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Assessment of the Contribution of Soil Biota and Litter Quality to Carbon Sequestration of Different Physiognomy in Shasha Forest Reserve, Nigeria

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DEDICATION

This research work is dedicated to my Late Mother, Mrs Oyinlola Adebola and mydarling wife, Mrs Anuoluwapo Deborah Adebola. They have been a great blessing to me.

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ABSTRACT

The study identified and compared plant species diversity, soil organism biodiversity and abundance, determined soil organic carbon (SOC) pool and litter biomass carbon together with other litter biochemical composition in six different physiognomies in Shasha Forest Reserve in Osun State. It also investigated the seasonal variation in soil carbon content and established relationship among the explanatory variables with a view to identifying the physiognomy most suitable for afforestation to mitigate climate change.

Physiognomies used for the study were; secondary re-growth natural forest (SRNF),*Terminalia superba* plantation (TSP), *Pinus caribaea* plantation (PCP), *Gmelina arborea* plantation (GAP), *Tectona grandis* plantation (TGP) and *Theobroma cacao* plantation (TCP). Eight plots (25 m x 25 m) were randomly selected in each physiognomy for the study. Tree species were identified and analysed using Shannon-Weiner diversity indices. The below-ground biodiversity assessed were; soil seed bank, earthworm, enchytraeid, millipede, collembola, beetle, termite, nematode, bacteria and fungi using standard methods. Freshly senesced litters were collected using litter trap, dried, ground, sieved and analysed for carbon, nitrogen, lignin and phenolic acid content. Composites soil samples were collected in both dry and wet seasons from three quadrats of 5 m x 5 m, within each 25 m x 25 m plot. The soil samples were analysed for bulk density, organic carbon, total nitrogen, pH and humic substances using standard methods. Data were subjected to appropriate descriptive and inferential statistics.

Floristic diversity indicated that both understory and overstory as well as tree saplings varied among the physiognomies with secondary re-growth natural forest, *T. superba* and *P. caribaea* plantations having the highest tree diversity. *Tectona grandis* (21) and *Theobroma cacao* (13) plantations had the least tree diversity. The belowground diversity showed that

highest tree emergence occurred in TSP (33.3%), while the least occurred in TCP (6.6%), TGP (6.6%)and PCP (6.6%) respectively. The highest enchytraeids (237), termite (1338), earthworm (753) and mite (293) were observed in GAP, while SRNF, TSP and TGP had highest millipede, beetle and collembola abundance respectively. The bacterial feeding nematode was found to be highest in PCP (32), while TSP had the highest fungi feeding nematode (28.6%). The Total Heterotrophic Bacterial and Total Heterotrophic Fungi counts were not significantly different ($p>0.05$) across the different physiognomies. The concentration of humin and humic acid were highest under SRNF (0.55± 0.02) and TSP (0.31 ± 0.01) soils respectively, while the highest fulvic acid was recorded in soil under TGP (0.18 ± 0.06). Litter carbon content was higher in PCP (54.51± 0.02%) compared to other physiognomies. The highest content of lignin and phenolic acid were observed under PCP (36.51± 0.73%) and TGP (0.58± 0.01%) and TSP (34.05± 0.03%), while C/N and Lignin/N were highest in TGP. The soil pH in all the physiognomies was slightly acidic (5.83 ± 0.296-6.23 ± 0.067). Bulk density was significantly ($p>0.05$) higher in TGP (1.21± .015 gcm^{-3}) relative to other physiognomies. There was seasonal variation in SOC accumulation, while highest value of SOC (22.65 MgC/ha) was recorded in TSP, the least was recorded in TGP (19.24 MgC/ha).

The study concluded that*Terminalia superba* (a native tree species) and *Pinus caribaea* plantation could be considered suitable for an afforestation project aiming to conserve biodiversity and enhance soil organic carbon (SOC) sequestration.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The emergence of plantations of different tree species in Nigeria forest reserves may limit the ability of existing protected areas to sequester more carbon (C) and enhance indigenous tree diversity conservation, if the right tree species are not planted to combat carbon (C) emission and biodiversity loss during reforestation programmes. The ecological implications of most tree species that were planted in most forest reserves in the tropic including Nigeria needs to be properly investigated, because earlier selection of most tree for forest plantations purposes were based on efficient timber production (Healey and Gara, 2003).Realizing the threat of global warming resulting from continued increase of carbon dioxide (CO_2) in the atmosphere, the global communities encouraged incentive for forest conservationand afforestation programme to mitigate greenhouse gasses (GHGs) in the atmosphere.

This fueled the interest of many developing nations, including Nigeria, in embarking on massive plantation establishment, which in recent times has created a widespread concern as a result of conversion of primary and secondary forest to plantations of both native and exotic tree species. This practice has encouraged massive taken-over of existing forest reserves and other free areas by plantations of all kinds of tree species, whose relative carbon emission mitigation and native biodiversity conservation ability are yet to be adequately verified. Since it takes more than a tree to perform the ecological function in a forest, relative abundance and productivity of predominant tree species and their traits are probably the principal factor determining soil C dynamics and co-habitation with other neighbouringplant species. Plant species of similar ecological requirement and functional role is expected to co-occur and jointly directly contribute to ecological functionality of their micro-habitat.However, this shift in tree species during conversion has been perceived to influence plant traits and soil fauna that drive soil C input and output, resulting in the alteration of biologically mediated movement of C within these pockets of forest that are planted. Deyn *et al.* (2008) emphasised on the importance of plant traits in regulating net C storage by controlling C assimilation, transfer, storage and release from soil. Houghton and Goodale (2004) observed that most changes in land use affect the amount of C held in vegetation and soil, either releasing carbon dioxide (CO_2) into or removing it from the atmosphere. Changes in the quality and quantity of plant litter input to the soil environment may be affected by forest management decisions, as is the case of promotion of exotic tree species for reforestation in Nigeria.

Although it is known that trees could sequester C, but there is a strong variation in the carbon sequestrating potential of different tree species. Chapin III *et al.* (2003) asserted that the control of C cycling through ecosystems depends on the physiological properties of plants, animals and soil microorganisms. He noted that the largest soil C accumulation frequently occurs in ecosystem where decomposition is retarded, which may said to occur in litter with high lignin or where microbial degradation is restricted by water. It is worthy to know that the capacity of the forest to remove carbon as CO_2 from the atmosphere and store it in biomass and soil depends on the productive potential of the soil, climate, soil fauna and nature of biomass in terms of quality and quantity (McDonald and Rodgers, 2010). The ability of tree species to contribute to sequestration of soil carbon is a function of ability of individual tree to remain recalcitrant to decomposition, with long turnover time based on the tree biochemical composition (Heal *et al*., 1997). The input of litter by plants represents the link between the above-ground and below-ground dimensions of terrestrial ecosystems that can influence the functioning of the whole ecosystem (Faboya *et al.,* 2015). Most widely accepted indices for assessing biological stability include nitrogen (N) concentration, C/N ratio, lignin and/or polyphenol concentration of organic material (Heal *et al*., 1997). Tree litter qualities, are the decay resistance substances which supply the limiting resources on decomposers. Differences in litter quality among species have been identified as an important mechanism by which tree species may affect C storage (Walela *et al.,* 2010). The magnitude and rate of SOC sequestration with afforestation depends on climate, soil type, nutrient management and tree species (Lal and Follet, 2009).

The relative proportion of carbon constituents and concentration of nutrients and secondary compounds determine the susceptibility of a substrate to attack by decomposers and thus control the rates of decomposition and nutrient release (Heal *et al.,* 1997). Lignin, being an essential biochemical component of plant litter, has being widely used also as an index of organic matter pool. Beside C:N ratio, lignin:N ratio has also been shown to correlate well with decomposition in numerous stands and a predictor of C pool through its effect on humus formation. Lignin in litter is highly resistant to decomposition and therefore, litter with high lignin would have slower decomposition rate (Mafongoya *et al.,* 1998).

At a community level like forest ecosystem, both the quantity and the quality of plant litter have important consequences for the below-ground decomposer system. Porazinska *et al.* (2003) observed that plant traits composition may influence soil decomposer diversity through the diversity of substrates and habitat provided. Power *et al.* (2009) noted that litter chemistry and soil fauna were major factors regulating decomposition and C input in the tropics. Decomposer communities in reaction to litter availability and palatability has a way of influencing C cycling (Hättenschwiler *et al*., 2005; Wardle 2006), especially during vegetation alteration. According to Goldman *et al.* (2008), improved understanding of how different plantations and other working landscapes affect biodiversity and ecosystem services is critical to forming socially and ecologically sustainable land-use policies. The paucity of information about the quantitative changes in indigenous species diversity and carbon input with shift in tree species during plantation establishment across a range of plantation types remains a serious information gap that may hamper decision making on sustainable forest management in Nigeria. Despite the importance of plantation forestry to the economy and green initiative project in