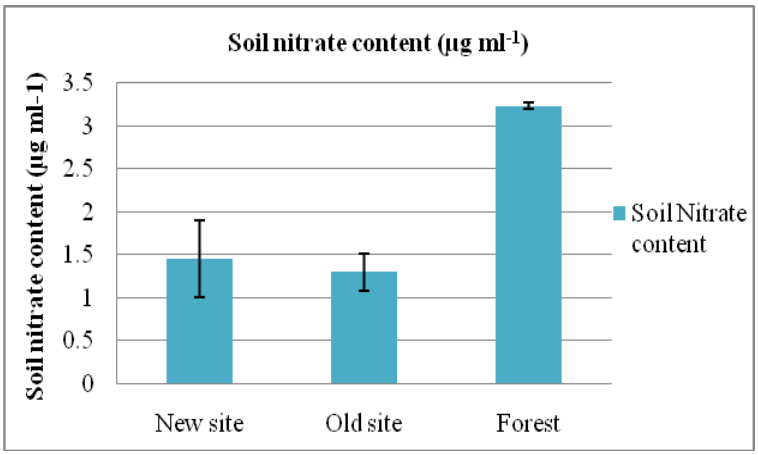

Fig 3.9 – Changes of soil nitrate content

Nitrate content has significantly decreased (P=0) from forest (3.25 µg ml^{-1}) to one year old (1.45 µg ml^{-1}) and further less(1.30 µg ml^{-1}) in ten years' time. This amount of old site is clearly lower than the forest indicating a significant variation. The possible reasons for the decreased of nitrate content could be high growth rate of Maize plants. Aweto(1981a) reported that lower nitrate concentrations under Maize plantations reflected the organic matter diminution as organic matter has a direct

influence on it[35]. Leaching and erosion due to less undercover and less moisture due to monoculture environment could also be a reason for reduced nitrate over the time. Kowal and Kassam(1978) stressed the nitrogen status of the soil is closely associated with the soil organic matter as it is the major source of soil nutrients [36]

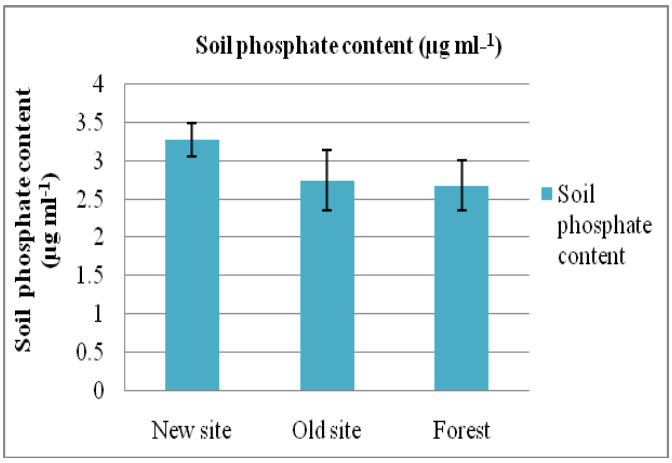

Fig 3.10 – Changes of phosphate content in different sites

The Phosphate content has significantly increased (P=0.003) from natural forest(2.70µg ml^{-1}) to one year old corn plantation(3.27µg ml^{-1}). When other results are considered together, there is no reason for this increase other than fertilizer application. Most fertilizers are enriched with phosphate and once they add, amounts of available phosphate go up. However, results clearly indicated that contents are going down over the time [30]. This may be due to the high absorbance by the plant.
As reported by Du Preez(1999), labile fraction of soil phosphate obtained through fertilizers is decreasing with time due to the formation of stable products in soil [37].

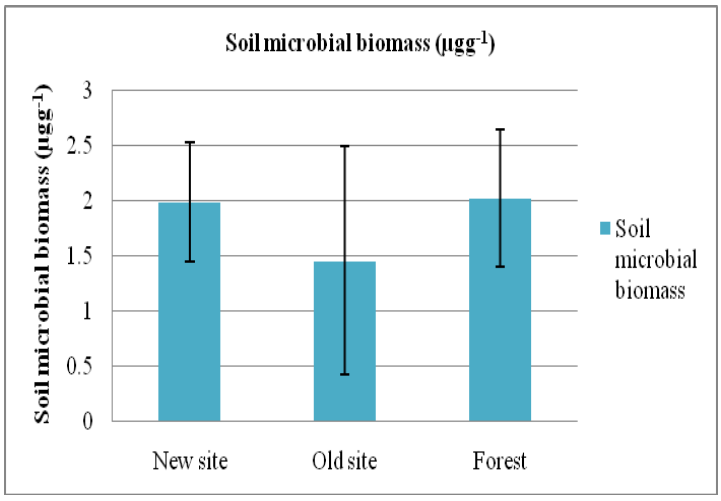

Fig 3.11 – Changes of soil microbial biomass over the years

Soil microbial biomass basically represents the activity of soil organisms[31]. The data indicated that microbial biomass has not been changed in the first year of corn cultivation indicating that corn monoculture has no much impact on the microbial biomass of soil. However, many studies have pointed out that surface microbial biomass is highly affected by various cultivations(Wander, (1999)[39] & Weerasinghe(2012) [18]. However, microbial biomass has decreased (P=0.301) over the ten years (2.00 – 1.45µg g-1) giving an indication that activity of microorganisms are reducing with continuous use of land for the same monoculture[6] even though the values are not significant. Reasons could be leaching nutrients with increased runoff, continuous use of fertilizers and pesticides and reduced soil organic matter.

IV. Conclusions

- It is obvious that the properties of soil have been changed leading to soil quality deterioration as a result of this maize (corn) cultivation over the number of years.
- Soil organic carbon content, Cation exchanging capacity, soil conductivity, Bulk density and microbial biomass of the soil seem to be the best indicators to determine the soil quality reduction and soil deterioration with maize monoculture cultivation.
- The results show that the soils in maize plantation have deviated from the natural forest soil conditions.
- It is important to find the consistency of the results by increasing the number of replicates and the number of plots.
- Based on the observations on soil properties, mulching and organic amendments could be applied as fertilizers to restore the soil or improve the soil quality.

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