# Effects of *Faidherbia albida* Del. A. Chev. on Soil Properties in Agroforestry Parkland Ecosystem in Garki Village, Katsina State, Nigeria

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## Abstract

*Faidherbia albida* is an important tree species which contributes to soil fertility in dry lands of Northern Nigeria. This study assessed the effects of *Faidherbia albida* on selected soil physiochemical properties with a view to providing information on the species' contribution to the nutrient status of dry land soils. Soil samples were obtained from the base of twenty one *Faidherbia albida* trees in two height and crown diameter classes. A total of 168 soil samples were collected at the end of 2019 cropping season to avoid masking of excessive salts from soil amendments and management practices. These comprised four samples taken at 2 m and 10 m radii round each *Faidherbia* tree at depths of 0 – 20 cm (top soil) and 20 – 40 cm (sub-soil). Soil composites were analysed for soil physico-chemical properties. Data were analysed using descriptive statistics and T-test. The soil properties beneath the tree canopy, at 2 m and 10 m radii, were influenced by the trees. However, there were no significant differences among the soil physico-chemical properties across the distances, except for bulk density. *Faidherbia albida* altered soil properties and would be a suitable candidate for soil improvement efforts in dry land soils of Northern Nigeria.

**Keywords: Agroforestry, Soil nutrients, Tree conservation, Smallholder farms**

## Introduction

Trees have been known to help conserve soil, maintain soil fertility and increase soil productivity, by increasing organic matter supplies, nitrogen fixation, nutrient uptake, water infiltration, soil moisture retrieval and improving soil structure (1). Trees also reduce soil acidity, salinity, and toxicity caused by pollution (2).

Working in different locations Bationo et al. (3); Mekonnen et al. (4); Tully et al. (5) and Sileshi et al. (6) have clearly shown that trees have significant effects on soil at different spatial scales. In Eastern Amazon for example, trees influenced the restoration of soil fertility, promotion of biological processes and ecological functions in agroforestry systems (7). Khaleel *et al.* (8) reported that soil organic carbon stocks in the 1.25 m depth within eight tree plantations were 16% higher beneath trees than the adjacent farmed fields in US Great Plains. Also studies that focused on the impact of trees on soil across the Sahel (Burkina Faso, Mali, Niger and Senegal) showed a significant increase in total carbon content under trees by a factor of 1.04–1.47 (9).

*Faidherbia albida* is regarded an important agro-silvo-pastoral species because of its ability to enhance nutrient availability under its canopy (10, 11). In Nigeria, several studies (12, 13) have reported a significant difference in soil properties such soil texture, organic matter, nitrogen concentrations and some exchangeable cations and cation exchange capacity with increasing distance from the tree species. Other studies across sub-Saharan Africa (Ethiopia and Sudan, Niger and Nigeria) have also associated tree species with soil fertility enhancement and soil physical, chemical and microbial population enrichment (14, 15, 16). Trees generally exert significant impact on soil in aggregate or isolated patterns (17, 18). However, long term effects of trees on soil properties differ in various ecotones: desert, forest and savanna (19, 20). Zheng *et al*. (21) indicated that soil bulk density, cation exchange capacity, and pH were influenced by variations in tree species in Huoditang Area of China. Wang *et al.* (22) also reported that soil bulk density repeatedly changed at a small range at all depths throughout China. However, the influence of single tree species stands on soil properties is not well documented (23).

Tree species such as *Faidherbia albida* have been used principally for soil improvement in agricultural production systems in the West African Sahel, South Africa and Ethiopia (24). For example, in Kotido district of Tanzania, some soils are known as ‘cool soils’ because they are under *Acacia campylacantha* and *Acacia nilotica* trees (25). Some other trees of interest in soil fertility improvement on farming landscapes across dry areas of Africa, include *Acacia spp.*, *Parkia biglobosa*, *Tamarindus indica*, *Combretum aculeatum* and *Piliostigma reticulatum* (20, 26). This study assessed the spatial variability of soils along two *Faidherbia* density gradients. It also examined the effects of *Faidherbia albida* trees on soil physical and chemical properties in the study area.

## Material and Methods

### Study Area

This study was carried out in Garki village in Baure Local Government Area of Katsina State. It is located between latitudes 12°50′10″ N and 12°50′29″ N and longitudes 8°44′47″ E and 08º48̉09’’ E (Figure 1). Garki village is 5.76 km away from the border of Niger Republic and 21.4 km to Magaria; an important socio-economic centre of Zinder Region of Niger Republic. The climate of the area is the tropical continental type, with distinct wet (May to September) and dry (October to April) seasons. The seasons are caused by the activities of the humid maritime winds from the Atlantic Ocean and tropical continental winds originating from the Sahara Desert (27). The main feature of climate of the area is a short rainy season (usually 3 - 4 months), which is interspersed with unpredictable droughts and high variability.

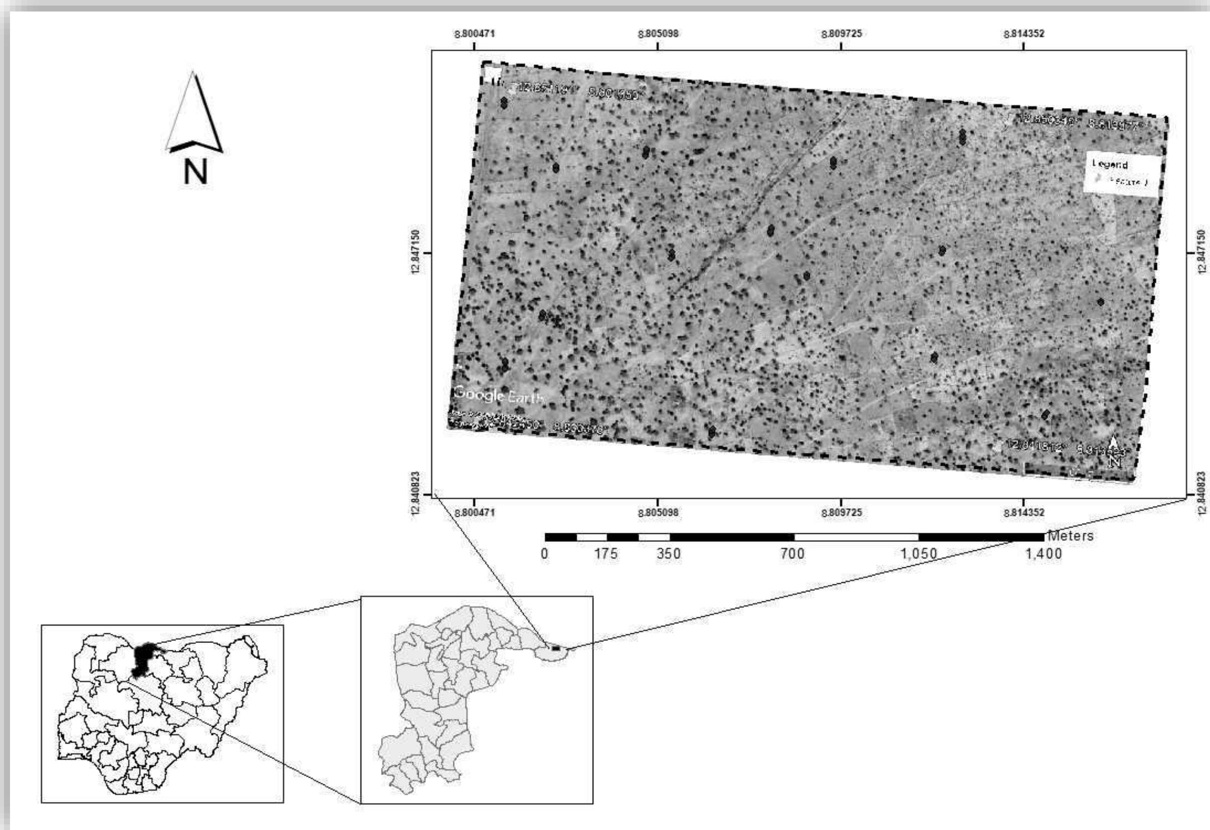


**Figure 1: Map of the Study Area (inset: Maps of Nigeria and Katsina state)**

The area has an estimated average monthly temperature of 36$^{o}$C which also fluctuates between the morning and afternoon and among seasons. Temperature lowers to an average 18$^{o}$C during the harmattan season (November to February) (28). Humidity level of the area also fluctuates among seasons and fall to 10% during the long dry season (28).

Soils in the area are derived from the Aeolian parent materials overlying quartz-rich geological formations such as crystalline rocks of the basement complex. Large parts of the area are covered by semi-arid brown and reddish brown soils. They are inherently fragile, low in carbon and poor in plant nutrients and predominantly sandy with low water holding capacity, and usually less than 150 cm deep (29).

The vegetation type of the area is the Sahel Savanna type distinguished by large expanse of grasslands with widely spaced short trees of varying heights and diversity. It consists largely of scrub vegetation and species which are endemic to the environment. The area supports the growth of drought resistant species such as *Hyphaene thebaica*, *Ziziphus spina-christii*, *Adansonia digitata*, *Faidherbia albida*, *Tamarindus indica*, *Borassus aethiopum*, *Balanites aegyptiaca*, *Acacia nilotica*, *Ziziphus mauritania Azadirachta indica*, *Annona senegalensis* and *Calotropis procera*. *Faidherbia albida* is a hardy species that survives well across the dry land of Northwestern Nigeria (18, 30).

**Sampling Procedure**

This study involved sampling of soil under *Faidherbia albida* trees in smallholder farms with an average size of 0.3 ha. Six smallholder farms were purposively sampled based on the possession of 4 *Faidherbia albida* trees which are between 6 - 20 m height and 2 – 8 m crown diameter (Table 1). This was based on the assertion that under favourable conditions, the tree attains height of 6 to 20 m before influencing soil conditions.

A total of one hundred and sixty eight soil samples were taken within 2 m and 10 m radii of each of the 21 *Fadherbia* trees after the cropping season of the year 2019 to avoid masking of excessive salts from soil amendments and management practices. The soil sampling was done in north and south directions of the trees with a view to quantifying soil nutrient reserves at both sides of the stand. Hence, eight samples were taken around each *Faidherbia* tree: two: 2m and 10m radii and at two depths (0 – 20 cm and 20 – 40 cm). Samples were not taken from under young *Faidherbia albida* trees with heights lower than 6 m as well as from under the canopies of the species that overlapped with other trees. These were not sampled to avoid overestimating or masking the actual effects of the species (31).

The soil samples were collected in a scoop, and placed on a mat under shade for one hour to dry in order to avoid contamination during packaging and labelling. The air dried soil samples (168) were bulked into 42 composites (two for each tree). They were then placed in well labelled cotton bags to aid aeration and prevent moisture loss. Soil samples were taken to the Soil Laboratory of the Department of Geography, Bayero University Kano for analysis. In addition measurements of soil temperature, pH and colour were done in the field.

Bulk density was determined using core method in line with (16). Soil Phosphorous (P), Manganese (Mn), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) were determined using Microwave Plasma Atomic Emission Spectrophotometer (4210 MP – AES). Total nitrogen was determined using CHNS analyzer. Organic carbon content of the soil was determined by the modified Walkley-Black method as described by (32). Soil pH was measured in a 1:1 soil/water suspension using a pH meter (Model 300408.1) (33). Electrical Conductivity (EC) was measured using conductivity meter (34). Soil colour was determined using Munsell colour chart. T-test was used to determine differences in soil properties between distances from tree stems.

**Table 1: Total number of *Faidherbia albida* stands encountered on the Sampled Farms**

| Height of species | 6-10 m | 11-15 m | 16-20 m |
|---|---|---|---|
| Number of Species | 11 | 6 | 4 |

**Table 2: Physical and chemical properties of soil under two crown diameters of *Faidherbia albida* trees**

| Height of *Faidherbia* Tree (m) | Soil Properties Relative to Distance from the Tree (2 m and 10 m) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BD | | Texture | | N (mg/kg) | | P (cmol/kg) | | K (cmol/kg) | | EC (cmol/kg) | |
| | 2m | 10m | 2m | 10m | 2m | 10m | 2m | 10m | 2m | 10m | 2m | 10m |
| 16 -20 | 1.26 | 1.3 | Sandy-clay-loam | Silt-clay | 0.05 | 0.05 | 5.47 | 2.6 | 0.1 | 0.1 | 2.88 | 3.05 |
| 11 – 15 | 1.28 | 1.3 | Silt-loam | Clay loam | 0.06 | 0.05 | 1.81 | 3.1 | 0.2 | 0.2 | 2.72 | 2.89 |
| 6 – 10 | 1.25 | 1.3 | Sandy-loam | Silt loam | 0.05 | 0.04 | 3.19 | 4.6 | 0.1 | 0.2 | 2.48 | 2.59 |
| **Height of *Faidherbia* Tree (m)** | **Soil Properties Relative to Distance from the Tree (2 m and 10 m)** | | | | | | | | | | | |
| | **Ca (cmol/kg)** | | **Mg (cmol/kg)** | | **Na (cmol/kg)** | | **Mn (cmol/kg)** | | **pH** | | **Organic carbon** | |
| | **2m** | **10m** | **2m** | **10m** | **2m** | **10m** | **2m** | **10m** | **2m** | **10m** | **2m** | **10m** |
| 16 -20 | 1.8 | 2.0 | 0.83 | 0.76 | 0.09 | 0.08 | 18.52 | 30 | 5.91 | 6.3 | 0.6 | 0.5 |
| 11 – 15 | 3.46 | 2.0 | 0.56 | 0.51 | 0.08 | 0.09 | 15.18 | 26 | 5.46 | 5.4 | 0.7 | 0.5 |
| 6 - 10 | 1.61 | 1.9 | 0.66 | 0.72 | 0.01 | 0.09 | 29.26 | 51 | 5.69 | 6.0 | 0.6 | 0.4 |

## Results and Discussion

### Soil Physical and Chemical Properties under *Faidherbia albida* Trees

The effect of *Faidherbia* tree on soil is varied and generally depended on sampling depth and distance from the tree. However, only BD differed significantly across tree distances (p =0.038). This study found that the concentrations of BD, OC, N, P, Ca, and Mg were higher beneath the trees while ECEC, Mn and Na were relatively higher farther away from the trees. The higher levels of BD, OC, N, P, Ca and Mg observed beneath the boles might be as a result of litter accumulation and decomposition under the trees. This agrees with Anka and Sanda (22) who reported that these minerals were higher due to amounts of litter fall and decomposition under trees. Potassium remained relatively constant across distances. However, soil cation exchange capacity (CEC) was extremely high under the matured trees (16 - 20m height) (Table 2) suggesting high nutrient uptake by the trees.

Soil pH was lower under *Faidherbia* trees of 11 – 15 m height (Table 2). This finding agrees with Desta *et al.* (37) who made similar observations in Central Rift Valley, Ethiopia. According to Boffa (14) small *Faidherbia* trees induce little fertility change in their soil environment. Rhoades (17) reported that small *Faidherbia albida* trees (6.6 m crown radius) did not increase net nitrogen mineralization rates relative to open sites while larger canopies (24 m) resulted in 170% more nitrogen production during the growing season.

The high levels of soil total nitrogen, phosphorus, organic carbon and other macronutrients beneath the trees corroborates

Umar *et al*. (35) who reported that soil organic matter and exchangeable cations accumulate under *F. albida* canopies. Adamu (13) found high values of organic carbon (1.25 to 2.35%) and nitrogen (0.15-0.25%) in plots with *Faidherbia albida* in Gezawa, Kano State, Nigeria. This may also be due to the species rooting system which ramifies the soil while foraging for nutrients. The high organic matter content leads to soil aggregation, thereby reducing the impact of aeolian soil erosion in the area. Furthermore, improved soil moisture availability in *Faidherbia albida* parklands result in increased infiltration and reduced evaporation from the soil surface (6). The higher concentrations of soil nutrients beneath trees may also be attributed to the trees ability to enhance biological recycling of decomposed leaf matter which is absorbed into the soil in the form of soil organic matter (36, 37).

**Conclusion**

This study revealed that soils under canopies of *Faidherbia albida* trees were rich in nutrients and cations, with the tree effect extending to 10 m radius. Consequently, mature *Faidherbia albida* trees have the potential to replenish soils under cultivation. The growth of this species should therefore be encouraged on small holder farms to help improve nutrient-deficient soils in dry lands of Northern Nigeria.

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