



# Effect of *Acacia mangium* Based Agroforestry Systems on Soil Physical and Chemical Properties

Prasannajit Mishra <sup>a</sup>, Manas Ranjan Nayak <sup>a\*</sup>,  
Bibhuti Bhusan Behera <sup>a</sup>, Debasmita Maharana <sup>a</sup>  
and Arun Kumar Handa <sup>b</sup>

<sup>a</sup> AICRP on Agroforestry, OUAT, Bhubaneswar, India.

<sup>b</sup> ICAR-CAFRI, Jhansi, India.

## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

## Article Information

DOI: <https://doi.org/10.9734/ijpss/2025/v37i75568>

## Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/139765>

**Original Research Article**

**Received: 01/05/2025**  
**Accepted: 04/07/2025**  
**Published: 08/07/2025**

## ABSTRACT

In an agroforestry system, woody perennial is deliberately combined with agricultural crops and/or animals in same land management unit, either in some form of spatial arrangement or temporal sequence. There are both ecological as well as economical interactions between the different components of agroforestry. An experiment was carried out to evaluate the effect of different agroforestry systems on soil physico-chemical properties. The present investigation was carried out at Central Research Station of Odisha University of Agriculture and Technology, Bhubaneswar, India. Soil chemical properties such as base saturation, cation exchange capacity (CEC), electrical conductivity (EC), pH, available nitrogen, phosphorus, potassium and organic carbon as affected

\*Corresponding author: E-mail: [mrnayak.forestry@ouat.ac.in](mailto:mrnayak.forestry@ouat.ac.in), [manas.forestry@gmail.com](mailto:manas.forestry@gmail.com);

by different *Acacia mangium* based agroforestry system. Mechanical analysis of the soil was done to find out the percentage of sand, silt and clay separately by means of bouyoucus hydrometer method to determine the texture of soil. The soil parameters we measured by using standard method. Data obtained from various observations were subjected to statistical analysis by adopting appropriate method of Analysis of Variance (ANOVA). The significance of the treatment effect was judged with the help of 'F' test (Variance ratio). The results revealed that different agroforestry system showed the positive impact on soil physico-chemical properties in comparison to the initial stage of the trial. Bulk density is found to decrease more in *Acacia mangium* with hybrid napier and with guinea grass systems (1.58 - 1.51 g/cm<sup>3</sup>) compared to less decrease in *Acacia mangium* with pineapple and with *Aloe vera* systems, the highest increase in porosity is found with *Acacia mangium* in combination with mango ginger and hybrid napier (35-38%). The base saturation showed a decreasing trend over the years, except in *Acacia mangium* with kalmegh system (43 %)., CEC is reported to increase in *Acacia mangium* with pineapple system (4.3 meq kg<sup>-1</sup>) and decrease in *Acacia mangium* with guinea grass system (4.1 meq kg<sup>-1</sup>). EC is also found to increase in *Acacia mangium* with mango ginger system (0.37 dS m<sup>-1</sup>) followed by *Acacia mangium* with pine apple and kalmegh systems (0.25 dS m<sup>-1</sup>). The highest change in soil acidity is observed in *Acacia mangium* with thin napier (pH 4.90 - 6.08) followed by *Acacia mangium* with pineapple system (pH 4.90 - 5.93). The OC, N and P content in soil was found to increase in all the systems and the highest OC (6.19 g kg<sup>-1</sup>), N (260.31 kg ha<sup>-1</sup>) was observed in *Acacia mangium* with kalmegh system. The highest available phosphorus was observed in *Acacia mangium* with pineapple system (82.90 kg ha<sup>-1</sup>) followed by *Acacia mangium* with kalmegh system (76.15 kg ha<sup>-1</sup>). *Acacia mangium* in combination with pine apple and mango ginger though observed increased potassium availability of 238.20 kg ha<sup>-1</sup> and 194.67 kg ha<sup>-1</sup> respectively; it was decreased maximum in the sole *Acacia mangium* system (121.28 kg ha<sup>-1</sup>) and other systems. Among all combinations, *Acacia mangium* with kalmegh, pineapple, mango ginger, and hybrid napier were particularly effective in improving specific soil parameters. Thus, agroforestry systems, especially those combining *Acacia mangium* with appropriate intercrops, are beneficial for enhancing soil health.

**Keywords:** Agroforestry; *acacia mangium*; CEC and soil organic carbon.

## 1. INTRODUCTION

"Agroforestry systems are productive land-use strategies that combine agriculture and forestry. However, the influence of the age of these systems on soil restoration is still poorly understood and serves to inform appropriate management practices. The inherent impacts of agricultural activities are related to disruptions in carbon and nutrient cycles, resulting in long-term consequences for the region's soil quality. In addition to impairing soil quality, these activities release greenhouse gases into the atmosphere, exacerbating climate change impacts and reducing agricultural and forestry productivity, especially due to more frequent dry periods and extreme weather events such as heat waves and intense rainfall" (Hamad-Sheip et al., 2021; de Souza et al., 2025). "Soil is the basis of production in agriculture and forestry, the nourisher of mankind and an important component of the human environment. The quality of soil is considered to be an important factor for the success of agricultural production. Soil health has been defined as the continued capacity of soil to function as a living system,

which sustained biological productivity, environmental quality, and plant and animal health" (FAO, 2015). Sustainable agriculture production depends on the scientific management of soil health to meet people's present and future needs. But now-a-days, the health of soil is facing high degradation problems due to increased pressure of human and livestock population on inadequate natural resources. Semwal et al., (2009) and Araujo et al., (2012) reported the possible reasons of soil degradation, such as unplanned and unscientific agricultural practices, deforestation, over grazing, over-construction and alignment of roads. Soil health is an important factor for controlling yields of the crops. In future, sustainable soil conservation efforts would be needed to tackle problems such as soil health depletion, climate change and food insecurity.

"*Acacia mangium* Willd. of the family Fabaceae is one of the most widely used fast-growing tree species in plantation forestry programmes throughout Asia and the Pacific due to its rapid growth, good wood quality and tolerance to a wide range of soils and environments"

(Krisnawati et al., 2011). "The characteristics of *A. mangium*, a fast-growing nitrogen fixer, may lead to soil acidification because base cations rapidly accumulate in its biomass; these base cations are matched by the extrusion of H<sup>+</sup> from roots, and base cation loss from the soil profile is associated with high leaching of nitrate anions. Soil acidity might compromise plantation performance by affecting the availability of essential soil nutrients and the solubility of potentially toxic elements, little is known about soil acidification in *A. mangium* plantations" (Yamashita et al., 2008). "Large-scale plantations of *A. mangium* are estimated to have a net area of about 453,000 ha, with about 99% of *A. mangium* plantations being located in tropical Asia where they are established for industrial purposes. Asian countries with major areas of *Acacia* plantation are Indonesia (67%) and Malaysia (14%) (FAO, 2002). The species fixes atmospheric nitrogen and produces rich and abundant litter which improves soils physical and chemical characteristics" (Garay et al., 2004). "As it is associated with atmospheric nitrogen-fixing bacteria and mycorrhizal fungi, it presents superior utilization of nutrients and growth under adverse soil conditions" (Dias et al., 1996).

"In an agroforestry system, woody perennials are deliberately combined with agricultural crops and/or animals in same land management unit, either in some form of spatial arrangement or temporal sequence. There are both ecological as well as economic interactions between the different components of agroforestry" (Nair, 2008). "The advantages of ecological interactions between trees and agricultural crops are *i.e.*, increase in soil fertility through nitrogen fixation, addition of organic matter production, recycling of nutrients" (Young, 1986), "more biomass production per unit area, uptake of more water and nutrients and trees act as a protective barrier against soil erosion or as wind breaks" (Wiersum, 1984). "Apart from the effect of agroforestry in improving the soil physical properties through the improvement in the soil structure and porosity, it also influences the chemical properties of the soil. Trees add a high amount of organic matter in the form of leaf litter, fine root biomass and pruning debris. They help in lowering down the pH and EC of soil through organic matter accumulation and addition of nitrogen, potassium and phosphorous. Soil microorganisms mineralize nutrients via organic matter decomposition. Soil organic matter decomposition by various microorganisms takes place through various enzymes which catalyze

innumerable reactions necessary for the life processes of microorganisms, decomposition of organic residues, nutrient cycling, organic matter formation and soil structure" (Dick, 1992). "Most of the soils are not so rich to supply all the nutrients for its optimum growth and development. Furthermore, it is difficult to sustain the yield of the crop and soil health for a longer duration without the integrated use of organics and inorganics. The removal of nitrogen, phosphorus and potassium by crops is much more than their replenishment through mineral fertilizers, thereby leading to nutrient mining but this problem can be overcome through agroforestry. Because agroforestry improves the soil fertility status by the addition of continuous organic matter in the soil in the form of leaves, twig and branches etc. The amount of litter addition, litter quality, their decomposition rate and an improvement of soil physico-chemical properties is controlled by kind of tree species, age and density of tree species" (Sarvade et al., 2014). The removal of nutrients from the soil can also be minimize by agroforestry because the tree root works as a binding agent against the soil erosion and enhance natural nutrient recycling into the soil. Thus, the Present study was conducted for the dynamics of soil physical and chemical properties under *Acacia mangium* based agroforestry system.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

The present investigation was carried out at Central Research Station of Odisha University of Agriculture and Technology, Bhubaneswar. The study site was located at 20° 15' N longitude and 85° 52' East latitude with an altitude of 25.9 meter above mean sea level. The climate and weather of Bhubaneswar is humid sub-tropical with mild winters and hot dry summers. The maximum temperature during crop growth period varying from 29.7° C to 38.8° C and minimum from 15.1° C to 26.9° C. Generally, south-west monsoon sets in the mid June and recedes by mid-October. The mean annual rainfall is about 1227.6 mm, of which 80-90 per cent is received during the wet season (July to September). The soils of the experimental site are loamy sand to sandy loam in texture. It is rich in oxides of iron and aluminium, but poor in di-basic cations and soluble salts. Soil samples were taken before actually conducting the experiment from a depth of 0-15 cm, taking all the possible precautions prescribed for soil sampling. The samples were

brought to the laboratory, air dried and crushed to pass through 2.0 mm mesh sieve. The processed samples were subjected to appropriate mechanical and chemical analyses. The results thus obtained are presented in Table 1.

## 2.2 Experimental Details

The experiment was laid out in a Randomised Block Design (RBD) with three replications. The experiment was on an agroforestry system which consists of silvicultural species such as *Acacia mangium* and four agricultural species such as *Ananas comosus* (Pineapple), *Aloe vera* (Aloe), *Andrographis paniculata* (Kalmegh), *Curcuma amda* (Mangoginger) and three fodder species Hybrid napier (NB-21), *Panicum polystachion* (thin napier) and *Panicum maximum* (Guinea) grass. The experimental plot was laid out into small plots of size 16m x 6m for different treatments. At the time of final land preparation, well decomposed FYM was applied @ 10 t/ha. A common dose of 25-50-50 kg of N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O per hectare was applied in the form of urea, diammonium phosphate (DAP) and murate of potash (MOP), respectively. The details of the treatments are in Table 2.

## 2.3 Physico-chemical Analysis of Soil

For soil physico-chemical analysis, composite samples were collected from 0-15 cm depth of treatment plots before planting of the annual crop and after harvesting of annual crops. The samples were air dried under shed, finely ground and passed through a 2 mm mesh sieve and finally 250 gram of such soil were taken from each treatment plot in polythene bag with proper label for analysis. Mechanical analysis of the soil was done to find out the percentage of sand, silt and clay separately by means of bouyoucus hydrometer method to determine the texture of soil (Piper, 1994). Bulk density was determined by oven-drying to a constant mass at 60° C. Higher temperatures could reduce the carbon in the sample and avoided. Bulk density was

determined by cylinder method with dividing the oven-dry soil sample by the total volume of the sample. Similarly, the Particle density of soil was taken as 2.65g/cm<sup>3</sup>. However it was determined by dividing the oven-dried sample by volume of solid (soil suspension-water). Soil porosity was determined by the formula  $\{1 - (\text{Bulk density}/\text{particle density})\}$ . The percentage base saturation of the soil was determined by dividing the basic cations (meq/100g) to cation exchange capacity CEC (meq/100gm) and multiplying with 100. The electrical conductivity of soil was determined in 1:2 soil water suspension by using the conductivity meter (Jackson,1967). Soil pH was determined in 1:2 soil and water suspension by using glass electrode pH meter (Jackson, 1967). Organic carbon content of the soil sample was determined by Walkley and Black's rapid titration method (Piper,1950). Available nitrogen in soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available Phosphorous was determined by Bray's-I method with shaking 5gram soil in 35 ml of extracting solution (0.03N NH<sub>4</sub>AF in 0.025N HCl) for 5 minutes. The filtrate was estimated by spectrophotometer for phosphorous after development of colour by SnCl<sub>2</sub> and measured at 660nm (Jackson, 1973). Available Potassium was determined by equilibrating 5 gram of soil in 25ml neutral normal ammonium acetate (Jackson, 1973) and reading of the extract was taken in flame photometer.

## 2.4 Statistical Analysis

For determining the significance between the treatment means and to draw valid conclusion, statistical analysis was made. Data obtained from various observations were subjected to statistical analysis by adopting the appropriate method of "Analysis of Variance". The significance of the treatment effect was judged with the help of 'F' test (Variance ratio). The difference of the treatments' mean was tested using Least Significant Difference (L.S.D.) /Critical Difference (CD) at 5% level of probability (Gomez and Gomez, 1984).

**Table 1. Mechanical composition of soil during initiation of the trial**

Particulars	Percentage of composition on air dry basis	Method adopted
Sand	82.2	Bouyoucos Hydrometer Method (Piper, 1994)
Silt	8.0	
Clay	9.8	
Textural Class	Sandy Loam	Black et al. (1965)

**Table 2. Treatment details**

Treatment	Details
T <sub>1</sub>	<i>Acacia mangium</i> + <i>Ananas comosus</i>
T <sub>2</sub>	<i>Acacia mangium</i> + <i>Aloe vera</i>
T <sub>3</sub>	<i>Acacia mangium</i> + <i>Andrographis paniculata</i>
T <sub>4</sub>	<i>Acacia mangium</i> + <i>Curcuma amda</i>
T <sub>5</sub>	<i>Acacia mangium</i> + Hybrid napier (NB-21)
T <sub>6</sub>	<i>Acacia mangium</i> + <i>Panicum polystachion</i>
T <sub>7</sub>	<i>Acacia mangium</i> + <i>Panicum maximum</i>
T <sub>8</sub>	<i>Acacia mangium</i> (Control)

### 3. RESULTS AND DISCUSSION

#### 3.1 Soil Physical Properties

Soil physical properties such as textural class, bulk density, and porosity are presented in Table 3. During the study, it was observed that the soil in the experimental field was sandy loam at the start of the experiment and there is no change in the texture of the soil in any of the *Acacia mangium* based agroforestry system at the end of the study. Bulk density is found to decrease more in *Acacia mangium* with hybrid napier and *Acacia mangium* with guinea grass systems (1.58 - 1.51 g/cm<sup>3</sup>) compared to less decrease in *Acacia mangium* with pineapple and *Acacia mangium* with *Aloe vera* systems (1.58 - 1.54 g/cm<sup>3</sup>). However, no change in bulk density is observed in sole *Acacia mangium* system. During this study, it is also found that porosity is increased in all the *Acacia mangium* systems. The reduction in soil bulk density under trees is attributed to the addition of organic matter through litter fall, fine root recycling, twigs etc. These results are similar to the report by Nayak et al., (2009) the significant reduction in soil bulk density as compared to sole agricultural cropping has been reported as under the canopy of *Prosopis juliflora*. The soil porosity (% pore space) was significantly higher under the different agroforestry tree species as compared to the sole *Acacia mangium*. The highest increase in soil porosity was found in *Acacia mangium* in combination with mango ginger and hybrid napier (35-38%) followed by *Acacia mangium* with kalmegh, *Acacia mangium* with pineapple and *Acacia mangium* with guinea grass systems while other systems recorded porosity similar to sole *Acacia mangium* system. The increase in soil porosity under different combinations as compared to the sole *Acacia mangium* might be due to the addition of organic matter through leaf litter and the penetration of fine roots of trees in the soil. Similar results were reported by (Tandel et al.,

2009), who concluded after their studies that the soil porosity and water holding capacity improved under Agroforestry as compared to the sole plantation.

#### 3.2 Soil Chemical Properties

Soil chemical properties such as base saturation, cation exchange capacity (CEC), electrical conductivity (EC), pH, available nitrogen, phosphorus, potassium and organic carbon as affected by different *Acacia mangium* based agroforestry system (Table 4). During the study the base saturation shows decreasing trend over the years. The base saturation found decrease more in *Acacia mangium* with thin napier system (40%) followed by *Acacia mangium* with *Aloe vera* and *Acacia mangium* with mango ginger (41%) while no change is observed in *Acacia mangium* in combination with pineapple, hybrid napier, guinea grass and sole *Acacia mangium*. CEC is reported to increase in *Acacia mangium* with the pineapple system (4.3 meq kg<sup>-1</sup>) and decrease in *Acacia mangium* with guinea grass system (4.1 meq kg<sup>-1</sup>) while there is no change in other *Acacia mangium* systems. Similarly, EC is also found to increase in *Acacia mangium* with mango ginger system (0.37 ds m<sup>-1</sup>) followed by *Acacia mangium* in combination pine apple and kalmegh systems (0.25 dS m<sup>-1</sup>) and decreased in *Acacia mangium* with guinea grass, *Aloe vera* and thin napier systems while no change is found in *Acacia mangium* with hybrid napier system (0.21 dS m<sup>-1</sup>). Cation exchange helps the soils to resist changes in pH in addition to retaining plant nutrients. Soil cation exchange capacity (CEC) increased with increase in plantation age of *Caragana microphylla* plantation and was reported positive correlated with soil pH (Zhang et al., 2013).

The pH of the soil in agroforestry systems is observed to increase and changing acidic nature of soil to slightly acidic. The highest change in soil acidity is observed in *Acacia mangium* with

thin napier (pH 4.90 - 6.08) followed by *Acacia mangium* with pineapple system (pH 4.90 - 5.93), compared to lowest change in sole *Acacia mangium* system (pH 4.90 - 5.32). The acidic nature of the soil changed to slightly acidic may be due to the addition of organic carbon, control in leaching of bases, an increase in porosity of the soil by the legume tree *Acacia mangium* and rotation of intercrops. Tree species significantly influence soil pH; lower pH under agroforestry ascribed to the increased accumulation of aboveground biomass, associated cation uptake and production of organic acids by the tree component of agroforestry systems (Gupta and Sharma 2009, Sarvade et al., 2014). In general soil macronutrient of the experimental field such as N, P, and OC shows increasing trend while K observed decreasing trend. The highest OC is observed in *Acacia mangium* with kalmegh system (6.19 g kg<sup>-1</sup>) followed by *Acacia mangium* with pineapple system (5.81 g kg<sup>-1</sup>) and lowest OC in sole *Acacia mangium* system (3.49 g kg<sup>-1</sup>). This increase in OC may be due to addition of litterfall of tree, microbial activities and addition of manures to the intercrops. Barua and Haque (2011) also reported that the organic carbon concentration and storage under agroforestry practice was significantly higher than those in the open land. Bendi and Lambert (2012) found significantly higher SOC concentration under agroforestry system which may be attributed to input of C through litter fall that occurs at the beginning of winter season and greater root biomass compared to sole annual crops. Similarly, the highest available nitrogen is observed in *Acacia mangium* with kalmegh system (260.31 kg ha<sup>-1</sup>) followed by *Acacia mangium* with mango ginger system (232.20 kg ha<sup>-1</sup>) compared to the lowest nitrogen in sole

*Acacia mangium* system (191.00 kg ha<sup>-1</sup>). The N is increased may be due to leguminous tree *Acacia mangium* and addition of manures and fertiliser to the intercrops over the years. Brockwell et al., (2005) opined that *Acacia* species are legumes and, in symbiotic association with root-nodule bacteria, are partners in fixation of atmospheric N. Singh et al., (2004) mentioned that the deposition and release of N through litter fall and its decomposition was highest in legume species of *Acacia senegal*, *Acacia auriculiformis*, *Albizia spp.* In plantations and in intercropping systems nitrogen content was found higher than sole cropping. The highest available phosphorus is observed in *Acacia mangium* with pineapple system (82.90 kg ha<sup>-1</sup>) followed by *Acacia mangium* with kalmegh system (76.15 kg ha<sup>-1</sup>) but lowest phosphorous is recorded in sole *Acacia mangium* system (32.09 kg ha<sup>-1</sup>). The available potassium is more decreased in sole *Acacia mangium* (121.28 kg ha<sup>-1</sup>) followed by hybrid napier system (126.78 kg ha<sup>-1</sup>) compare to less decrease in *Acacia mangium* with *Aloe vera* system (183.29 kg ha<sup>-1</sup>) however, *Acacia mangium* in combination with pine apple, mango ginger observed increased potassium availability of 238.20 kg ha<sup>-1</sup> and 194.67 kg ha<sup>-1</sup> respectively compared to initial status of 190.00 kg/ha. Spears et al., (2001) reported that nitrogen-fixing species have high P requirements, which are essential in high levels during N-fixation, and therefore lower available soil P concentrations may result under nitrogen-fixing species than under non-fixing species. In our study the K is found to decrease in all the systems except in *Acacia mangium* with pineapple and mangoginger systems. Similar findings have also been reported by Ahmed et al., (2012).

**Table 3. Changes in physical properties of *Acacia mangium* based agroforestry systems**

Treatment	Textural class	Bulk density (g/ cm <sup>3</sup> )	Porosity (%)
<i>Acacia mangium</i> + Pineapple	Sandy loam	1.54	37
<i>Acacia mangium</i> + <i>Aloe vera</i>	Sandy loam	1.54	36
<i>Acacia mangium</i> + Mango ginger	Sandy loam	1.53	38
<i>Acacia mangium</i> + Kalmegh	Sandy loam	1.52	37
<i>Acacia mangium</i> + Hybrid napier	Sandy loam	1.51	38
<i>Acacia mangium</i> + Thin napier	Sandy loam	1.52	36
<i>Acacia mangium</i> + Guinea grass	Sandy loam	1.51	37
Control (Sole <i>Acacia mangium</i> )	Sandy loam	1.58	36
Initial (2000)	Sandy loam	1.58	35

**Table 4. Changes in chemical properties of *Acacia mangium* based agroforestry system**

Treatment	Base saturation (%)	CEC (meq/kg)	EC (dS/m)	pH	Organic carbon (g/kg)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
<i>Acacia mangium</i> + Pineapple	42	4.3	0.25	5.93	5.81	208.27	82.90	238.20
<i>Acacia mangium</i> + Aloe vera	41	4.2	0.20	5.67	4.69	213.08	65.70	183.29
<i>Acacia mangium</i> + Mango ginger	41	4.2	0.37	5.90	4.48	232.20	66.30	194.67
<i>Acacia mangium</i> + Kalmegh	43	4.2	0.25	5.62	6.19	260.31	76.15	170.89
<i>Acacia mangium</i> + Hybrid napier	42	4.2	0.21	5.34	5.02	195.23	34.60	126.78
<i>Acacia mangium</i> + Thin napier	40	4.2	0.17	6.08	4.38	210.40	35.38	136.05
<i>Acacia mangium</i> + Guinea grass	42	4.1	0.16	5.88	4.21	201.79	34.28	138.87
Control	42	4.2	0.17	5.32	3.49	191.0	32.09	121.28
Initial (2000)	42	4.2	0.21	4.90	3.2	102.0	4.5	190.0

#### 4. CONCLUSION

The experiment concludes that agroforestry systems incorporating *Acacia mangium* with various intercrops positively influence soil physico-chemical properties compared to the initial state of the soil. Different combinations showed varying degrees of improvement, with notable enhancements in: Soil structure (reduced bulk density, increased porosity), Nutrient content (increased organic carbon, nitrogen, and phosphorus), Soil pH (reduction in acidity in some systems), and selective increases in CEC and EC depending on the intercrop. Among all combinations, *Acacia mangium* with kalmegh, pineapple, mango ginger, and hybrid napier were particularly effective in improving specific soil parameters. Thus, agroforestry systems, especially those combining *Acacia mangium* with appropriate intercrops, are beneficial for enhancing soil health.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

#### REFERENCES

- Ahmed, N. M. Z., Bin, W., Yuqing, Z. & Rahmat, U. M. (2012). Assessment of Yield and Soil Properties using Agroforestry Practices in a Degraded Land. *International Conference on Environment, Energy and Biotechnology*, IPCBEE 3p.
- Araujo, A. S. F., Leite, L. F. C., Iwata, B. F., Jr M. de A. L., Xavier, G. R., & Figueiredo, M. V. B. (2012). Microbiological process in agroforestry systems. A review, *Agronomy for Sustainable Development*; 32, 215-226.
- Barua, S. K., & Haque, S. M. S. (2011). Soil characteristics and carbon sequestration potentials of vegetation in degraded hills of Chittagong, Bangladesh. *Land degradation & development*. DOI: 10.1002/ldr.1107 204.
- Bendi, J., & Lambert, M. J. (2012). Nutrient cycling in age sequences of two Eucalyptus plantation species. *Forest Ecology Management*; 255: 1701-1712.
- Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., & Clark, F. E. (Editors),

- (1965). Methods of Soil Analysis. Part 1, Agronomy No. 9. American Society of Agronomy. Inc. Madison. 770 pp.
- Brockwell, J., Searle, S. D., Jeavons, A. C., & Waayers, M. (2005). Nitrogen fixation in acacias: an untapped resource for sustainable plantations, farm forestry and land reclamation. Australian Centre for International Agricultural Research (ACIAR) *Monograph*; 115: 132p.
- de Souza, F. E. D., dos Santos Oliveira, J. D. N., dos Santos, C. R. C., de Oliveira Ferreira, E. V., da Silva, R. T. L., de Paula, M. T., ... & Martins, W. B. R. (2025). Physical and chemical soil quality and litter stock in agroforestry systems in the Eastern Amazonia. *Agriculture, Ecosystems & Environment*, 382, 109479.
- Dias, L. E., Franco, A. A., Campillo, E. F. C., & de Faria, S. M. (1996). The use of leguminous trees in reclamation of tropical mined soils. Paper presented at the 13th annual meeting of American society for surface mining and reclamation, Knoxville. 601–612 pp.
- Dick, R. P. (1992). A review: Long-term effects of agricultural systems on soil biochemical and microbial parameters. *Agricultural Ecosystems*; 4:25-36.
- FAO, (2002). Tropical Forest Plantation Areas. 1995 Data set by D. Pandey. Forest Plantations Working Paper No. 18. Rome, Italy: Forest Resources Development Service, Forest Resources Division, FAO.
- FAO, (2015). Healthy soils are the basis for healthy food production. Rome, Italy pp 4.
- Garay, I., Pellens, R., Kindel, A., Barros, E. & Franco, A. A. (2004). Evaluation of soil conditions in fastgrowing plantations of *Eucalyptus grandis* and *Acacia mangium* in Brazil: a contribution to the study of sustainable land use. *Application of Soil Ecology, Holanda*; 27:177–187.
- Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. Wiley Inter-science Publication, John Wiley & Sons, New York, USA.
- Gupta, M. K. & Sharma, S. D. (2009). Effect of tree plantation on soil properties, profile morphology and productivity index: poplar in Yamunanagar district of Haryana. *Annals of Forestry*; 17(1) 43-70.
- Hamad-Sheip, Y., Abdul-Hamid, H., Abiri, R., Saleh, M. N., Mohamed, J., Jalil, A. M., & Naji, H. R. (2021). Effect of *Acacia mangium* canopy on physicochemical characteristics and nutrient concentrations of the soil at Ayer Hitam Forest Reserve, Malaysia. *Forests*, 12(9), 1259.
- Jackson, M. L. (1967). Soil Chemical Analysis, Prentice Hall, New Delhi, India.
- Jackson, M. L. (1973). Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd. New Delhi.
- Krisnawati, H., Kallioand, M. & Kanninen, M. (2011). *Acacia Mangium* Wild.: Ecology, Silviculture and Productivity. Bogor, Indonesia: Centre for International Forestry Research.
- Nair, P. K. R. (2008). An Introduction to Agroforestry. Springer (India) Pvt. Ltd., New Delhi.
- Nayak, A. K., Khan, U., Sharma, D. K., Mishra, V. K., Sharma, C. J., Singh, R., & Singh, G. (2009). Spatial variability of soil physico-chemical properties under *Prosopis juliflora* and *Terminalia arjuna* in sodic soil of Indogangetic plains. *Journal of Indian Society of Soil Science*; 57(1):31-38.
- Piper, C. S. (1950). 'Soil and plant analysis.' The University of Adelaide, Australia.
- Piper, C. S. (1994). Soil and plant analysis, Adelaide.
- Sarvade, S., Mishra, H. S., Kaushal, R., Chaturvedi, S., & Tewari, S. (2014). Wheat (*Triticum aestivum* L.) yield and soil properties as influenced by different agri-silviculture systems of Terai Region, Northern India, *International Journal of Bio-resource and Stress Management*; 5(3): 350-355.
- Semwal, D. P., Uniyal, P. L., Bahuguna, Y. M., & Bhatt, A. B. (2009). Soil nutrient storage under different forest types in a part of Central Himalayas, India. *Annals of Forestry*; 17(1): 43-52.
- Singh, A. N., Raghubanshi, A. S., & Singh, J.S. (2004). Comparative performance and restoration potential of two *Albizia* species planted on mine spoil in a dry tropical region, India. *Ecological Engineering*; 22: 123-140.
- Singh, I., Rawat, P., Kumar, A., & Bhatt, P. (2018). Soil physico-bio-chemical properties under different agroforestry systems in Terai region of the Garhwal Hiamalayas. *Journal of Pharmacognosy and Phytochemistry*, 7(5), 2813-2821.
- Spears, J. D. H., Lajtha, K., Caldwell, B. A., Pennington, S. B., & Vanderbilt, K. (2001). Species effect of *Ceanothus velutinus* versus *Pseudotsuga menziesii*, Douglas-fir, on soil phosphorus and nitrogen properties in the Oregon cascades. *Forest Ecology and Management*; 149:205-216.

- Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for estimation of available nitrogen in soils. *Current Science*, 25: 259-260.
- Tandel, M. B., Kukaldia, B. N., Kolambe & Jadeja, D. B. (2009). Influence of tree cover on physical properties of soil. *Indian Forester*; 135(5):420-424.
- Wiersum, K. F. (1984). Surface erosion under various agroforestry systems. In *Proc. Symp. Effects of forest land use on erosion and slope stability*. Environment & Policy Institute East-West Center, Honolulu, 231-239.
- Yamashita, N., Ohta, S., & Hardjono, A. (2008). Soil changes induced by Acacia mangium plantation establishment: comparison with secondary forest and Imperata cylindrica grassland soils in South Sumatra, Indonesia. *Forest Ecology and Management*, 254(2), 362-370.
- Young, A. (1986). *Agroforestry for soil management*. CAB International, Walling Ford, U.K.
- Zhang, Y., Xu, Z., Jiang, D., & Jiang, Y. (2013). Soil exchangeable base cations along a chronosequence of *Caragana microphylla* plantation in a semi-arid sandy land, China. *Journal of Arid Land*, 5(1) 42-50. DOI: 10.1007/s40333-013-0140-8

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2025): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:

<https://pr.sdiarticle5.com/review-history/139765>