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# The Properties of Soil Under the Canopy of the Locust Bean Tree (Parkia biglobosa), in Relation to Tree Biomass, in Farmland in Oyo Area, South Western Nigeria

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**Abstract**
The African locust bean (*Parkia biglobosa*) is a multi-purpose tree that is commonly retained on small-holder farms in the savanna region of West Africa. Studies that examined the effects of the tree on soils underneath its crown did not examine the biomass parameters of the tree while those that studied the biomass parameters of the tree species did not consider the soil. This study examines the properties of soil under the locust bean tree canopy in farmland in the derived savanna of Oyo area, south-western Nigeria. It also quantitatively characterized the girth, height and crown diameter of locust bean trees in the peasant farms and correlated them with the properties of soils underneath the trees. The soil was sampled at two depths of 0- 10 and 10- 20 cm under and outside *Parkia* canopies. The t-test was used to compare the means of soil properties under and outside *Parkia* canopy in order to ascertain whether statistically significant differences exist between them. Organic matter was slightly higher (18- 19%) under *Parkia* canopy. Exchangeable magnesium, calcium and cation exchange capacity were significantly higher in soil under the tree canopy. This is due to the slightly higher organic matter, reduced leaching under the tree canopy as a result of rainfall interception, the trapping of dust and aerosols by tree crowns and the greater concentration of earthworm casts under *Parkia* canopy. The properties of the 0- 10 cm layer were more strongly correlated with *Parkia* biomass parameters than those of the 10- 20 cm layer. Tree height was strongly and positively correlated with soil clay (0.70), organic matter (0.73), total nitrogen (0.69) but negatively correlated with sand content (-0.80) of the 0-10 cm layer. The growth of *Parkia* trees and seedlings will be enhanced in the more clayey sites but would be retarded in areas with predominantly sandy soils and this should be taken into consideration in afforestation, community forestry and shelterbelt projects involving the establishment of *Parkia* trees.
**Keywords**: *Parkia biglobosa*, tree canopy, tree biomass, soil physical properties, soil chemical properties, soil-plant correlation

## 1.0 Introduction

The African locust bean ( *Parkia biglobosa* (Jacq.) Benth.) is a tree legume that is an important element of the flora of the savanna lands of West Africa. It is distributed extensively from the humid savannas of the southern Guinea and derived savanna ecological zones to the semi-arid savanna of the Sahel in the northern part of the region. Although, the tree grows wild in the savanna lands of West Africa, it is also widely retained in farmers' fields as a traditional agroforestry practice and also afforded some measure of protection in both cultivated fields and bush fallow vegetation in order to conserve it. The tree provides shade in cultivated fields and also fruits for small-holder farmers. Other benefits farmers and local communities derive from the tree include improved soil fertility and hence, increased crop yield (Dupriez & De Leener 1998), the provision of forage for livestock while the bark yields dyes and tannin (Gledhill 1972). The tree is a valuable economic tree that makes an important contribution to the rural economy through the sale of wood products such as pestles and mortars (Irvine 1961). The fermented seeds of *Parkia* trees are used as soup condiment and are widely consumed in the savanna region of West Africa, including northern Togo, Nigeria and Ghana (Campbell-Platt 1980).

Studies on the African locust bean in West African include those on the nutritional composition of the seeds (Alabi *et al.* 2005; Esenwah & Ikenebomeh 2008; Elemo *et al.* 2011), medicinal uses of the plant (Kouadio *et al.* 2000; Odetola *et al.* 2006; El-Mahmood & Ameh 2007) and on the production of crops such as sorghum, pearl millet and cotton under the tree canopy ( Kater *et al.* 1992; Kesseler 1992). Studies on the effects of the locust bean tree on the soil underneath its canopy in West Africa (Tomlinson *et al*. 1995; Jonsson *et al.* 1999; Bayala *et al*. 2008, Buba, 2015) did not consider the biomass parameters of the trees. Similarly, the studies on the biomass parameters of locust been trees in small-holder farms in West Africa (Odebiyi *et al*. 2004; Delvaux *et al*. 2010; Sanou *et al*. 2012, 2017; Padakale *et al*. 2015; Chabi *et al.* 2016; Oyerinde *et al*. 2018) did not examine the properties of the soil underneath the trees. It is also pertinent to observe that studies that quantified the biomass of other tree species in West Africa (Guendehou *et al*. 2012; Mbow *et al*. 2014; Goussanou *et al*. 2016) also did not examine the characteristics of the soil underneath the tree species. Aweto (1981, 2013) have pointed out that vegetation (and hence the plants in an area) and the soil are functionally interdependent and they exert reciprocal effects on one another. It was therefore considered important in the current study not only to quantitatively characterize the properties of soil under locust bean trees in Oyo area of south western Nigeria and the biomass parameters of the trees but also to correlate the soil and tree biomass parameters in order to examine the nature and strength of the relationships between them.

## 2.0 Materials and methods

### 2.1 Study Area

This study was carried out in Oyo area, some fifty kilometres to the north of Ibadan in south western Nigeria. The area was previously a part of the rainforest zone but it has been transformed into derived savanna as a result of several centuries of farming that involved the use of fire (Keay 1959) to burn the cut slash of fallow vegetation in order to open up the land for cultivation and release nutrients immobilized in fallow vegetation into the soil as ash. The climate of the area is characterized by a long wet season, that usually lasts from March to October and a short dry season that begins in November and lasts till February. The mean annual rainfall is about 1060 mm while the average annual temperature is $27^{o}$ C with no significant seasonal departure from the annual average. The vegetation is derived savanna that is characterized by a ground layer of tall grasses such as *Andropogon tectorum*, *Hyparrhenia* spp. and *Panicum maximum* (guinea grass), with scattered trees and shrubs. The main trees include *Vitellaria paradoxa* (shea butter tree), *Parkia biglobosa* (African locust bean), and the shrub, *Pilostigma reticulatum* (camel's foot). Fruit trees, including mango (*Mangifera indica*), the oil palm (*Elaeis guineensis*) and the African locust bean, are frequently retained by farmers on the cultivated fields to provide additional income, shade and food and also to help maintain soil nutrient status. The soils are Alfisols, mainly Ustalfs, according to US soil taxonomy (United States Department of Agriculture 2014) and have formed mainly from basement complex rocks especially banded gneisses and granite. Arable farming involves the cultivation of field crops such as cassava, yams, cowpea, maize and okra. The rotational bush fallow is the main agricultural system practised in the study area and it involves growing field crops for a year or two and thereafter, the land is fallowed for three years, and occasionally longer, to help replenish its fertility status.

### 2.2 Soil Sampling and Analysis

For the purpose of soil sampling, the topographical map of the study area (Oyo area) was divided into grids of 1.8 km by 1.8 km. There were a total of 36 grids and five of these were randomly selected for study using a table of random numbers, after the grids have been numbered serially. Within each grid, two quadrats measuring 30 metres by 30 metres were selected, after it was ascertained in the field that they contained farmlands, with stands of locust bean trees that can be used for the study. The approach adopted in the current study was to sample the soil under and outside the canopies of isolated stands of *Parkia* trees and compare their properties in order to evaluate the effects of the tree canopies on the soil underneath them. This approach has been adopted by Belsky *et al*. (1993), Wazel *et al.* (2000) and Aweto & Dikinya (2003) to study the effects of trees on the soil under their canopies. Soil sampling was restricted to areas on the same rock type – banded gneiss. Also, only sites on flat or gently sloping upper slope location in the landscape were sampled in order to ensure that variations in soil properties, as a result of the catena effect, were minimal. Three matured *Parkia* trees were selected within each quadrat and two soil samples each were collected under and outside the tree canopies using a core sampler. The soil samples were collected from the depths of 0- 10 cm and 10 – 20 cm. The soil samples, except those used for bulk density determination, were air-dried and passed through a 2 mm sieve, prior to chemical and physical analysis. Soil particle size composition was analyzed using the hydrometer method (Bouyoucos 1962), bulk density by the core method (Blake & Hartge 1986) while total porosity values were calculated from bulk density values using the mean particle density value of 2.65 g $cm^{-3}$ (Vomocil 1965). The soils were leached with 1M ammonium acetate solution and the extracts used for determining soil exchangeable cations. Exchangeable calcium, potassium and sodium were determined by flame photometry and magnesium by atomic absorption spectrophotometry while cation exchange capacity was determined by the summation method (Sumner & Miller 1996). Soil pH was determined potentiometrically in 1M potassium chloride using a soil to solution ratio of 1:2, organic carbon by chromic acid digestion method of Walkley & Black (1934) and available phosphorus by the method of Bray & Kurtz (1945).

### 2.3 Biomass Measurement

The biomass parameters of locust bean trees measured were those that can be easily observed by native farmers and also easily measured in the field. Three biomass characteristics were measured namely: 1) tree height, 2) tree girth at breast height and 3) crown diameter of the trees. Tree girth was measured at breast height, i.e. at an elevation of 1.5 metres above the base of the tree. Tree heights were estimated using a graduated pole. Crown diameter was measured by projecting the edge of the crown vertically to the ground at two opposite ends of the crown and measuring the distance between them on the ground.

2.4 Data Analysis

The t-test was used to compare the means of soil properties under and outside *Parkia* canopy in order to ascertain whether the differences between them were significant at the 1% confidence level. Pearson's correlation coefficients were used to examine the strength and nature of the relationships between the biomass parameters of locust bean trees and the characteristics of the soil underneath their canopies at 5% confidence level.

**3.0 Results and Discussion**

3.1 Comparison of Soil Properties Under and Outside Parkia Canopy

It is important to begin the discussion of results by examining soil particle size composition. This is primarily with the view of ascertaining whether or not the soils under and outside the canopy of *Parkia biglobosa* are texturally similar. Soil texture is an important physical property of soils that is not easily changed by humans as result of changes in land use (Brady & Weil 2014). In the 0 -10 cm layer, the mean proportions of sand, silt and clay in soil under *Parkia* canopy are 87.6%, 6.7% and 5.7% respectively. The corresponding values of sand, silt and clay in soil outside *Parkia* canopy are 87.1%, 7.3% and 5.6% respectively. There were no significant differences between the soil under and outside *Parkia* canopy with respect to the mean proportions of sand, silt and clay in the 0 -10 cm layer (Table 1). Similarly, there were no significant differences between soil under and outside *Parkia* canopy with respect to soil textural composition of the 10 -20 cm layer (Table 2). The soils under and outside *Parkia* canopy are texturally similar. Hence, any observed differences between them in respect of soil physical and chemical properties, are most likely due to the effects of the tree canopy. There were no significant differences between the soil under and outside *Parkia* canopy with respect to soil bulk density and total porosity of the 0- 10 cm and 10- 20 cm layers (Tables 1 and 2). This can be attributed to the fact that there were no significant differences between the mean levels of soil organic matter under and outside the tree canopy (Tables 1 and 2). Soil bulk density was significantly lower and total porosity higher under isolated stands of two tree species (*Peltophorum africanum* and *Combretum apiculatum*) in semi-arid savanna in south eastern Botswana (Aweto & Dikinya 2003). The savanna vegetation in Botswana is not burnt regularly as in the study area. Hence, the improvement in soil physical status under tree canopies in Botswana savanna is due to significant accretion of soil organic matter under the trees as a result of *in situ* decomposition of plant litter.

The levels of organic matter in soils under and outside the canopy of *Parkia* are generally very low for both the 0 - 10 cm and 10 – 20 cm layers. This is primarily due to the predominantly sandy nature of the soils, the farming practice of burning the cut slash of fallow vegetation prior to cultivation and savanna vegetation burning during the fallow period. In the 0- 10 cm layer, there were no significant differences between the organic matter status of soil under and outside the canopy of *Parkia*, although, the mean level under the tree canopy is 19.0% higher than in soil outside the canopy. Similarly, in the 10 – 20 cm layer, there was no significant difference between soil under and outside the tree canopy in respect of soil organic matter level, but the former was 17.9% higher than the latter. Tomlinson *et al.* (1995) also observed no significant accretion of organic matter under *Parkia* canopy in savanna ecosystems in Nigeria and Burkina Faso. There was no substantial accretion of organic matter in the soil under *Parkia* canopy in the current study, relative to sites outside the influence of the tree crown, due to two main reasons. First, as pointed out earlier, as part of land preparation for cultivation, the cut slash of fallow vegetation is allowed to dry and subsequently burnt. The fire not only consumes the cleared vegetation slash and crop residue but also litter that accumulates under trees left in farmland. The implication of this is that leaf and twig litter of trees in cultivated fields is not allowed to decompose *in situ* to add organic matter to the soil. Second, when cultivated land is allowed to lie fallow, the regenerating fallow vegetation is burnt annually to drive animals out from hiding to kill them and also to destroy ticks and crop pests. Areola (1980) observed that the accumulation of organic matter in derived savanna fallow soil in Ibarapa area of south western Nigeria was slow and fortuitous due the practice of savanna burning. Also, Kho *et al*. (2001) observed that the levels of organic matter, exchangeable calcium, magnesium and potassium were only 5-20% higher in the topsoil under the canopy of *Faidherbia* (*Acacia*) *albida* in Niger than in the open savanna. *Faidherbia albida* has been widely acclaimed as a fertilizer tree that improves soil organic matter and nutrients, especially in semi-arid savannas of Africa (Centre Technique Forestier Tropical 1989). The low levels of organic matter and nutrients in the topsoil under *Faidherbia albida* canopy in Niger Republic, relative to levels in the open savanna, were due to the cultivation of soil under the tree canopy.

There were no significant differences between the soil under and outside *Parkia* canopies with respect to soil total nitrogen status in both the 0 -10 cm and 10 -20 cm layers (Tables 1 and 2). This should be expected as there was no significant accretion of organic matter in the soil under *Parkia* canopy. Buba (2015) who compared the properties of soil under and outside the canopy of locust bean trees in the Guinea savanna zone of Nigeria, recorded no significant build-up of total nitrogen under the tree canopy. Similarly, there were no significant differences between the soil under and outside *Parkia* canopy in respect of the available phosphorus status of both the 0-10 and 10-20 cm soil layers. In general, the soils are deficient in available phosphorus and phosphorus deficiency is likely to be an important factor limiting crop yield as the levels of the nutrient are well below 10 mg $kg^{-1}$.The low phosphorus status of the soils can be adduced to the practice of burning prior to cultivation, frequent cultivation and the slow rate of organic matter accretion in savanna fallow soil referred to above. There was no significant accretion of exchangeable potassium in the soil under *Parkia* canopy, relative to the levels in sites outside the tree canopy. There were, however, a significant build-up of exchangeable calcium and magnesium and an increase in the mean level of cation exchange capacity in the 0 – 10 cm layer of the soil under *Parkia* canopy (Table 1). In the 10 -20 cm layer, there was a significant increase in exchangeable calcium and cation exchange capacity (CEC) in the soil under the tree canopy (Table 2). Tomlinson *et al*. (1995) also recorded no significant accumulation of organic matter under the locust bean canopy but observed a significant accretion of total nitrogen and available potassium under the tree canopy. Their findings seem to suggest that factors other than soil organic matter, most likely accounted for the accumulation of nutrients under the tree canopy. The slight increase in the levels of organic matter in the soil under *Parkia* canopy, observed in the current study, does not seem to adequately explain the increase in the mean levels of exchangeable calcium, magnesium and CEC in the soil under the tree canopy. Two factors contributing to the significant accumulation of nutrients under the tree canopy appear to be rain interception by the tree canopy which reduces leaching of soil nutrients under the trees and the activities of earthworms which result in the accumulation of more earthworm casts under the trees, particularly during the wet season. The study of Honda & Durigan (2016) has shown that 20.3% of the gross rainfall over a five year period was intercepted by close-canopied savanna in the Ecological Station of Assis, in south western Sao Paulo State, Brazil. This implied that slightly less than 80% of gross rainfall reached the ground under tree canopies as a result of interception. Hence, leaching would be less in the soil under tree canopy than in sites outside the canopy. Secondly, due to the shade cast by tree crowns, the soil under *Parkia* canopy does not dry out completely and as quickly as the soil outside the tree crown. This factor coupled with the increased availability of plant litter under the tree crowns would increase earthworm population under tree canopy and enhance their activities relative to the soil outside the canopy that dries up more quickly. Consequently, earthworm casts are more abundant in sites under *Parkia* canopy. This is particularly so during the wet season when the soil under tree canopies have high soil moisture content for prolonged periods relative to the levels in the soil outside the influence of tree canopies. Earthworm casts help to improve the nutrient content of surface soil layers (Brady & Weil 2014). The study of de Vleeschauwer & Lal (1981) has shown that the CEC, exchangeable calcium and potassium content of earthworm casts in secondary forest in Nigeria were 3 – 4.4 times the levels in soil (without earthworm casts) and this would help to improve the topsoil nutrient and CEC levels when the casts are incorporated into the soil. In addition, tree crowns trap dust and aerosols. These are ultimately deposited in the soil as wet or dry deposition to increase the nutrient content of soil under tree canopies compared with soil outside tree canopy. In the Sahelian zone of southern Niger Republic, Wezel *et al*. (2000) reported that trees and shrubs in cultivated fields and fallow land have the salutary effect of enhancing nutrient accretion in the soil under their canopies by trapping soil blown by the wind and subsequently accumulating it below their crowns and this process ultimately results in the formation of islands of fertility around the trees and shrubs. In a study of a wooded "cerrado" savanna in the State of Minas Gerais in Brazil, Lilienfein & Wilcke (2004) observed that the combined input of nitrogen, calcium, magnesium and potassium into the soil as result of dry and wet deposition varied between 2.2 and 9.5 kg $ha^{-1}$ $yr^{-1}$. Although, the dust load of the air in the study area is much lower than in the Sahel, it increases substantially during the harmattan season when a lot of dust is blown from the Sahara and the Sahel to the coastal areas of West Africa.

3.2 Biomass Parameters and Their Correlation with Soil Properties

Three *Parkia* biomass parameters will be discussed here, namely: tree height, tree girth at breast height and crown diameter. The height of the *Parkia* trees varied between 9.7 and 15.2 metres with a mean of 13.9 metres ± 2.0 while girth at breast height varied between 90 and 190 cm with a mean of 148 cm ± 9.1. *Parkia* usually grows to the height of about 15 metres (Gledhill 1972). The mean height of the tree we observed in the sample plots was reasonably close to the height of 15 metres, suggesting that the locust bean trees are mature and are likely to have been growing on the farmland for several decades to enable them exert significant effects on the soil underneath their canopies. Crown diameter varied between 12.0 and 19.0 metres with a mean of 15.7 metres ± 0.7. The trees usually have large, wide-spreading crowns (Orwa *et al*. 2009) as was observed in the current study. The mean girth of *Parkia* trees recorded in this study is similar to that observed by Oyerinde *et al*. (2018) for *Parkia* trees in three states in the humid savanna zone of south western Nigeria. This is largely due to similarity in climatic conditions between the two areas in which the two studies were conducted. However, the mean tree height and crown diameter observed in our current study are higher than those obtained by Oyerinde et al. (2018) and this may be due to differences in soil/site factors and the way farmers manage trees on their farmland. It is also pertinent to note that the mean height of *Parkia* trees observed in the current study is greater than the average height obtained by Sanoe *et al.* (2012) for locust bean trees in the Sudan savanna of southern Burkina Faso. This is likely due to the lower rainfall in the latter which reduces net primary production.

Similarly, the mean girth of *Parkia* trees observed in this study is greater than those recorded by Padakale *et al.* (2015) for locust bean trees in young and old fallows in the Sudanian zone of Togo and this is presumably due the drier climatic conditions in northern Togo.

Table 3 shows the correlations between *Parkia* biomass parameters and the properties of soil in the 0-10 cm layer of the small-holder farmland. The girth of *Parkia* trees is weakly correlated with soil physical and chemical properties. In contrast, tree height is significantly correlated with organic matter, total nitrogen and soil sand, silt and clay contents. The strong positive correlations between *Parkia* height on the one hand and soil organic matter and total nitrogen on the other indicate a reciprocal relationship between the soil and the locust bean trees growing on the soil medium. It indicates that the taller, and hence the larger the biomass of *Parkia* trees, the higher would be soil organic matter and total nitrogen status. It also implies that the higher the organic matter and nitrogen levels in the soil, the taller the trees would be. It is not unexpected that sites with taller *Parkia* trees are associated with higher soil organic matter and nitrogen status as the bigger trees would generate more litter than smaller trees and also afford the soil greater protection from soil organic matter and nutrient losses through leaching and erosion. In addition, Aweto & Dikinya (2003) have pointed out that trees cast shade on the ground, thereby lowering soil temperatures and consequently reducing the rate of thermally-induced loss of organic matter and nutrients from the soil. On the other hand, sites underneath *Parkia* canopies with higher organic matter and nitrogen status would increase the rate of growth of the trees. This is mainly because soil organic matter increases availability of plant nutrients and also improves soil physical status, including enhanced soil water-holding capacity (Brady & Weil 2014). It is also pertinent to note that the textural composition of the 0-10 cm soil layer is strongly correlated with the height of *Parkia* trees. The proportion of sand in the soil is significantly and negatively associated with the tree height while the proportions of silt and clay are positively correlated with *Parkia* height. As soil particle size composition cannot be substantially altered by biotic influences (Brady & Weil 2014), the relationship between the proportions of sand, silt and clay on the one hand and *Parkia* height on the other, should be interpreted as indicating a unidirectional relationship namely: soil sand, silt and clay fractions exert significant effects on *Parkia* height and not vice versa. The negative correlation of -0.80 between sand and *Parkia* height indicates that the growth of *Parkia* trees tends to be retarded on sites with very sandy soils. This should be expected as sand is chemically inert and it does not improve soil water-holding and nutrient –holding capacity. Soils that are very sandy are deficient in plant nutrients and are excessively drained and so cannot retain enough water for plants over a long period. In contrast, silt and clay fractions of the soil are positively correlated with *Parkia* height. Soil clay and fine silt are chemically active and they improve nutrient and water availability in the soil. Hence, the more clayey sites in predominantly sandy soils, such as occur in the study area, would be associated with enhanced nutrient and water supply to plants and hence, improved growth of *Parkia* trees as is evident in the greater height of the tree specimens in the more clayey sites. The correlations between *Parkia* biomass parameters and the properties of the underlying 10- 20cm layer are much weaker than those of the 0-10 cm layer, implying that the subsoil layer exerts less effects on the growth of *Parkia* trees than the 0-10 cm layer. It also implies, as to be expected, that the tree exerts less influence on the subsoil layer. It should be expected that under isolated tree stands (such as occurs in small-holder farms in the study area and in West Africa generally) the correlations between soil properties and the biomass of trees would be greater for the topsoil layer as leaf and twig litter, which are the main means through which organic matter and nutrients are returned to the soil, accumulate on the soil surface. However, *Parkia* height is strongly correlated with the cation exchange capacity of the subsoil (Table 4). This implies the availability of nutrients in the subsoil, as with the topsoil layer, enhances the growth of locust bean trees. It is also important to note that the crown diameter of *Parkia* trees is has a moderate correlation of 0.58 with the exchangeable magnesium level of the subsoil layer, implying that trees with larger crowns have greater potentials of inputting litter to the soil and enhancing organic matter and nutrient accretion in the soil.

## 4.0 Conclusion

Despite the fact that the land is cultivated at frequent intervals in the peri-urban area of Oyo, where this study was carried out, the African locust bean trees retained on the farmland have some beneficial effects on the soil underneath their canopies. In the 0-10 cm and 10-20 cm layers, the mean organic matter levels of the soil under *Parkia* canopy were slightly higher, being 18- 19% higher than in soil outside the influence of any tree canopy. The build-up of organic matter under the tree canopy was not substantial due to frequent cultivation that involved site burning that destroys plant litter that would have been converted into soil organic matter when allowed to decompose *in situ*.

The mean levels of exchangeable calcium, magnesium and CEC in soil under *Parkia* canopy were significantly higher than in soil outside the influence of tree canopies. The increase in nutrient and CEC levels in soil under the tree canopy is mainly attributable to the reduced leaching under the trees as a result of rain interception by tree canopy, the greater activity of earthworms under the trees (especially during the wet season) and the trapping of wet and dry deposition by tree canopies that are ultimately incorporated into the soil. The study of Lilienfein & Wilcke (2004) in Brazilian "cerrado" savanna has shown that vegetation dominated by trees (*Pinus caribaea* plantation) trapped more nutrients from the atmosphere than continuously cultivated farms cropped to corn and soybean. Nutrient input into ecosystems through wet and dry deposition is usually considerable, even in humid forest ecosystems. Jordan (1982) observed that the atmospheric input (mainly by wet and dry deposition) of calcium, magnesium and potassium into a rainforest ecosystem on intensely weathered soil (oxisols) near San Carlos, Venezuela, was greater than the losses of the nutrients from the ecosystem as a result of leaching.

Small-holder farmers in the study area are likely to plant or retain more trees on their farms in the foreseeable future in order to achieve food security and due to the increasing scarcity of fuelwood for domestic use and the increasing cost of imported fertilizers. In the Sahelian zone of southern Niger, Burkina Faso, Mali and Senegal, small-scale farmers have promoted the natural regeneration of trees in over five million hectares of farmland, under an initiative known as the "farmer-managed natural regeneration" and this has enabled them to improve soil fertility, increase crop yield and fuelwood supplies and also to produce more fodder for livestock (Neate 2013). The success of tree regeneration on farmlands would depend partly on soil characteristics. The findings of the current study have shown that the establishment of trees such as *Parkia biglobosa* would be problematic in very sandy sites (as evidenced by the strong negative correlation between soil sand content and the height of locust bean trees) while its establishment and regeneration would be enhanced in sites with more clayey soils. In addition, the savanna lands of West Africa are prone to drought and desert encroachment. The sub-humid savannas, such as occurs in the study area are not immune from drought and small-scale farmers often experience crop failure as a result of irregularity in rainfall distribution or delayed onset of the wet season. *Parkia biglobosa* is drought-resistant and has been widely advocated for use in community forestry and afforestation projects as well as for use in shelterbelt establishment in order to combat and mitigate the ravaging effects of desertification (Odebiyi *et al*. 2005; Orwa *et al.* 2009). As pointed out above, the success of programmes designed to establish the locust bean tree in community woodlot, farmland agroforestry and afforestation projects or in shelterbelts should take cognizance of the nature of the soil, especially its textural composition. Such afforestation, shelterbelt or even agroforestry projects have better chances of succeeding in areas with more clayey soils than those that are characterized by predominantly sandy soils of low nutrient and water-holding capacity. Finally, the height of locust bean trees is significantly and positively correlated with soil organic matter and total nitrogen. This implies that the larger trees have greater potentials of enhancing organic matter and nutrient accretion in the soil under their canopies. It is suggested that the small-holder farmers should avoid the practice of land burning before cultivation as fire damages or kills savanna trees. Such measure would ensure that the growth of trees in farmers' fields is not retarded, and hence, they can exert maximal effects of accumulating organic matter and nutrients in the soil.

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Table 1: Properties of the 0 – 10 cm layer of soil under and outside *Parkia* canopies.[1]

| Soil properties | Under canopy | Outside canopy | t- value |
|---|---|---|---|
| Sand (%) | 87.60±4.81 | 87.10±3.00 | 0.28 |
| Silt (%) | 6.70±2.17 | 7.30±1.10 | 0.76 |
| Clay (%) | 5.70± 3.25 | 5.60±2.40 | 0.08 |
| Bulk density (g cm-3) | 1.59±0.14 | 1.64±0.11 | 0.91 |
| Total porosity (%) | 40.00±5.81 | 38.11±4.62 | 0.80 |
| Organic matter (%) | 1.36±0.64 | 1.10±0.41 | 1.08 |
| Total nitrogen (%) | 0.20±0.09 | 0.18±0.10 | 0.48 |
| Exchangeable calcium (cmol $kg^{-1}$) | 0.76±0.13 | 0.44±0.13 | 5.51* |
| Exchangeable magnesium (cmol $kg^{-1}$) | 0.21±0.04 | 0.12±0.05 | 4.04* |
| Exchangeable potassium (cmol $kg^{-1}$) | 0.19±0.03 | 0.19±0.03 | 0.00 |
| Exchangeable sodium (cmol $kg^{-1}$) | 0.21±0.04 | 0.21±0.06 | 0.00 |
| Cation exchange capacity (cmol $kg^{-1}$) | 1.80±0.28 | 1.40±0.24 | 3.51* |
| Available phosphorus (µg $kg^{-1}$) | 1.67±1.60 | 2.11±1.82 | 0.57 |
| pH | 5.78±0.92 | 6.17 ±0.45 | 1.20 |

1 - Values are means ± standard deviation.
*Difference between means is significant at 1% confidence level.

Table 2: Properties of the 10 – 20 cm layer of soil under and outside *Parkia* canopies.[1]

| Soil properties | Under canopy | Outside canopy | t- value |
|---|---|---|---|
| Sand (%) | 86.40±3.60 | 86.60±3.60 | 0.06 |
| Silt (%) | 7.50±1.90 | 7.30±1.50 | 0.26 |
| Clay (%) | 6.10±2.40 | 6.10±3.00 | 0.00 |
| Bulk density (g cm-3) | 1.64±0.05 | 1.56±0.13 | 1.79 |
| Total porosity (%) | 38.11±4.37 | 41.13±3.86 | 1.88 |
| Organic matter (%) | 1.34± 0.52 | 1.10± 0.43 | 1.15 |
| Total nitrogen (%) | 0.20±0.07 | 0.16±0.07 | 1.25 |
| Exchangeable calcium (cmol $kg^{-1}$) | 0.41±0.04 | 0.11±0.01 | 14.70* |
| Exchangeable magnesium (cmol $kg^{-1}$) | 0.10±0.02 | 0.11±0.01 | 0.30 |
| Exchangeable potassium (cmol $kg^{-1}$) | 0.20±0.03 | 0.19±0.03 | 0.74 |
| Exchangeable sodium (cmol $kg^{-1}$) | 0.23±0.08 | 0.19±0.04 | 1.54 |
| Cation exchange capacity (cmol $kg^{-1}$) | 1.41±0.13 | 1.20±0.09 | 4.20* |
| Available phosphorus (µg $kg^{-1}$) | 1.70± 1.93 | 1.32±1.41 | 0.50 |
| pH | 6.03±0.20 | 5.92±0.52 | 0.59 |

1 - Values are means ± standard deviations.
*Difference between means is significant at 1% confidence level.

Table 3: Correlations between *Parkia* biomass parameters and the properties of the 0 -10 cm soil layer.

| Soil properties | *Parkia* girth | *Parkia* height | *Parkia* crown diameter |
|---|---|---|---|
| Sand | 0.15 | -0.80* | 0.15 |
| Silt | 0.05 | 0.73* | 0.09 |
| Clay | -0.27 | 0.70* | -0.28 |
| Bulk density | 0.18 | -0.50 | 0.10 |
| Total porosity | -0.13 | 0.42 | -0.15 |
| Organic matter | 0.30 | 0.73* | 0.06 |
| Total nitrogen | 0.30 | 0.69* | 0.05 |
| Exchangeable calcium | 0.20 | 0.33 | 0.13 |
| Exchangeable magnesium | 0.33 | -0.15 | 0.58 |
| Exchangeable potassium | 0.03 | -0.14 | -0.13 |
| Exchangeable sodium | -0.01 | -0.17 | -0.12 |
| Cation exchange capacity | 0.18 | -0.05 | 0.09 |
| Available phosphorus | 0.08 | -0.22 | 0.07 |
| pH | -0.12 | -0.58 | -0.01 |

* Correlation coefficient is statistically significant at 5% confidence level.

Table 4: Correlations between *Parkia* biomass parameters and the properties of the 10 -20 cm soil layer.

| Soil properties | *Parkia* girth | *Parkia* height | *Parkia* crown diameter |
|---|---|---|---|
| Sand | 0.33 | -0.12 | -0.06 |
| Silt | -0.32 | -0.13 | -0.05 |
| Clay | -0.24 | 0.25 | 0.14 |
| Bulk density | 0.31 | 0.03 | 0.07 |
| Total porosity | -0.37 | -0.05 | 0.12 |
| Organic matter | 0.30 | 0.32 | 0.17 |
| Total nitrogen | 0.46 | 0.28 | 0.28 |
| Exchangeable calcium | 0.20 | 0.33 | 0.13 |
| Exchangeable magnesium | 0.20 | -0.13 | 0.30 |
| Exchangeable potassium | -0.05 | 0.29 | 0.30 |
| Exchangeable sodium | -0.19 | 0.56 | -0.39 |
| Cation exchange capacity | 0.23 | 0.74* | 0.05 |
| Available phosphorus | 0.06 | 0.21 | 0.17 |
| pH | -0.02 | 0.15 | 0.12 |

* Correlation coefficient is statistically significant at the 5% confidence level.