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Original Research Article

Soil Fertility Improvement through the Influence of Organic Mulch: Comparative Assessment of Leafy Biomass from Selected Tree Species in Sudan Savannah

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ABSTRACT
Continuous cropping, erosion, and low organic matter cause declining soil fertility and reducing crop productivity. Farmers possess inadequate access to inorganic fertilizers, while tree leafy biomass remains underutilized as mulch despite its potential to recycle nutrients and improve soil structure. This study, therefore evaluates and compares the effect of organic mulch from selected tree species in sudan savannah. A split-plot design was conducted in a forest nursery using leafy biomass mulch from Azadirachta indica, Tamarindus indica, Parkia biglobosa, and Moringa oleifera. A 10 × 10 m area was divided into 20 micro-plots of 1.5 m × 1.5 m, with 0.25 m buffers. Five treatments including control were replicated four times. Mature leaves were applied at 5 t ha^{-1}. Surface soil (0–15 cm) was sampled at 4 and 8 weeks after application. Soil pH, organic carbon, total nitrogen, and exchangeable Ca, Mg, and K were analyzed using standard laboratory procedures. Data were subjected to two-way ANOVA and means separated with Least Significant Differences at $p < 0.05$. All mulches maintained a stable, slightly basic soil pH (7.9–8.47), favorable for crop and microbial activity. Parkia biglobosa mulch produced the highest soil organic carbon (3.13%), total nitrogen (0.29%), and magnesium, significantly improving soil fertility. Neem gave the highest available phosphorus, while Moringa provided the highest calcium and potassium levels. Tamarindus indica showed the lowest contributions to organic carbon and nitrogen. P. biglobosa and A. indica were most effective for enhancing soil fertility, with species-specific nutrient benefits supporting targeted mulch selection based on soil deficiencies. Tree leaf mulches from Parkia, neem and Moringa significantly enhanced soil fertility in the Sudan Savannah. Parkia was most effective, boosting organic carbon, nitrogen, and magnesium. A. indica enriched phosphorus while offering pest control, and Moringa increased calcium and potassium. Promote P. biglobosa for general soil improvement, adopt species-specific mulching, and integrate tree mulches into sustainable land management to reduce chemical fertilizer dependence.

INTRODUCTION

Soil fertility is critical component of agricultural productivity and ecosystem health, continuous cropping, deforestation, and poor land management have led to declining soil fertility in many regions in Nigeria (Oyun *et al.,* 2025). Organic mulching particularly using leafy biomass from leguminous indigenous tree species offers a sustainable approach to restoring soil health. Most soils in the tropics are deficient in soil nitrogen (N), phosphorus (P), or both and even organic carbon (OC) (Pandey *et al.,* 2006). Many of the tropical soils are acidic, infertile and cannot support sustainable crop production without external inputs of fertilizers due to continuous cropping system. Some soils which were once fertile have become depleted and can no longer sustain crop production (Opoku *et al.,* 2026; Oyebamiji *et al*. 2017). Application of nitrogenous and phosphorus fertilizers are more importance practice in nursery establishment. *Faiherbia albida* and *Leucanea leucocephala* observed to fix nitrogen to the soil while mycorrhiza is essential for Pinus caribea (Pines) propagation (Salami *et al.,* 2020). Fertilizers which are inorganic in form, are not readily available to farmers. Sometimes, when available, they are being sold at exorbitant prices. The high population pressure on land and the shortened fallow period have made it difficult to increase and sustain food production on the infertile soils of the tropics (Kang, 1993; Oke, 2005). Consequently, the issue of biomass transfer has been noted as alternative method to improve soil fertility (Oke, 2005). The use of plant biomass has sparked interest in the productivity improvement of agricultural crops. However, the amount and kind of nutrients released and thus added to the soil depends on the composition of the added plant biomass. The transfer of nutrients *Azadirachta indica* (Neem), *Tamarindus indica* (Tamarind*), Parkia biglobosa* (African Locus Bean), *Moringa oliefera* on soil fertility. Nutrient through tree biomass can contribute to micro variability in soil fertility and plant growth (Ahmed *et al.,* 2026).

According to Manfongoya *et al*. (1998), the potentials of tree biomass to supply nutrient on their resource quality is based on the quality of the organic material present, the environment and the type of organism present, that influence decomposition and nutrient release. Salako and Tian (2001) also emphasized that the efficient conversion of plant biomass to humus by soil organisms largely depends on climatic factors and the plant tissue quality. Agroforestry systems are viable and sustainable land use alternatives, because of the benefits of trees in maintaining soil fertility. Trees maintain and enhance soil fertility by adding nitrogen through fixation, nutrients through litter fall or pruning, or importing nutrients through biomass transfer systems (Oyebamiji *et al*. 2016). The nutrients released therefore are made available to crops through the decomposition of the tree pruning and litter (Manfongoya *et al.,* 1998).

Soil organic residues such as leaves, twigs, reproductive parts, bark, and wood, roots and dead bodies of animals can serve as humus for soil amendments (Wanek *et al*. 2008; Alfredo, 2015). Continuous cropping, erosion, and the removal of natural vegetation have led to significant depletion of essential soil nutrients, resulting in reduced crop yield and land degradation. However limited research exists on the comparative effectiveness of mulch derived from different indigenous tree species. Major challenges of the developing countries are the production of sufficient food for the rapidly increasing population and over cultivation of land resulting in soil infertility. Hence the transfer of nutrient through tree biomass contribute to micro variability in soil fertility and plant growth. In this work, the use of leafy biomass of some selected agroforestry tree species A*nogeissus leiocarpus, Enterolobium cyclocarpum, Gliricidia sepium, Leucaena leucocephala* and *Treculia africana,* which are leguminous in nature, that is, having ability to fix nitrogen into the soil) were tested. Therefore, the study focused on the effect of organic mulch on soil fertility improvement from leafy biomass from selected tree Species in Sudan Savannah in view of recommending best fertility dose to the farmers and soil users.

MATERIALS AND METHODS

Description of the study site

The study area is situated at 11°70’ N latitude and 9°34’ E longitude, with an altitude of 460 meters above sea level (Olatunde *et al.,* 2025). The area, characterized by a tropical climate, receives a mean annual rainfall of 750mm, which provides a favorable condition for agricultural activities (Gidado *et al.,* 2023). The mean annual temperature in the area supports the growth of variety of plants. The area's relatively uniform climate and soil conditions ensured that the results obtained from the study were reliable and applicable to similar agro-ecological zones. The topography of the area is generally flat, with a high land area of approximately 750 meters. The soil type in this region is predominantly sandy-loam, as reported in previous studies (Garba *et al*., 2021). This soil type is characterized by a mix of sand, silt, and clay, providing a suitable medium for plant growth.

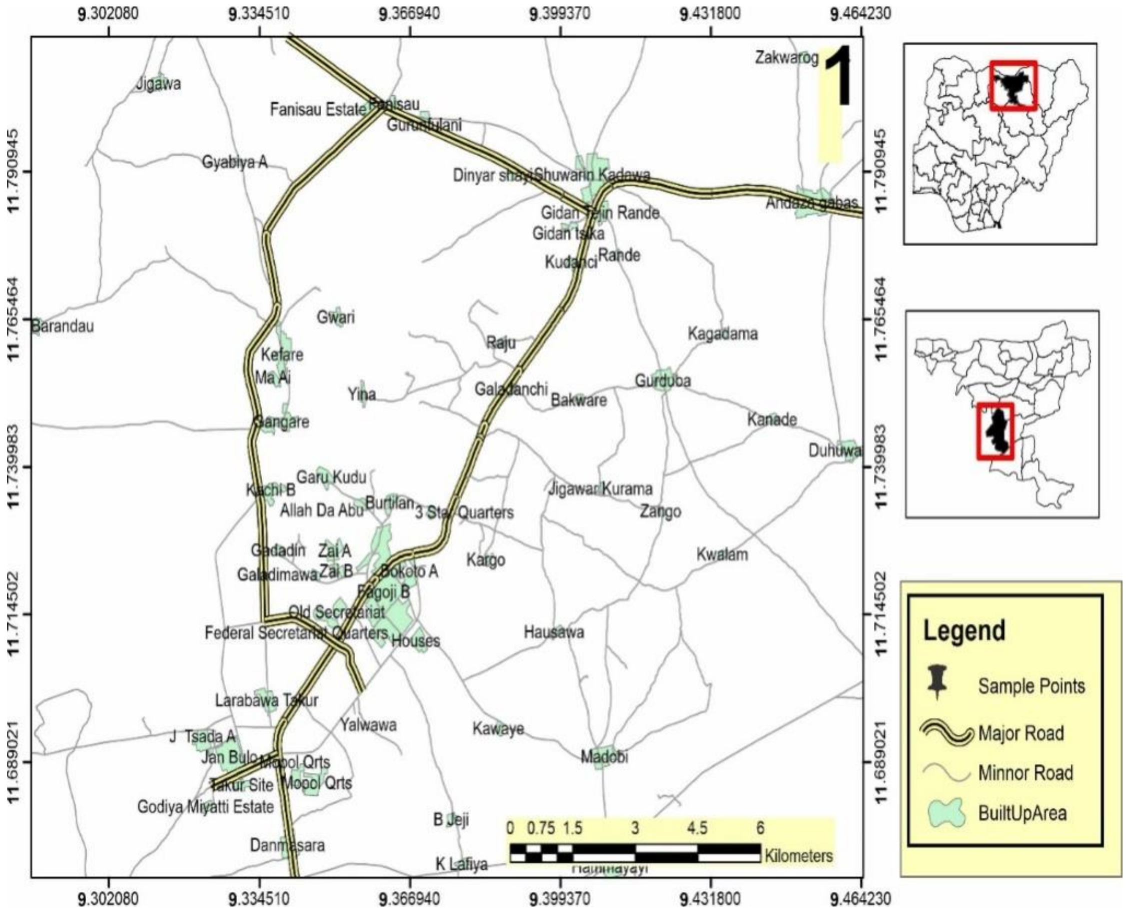


Figure 1: Map of the study area
Source: Map of Dutse Local Government Area (LGA)
Adapted from: GIS and Remote Sensing Software Arc Map Department of Geography ABU, Zaria, Kaduna State

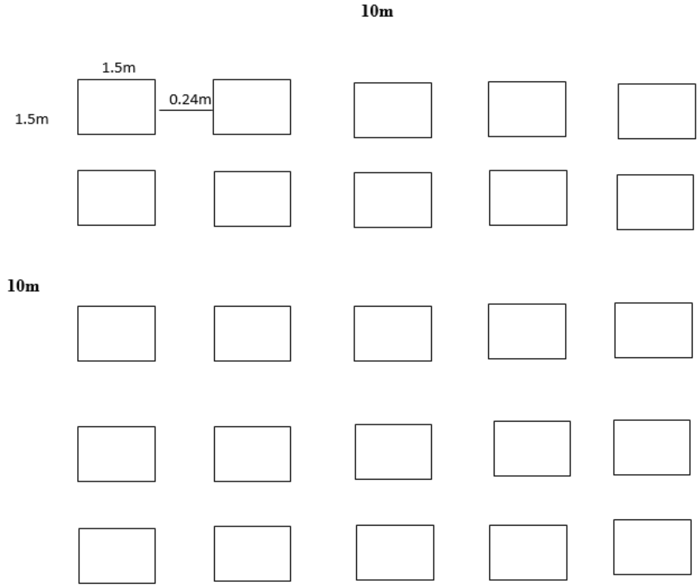
Data collection
Fresh leafy biomass from A. *indica, T. indica, and P. biglobosa, Moringa oliefera*. Mature but not senescent leaves were carefully select from the woody species of A. *indica, T. indica, and P. biglobosa, Moringa oliefera* pruned for mulch.

Soil Sampling
Surface soil (0-15 cm) samples were collected with aid of auger. The soil was taken in each of the micro-plots and then bulked to homogenize. The soil samples from each micro-plot will be collected at 4 and 8 weeks after application (WAP) and then taken to the laboratory for analysis.

Procedure
Chemical Analysis
Soil pH is measure with an electronic pH meter in a 1: 2.5 soil/water suspension. Soil organic carbon will determine by wet oxidation. Total nitrogen in the soil will be determined using semi micro Kjeldahl method. Soil samples will be leached with ammonium acetate solution to obtain the extracts used in the determination of exchangeable cations. Calcium and magnesium in the leachate will be determined by Ethylene Tetra-acetic Acid (EDTA) titration while potassium was determined by flame photometry following the procedure of (Oke, 2005; Oladoye *et al*., 2020)

Experimental Design
The experimental design used was split plot design with the main plots being the time of soil sampling, and the sub-plots were the mulch type sited in the forest nursery (Oladoye *et al.,* 2020). An area of 10 m x 10 m was partitioned into 20 micro-plots of 1.5 m x 1.5 m dimension. Adjacent micro-plots are separated by a buffer of 0.25 m wide. Five (5) treatments which include biomass was randomly be applied to the plots including the control with four (4) replicates. Mature but not senescent leaves were carefully select from the woody species of A. *indica, T. indica, and P. biglobosa, Moringa oliefera* pruned for mulch. Each of the treatments was applied at the rate of 5 tons per hectare (5t ha^{-1}), meaning that 5 kg from each species was apply 1.5 by 1.5 m micro-plots assigned to the species which were randomly selected (Oladoye *et al.,* 2020).

Experimental Layout



Data analysis

Data collected was analyzed using two-way Analysis of Variance (ANOVA) and Least Significant difference was used to separate means ($p < 0.05$).

RESULTS AND DISCUSSION

The results indicated that the soil remained slightly basic across all treatments, with pH values above 7. *Parkia biglobosa* mulch showed the highest pH at 8.47, while *Moringa oleifera* had the lowest at 7.9, but these differences were not statistically significant. This suggests that using any of these tree mulches will not drastically change the soil's acidity or alkalinity. Maintaining a stable, slightly basic pH is beneficial because most crops and soil microorganisms thrive in this range, supporting healthy plant growth and soil function. They all helped to maintain a stable pH level, which is good for most plants and soil.

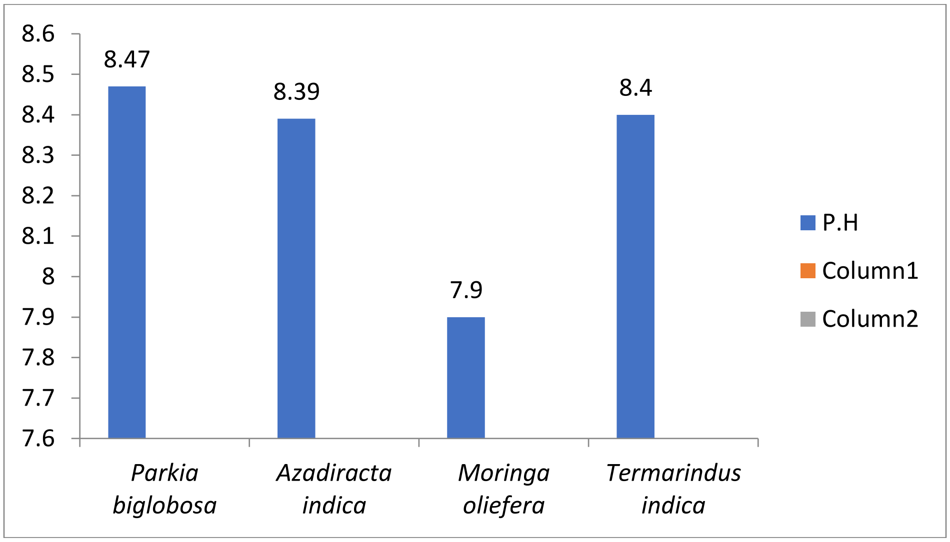


Figure 2: Showing the Mean of the pH from the Soil Sample

Parkia biglobosa mulch contributed the highest amount of organic carbon to the soil at 3.13%, significantly more than the other tree species. Both *Azadirachta indica* and *Moringa oleifera* added the same moderate level of organic carbon (1.86%), while *Tamarindus indica* contributed the least (1.00%). This is important because organic carbon plays a key role in improving soil structure, increasing water retention, and providing nutrients for beneficial soil organisms. Therefore, using *Parkia biglobosa* mulch is the best option for quickly boosting the soil's organic matter and overall health.

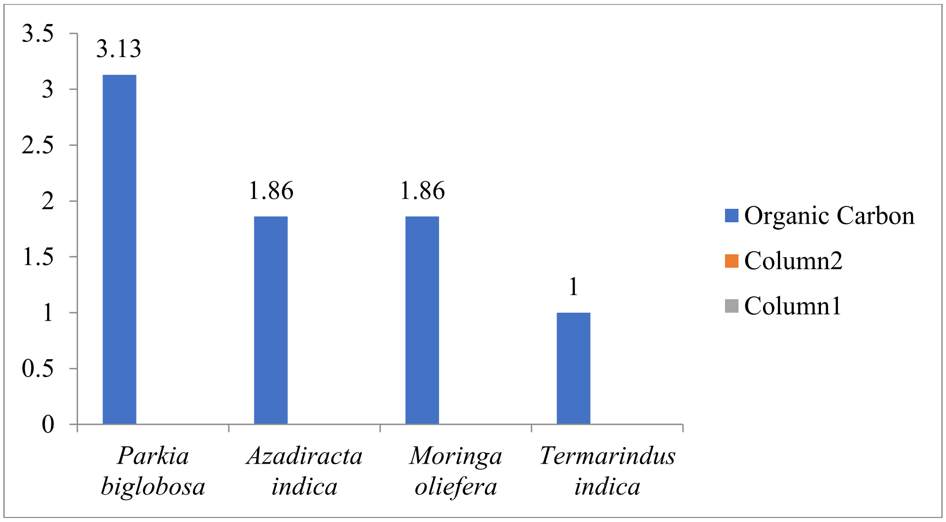


Figure 3: Showing the Mean of the Organic carbon from the Soil Sample

The amount of nitrogen in the soil followed a similar pattern to organic carbon. *Parkia biglobosa* released the most nitrogen (0.29%), which was significantly higher than the others. This was expected because *Parkia* is a leguminous tree. *Moringa oleifera*, which is also known to be rich in nutrients, released less nitrogen than *Parkia*. *Tamarindus indica* released the least nitrogen. This clearly shows that using *Parkia biglobosa* as mulch can be a very effective way to add natural nitrogen to the soil, reducing the need for chemical fertilizers.

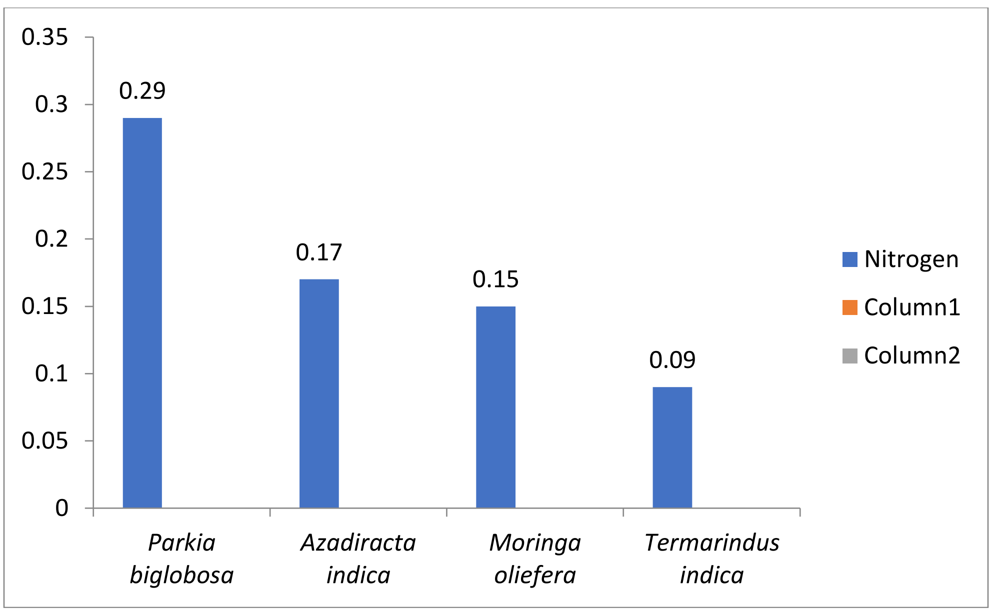


Figure 4: Showing the Mean of the Nitrogen from the Soil Sample

The results indicated significant variation in phosphorus and potassium composition among the tree species studied. *Azadirachta indica* (33.18 mg/kg) and *Parkia biglobosa* (32.4 mg/kg) recorded the highest phosphorus values, and the difference between them was not statistically significant. In contrast, Moringa oleifera had the lowest phosphorus concentration. For potassium, *Moringa oleifera* and *Parkia biglobosa* had the highest amounts. This variation suggests that different tree species have distinct nutrient profiles and would therefore have different effects on soil fertility when used as mulch. Consequently, mulch selection should be guided by soil nutrient deficiencies. For soils deficient in phosphorus, *A. indica* or *P. biglobosa* mulch would be more suitable. For potassium-deficient soils, *M. oleifera* or *P. biglobosa* would be the better option. These findings support the practice of targeted organic mulching to address specific soil fertility limitations.

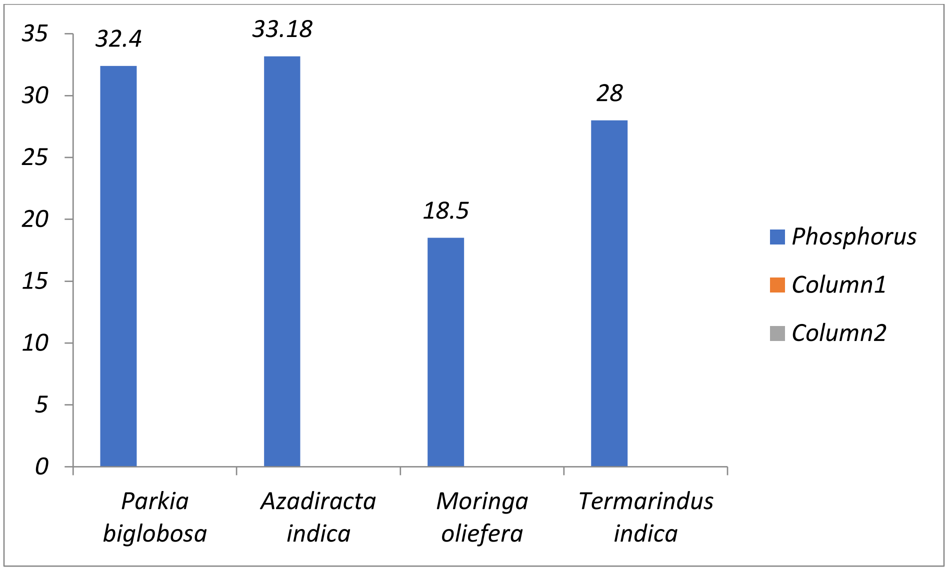


Figure 5: Showing the Mean of the phosphorus from the Soil Sample

As presented in Figure 6, *Moringa oleifera* and *Parkia biglobosa* mulches resulted in the highest mean soil potassium concentrations of 0.61 and 0.60 cmol/kg, respectively, with no statistically significant difference between the two treatments. *Azadirachta indica* produced a moderate potassium level of 0.50 cmol/kg, while *Tamarindus indica* recorded the lowest value at 0.35 cmol/kg. Potassium plays a critical role in plant water regulation, enzyme activation, and disease resistance. The elevated potassium under *M. oleifera* mulch can be attributed to its nutrient-rich leaf biomass and rapid decomposition rate, which facilitates the quick release of available K into the soil. Similarly, the high K contribution from P. biglobosa is likely due to its deep, extensive root system that mines subsoil nutrients and returns them to the surface via litter fall. Conversely, the lower K value observed with *T. indica* may reflect slower decomposition or a lower inherent potassium content in its biomass. Therefore, for potassium-deficient soils in the Sudan Savannah zone, *M. oleifera* and *P. biglobosa* mulches are recommended as effective organic amendments.

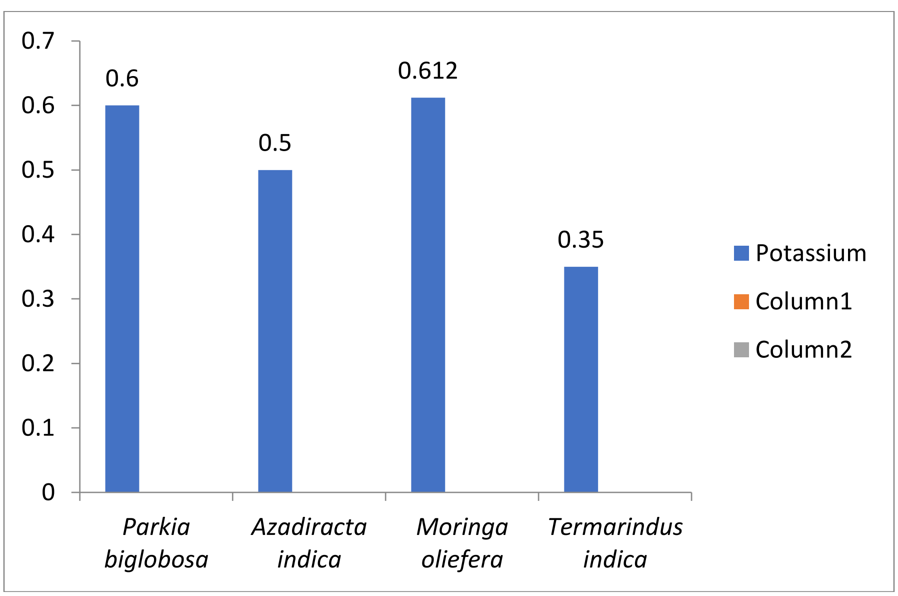


Figure 6: Showing the Mean of the Potassium from the Soil Sample

Moringa oleifera mulch led to the highest level of calcium in the soil (8.00), which was significantly higher than the other species. For magnesium, *Parkia biglobosa* again had the highest value (3.0). This supports the idea that Moringa is a nutrient-rich plant, especially for calcium, which is important for strong plant cell walls.

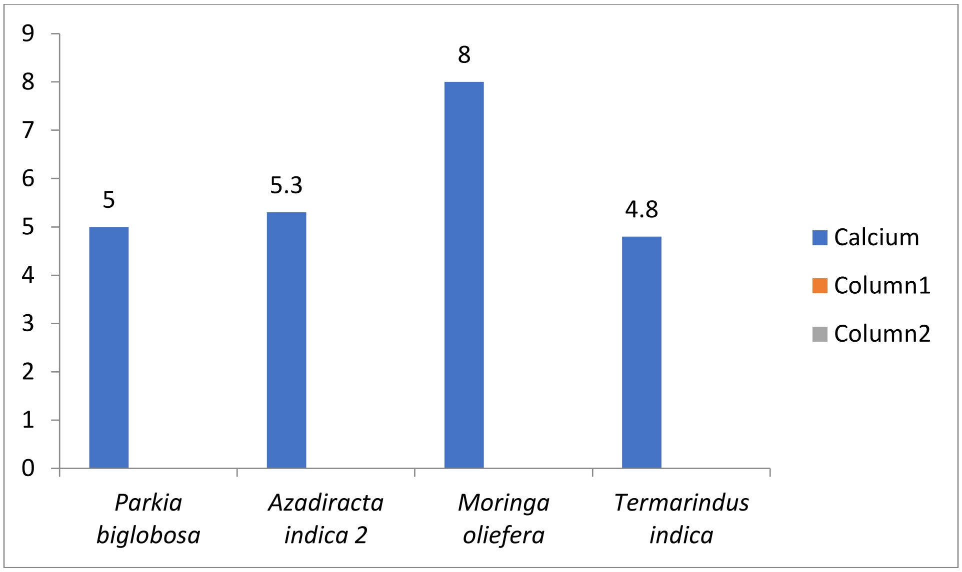


Figure 7: Showing the Mean of the Calcium from the Soil Sample

Figure 8 shows that *Parkia biglobosa* mulch produced the highest mean soil magnesium level at 3.0 cmol/kg, significantly greater than other treatments. *Moringa oleifera* was next at 2.2 cmol/kg, followed by *Azadirachta indica* with 1.7 cmol/kg, while *Tamarindus indica* had the lowest at 1.1 cmol/kg. This indicates that *P. biglobosa* is the most effective species for enriching soil magnesium, a critical nutrient for chlorophyll formation and photosynthesis. Its deep root system likely recycles magnesium from subsoil layers, releasing it through litter decomposition. The moderate levels from *M. oleifera* and *A. indica* still contribute to magnesium improvement, but *T. indica* showed limited benefit. For magnesium-deficient soils in the Sudan Savannah, using *P. biglobosa* mulch is recommended as a sustainable amendment to enhance photosynthetic efficiency and overall crop productivity.

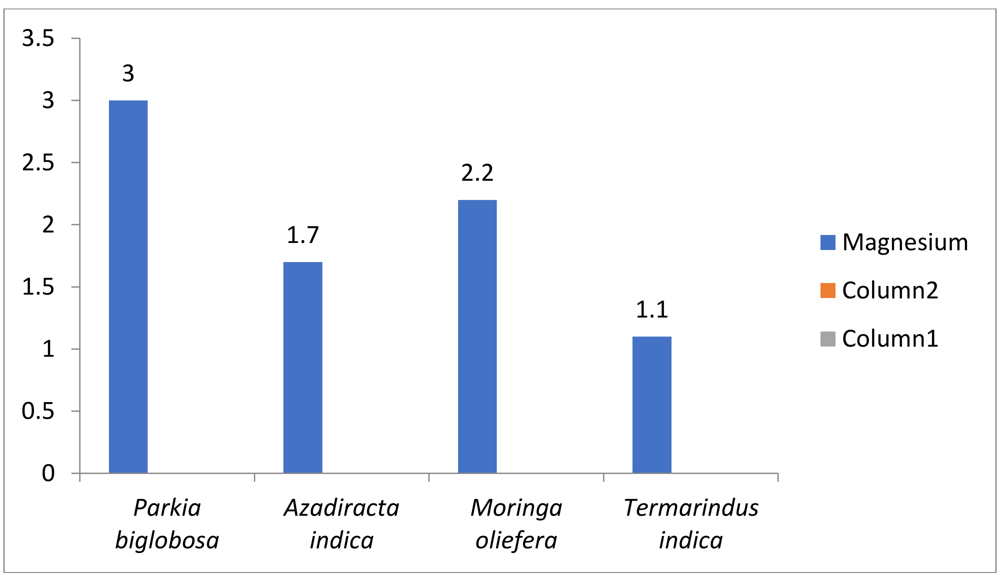


Figure 8: Showing the Mean of the Magnesium from the Soil Sample

Figure 9 indicates that sodium levels remained low across all mulch treatments, with *Tamarindus indica* recording the highest mean at 0.09 cmol/kg. *Parkia biglobosa* and*Moringa oleifera* both had 0.08 cmol/kg, while *Azadirachta indica* showed the lowest at 0.06 cmol/kg. Differences among treatments were not statistically significant. These low sodium values are beneficial, as excess sodium can degrade soil structure, reduce permeability, and impair plant growth. The results suggest that none of the tree mulches pose a sodicity risk. Even the slightly higher sodium from *T. indica* remains well below levels that cause soil dispersion. Therefore, all four species are safe for use as mulch without increasing soil salinity or sodium hazards, supporting their adoption in sustainable soil fertility management in the Sudan Savanna.

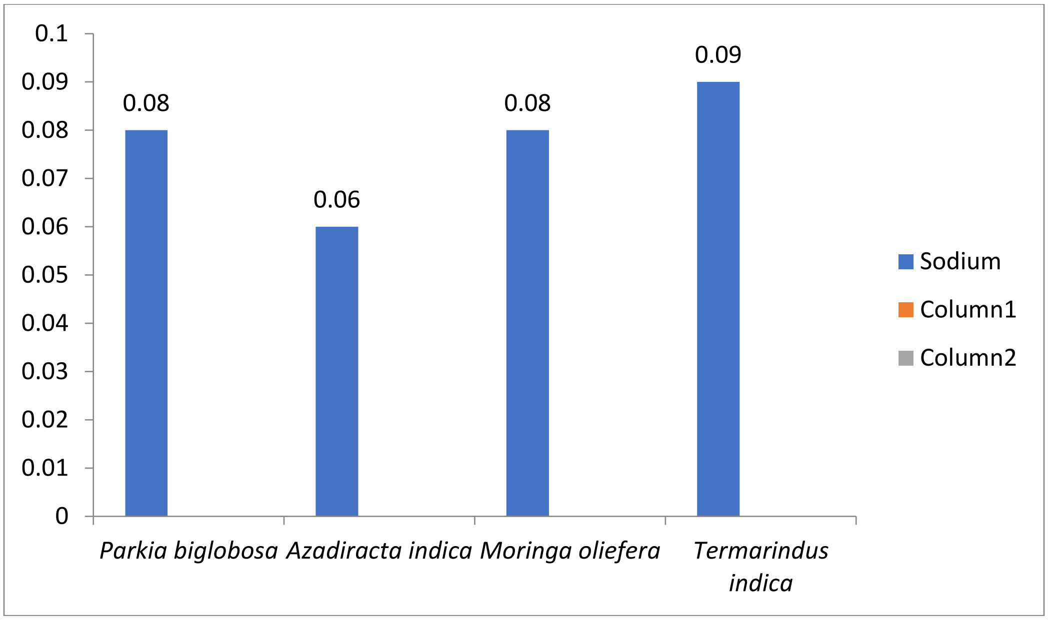


Figure 9: Showing the Mean of the Sodium from the Soil Sample

The analysis of soil physicochemical properties under different tree species reveals notable variations that can influence soil fertility and land management practices. *Parkia biglobosa* recorded the highest soil organic carbon (3.13%) and total nitrogen (0.29%), indicating strong organic matter input and nutrient cycling potential, which supports better soil fertility. Its pH value of 8.47 suggests slightly alkaline conditions, suitable for many crops, and it also maintained relatively good levels of calcium (5.0 cmol/kg), magnesium (3.0 cmol/kg), and sodium (0.08 cmol/kg), making it a favorable species for enhancing soil quality. *Azadirachta indica* also showed good nutrient content, with a slightly lower organic carbon and nitrogen than Parkia but higher available phosphorus (33.18 mg/kg) and calcium (5.3 cmol/kg), making it valuable for soil improvement. *Moringa oleifera* had moderate values across most parameters, notably the highest calcium (8.0 cmol/kg), which may improve soil structure and plant uptake of other nutrients. Tamarindus indica had the lowest values for organic carbon (1.0%) and total nitrogen (0.09%), suggesting poor litter contribution and lower fertility enhancement capacity. However, it had the highest sodium content, which, if not managed, could affect soil structure. Overall, *Parkia biglobosa* and *Azadirachta indica* appear to contribute more positively to soil fertility, while *Tamarindus indica* may require soil amendments for improved productivity.

Table 1: Mean Separation for Physicochemical for Leaf Mulching of Four Plant

Species	pH	S. O. C.	T. N	P	K	Ca	Mg	Na
Parkia biglobosa	8.47±0.48^{a}	3.13±1.27^{a}	0.29±13.79^{a}	32.4±0.12ab	0.60±0.66^{a}	5.0±0.8^{b}	3.0±1.33^{a}	0.08±50^{a}
Azadirachta indica	8.39±0.48^{a}	1.86±2.15^{b}	0.17±23.52^{b}	33.18±0.12^{a}	0.50±8.0^{ab}	5.3±0.75^{ab}	1.7±2.35^{b}	0.06±66.6^{ab}
Moringa oleifera	7.9±0.50^{a}	1.86±2.15^{b}	0.15±26.66^{b}	18.5±0.21^{bc}	0.61±6.53^{a}	8.0±0.5^{a}	2.2±1.81^{ab}	0.08±50^{a}
Tamarind indica	8.4±0-47^{a}	1.0±4.0^{c}	0.09±44.44^{c}	28±0.14^{b}	0.35±11.42^{b}	4.8±0.83^{b}	1.1±3.63^{c}	0.09±44.44^{a}

Mean of the same letter along the treatment is not significantly different at ≤0.05

Discussion

pH

The results indicate that all tree species had a slightly alkaline effect on soil pH, with values ranging from 7.9 in *Moringa oleifera* to 8.47 in *Parkia biglobosa*. Although the variation among the species was not statistically significant, the consistently basic pH levels suggest that the soils beneath these trees are buffered against acidification. Slightly alkaline soils are generally favorable for microbial activity and nutrient availability, especially for elements like calcium, magnesium, and molybdenum (Mandal *et al.,* 2021). The highest pH under *Parkia* biglobosa may be due to its high organic matter content, which can release basic cations such as Ca^{2+} and Mg^{2+} into the soil, improving pH buffering (Adjei-Gyapong *et al.,* 2023). Moringa oleifera, while still basic, had the lowest pH, potentially reflecting its lower organic matter decomposition rate or a different litter composition that slightly acidifies the soil. Maintaining pH in the range of 6.5–8.0 is crucial for most crops and beneficial microorganisms, as extreme pH levels can limit nutrient uptake and microbial diversity (Adewunmi *et al*., 2022). Therefore, the findings reinforce that tree litter contributes to pH stabilization, enhancing soil health over time.

Soil Organic Carbon

The application of *Parkia biglobosa* mulch significantly increased soil organic carbon (OC) content, reaching 3.13%, which was notably higher than the other tree species. This indicates that *Parkia biglobosa* contributes more organic residues that decompose effectively and enrich the soil with carbon. In comparison, *Azadirachta indica and Moringa oleifera* recorded moderate OC levels of 1.86%, while *Tamarindus indica* contributed the least (1.00%), suggesting lower organic matter input or slower decomposition. Organic carbon is a vital component of soil health. It enhances soil aggregation, improves water retention, boosts nutrient availability, and supports microbial activity (Lal, 2020). The superior performance of *Parkia biglobosa* may be due to its litter quality rich in lignin and cellulose which breaks down gradually, promoting long-term carbon sequestration (Adewuyi *et al*., 2021). Its deep root system may also recycle nutrients and support higher biomass return. Mulching with species that contribute high organic carbon, such as *Parkia biglobosa*, is essential in sustainable land management, especially in semi-arid regions where organic matter is often depleted. Increasing soil carbon not only improves fertility but also enhances resilience to drought and erosion (FAO, 2022).

Effect on Soil Nitrogen

The nitrogen content in the soil showed a clear trend, mirroring the pattern observed in organic carbon levels. *Parkia biglobosa* contributed the highest nitrogen value (0.29%), significantly more than other species. This outcome aligns with its biological nature as a leguminous tree, which enhances soil nitrogen through biological nitrogen fixation: a process in which symbiotic bacteria in root nodules convert atmospheric nitrogen into forms usable by plants (Dakora and Keya, 2020). In contrast, *Moringa oleifera*, though rich in nutrients and organic content, released only 0.15% nitrogen, while Tamarindus indica released the least (0.09%). This suggests that not all nutrient-rich plants contribute equally to nitrogen enrichment. *Parkia biglobosa's* superior performance could be due to its nitrogen-fixing ability, coupled with high biomass litter, which decomposes to release nitrogen gradually into the soil. Using *Parkia biglobosa* mulch can therefore serve as a natural and sustainable alternative to chemical nitrogen fertilizers. This reduces input costs, improves soil fertility, and enhances environmental sustainability, especially in low-input agricultural systems (Bationo *et al*., 2018). The practice aligns well with agroecological approaches promoting soil health and long-term productivity.

Effect on Soil Phosphorus and Potassium

The results clearly show that different tree species enrich the soil with different nutrients, emphasizing the importance of species selection based on soil needs. *Azadirachta indica* (Neem) and *Parkia biglobosa* (African locust bean) provided the highest phosphorus levels (33.18 and 32.4 mg/kg respectively), and their values were statistically similar. Phosphorus is essential for root development, flowering, and fruiting, but it's often deficient in tropical soils due to fixation by iron and aluminum compounds. Therefore, applying mulch from Neem or Parkia is beneficial for replenishing phosphorus, especially in degraded or phosphorus-poor soils (Nziguheba *et al.,* 2021).

Effect on Potassium

Potassium, vital for plant water regulation, disease resistance, and overall vigor, was highest in soils mulched with *Moringa oleifera* and *Parkia biglobosa*, showing their strong potential as natural potassium sources. This aligns with findings by Gindaba *et al*. (2015), who noted that Moringa leaves are rich in potassium and other micronutrients, making them excellent for compost or mulch. These results suggest a targeted approach to soil fertility: if a farmer's land is lacking in phosphorus, using Neem or Parkia mulch is effective. If potassium is the main concern, Moringa or Parkia would be better suited. This strategy promotes cost-effective and environmentally friendly nutrient management through agroforestry.

Effect on Calcium and Magnesium

The findings show that *Moringa oleifera* mulch significantly improved soil calcium levels, reaching 8.00 cmol/kg, which was notably higher than other treatments. Calcium is essential for plant development, particularly in cell wall strength, root growth, and nutrient uptake regulation. The ability of Moringa to enhance soil calcium is consistent with its known high mineral content. As reported by Foidl *et al.* (2001), Moringa leaves contain substantial levels of calcium, making them a valuable source for soil enrichment when used as mulch or compost. On the other hand, Parkia biglobosa contributed the most magnesium (3.0 cmol/kg). Magnesium is critical for photosynthesis, being the central atom in the chlorophyll molecule. The release of high magnesium from Parkia aligns with its deep-rooted nature and nutrient recycling abilities, which enable it to access and return subsoil nutrients to the surface. According to Kang and Akinnifesi (2000), leguminous trees like Parkia enhance soil fertility through biomass decomposition and nutrient cycling. Together, these results highlight the nutritional benefits of species-specific mulches. Moringa is ideal for improving calcium-deficient soils, while Parkia supports magnesium enrichment. This supports sustainable agriculture by reducing dependence on synthetic fertilizers and promoting eco-friendly soil fertility management through agroforestry.

Parkia biglobosa (African Locust Bean) stood out as the best performer. Its mulch significantly increased organic carbon (3.13%), nitrogen (0.29%), and magnesium (3.0 cmol/kg), making it a powerful natural soil amendment. Being a leguminous tree, Parkia fixes nitrogen biologically and improves soil fertility through its nutrient-rich litter. This supports findings by Olawoyin *et al*. (2020), who reported Parkia's strong contribution to soil fertility in agroforestry systems. *Azadirachta indica* (Neem) was especially effective in boosting phosphorus (33.18 mg/kg) and performed reasonably well in other nutrients. In addition to this, Neem is known for its bio pesticidal properties, offering dual benefits: soil enrichment and pest deterrence (Subapriya and Nagini, 2005). This makes Neem mulch valuable in sustainable, low-input farming systems. *Moringa oleifera* proved to be a quick nutrient-releasing species, especially rich in calcium (8.00 cmol/kg) and potassium. Moringa's soft tissues decompose rapidly, providing a fast source of nutrients. Makkar and Becker (1996) also noted the high mineral content of Moringa, making it beneficial for quick soil amendments, especially in nutrient-poor soils. In contrast, *Tamarindus indica* had the lowest impact on most nutrients, especially organic carbon (1.0%) and nitrogen (0.09%). While not ideal for quick nutrient enrichment, it may offer value as a long-term mulch that provides soil cover and improves structure over time.

CONCLUSION

This study confirms that tree leaf mulch especially from *Parkia biglobosa, Azadirachta indica*, and *Moringa oleifera* can significantly improve soil fertility in the Sudan Savannah region. Parkia biglobosa proved to be the most effective overall, enriching the soil with high levels of organic carbon, nitrogen, and magnesium, making it ideal for general soil improvement. Neem leaves excelled in phosphorus enrichment and offer pest-repelling benefits, while Moringa was particularly rich in calcium and potassium. Using these local, natural resources provides farmers with a sustainable, low-cost alternative to chemical fertilizers, tailored to their soil's specific nutrient needs and supporting long-term agricultural productivity.

RECOMMENDATIONS

Base on the findings derived from the study conducted. The following recommendations were made:

1. Promote the use of *Parkia biglobosa* leaves as organic mulch among farmers in the Sudan Savannah due to its proven ability to improve soil nitrogen, organic carbon, and overall fertility.
2. Encourage species-specific mulching, where farmers use *Moringa oleifera* for calcium and potassium enhancement, and *Azadirachta indica* (Neem) for phosphorus improvement and natural pest control.
3. Integrate tree-based mulch practices into sustainable land management and soil restoration programs to reduce dependence on synthetic fertilizers.
4. Conduct long-term studies on the decomposition rate and nutrient release patterns of various tree mulches to better guide application timing and frequency.
5. Train farmers and extension agents on proper mulch collection, application methods, and matching tree species with soil nutrient deficiencies for better crop yields and soil health.

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